Arrays

CS 18000
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Problem

Write a program that inputs 3 numbers from the user and computes the average and standard deviation.

Solution

```
public class AverageStdDev {
    public static void main(String[] args){
        double d1, d2, d3;
        double avg, varianceSum, variance, stdDev;

        d1 = Double.parseDouble(JOptionPane.showInputDialog(null, "Enter number"));
        d2 = Double.parseDouble(JOptionPane.showInputDialog(null, "Enter number"));
        d3 = Double.parseDouble(JOptionPane.showInputDialog(null, "Enter number"));

        avg  = (d1 + d2 + d3) / 3.0;

        varianceSum = Math.pow((d1-avg),2) + Math.pow((d2-avg),2) + Math.pow((d3-avg),2);
        variance = varianceSum/3;

        stdDev = Math.sqrt(variance);

        System.out.printf("Average is %.3f, Deviation is %.4f\n", avg, stdDev);
    }
}
```

Problem

Create a program that inputs 10000 numbers from the user and computes the average and standard deviation.

Arrays

- Having a separate variable for each value is cumbersome
- Each value is similar, so can we treat them as part of a collection of numbers?
- Arrays are an important type of collection
- The collection has a name, and each member is referenced by a number.
- In Java, an array is an indexed collection of data values of the same type (primitive or object).

Solution

Declaring an array of doubles

Creating the array.

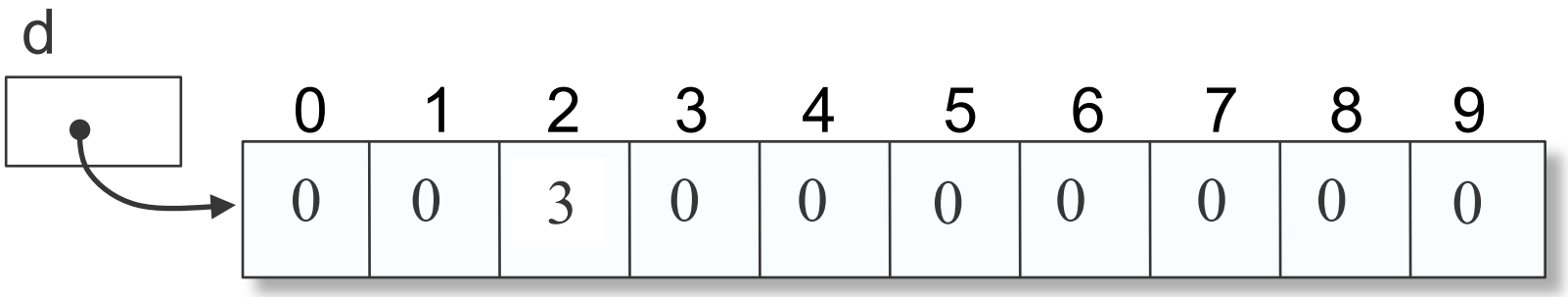
Accessing elements of the array.

```
    double d[];
    double avg, sum, varianceSum, variance, stdDev;
    int i;

    d = new double[100];

    for (i = 0; i < 100; i++)
        d[i] = Double.parseDouble(JOptionPane.showInputDialog(null, "Enter
number" + i));

    sum = 0;
    for (i = 0; i < 100; i++)
        sum += d[i];

    avg = sum / 100;

    varianceSum = 0;
    for (i = 0; i < 100; i++)
        varianceSum += Math.pow((d[i] - avg), 2);

    variance = varianceSum / 100;

    stdDev = Math.sqrt(variance);
    System.out.printf("Average is %.3f, Deviation is %.4f\n", avg, stdDev);
```

Arrays are objects

```
double d[];
```

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




```
d[2] = 3;
```

```
j = 2 + d[2];
```

$j = 5$

Average Wages

```
double[] wages = new double[7];
String[] dayOfWeek = new String[7];
dayOfWeek[0] = "Monday";
dayOfWeek[1] = "Tuesday";
dayOfWeek[2] = "Wednesday";
dayOfWeek[3] = "Thursday";
dayOfWeek[4] = "Friday";
dayOfWeek[5] = "Saturday";
dayOfWeek[6] = "Sunday";

double averageWage, sum = 0.0;

for (int i = 0; i < 7; i++) {
    wages[i] = Double.parseDouble(
            JOptionPane.showInputDialog(null,
                    "Wages for " + dayOfWeek[i]));
    sum += wages[i];
}

averageWage = sum / 7;
```

The same pattern for the remaining five days.

The actual day name instead of a number.

Index out of bounds

- Whenever an array member is accessed, the index must be a valid value between 0 and *length of array - 1*
- If it is not, then the program will terminate with an error:
  - A run time exception called *ArrayIndexOutOfBoundsException*
  - How to handle this situation will be dealt with later in the course.
  - For now -- it should be avoided.

Variable-size Declaration

- Unlike some other languages, Java allows the size of the array to be determined at runtime.
- The following code prompts the user for the size of an array and declares an array of the designated size:

```
int size;
int[] number;
size= Integer.parseInt(JOptionPane.showInputDialog(null,
        "Size of the array:"));
number = new int[size];
```

Length of an array

- Each array has a special data member that records the number of members of the array: *length*
  - Note: not a method as in String.length()

```
double d[];
. . .
System.out.println("Array d has "+ d.length + " elements");
```

Array Initialization

- Like other data types, it is possible to declare and initialize an array at the same time.
- The size of the array is equal to the number of items in the initialization.

```
int[] primes = { 2, 3, 5, 7, 11, 13, 17, 19};

double[] measurements = { 45, 3.42, 2.66 };

String[] daysOfWeek = {"Monday", "Tuesday", "Wednesday",
        "Thursday", "Friday", "Saturday", "Sunday" };
```

Initializing arrays

- If we do not initialize values at creation time, then the elements are initialized to the default value of the corresponding type.
- It is also common to initialize an array using a for loop.

```
int[] odd, even;
odd = new int[100000];
even = new int[100000];

for(int i = 0; i< 100000; i++){
    odd[i] = 2*i+1;
    even[i] = 2*i;
}
```

Problem

Create a program that manages all students for CS180.

Each student object will have:

- *an ID (string)*
- *Last Name*
- *GPA*

Arrays of Objects

- In addition to arrays of primitive data types, we can declare arrays of objects
- An array of primitive data is a powerful tool, but an array of objects is even more powerful.
- The use of an array of objects allows us to model the application more cleanly and logically.

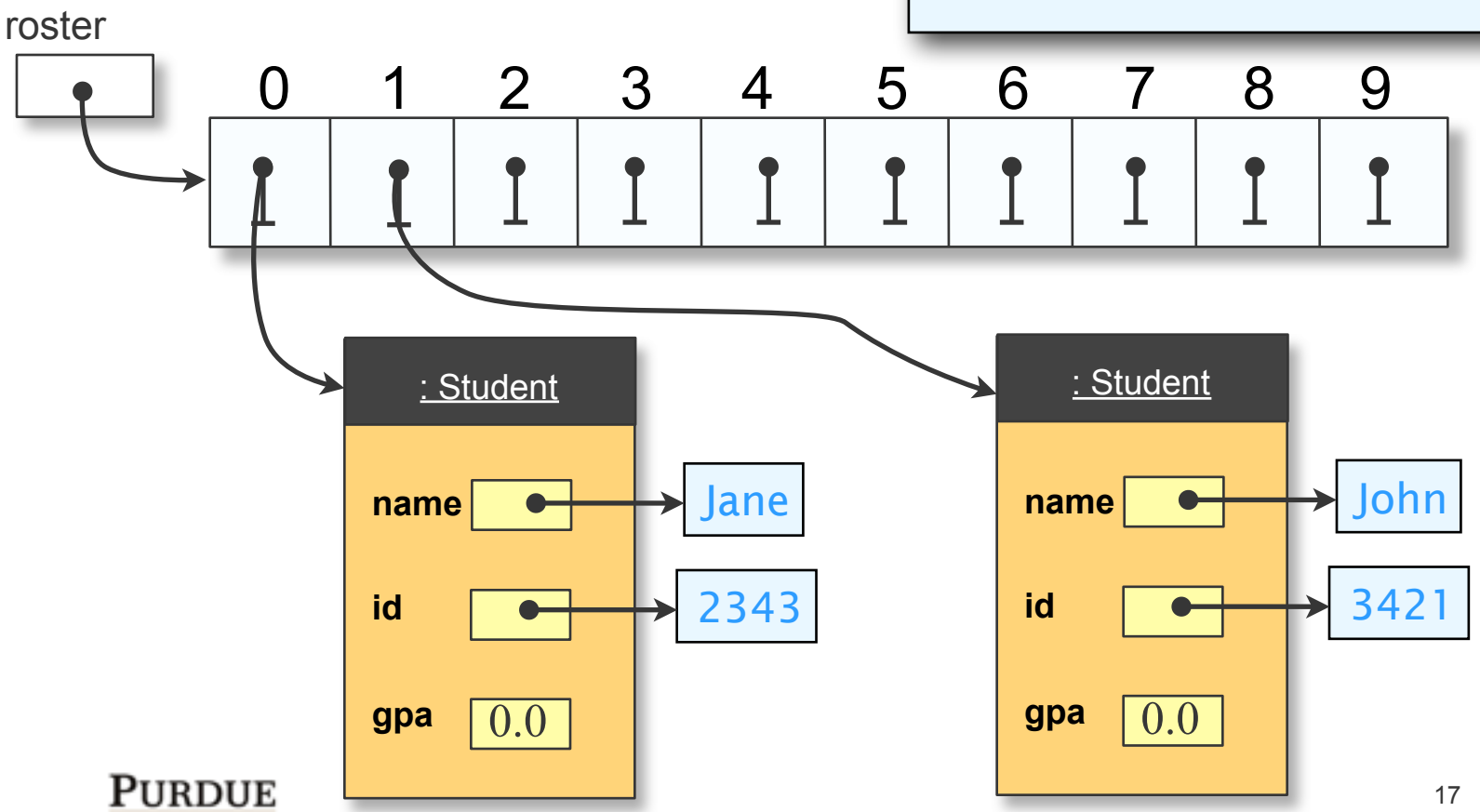
The Student Class

```
class Student {
    private String name, id;
    private double gpa;

    public Student(){
        name = JOptionPane.showInputDialog(null,
"Enter Name:");
        id = JOptionPane.showInputDialog(null,
"Enter ID:");
        gpa = 0.0;
    }

    public void printNeatly(){
        System.out.println("    " + name);
        System.out.println("    ID: " +  id);
        System.out.println("    GPA: " +  gpa);
    }

    public void setName(String studentName){
        name = studentName;
    }
    public String getName(){
        return name;
    }
// CONTINUED ...
```

```
// ...
  public String getId(){
        return id;
    }

    public double getGpa(){
        return gpa;
    }

    public void setGpa(double g){
        gpa = g;
    }
}
```

Creating the Roster object array

```
Student[ ]  roster;
roster = new Student[10];
roster[0] = new Student( );
roster[1] = new Student( );
```



Class Roster

```
public class Roster{
    public static void main(String[] args) {
        Student[] roster;
        int i;

        roster = initializeRoster();
        for(i=0; i < roster.length; i++)
            roster[i].printNeatly();
    }
    public static Student[] initializeRoster(){
        Student[] st;
        int classSize, i;
        classSize = Integer.parseInt(
                JOptionPane.showInputDialog(null,
                        "Enter number of students in class"));
        st = new Student[classSize];
        for(i=0; i<classSize;i++)
            st[i] = new Student();
        return st;
    }
}
```

Caution

- Creating an array of objects only creates the references.
- They are all initialized to null values -- i.e. they don't reference valid objects.
- Trying to access this reference will cause an error: a Null Pointer Exception.

```
public class Roster{
    public static void main(String[] args) {
        Student[] roster;
        roster = new Student[10];
        roster[0].printNeatly();
    }
}
```

Finding a Student

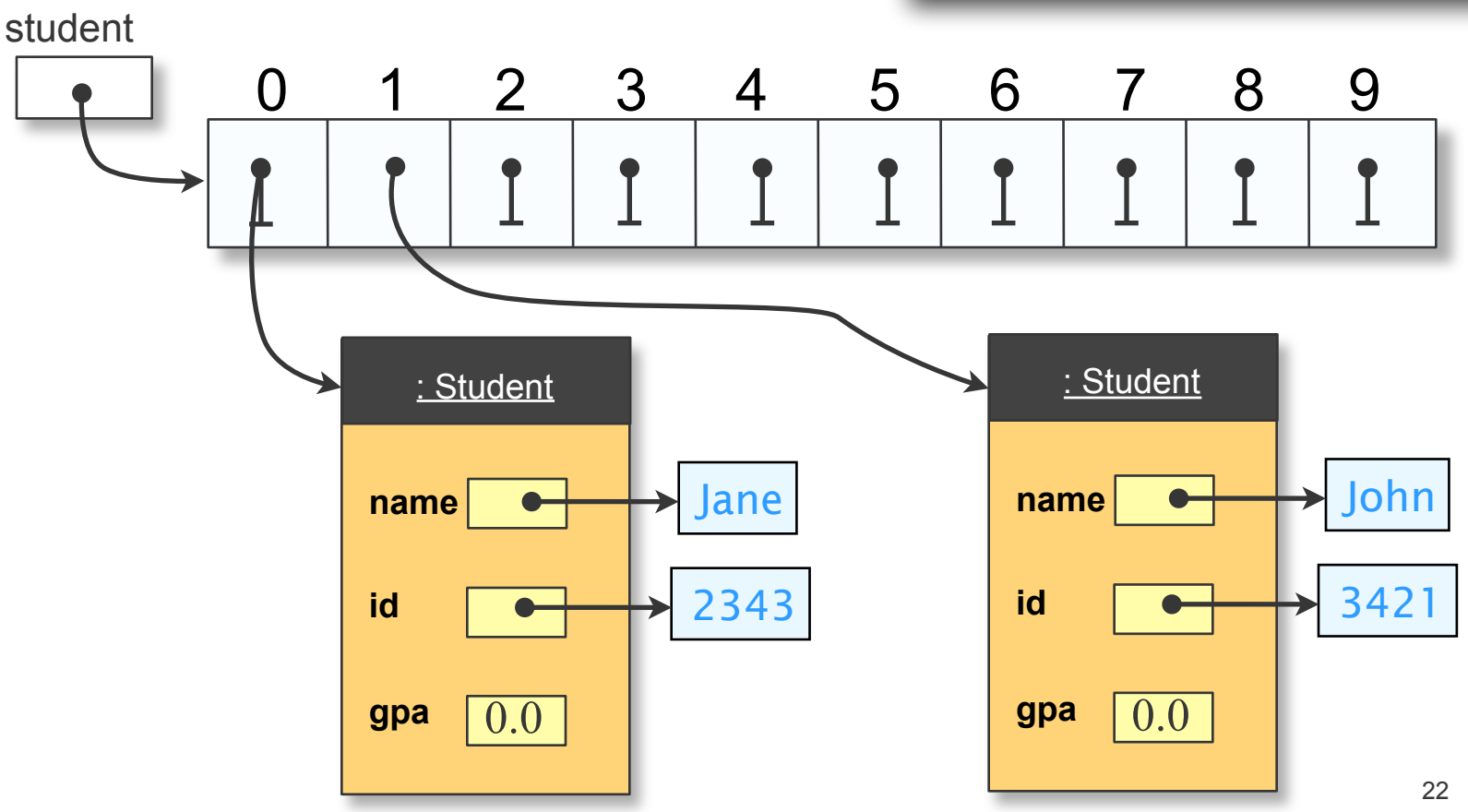
```
public class Roster{
    public static void main(String[] args) {
        Student[] studentList;
        Student student1;

        studentList = initializeRoster();
        student1 = findStudent("2334", studentList);
        if(student1 == null)
            System.out.println("Student with id 2334 not found in
class");
        else
            student1.printNeatly();
    }
    public static Student findStudent(String id, Student[] sList){
        Student s;
        int i;
        for(i=0; i < sList.length;i++)
            if(id.equals(sList[i].getId()))
                return sList[i];
        return null;
    }
}
```

Finding Student with Highest GPA

```
public class Roster{
    public static void main(String[] args) {
        Student[] studentList;
        Student student1;

        studentList = initializeRoster();
        student1 = findTopStudent(studentList);
        student1.printNeatly();
    }
    public static Student findTopStudent(Student[] sList){
        Student maxStudent = sList[0];
        double maxGpa = maxStudent.getGpa();
        for(int i=1; i < sList.length;i++)
            if(sList[i].getGpa()>maxGpa){
                maxGpa = sList[i].getGpa();
                maxStudent = sList[i];
            }
        return maxStudent;
    }
}
```

Deleting an object from an array

```
student[0] = null;
```



Deletion

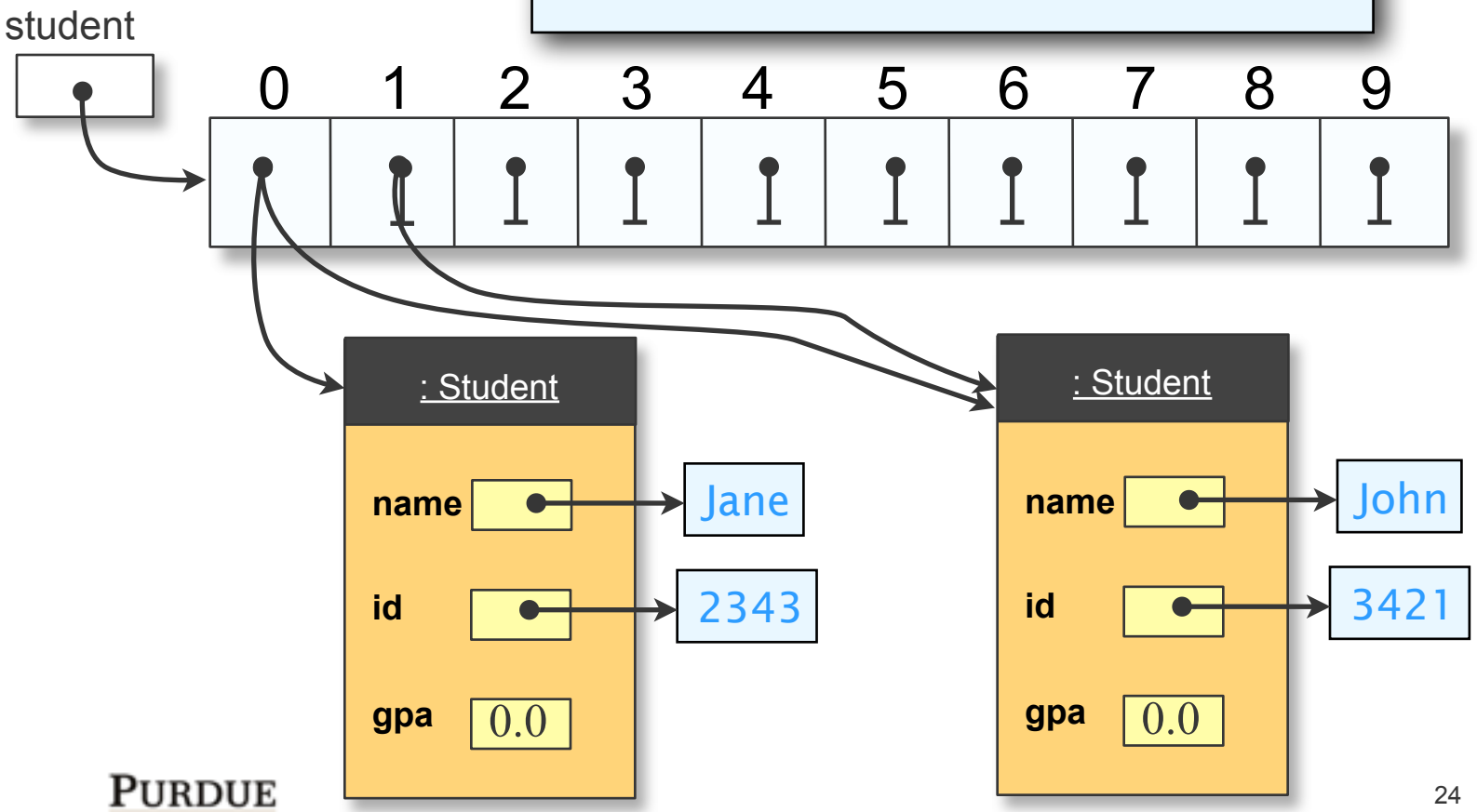
- With the approach of setting the deleted reference to **`null`**, we have to be careful to test each member before accessing the referenced object.

```
if(student[0]!= null) {
    student[0].printNeatly();
}
```

- Otherwise the program could crash.

Deleting an object from an array

```
lastEntryIndex = 1;
student[0] = student[lastEntryIndex];
student[lastEntryIndex] = null;
```



Finding a Student

- With keeping the array packed -- the first null element indicates the end of the array.

```
public static Student findStudent(String id, Student[] sList){
    Student s;
    int i = 0;
    while(sList[i] != null && !(id.equals(sList[i].getId())))
        i++;
    if(sList[i] == null)
        return null;
    return sList[i];
}
```

Array data type

- An array with elements of type T is a new data type represented as T[ ]
  - `int [] age;`
  - `double salary[ ];`
  - `Person student[ ];`
  - `age` is of type `int[]`
  - `salary` is of type `double[]`
  - `student` is of type `Person[]`
- Each element of this array is of type T
  - `age[0], salary[0]` are int data types
  - `student[1]` is a Person object.

Declaring and Creating Arrays

- There are two acceptable alternatives.

```
double[] array1, array2;
double array3[], array4[];
```

  - all four are arrays of double values.

```
double array5[], d1;
```

  - array5 is an array of doubles, but d1 is a single double variable

```
array1 = new double[10];
array1 = new double[10];
array1 = new double[20];
```

  - A new array is created each time. Reference to old array is lost.

Arguments and return values

- An array can be returned by a method.
- The return type must be an array in this case.

```
public int[ ] doubleValues(int [ ] inArray)
```

- An element can be passed to any method that accepts an argument of the base type of the array.

```
double x[ ] = new double[5];
y = Math.exp(x[2]);
```

The main method

- Recall the only argument to main:
  ```
  public static void main(String[] arg)
  ```
- The argument is an array of strings. Each element of this array is set to the words that follow the program name when executing:

  ```
  %java Test one two three
  ```
- In main: `args[0]` is **"one"**, `args[1]` is **"two"** and `args[2]` is **"three"**.
- Also, `args.length` will be 3 for this case.

Multi-Dimensional Arrays

- Multi-dimensional arrays are useful for representing multi-dimensional data. E.g.,
  - Grid cells in a checkers game.
  - a distance table between cities
  - a list of coordinates (2D or 3D) of polygon

Declaring and Creating a 2-D Array

```
int[][] ticTacToeCells;
ticTacToeCells = new int[3][3];
```

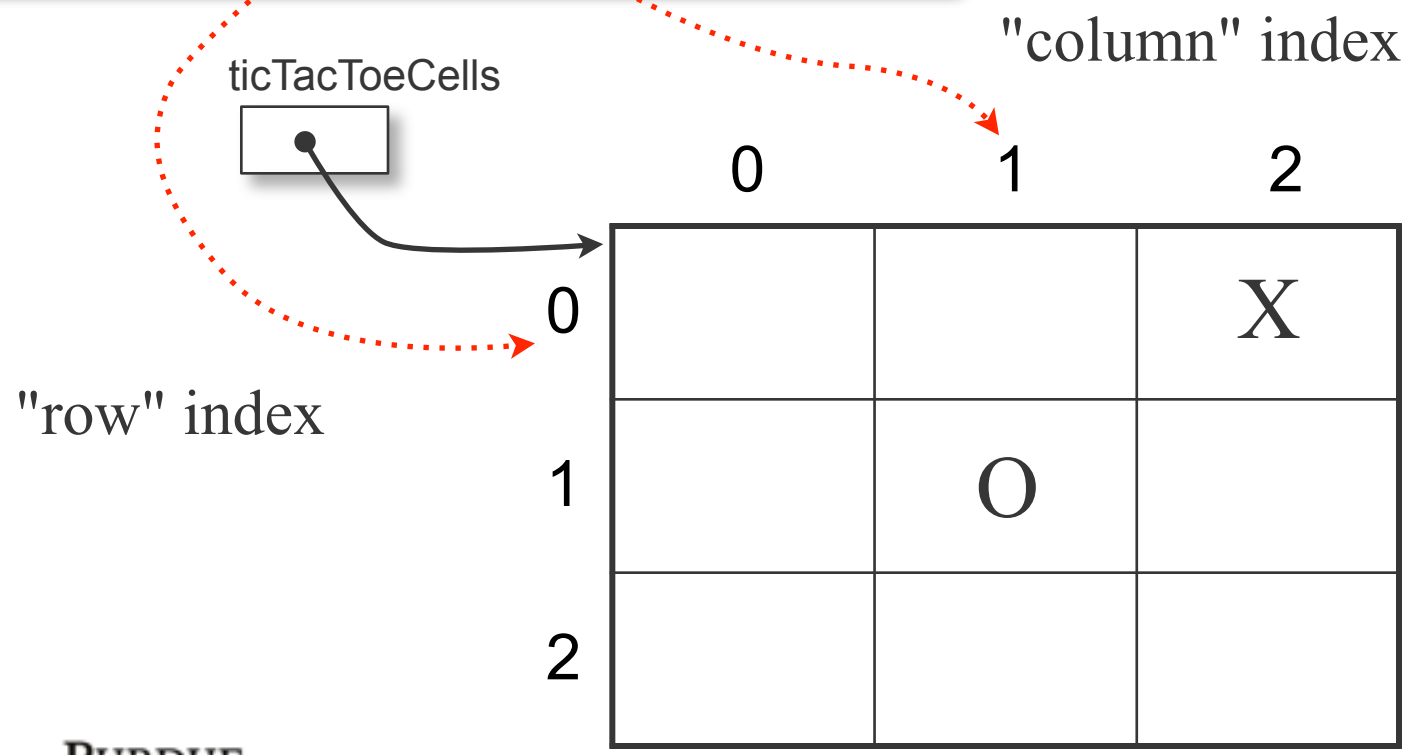
```
int ticTacToeCells [][];
ticTacToeCells = new int[3][3];
```

```
int [][] ticTacToeCells = new int[3][3];
```

```
int ticTacToeCells [][] = new int[3][3];
```

2D Array

```
char[][] ticTacToeCells;
ticTacToeCells = new char[3][3];
ticTacToeCells[0][2] = 'X';
ticTacToeCells[1][1] = 'O';
```



Problem

- *Create a program to input the pay hours worked by 5 employees over 10 days. The program should output the the total hours per employee and the total hours per day.*
  - *Each employee is identified as a number (0-4)*
  - *Each day is identified as a number (0-9)*

Hours Worked: Data Input

```
public class HoursWorked{
    public static void main(String[] args) {
        int[][] hours = new int[5][10];
        int emp, day, total;

        for(emp = 0; emp < 5; emp++)
            for(day = 0; day < 10; day++)
                hours[emp][day] = Integer.parseInt(
                        JOptionPane.showInputDialog(null,
                                "Enter hours for Employee " +
                                 emp + " day " + day));
    }
}
```

Hours Worked: Employee Total

```
public class HoursWorked{
    public static void main(String[] args) {
        int[][] hours = new int[5][10];
        int emp, day, total;
        . . . // input hourly data
        for(emp=0; emp<5; emp++){
            total = 0;
            for(day=0; day < 10; day++)
                total += hours[emp][day];
            System.out.println("Employee " +
                emp + " worked " + total + " hours");
        }
    }
}
```

Hours Worked: Day Total

```
public class HoursWorked{
    public static void main(String[] args) {
        int[][] hours = new int[5][10];
        int emp, day, total;
        . . . // input hourly data
        for(day = 0; day < 10; day++) {
            total = 0;
            for(emp = 0; emp < 5; emp++)
                total += hours[emp][day];

            System.out.println(total +
                 " hours worked on day " + day);
        }
    }
}
```

Java Implementation of 2-D Arrays

- The sample array creation

```
hours = new int[4][5];
```

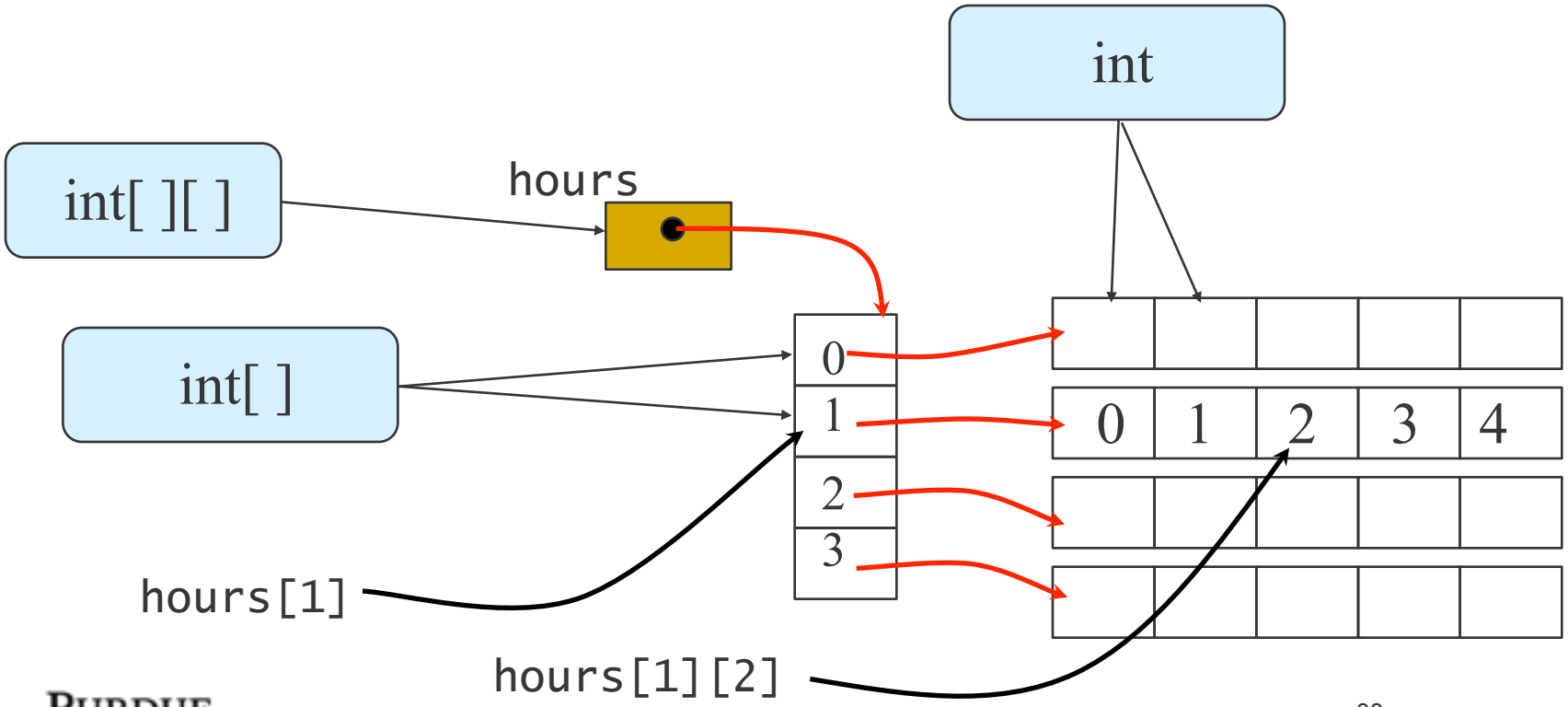
is really a shorthand for

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

hours[0] = new int [5];
hours[1] = new int [5];
hours[2] = new int [5];
hours[3] = new int [5];
```

Java Implementation

```
hours = new int [4][5];
```

```
hours = new int [4][];
hours[0] = new int [5];
```

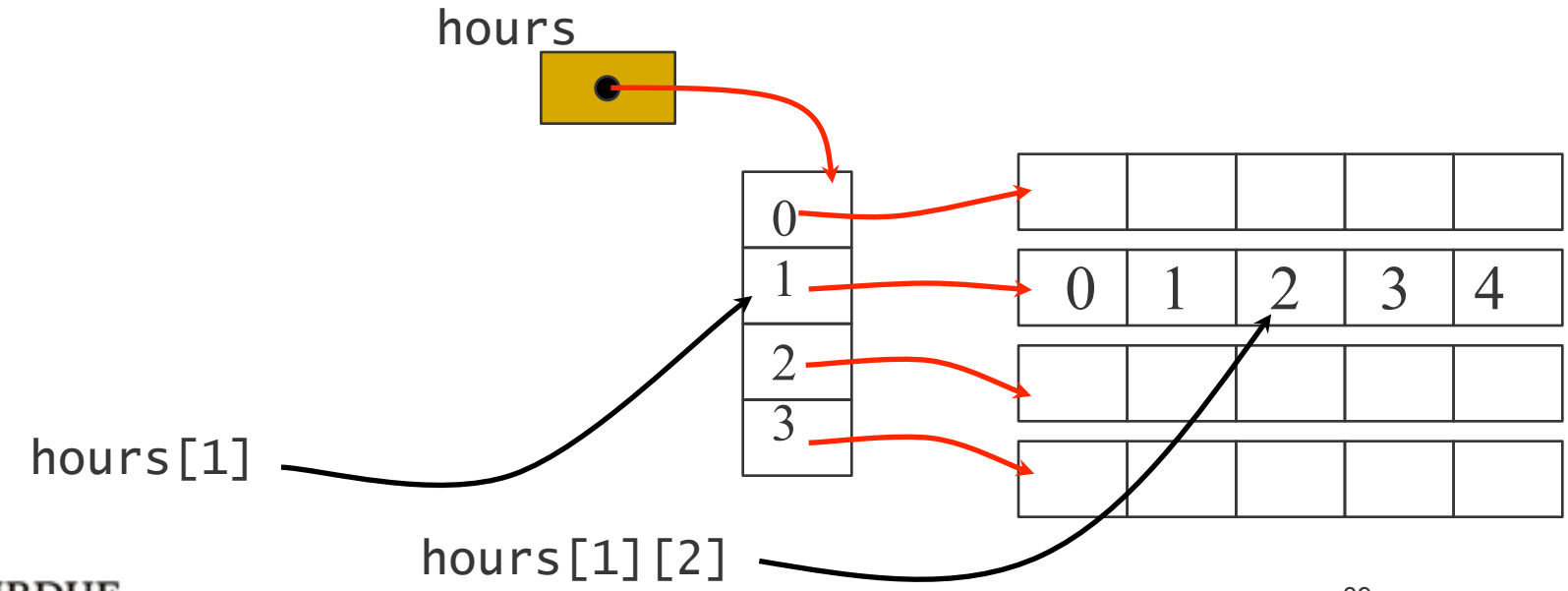


Java Implementation

`hours.length` → 4

`hours[1].length` → 5

`hours[1][2].length` → ERROR!

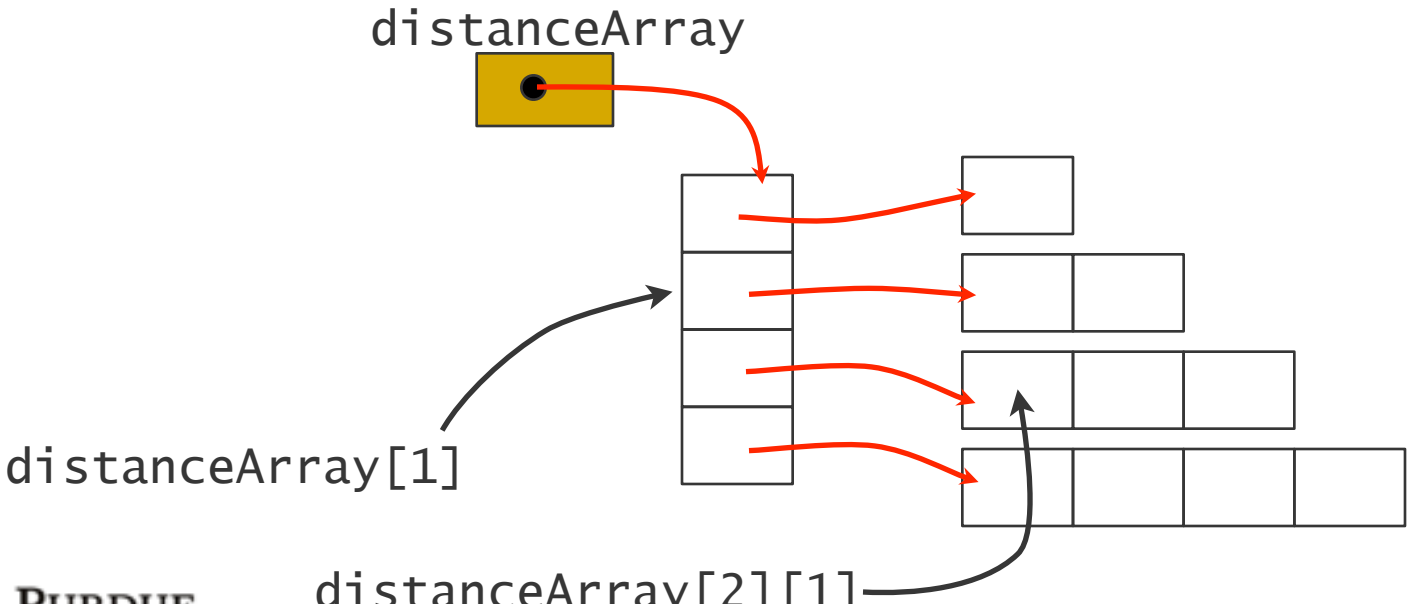


Two-Dimensional Arrays

- In Java, subarrays may have different lengths.

```
double hours[][] = new double [4][];
for(int i = 0; i < 4; i++)
  distanceArray[i] = new double[i+1];
```

results in an array that looks like:



Distance Array

```
public class DistanceArray {
    public static void main(String[] args){
        final int NUMCITIES = 4;    // Number of cities
        double[][] distance;        // Distance array
        int i,j;
        Random random = new Random(); //Random number generator

        // create Jagged array
        distance = new double[NUMCITIES][];
        for(i = 0; i < NUMCITIES; i++)
            distance[i] = new double[i+1];

        //initialize array with random values
        for(i=0; i < NUMCITIES; i++)
            for(j = 0; j < distance[i].length; j++)
                distance[i][j] = random.nextInt(10000);
    }
}
```

Limitation of Arrays

- Once an array object is created, its size is fixed -- it cannot be changed.
- If we need to store more elements than the size with which an array was created, we have to
  - Create a new larger array
  - Copy all elements from current to new array
  - Change the reference to the new array
- Alternatively, we can use Java Collections: more later in course.