Arrays: The Concept

- There are a wide variety of data structures that we can use or create to attempt to hold data in useful, organized, efficient ways.

- The **Polynomial** class you are writing as part of Project 4 is a simple data structure in some ways. It holds three values; one coefficient for each of the three terms.

- An array is a linear, contiguous, homogenous structure that can hold an arbitrary number of elements (as long as we know how many we want it to hold in advance).
Arrays: Some Properties

- Elements in an array of size $n$ are numbered $0..n-1$.
- We can use those numbers to directly access an array position to read from or write into it.
- The data structure has a "first" and "last" position.
- In an array with more than 1 element, any position other than the first has a "previous" position and any position other than the last has a "next" position.
- We generally need to specify how many elements an array will have room for when we declare it.

<table>
<thead>
<tr>
<th>index</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>values</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Arrays in Java

- In Java, an array is an object and we will have a variable serve as a reference to that object.
- We will indicate the type of elements that will be stored when we declare it.
  ```java
datatype[] arrayName;
```
- We will allocate the actual array.
  ```java
arrayName = new datatype[size];
```
- We will access a position within an array by using the name of the reference variable, square brackets, with the position inside the brackets.
  ```java
arrayName[position] = value;
```
Some Motivation

• We have actually been using arrays quite a bit, they've just been behind the scenes.
• The String and StringBuffer classes both hold characters in an array.
• To better understand the efficiency example we saw, we need to consider how arrays are allocated and used.

A Simple Problem

What if I asked you to write a program that would allow the user to specify how many numbers they wanted to enter, then read them in, and print them out backwards?
What might we need to do?

• Declare some variables like an integer to store the answer when we ask the user how many numbers they want to enter and a variable to act as a reference to an array.
• Get the size request from the user.
• Allocate an array big enough to hold them all.
• Allow the user to enter those numbers one at a time and store them in the array.
• Traverse through the array backwards and print them out.

```c
int[] dataArray;
int numberOfElements;
```

What might we need to do?

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• Allocate an array big enough to hold them all.
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What might we need to do?

int[] dataArray;
int numberOfElements;
numberOfElements = sc.nextInt();

• Allocate an array big enough to hold them all.
• Allow the user to enter those numbers one at a time and store them in the array.
• Traverse through the array backwards and print them out.

What might we need to do?

int[] dataArray;
int numberOfElements;
numberOfElements = sc.nextInt();
dataArray = new int[numberOfElements];

• Allow the user to enter those numbers one at a time and store them in the array.
• Traverse through the array backwards and print them out.
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- Allow the user to enter those numbers one at a time and store them in the array.
- Traverse through the array backwards and print them out.

```java
int[] dataArray;
int numberOfElements;
numberOfElements = sc.nextInt();
dataArray = new int[numberOfElements];

for (int i=0; i<numberOfElements; i++) {
    dataArray[i] = sc.nextInt();
}

for (int i=numberOfElements-1; i>=0; i--){
    System.out.print(dataArray[i] + " ");
}
```
Length of an Array

- After allocating an array, we have a variable that contains the size we requested.
- In some languages (including Java) an array will have an instance variable within that stores that size, but other languages (like C++) do not, so we need to keep track of it.
- In Java, if you can access the size of the array via the instance variable `length`.
  
  ```java
  arrayName.length
  ```
- This is a read-only value. You cannot grow an array by just changing this number!

Operations on an Array

- You can allocate and initialize an array at the same time if you know all of the information in advance.
  
  ```java
  int[] firstFivePrimes = {2,3,5,7,11};
  ```
- Remember that the variable we are using is a reference to an object. The following just makes a copy of the reference.
  
  ```java
  int[] notCopied = firstFivePrimes;
  ```
- We'll look at three types of copies a little later in our discussion.
"Growing" an Array

• We can't really grow an array once it has been allocated.
• What we can do is allocate a new array, copy the information from the old one into the new one, and move the array reference to point to this new array object.
• Imagine we have an array named myData and we want to make it twice as large...

```java
int[] tempName = new int[myData.length*2];
for (int i=0; i<myData.length; i++){
    tempName[i] = myData[i];
}
myData = tempName;
```
• Time consuming, isn't it...

Why StringBuffer was much faster!

• Every time we appended something onto our String, a whole new String object was created and the characters copied into it.
• With the StringBuffer, an initial size array is allocated, and only when that size is going to be exceeded by an operation is a new array allocated and all of the information copied in.
• In the current Java implementation, each time the size is going to be exceeded, the new array allocated is twice as large!
• What are the pros and cons of this?
Arrays of Objects

Arrays elements can be references to objects as well. If so, the array will hold the references to those objects, not the actual objects.

```java
String[] hosts = {"Colbert", "Stewart"};

StringBuffer[] hosts = new StringBuffer[2];
    hosts[0] = new StringBuffer("Colbert");
    hosts[1] = new StringBuffer("Stewart");

String[] rally = new String[215000];
```

Reference, Shallow, Deep Copies

- Reference Copy
  ```java
  Student[] array1 = new Student[10];
  //some code here which fills in the array with data
  Student[] array2 = array1;
  ```

- Shallow Copy
  ```java
  Student[] array1 = new Student[10];
  //some code here which fills in the array with data
  Student[] array2 = new Student[array1.length];
  for (int i=0; i<array1.length; i++) {
      array2[i] = array1[i];
  }
  ```
Reference, Shallow, Deep Copies

• Deep Copy

```java
Student[] array1 = new Student[10];
//some code here which fills in the array with data
Student[] array2 = new Student[array1.length];
for (int i=0; i<array1.length; i++) {
    array2[i] = new Student(array1[i]);
}
```

• What is the danger in the above approach that neither reference nor shallow copies faced?

To what "value" are the elements of an array of references automatically initialized by default in Java?

0% 1. zero
0% 2. null
0% 3. it depends on the data type
0% 4. they aren’t initialized
Arrays class

- There is a useful library class `Arrays` which contains a variety of static methods.
- One subset of these that can be useful when exploring arrays is the group of `toString()` methods which take an array and generate an ASCII visualization of that array.
- Another useful ability it provides is the ability to sort the contents of an array. This works for arrays of primitives and certain types of objects (we will see more of this later).

Arrays as Arguments

- A reference to an array can be passed as an argument into a method.
- You do NOT specify the size of the array since the array itself isn't really being passed into the method, just the reference to it.
- Once the reference to the array is passed into a method, that method can access and alter the elements stored within the array.
initArray1

0%  1. 9999999999
0%  2. 012345678
0%  3. Not Sure

initArray2

0%  1. 9999999999
0%  2. 012345678
0%  3. Not Sure
"Privacy" Issues

- Even without arrays, object references create certain "privacy" issues.

- Consider how references to objects work and what it means when a method returns a reference to an object.
  - If it returns a reference to (for example) a private instance variable then the "outside world" now has direct access to it even though it is marked as private.
  - This doesn't "really" matter for immutable objects, but for mutable ones it would allow code from outside of the class to alter the contents of private data.

- With arrays, even though the size of the array is immutable, the contents aren't.

Multi-Dimensional Arrays

- It is sometimes useful to have a multi-dimensional structure for data storage.
  - Consider representing things such as a chess board or storage warehouse.

- Declaring them as an "Array of Arrays"
  - Allows us to have "ragged edged" arrays.

- Declaring them as a "xD Array"
  - Doesn't give any real advantage in Java as far as I can tell but might depending on the language.
2D Arrays – Syntax Examples

• Rectangular
  ```java
  int[][] arr = new int[rows][cols];
  ```

• Ragged
  ```java
  int[][] arr = new int[rows][];
  arr[0] = new int[colsInRow0];
  arr[1] = new int[colsInRow1];
  arr[2] = new int[colsInRow2];
  arr[3] = new int[colsInRow3];
  :  
  :  
  ```

Upper Left-Hand Right Triangle

• We want to create a structure in which we store the distance from the "origin" to each cell in the structure, but only for the upper left-hand right triangle starting at that origin.

• Rectangular array or Ragged array?

• How do we make it work for a triangle with sides of length `triangleSize`?
Dealing with Ragged Arrays Generically

```java
int[][] reallyRagged;
    reallyRagged = new int[5][];
    reallyRagged[0] = new int[9];
    reallyRagged[1] = new int[3];
    reallyRagged[2] = new int[7];
    reallyRagged[3] = new int[0];
    reallyRagged[4] = new int[12];
```

How could you go in and perform an operation on each element without having to hard-code the different lengths?

Self-awareness

Recall that arrays know their own length!

```java
counter = 0;
for (r=0; r<reallyRagged.length; r++) {
    for (c=0; c<reallyRagged[row].length; c++) {
        reallyRagged[r][c] = counter++;
    }
}
```

What would happen if we'd used this?

```java
reallyRagged[3] = new int[0];
```