BIRZEIT UNIVERSITY

COMPUTER SCIENCE DEPARTMENT FACULTY OF ENGINEERING AND TECHNOLOGY

ADVANCED PROGRAMMING COMP231

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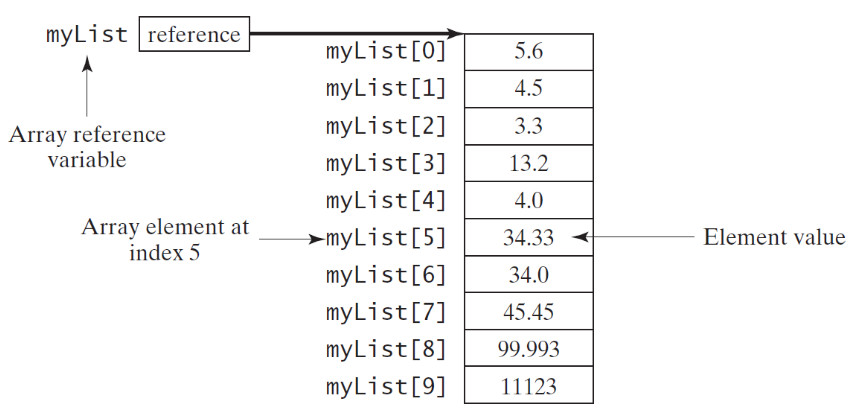
Chapter 7+8 Arrays

Introducing Arrays

Array is a data structure that represents a collection of the same types of data.

```
double[] myList = new double[10];
```



Declaring Array Variables

- `datatype[] arrayRefVar;`

  Example:

  `double[] myList;`

- `datatype arrayRefVar[];` // This style is allowed, but not preferred

  Example:

  `double myList[];`

Creating Arrays

`arrayRefVar = new datatype[arraySize];`

Example:

`myList = new double[10];`

`myList[0]` references the first element in the array.

`myList[9]` references the last element in the array.

Declaring and Creating in One Step

- `datatype[] arrayRefVar = new  datatype[arraySize];`

  `double[] myList = new double[10];`

- `datatype arrayRefVar[] = new  datatype[arraySize];`

  `double myList[] = new double[10];`

The Length of an Array

Once an array is created, its size is fixed. It cannot be changed. You can find its size using

arrayRefVar.length

For example,

myList.length returns 10

Default Values

When an array is created, its elements are assigned the default value of

0 for the numeric primitive data types,
'\u0000' for char types, and
false for boolean types.

Indexed Variables

The array elements are accessed through the index. The array indices are *0-based*, i.e., it starts from 0 to arrayRefVar.length-1. In the example in Figure 6.1, myList holds ten double values and the indices are from 0 to 9.

Each element in the array is represented using the following syntax, known as an *indexed variable*:

```
arrayRefVar[index];
```

Using Indexed Variables

After an array is created, an indexed variable can be used in the same way as a regular variable. For example, the following code adds the value in myList[0] and myList[1] to myList[2].

```
myList[2] = myList[0] + myList[1];
```


Declaring, creating, initializing Using the Shorthand Notation

```
double[] myList = {1.9, 2.9, 3.4, 3.5};
```

This shorthand notation is equivalent to the following statements:

```
double[] myList = new double[4];
myList[0] = 1.9;
myList[1] = 2.9;
myList[2] = 3.4;
myList[3] = 3.5;
```

CAUTION

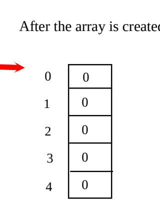
Using the shorthand notation, you have to declare, create, and initialize the array **all in one statement**. Splitting it would cause a syntax error. For example, the following is wrong:

```
double[] myList;

myList = {1.9, 2.9, 3.4, 3.5};
```


Trace Program with Arrays

Declare array variable values, create an array, and assign its reference to values

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```



Initializing arrays with input values

```
Scanner input = new java.util.Scanner(System.in);
System.out.print("Enter " + myList.length + " values: ");

for (int i = 0; i < myList.length; i++)
  myList[i] = input.nextDouble();
```

Initializing arrays with random values

```
for (int i = 0; i < myList.length; i++) {
  myList[i] = Math.random() * 100;
}
```


Printing arrays

```
for (int i = 0; i < myList.length; i++) {
  System.out.print(myList[i] + " ");
}
```

Summing all elements

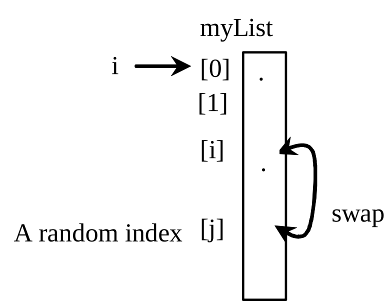
```
double total = 0;
for (int i = 0; i < myList.length; i++) {
  total += myList[i];
}
```

Finding the largest element

```
double max = myList[0];
for (int i = 1; i < myList.length; i++) {
  if (myList[i] > max)
    max = myList[i];
}
```

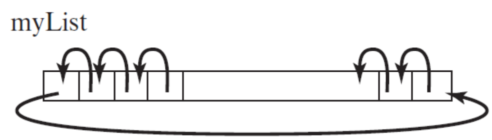

Random shuffling

```
for (int i = 0; i < myList.length - 1; i++) {
  // Generate an index j randomly
  int j = (int)(Math.random()
    * myList.length);

  // Swap myList[i] with myList[j]
  double temp = myList[i];
  myList[i] = myList[j];
  myList[j] = temp;
}
```



Shifting Elements

```
double temp = myList[0]; // Retain the first element

// Shift elements left
for (int i = 1; i < myList.length; i++) {
  myList[i - 1] = myList[i];
}

// Move the first element to fill in the last position
myList[myList.length - 1] = temp;
```



Enhanced for Loop (for-each loop)

JDK 1.5 introduced a new for loop that enables you to traverse the complete array sequentially without using an index variable. For example, the following code displays all elements in the array myList:

```
for (double value: myList)
  System.out.println(value);
```

In general, the syntax is

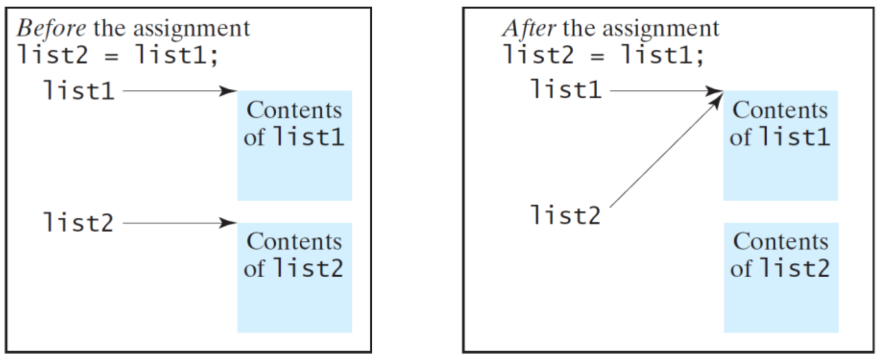
```
for (elementType value: arrayRefVar) {
  // Process the value
}
```

You still have to use an index variable if you wish to traverse the array in a different order or change the elements in the array.

Copying Arrays

Often, in a program, you need to duplicate an array or a part of an array. In such cases you could attempt to use the assignment statement (=), as follows:

list2 = list1;



Copying Arrays

Using a loop:

```
int[] sourceArray = {2, 3, 1, 5, 10};
int[] targetArray = new
 int[sourceArray.length];

for (int i = 0; i < sourceArrays.length; i++)
   targetArray[i] = sourceArray[i];
```

The arraycopyUtility:

System.arraycopy(sourceArray, src_pos, targetArray, tar_pos, length);

Example:

```
System.arraycopy(sourceArray, 0, targetArray, 0,
sourceArray.length);
```


Passing Arrays to Methods

```
public static void printArray(int[] array) {
  for (int i = 0; i < array.length; i++) {
    System.out.print(array[i] + " ");
  }
}
```

```
Invoke the method

int[] list = {3, 1, 2, 6, 4, 2};
printArray(list);
```

```
Invoke the method
printArray(new int[]{3, 1, 2, 6, 4, 2});
```

Anonymous array

Anonymous Array

The statement

`printArray(new int[]{3, 1, 2, 6, 4, 2});`

creates an array using the following syntax:

`new dataType[]{literal0, literal1, ..., literalk};`

There is no explicit reference variable for the array. Such array is called an *anonymous array*.

Pass By Value

Java uses *pass by value* to pass arguments to a method. There are important differences between passing a value of variables of primitive data types and passing arrays.

- For a parameter of a primitive type value, the actual value is passed. Changing the value of the local parameter inside the method does not affect the value of the variable outside the method.

- For a parameter of an array type, the value of the parameter contains a reference to an array; this reference is passed to the method. Any changes to the array that occur inside the method body will affect the original array that was passed as the argument.

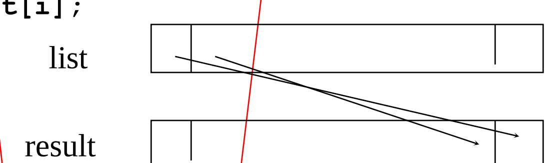
Simple Example

```
public class Test {
  public static void main(String[] args) {
    int x = 1; // x represents an int value
    int[] y = new int[10]; // y represents an array of int values

    m(x, y); // Invoke m with arguments x and y

    System.out.println("x is " + x);
    System.out.println("y[0] is " + y[0]);
  }

  public static void m(int number, int[] numbers) {
    number = 1001; // Assign a new value to number
    numbers[0] = 5555; // Assign a new value to numbers[0]
  }
}
```

```
x is 1
y[0] is 5555
```


Returning an Array from a Method

```
public static int[] reverse(int[] list) {
  int[] result = new int[list.length];

  for (int i = 0, j = result.length - 1;
       i < list.length; i++, j--) {
    result[j] = list[i];
  }

  return result;
}
```




```
int[] list1 = {1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

Trace the reverse Method

```
int[] list1 = {1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);

  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

Declare result and create array

list	1	2	3	4	5	6
result	0	0	0	0	0	0

Trace the reverse Method, cont.

```
int[] list1 = {1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);

  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

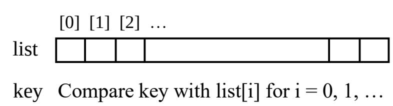
After this, i becomes 6 and j becomes -1

list	1	2	3	4	5	6
result	6	5	4	3	2	1

Searching Arrays

Searching is the process of looking for a specific element in an array; for example, discovering whether a certain score is included in a list of scores. Searching is a common task in computer programming. There are many algorithms and data structures devoted to searching. In this section, two commonly used approaches are discussed, *linear search* and *binary search*.

```
public class LinearSearch {
  /** The method for finding a key in the list */
  public static int linearSearch(int[] list, int key) {
    for (int i = 0; i < list.length; i++)
      if (key == list[i])
        return i;
    return -1;
  }
}
```



Linear Search

The linear search approach compares the key element, key, *sequentially* with each element in the array list. The method continues to do so until the key matches an element in the list or the list is exhausted without a match being found. If a match is made, the linear search returns the index of the element in the array that matches the key. If no match is found, the search returns -1.

Binary Search, cont.

key is 11

key < 50

	low						mid						high
	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
list	2	4	7	10	11	45	**50**	59	60	66	69	70	79

key > 7

	low		mid			high
	[0]	[1]	[2]	[3]	[4]	[5]
list	2	4	7	10	11	45

key == 11

	low	mid	high
	[3]	[4]	[5]
list	10	11	45

Binary Search, cont.

key is 54

key > 50

	low						mid						high
	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
list	2	4	7	10	11	45	**50**	59	60	66	69	70	79

key < 66

								low		mid			high
	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
list								59	60	66	69	70	79

key < 59

	low mid	high
	[7]	[8]
list	59	60

low high

[6]	[7]	[8]
	59	60

Binary Search, cont.

The binarySearch method returns the index of the element in the list that matches the search key if it is contained in the list. Otherwise, it returns

-insertion point - 1.

The insertion point is the point at which the key would be inserted into the list.

From Idea to Soluton

```
/** Use binary search to find the key in the list */
public static int binarySearch(int[] list, int key) {
  int low = 0;
  int high = list.length - 1;

  while (high >= low) {
    int mid = (low + high) / 2;
    if (key < list[mid])
      high = mid - 1;
    else if (key == list[mid])
      return mid;
    else
      low = mid + 1;
  }

  return -1 - low;
}
```

The Arrays.binarySearch Method

Since binary search is frequently used in programming, Java provides several overloaded binarySearch methods for searching a key in an array of int, double, char, short, long, and float in the java.util.Arrays class. For example, the following code searches the keys in an array of numbers and an array of characters.

```
int[] list = {2, 4, 7, 10, 11, 45, 50, 59, 60, 66, 69, 70, 79};
System.out.println("Index is " +
  java.util.Arrays.binarySearch(list, 11));
```

Return is 4

```
char[] chars = {'a', 'c', 'g', 'x', 'y', 'z'};
System.out.println("Index is " +
  java.util.Arrays.binarySearch(chars, 't'));
```

Return is –4 (insertion point is 3, so return is -3-1)

For the binarySearch method to work, the array must be pre-sorted in increasing order.

Sorting Arrays

Sorting, like searching, is also a common task in computer programming. Many different algorithms have been developed for sorting. This section introduces a simple, intuitive sorting algorithms: *selection sort*.

Command-Line Parameters

```
class TestMain {
  public static void main(String[] args) {
  ...
  }
}
```

```
java TestMain arg0 arg1 arg2 ... argn
```


Main Method Is Just a Regular Method

You can call a regular method by passing actual parameters. Can you pass arguments to main? Of course, yes. For example, the main method in class B is invoked by a method in A, as shown below:

```
public class A {
  public static void main(String[] args) {
    String[] strings = {"New York",
      "Boston", "Atlanta"};
    B.main(strings);
  }
}
```

```
class B {
  public static void main(String[] args) {
    for (int i = 0; i < args.length; i++)
      System.out.println(args[i]);
  }
}
```

Processing
Command-Line Parameters

In the main method, get the arguments from `args[0], args[1], ..., args[n]`, which corresponds to `arg0, arg1, ..., argn` in the command line.

Problem: Calculator

- Objective: Write a program that will perform binary operations on integers. The program receives three parameters: an operator and two integers.

Calculator

Run

java Calculator 2 + 3

java Calculator 2 - 3

java Calculator 2 / 3

java Calculator 2 . 3

2 Dimensional array

```
double[][] distances = {
  {0, 983, 787, 714, 1375, 967, 1087},
  {983, 0, 214, 1102, 1763, 1723, 1842},
  {787, 214, 0, 888, 1549, 1548, 1627},
  {714, 1102, 888, 0, 661, 781, 810},
  {1375, 1763, 1549, 661, 0, 1426, 1187},
  {967, 1723, 1548, 781, 1426, 0, 239},
  {1087, 1842, 1627, 810, 1187, 239, 0},
};
```


Declare/Create Two-dimensional Arrays

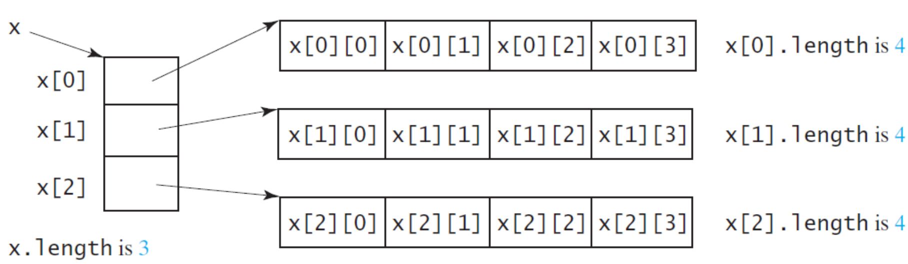
```
// Declare array ref var
dataType[][] refVar;

// Create array and assign its reference to variable
refVar = new dataType[10][10];

// Combine declaration and creation in one statement
dataType[][] refVar = new dataType[10][10];

// Alternative syntax
dataType refVar[][] = new dataType[10][10];
```

Declaring Variables of Two-dimensional Arrays and Creating Two-dimensional Arrays

```
int[][] matrix = new int[10][10];
 or
int matrix[][] = new int[10][10];
matrix[0][0] = 3;

for (int i = 0; i < matrix.length; i++)
  for (int j = 0; j < matrix[i].length; j++)
    matrix[i][j] = (int)(Math.random() * 1000);

double[][] x;
```


Lengths of Two-dimensional Arrays

int[][] x = new int[3][4];



Lengths of Two-dimensional Arrays, cont.

```
int[][] array = {
  {1, 2, 3},
  {4, 5, 6},
  {7, 8, 9},
  {10, 11, 12}
};
```

array.length
array[0].length
array[1].length
array[2].length
array[3].length

array[4].length ArrayIndexOutOfBoundsException

Ragged Arrays

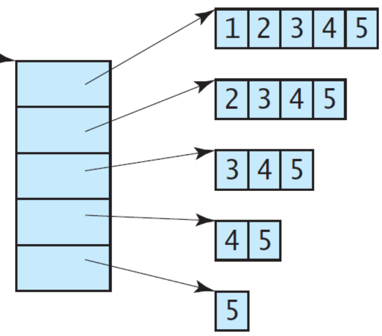
Each row in a two-dimensional array is itself an array. So, the rows can have different lengths. Such an array is known as *a ragged array*. For example,

```
int[][] matrix = {
  {1, 2, 3, 4, 5},
  {2, 3, 4, 5},
  {3, 4, 5},
  {4, 5},
  {5}
};
```

matrix.length is 5
matrix[0].length is 5
matrix[1].length is 4
matrix[2].length is 3
matrix[3].length is 2
matrix[4].length is 1

Ragged Arrays, cont.

```
int[][] triangleArray = {
  {1, 2, 3, 4, 5},
  {2, 3, 4, 5},
  {3, 4, 5},
  {4, 5},
  {5}
};
```



Initializing arrays with input values

```
Scanner input = new Scanner(System.in);
System.out.println("Enter " + matrix.length + " rows and " +
  matrix[0].length + " columns: ");

for (int row = 0; row < matrix.length; row++) {
  for (int column = 0; column < matrix[row].length; column++) {
    matrix[row][column] = input.nextInt();
  }
}
```

Printing arrays

```
for (int row = 0; row < matrix.length; row++) {
  for (int column = 0; column < matrix[row].length; column++) {
    System.out.print(matrix[row][column] + " ");
  }

  System.out.println();
}
```


Summing all elements

```
int total = 0;
for (int row = 0; row < matrix.length; row++) {
  for (int column = 0; column < matrix[row].length; column++) {
    total += matrix[row][column];
  }
}
```

Summing elements by column

```
for (int column = 0; column < matrix[0].length; column++) {
  int total = 0;
  for (int row = 0; row < matrix.length; row++)
    total += matrix[row][column];
  System.out.println("Sum for column " + column + " is "
    + total);
}
```


Problem: Grading Multiple-Choice Test

Students' answer

	0	1	2	3	4	5	6	7	8	9
Student 0	A	B	A	C	C	D	E	E	A	D
Student 1	D	B	A	B	C	A	E	E	A	D
Student 2	E	D	D	A	C	B	E	E	A	D
Student 3	C	B	A	E	D	C	E	E	A	D
Student 4	A	B	D	C	C	D	E	E	A	D
Student 5	B	B	E	C	C	D	E	E	A	D
Student 6	B	B	A	C	C	D	E	E	A	D
Student 7	E	B	E	C	C	D	E	E	A	D

Objective: write a program that grades multiple-choice test.

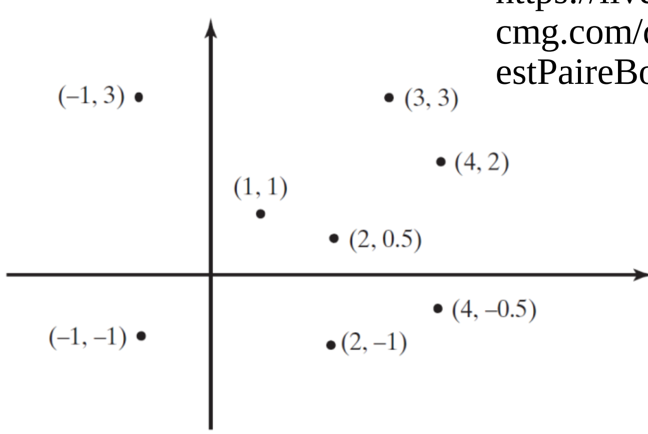
Key to the Questions:

	0	1	2	3	4	5	6	7	8	9
Key	D	B	D	C	C	D	A	E	A	D

```java
public class GradeExam {
  /** Main method */
  public static void main(String[] args) {
    // Students' answers to the questions
    char[][] answers = {
      {'A', 'B', 'A', 'C', 'C', 'D', 'E', 'E', 'A', 'D'},
      {'D', 'B', 'A', 'B', 'C', 'A', 'E', 'E', 'A', 'D'},
      {'E', 'D', 'D', 'A', 'C', 'B', 'E', 'E', 'A', 'D'},
      {'C', 'B', 'A', 'E', 'D', 'C', 'E', 'E', 'A', 'D'},
      {'A', 'B', 'D', 'C', 'C', 'D', 'E', 'E', 'A', 'D'},
      {'B', 'B', 'E', 'C', 'C', 'D', 'E', 'E', 'A', 'D'},
      {'B', 'B', 'A', 'C', 'C', 'D', 'E', 'E', 'A', 'D'},
      {'E', 'B', 'E', 'C', 'C', 'D', 'E', 'E', 'A', 'D'}};

    // Key to the questions
    char[] keys = {'D', 'B', 'D', 'C', 'C', 'D', 'A', 'E', 'A', 'D'};

    // Grade all answers
    for (int i = 0; i < answers.length; i++) {
      // Grade one student
      int correctCount = 0;
      for (int j = 0; j < answers[i].length; j++) {
        if (answers[i][j] == keys[j])
          correctCount++;
      }

      System.out.println("Student " + i + "'s correct count is " +
        correctCount);
    }
  }
}
```


Problem: Finding Two Points Nearest to Each Other

https://liveexample.pearsoncmg.com/dsanimation/ClosestPaireBook.html



	x	y
0	–1	3
1	–1	–1
2	1	1
3	2	0.5
4	2	–1
5	3	3
6	4	2
7	4	–0.5

```java
import java.util.Scanner;

public class FindNearestPoints {
  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);
    System.out.print("Enter the number of points: ");
    int numberOfPoints = input.nextInt();

    // Create an array to store points
    double[][] points = new double[numberOfPoints][2];
    System.out.print("Enter " + numberOfPoints + " points: ");
    for (int i = 0; i < points.length; i++) {
      points[i][0] = input.nextDouble();
      points[i][1] = input.nextDouble();
    }

    // p1 and p2 are the indices in the points array
    int p1 = 0, p2 = 1; // Initial two points
    double shortestDistance = distance(points[p1][0], points[p1][1],
      points[p2][0], points[p2][1]); // Initialize shortestDistance

    // Compute distance for every two points
    for (int i = 0; i < points.length; i++) {
      for (int j = i + 1; j < points.length; j++) {
        double distance = distance(points[i][0], points[i][1],
          points[j][0], points[j][1]); // Find distance
```



```java
        if (shortestDistance > distance) {
          p1 = i; // Update p1
          p2 = j; // Update p2
          shortestDistance = distance; // Update
shortestDistance
        }
      }
    }

    // Display result
    System.out.println("The closest two points are " +
      "(" + points[p1][0] + ", " + points[p1][1] + ") and
(" +
      points[p2][0] + ", " + points[p2][1] + ")");
  }

  /** Compute the distance between two points (x1, y1) and
(x2, y2)*/
  public static double distance(
      double x1, double y1, double x2, double y2) {
    return Math.sqrt((x2 - x1) * (x2 - x1) + (y2 - y1) *
(y2 - y1));
  }
}
```

Multidimensional Arrays

```
double[][][] scores = {
  {{7.5, 20.5}, {9.0, 22.5}, {15, 33.5}, {13, 21.5}, {15, 2.5}},
  {{4.5, 21.5}, {9.0, 22.5}, {15, 34.5}, {12, 20.5}, {14, 9.5}},
  {{6.5, 30.5}, {9.4, 10.5}, {11, 33.5}, {11, 23.5}, {10, 2.5}},
  {{6.5, 23.5}, {9.4, 32.5}, {13, 34.5}, {11, 20.5}, {16, 7.5}},
  {{8.5, 26.5}, {9.4, 52.5}, {13, 36.5}, {13, 24.5}, {16, 2.5}},
  {{9.5, 20.5}, {9.4, 42.5}, {13, 31.5}, {12, 20.5}, {16, 6.5}}
};
```

```
Which student          Which exam       Multiple-choice or essay

                 scores[ i ] [ j ] [ k ]
```