Chapter 8
Arrays

Java Software Solutions
Foundations of Program Design
9th Edition

John Lewis
William Loftus
It is not that I'm so smart. But I stay with the questions much longer.
A. Einstein
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
  – polygons and polylines
  – choice boxes
Outline

Declaring and Using Arrays
Arrays of Objects
Variable Length Parameter Lists
Two-Dimensional Arrays
Polygons and Polylines
Array of Color Objects
Choice Boxes
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` (so what is the difference?)

- 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:

![Array diagram]

The entire array has a single name

Each value has a numeric index

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

   \[
   \text{scores}[2]
   \]

refers to the value 94 (the 3rd value in the array – see previous slide).

• 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(10)];
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:

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

The name of the array is an object reference variable.
Declaring Arrays

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

```java
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:

```java
int[] weights = new int[2000];
double[] prices = new double[500];
boolean[] flags;
char[] codes = new char[1750];
flags = new boolean[20];
```
Using Arrays

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

```java
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 (why?)

• See BasicArray.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
        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 + "  ");
        }
    }
}
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 + " ");
    }
}
### Basic Array Example

The array is created with 15 elements, indexed from 0 to 14.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

After three iterations of the first loop:

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

After completing the first loop:

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

After changing the value of `list[5]`:

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

Copyright © 2012 Pearson Education, Inc.
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.
Write an array declaration to represent the ages of 100 children.

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

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

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

• Once an array is created, it has a **fixed size** (e.g. N)

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

• It’s common to introduce *off-by-one errors* when using arrays:
  ```java
  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
import java.util.Scanner;

public class ReverseOrder {

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

// Count the number of each letter occurrence
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
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."

<table>
<thead>
<tr>
<th>Character</th>
<th>Upper Case</th>
<th>Lower Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>G</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>H</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>I</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>J</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>K</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>L</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>M</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>N</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>O</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>P</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Q</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Non-alphabetic characters: 14

Sample Run (continued)

<table>
<thead>
<tr>
<th>Character</th>
<th>Upper Case</th>
<th>Lower Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>S</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>T</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>U</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>V</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>W</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Y</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Z</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Non-alphabetic characters: 14
Quiz

To swap the 3rd and 4th elements in the int array values, you would do:

values[3] = values[4];
values[4] = values[3];

True or False?
Quiz

To swap the 3rd and 4th elements in the int array values, you would do:

```c
values[3] = values[4];
values[4] = values[3];
```

False

```c
int temp = values[3];
values[3] = values[4];
values[4] = temp;
```
Quiz

Which of the following loops would adequately add 1 to each element stored in values?

A) for (j=1; j<values.length; j++) values[j]++;
B) for (j=0; j<values.length; j++) values[j]++;
C) for (j=0; j<=values.length; j++) values[j]++;
D) for (j=0; j<values.length-1; j++) values[j]++;
E) for (j=1; j<values.length-1; j++) values[j]++;

values.length gives the number of elements in the array
Quiz

Which of the following loops would adequately add 1 to each element stored in values?

A) for (j=1; j<values.length; j++)  values[j]++;  
B) for (j=0; j<values.length; j++)  values[j]++;  
C) for (j=0; j<=values.length; j++)  values[j]++;  
D) for (j=0; j<values.length-1; j++) values[j]++;  
E) for (j=1; j<values.length-1; j++)  values[j]++;  

The first array element is values[0], so the for-loop must start at 0, not 1. There are values.length elements in the array where the last element is at values.length-1, so the for loop must stop before reaching values.length.
Quiz

• Implement a class ArrayUtil with a static method that checks if two arrays of integers (parameters) are equal, i.e., they contain exactly the same number of elements and the same elements (return a boolean)
Quiz

- Implement a class ArrayUtil with a static method that checks if two arrays of integers (parameters) are equal, i.e., they contain exactly the same number of elements and the same elements (return a boolean)

```java
public class ArrayUtil {

    public static boolean equals(int[] a1, int[] a2) {
        if (a1.length != a2.length)
            return false;
        for (int i=0; i < a1.length; i++)
            if (a1[i] != a2[i])
                return false;
        return true;
    }
}
```
public static boolean equals(int[] a1, int[] a2) {
    boolean res = false;
    if (a1.length == a2.length) {
        res = true;
        int size = a1.length;
        while (res && size > 0) {
            size--;
            res = a1[size] == a2[size];
        }
    }
    return res;
}
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.
Quiz

Given the following declarations, which of the following variables are arrays?

\[
\begin{align*}
\text{int[ ] } & \ a, \ b; \\
\text{int } & \ c, \ d[ ];
\end{align*}
\]

A) a  
B) a and b  
C) a and d  
D) a, b and d  
E) a, b, c and d
Quiz

Given the following declarations, which of the following variables are arrays?

\[
\begin{align*}
\text{int[ ] a, b;} \\
\text{int c, d[ ];}
\end{align*}
\]

A) a  
B) a and b  
C) a and d  
D) a, b and d  
E) a, b, c and d

The first declaration declares both a and b to be int arrays. The second declaration declares c and d to be ints but in the case of d, an int array.
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:

```java
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`
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 + "  ");
    }
}
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 + "  ");
    }
}
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
public static void main (String[] args) {
    int[] myArray = {1,2,3};
    foo(myArray);
    for(int value : myArray)
        System.out.println(value);
}
private static void foo(int[] values) {
    values[0] = 0;
}

What is going to be printed by the main method?
Quiz

In Java, arrays are
A) primitive data types
B) objects
C) interfaces
D) primitive data types if the type stored in the array is a primitive data type and objects if the type stored in the array is an object
E) Strings
Quiz

In Java, arrays are
A) primitive data types
B) objects
C) interfaces
D) primitive data types if the type stored in the array is a primitive data type and objects if the type stored in the array is an object
E) Strings

In Java, arrays are implemented as objects. The variable is a reference variable to the block of memory that stores the entire array. However, arrays are accessed using the notation name[index] rather than by message passing (method invocation).
Quiz

What does the following code do? Assume list is an array of int values, temp is some previously initialized int value, and c is an int initialized to 0.

```java
for (int j = 0; j < list.length; j++)
    if (list[j] < temp) c++;
```
Quiz

What does the following code do? Assume list is an array of int values, temp is some previously initialized int value, and c is an int initialized to 0.

```java
for (int j = 0; j < list.length; j++)
    if (list[j] < temp) c++;
```

It counts the number of elements in list that are less than temp
Outline

Declaring and Using Arrays
Arrays of Objects
Variable Length Parameter Lists
Two-Dimensional Arrays
Polygons and Polylines
Array of Color Objects
Choice Boxes
Arrays of Objects

- The **elements** of an array can be **object references**

- The following declaration reserves space to store **5 references** to **String objects**

  ```java
  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:

  ```java
  System.out.println(words[0]);
  ```

- At this point, the following line of code will print `null`:
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 (e.g. "I am a literal")

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

```java
String[] verbs = {"play", "work", "eat", "sleep", "run"};
```
Arrays of Objects

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

• The letter grades include plus and minus designations, so must be stored as strings instead of char

• See GradeRange.java
• See Grade.java
public class GradeRange {

    // Creates an array of Grade objects and prints them.
    public static void main (String[] args) {
        Grade[] grades = {
            new Grade("A", 95), new Grade("A-", 90),
            new Grade("B+", 87), new Grade("B", 85), new Grade("B-", 80),
            new Grade("C+", 77), new Grade("C", 75), new Grade("C-", 70),
            new Grade("D+", 67), new Grade("D", 65), new Grade("D-", 60),
            new Grade("F", 0)
        };

        for (Grade letterGrade : grades)
            System.out.println (letterGrade);
    }
}
public class GradeRange {
    public static void main(String[] args) {
        Grade[] grades = {
            new Grade("A", 95),
            new Grade("A-", 90),
            new Grade("B+", 87),
            new Grade("B", 85),
            new Grade("B-", 80),
            new Grade("C+", 77),
            new Grade("C", 75),
            new Grade("C-", 70),
            new Grade("D+", 67),
            new Grade("D", 65),
            new Grade("D-", 60),
            new Grade("F", 0)
        };
        for (Grade letterGrade : grades) {
            System.out.println(letterGrade);
        }
    }
}
public class Grade
{
    private String name;
    private int lowerBound;

    public Grade (String grade, int cutoff)
    {
        name = grade;
        lowerBound = cutoff;
    }

    public String toString()
    {
        return name + "\t" + lowerBound;
    }
}

//***********
//-----------------------------
// Name mutator.
//-----------------------------
public void setName (String grade) {
    name = grade;
}

//-----------------------------
// Lower bound mutator.
//-----------------------------
public void setLowerBound (int cutoff) {
    lowerBound = cutoff;
}

continue
continue

// -----------------------------
//  Name accessor.
// -----------------------------
public String getName()
{
    return name;
}

// -----------------------------
//  Lower bound accessor.
// -----------------------------
public int getLowerBound()
{
    return lowerBound;
}
Exercise

• Write a declaration that creates an array of \texttt{Integer} objects called \texttt{primes} and fills it with the first four \texttt{Integer} primes created using the \texttt{new} operator.

• Hint: use an initializer list and for each element of the list use the \texttt{new} operator for instantiating \texttt{Integer} objects.
Exercise

• Write a declaration that creates an array of Integer objects called primes and fills it with the first four Integer primes created using the new operator

```
Integer[] intArray = {new Integer(2),
                     new Integer(3), new Integer(5),
                     new Integer(7)};
```
Arrays of Objects

• Now let's look at an example that manages a collection of DVD objects

• An initial capacity of 100 is created for the collection

• If more room is needed, a private method is used to create a larger array and transfer the current DVDs

• See Movies.java
• See DVDCollection.java
• See DVD.java
Arrays of Objects

- A UML diagram for the Movies program:
public class Movies
{
    public static void main (String[] args)
    {
        DVDCollection movies = new DVDCollection();

        movies.addDVD ("The Godfather", "Francis Ford Coppala", 1972, 24.95, true);
        movies.addDVD ("District 9", "Neill Blomkamp", 2009, 19.95, false);
        movies.addDVD ("Iron Man", "Jon Favreau", 2008, 15.95, false);
        movies.addDVD ("All About Eve", "Joseph Mankiewicz", 1950, 17.50, false);
        movies.addDVD ("The Matrix", "Andy & Lana Wachowski", 1999, 19.95, true);

        System.out.println (movies);

        movies.addDVD ("Iron Man 2", "Jon Favreau", 2010, 22.99, false);
        movies.addDVD ("Casablanca", "Michael Curtiz", 1942, 19.95, false);

        System.out.println (movies);
    }
}
public class Movies {

    //-------------------------------------------------------------------
    //  Creates a DVDCollection object and adds some DVDs to it. Prints
    //  reports on the status of the collection.
    //-------------------------------------------------------------------
    public static void main (String[] args) {
        DVDCollection movies = new DVDCollection();
        movies.addDVD("The Godfather", "Francis Ford Coppala", 1972, 24.95, true);
        movies.addDVD("District 9", "Neill Blomkamp", 2009, 19.95, false);
        movies.addDVD("Iron Man", "Jon Favreau", 2008, 15.95, false);
        movies.addDVD("All About Eve", "Joseph Mankiewicz", 1950, 17.50, false);
        movies.addDVD("The Matrix", "Andy & Lana Wachowski", 1999, 19.95, true);
        System.out.println(movies);
        movies.addDVD("Iron Man 2", "Jon Favreau", 2010, 22.99, false);
        movies.addDVD("Casablanca", "Michael Curtiz", 1942, 19.95, false);
        System.out.println(movies);    
    }
}

Output

--------------------------------------------------------
My DVD Collection

Number of DVDs: 5
Total cost: $98.30
Average cost: $19.66

DVD List:
$24.95 1972  The Godfather  Francis Ford Coppala  Blu-Ray
$19.95 2009  District 9  Neill Blomkamp
$15.95 2008  Iron Man  Jon Favreau
$17.50 1950  All About Eve  Joseph Mankiewicz
$19.95 1999  The Matrix  Andy & Lana Wachowski  Blu-Ray

continue
public class Movies {
    public static void main (String[] args) {
        DVDCollection movies = new DVDCollection();
        movies.addDVD("The Godfather", "Francis Ford Coppala", 1972, 24.95, true);
        movies.addDVD("District 9", "Neill Blomkamp", 2009, 19.95, false);
        movies.addDVD("Iron Man", "Jon Favreau", 2008, 15.95, false);
        movies.addDVD("All About Eve", "Joseph Mankiewicz", 1950, 17.50, false);
        movies.addDVD("The Matrix", "Andy & Lana Wachowski", 1999, 19.95, true);
        System.out.println(movies);
        movies.addDVD("Iron Man 2", "Jon Favreau", 2010, 22.99, false);
        movies.addDVD("Casablanca", "Michael Curtiz", 1942, 19.95, false);
        System.out.println(movies);
    }
}
import java.text.NumberFormat;

public class DVD {

    private String title, director;
    private int year;
    private double cost;
    private boolean bluRay;

    //---------------------------------------------------------------------
    //  Creates a new DVD with the specified information.
    //---------------------------------------------------------------------
    public DVD (String title, String director, int year, double cost, boolean bluRay) {
        this.title = title;
        this.director = director;
        this.year = year;
        this.cost = cost;
        this.bluRay = bluRay;
    }

    continue
```
public String toString()
{
    NumberFormat fmt = NumberFormat.getCurrencyInstance();

    String description;

    description = fmt.format(cost) + "\t" + year + "\t"
    description += title + "\t" + director;

    if (bluRay)
        description += "\t" + "Blu-Ray"

    return description;
}
```
import java.text.NumberFormat;

public class DVDCollection {
    private DVD[] collection;
    private int count;
    private double totalCost;

    // Constructor: Creates an initially empty collection.
    public DVDCollection () {
        collection = new DVD[100];
        count = 0;
        totalCost = 0.0;
    }
}

continue
public void addDVD (String title, String director, int year, double cost, boolean bluRay)
{
    if (count == collection.length)
        increaseSize();

    collection[count] = new DVD (title, director, year, cost, bluRay);
    totalCost += cost;
    count++;
}
public String toString()
{
    NumberFormat fmt = NumberFormat.getCurrencyInstance();

    String report = "~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
    My DVD Collection
    Number of DVDs: " + count + "\n"
    report += "Total cost: " + fmt.format(totalCost) + "\n"
    report += "Average cost: " + fmt.format(totalCost/count);

    report += "\n\nDVD List:
";

    for (int dvd = 0; dvd < count; dvd++)
        report += collection[dvd].toString() + "\n";

    return report;
}

Can we implement this loop using a for each statement?
for (DVD dvdObj : collection)
    report += dvdObj + "\n";
continue

// Increases the capacity of the collection by creating a
// larger array and copying the existing collection into it.
private void increaseSize ()
{
    DVD[] temp = new DVD[collection.length * 2];

    for (int dvd = 0; dvd < collection.length; dvd++)
        temp[dvd] = collection[dvd];

    collection = temp;
}

Quiz

• Suppose \texttt{team} is an array of strings meant to hold the names: Amanda, Clare, Emily, Julie, Katie, and Maria.
  – Write an array \texttt{declaration} for \texttt{team}

  – Show how to both \texttt{declare} and \texttt{populate} \texttt{team} using an initializer list.
Quiz

• Suppose `team` is an array of strings meant to hold the names: Amanda, Clare, Emily, Julie, Katie, and Maria.
  – Write an array declaration for `team`

    ```java
    String[] team = new String[6];
    ```

  – Show how to both declare and populate `team` using an initializer list.

    ```java
    String[] team = {"Amanda", "Clare", "Emily", "Julie", "Katie", "Maria"};
    ```
Quiz

Assume that BankAccount is a predefined class and that the declaration BankAccount[] firstEmpireBank; has already been performed. Then the following instruction reserves memory space for …

    firstEmpireBank = new BankAccount[1000];

A) a reference variable to the memory that stores all 1000 BankAccount entries
B) 1000 reference variables, each of which point to a single BankAccount entry
C) a single BankAccount entry
D) 1000 BankAccount entries
E) 1000 reference variables and 1000 BankAccount entries
Quiz

Assume that BankAccount is a predefined class and that the declaration BankAccount[ ] firstEmpireBank; has already been performed. Then the following instruction reserves memory space for

```
    firstEmpireBank = new BankAccount[1000];
```

A) a reference variable to the memory that stores all 1000 BankAccount entries

B) 1000 reference variables, each of which point to a single BankAccount entry

C) a single BankAccount entry

D) 1000 BankAccount entries

E) 1000 reference variables and 1000 BankAccount entries
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 the **main method** of the **StateEval** program:

  ```
  java StateEval pennsylvania texas arizona
  ```

• **See** **NameTag.java**
//********************************************************************
// NameTag.java       Author: Lewis/Loftus
//
// Demonstrates the use of command line arguments.
//********************************************************************

public class NameTag
{
    //-----------------------------------------------------------------
    // Prints a simple name tag using a greeting and a name that is
    // specified by the user.
    //-----------------------------------------------------------------
    public static void main (String[] args)
    {
        System.out.println();
        System.out.println("     " + args[0]);
        System.out.println("My name is " + args[1]);
    }
}

public class NameTag {
    public static void main (String[] args) {
        System.out.println();
        System.out.println("     "+args[0]);
        System.out.println("My name is "+args[1]);
    }
}
Outline

Declaring and Using Arrays
Arrays of Objects
Variable Length Parameter Lists
Two-Dimensional Arrays
Polygons and Polylines
Array of Color Objects
Choice Boxes
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

```java
// 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 additional parameter

• 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

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

Indicates a variable length parameter list

`element type` `array name`
public double average (int ... list) {
    double result = 0.0;

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

    return result;
}
Variable Length Parameter Lists

• The type of the parameter can be any primitive or object type:

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

Write method called \texttt{distance} that accepts a variable number of integers (which each represent the distance of one leg of a trip) and returns the total distance of the trip.
Quick Check

Write method called `distance` that accepts a variable number of integers (which each represent the distance of one leg of a trip) and returns the total distance of the trip.

```java
public int distance (int ... list){
    int sum = 0;
    if (list.length != 0)
        for (int num : list)
            sum = sum + num;
    return sum;
}
```
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:

```java
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 method cannot accept two sets of varying parameters

• Constructors can also be set up to accept a variable number of parameters

• See VariableParameters.java
• See Family.java
public class VariableParameters
{
    // ------------------------------
    // Creates two Family objects using a constructor that accepts
    // a variable number of String objects as parameters.
    // ------------------------------
    public static void main (String[] args)
    {
        Family lewis = new Family ("John", "Sharon", "Justin", "Kayla",
                                  "Nathan", "Samantha");

        Family camden = new Family ("Stephen", "Annie", "Matt", "Mary",
                                   "Simon", "Lucy", "Ruthie", "Sam", "David");

        System.out.println(lewis);
        System.out.println();
        System.out.println(camden);
    }
}
public class VariableParameters {
    public static void main (String[] args) {
        Family lewis = new Family("John", "Sharon", "Justin", "Kayla",
                                  "Nathan", "Samantha");
        Family camden = new Family("Stephen", "Annie", "Matt", "Mary",
                                  "Simon", "Lucy", "Ruthie", "Sam", "David");

        System.out.println(lewis);
        System.out.println(camden);
    }
}

Output
John
Sharon
Justin
Kayla
Nathan
Samantha
Stephen
Annie
Matt
Mary
Simon
Lucy
Ruthie
Sam
David

Write the code of the class Family – instance data and constructor
public class Family {
    private String[] members;

    public Family (String ... names) {
        members = names;
    }

    continue
public String toString()
{
    String result = "";

    for (String name : members)
    
        result += name + "\n";

    return result;
}
Declaration and Using Arrays
Arrays of Objects
Variable Length Parameter Lists
Two-Dimensional Arrays
Polygons and Polylines
Array of Color Objects
Choice Boxes
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:

```java
int[][] table = new int[12][50];
```

• An array element is referenced using two index values:

```java
value = table[3][6]
```

• The array stored in one row can be specified using one index (**table[0]** is the first row array)
# Two-Dimensional Arrays

<table>
<thead>
<tr>
<th>Expression</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>table</code></td>
<td><code>int[][]</code></td>
<td>2D array of integers, or array of integer arrays</td>
</tr>
<tr>
<td><code>table[5]</code></td>
<td><code>int[]</code></td>
<td>array of integers</td>
</tr>
<tr>
<td><code>table[5][12]</code></td>
<td><code>int</code></td>
<td>integer</td>
</tr>
</tbody>
</table>

- See [TwoDArray.java](#)
- See [SodaSurvey.java](#)
public class TwoDArray
{
    // *-----------------------------------------------------------------
    //  Creates a 2D array of integers, fills it with increasing integer values, then prints them out.
    // *-----------------------------------------------------------------
    public static void main (String[] args)
    {
        int[][] table = new int[5][10];

        // Load the table with values
        for (int row=0; row < table.length; row++)
        {
            for (int col=0; col < table[row].length; col++)
                table[row][col] = row * 10 + col;
        }

        // Print the table
        for (int row=0; row < table.length; row++)
        {
            for (int col=0; col < table[row].length; col++)
                System.out.print (table[row][col] + " \t");
            System.out.println();
        }
    }
}
public static void main (String[] args)
{
    int[][] table = new int[5][10];

    // Load the table with values
    for (int row=0; row < table.length; row++)
        for (int col=0; col < table[row].length; col++)
            table[row][col] = row * 10 + col;

    // Print the table
    for (int row=0; row < table.length; row++)
    {
        for (int col=0; col < table[row].length; col++)
            System.out.print (table[row][col] + "\t");
        System.out.println();
    }
}
import java.text.DecimalFormat;

public class SodaSurvey
{
    // Determines and prints the average of each row (soda) and each column (respondent) of the survey scores.
    public static void main (String[] args)
    {
        int[][] scores = { {3, 4, 5, 2, 1, 4, 3, 2, 4, 4},
                           {2, 4, 3, 4, 3, 3, 2, 1, 2, 2},
                           {3, 5, 4, 5, 5, 3, 2, 5, 5, 5},
                           {1, 1, 1, 3, 1, 2, 1, 3, 2, 4} };

        final int SODAS = scores.length;
        final int PEOPLE = scores[0].length;

        int[] sodaSum = new int[SODAS];
        int[] personSum = new int[PEOPLE];
for (int soda=0; soda < SODAS; soda++)
   for (int person=0; person < PEOPLE; person++)
   {
      sodaSum[soda] += scores[soda][person];
      personSum[person] += scores[soda][person];
   }

DecimalFormat fmt = new DecimalFormat("0.#");
System.out.println("Averages:
");

for (int soda=0; soda < SODAS; soda++)
   System.out.println("Soda #" + (soda+1) + ": " +
      fmt.format((float)sodaSum[soda]/PEOPLE));

System.out.println();
for (int person=0; person < PEOPLE; person++)
   System.out.println("Person #" + (person+1) + ": " +
      fmt.format((float)personSum[person]/SODAS));
Output

Averages:

Soda #1: 3.2
Soda #2: 2.6
Soda #3: 4.2
Soda #4: 1.9

Person #1: 2.2
Person #2: 3.5
Person #3: 3.2
Person #4: 3.5
Person #5: 2.5
Person #6: 3
Person #7: 2
Person #8: 2.8
Person #9: 3.2
Person #10: 3.8
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
Quiz

• The trace of an n x m bidimensional matrix A, with entries $a_{ij}$ is defined as:

$$trace(A) = \sum_{i=1}^{\min(n,m)} a_{ii}$$

• Implement a static method of the class ArrayUtil that computes the trace of an int matrix (int[][] a) passed as parameter to the method

• Index runs from 0 to Math.min(a.length, a[0].length)
Solution

public static int trace(int[][] m) {
    int res = 0;
    int min = Math.min(m.length, m[0].length);
    for (int i = 0; i < min; i++) {
        res += m[i][i];
    }
    return res;
}
Arrays class

- Provides a number of useful **static** methods for manipulating arrays

  - `asList(T ... a)` : returns a `List<T>` object containing the input objects. For example:
    ```java
    List<String> stooges = Arrays.asList("Larry", "Moe", "Curly");
    ```

  - `binarySearch(int[] a, int key)` : searches the specified array of ints for the specified value. Returns index of the search key, if it is contained in the array (otherwise a negative value)

  - `copyOf(long[] original, int newLength)` : returns a copy the specified array, truncating or padding with zeros (if necessary) so the copy has the specified length
Polygons and Polylines

• Arrays can be helpful in graphics processing

• For example, they can be used to store a list of coordinates

• A *polygon* is a multisided, closed shape

• A *polyline* is similar to a polygon except that its endpoints do not meet, and it cannot be filled

• See *Rocket.java*
import javafx.application.Application;
import javafx.scene.Group;
import javafx.scene.Scene;
import javafx.scene.paint.Color;
import javafx.scene.shape.Polygon;
import javafx.scene.shape.Polyline;
import javafx.stage.Stage;

******************************************************************************
// Rocket.java Author: Lewis/Loftus
//
// Demonstrates the use of polygons and polylines.
******************************************************************************

public class Rocket extends Application {

    //----------------------------------------------------------------------------
    // Displays a rocket lifting off. The rocket and hatch are polygons
    // and the flame is a polyline.
    //----------------------------------------------------------------------------
    public void start(Stage primaryStage) {
        double[] hullPoints = {200, 25, 240, 60, 240, 230, 270, 260,
                                270, 300, 140, 300, 140, 260, 160, 230, 160, 60};

        Polygon rocket = new Polygon(hullPoints);
        rocket.setFill(Color.BEIGE);

        continue
double[] hatchPoints = {185, 70, 215, 70, 220, 120, 180, 120};

Polygon hatch = new Polygon(hatchPoints);
hatch.setFill(Color.MAROON);


Polyline flame = new Polyline(flamePoints);
flame.setStroke(Color.RED);
flame.setStrokeWidth(3);

Group root = new Group(rocket, hatch, flame);

Scene scene = new Scene(root, 400, 400, Color.BLACK);

primaryStage.setTitle("Rocket");
primaryStage.setScene(scene);
primaryStage.show();

}
double[] hatchPoints = {185, 70, 215, 70, 220, 120, 180, 120};
Polygon hatch = new Polygon(hatchPoints);
hatch.setFill(Color.MAROON);

double[] flamePoints = {142, 310, 142, 330, 150, 325, 155, 380,
                       165, 340, 175, 360, 190, 350, 200, 375, 215, 330, 220, 360,
                       225, 355, 230, 370, 240, 340, 255, 370, 260, 335, 268, 340,
                       268, 310};
Polyline flame = new Polyline(flamePoints);
flame.setStroke(Color.RED);
flame.setStrokeWidth(3);

Group root = new Group(rocket, hatch, flame);
Scene scene = new Scene(root, 400, 400, Color.BLACK);
primaryStage.setTitle("Rocket");
primaryStage.setScene(scene);
primaryStage.show();
Outline

Declaring and Using Arrays
Arrays of Objects
Variable Length Parameter Lists
Two-Dimensional Arrays
Polygons and Polylines
Array of Color Objects
Choice Boxes
Arrays of Color Objects

• Let's look at an example that uses an array of Color objects

• When the mouse button is clicked, a colored dot is displayed

• A double-click clears the window

• See Dots.java
import javafx.application.Application;
import javafx.scene.Group;
import javafx.scene.Scene;
import javafx.scene.input.MouseEvent;
import javafx.scene.paint.Color;
import javafx.scene.shape.Circle;
import javafx.scene.text.Font;
import javafx.scene.text.Text;
import javafx.stage.Stage;

//************************************************************************
// Dots.java          Author: Lewis/Loftus
//************************************************************************

public class Dots extends Application
{
    private Color[] colorList = {Color.RED, Color.CYAN, Color.MAGENTA,
        Color.YELLOW, Color.LIME, Color.WHITE};

    private int colorIndex = 0;
    private int count = 0;
    private Text countText;
    private Group root;

    continue
public void start(Stage primaryStage) {
    countText = new Text(20, 30, "Count: 0");
    countText.setFont(new Font(18));
    countText.setFill(Color.WHITE);

    root = new Group(countText);

    Scene scene = new Scene(root, 400, 300, Color.BLACK);
    scene.setOnMouseClicked(this::processMouseClick);

    primaryStage.setTitle("Dots");
    primaryStage.setScene(scene);
    primaryStage.show();
}
// Process a mouse click by adding a circle to that location. Circle colors rotate through a set list of colors. A double click clears the dots and resets the counter.

public void processMouseClick(MouseEvent event) {
    if (event.getClickCount() == 2) // double click
    {
        count = 0;
        colorIndex = 0;
        root.getChildren().clear();
        countText.setText("Count: 0");
        root.getChildren().add(countText);
    }
    else
    {
        Circle circle = new Circle(event.getX(), event.getY(), 10);
        circle.setFill(colorList[colorIndex]);
        root.getChildren().add(circle);

        colorIndex = (colorIndex + 1) % colorList.length;

        count++;
        countText.setText("Count: " + count);
    }
}

// Process a mouse click by adding a circle to that location. Circle colors rotate through a set list of colors. A double click clears the dots and resets the counter.

public void processMouseClick(MouseEvent event) {
    if (event.getClickCount() == 2) // double click
    {
        count = 0;
        colorIndex = 0;
        root.getChildren().clear();
        countText.setText("Count: 0");
        root.getChildren().add(countText);
    }
    else
    {
        Circle circle = new Circle(event.getX(), event.getY(), 10);
        circle.setFill(colorList[colorIndex]);
        root.getChildren().add(circle);
        colorIndex = (colorIndex + 1) % colorList.length;
        count++;
        countText.setText("Count: " + count);
    }
}
Outline

Declaring and Using Arrays
Arrays of Objects
Variable Length Parameter Lists
Two-Dimensional Arrays
Polygons and Polylines
Array of Color Objects
Choice Boxes
Choice Boxes

• A *choice box* lets the user select one of several options from a drop-down menu

• The **JukeBox** example allows the user to select a song from a choice box

• Play and Stop buttons control the song playback

• See **JukeBox.java**
import java.io.File;
import javafx.application.Application;
import javafx.event.ActionEvent;
import javafx.geometry.Insets;
import javafx.geometry.Pos;
import javafx.scene.Scene;
import javafx.scene.control.Button;
import javafx.scene.control.ChoiceBox;
import javafx.scene.control.Label;
import javafx.scene.layout.HBox;
import javafx.scene.layout.VBox;
import javafx.scene.media.AudioClip;
import javafx.stage.Stage;

//************************************************************************
// JukeBox.java       Author: Lewis/Loftus
//
// Demonstrates the use of a combo box and audio clips.
//************************************************************************

public class JukeBox extends Application
{
    private ChoiceBox<String> choice;
    private AudioClip[] tunes;
    private AudioClip current;
    private Button playButton, stopButton;

    continue
Presents an interface that allows the user to select and play a tune from a drop down box.

```java
public void start(Stage primaryStage)
{

    File[] audioFiles = {new File("westernBeat.wav"),
        new File("classical.wav"), new File("jeopardy.mp3"),
        new File("eightiesJam.wav"), new File("newAgeRythm.wav"),
        new File("lullaby.mp3"), new File("hitchcock.wav")};

    tunes = new AudioClip[audioFiles.length];
    for (int i = 0; i < audioFiles.length; i++)
        tunes[i] = new AudioClip(audioFiles[i].toURI().toString());

    current = tunes[0];

    Label label = new Label("Select a tune:");
}
choice = new ChoiceBox<String>();
choice.getItems().addAll(names);
choice.getSelectionModel().selectFirst();
choice.setOnAction(this::processChoice);

playButton = new Button("Play");
stopButton = new Button("Stop");
HBox buttons = new HBox(playButton, stopButton);
buttons.setSpacing(10);
buttons.setPadding(new Insets(15, 0, 0, 0));
buttons.setAlignment(Pos.CENTER);

playButton.setOnAction(this::processButtonPush);
stopButton.setOnAction(this::processButtonPush);

VBox root = new VBox(label, choice, buttons);
root.setPadding(new Insets(15, 15, 15, 25));
root.setSpacing(10);
root.setStyle("-fx-background-color: skyblue");

Scene scene = new Scene(root, 300, 150);

primaryStage.setTitle("Java Juke Box");
primaryStage.setScene(scene);
primaryStage.show();

continue
// When a choice box selection is made, stops the current clip (if one was playing) and sets the current tune.

public void processChoice(ActionEvent event) {
    current.stop();
    current = tunes[choice.getSelectionModel().getSelectedIndex()];
}

// Handles the play and stop buttons. Stops the current clip in either case. If the play button was pressed, (re)starts the current clip.

public void processButtonPush(ActionEvent event) {
    current.stop();

    if (event.getSource() == playButton)
        current.play();
}

When a choice box selection is made, stops the current clip (if one was playing) and sets the current tune.

```java
public void processChoice(ActionEvent event) {
    current.stop();
    current = tunes[choice.getSelectionModel().getSelectedIndex()];
}
```

Handles the play and stop buttons. Stops the current clip in either case. If the play button was pressed, (re)starts the current clip.

```java
public void processButtonPush(ActionEvent event) {
    current.stop();
    if (event.getSource() == playButton) current.play();
}
```
Summary

• Chapter 8 has focused on:
  – array declaration and use
  – bounds checking and capacity
  – arrays that store object references
  – variable length parameter lists
  – multidimensional arrays
  – polygons and polylines
  – choice boxes
Given the following method:

```java
public static void differentArray(float[] x)
{
    x = new float[100];
    x[0] = 26.9f;
}
```

what is the output after the following code is run?

```java
float[] xx = new float[100];
xx[0] = 55.8f;
differentArray(xx);
System.out.println("xx[0] = " + xx[0]);
```
Quiz

Given the following method:

```java
public void differentArray(float[] x)
{
    x = new float[100];
    x[0] = 26.9f;
}
```

what is the output after the following code is run?

```java
float[] xx = new float[100];
xx[0] = 55.8f;
differentArray(xx);
System.out.println("xx[0] = " + xx[0]);
```

`xx[0] = 55.8`
public static void tryString(String s) {
    s = "a different string";
}

When the following code is executed, what does the print statement produce?

String str = "This is a string literal.";
tryString(str);
System.out.println("str = " + str);
public static void tryString(String s)
{
    s = "a different string";
}

When the following code is executed, what does the print statement produce?

String str = "This is a string literal.";
tryString(str);
System.out.println("str = " + str);

str = This is a string literal.
Exercise

• What does the following code fragment print?

```java
int[] a = new int[10];
for (int i = 0; i < 10; i++)
    a[i] = 9 - i;
for (int i = 0; i < 10; i++)
    a[i] = a[a[i]];
for (int i = 0; i < 10; i++)
    System.out.println(a[i]);
```
These values (last row) will be printed.
Exercise

• Write a method that takes a square int matrix of size nxn as parameter and \textbf{transforms} it into the transpose matrix

• This means that there is side effect on the original matrix

• \([A^T]_{ij} = [A]_{ji}\)
Solution

```java
public static void transpose(int[][] a) {
    int n = Math.min(a.length, a[0].length);
    for (int i = 0; i < n; i++)
        for (int j = i + 1; j < n; j++) {
            int p = a[i][j];
            a[i][j] = a[j][i];
            a[j][i] = p;
        }
}
```

This is not raising an exception if the input matrix is not a square matrix.
Exercise

• Write a method that takes a square int matrix of size nxn as parameter and returns a new matrix that is the transpose of the input (no side effect on the original matrix)
public static int[][] cTranspose(int[][] a) {
    int n = Math.min(a.length, a[0].length);
    int[][] b = new int[n][n];
    for (int i = 0; i < n; i++)
        for (int j = 0; j < n; j++)
            b[j][i] = a[i][j];
    return b;
}
Exercise

• Write a method that **randomly shuffles the elements in an array of double values**

• Hint: swap each index position $i$ of the array with a random entry in position $j$: $i \leq j < \text{array.length}$

• For instance if the input is an array `myAr` of length 3 you must swap
  
  – At the first step, the value of `myAr[0]` with the value stored in a random position among 0, 1, 2
  
  – At the second step, the value of `myAr[1]` with the value stored in a random position among 1, 2
Solution

```java
public static void shuffle(double[] a) {
    int N = a.length;
    Random gen = new Random();
    for (int i = 0; i < N; i++) {
        // Exchange a[i] with random element in a[i..N-1]
        int r = i + gen.nextInt(N - i);
        double temp = a[i];
        a[i] = a[r];
        a[r] = temp;
    }
}
```
Exercise

• Write a method that given two int matrices with compatible size it returns a matrix that is the multiplication of the two matrices.
• If the two matrices have not compatible size the method returns an empty matrix.
• Matrices A and B can be multiplied if the number of columns of A is equal to the number of rows of B.

\[(AB)_{ij} = \sum_{k=1}^{m} A_{ik} B_{kj}\]
public static int[][] mult(int[][] a, int[][] b) {
    int size = b.length;
    if (a[0].length != size)
        return new int[][];
    // Empty matrix if multiplication is not feasible
    int rows = a.length;
    int cols = b[0].length;
    int[][] c = new int[rows][cols];

    for (int i = 0; i < rows; i++)
        for (int j = 0; j < cols; j++)
            for (int k = 0; k < size; k++)
                c[i][j] += a[i][k] * b[k][j];

    return c;
}
Exercise

• Write a static method that computes for each number \( k \) between 0 and \( 2n \) (included) the probability that the sum of the face values of two dice with \( n \) faces is \( k \).
  – static void genProbs(double[] dist, int n)
  – After the execution of the method, the array \( \text{dist} \) of size \((2n+1)\) will store the computed probabilities (at index \( k \) the probability that the sum is \( k \)).

• Hint: generate in a nested loop all the possible \( n^2 \) combinations of the face values of the two dice and increment \( \text{dist}[k] \) when the sum of the face values is \( k \). Then divide the \( \text{dist} \) entries by the number of possible combinations of face values, \( n^2 \).
public class TwoDiceProb {

    public static void genProbs(double[] dist, int n) {
        for (int i = 1; i <= n; i++)
            for (int j = 1; j <= n; j++)
                dist[i + j] += 1.0;
        for (int k = 2; k <= 2 * n; k++)
            dist[k] /= n * n;
    }

    public static void main(String[] args) {
        int n = 7;
        double[] dist = new double[2 * n + 1]; //0.0 elem.
        genProbs(dist, n);
        for (int i = 0; i <= 2 * n; i++)
            System.out.println("prob sum " + i + " = " + dist[i]);
    }
}
Exercise

• Write a method that creates an N-by-N boolean array $a[][$] such that, for all $0 < i, j < N$ $a[i][j]$ is true if $i$ and $j$ are relatively prime (i.e., $1$ is the only integer that divides both of them) and false otherwise.

• Note that we do not use row 0 and column 0 of the matrix $a$.

• Hint: use the Euclid's algorithm for finding the GCD of two numbers. This means that the requested method must use the GCD method.
public static int gcd(int p, int q) {
    if (q == 0)
        return p;
    int r = p % q;
    return gcd(q, r);
}

public static boolean[][] relPrime(int n) {
    boolean[][] matrix = new boolean[n][n];
    for (int i = 1; i < n; i++)
        for (int j = 1; j < n; j++)
            matrix[i][j] = gcd(i, j) == 1;
    return matrix;
}