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
  - mouse events and keyboard events
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:

The entire array has a single name

Each value has a numeric index

scores

0  1  2  3  4  5  6  7  8  9

79 87 94 82 67 98 87 81 74 91

An array of size N is indexed from zero to N-1

This array holds 10 values that are indexed from 0 to 9
Arrays

• A particular value in an array is **referenced** using the array name followed by the index in brackets.

• For example, the expression

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

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:

The name of the array is an object reference variable

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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

<table>
<thead>
<tr>
<th>The array is created with 15 elements, indexed from 0 to 14</th>
<th>After three iterations of the first loop</th>
<th>After completing the first loop</th>
<th>After changing the value of list[5]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td>13</td>
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<tr>
<td>14</td>
<td>140</td>
<td>140</td>
<td>14</td>
</tr>
</tbody>
</table>
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.
Quick Check

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);
```
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.
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:

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

• It’s common to introduce off-by-one errors when using arrays:

  ```
  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
//********************************************************************
//  ReverseOrder.java       Author: Lewis/Loftus
//
//  Demonstrates array index processing.
//********************************************************************

import java.util.Scanner;

public class ReverseOrder
{
    //-----------------------------------------------------------------
    //  Reads a list of numbers from the user, storing them in an
    //  array, then prints them in the opposite order.
    //-----------------------------------------------------------------
    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
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 {
    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

    // 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>Letter</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
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<tr>
<td>C</td>
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<td>D</td>
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<td>E</td>
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<td>F</td>
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<td>y</td>
<td>3</td>
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<tr>
<td>z</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:

```c
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

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

- Implement a class `ArrayUtil` with a static method that checks if two arrays of integers are equal, i.e., they contain 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;
    }
}
```
A "better" solution

```java
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;
}
```

There is only one return statement.
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?

int[ ] a, b;
int c, d[ ];

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?

```java
int[ ] a, b;
int c, d[ ];
```

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
Example

... 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
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++;
```

A) It finds the smallest value and stores it in temp
B) It finds the largest value and stores it in temp
C) It counts the number of elements equal to the smallest value in list
D) It counts the number of elements in list that are less than temp
E) It sorts the values in list to be in ascending order
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++;
```

A) It finds the smallest value and stores it in temp
B) It finds the largest value and stores it in temp
C) It counts the number of elements equal to the smallest value in list
D) It counts the number of elements in list that are less than temp
E) It sorts the values in list to be in ascending order
Outline

Declaring and Using Arrays

Arrays of Objects

Variable Length Parameter Lists

Two-Dimensional Arrays

Polygons and Polylines

Mouse Events and Key Events
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:

```
words
  null
  null
  null
  null
  null
null
```

• At this point, the following line of code will print *null*:

```java
System.out.println(words[0]);
```
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"};
    ```
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 new operator.
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

• 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 {
    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);
        }
    }
}

// ************************************************************************* //
// GradeRange.java Author: Lewis/Loftus //
// Demonstrates the use of an array of objects. //*************************************************************************** //
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;
    }
}

continue
continue

//  Name mutator.

public void setName (String grade)
{
    name = grade;
}

//  Lower bound mutator.

public void setLowerBound (int cutoff)
{
    lowerBound = cutoff;
}
// ----------------------------------
// Name accessor.
// ----------------------------------
public String getName()
{
    return name;
}

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

// Returns a report describing the DVD collection.
//
public String toString()
{
    NumberFormat fmt = NumberFormat.getCurrencyInstance();

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

    report += 

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

    return report;
}

Can we implement this loop using a for each statement?
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 `team` is an array of strings meant to hold the names: Amanda, Clare, Emily, Julie, Katie, and Maria.
  - Write an array `declaration` for `team`
    - Show how to both `declare` and `populate` `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"};
```
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 …

```java
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

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

• **See** **NameTag.java**
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]);
    }
}
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]);
    }
}

Command-Line Execution

> java NameTag Howdy John

    Howdy
    My name is John

> java NameTag Hello Bill

    Hello
    My name is Bill
Outline

Declaring and Using Arrays

Arrays of Objects

Variable Length Parameter Lists

Two-Dimensional Arrays

Polygons and Polylines

Mouse Events and Key Events
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

- `public double average (int ... 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 `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.

    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");


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

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;
}
Outline

Declaring and Using Arrays
Arrays of Objects
Variable Length Parameter Lists
Two-Dimensional Arrays
Polygons and Polylines
Mouse Events and Key Events
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];
  ```

• A 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>table</td>
<td>int[][]</td>
<td>2D array of integers, or array of integer arrays</td>
</tr>
<tr>
<td>table[5]</td>
<td>int[]</td>
<td>array of integers</td>
</tr>
<tr>
<td>table[5][12]</td>
<td>int</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, 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];

        continue


```
continue

    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:\n");

    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));
}
```
continue

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));

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)
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](#)
- See [RocketPanel.java](#)
import javax.swing.JFrame;

public class Rocket {
    //---
    // Creates the main frame of the program.
    //---
    public static void main (String[] args) {
        JFrame frame = new JFrame("Rocket");
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        RocketPanel panel = new RocketPanel();
        frame.getContentPane().add(panel);
        frame.pack();
        frame.setVisible(true);
    }
}
import javax.swing.JFrame;

public class Rocket {
    // Creates the main frame of the program.
    public static void main(String[] args) {
        JFrame frame = new JFrame("Rocket");
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

        RocketPanel panel = new RocketPanel();
        frame.getContentPane().add(panel);
        frame.pack();
        frame.setVisible(true);
    }
}
// RocketPanel.java       Author: Lewis/Loftus
// Demonstrates the use of polygons and polylines.
//********************************************************************
import javax.swing.JPanel;
import java.awt.*;

public class RocketPanel extends JPanel
{
    private int[] xRocket = {100, 120, 120, 130, 130, 70, 70, 80, 80};
    private int[] yRocket = {15, 40, 115, 125, 150, 150, 125, 115, 40};

    private int[] xWindow = {95, 105, 110, 90};
    private int[] yWindow = {45, 45, 70, 70};

    private int[] xFlame = {70, 70, 75, 80, 90, 100, 110, 115, 120,
                            130, 130};
    private int[] yFlame = {155, 170, 165, 190, 170, 175, 160, 185, 160, 175, 155};
// Constructor: Sets up the basic characteristics of this panel.
//-----------------------------------------------------------------
public RocketPanel()
{
    setBackground (Color.black);
    setPreferredSize (new Dimension(200, 200));
}

// Draws a rocket using polygons and polylines.
//-----------------------------------------------------------------
public void paintComponent (Graphics page)
{
    super.paintComponent (page);

    page.setColor (Color.cyan);
    page.fillPolygon (xRocket, yRocket, xRocket.length);

    page.setColor (Color.gray);
    page.fillPolygon (xWindow, yWindow, xWindow.length);

    page.setColor (Color.red);
    page.drawPolyline (xFlame, yFlame, xFlame.length);
}
The Polygon Class

- The Polygon class can also be used to define and draw a polygon

- It is part of the java.awt package

- Versions of the overloaded drawPolygon and fillPolygon methods (of the Graphics class) take a single Polygon object as a parameter instead of arrays of coordinates
Mouse Events

- Events related to the mouse are separated into *mouse events* and *mouse motion events*

- Mouse Events:

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>mouse pressed</td>
<td>The mouse button is pressed down</td>
</tr>
<tr>
<td>mouse released</td>
<td>The mouse button is released</td>
</tr>
<tr>
<td>mouse clicked</td>
<td>The mouse button is pressed down and released without moving the mouse in between</td>
</tr>
<tr>
<td>mouse entered</td>
<td>The mouse pointer is moved onto (over) a component</td>
</tr>
<tr>
<td>mouse exited</td>
<td>The mouse pointer is moved off of a component</td>
</tr>
</tbody>
</table>
Mouse Events

• Mouse **motion events**:

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>mouse moved</td>
<td>the mouse is moved</td>
</tr>
<tr>
<td>mouse dragged</td>
<td>the mouse is moved while the mouse button is pressed down</td>
</tr>
</tbody>
</table>

• Listeners for mouse events are created using the `MouseListener` and `MouseMotionListener` interfaces

• A `MouseEvent` object is passed to the appropriate method when a mouse event occurs
Mouse Events

• For a given program, we may only care about one or two mouse events

• To satisfy the implementation of a listener interface, empty methods must be provided for unused events

• See Dots.java
• See DotsPanel.java
import javax.swing.JFrame;

public class Dots {
    // --------------------------------------------------------------------------
    // Creates and displays the application frame.
    // --------------------------------------------------------------------------
    public static void main (String[] args) {
        JFrame frame = new JFrame ("Dots");
        frame.setDefaultCloseOperation (JFrame.EXIT_ON_CLOSE);
        frame.getContentPane().add (new DotsPanel());
        frame.pack();
        frame.setVisible(true);
    }
}
import javax.swing.JFrame;

public class Dots {

    public static void main (String[] args) {
        JFrame frame = new JFrame ("Dots");
        frame.setDefaultCloseOperation (JFrame.EXIT_ON_CLOSE);

        frame.getContentPane().add (new DotsPanel());

        frame.pack();
        frame.setVisible(true);
    }
}
import java.util.ArrayList;
import javax.swing.JPanel;
import java.awt.*;
import java.awt.event.*;

public class DotsPanel extends JPanel {
    private final int SIZE = 6; // radius of each dot

    private ArrayList<Point> pointList;
}

continue
public DotsPanel()
{
    pointList = new ArrayList<Point>();

    addMouseListener (new DotsListener());
    setBackground (Color.black);
    setPreferredSize (new Dimension(300, 200));
}

public void paintComponent (Graphics page)
{
    super.paintComponent(page);
    page.setColor (Color.green);

    for (Point spot : pointList)
    {
        page.fillOval (spot.x - SIZE, spot.y - SIZE, SIZE*2, SIZE*2);
    }
    page.drawString ("Count: " + pointList.size(), 5, 15);
}
private class DotsListener implements MouseListener
{

    // Adds the current point to the list of points and redraws
    // the panel whenever the mouse button is pressed.
    public void mousePressed (MouseEvent event)
    {
        pointList.add(event.getPoint());
        repaint();
    }

    // Provide empty definitions for unused event methods.
    public void mouseClicked (MouseEvent event) {}
    public void mouseReleased (MouseEvent event) {}
    public void mouseEntered (MouseEvent event) {}
    public void mouseExited (MouseEvent event) {}
}
Mouse Events

• *Rubberbanding* is the visual effect in which a shape is "stretched" as it is drawn using the mouse

• The following example continually redraws a line as the mouse is dragged

• See RubberLines.java
• See RubberLinesPanel.java
import javax.swing.JFrame;

public class RubberLines {

    public static void main (String[] args) {
        JFrame frame = new JFrame ("Rubber Lines");
        frame.setDefaultCloseOperation (JFrame.EXIT_ON_CLOSE);

        frame.getContentPane().add (new RubberLinesPanel());

        frame.pack();
        frame.setVisible (true);
    }
}
import javax.swing.JFrame;

public class RubberLines {

    //---------
    //  Creates and displays the application frame.
    //---------
    public static void main (String[] args) {
        JFrame frame = new JFrame ("Rubber Lines");
        frame.setDefaultCloseOperation (JFrame.EXIT_ON_CLOSE);

        frame.getContentPane().add (new RubberLinesPanel());

        frame.pack();
        frame.setVisible(true);
    }
}
import javax.swing.JPanel;
import java.awt.*;
import java.awt.event.*;

public class RubberLinesPanel extends JPanel
{
    private Point point1 = null, point2 = null;

    public RubberLinesPanel()
    {
        LineListener listener = new LineListener();
        addMouseListener (listener);
        addMouseMotionListener (listener);

        setBackground (Color.black);
        setPreferredSize (new Dimension(400, 200));
    }

    continue
// Draws the current line from the initial mouse-pressed point to
// the current position of the mouse.

public void paintComponent (Graphics page)
{
    super.paintComponent (page);
    page.setColor (Color.yellow);
    if (point1 != null && point2 != null)
        page.drawLine (point1.x, point1.y, point2.x, point2.y);
}

//*****************************************************************
// Represents the listener for all mouse events.
//*****************************************************************
private class LineListener implements MouseListener, MouseMotionListener
{
    // Captures the initial position at which the mouse button is
    // pressed.

    public void mousePressed (MouseEvent event)
    {
        point1 = event.getPoint();
    }
}
// Gets the current position of the mouse as it is dragged and
// redraws the line to create the rubberband effect.
public void mouseDragged (MouseEvent event)
{
    point2 = event.getPoint();
    repaint();
}

// Provide empty definitions for unused event methods.
public void mouseClicked (MouseEvent event) {}
public void mouseReleased (MouseEvent event) {}
public void mouseEntered (MouseEvent event) {}
public void mouseExited (MouseEvent event) {}
public void mouseMoved (MouseEvent event) {}
}
Key Events

- A *key event* is generated when the user types on the keyboard.

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>key pressed</td>
<td>a key on the keyboard is pressed down</td>
</tr>
<tr>
<td>key released</td>
<td>a key on the keyboard is released</td>
</tr>
<tr>
<td>key typed</td>
<td>a key on the keyboard is pressed down and released</td>
</tr>
</tbody>
</table>

- Listeners for key events are created by implementing the **KeyListener** interface.

- A **KeyEvent** object is passed to the appropriate method when a key event occurs.
Key Events

• The component that generates a key event is the one that has the current *keyboard focus*

• Constants in the `KeyEvent` class can be used to determine which key was pressed

• The following example "moves" an image of an arrow as the user types the keyboard arrow keys

• See `Direction.java`
• See `DirectionPanel.java`
import javax.swing.JFrame;

public class Direction {
    // Creates and displays the application frame.
    public static void main (String[] args) {
        JFrame frame = new JFrame ("Direction");
        frame.setDefaultCloseOperation (JFrame.EXIT_ON_CLOSE);

        frame.getContentPane().add (new DirectionPanel());

        frame.pack();
        frame.setVisible(true);
    }
}
import javax.swing.JFrame;

public class Direction {
    public static void main (String[] args) {
        JFrame frame = new JFrame("Direction");
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        frame.getContentPane().add(new DirectionPanel());
        frame.pack();
        frame.setVisible(true);
    }
}
import javax.swing.*;
import java.awt.*;
import java.awt.event.*;

public class DirectionPanel extends JPanel
{
    private final int WIDTH = 300, HEIGHT = 200;
    private final int JUMP = 10;  // increment for image movement

    private final int IMAGE_SIZE = 31;

    private ImageIcon up, down, right, left, currentImage;
    private int x, y;

    continue
// Constructor: Sets up this panel and loads the images.
public DirectionPanel()
{
    addKeyListener (new DirectionListener());

    x = WIDTH / 2;
    y = HEIGHT / 2;

    up = new ImageIcon ("arrowUp.gif");
down = new ImageIcon ("arrowDown.gif");
left = new ImageIcon ("arrowLeft.gif");
right = new ImageIcon ("arrowRight.gif");

    currentImage = right;

    setBackground (Color.black);
    setPreferredSize (new Dimension(WIDTH, HEIGHT));
    setFocusable(true);
}
public void paintComponent (Graphics page)
{
    super.paintComponent (page);
    currentImage.paintIcon (this, page, x, y);
}

private class DirectionListener implements KeyListener
{
    public void keyPressed (KeyEvent event)
    {
        switch (event.getKeyCode())
        {
            case KeyEvent.VK_UP:
                currentImage = up;
                y -= JUMP;
                break;
        }
    }
}
continue

    case KeyEvent.VK_DOWN:
        currentImage = down;
        y += JUMP;
        break;
    case KeyEvent.VK_LEFT:
        currentImage = left;
        x -= JUMP;
        break;
    case KeyEvent.VK_RIGHT:
        currentImage = right;
        x += JUMP;
        break;
    }

    repaint();
}

//--- Provide empty definitions for unused event methods.
public void keyTyped (KeyEvent event) {} public void keyReleased (KeyEvent event) {}
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
  – mouse events and keyboard events
Quiz

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]);
```

```
x[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(i);
Exercise

• Write a method that takes a square int matrix of size nxn as parameter and **transforms** it into the transpose matrix (side effect on the original matrix)
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; j < n; j++)
            {
            int p = a[i][j];
            a[i][j] = a[j][i];
            a[j][i] = p;
            }
}
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 $j$: $i \leq j < \text{array.length}$
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 the multiplication of the two matrices.

• 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 method that computes for each number n between 0 and 2*k (included) the probability that the sum of the face values of two dice with k faces is n.

• Hint: generate all the possible combinations of face values of the two dice and use an array (double[] freq) to initially store how many times the sum of the generated two face values is n. Then divide the freq entries by the number of possible combinations of face values.

• Write a static method:
  – static void genProbs(double[] dist, int n)
  – Given an empty array of size (2*n + 1) the method fills in the array the computed probabilities.
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];
        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 \(a[i][j]\) is true if \(i\) and \(j\) are relatively prime (i.e., 1 is the only integer that divides both of them) and false otherwise.

• 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 + 1][n + 1];
    for (int i = 1; i <= n; i++)
        for (int j = 1; j <= n; j++)
            matrix[i][j] = gcd(i, j) == 1;
    return matrix;
}