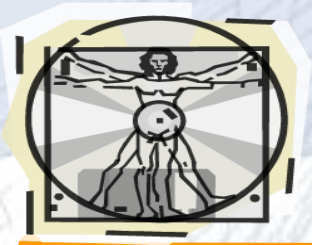
# Programming Languages - II
# Multi Dimensional Arrays

Özgür Koray ŞAHİNGÖZ
Prof.Dr.

Biruni University
Computer Engineering Department

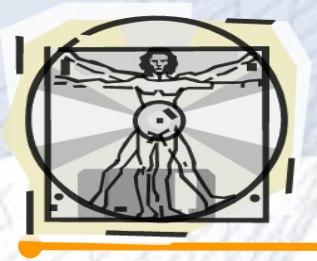


# Motivations

Thus far, you have used one-dimensional arrays to model linear collections of elements. You can use a two-dimensional array to represent a matrix or a table. For example, the following table that describes the distances between the cities can be represented using a two-dimensional array.

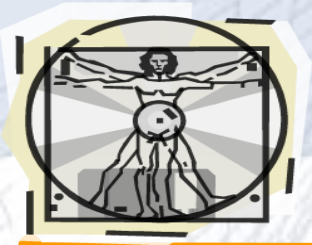
Distance Table (in miles)

| | Chicago | Boston | New York | Atlanta | Miami | Dallas | Houston |
|---|---|---|---|---|---|---|---|
| Chicago | 0 | 983 | 787 | 714 | 1375 | 967 | 1087 |
| Boston | 983 | 0 | 214 | 1102 | 1763 | 1723 | 1842 |
| New York | 787 | 214 | 0 | 888 | 1549 | 1548 | 1627 |
| Atlanta | 714 | 1102 | 888 | 0 | 661 | 781 | 810 |
| Miami | 1375 | 1763 | 1549 | 661 | 0 | 1426 | 1187 |
| Dallas | 967 | 1723 | 1548 | 781 | 1426 | 0 | 239 |
| Houston | 1087 | 1842 | 1627 | 810 | 1187 | 239 | 0 |



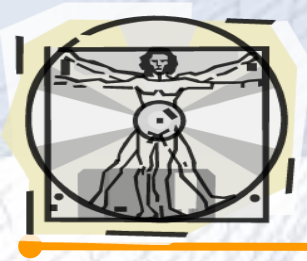
# Motivations

```
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},
};
```



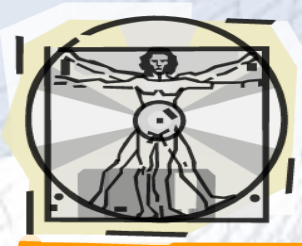
# Objectives

- To give examples of representing data using two-dimensional arrays (§8.1).
- To declare variables for two-dimensional arrays, create arrays, and access array elements in a two-dimensional array using row and column indexes (§8.2).
- To program common operations for two-dimensional arrays (displaying arrays, summing all elements, finding the minimum and maximum elements, and random shuffling) (§8.3).
- To pass two-dimensional arrays to methods (§8.4).
- To write a program for grading multiple-choice questions using two-dimensional arrays (§8.5).
- To solve the closest-pair problem using two-dimensional arrays (§8.6).
- To check a Sudoku solution using two-dimensional arrays (§8.7).
- To use multidimensional arrays (§8.8).



# 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];
```



# 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;
```

# Two-dimensional Array Illustration

| | [0] | [1] | [2] | [3] | [4] |
|---|---|---|---|---|---|
| [0] | 0 | 0 | 0 | 0 | 0 |
| [1] | 0 | 0 | 0 | 0 | 0 |
| [2] | 0 | 0 | 0 | 0 | 0 |
| [3] | 0 | 0 | 0 | 0 | 0 |
| [4] | 0 | 0 | 0 | 0 | 0 |

```
matrix = new int[5][5];
```

(a)

| | [0] | [1] | [2] | [3] | [4] |
|---|---|---|---|---|---|
| [0] | 0 | 0 | 0 | 0 | 0 |
| [1] | 0 | 0 | 0 | 0 | 0 |
| [2] | 0 | 7 | 0 | 0 | 0 |
| [3] | 0 | 0 | 0 | 0 | 0 |
| [4] | 0 | 0 | 0 | 0 | 0 |

```
matrix[2][1] = 7;
```

(b)

| | [0] | [1] | [2] |
|---|---|---|---|
| [0] | 1 | 2 | 3 |
| [1] | 4 | 5 | 6 |
| [2] | 7 | 8 | 9 |
| [3] | 10 | 11 | 12 |

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

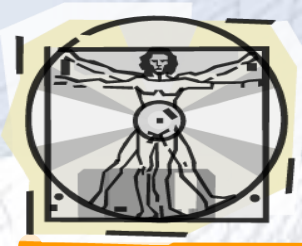
(c)

**matrix.length? 5**

**matrix[0].length? 5**

**array.length? 4**

**array[0].length? 3**



# Declaring, Creating, and Initializing Using Shorthand Notations

You can also use an array initializer to declare, create and initialize a two-dimensional array. For example,

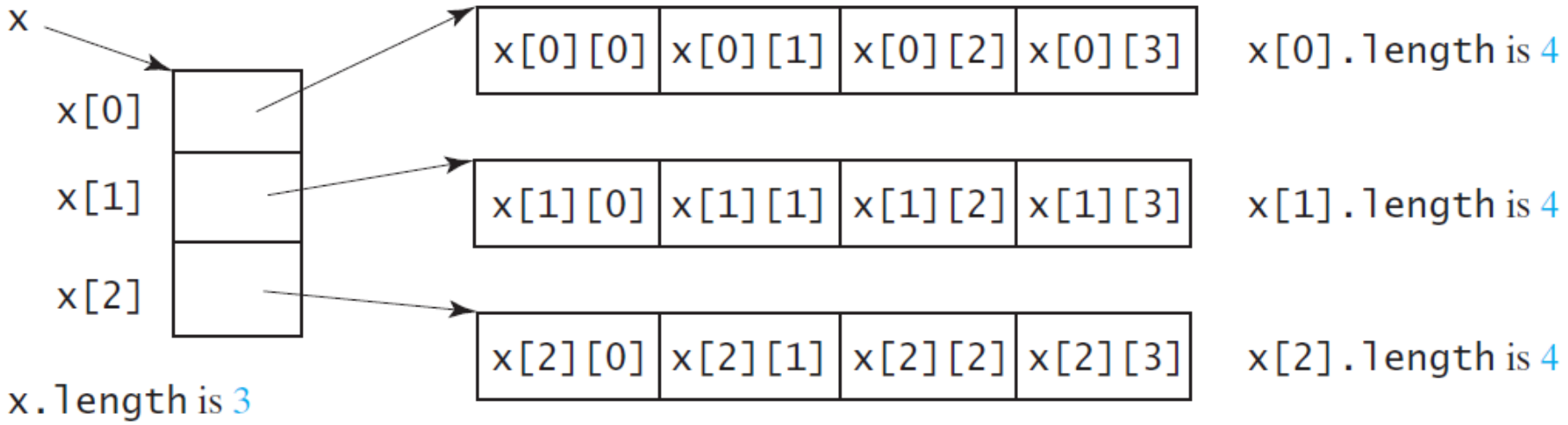
```
int[][] array = {
  {1, 2, 3},
  {4, 5, 6},
  {7, 8, 9},
  {10, 11, 12}
};
```

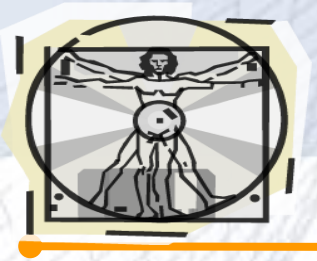
**Same as**

```
int[][] array = new int[4][3];
array[0][0] = 1; array[0][1] = 2; array[0][2] = 3;
array[1][0] = 4; array[1][1] = 5; array[1][2] = 6;
array[2][0] = 7; array[2][1] = 8; array[2][2] = 9;
array[3][0] = 10; array[3][1] = 11; array[3][2] = 12;
```

# 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**

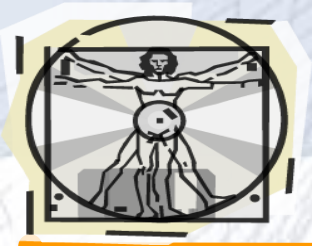
**array[1].length**

**array[2].length**

**array[3].length**

**array[4].length**

**ArrayIndexOutOfBoundsException**

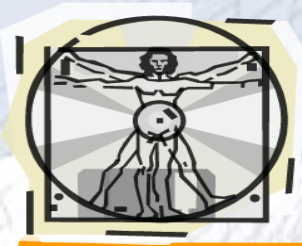


# Ragged Arrays

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,

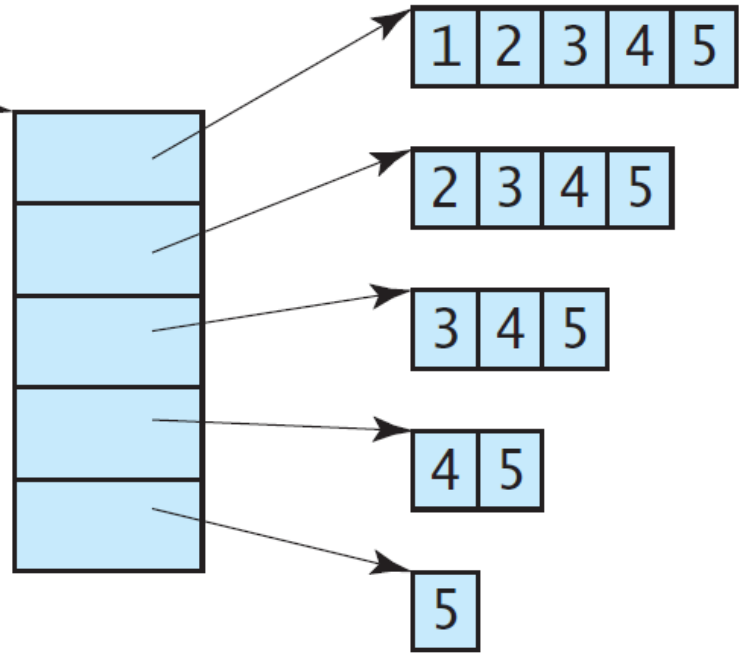
```
int[][] matrix = {
  {1, 2, 3, 4, 5},
  {2, 3, 4, 5},
  {3, 4, 5},
  {4, 5},
  {5}
};
```

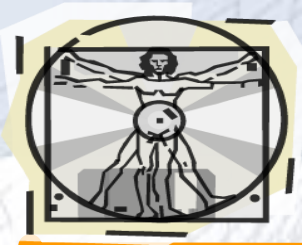
**matrix.length is 5**
**matrix[0].length is 5**
**matrix[1].length is 4**
**matrix[2].length is 3**
**matrix[3].length is 2**
**matrix[4].length is 1**



# Ragged Arrays, cont.

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

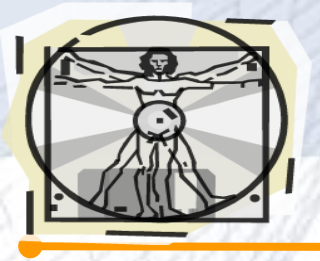




# Processing Two-Dimensional Arrays

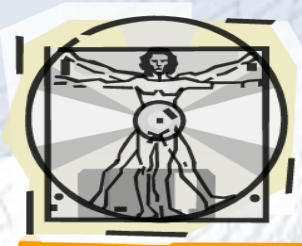
See the examples in the text.

1. (Initializing arrays with input values)
2. (Printing arrays)
3. (Summing all elements)
4. (Summing all elements by column)
5. (Which row has the largest sum)
6. (Finding the smallest index of the largest element)
7. (*Random shuffling*)



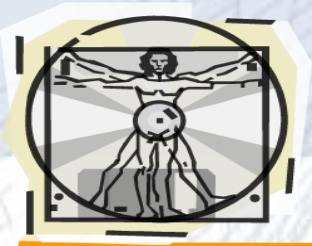
# Initializing arrays with input values

```
java.util.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();
  }
}
```



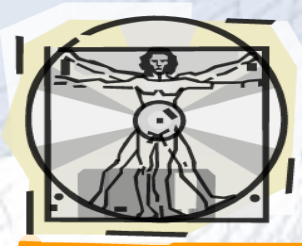
# Initializing arrays with random values

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



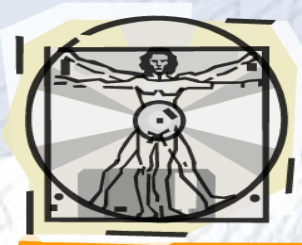
# Printing arrays

```
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();
}
```



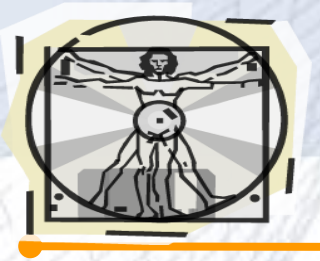
# Summing all elements

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



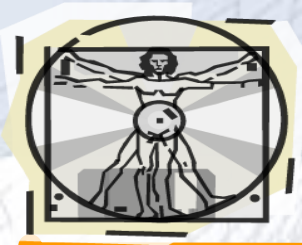
# Summing elements by column

```
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);
}
```



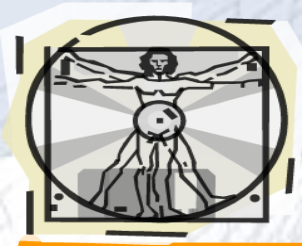
# Random shuffling

```
for (int i = 0; i < matrix.length; i++) {
  for (int j = 0; j < matrix[i].length; j++) {
    int i1 = (int)(Math.random() * matrix.length);
    int j1 = (int)(Math.random() * matrix[i].length);
          // Swap matrix[i][j] with matrix[i1][j1]
    int temp = matrix[i][j];
    matrix[i][j] = matrix[i1][j1];
    matrix[i1][j1] = temp;
  }
}
```



# Passing Tow-Dimensional Arrays to Methods

PassTwoDimensionalArray Run



# Problem: Grading Multiple-Choice Test

Objective: write a program that grades 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 |

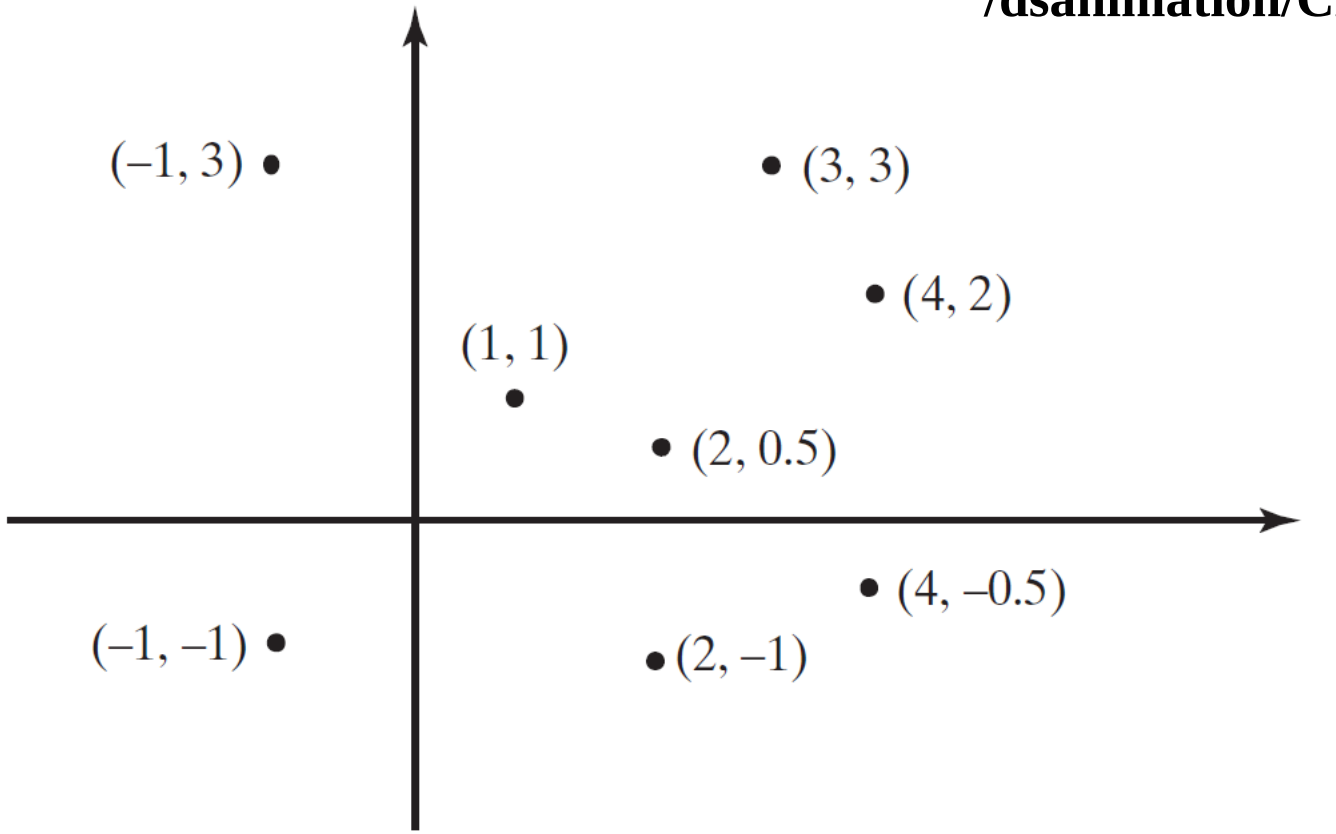
Key to the Questions:

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

**PassTwoDimensionalArray** **Run**

# 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 |

PassTwoDimensionalArray

Run

# What is Sudoku?

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 | 3 | | | 7 | | | | |
| 6 | | | 1 | 9 | 5 | | | |
| | 9 | 8 | | | | | 6 | |
| 8 | | | | 6 | | | | 3 |
| 4 | | | 8 | | 3 | | | 1 |
| 7 | | | | 2 | | | | 6 |
| | 6 | | | | | | | |
| | | | 4 | 1 | 9 | | | 5 |
| | | | | 8 | | | 7 | 9 |

**https://liveexample.pearsoncmg.com/dsanimation/Sudoku.html**

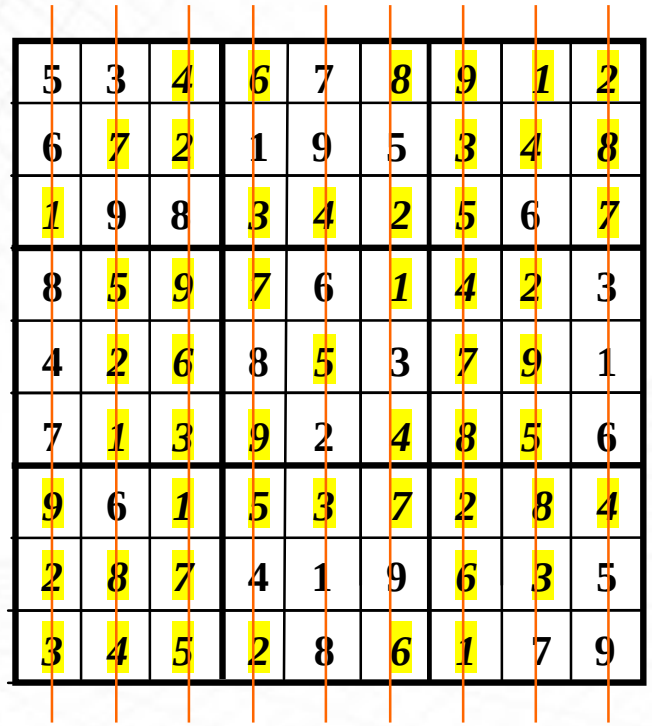
# Every row contains the numbers 1 to 9

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 | 3 | | | 7 | | | | |
| 6 | | | 1 | 9 | 5 | | | |
| | 9 | 8 | | | | | 6 | |
| 8 | | | | 6 | | | | 3 |
| 4 | | | 8 | | 3 | | | 1 |
| 7 | | | | 2 | | | | 6 |
| | 6 | | | | | | | |
| | | | 4 | 1 | 9 | | | 5 |
| | | | | 8 | | | 7 | 9 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 | 3 | *4* | *6* | 7 | *8* | *9* | *1* | *2* |
| 6 | *7* | *2* | 1 | 9 | 5 | *3* | *4* | *8* |
| *1* | 9 | 8 | *3* | *4* | *2* | *5* | 6 | *7* |
| 8 | *5* | *9* | *7* | 6 | *1* | *4* | *2* | 3 |
| 4 | *2* | *6* | 8 | *5* | 3 | *7* | *9* | 1 |
| 7 | *1* | *3* | *9* | 2 | *4* | *8* | *5* | 6 |
| *9* | 6 | *1* | *5* | *3* | *7* | *2* | *8* | *4* |
| *2* | *8* | *7* | 4 | 1 | 9 | *6* | *3* | 5 |
| *3* | *4* | *5* | *2* | 8 | *6* | *1* | 7 | 9 |

# Every column contains the numbers 1 to 9

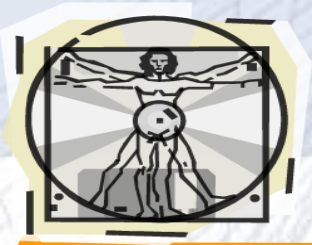
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 | 3 | | | 7 | | | | |
| 6 | | | 1 | 9 | 5 | | | |
| | 9 | 8 | | | | | 6 | |
| 8 | | | | 6 | | | | 3 |
| 4 | | | 8 | | 3 | | | 1 |
| 7 | | | | 2 | | | | 6 |
| | 6 | | | | | | | |
| | | | 4 | 1 | 9 | | | 5 |
| | | | | 8 | | | 7 | 9 |



# Every 3×3 box contains the numbers 1 to 9

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 | 3 | | | 7 | | | | |
| 6 | | | 1 | 9 | 5 | | | |
| | 9 | 8 | | | | | 6 | |
| 8 | | | | 6 | | | | 3 |
| 4 | | | 8 | | 3 | | | 1 |
| 7 | | | | 2 | | | | 6 |
| | 6 | | | | | | | |
| | | | 4 | 1 | 9 | | | 5 |
| | | | | 8 | | | 7 | 9 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 | 3 | 4 | 6 | 7 | 8 | 9 | 1 | 2 |
| 6 | 7 | 2 | 1 | 9 | 5 | 3 | 4 | 8 |
| 1 | 9 | 8 | 3 | 4 | 2 | 5 | 6 | 7 |
| 8 | 5 | 9 | 7 | 6 | 1 | 4 | 2 | 3 |
| 4 | 2 | 6 | 8 | 5 | 3 | 7 | 9 | 1 |
| 7 | 1 | 3 | 9 | 2 | 4 | 8 | 5 | 6 |
| 9 | 6 | 1 | 5 | 3 | 7 | 2 | 8 | 4 |
| 2 | 8 | 7 | 4 | 1 | 9 | 6 | 3 | 5 |
| 3 | 4 | 5 | 2 | 8 | 6 | 1 | 7 | 9 |

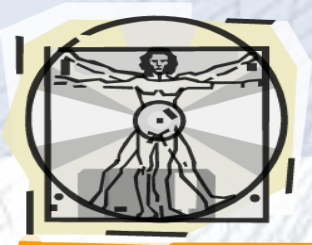


# Checking Whether a Solution Is Correct

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 | 3 | | | 7 | | | | |
| 6 | | | 1 | 9 | 5 | | | |
| | 9 | 8 | | | | | 6 | |
| 8 | | | | 6 | | | | 3 |
| 4 | | | 8 | | 3 | | | 1 |
| 7 | | | | 2 | | | | 6 |
| | 6 | | | | | | | |
| | | | 4 | 1 | 9 | | | 5 |
| | | | | 8 | | | 7 | 9 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 | 3 | *4* | *6* | 7 | *8* | *9* | *1* | *2* |
| 6 | *7* | *2* | 1 | 9 | 5 | *3* | *4* | *8* |
| *1* | 9 | 8 | *3* | *4* | *2* | *5* | 6 | *7* |
| 8 | *5* | *9* | *7* | 6 | *1* | *4* | *2* | 3 |
| 4 | *2* | *6* | 8 | *5* | 3 | *7* | *9* | 1 |
| 7 | *1* | *3* | *9* | 2 | *4* | *8* | *5* | 6 |
| *9* | 6 | *1* | *5* | *3* | *7* | *2* | *8* | *4* |
| *2* | *8* | *7* | 4 | 1 | 9 | *6* | *3* | 5 |
| *3* | *4* | *5* | *2* | 8 | *6* | *1* | 7 | 9 |

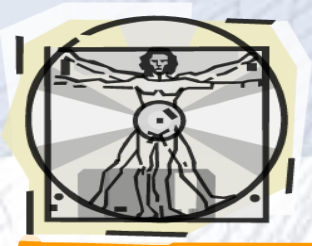
**CheckSudokuSolution** **Run**



# Multidimensional Arrays

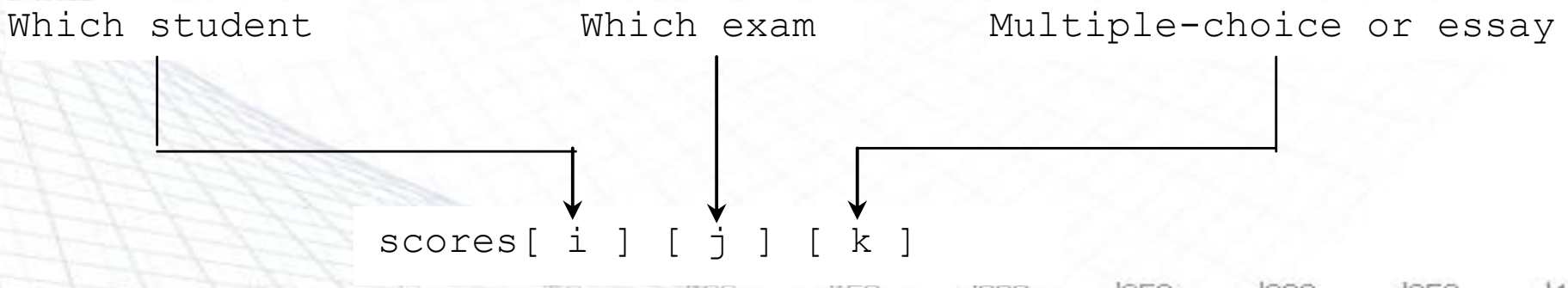
Occasionally, you will need to represent n-dimensional data structures. In Java, you can create n-dimensional arrays for any integer n.

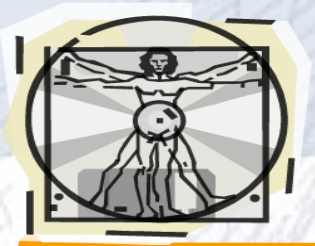
The way to declare two-dimensional array variables and create two-dimensional arrays can be generalized to declare n-dimensional array variables and create n-dimensional arrays for n >= 3.



# 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}}
};
```

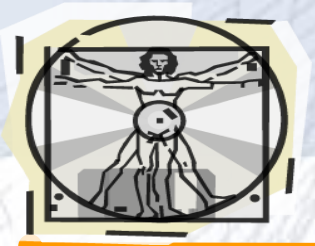




# Problem: Calculating Total Scores

Objective: write a program that calculates the total score for students in a class. Suppose the scores are stored in a three-dimensional array named scores. The first index in scores refers to a student, the second refers to an exam, and the third refers to the part of the exam. Suppose there are 7 students, 5 exams, and each exam has two parts--the multiple-choice part and the programming part. So, scores[i][j][0] represents the score on the multiple-choice part for the i's student on the j's exam. Your program displays the total score for each student.

**TotalScore** **Run**



# Problem: Weather Information

Suppose a meteorology station records the temperature and humidity at each hour of every day and stores the data for the past ten days in a text file named weather.txt. Each line of the file consists of four numbers that indicate the day, hour, temperature, and humidity. Your task is to write a program that calculates the average daily temperature and humidity for the 10 days.

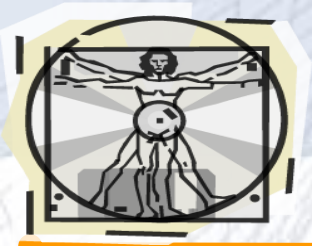
```
1 1 76.4 0.92
1 2 77.7 0.93
...
10 23 97.7 0.71
10 24 98.7 0.74
```

(a)

```
10 24 98.7 0.74
1 2 77.7 0.93
...
10 23 97.7 0.71
1 1 76.4 0.92
```

(b)

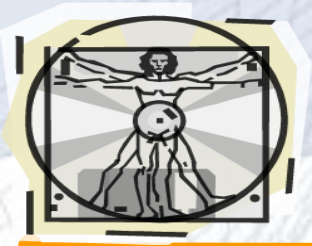
Weather Run



# Problem: Guessing Birthday

Listing 4.3, GuessBirthday.java, gives a program that guesses a birthday. The program can be simplified by storing the numbers in five sets in a three-dimensional array, and it prompts the user for the answers using a loop.

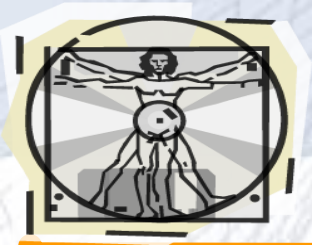
**GuessBirthdayUsingArray** **Run**



# Opening Problem

Read one hundred numbers, compute their average,

and find out how many numbers are above the average.



# Objectives

- To describe why arrays are necessary in programming (§7.1).
- To declare array reference variables and create arrays (§§7.2.1–7.2.2).
- To obtain array size using **arrayRefVar.length** and know default values in an array (§7.2.3).
- To access array elements using indexes (§7.2.4).
- To declare, create, and initialize an array using an array initializer (§7.2.5).
- To program common array operations (displaying arrays, summing all elements, finding the minimum and maximum elements, random shuffling, and shifting elements) (§7.2.6).
- To simplify programming using the foreach loops (§7.2.7).
- To apply arrays in application development (**AnalyzeNumbers**, **DeckOfCards**) (§§7.3–7.4).
- To copy contents from one array to another (§7.5).
- To develop and invoke methods with array arguments and return values (§§7.6–7.8).
- To define a method with a variable-length argument list (§7.9).
- To search elements using the linear (§7.10.1) or binary (§7.10.2) search algorithm.
- To sort an array using the selection sort approach (§7.11).
- To use the methods in the **java.util.Arrays** class (§7.12).
- To pass arguments to the main method from the command line (§7.13).