Introduction to Arrays

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CS 2401 (Fall 2010)

Elementary Data Structures and Algorithms

Arrays

- Arguably the most fundamental data structure
  - Other data structures built using arrays
  - Computer memory is like a giant array
- Convenient way to process large amounts of related data

Example: print three integers in reverse order (without array)

```
public static void main(String[] args) {
      int num1,num2,num3;
      System.out.println("Enter three integers:");

      num1=console.nextInt();
      num2=console.nextInt();
      num3=console.nextInt();

      System.out.println(num3);
      System.out.println(num2);
      System.out.println(num1);
}
```

Example: print three integers in reverse order (without array)

```
public static void main(String[] args) {
      int[] num = new int[3];
      system.out.println("Enter three integers:");

      for(int i=0; i<3; i++){
            num[i]=console.nextInt();
      }

      for(int i=2; i>=0; i--)
            system.out.println(num[i]);
      }
}
```

Array Definition

- A structured data type with a **fixed** number of components
- Every component is of the same type
- Components are accessed using their relative positions in the array
- In Java, arrays are objects

Example Array

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

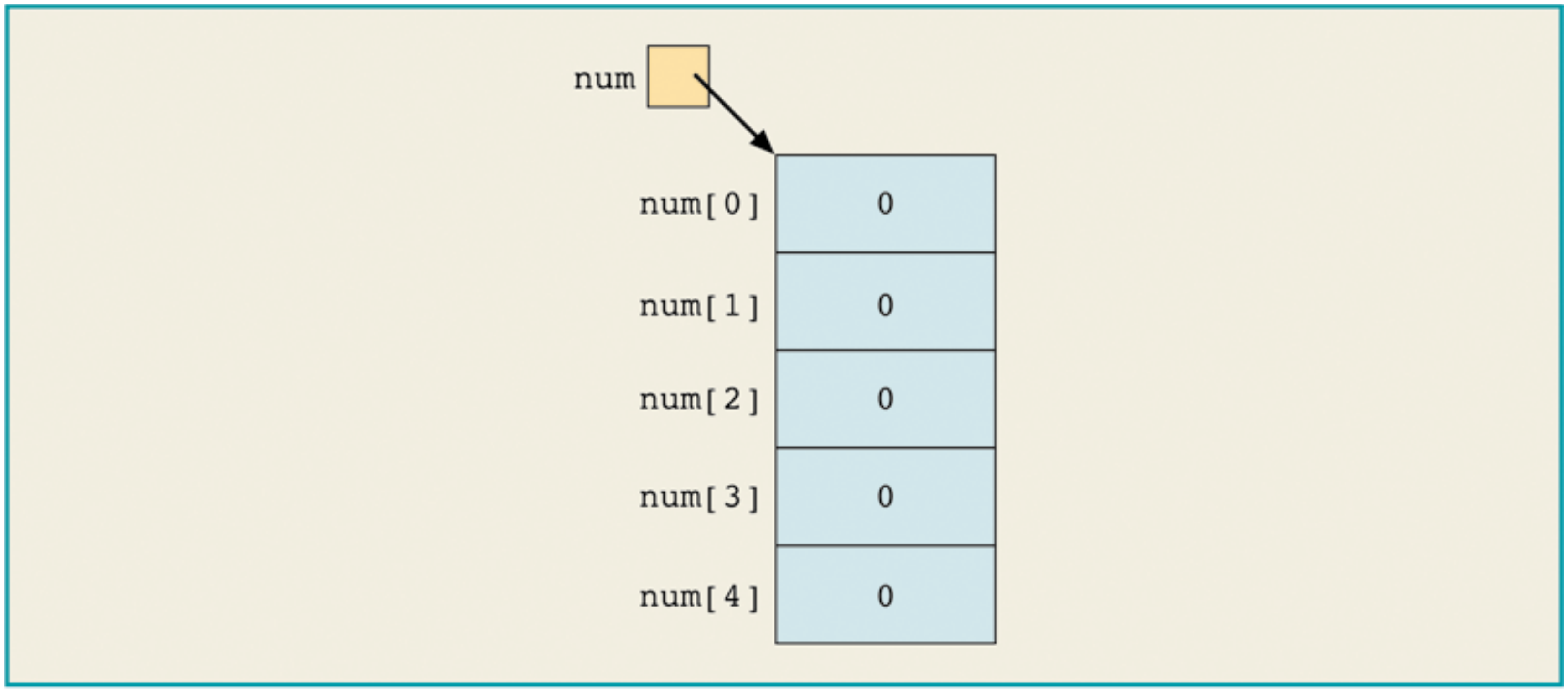


Figure 9-1 Array num

Example 2

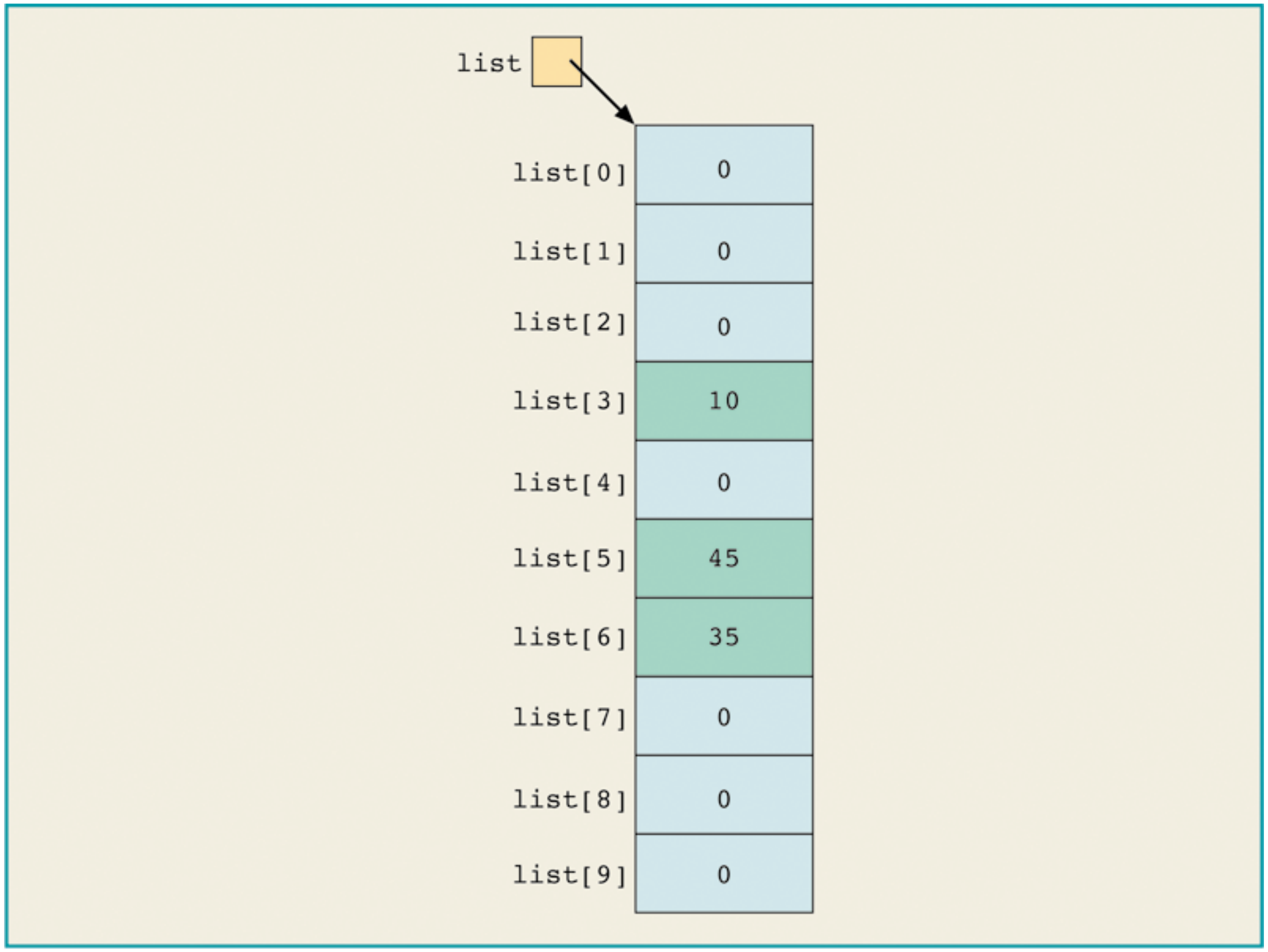


Figure 9-4 Array `list` after the statements `list[3]= 10;`, `list[6]= 35;`, and `list[5] = list[3] + list[6];` execute

Array Syntax

- Syntax to declare an array:
  - `dataType[] arrayName;`
    `arrayName = new dataType[N]`
  - `dataType[] arrayName = new dataType[N]`
  - `dataType[] arrayName1, arrayName2;`

- Syntax to access an array component:
  - `arrayName[index]`
  - `0 <= index < length of array`

Array Initialization During Declaration

```
double[] sales = {12.25, 32.50, 16.90, 23};
```

- Array size is determined by the number of initial values within the braces
- If an array is declared and initialized simultaneously, do not use the operator `new` to instantiate the array object

Specifying Array Size During Program Execution

```
int arraySize;
System.out.print("Enter the size of "
               + "the array: ");
arraySize = console.nextInt();
System.out.println();
int[] list = new int[arraySize];
```

Must wait until you know the size to initialize

Array Default Values

What does the following code snippet print?

```
int[] numList = new int[10];
System.out.println(numList[6]);
```

Arrays are initialized to the default value for the type

int: 0

boolean: false

String: null

Array Initialization

What does the following code snippet print?

```
int[] numList = new int[10];
Arrays.fill(numList, 15);
System.out.println(numList[6]);
```

Array Length

- A `public` instance variable `length` is associated with each array that has been instantiated
- `length` contains the size of the array

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

- The value of `numList.length` is `10`

Processing One-Dimensional Arrays

- Loops used to step through elements in array and perform operations

```
int[] list = new int[100];

for (int i = 0; i < list.length; i++)
   //process list[i], the (i + 1)th
   //element of list

for (int i = 0; i < list.length; i++)
    list[i] = console.nextInt();


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

Determining Largest Element in Array

```
int[] sales = {5, 12, 14, 11, 19};
maxIndex = 0;

for (int i=1; i<sales.length; i++) {
     if (sales[maxIndex] < sales[i]) {
       maxIndex = i;
     }
}
largestSale = sales[maxIndex];
```

Extermination Exercise

```
int[] numList = {1,2.8,4,6.7};
double ave = 0;

for (int i=1; i<=numList.length(); i++) {
  ave += numList[i]
}
ave = ave / numList.length;
System.println("Average: " + ave);
```

Extermination Exercise

```
double[] numList = {1,2.8,4,6.7};
double ave = 0;

for (int i=0; i<numList.length~~()~~; i++) {
  ave += numList[i];
}
ave = ave / numList.length;
System.out.println(“Average: “ + ave);
```

Array Index Out of Bounds

- An array is in bounds if:

  `0 <= index <= arraySize - 1`
- If `index < 0` or `index > arraySize`:

  `ArrayIndexOutOfBoundsException` exception is thrown

Declaring Arrays as Formal Parameters to Methods

- General syntax to declare an array as a formal parameter: `dataType[] arrayName`

```
public static void arraysAsFormalParameter(int[] listA,
                                double[] listB, int num)
{
    //...
}

int[] intList = new int[10];
double[] doubleNumList = new double[15];
int number;


arraysAsFormalParameter(intList, doubleNumList, number);
```

Array Copying

```
int[] listA = {5, 10, 15, 20, 25, 30, 35};
int[] listB = {0, 0, 0, 0, 0, 0, 0};

listB = listA;
System.out.println("Test1: " + listB[3]);


listB[2] = -1;
System.out.println("Test2: " + listA[2]);
```

The Assignment Operators and Arrays

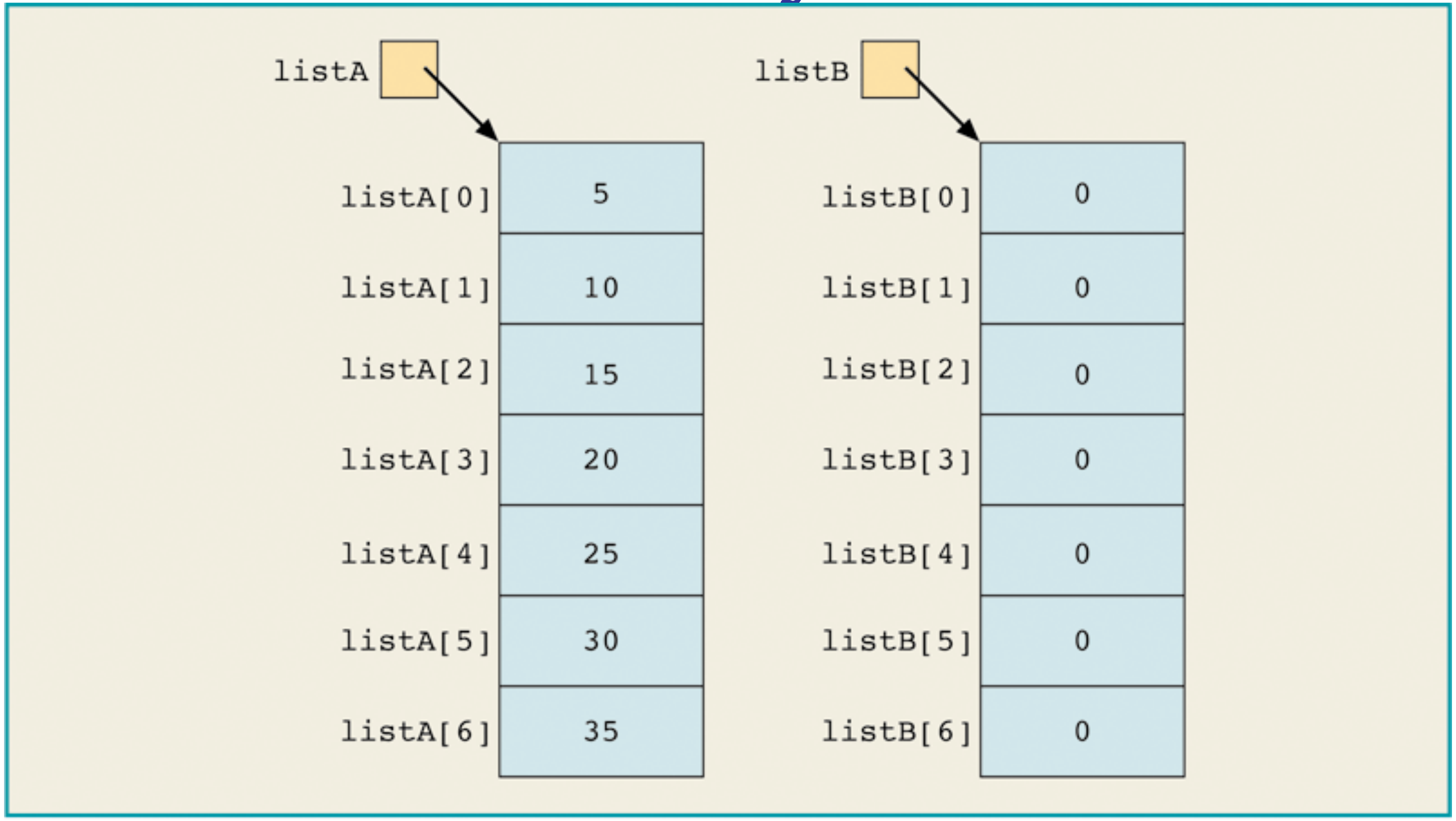


Figure 9-6 Arrays `listA` and `listB`

The Assignment Operators and Arrays (continued)

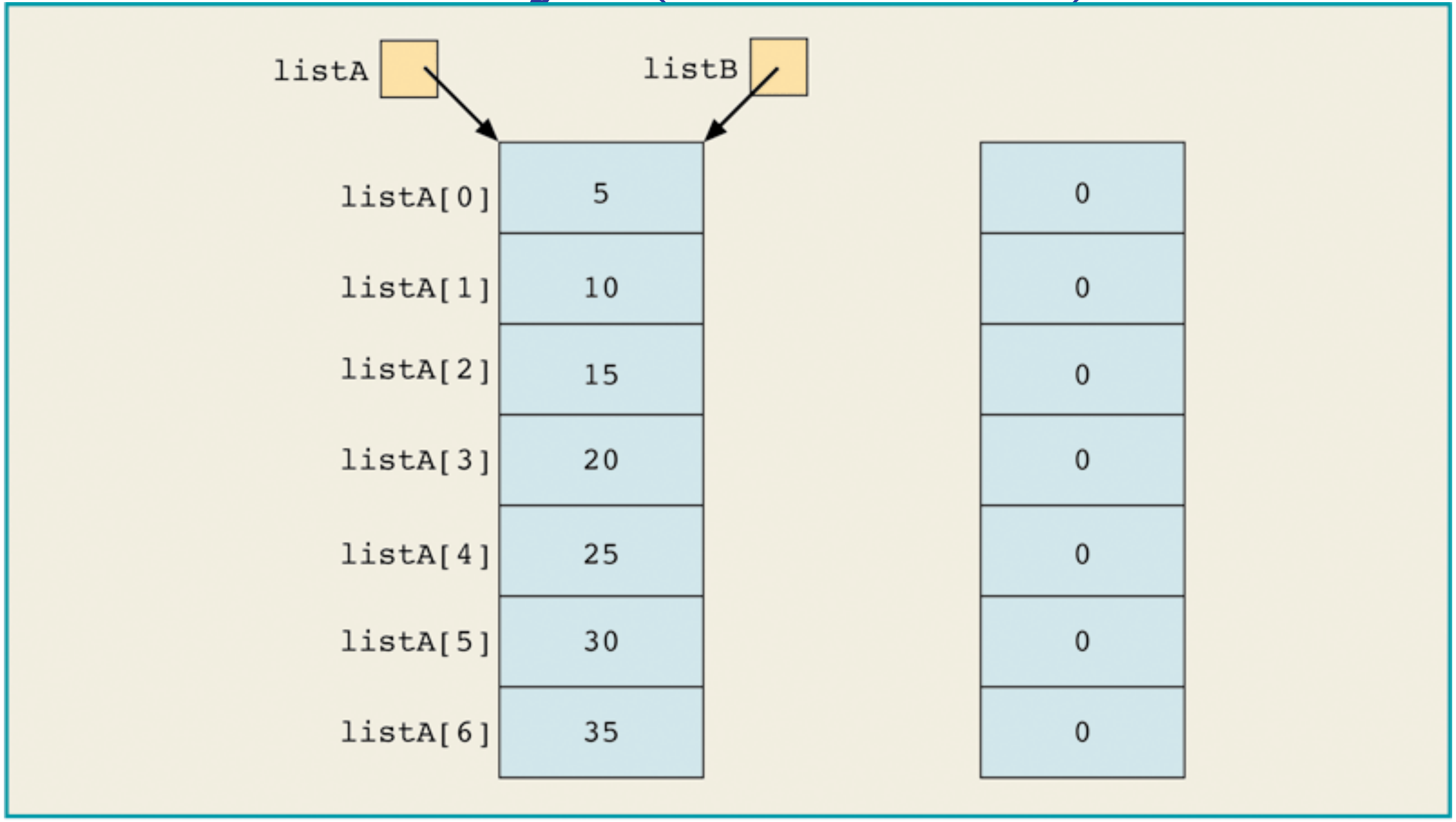


Figure 9-7 Arrays after the statement `listB = listA;` executes

How do you copy an array?

- Use a for loop
- Use Arrays.copyOf()

```
int[] copy = Arrays.copyOf(original,
        original.length);
```

- Use System.arrayCopy();

```
int[] copy = new int[original.length];
System.arrayCopy(original, 0, copy, 0,
                 original.length);
```

Relational Operators Arrays

```
if (listA == listB)
        ...
```

- The expression `listA == listB` determines if the values of `listA` and `listB` are the same (refer to the same array)
- To determine whether `listA` and `listB` contain the same elements, compare them component by component
- You can write a method that returns `true` if two `int` arrays contain the same elements

Testing Array Equality

```
boolean isEqualArrays(int[] firstArray,
                      int[] secondArray)
{
    if (firstArray.length != secondArray.length)
        return false;
    for (int index = 0; index < firstArray.length;
                        index++)
        if (firstArray[index] != secondArray[index])
            return false;
    return true;
}
```

Check out Arrays.equals()

Arrays of Objects

- Can use arrays to manipulate objects
- Example: Create an array named `array1` with `N` objects of type `T`:

```
T[] array1 = new T[N]
```

- Can instantiate `array1` as follows:

```
for(int j=0; j <array1.length; j++)
   array1[j] = new T();
```

Array of `String` Objects

```
String[] nameList = new String[5];

nameList[0] = "Amanda Green";
nameList[1] = "Vijay Arora";
nameList[2] = "Sheila Mann";
nameList[3] = "Rohit Sharma";
nameList[4] = "Mandy Johnson";
```

Array of `String` Objects (continued)

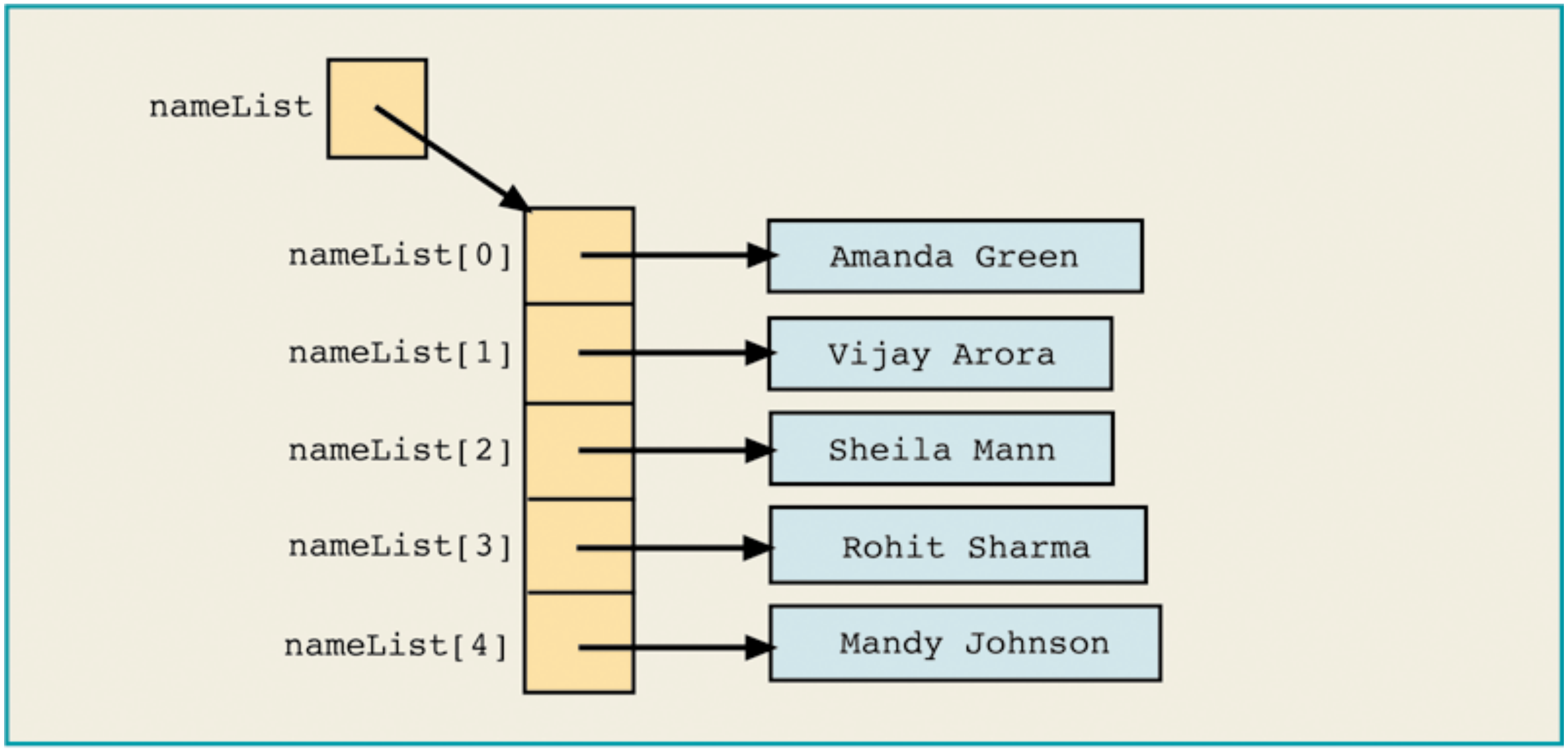


Figure 9-9 Array `nameList`

Arrays of Objects

```
Clock[] arrivalTimeEmp = new Clock[100];
```

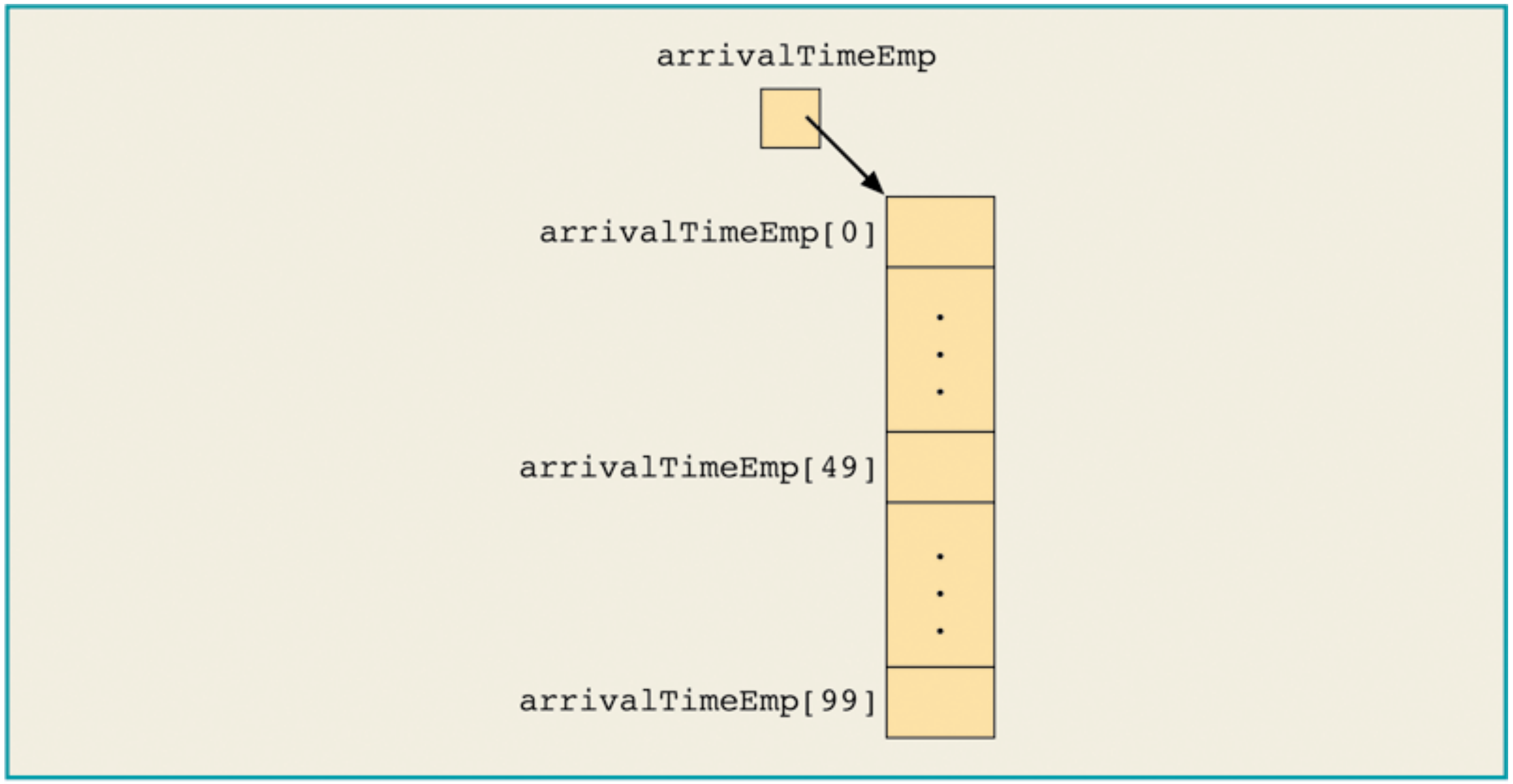


Figure 9-10 Array `arrivalTimeEmp`

Instantiating Array Objects

```
for (int j = 0; j < arrivalTimeEmp.length; j++)
    arrivalTimeEmp[j] = new Clock();
```

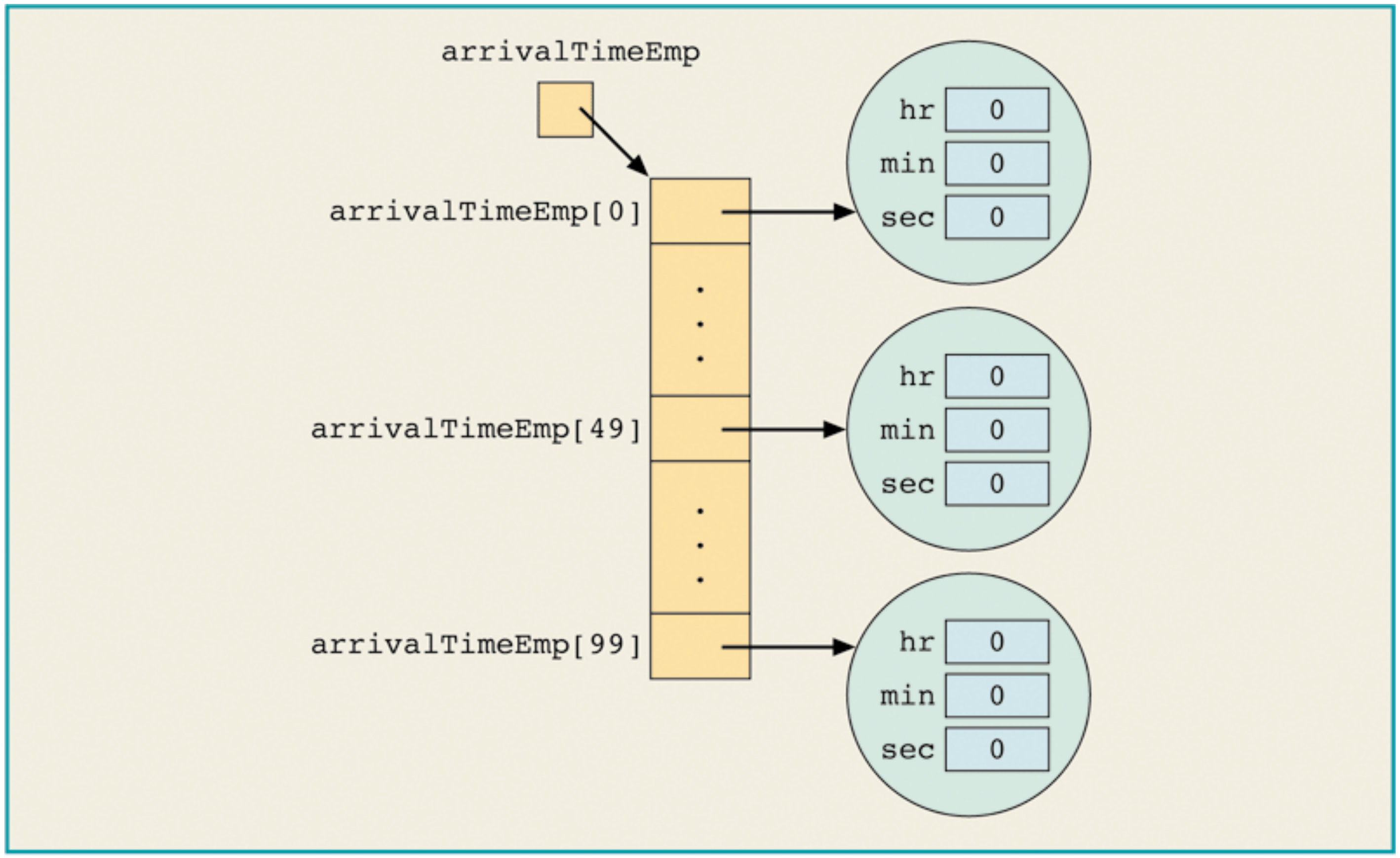


Figure 9-11 Array `arrivalTime` after instantiating the objects for each component

Instantiating Array Objects

```
arrivalTimeEmp[49].setTime(8, 5, 10);
```

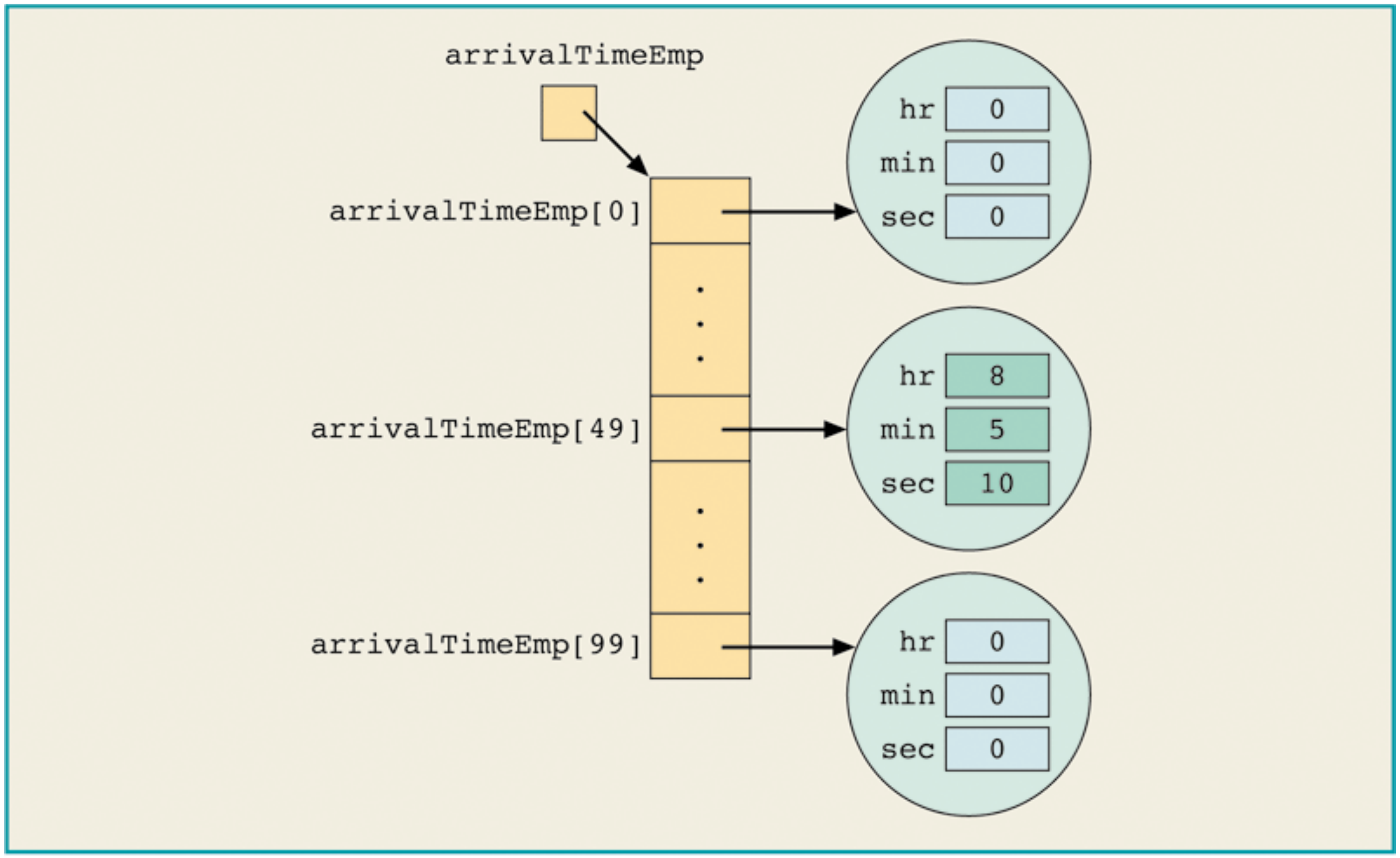


Figure 9-12 Array `arrivalTimeEmp` after setting the time of employee `49`

Arrays and Variable Length Parameter List

- The syntax to declare a variable length formal parameter (list) is:

```
dataType ... identifier
```

Arrays and Variable Length Parameter List (continued)

```
public static double largest(double ... numList)
{
    double max;
    int index;
    if (numList.length != 0)
    {
        max = list[0];
        for (index = 1; index < numList.length;
                        index++)
        {
            if (max < numList [index])
                max = numList [index];
        }
        return max;
    }
    return 0.0;
}
```

`foreach` loop

- The syntax to use `for` loop to process the elements of an array is:

```
for (dataType identifier : arrayName)
      statements
```

- `identifier` is a variable, and the data type of `identifier` is the same as the data type of the array components

`foreach` loop

```
sum = 0;
for (double num : list)
    sum = sum + num;
```

- The `for` statement is read for each `num` in `list`
- The identifier `num` is initialized to `list[0]`
- In the next iteration, the value of `num` is `list[1]`, and so on

Multi-Dimensional Arrays

Multi-Dimensional Arrays

We can have arrays of objects

Arrays are objects…

Can we have an array of arrays?

Why?

- Great for storing and manipulating “matrix” data
- Examples
  - Board Games
  - Excel Spreadsheets
  - Others?

Two-Dimensional Arrays

- To declare/instantiate a two-dimensional array:

```
dataType[][] name = new dataType[4][3];
```

- To initialize in the declaration:

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

Accessing 2d Arrays

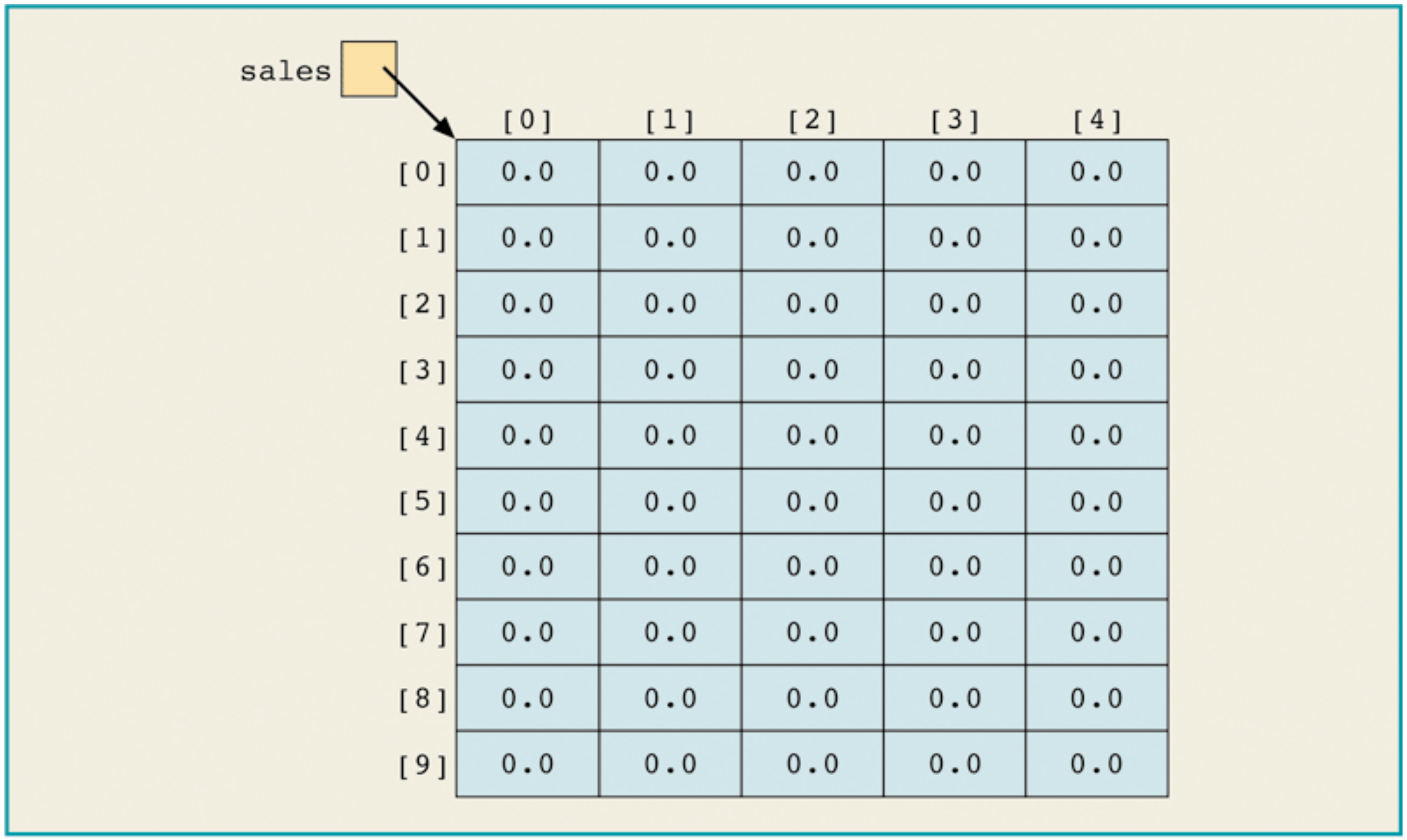
- To access a component of a two-dimensional array:

  `arrayName[index1][index2];`

  - `index1` = row position
  - `index2` = column position

Two-Dimensional Arrays

```
double[][]sales = new double[10][5];
```



	[0]	[1]	[2]	[3]	[4]
[0]	0.0	0.0	0.0	0.0	0.0
[1]	0.0	0.0	0.0	0.0	0.0
[2]	0.0	0.0	0.0	0.0	0.0
[3]	0.0	0.0	0.0	0.0	0.0
[4]	0.0	0.0	0.0	0.0	0.0
[5]	0.0	0.0	0.0	0.0	0.0
[6]	0.0	0.0	0.0	0.0	0.0
[7]	0.0	0.0	0.0	0.0	0.0
[8]	0.0	0.0	0.0	0.0	0.0
[9]	0.0	0.0	0.0	0.0	0.0

Figure 9-14 Two-dimensional array `sales`

Accessing Two-Dimensional Array Components

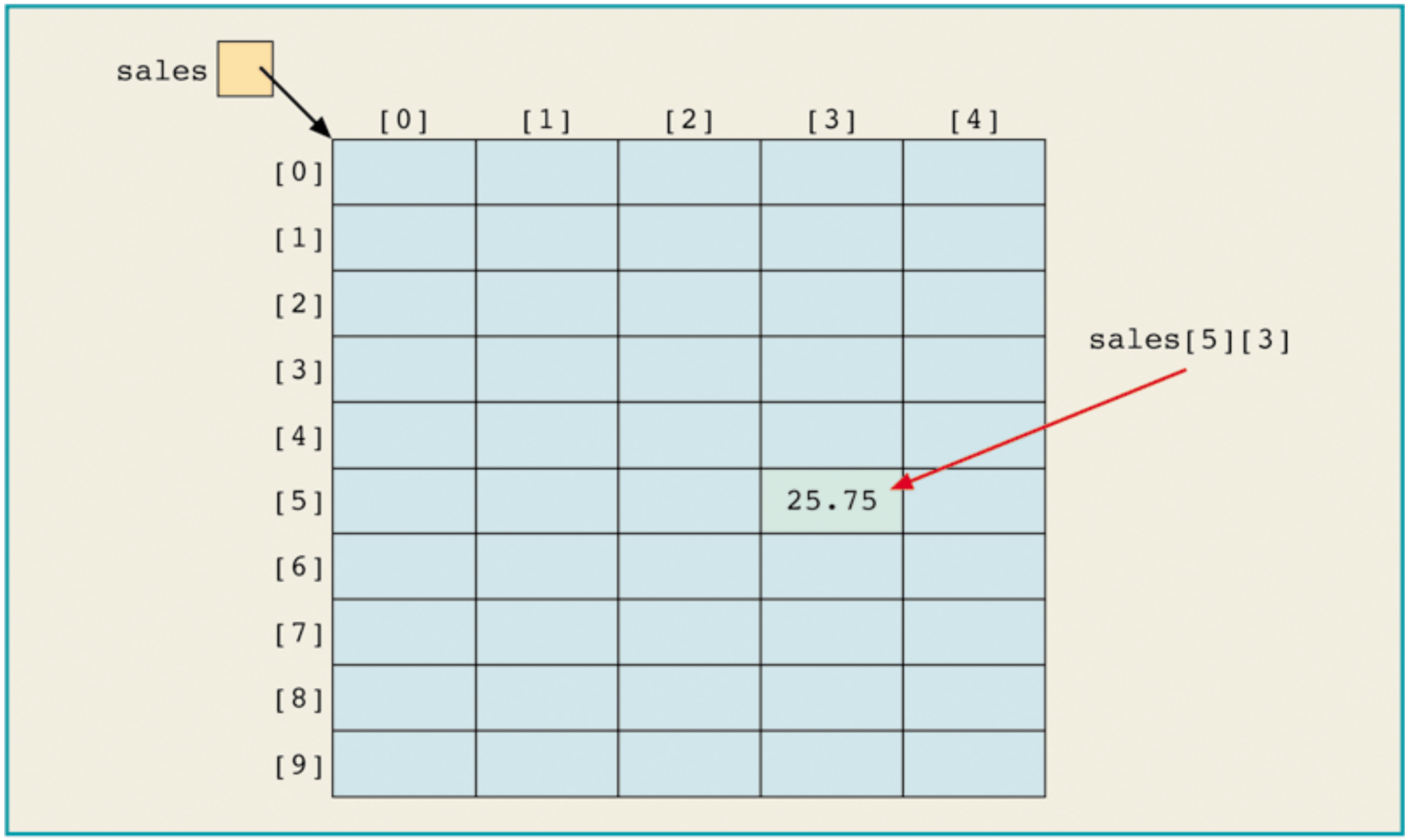


Figure 9-15 `sales[5][3]`

Example: Seating Chart

- Suppose I want to write a program to store the names of everyone in this course, organized by where they are currently sitting
- Write a piece of code to declare a data structure to store this information
- Initialize the correct element with your name
    - Front row is “0”
    - Left column is “0”

Size of 2d Arrays

```
dataType[][] name = new dataType[4][3];
```

- How do we get the number of rows in a 2d array?

```
numRows = name.length; // 4
```

- How do we get the number of columns?

```
numCols = name[0].length; // 3
```

Processing 2d Arrays

- Three ways to process two-dimensional arrays:
  - Entire array
  - Particular row of array (row processing)
  - Particular column of array (column processing)
- Processing algorithms is similar to processing algorithms of one-dimensional arrays
- Use two for loops

Processing 2d Arrays

Initialization

```
for (row = 0; row < matrix.length; row++)
  for (col = 0; col < matrix[row].length; col++)
     matrix[row][col] = 10;
```

Print

```
for (row = 0; row < matrix.length; row++) {
  for (col = 0; col < matrix[row].length; col++) {
    System.out.printf("%7d", matrix[row][col]);
  }
  System.out.println();
}
```

Processing 2d Arrays

Exercise: write code to output the sum of each ***row*** of a 2d matrix

Sum by Row

```
for (row = 0; row < matrix.length; row++) {
   sum = 0;
   for (col = 0; col < matrix[row].length; col++) {
      sum = sum + matrix[row][col];
   }
   System.out.println("Sum of row " + (row + 1)
                                 + " = "+ sum);
  }
}
```

Processing 2d Arrays

Exercise: write code to output the sum of each ***column*** of a 2d matrix

Sum by Column

```
for (col = 0; col < matrix[0].length; col++) {
    sum = 0;
    for (row = 0; row < matrix.length; row++) {
      sum = sum + matrix[row][col];
    }
    System.out.println("Sum of column " + (col + 1)
                           + " = " + sum);
}
```

Processing 2d Arrays

Exercise: write code to output the maximum element of each row in a 2d matrix

```
for (row = 0; row < matrix.length; row++) {
  largest = matrix[row][0];
  for (col = 1; col < matrix[row].length col++) {
    if (largest < matrix[row][col]) {
       largest = matrix[row][col];
    }
  }
  System.out.println("The largest element of row "
                    + (row + 1) + " = " + largest);
}
```

Multi-Dimensional Arrays (continued)

Exercise: Reverse an Array

Write code to reverse the elements of an array

```
double[] a = {9.3, 1.1, 7.8, 8.9, 3.0};
double[] b = new double[a.length];

for (int i = 0; i < a.length; i++) {
  b[a.length-i-1] = a[i];
}
```

Reverse an Array (without declaring a new array)

```java
double[] a = {9.3, 1.1, 7.8, 8.9, 3.0};

int N = a.length;
for (int i = 0; i < N/2; i++)  {
  double temp = a[N-i-1];
  a[N-i-1] = a[i];
  a[i] = temp;
}
```

“Ragged” Arrays

Does every row in a 2d array need to be the same size?

No!

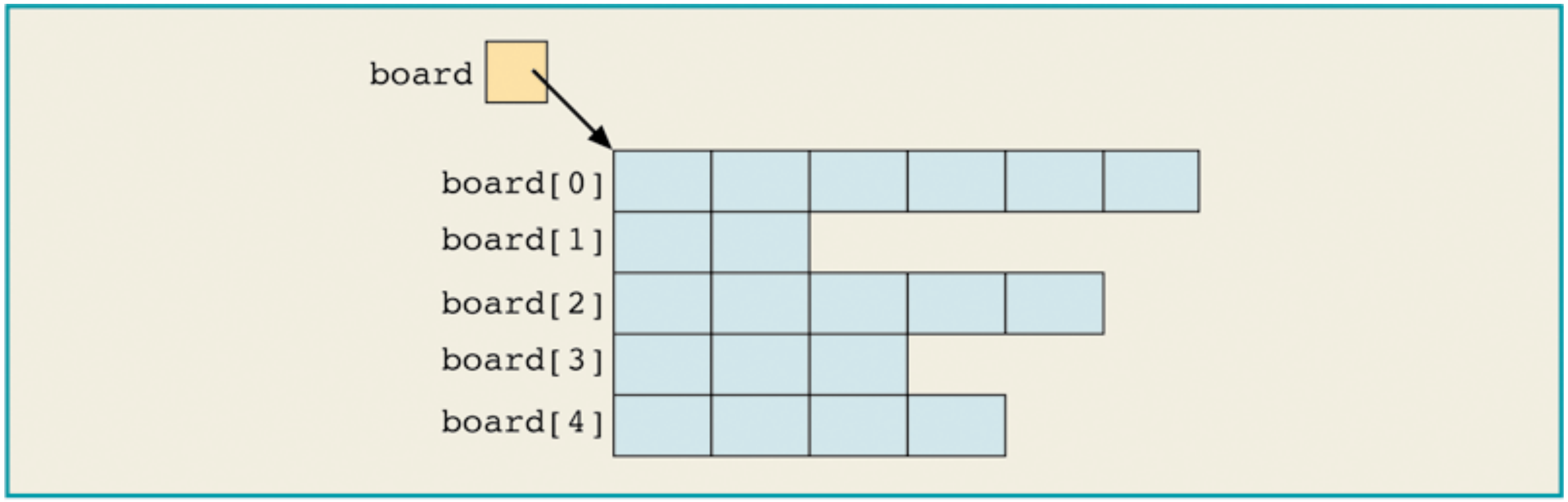


Figure 9-16 Two-dimensional array board

Initializing Ragged Arrays

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


dataType[][] name = new datatype[3][];

name[0] = new dataType[2];
name[1] = new dataType[3];
name[2] = new dataType[4];
```

Processing Ragged Arrays

- Ragged arrays can be useful, but have a big pitfall
- It is very easy to get ***ArrayIndexOutOfBounds***

```
for (row = 0; row < matrix.length; row++) {
  for (col = 0; col < matrix[0].length; col++) {
    System.out.printf("%7d", matrix[row][col]);
  }
  System.out.println();
}
```

Exercise

- Write a method to determine if an array is ragged.

```
boolean isRagged(int [][] X) {
  for(int i=1; i<X.length; i++) {
    if (X[i].length != X[0].length) {
      return true;
    }
  }
  return false;
}
```

Multidimensional Arrays

- Can define three-dimensional arrays or n-dimensional arrays (n can be any number)
- Syntax to declare and instantiate array:

```
dataType[][]…[] arrayName = new
          dataType[intExp1][intExp2]…[intExpn];
```

- Syntax to access component:

```
arrayName[indexExp1][indexExp2]…[indexExpn]
```

  - `intExp1`, `intExp2`, ..., `intExpn` = positive integers
  - `indexExp1`, `indexExp2`, ..., `indexExpn` = non-negative integers

Loops to Process Multidimensional Arrays

```
double[][][] carDealers = new double[10][5][7];

for (i = 0; i < 10; i++)
      for (j = 0; j < 5; j++)
            for (k = 0; k < 7; k++)
                carDealers[i][j][k] = 10.00;
```

Arrays in Memory

- What does a multi-dimensional array look like in computer memory?
- How is the space allocated?

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

Exercise

- Can we create a class that implements a 2d array using a 1d array?

2d Array Using 2d

```
public class Array2d  {

  Object[] array;
  int nRows;
  int nCols;

  public Array2d(int nRows, int nCols) {
    this.nRows = nRows;
    this.nCols = nCols;
    array = new Object[nRows * nCols];
  }
```

2d Array Using 1d (cont)

```
 private computeIndex(int row, int col) {
     return ((nCols * row) + col);
  }

  public void set(int row, int col, Object value) {
    array[computeIndex(row,col)] = value;
  }

  public Object get(int row, int col) {
    return array[computeIndex(row,col)];
  }
}
```

Arrays and Memory

What is the problem with the following code?

```
int N = 1000;
int[] a = new int[N*N*N*N];
```

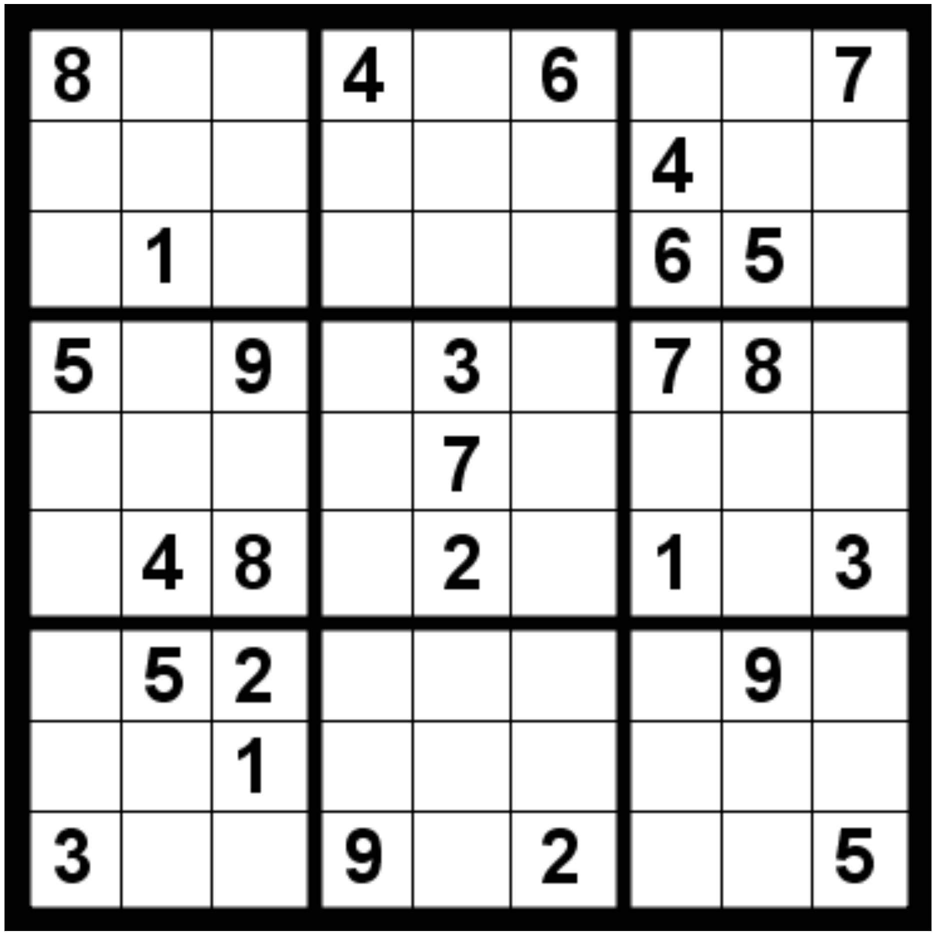
Exercise

- Write a program the counts the number of times each digit between 0 and 9 occurs in a 2d array.

```
int[] counts = new int[10];
countOcc(myArray, counts);

public void countOcc(int[][] array,
                     int[] counts) {



}
```

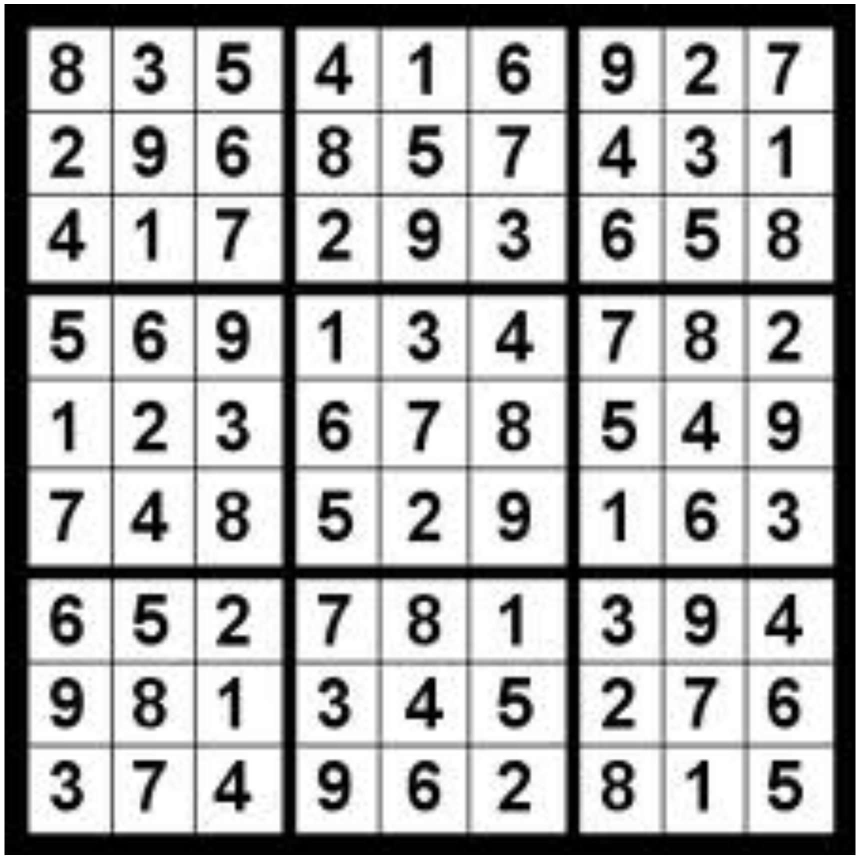
```
int[] counts = new int[10];
countOcc(myArray, counts);

public void countOcc(int[][] a,
                     int[] counts) {
  for (int i = 0; i < a.length; i++) {
    for (int j = 0; j < a[i].length; j++) {
      if (a[i][j] < 0) continue;
      if (a[i][j] > 9) continue;
      counts[a[i][j]]++;
    }
  }
}
```

Exercise: Sudoku



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

Exercise: Sudoku



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

Group Exercise

- Write a program to determine if a 2d input matrix is a valid Sodoku solution
- Hint: write a method similar to the previous example, and use this method repeatedly
- Solution posted on website