Single-Dimensional Arrays and Multidimensional Arrays

Introduction to Programming and Computational Problem Solving - 2

CSE 8B

Lecture 5

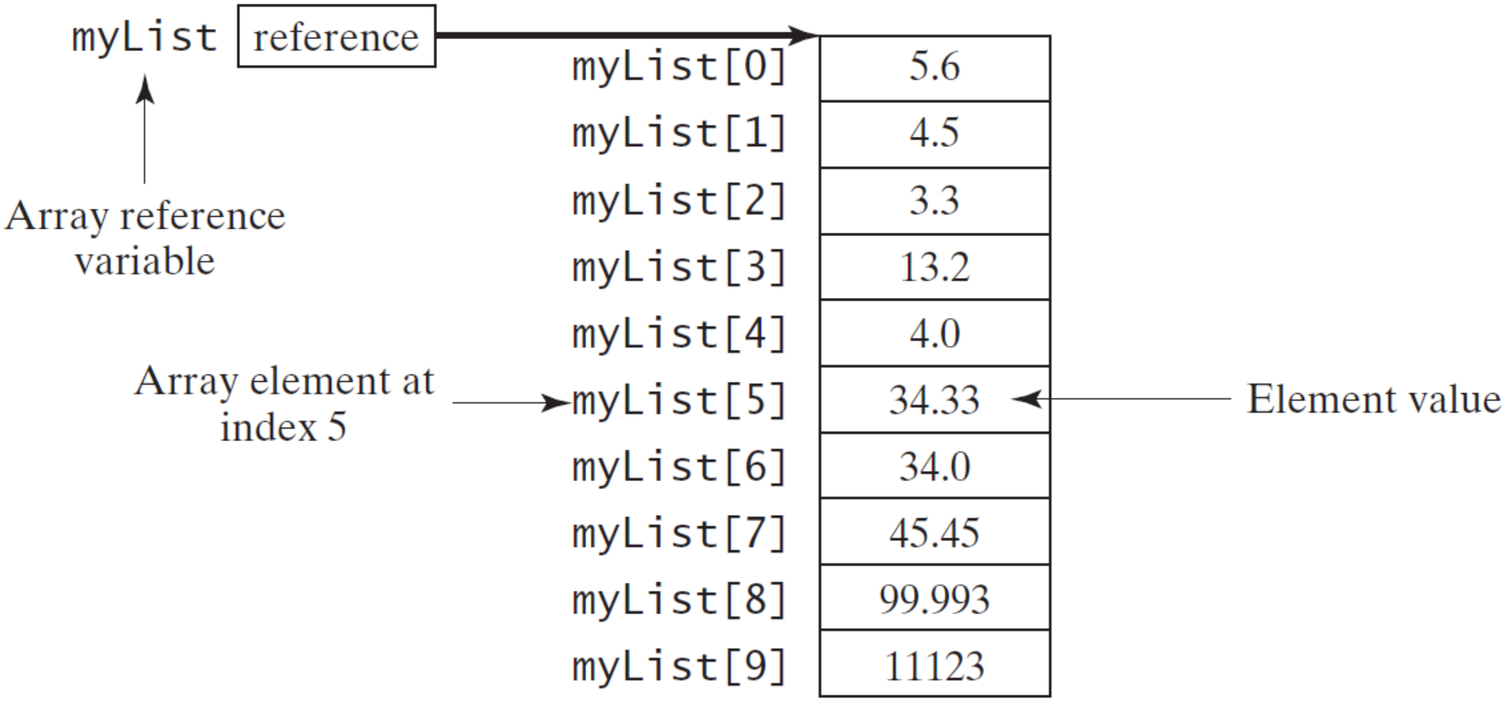
Announcements

- Assignment 2 is due Apr 13, 11:59 PM
- Assignment 3 will be released Apr 13
  - Due Apr 20, 11:59 PM
- Reading
  - Liang
    - Chapters 7 and 8

Arrays

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

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



myList reference

Array reference variable

Array element at index 5

Element value

myList[0]	5.6
myList[1]	4.5
myList[2]	3.3
myList[3]	13.2
myList[4]	4.0
myList[5]	34.33
myList[6]	34.0
myList[7]	45.45
myList[8]	99.993
myList[9]	11123

Declaring array variables

```
datatype[] arrayRefVar;
```

- For example

```
double[] myList;
```

If a variable does not contain a reference to an array, the value of the variable is `null`

```
datatype arrayRefVar[];
```

This style is allowed, but not preferred

- For example

```
double myList[];
```

Creating arrays

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

- For example

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

  - `myList[0]` references the first element in the array
  - `myList[9]` references the last element in the array

Declaring and creating in one step

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

- For example

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

The length of an array

- Once an array is created, its size is fixed (i.e., it cannot be changed)
- You can find its size using

  `arrayRefVar.length`
- For example,

  ```
  double[] myList = new double[10];
  ```
  `myList.length` returns `10`

Default values

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

  `0` for the numeric primitive data types

  `'\u0000'` for `char` type

  `false` for `boolean` type

Indexed variables

- The array elements are accessed through the index
- The array indices are **0-based**
  - From `0` to `arrayRefVar.length-1`
- Each element in the array is represented using the following syntax, known as an *indexed variable*

```
arrayRefVar[index];
```

Using indexed variables

- After an array is created, an indexed variable can be used in the same way as a regular variable
- For example

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

Array initializers

- Declaring, creating, and initializing in one step

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

- This shorthand syntax must be in one statement
  - The above statement is equivalent to the following statements

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

Initializing arrays

- Initializing arrays with input values

```
java.util.Scanner input = new java.util.Scanner(System.in);
System.out.print("Enter " + myList.length + " values: ");
for (int i = 0; i < myList.length; i++)
  myList[i] = input.nextDouble();
```

- Initializing arrays with random values

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

Processing arrays

- Summing all elements

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

- Finding the largest element

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

Printing arrays

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

Foreach loops

- Traverse the complete array **sequentially** without using an index variable

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

- For example

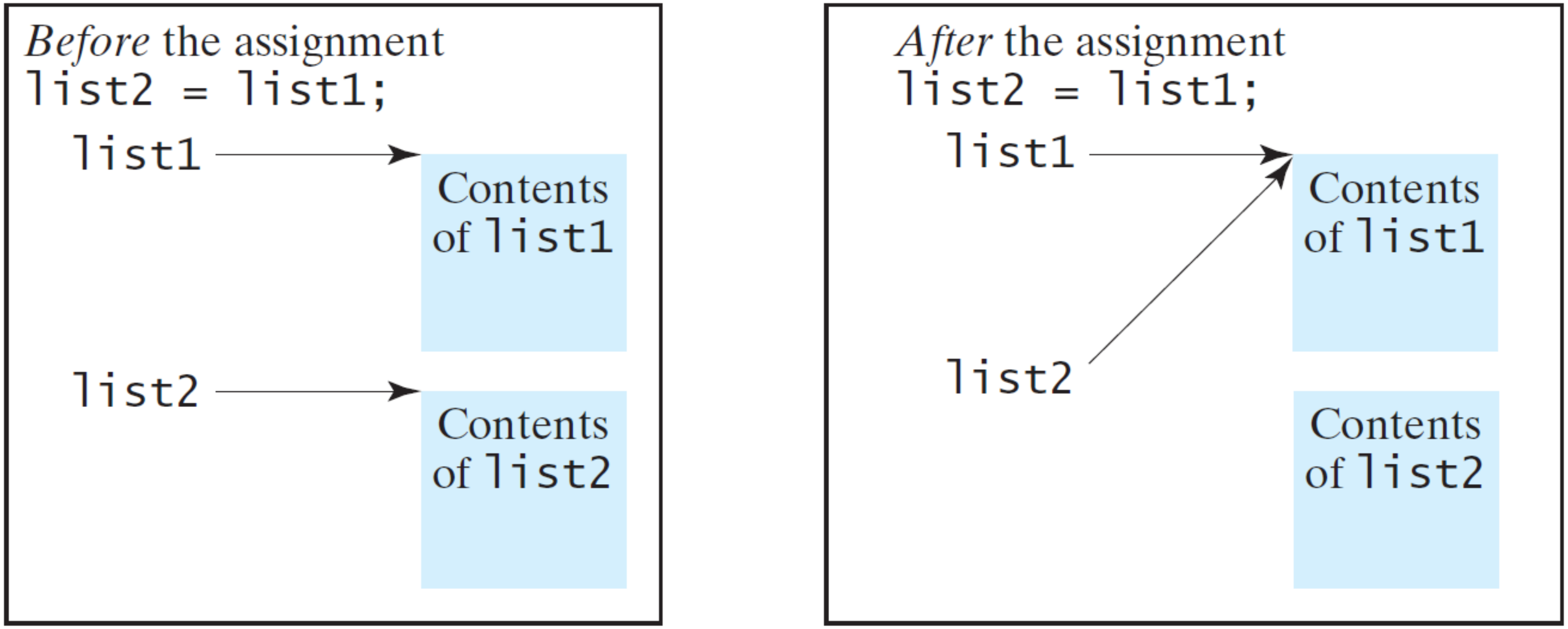
```
for (double value : myList)
  System.out.println(value);
```

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

Copying arrays

- **The assignment statement does not copy the contents**, it only copies the *reference value*

```
list2 = list1;
```



Copying arrays

- **To copy contents of one array to another, you must copy the array’s individual elements to the other array**

Copying arrays

- Using a loop

```
int[] sourceArray = {2, 3, 1, 5, 10};
int[] targetArray = new int[sourceArray.length];
for (int i = 0; i < sourceArray.length; i++)
   targetArray[i] = sourceArray[i];
```

- Using the System.arraycopy method

```
arraycopy(sourceArray, src_pos, targetArray, tar_pos, length);
```

  – For example:

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

Passing arrays to methods

- When passing an array to a method, the **reference** of the array is passed to the method

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

Invoke the method, example 1:

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

Invoke the method, example 2:

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

Anonymous array

Anonymous array

- The statement

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

  creates an array using the syntax

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

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

Pass by value

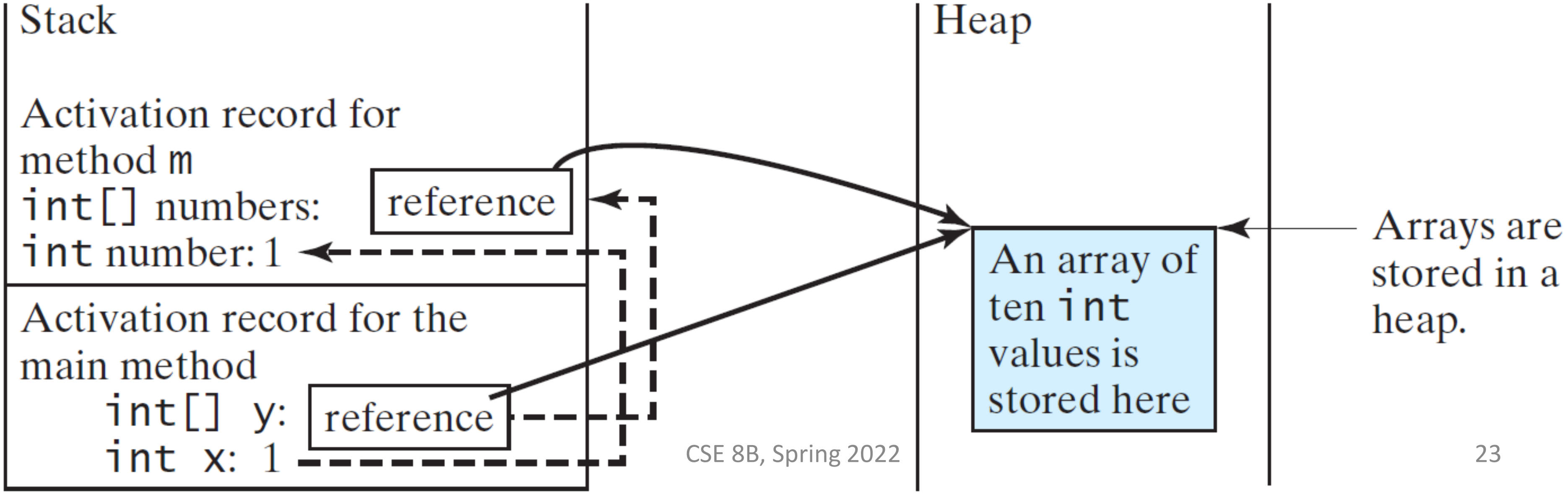
- Remember, Java uses **pass by value** to pass arguments to a method
- For a parameter of a primitive type, the **actual value** is passed
  - Changing the value of the local parameter inside the method **does not** affect the value of the variable outside the method
- For a parameter of an array type, the **reference value** is passed
  - Any changes to the array that occur inside the method body **does** affect the original array that was passed as the argument

Pass by value

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

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

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

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

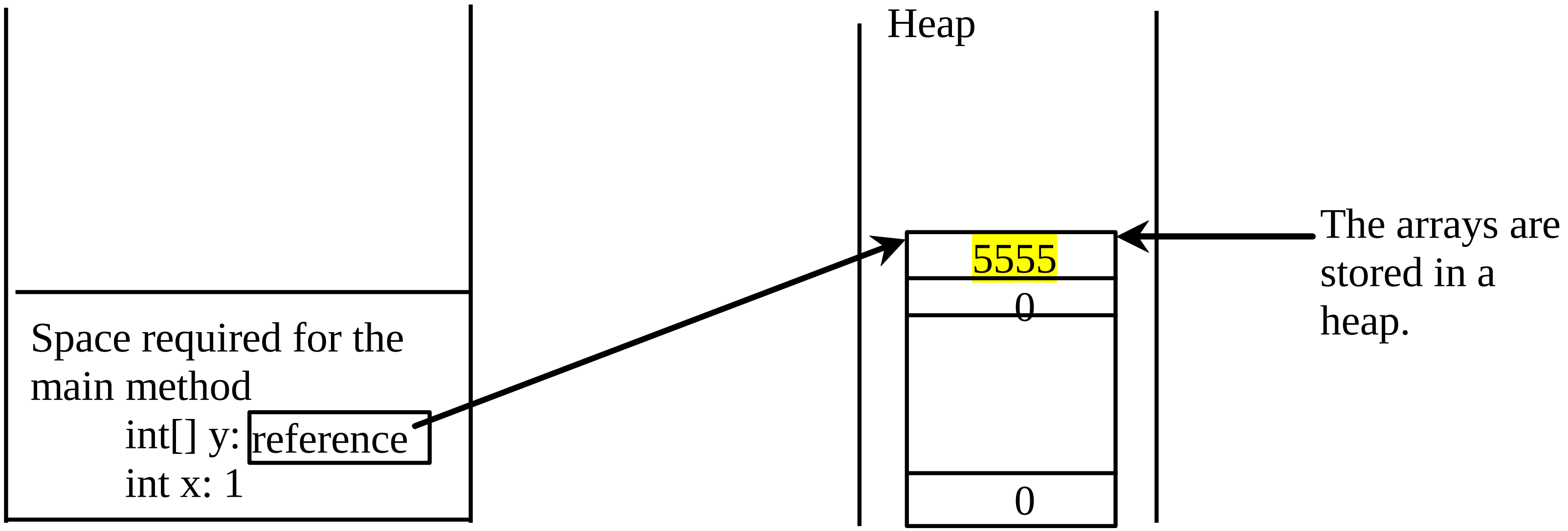
Pass by value

- When invoking `m(x, y)`, the values of `x` and `y` are passed to `number` and `numbers`
- Since `y` contains the reference value to the array, `numbers` now contains the same reference value to the same array


Stack
Activation record for method m
int[] numbers:
reference
int number: 1
Activation record for the main method
int[] y:
reference
int x: 1
Heap
An array of ten int values is stored here
Arrays are stored in a heap.

Heap

- The JVM stores the array in an area of memory called the *heap*, which is used for dynamic memory allocation


Heap
5555
0
0
Space required for the main method
int[] y: reference
int x: 1
The arrays are stored in a heap.

Returning an array from a method

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


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

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

    return result;
  }
```

Array operations

- The `java.util.Arrays` class contains useful methods for common array operations
  https://docs.oracle.com/javase/8/docs/api/java/util/Arrays.html
  https://docs.oracle.com/en/java/javase/11/docs/api/java.base/java/util/Arrays.html
  - Sorting arrays
    - For example, `java.util.Arrays.sort`
  - Searching arrays
    - For example, `java.util.Arrays.binarySearch` (a sorted in ascending order array)
  - Check whether two arrays are strictly equal
    - `java.util.Arrays.equals`
  - Fill all or part of an array
    - `java.util.Arrays.fill`
  - Return a string that represents all elements in an array
    - `java.util.Arrays.toString`

Command-line parameters

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

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

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

Two-dimensional arrays

```
// Declare array reference variable
dataType[][] refVar; // preferred
dataType refVar[][];
```

If a variable does not contain a reference to an array, the value of the variable is `null`

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


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

Two-dimensional arrays

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

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

Same as

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

A two-dimensional array is an *array of arrays*

Two-dimensional arrays

	[0]	[1]	[2]	[3]	[4]
[0]	0	0	0	0	0
[1]	0	0	0	0	0
[2]	0	0	0	0	0
[3]	0	0	0	0	0
[4]	0	0	0	0	0

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

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

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

Row Column

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

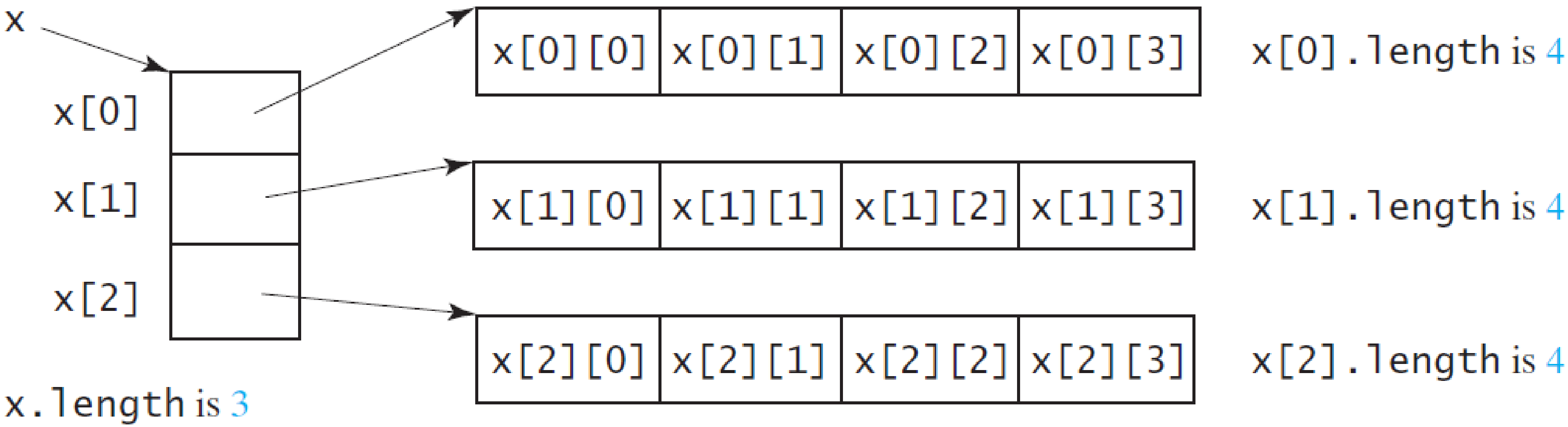
```
int[][] array = {
  {1, 2, 3},
  {4, 5, 6},
  {7, 8, 9},
  {10, 11, 12}
};
```

A two-dimensional array is an *array of arrays*

Lengths of two-dimensional arrays

- A two-dimensional array is an *array of arrays*

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


x
x[0]
x[1]
x[2]
x.length is 3
x[0][0] x[0][1] x[0][2] x[0][3]
x[1][0] x[1][1] x[1][2] x[1][3]
x[2][0] x[2][1] x[2][2] x[2][3]
x[0].length is 4
x[1].length is 4
x[2].length is 4

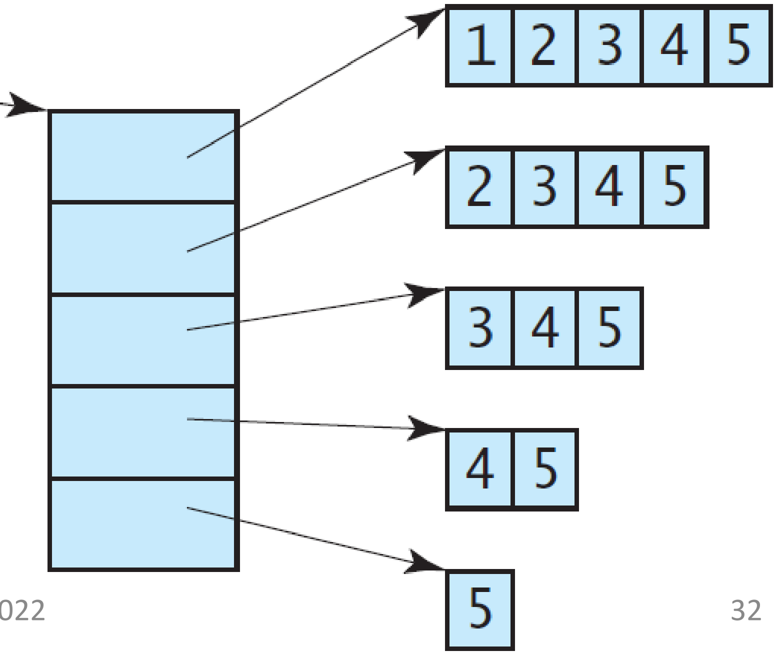
- Remember, last array is `x[x.length – 1]`

Ragged arrays

- Each row in a two-dimensional array is itself an array
- The rows can have different lengths
- If so, then the array is called a *ragged array*

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

```
triangleArray.length is 5
triangleArray[0].length is 5
triangleArray[1].length is 4
triangleArray[2].length is 3
triangleArray[3].length is 2
triangleArray[4].length is 1
```



Initializing two-dimensional arrays

- Initializing arrays with input values

```
java.util.Scanner input = new Scanner(System.in);
System.out.println("Enter " + matrix.length + " rows and " +
  matrix[0].length + " columns: ");
for (int row = 0; row < matrix.length; row++) {
  for (int column = 0; column < matrix[row].length; column++) {
    matrix[row][column] = input.nextInt();
  }
}
```

- Initializing arrays with random values

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

Two-dimensional arrays

- Nested `for` loops are often used to process a two-dimensional array
- When passing a two-dimensional array to a method, the reference of the array is passed to the method
  - Just like methods and one-dimensional arrays
  - Any changes to the array that occur inside the method body will affect the original array that was passed as the argument

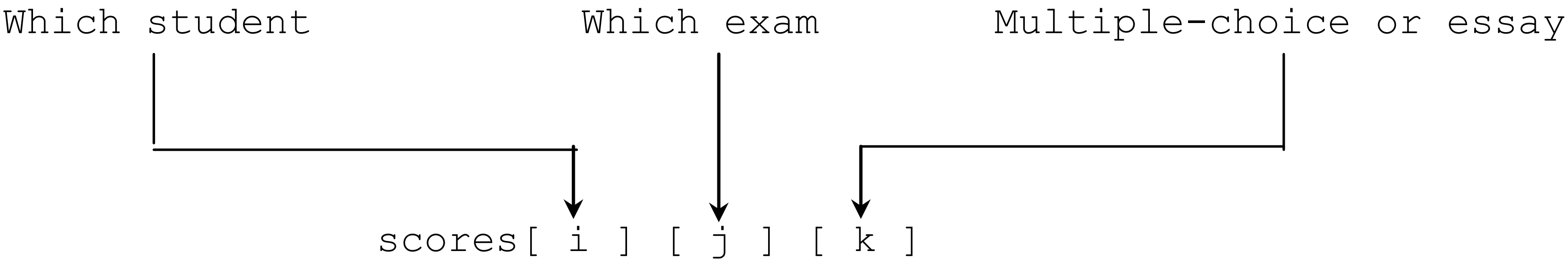
Higher dimensional arrays

- Occasionally, you will need to represent *n*-dimensional data structures
- In Java, you can create *n*-dimensional arrays for any integer *n*
- The way to declare two-dimensional array variables and create two-dimensional arrays can be generalized to declare *n*-dimensional array variables and create *n*-dimensional arrays for $n \geq 3$

Three-dimensional arrays

- A three-dimensional array is an array of two-dimensional arrays

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



Which student

Which exam

Multiple-choice or essay

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

Next Lecture

- Objects and classes
- Reading
  - Liang
    - Chapter 9