Chapter 8:
Arrays and the ArrayList Class

Chapter Topics

Chapter 8 discusses the following main topics:

- Introduction to Arrays
- Processing Array Contents
- Passing Arrays as Arguments to Methods
- Some Useful Array Algorithms and Operations
- Returning Arrays from Methods
- String Arrays
- Arrays of Objects

Chapter Topics

Chapter 8 discusses the following main topics:

- The Sequential Search Algorithm
- Parallel Arrays
- Two-Dimensional Arrays
- Arrays with Three or More Dimensions
- The Selection Sort and the Binary Search
- Command-Line Arguments
- The `ArrayList` Class

Introduction to Arrays

A contiguous sequence of homogenous elements

Introduction to Arrays

- Primitive variables are designed to hold only one value at a time.
- Arrays allow us to create a collection of like values that are indexed.
- An array can store any type of data but only one type of data at a time.
- An array is a list of data elements.

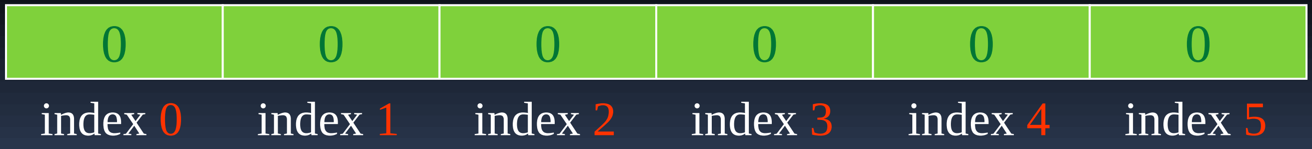
Creating Arrays

- An array is an object so it needs an object reference.

```
// Declare a reference to an array that will hold integers.
int[] numbers;
```

- The next step creates the array and assigns its address to the `numbers` variable.

```
// Create a new array that will hold 6 integers.
numbers = new int[6];
```



Array element values are initialized to 0.
Array indexes always start at 0.

Creating Arrays

- It is possible to declare an array reference and create it in the same statement.

```
int[] numbers = new int[6];
```

- Arrays may be of any type.

```
float[] temperatures = new float[100];
char[] letters = new char[41];
long[] units = new long[50];
double[] sizes = new double[1200];
```

Creating Arrays

- The array size must be a non-negative number.
- It may be a literal value, a constant, or variable.

```
final int ARRAY_SIZE = 6;
int[] numbers = new int[ARRAY_SIZE];
```

- Once created, an array size is fixed and cannot be changed.

Accessing the Elements of an Array

20	0	0	0	0	0
numbers[0]	numbers[1]	numbers[2]	numbers[3]	numbers[4]	numbers[5]

- An array is accessed by:
  - the reference name
  - a subscript that identifies which element in the array to access.

```
numbers[0] = 20; //pronounced "numbers at index zero"
```

Inputting and Outputting Array Elements

- Array elements can be treated as any other variable.
- They are simply accessed by the same name and a subscript.
- See example: ArrayDemo1.java
- Array subscripts can be accessed using variables (such as for loop counters).
- See example: ArrayDemo2.java

Bounds Checking

- Array indexes always start at zero and continue to (array length - 1).

```
int values = new int[10];
```

- This array would have indexes 0 through 9.
- See example: InvalidSubscript.java
- In `for` loops, it is typical to use *i*, *j*, and *k* as counting variables.
    - It might help to think of *i* as representing the word *index*.

Off-by-One Errors

- It is very easy to be off-by-one when accessing arrays.

```
// This code has an off-by-one error.
int[] numbers = new int[100];
for (int i = 1; i <= 100; i++)
  numbers[i] = 99;
```

- Here, the equal sign allows the loop to continue on to index 100, where 99 is the last index in the array.
- This code would throw an **`ArrayIndexOutOfBoundsException`**.

Array Initialization

- When relatively few items need to be initialized, an initialization list can be used to initialize the array.

```
int[]days = {31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31};
```

- The numbers in the list are stored in the array in order:
  - `days[0]` is assigned 31,
  - `days[1]` is assigned 28,
  - `days[2]` is assigned 31,
  - `days[3]` is assigned 30,
  - etc.
- See example: ArrayInitialization.java

Alternate Array Declaration

- Previously we showed arrays being declared:
  ```
  int[] numbers;
  ```
  - However, the brackets can also go here:
    ```
    int numbers[];
    ```
  - These are equivalent but the first style is typical.
- Multiple arrays can be declared on the same line. Please don't.
  ```
  int[] numbers, codes, scores;
  ```
- With the alternate notation each variable must have brackets.
  ```
  int numbers[], codes[], scores;
  ```
  - The `scores` variable in this instance is simply an `int` variable.

Processing Array Contents

- Processing data in an array is the same as any other variable.

```
grossPay = hours[3] * payRate;
```

- Pre and post increment works the same:

```
int[] score = {7, 8, 9, 10, 11};
++score[2]; // Pre-increment operation
score[4]++; // Post-increment operation
```

- See example: PayArray.java

Processing Array Contents

- Array elements can be used in relational operations:

```
if(cost[20] < cost[0])
{
  //statements
}
```

- They can be used as loop conditions:

```
while(value[count] != 0)
{
  //statements
}
```

Array Length

- Arrays are objects and provide a public field named `length` that is a constant that can be tested.

```
double[] temperatures = new double[25];
```

  - The length of this array is 25.

- The length of an array can be obtained via its `length` constant.

```
int size = temperatures.length;
```

  - The variable `size` will contain 25.

The Enhanced `for` Loop

- Simplified array processing (read only)
- Always goes through all elements
- General format:

```
for(datatype elementVariable : array)
   statement;
```

The Enhanced `for` Loop

Example:

```
int[] numbers = {3, 6, 9};
for(int val : numbers)
{
  System.out.println("The next value is " +
                     val);
}
```

Array Size

- The `length` constant can be used in a loop to provide automatic bounding.

Index subscripts start at 0 and end at one ***less than*** the array length.

```
for(int i = 0; i < temperatures.length; i++)
{
  System.out.println("Temperature " + i ": "
                                 + temperatures[i]);
}
```

Array Size

- You can let the user specify the size of an array:

```
int numTests;
int[] tests;
Scanner keyboard = new Scanner(System.in);
System.out.print("How many tests do you have? ");
numTests = keyboard.nextInt();
tests = new int[numTests];
```

- See example: DisplayTestScores.java

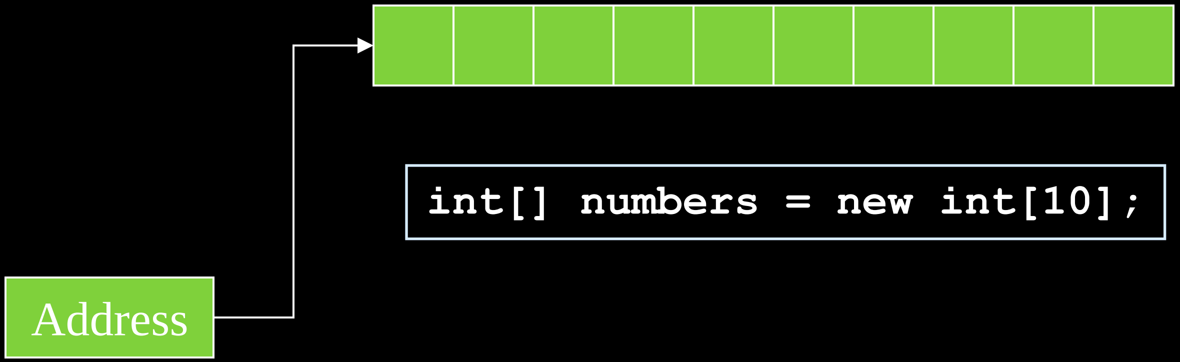
Reassigning Array References

- An array reference can be assigned to another array of the same type.

```
// Create an array referenced by the numbers variable.
int[] numbers = new int[10];
// Reassign numbers to a new array.
numbers = new int[5];
```

- If the first (10 element) array no longer has a reference to it, it will be garbage collected.

Reassigning Array References

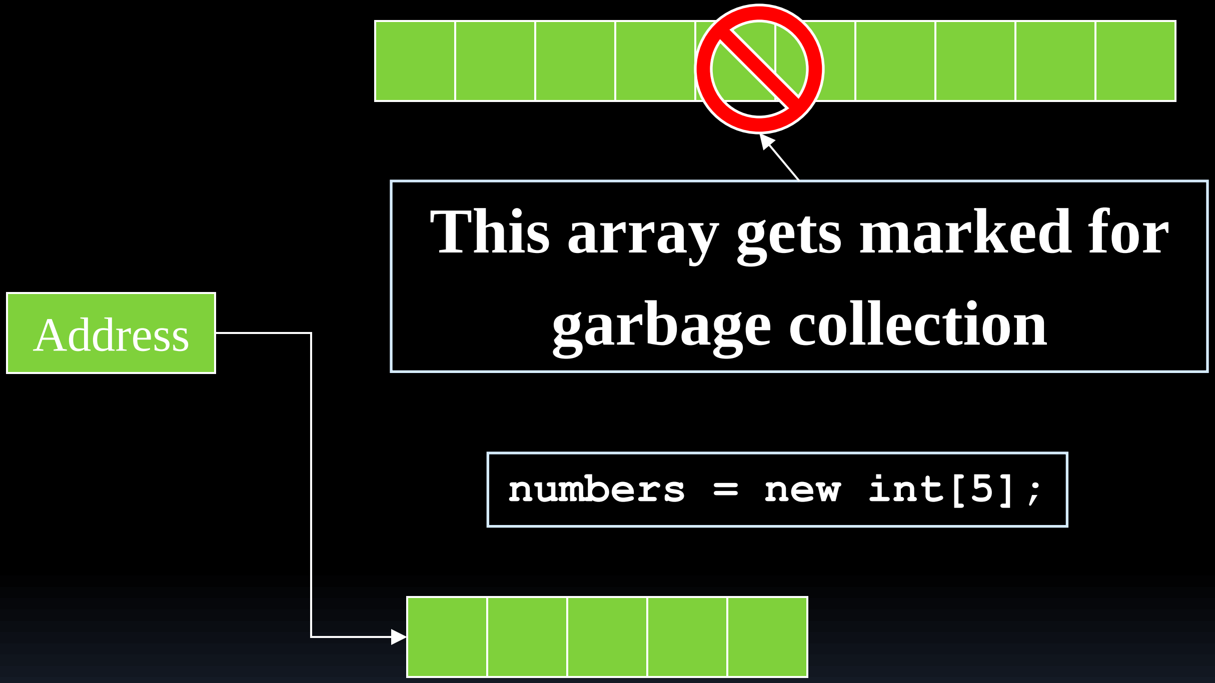


```
int[] numbers = new int[10];
```

The `numbers` variable holds the address of an `int` array.

Reassigning Array References

The `numbers` variable holds the address of an `int` array.

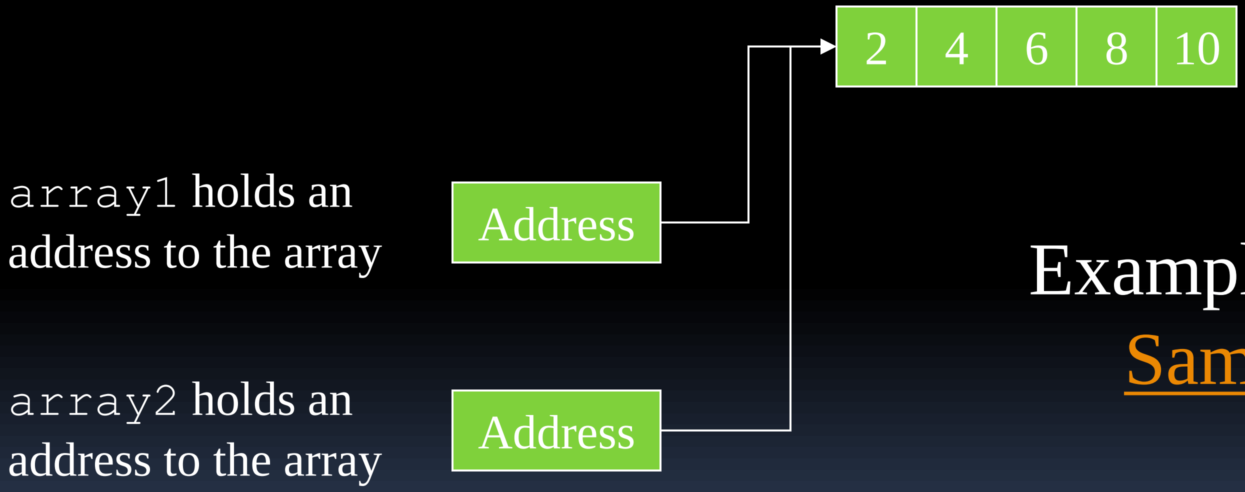


```
numbers = new int[5];
```

Copying Arrays

- This is *not* the way to copy an array.

```
int[] array1 = { 2, 4, 6, 8, 10 };
int[] array2 = array1; // This does not copy array1.
```



2
4
6
8
10
array1 holds an address to the array
Address
array2 holds an address to the array
Address

Example:
SameArray.java

Copying Arrays

- You cannot copy an array by merely assigning one reference variable to another.
- You need to copy the individual elements of one array to another.

```
int[] firstArray = {5, 10, 15, 20, 25 };
int[] secondArray = new int[5];
for (int i = 0; i < firstArray.length; i++)
  secondArray[i] = firstArray[i];
```

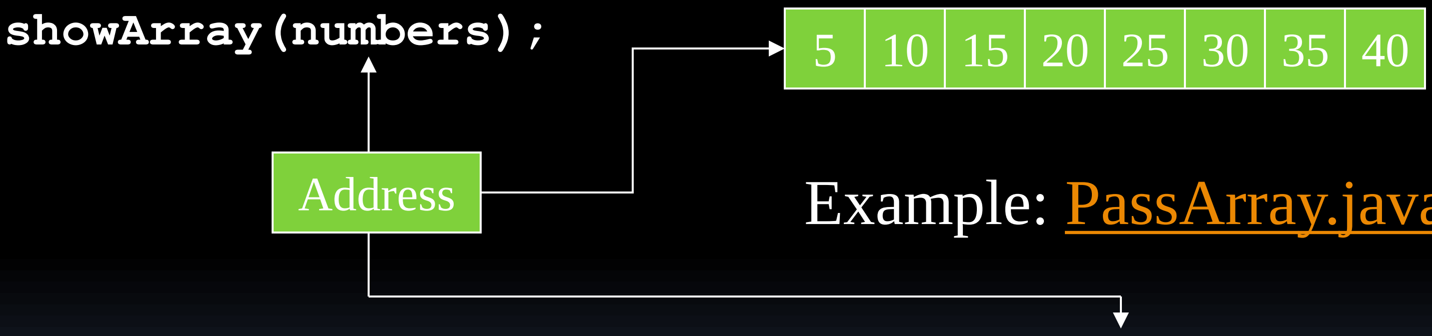
- This code copies each element of `firstArray` to the corresponding element of `secondArray`.

Passing Array Elements to a Method

- When a single element of an array is passed to a method it is handled like any other variable.
- See example: PassElements.java
- More often you will want to write methods to process array data by passing the entire array, not just one element at a time.

Passing Arrays as Arguments

- Arrays are objects.
- Their references can be passed to methods like any other object reference variable.



Example: PassArray.java

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

Comparing Arrays

- The == operator determines only whether array references point to the same array object.

```
int[] firstArray = { 5, 10, 15, 20, 25 };
int[] secondArray = { 5, 10, 15, 20, 25 };

if (firstArray == secondArray) // This is a mistake.
   System.out.println("The arrays are the same.");
else
   System.out.println("The arrays are not the same.");
```

Comparing Arrays: Example

```
int[] firstArray = { 2, 4, 6, 8, 10 };
int[] secondArray = { 2, 4, 6, 8, 10 };
boolean arraysEqual = true;
int i = 0;

// First determine whether the arrays are the same size.
if (firstArray.length != secondArray.length){
  arraysEqual = false;
}
// Next determine whether the elements contain the same data.
while (arraysEqual && i < firstArray.length)
{
  if (firstArray[i] != secondArray[i]){
    arraysEqual = false;
  }
  i++;
}
if (arraysEqual){
  System.out.println("The arrays are equal.");
}
else{
  System.out.println("The arrays are not equal.");
}
```

Useful Array Operations

- Finding the Highest Value

```
int [] numbers = new int[50];
int highest = numbers[0];
for (int i = 1; i < numbers.length; i++)
{
     if (numbers[i] > highest){
             highest = numbers[i];
     }
}
```

- Finding the Lowest Value

```
int lowest = numbers[0];
for (int i = 1; i < numbers.length; i++)
{
     if (numbers[i] < lowest){
             lowest = numbers[i];
     }
}
```

Useful Array Operations

- Summing Array Elements:

```
int total = 0; // Initialize accumulator
for (int i = 0; i < units.length; i++){
  total += units[i];
}
```

- Averaging Array Elements:

```
double total = 0; // Initialize accumulator
double average; // Will hold the average
for (int i = 0; i < scores.length; i++){
  total += scores[i];
}
average = total / scores.length;
```

- Example: SalesData.java, Sales.java

Partially Filled Arrays

- Typically, if the amount of data that an array must hold is unknown:
  - size the array to the largest expected number of elements.
  - use a counting variable to keep track of how much valid data is in the array.

```
…
int[] array = new int[100];
int count = 0;
…
   System.out.print("Enter a number or -1 to quit: ");
   number = keyboard.nextInt();
   while (number != -1 && count <= 99)
   {
      array[count] = number;
      count++;
      System.out.print("Enter a number or -1 to quit: ");
      number = keyboard.nextInt();
   }
…
```

input, number and keyboard were previously declared and keyboard references a Scanner object

Arrays and Files

- Saving the contents of an array to a file:

```
int[] numbers = {10, 20, 30, 40, 50};

PrintWriter outputFile =
     new PrintWriter ("Values.txt");

for (int i = 0; i < numbers.length; i++){
  outputFile.println(numbers[i]);
}

outputFile.close();
```

Arrays and Files

- Reading the contents of a file into an array:

```
final int SIZE = 5; // Assuming we know the size.
int[] numbers = new int[SIZE];
int i = 0;
File file = new File ("Values.txt");
Scanner inputFile = new Scanner(file);
while (inputFile.hasNext() && i < numbers.length)
{
  numbers[i] = inputFile.nextInt();
  i++;
}
inputFile.close();
```

Returning an Array Reference

- A method can return a reference to an array.
- The return type of the method must be declared as an array of the right type.

```
public static double[] getArray()
{
  double[] array = { 1.2, 2.3, 4.5, 6.7, 8.9 };
  return array;
}
```

- The `getArray` method is a public static method that returns an array of doubles.
- See example: ReturnArray.java

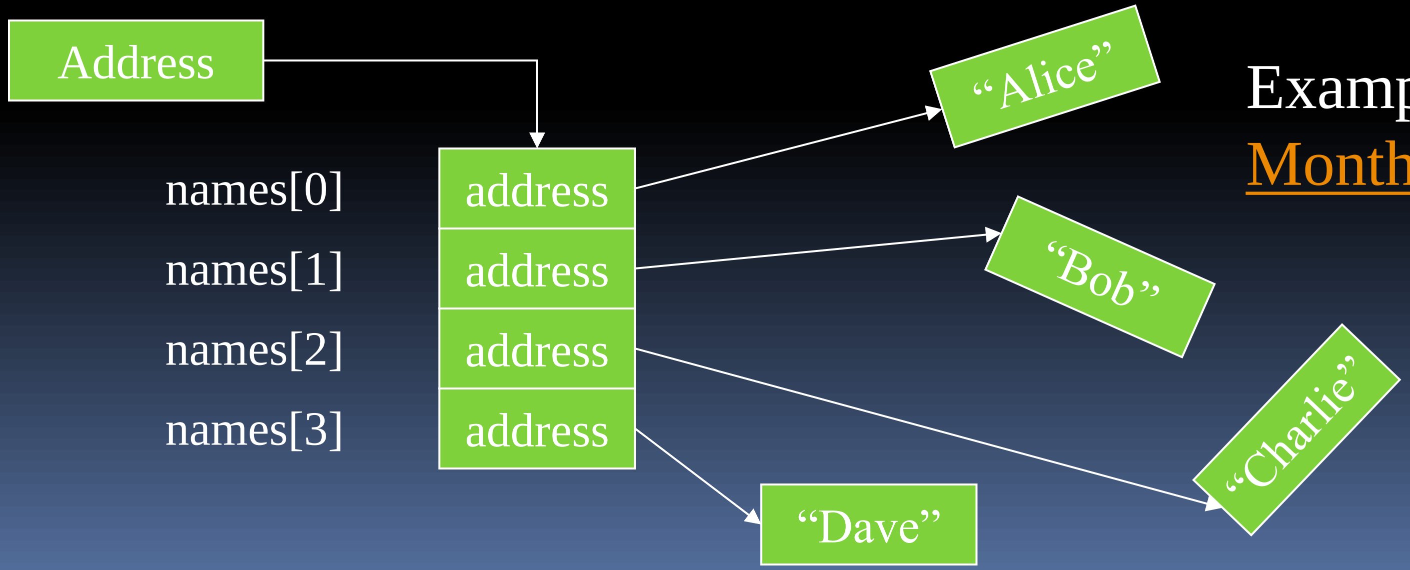
String Arrays

- Arrays are not limited to primitive data.
- An array of String objects can be created:

```
String[] names = { "Alice", "Bob", "Charlie", "Dave" };
```

The names variable holds the address to the array.

A String array is an array of references to String objects.

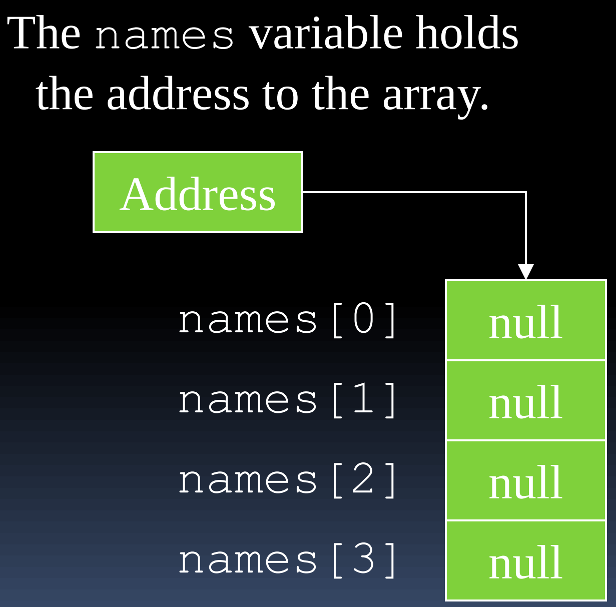


Example: MonthDays.java

String Arrays

- If an initialization list is not provided, the `new` keyword must be used to create the array:

```
String[] names = new String[4];
```

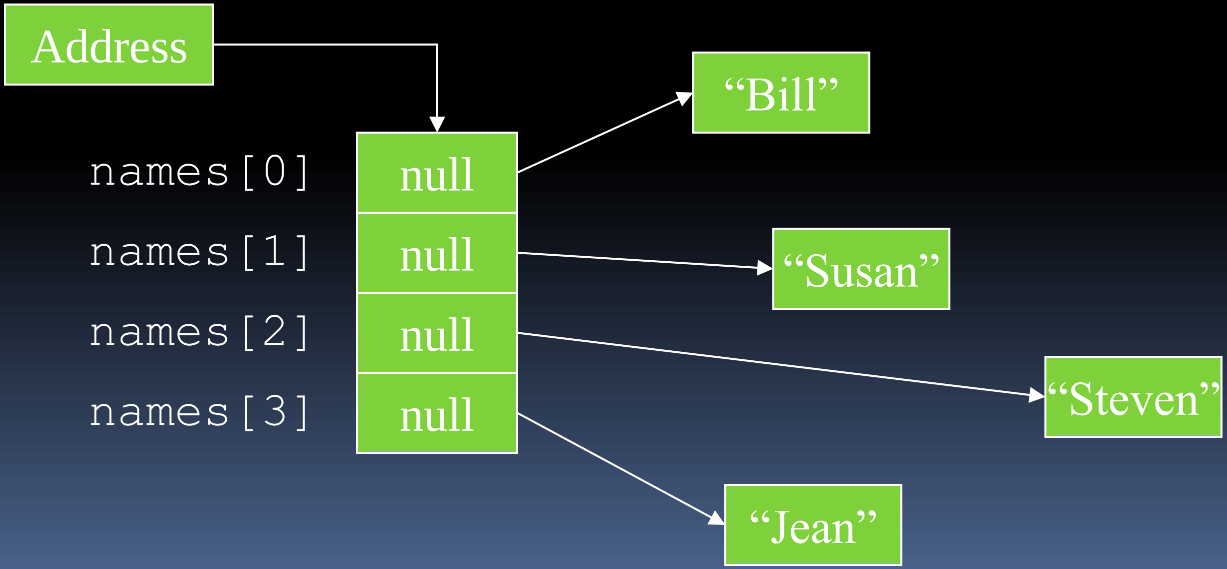


String Arrays

- When an array is created in this manner, each element of the array must be initialized.

```
names[0] = "Bill";
names[1] = "Susan";
names[2] = "Steven";
names[3] = "Jean";
```

The `names` variable holds the address to the array.



Calling String Methods On Array Elements

- String objects have several methods, including:
  - toUpperCase
  - compareTo
  - equals
  - charAt
- Each element of a String array is a String object.
- Methods can be used by using the array name and index as before.

```
System.out.println(names[0].toUpperCase());
char letter = names[3].charAt(0);
```

The `length` Field & The `length` Method

- Arrays have a **`final`** **field** named `length`.
- String objects have a **method** named `length`.
- To display the length of each string held in a `String` array:

```
for (int i = 0; i < names.length; i++)
   System.out.println(names[i].length());
```

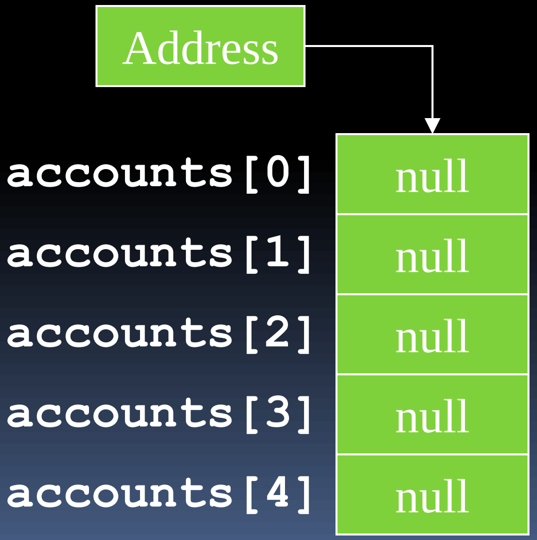
- An array's `length` is a **field**
  - You <u>do not</u> write a set of parentheses after its name.
- A `String`'s `length` is a **method**
  - You <u>do</u> write the parentheses after the name of the `String` class's `length` method.

Arrays of Objects

- Because `Strings` are objects, we know that arrays can contain objects.

```
BankAccount[] accounts = new BankAccount[5];
```

The `accounts` variable holds the address of an `BankAccount` array.



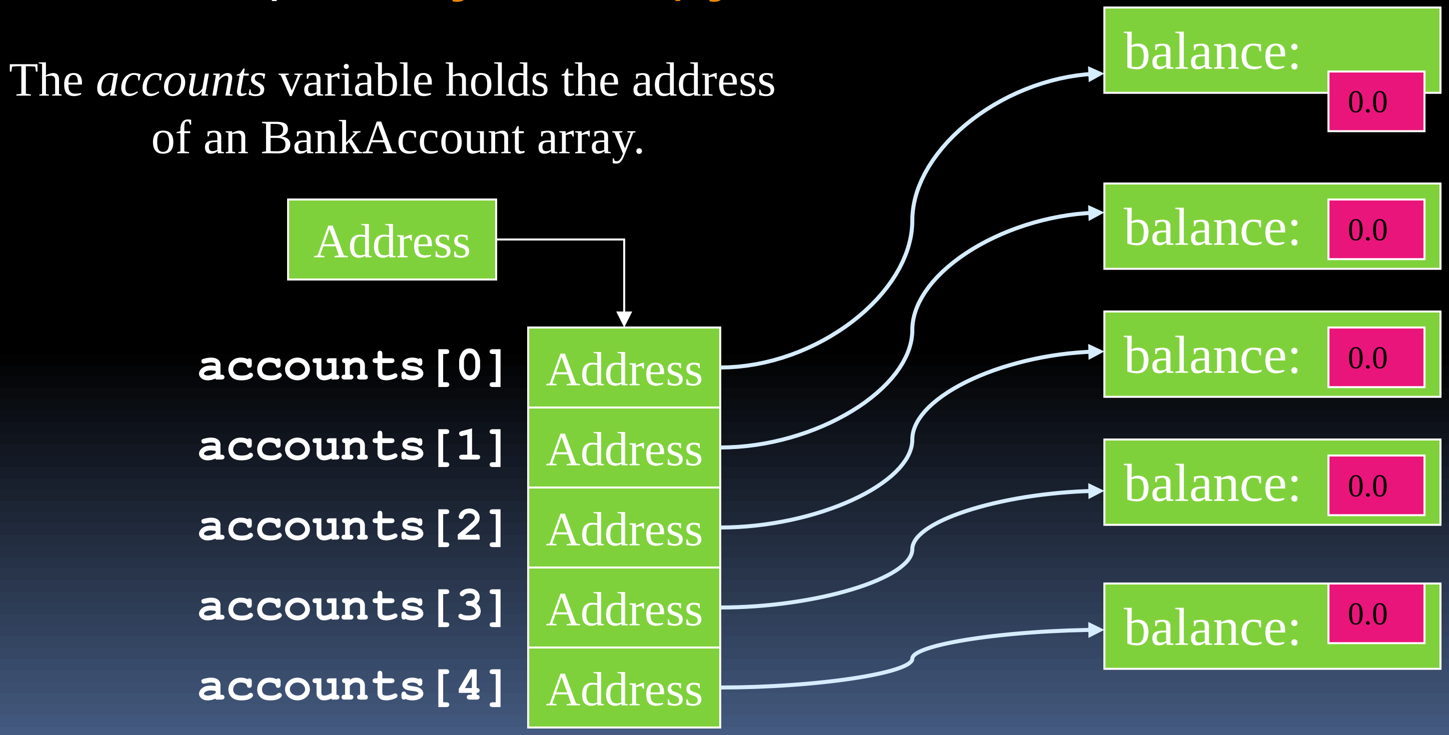
The array is an array of references to `BankAccount` objects.

Arrays of Objects

- Each element needs to be initialized.

```
for (int i = 0; i < accounts.length; i++)
   accounts[i] = new BankAccount();
```

- See example: ObjectArray.java

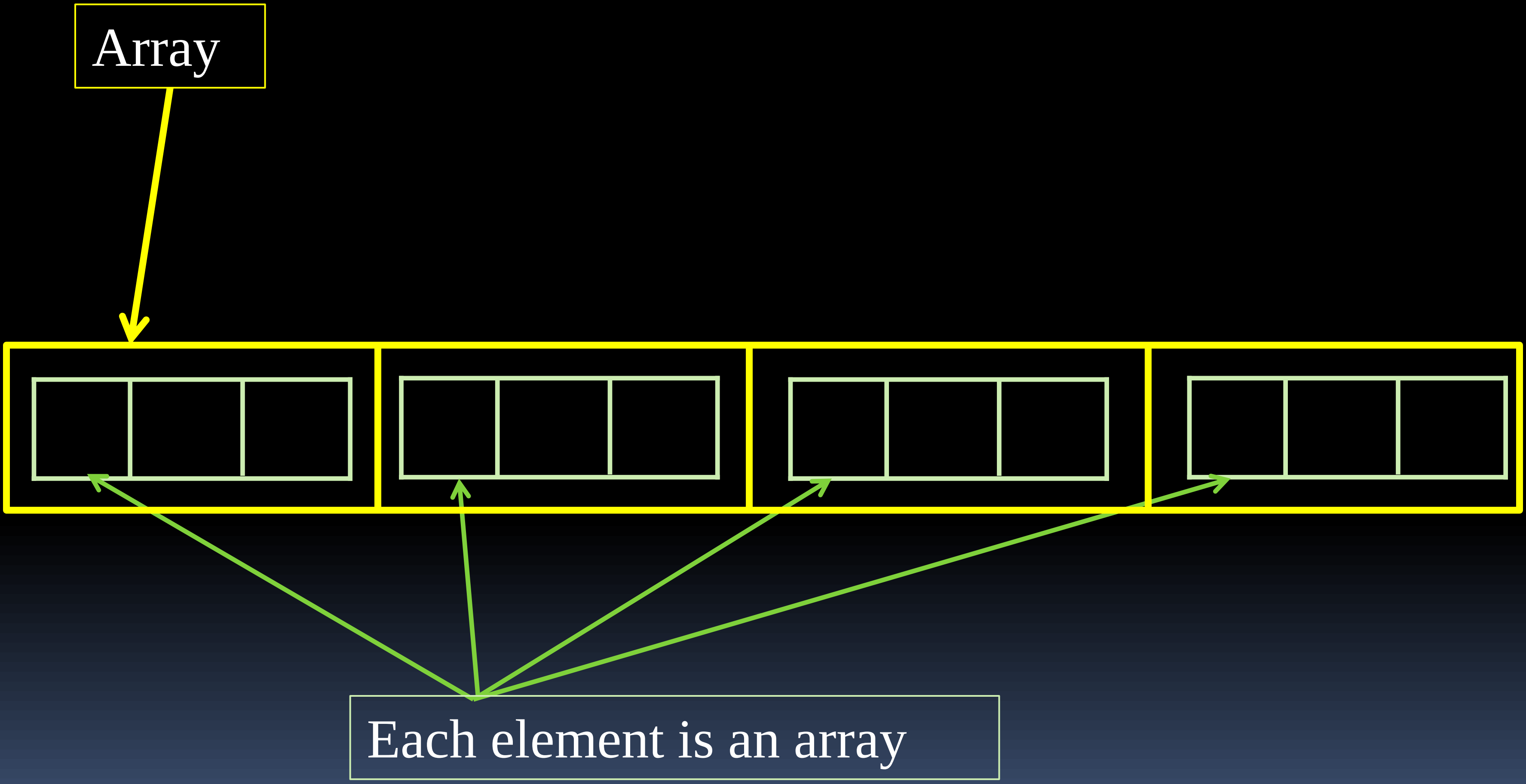


The Sequential Search Algorithm

- A search algorithm is a method of locating a specific item in a larger collection of data.
- The *sequential search algorithm* uses a loop to:
  - sequentially step through an array,
  - compare each element with the search value, and
  - stop when
    - the value is found or
    - the end of the array is encountered.
- See example: SearchArray.java

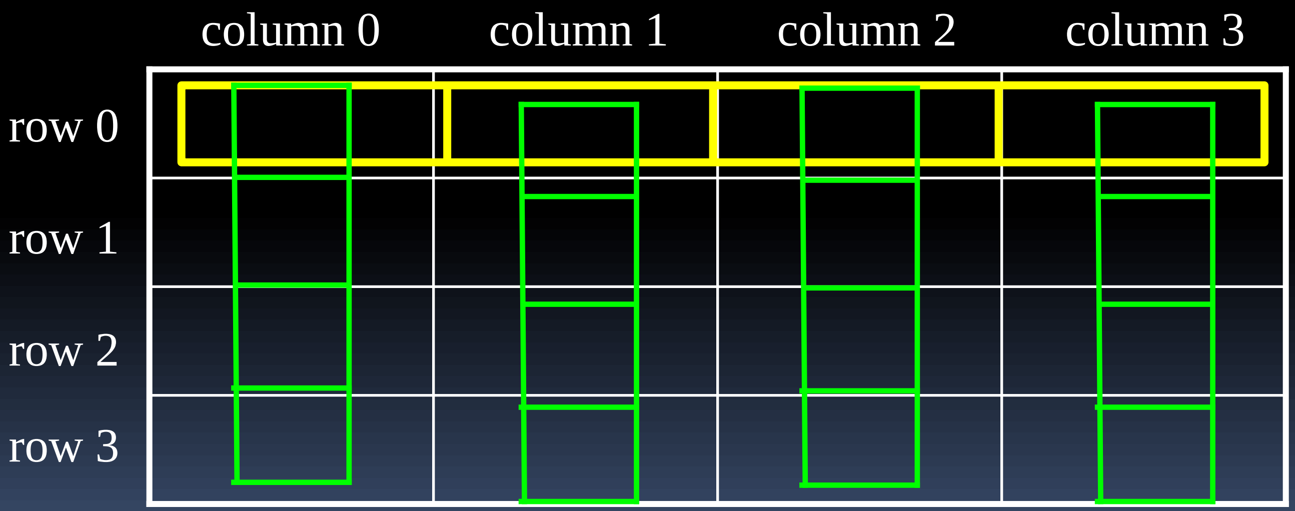
Two-Dimensional Arrays

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



Two-Dimensional Arrays

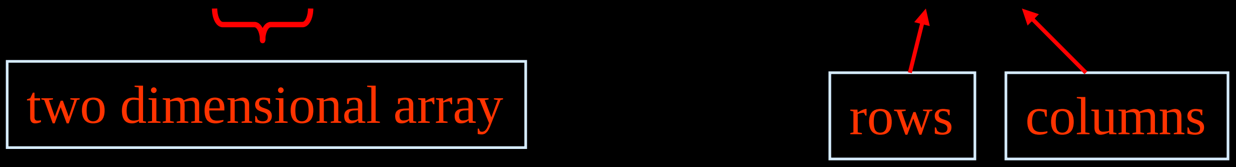
- A two-dimensional array is an array of arrays.
- It can be thought of as having rows and columns.



Two-Dimensional Arrays

- Declaring a two-dimensional array requires two sets of brackets and two size declarators
  - The first one is for the number of rows
  - The second one is for the number of columns.

```
double[][] scores = new double[3][4];
```



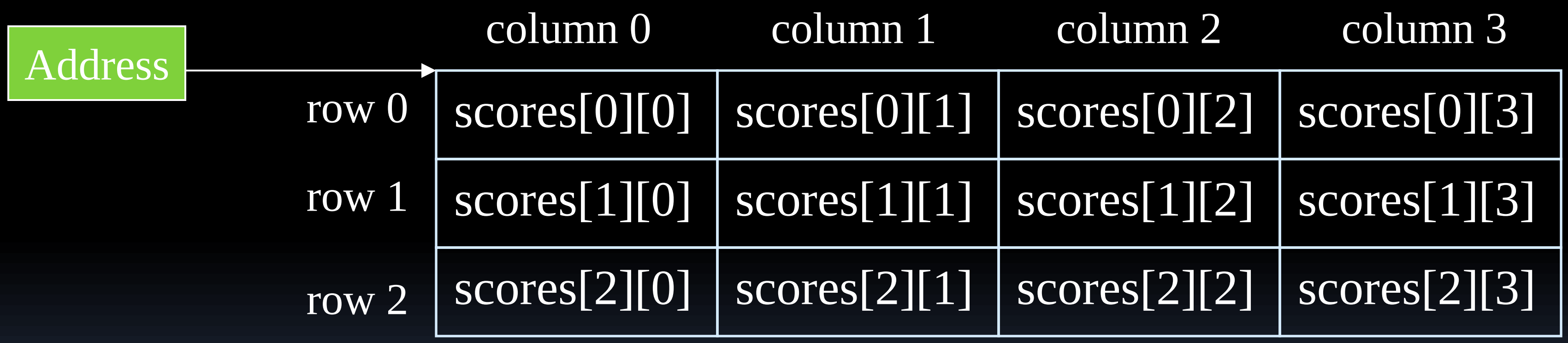
- The two sets of brackets in the data type indicate that the scores variable will reference a two-dimensional array.
- Notice that each size declarator is enclosed in its own set of brackets.

Accessing Two-Dimensional Array Elements

- When processing the data in a two-dimensional array, each element has two subscripts:
  - one for its row and
  - another for its column.

Accessing Two-Dimensional Array Elements

The `scores` variable holds the address of a 2D array of `double`s.



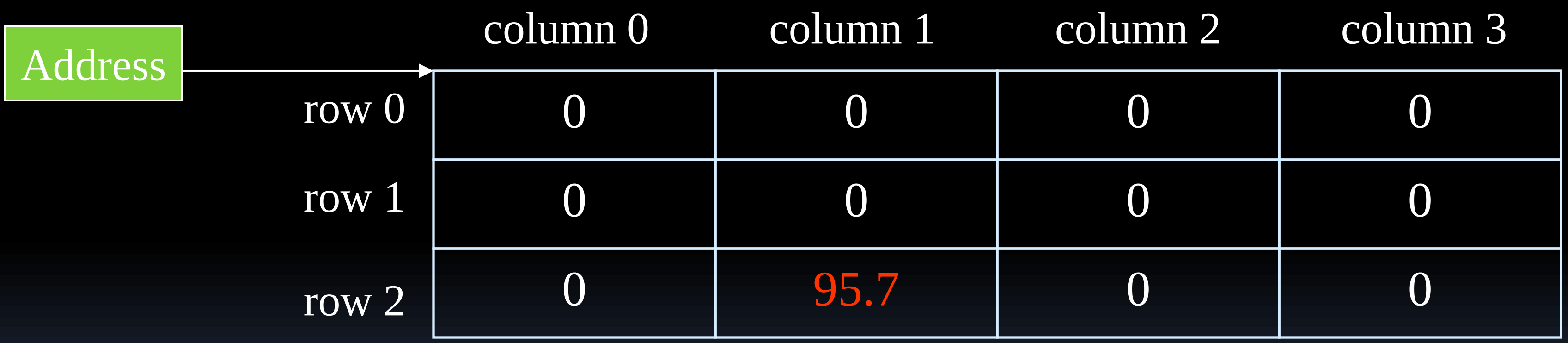
	column 0	column 1	column 2	column 3
row 0	scores[0][0]	scores[0][1]	scores[0][2]	scores[0][3]
row 1	scores[1][0]	scores[1][1]	scores[1][2]	scores[1][3]
row 2	scores[2][0]	scores[2][1]	scores[2][2]	scores[2][3]

Accessing Two-Dimensional Array Elements

Accessing one of the elements in a two-dimensional array requires the use of both subscripts.

The `scores` variable holds the address of a 2D array of `double`s.

```
scores[2][1] = 95.7;
```



	column 0	column 1	column 2	column 3
row 0	0	0	0	0
row 1	0	0	0	0
row 2	0	95.7	0	0

Accessing Two-Dimensional Array Elements

- Programs that process two-dimensional arrays can do so with nested loops.
- To fill the scores array:

Number of rows, not the largest subscript

Number of columns, not the largest subscript

```
for (int row = 0; row < 3; row++)
{
   for (int col = 0; col < 4; col++)
   {
      System.out.print("Enter a score: ");
      scores[row][col] = keyboard.nextDouble();
   }
}
```

`keyboard` references a `Scanner` object

Accessing Two-Dimensional Array Elements

- To print out the `scores` array:

```
for (int row = 0; row < 3; row++)
{
  for (int col = 0; col < 4; col++)
  {
    System.out.println(scores[row][col]);
  }
}
```

- See example: CorpSales.java

Initializing a Two-Dimensional Array

- Initializing a two-dimensional array requires enclosing each row's initialization list in its own set of braces.

```
int[][] numbers = { {1, 2, 3}, {4, 5, 6}, {7, 8, 9} };
```

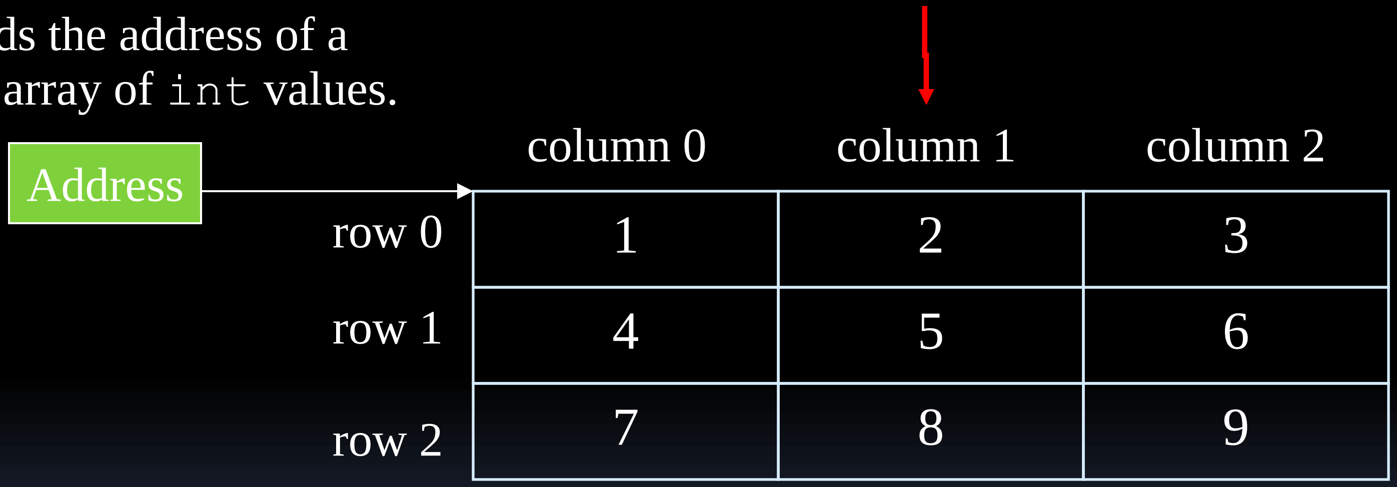
- Java automatically creates the array and fills its elements with the initialization values.
  - row 0 {1, 2, 3}
  - row 1 {4, 5, 6}
  - row 2 {7, 8, 9}
- Declares an array with three rows and three columns.

Initializing a Two-Dimensional Array

```
int[][] numbers = {{1, 2, 3},
                   {4, 5, 6},
                   {7, 8, 9}};
```

produces:

The `numbers` variable holds the address of a 2D array of `int` values.



	column 0	column 1	column 2
row 0	1	2	3
row 1	4	5	6
row 2	7	8	9

The `length` Field

- Two-dimensional arrays are arrays of one-dimensional arrays.
- The length field of the array gives the number of rows in the array.
- Each row has a length constant tells how many columns is in that row.
- Each row can have a different number of columns.

The `length` Field

- To access the `length` fields of the array:

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

for (int row = 0; row < numbers.length; row++)
{
  for (int col = 0; col < numbers[row].length; col++)
    System.out.println(numbers[row][col]);
}
```

Number of rows

Number of columns in this row.

- See example: Lengths.java

The array can have variable length rows.

Summing The Elements of a Two-Dimensional Array

```
int[][] numbers = { { 1, 2, 3, 4 },
                    {5, 6, 7, 8},
                    {9, 10, 11, 12} };
int total;
total = 0;
for (int row = 0; row < numbers.length; row++)
{
  for (int col = 0; col < numbers[row].length; col++)
    total += numbers[row][col];
}

System.out.println("The total is " + total);
```

Summing The Rows of a Two-Dimensional Array

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

for (int row = 0; row < numbers.length; row++)
{
   total = 0;
   for (int col = 0; col < numbers[row].length; col++){
     total += numbers[row][col];
   }
   System.out.println("Total of row "
                  + row + " is " + total);
}
```

Summing The Columns of a Two-Dimensional Array

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

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

Passing and Returning Two-Dimensional Array References

- There is no difference between passing a single or two-dimensional array as an argument to a method.
- The method must accept a two-dimensional array as a parameter.
- See example: Pass2Darray.java

Ragged Arrays

- When the rows of a two-dimensional array are of different lengths, the array is known as a *ragged array*.
- You can create a ragged array by creating a two-dimensional array with a specific number of rows, but no columns.

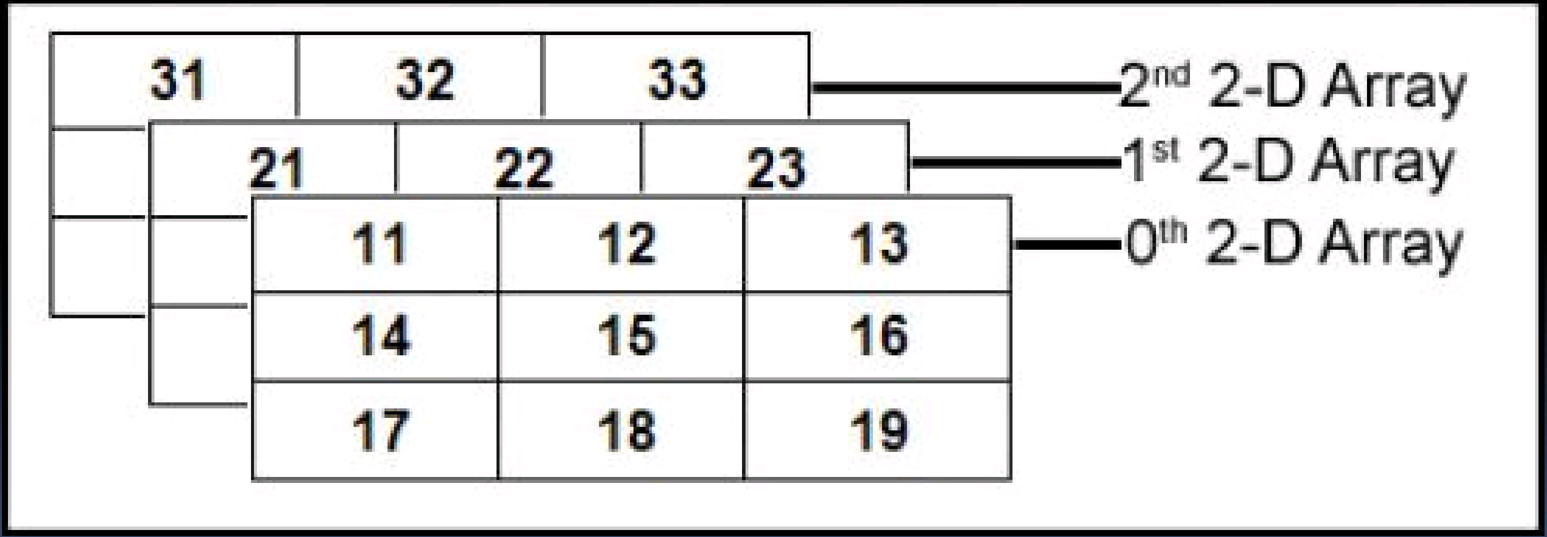
```
int [][] ragged = new int [4][];
```

- Then create the individual rows.

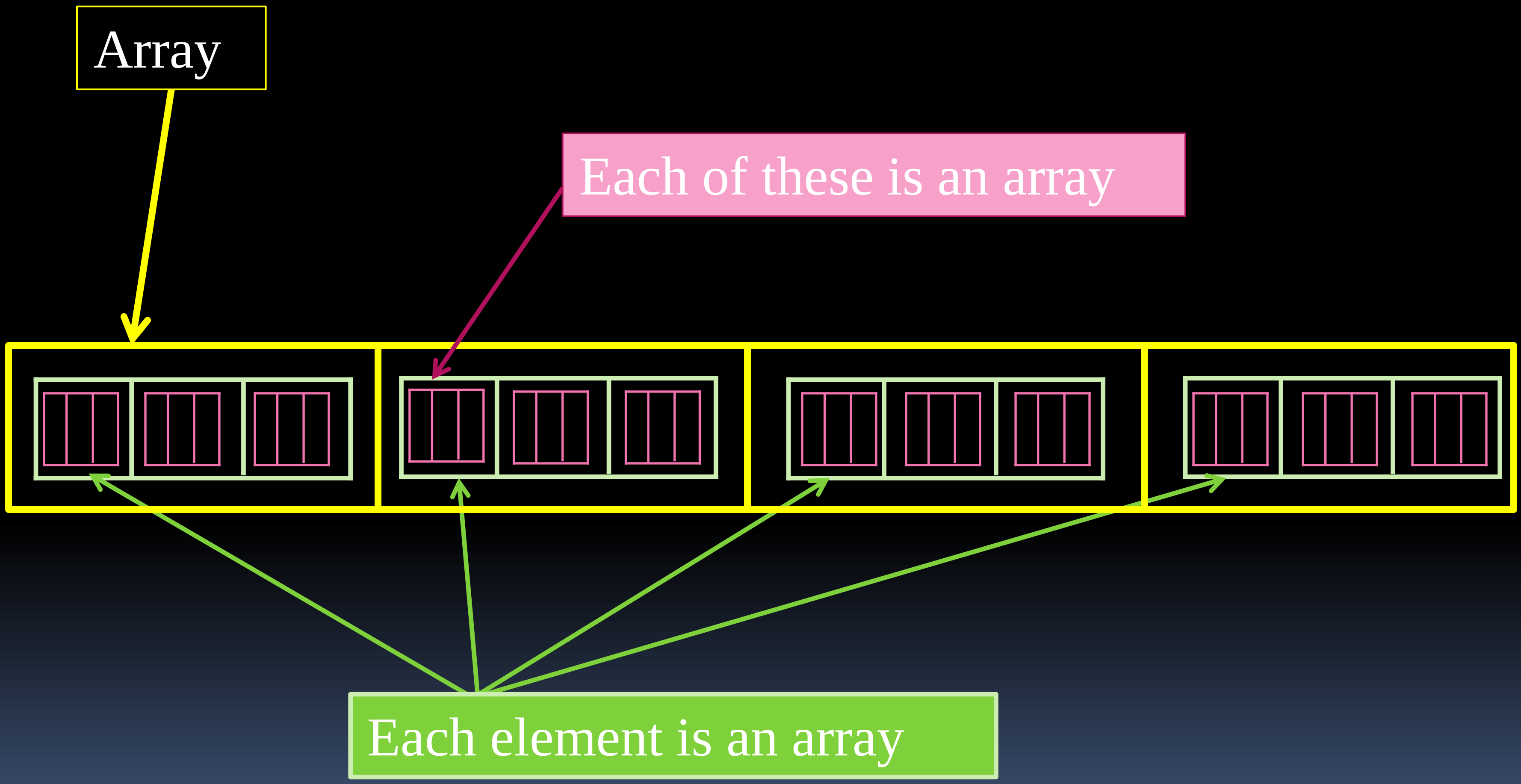
```
ragged[0] = new int [3];
ragged[1] = new int [4];
ragged[2] = new int [5];
ragged[3] = new int [6];
```

More Than Two Dimensions

- Java does not limit the number of dimensions that an array may be.
- More than three dimensions is hard to visualize, but can be useful in some programming problems.



More than Two Dimensions



Binary Search

- A binary search:
  - requires an array sorted in ascending order.
  - starts with the element in the middle of the array.
  - If that element is the desired value, the search is over.
  - Otherwise, the value in the middle element is either greater or less than the desired value
  - If it is greater than the desired value, search in the first half of the array.
  - Otherwise, search the last half of the array.
  - Repeat as needed while adjusting start and end points of the search.
- See example: BinarySearchDemo.java

The `ArrayList` Class

- Similar to an array, an `ArrayList` allows object storage
- Unlike an array, an `ArrayList` object:
  - Automatically expands when a new item is added
  - Automatically shrinks when items are removed
- Requires:

```
import java.util.ArrayList;
```

Creating an `ArrayList`

```
ArrayList<String> nameList = new ArrayList<String>();
```

Notice the word `String` written inside angled brackets <>

This specifies that the `ArrayList` can hold `String` objects.

If we try to store any other type of object in this `ArrayList`, an error will occur.

Using an `ArrayList`

- To populate the `ArrayList`, use the `add` method:
  - `nameList.add("James");`
  - `nameList.add("Catherine");`

- To get the current size, call the `size` method
  - `nameList.size();   // returns 2`

Using an `ArrayList`

- To access items in an `ArrayList`, use the `get` method

  ```
  nameList.get(1);
  ```

  In this statement 1 is the index of the item to get.

- Example: ArrayListDemo1.java

Using an `ArrayList`

- The `ArrayList` class's `toString` method returns a string representing all items in the `ArrayList`

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

This statement yields :

```
[ James, Catherine ]
```

- The `ArrayList` class's `remove` method removes designated item from the `ArrayList`

```
nameList.remove(1);
```

This statement removes the second item.

- See example: ArrayListDemo3.java

Using an `ArrayList`

- The `ArrayList` class's `add` method with one argument adds new items to the end of the `ArrayList`
- To insert items at a location of choice, use the `add` method with two arguments:

```
nameList.add(1, "Mary");
```

  This statement inserts the `String` "Mary" at index 1

- To replace an existing item, use the `set` method:

```
nameList.set(1, "Becky");
```

  This statement replaces “Mary” with “Becky”

- See example: ArrayListDemo5.java

Using an `ArrayList`

- An `ArrayList` has a capacity, which is the number of items it can hold without increasing its size.
- The default capacity of an `ArrayList` is 10 items.
- To designate a different capacity, use a parameterized constructor:

```
ArrayList<String> list = new ArrayList<String>(100);
```

Using an `ArrayList`

- You can store any type of *object* in an `ArrayList`

```
ArrayList<BankAccount> accountList =
                new ArrayList<BankAccount>();
```

This creates an `ArrayList` that can hold `BankAccount` objects.

Using an ArrayList

```
// Create an ArrayList to hold BankAccount objects.
ArrayList<BankAccount> list = new ArrayList<BankAccount>();

// Add three BankAccount objects to the ArrayList.
list.add(new BankAccount(100.0));
list.add(new BankAccount(500.0));
list.add(new BankAccount(1500.0));

// Display each item.
for (int index = 0; index < list.size(); index++)
{
   BankAccount account = list.get(index);
   System.out.println("Account at index " + index +
                "\nBalance: " + account.getBalance());
}
```

See: ArrayListDemo6.java

Filling an ArrayList

```
private ArrayList<Integer> numbers;
private String filename = "data.txt";

    public void run(){
        try{
            File file = new File(filename);
            Scanner fin = new Scanner(file);

            while(fin.hasNextInt()){
                numbers.add(fin.nextInt());
            }

            fin.close();

            for(Integer number:numbers){
                System.out.print(number+" ");
            }
            System.out.print("\n");

            java.util.Collections.sort(numbers);

            for(Integer number:numbers){
                System.out.print(number+" ");
            }
            System.out.print("\n");
        }
        catch(java.io.FileNotFoundException e){
             System.out.println("Error opening "+filename+", ending program");
             System.exit(1);
        }
    }
```

FileAndArrayList.java