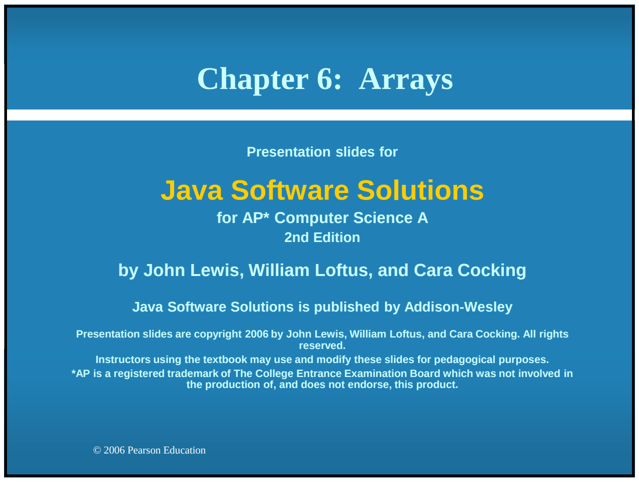

Chapter 6: Arrays

Presentation slides for

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for AP* Computer Science A

2nd Edition

by John Lewis, William Loftus, and Cara Cocking

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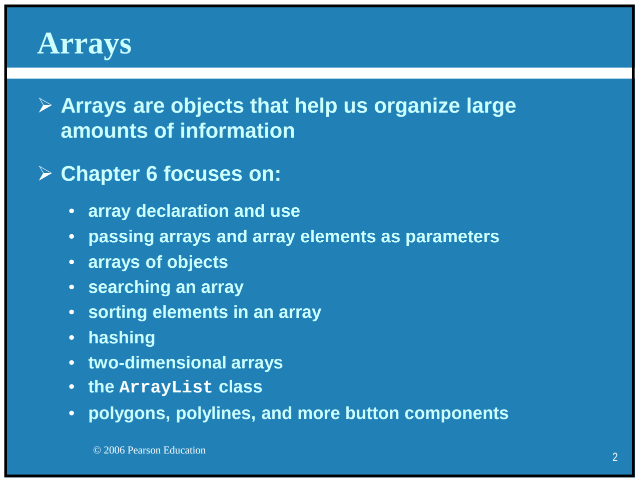
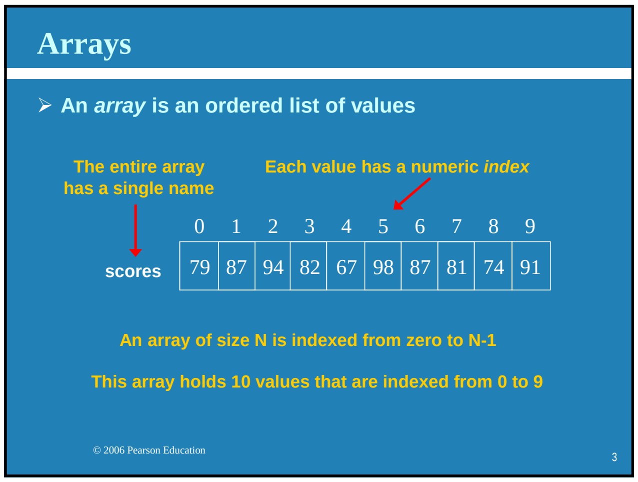


Arrays

- Arrays are objects that help us organize large amounts of information
- Chapter 6 focuses on:
  - array declaration and use
  - passing arrays and array elements as parameters
  - arrays of objects
  - searching an array
  - sorting elements in an array
  - hashing
  - two-dimensional arrays
  - the `ArrayList` class
  - polygons, polylines, and more button components



Arrays

- An *array* is an ordered list of values

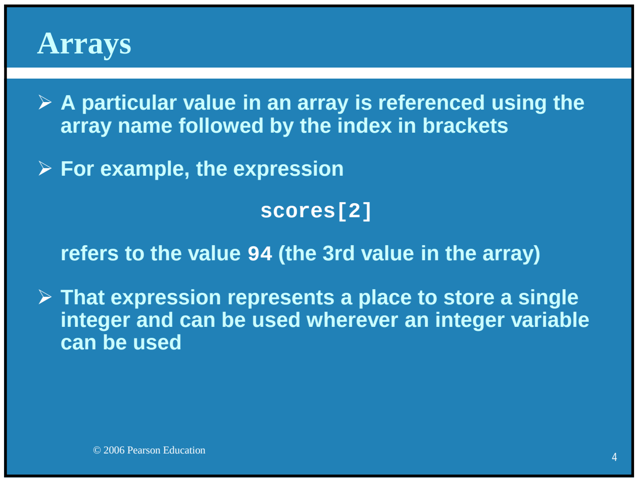
The entire array has a single name

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

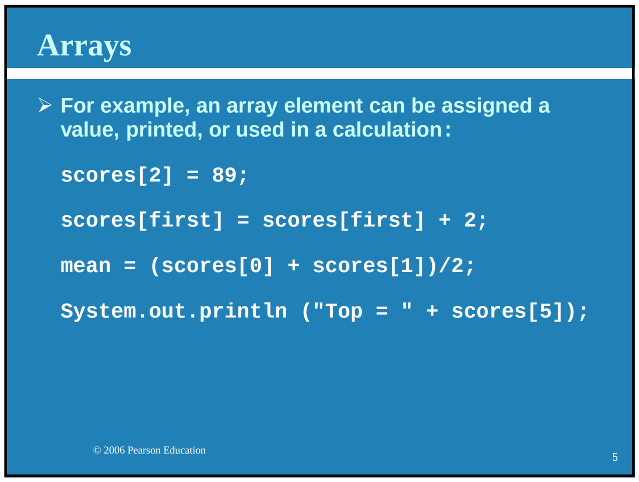


Arrays

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

  `scores[2]`

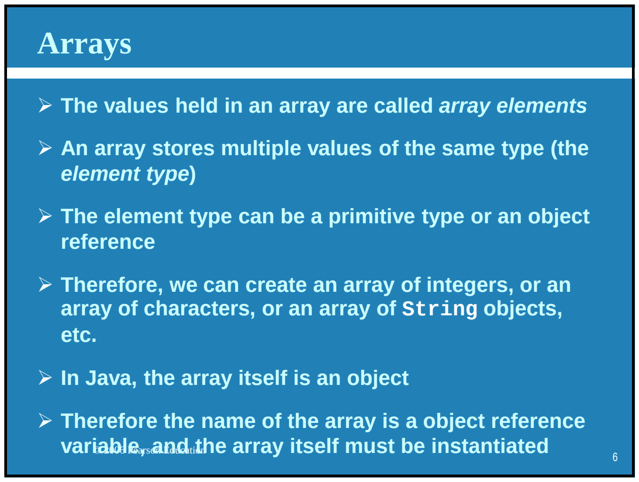
  refers to the value `94` (the 3rd value in the array)
- That expression represents a place to store a single integer and can be used wherever an integer variable can be used



Arrays

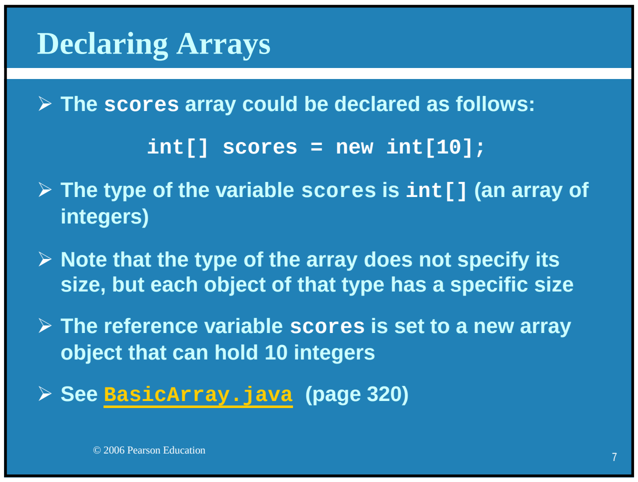
- For example, an array element can be assigned a value, printed, or used in a calculation:

```
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, or an array of characters, or an array of `String` objects, etc.
- In Java, the array itself is an object
- Therefore the name of the array is a object reference variable, and the array itself must be instantiated

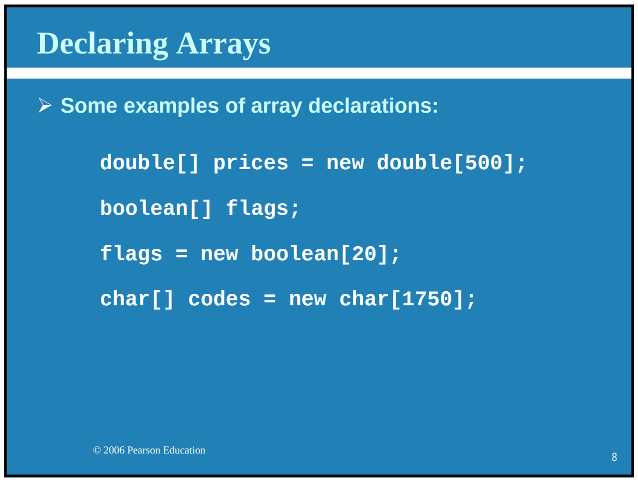


Declaring Arrays

- 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 type of the array 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
- See `BasicArray.java` (page 320)



Declaring Arrays

- Some examples of array declarations:

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

boolean[] flags;

flags = new boolean[20];

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

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 bounds (0 to N-1)
- The Java interpreter throws an `ArrayIndexOutOfBoundsException` if an array index is out of bounds
- This is called *automatic bounds checking*

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Bounds Checking

- For example, if the array `codes` can hold 100 values, it can be indexed using only the numbers 0 to 99
- If `count` has the value 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;
```

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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 322)
- See `LetterCount.java` (page 324)

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Initializer Lists

- An *initializer list* can be used to instantiate and initialize 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'};
```

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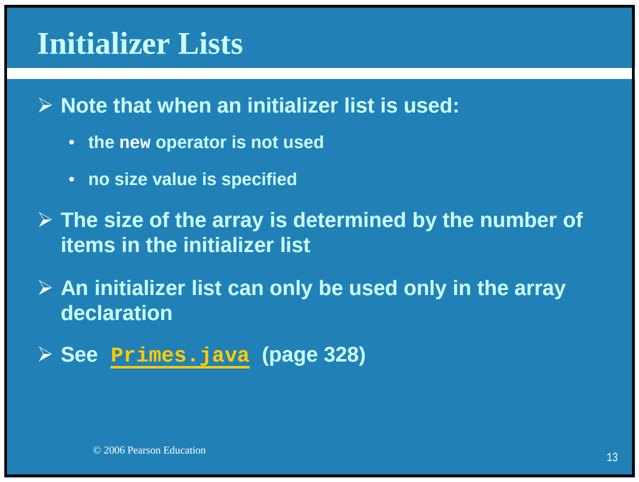
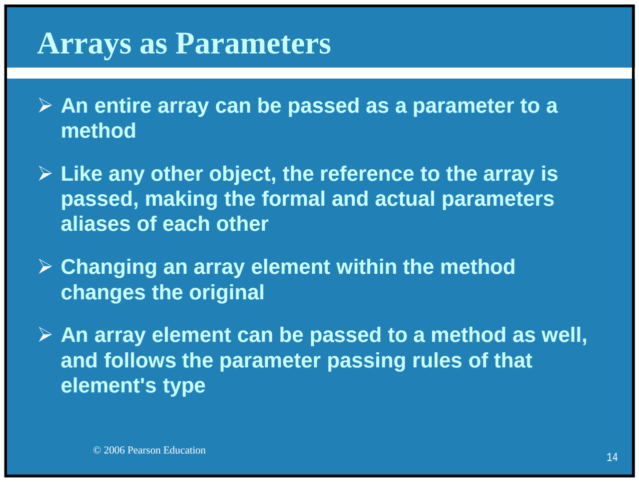


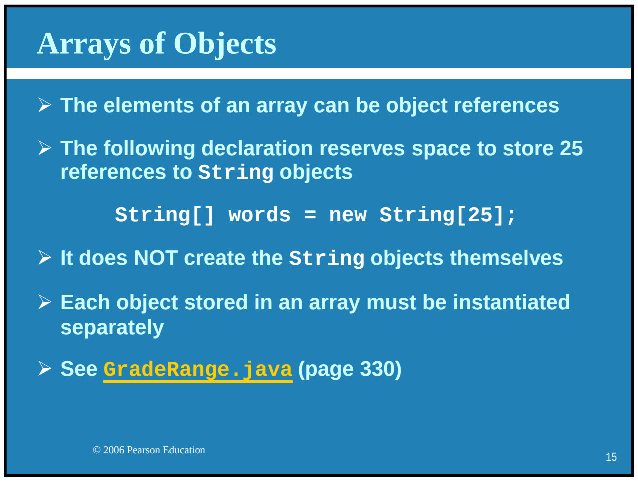
Initializer Lists

- 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 only be used only in the array declaration
- See `Primes.java` (page 328)



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
- Changing an array element within the method changes the original
- An array element can be passed to a method as well, and follows the parameter passing rules of that element's type

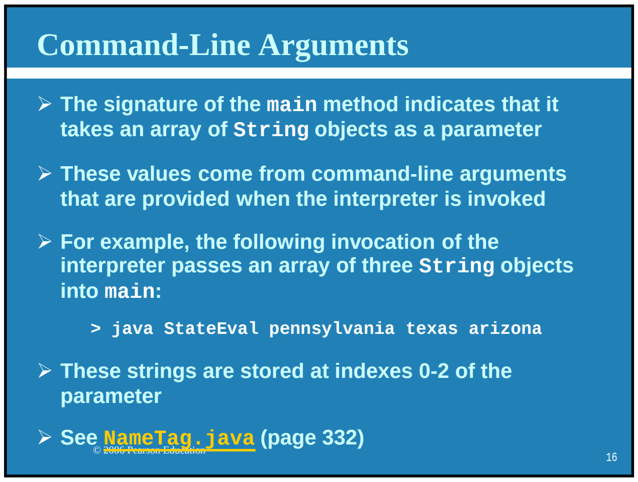


Arrays of Objects

- The elements of an array can be object references
- The following declaration reserves space to store 25 references to `String` objects

```
String[] words = new String[25];
```

- It does NOT create the `String` objects themselves
- Each object stored in an array must be instantiated separately
- See `GradeRange.java` (page 330)



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 an array of three `String` objects into `main`:

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

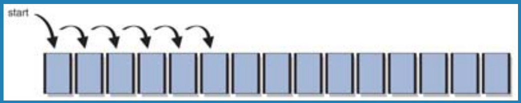
- These strings are stored at indexes 0-2 of the parameter
- See `NameTag.java` (page 332)

Arrays of Objects

- Objects can have arrays as instance variables
- Many useful structures can be created with arrays and objects
- The software designer must determine carefully an organization of data and objects that makes sense for the situation
- See `Tunes.java` (page 333)
- See `CDCollection.java` (page 335)
- See `CD.java` (page 337)

Searching

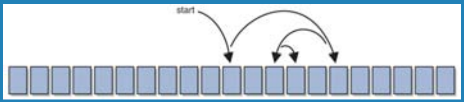
- A common task when working with arrays is to search an array for a particular element
- A linear or sequential search examines each element of the array in turn until the desired element is found



- See `Guests.java` (page 339)

Searching

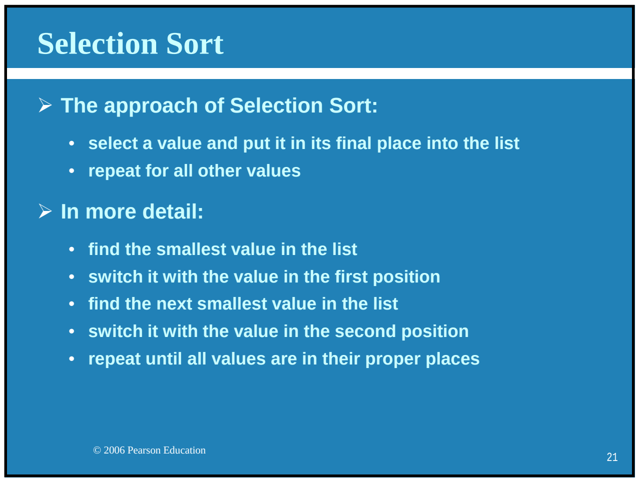
- A binary search is more efficient than a linear search but it can only be performed on an ordered list
- A binary search examines the middle element and moves left if the desired element is less than the middle, and right if the desired element is greater
- This process repeats until the desired element is found



- See `Searches.java` (page 340)

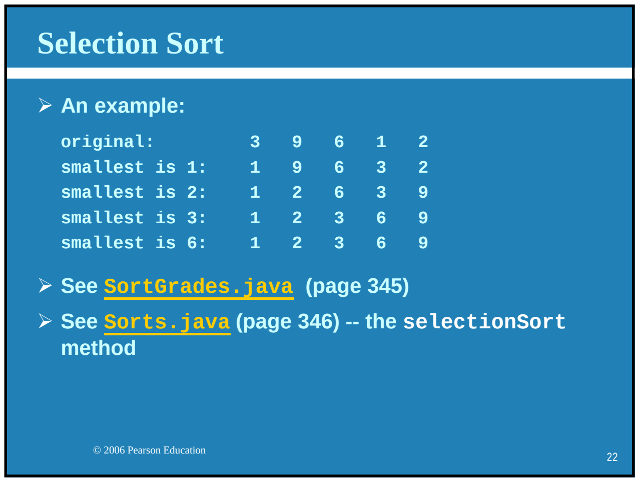
Sorting

- Sorting is the process of arranging a list of items in a particular order
- The sorting process is based on specific value(s)
  - sorting a list of test scores in ascending numeric order
  - sorting a list of people alphabetically by last name
- There are many algorithms for sorting a list of items
- These algorithms vary in efficiency
- We will examine two specific algorithms:
  - Selection Sort
  - Insertion Sort



Selection Sort

- The approach of Selection Sort:
  - select a value and put it in its final place into the list
  - repeat for all other values
- In more detail:
  - find the smallest value in the list
  - switch it with the value in the first position
  - find the next smallest value in the list
  - switch it with the value in the second position
  - repeat until all values are in their proper places

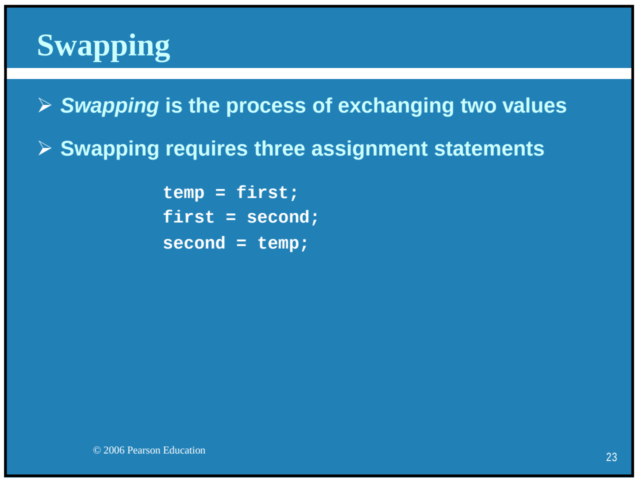


Selection Sort

- An example:

```
original:         3   9   6   1   2
smallest is 1:    1   9   6   3   2
smallest is 2:    1   2   6   3   9
smallest is 3:    1   2   3   6   9
smallest is 6:    1   2   3   6   9
```

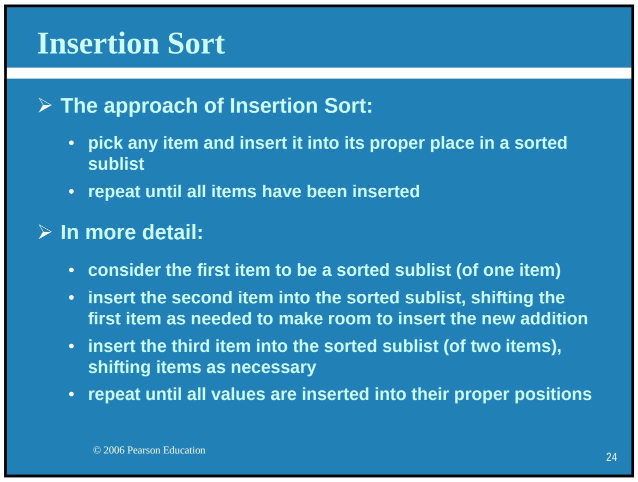
- See `SortGrades.java` (page 345)
- See `Sorts.java` (page 346) -- the `selectionSort` method



Swapping

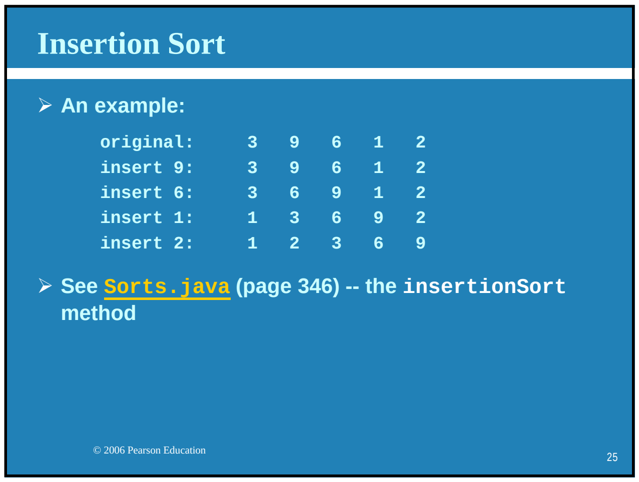
- *Swapping* is the process of exchanging two values
- Swapping requires three assignment statements

```
temp = first;
first = second;
second = temp;
```



Insertion Sort

- The approach of Insertion Sort:
  - pick any item and insert it into its proper place in a sorted sublist
  - repeat until all items have been inserted
- In more detail:
  - consider the first item to be a sorted sublist (of one item)
  - insert the second item into the sorted sublist, shifting the first item as needed to make room to insert the new addition
  - insert the third item into the sorted sublist (of two items), shifting items as necessary
  - repeat until all values are inserted into their proper positions



Insertion Sort

- An example:

```
original:    3   9   6   1   2
insert 9:    3   9   6   1   2
insert 6:    3   6   9   1   2
insert 1:    1   3   6   9   2
insert 2:    1   2   3   6   9
```

- See `Sorts.java` (page 346) -- the `insertionSort` method

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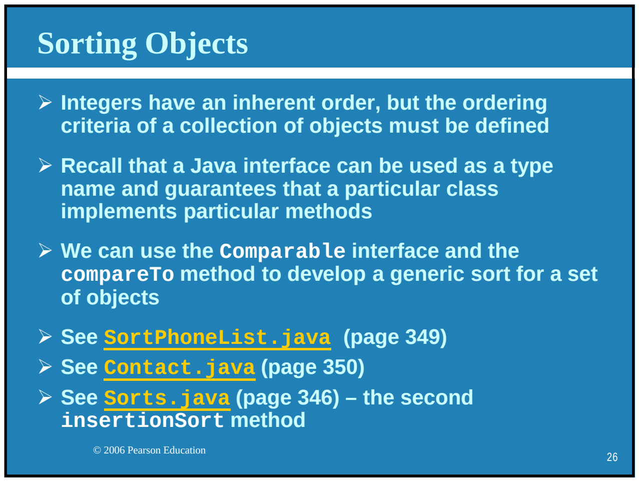

Sorting Objects

- Integers have an inherent order, but the ordering criteria of a collection of objects must be defined
- Recall that a Java interface can be used as a type name and guarantees that a particular class implements particular methods
- We can use the `Comparable` interface and the `compareTo` method to develop a generic sort for a set of objects
- See `SortPhoneList.java` (page 349)
- See `Contact.java` (page 350)
- See `Sorts.java` (page 346) – the second `insertionSort` method

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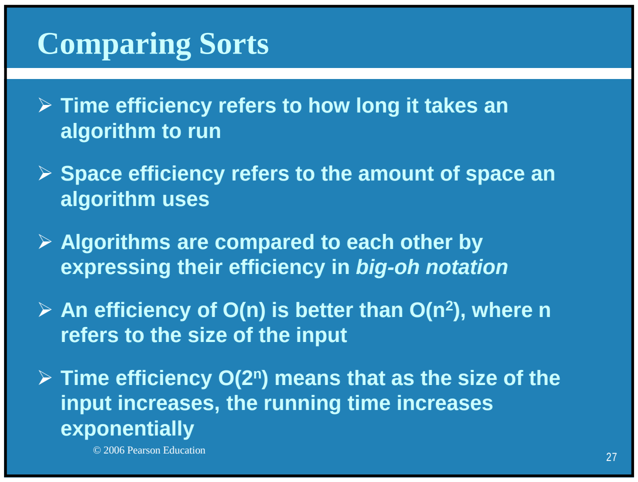

Comparing Sorts

- Time efficiency refers to how long it takes an algorithm to run
- Space efficiency refers to the amount of space an algorithm uses
- Algorithms are compared to each other by expressing their efficiency in *big-oh notation*
- An efficiency of O(n) is better than O(n^2), where n refers to the size of the input
- Time efficiency O(2^n) means that as the size of the input increases, the running time increases exponentially

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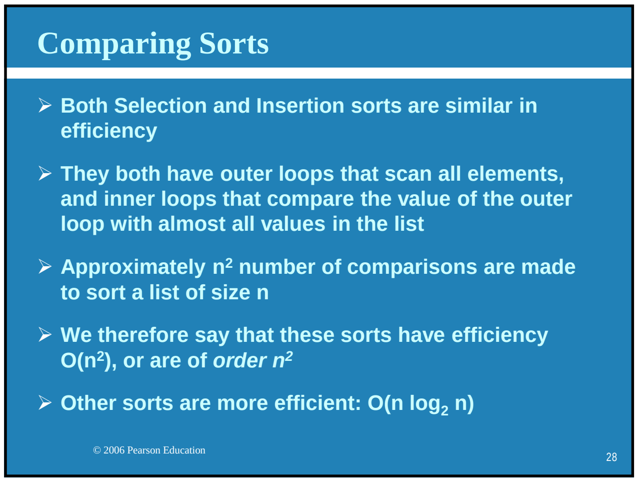

Comparing Sorts

- Both Selection and Insertion sorts are similar in efficiency
- They both have outer loops that scan all elements, and inner loops that compare the value of the outer loop with almost all values in the list
- Approximately n^2 number of comparisons are made to sort a list of size n
- We therefore say that these sorts have efficiency O(n^2), or are of *order n^2*
- Other sorts are more efficient: O(n $\log_2$ n)

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Hashing

- Hashing is a technique used to efficiently store and retrieve data in an array
- An array used for hashing is called a hash table
- A hash function calculates a hash code for each data item.
- The hash code is used as an index into the array, telling where the data item should be stored
- Example: hash function f(n) = n % 7
  - Element 18 would be stored in array cell 18 % 7 or 4

Two-Dimensional Arrays

- To be precise, a two-dimensional array in Java 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];
```

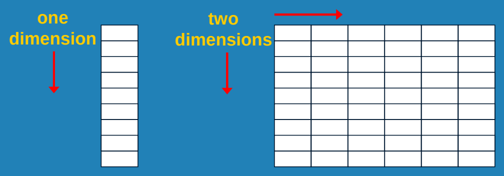
- A two-dimensional array element is referenced using two index values

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

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

Two-Dimensional Arrays

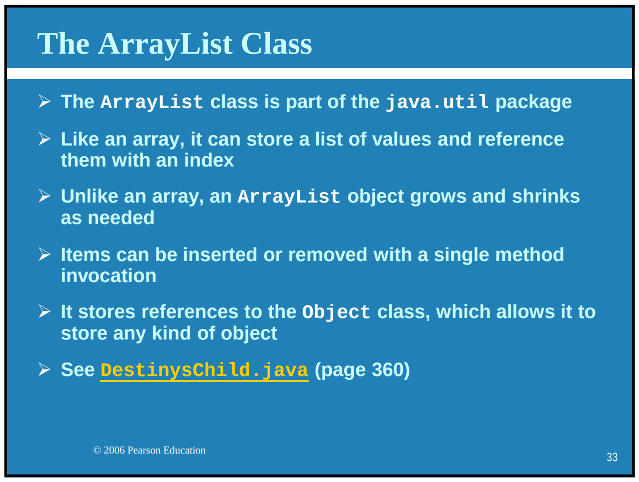
- A *one-dimensional array* stores a list of elements
- A *two-dimensional array* can be thought of as a table of elements, with rows and columns



Two-Dimensional Arrays

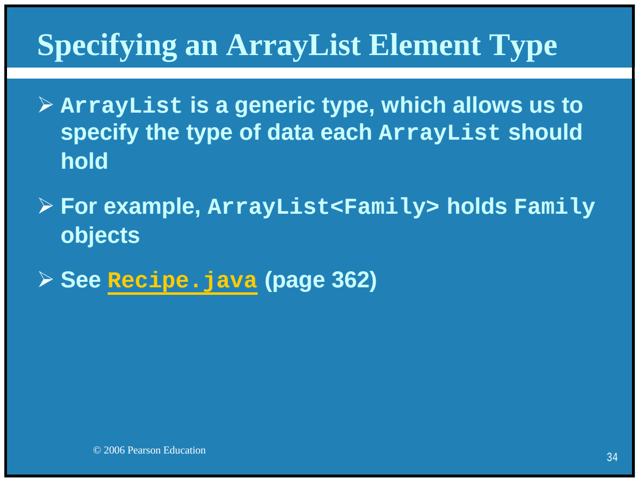
Expression	Type	Description
`scores`	`int[][]`	2D array of integers, or array of integer arrays
`scores[5]`	`int[]`	array of integers
`scores[5][12]`	`int`	integer

- See `TwoDArray.java` (page 356)
- See `SodaSurvey.java` (page 357)



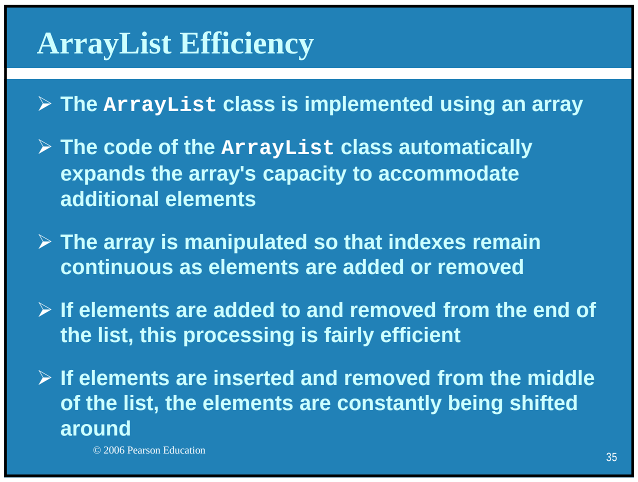
The ArrayList Class

- The `ArrayList` class is part of the `java.util` package
- Like an array, it can store a list of values and reference them with an index
- Unlike an array, an `ArrayList` object grows and shrinks as needed
- Items can be inserted or removed with a single method invocation
- It stores references to the `Object` class, which allows it to store any kind of object
- See `DestinysChild.java` (page 360)



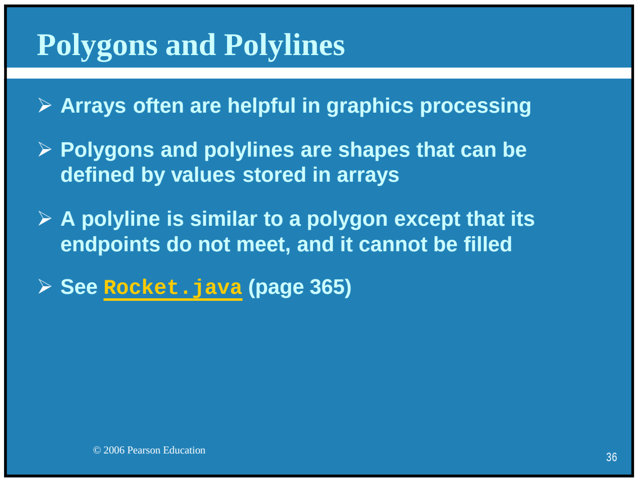
Specifying an ArrayList Element Type

- `ArrayList` is a generic type, which allows us to specify the type of data each `ArrayList` should hold
- For example, `ArrayList<Family>` holds `Family` objects
- See `Recipe.java` (page 362)



ArrayList Efficiency

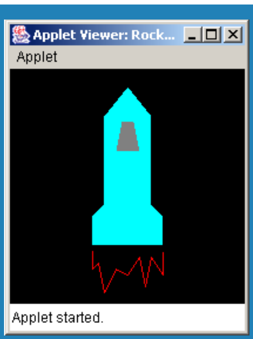
- The `ArrayList` class is implemented using an array
- The code of the `ArrayList` class automatically expands the array's capacity to accommodate additional elements
- The array is manipulated so that indexes remain continuous as elements are added or removed
- If elements are added to and removed from the end of the list, this processing is fairly efficient
- If elements are inserted and removed from the middle of the list, the elements are constantly being shifted around



Polygons and Polylines

- Arrays often are helpful in graphics processing
- Polygons and polylines are shapes that can be defined by values stored in arrays
- A polyline is similar to a polygon except that its endpoints do not meet, and it cannot be filled
- See `Rocket.java` (page 365)

The Rocket Program



The Polygon Class

- The `Polygon` class, defined in the `java.awt` package can be used to define and draw a polygon
- Two versions of the overloaded `drawPolygon` and `fillPolygon` methods each take a single `Polygon` object as a parameter
- A `Polygon` object encapsulates the coordinates of the polygon

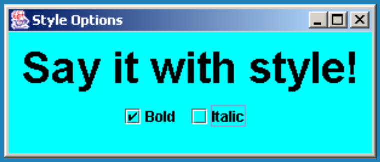
Check Boxes

- A *check box* is a button that can be toggled on or off
- A check box is represented by the `JCheckBox` class
- A change of state generates an *item event*
- The `ItemListener` interface corresponds to item events
- The `itemStateChanged` method of the listener responds when a check box changes state

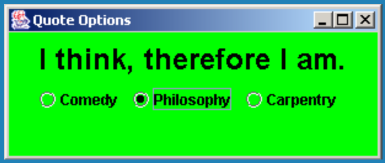
The StyleOptions Program

- A *frame* is a container that can be used to create stand-alone GUI applications
- A frame is represented by the `JFrame` class
- A `Font` object represents by the font's:
  - family name (such as Times or Courier)
  - style (bold, italic, or both)
  - font size
- See StyleOptions.java (page 369)
- See StyleGUI.java (page 370)

The StyleOptions Program



The QuoteOptions Program



Radio Buttons

- A set of *radio buttons* represents a set of mutually exclusive options
- When a radio button from a group is selected, the other button currently "on" in the group is toggled off
- A radio button generates an action event
- See `QuoteOptions.java` (page 372)
- See `QuoteGUI.java` (page 374)

Summary

- Chapter 6 has focused on:
  - array declaration and use
  - passing arrays and array elements as parameters
  - arrays of objects
  - searching an array
  - sorting elements in an array
  - hashing
  - two-dimensional arrays
  - the `ArrayList` class
  - polygons, polylines, and more button components