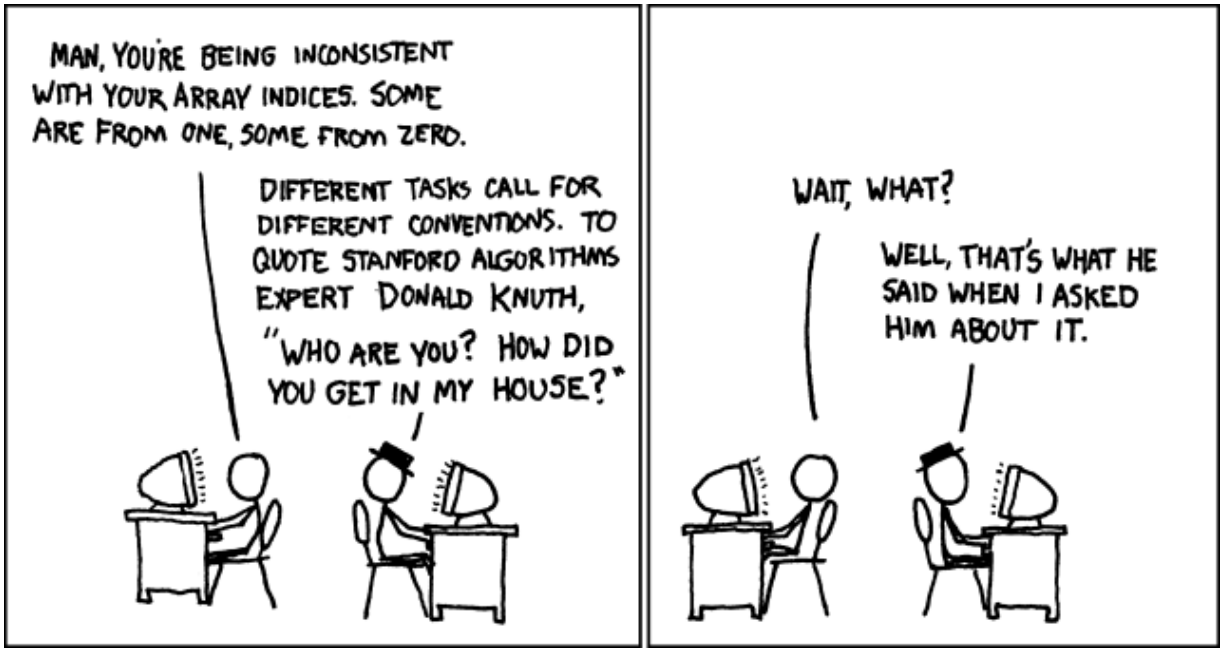
ARRAY-BASED IMPLEMENTATIONS



REVIEW OF ARRAYS

Arrays

- An *array* is an ordered list of values.
- An array has a single name and holds several values.
  - Each value has a numeric index.
  - An array of size *n* is indexed from 0 to *n-1*.
- The size of an array can be accessed with .length
- Arrays store elements of the same type.
  - Arrays can hold primitives or objects.

Array Size

- The size of an array cannot be changed once it is set during initialization.
- You can change what is stored in the array, but you **cannot** change *how many* elements can be stored in that contiguous space in memory.

Arrays are Objects

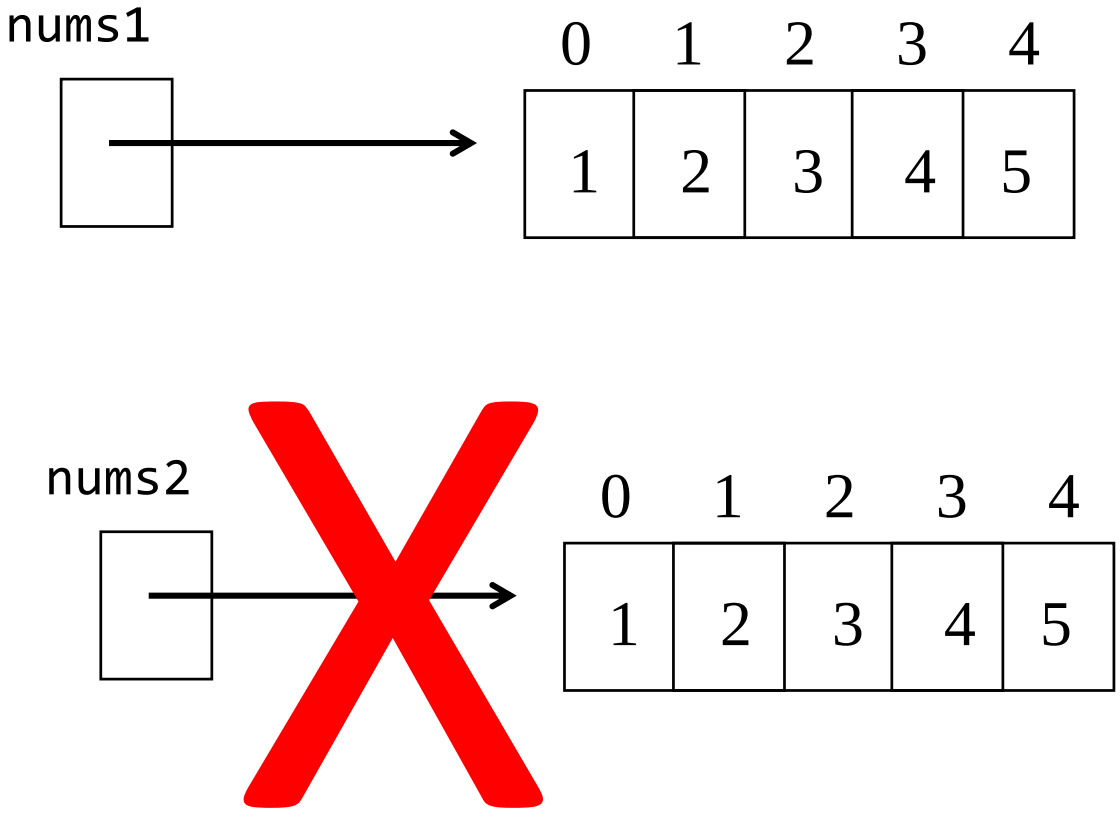
- Remember that everything in Java is either a primitive or an object.
- Arrays are objects!
  - The variable name of an array holds a *reference* or *pointer* to the place in memory where the elements are stored.
- Recall what this means about using direct assignment!

Arrays are Objects

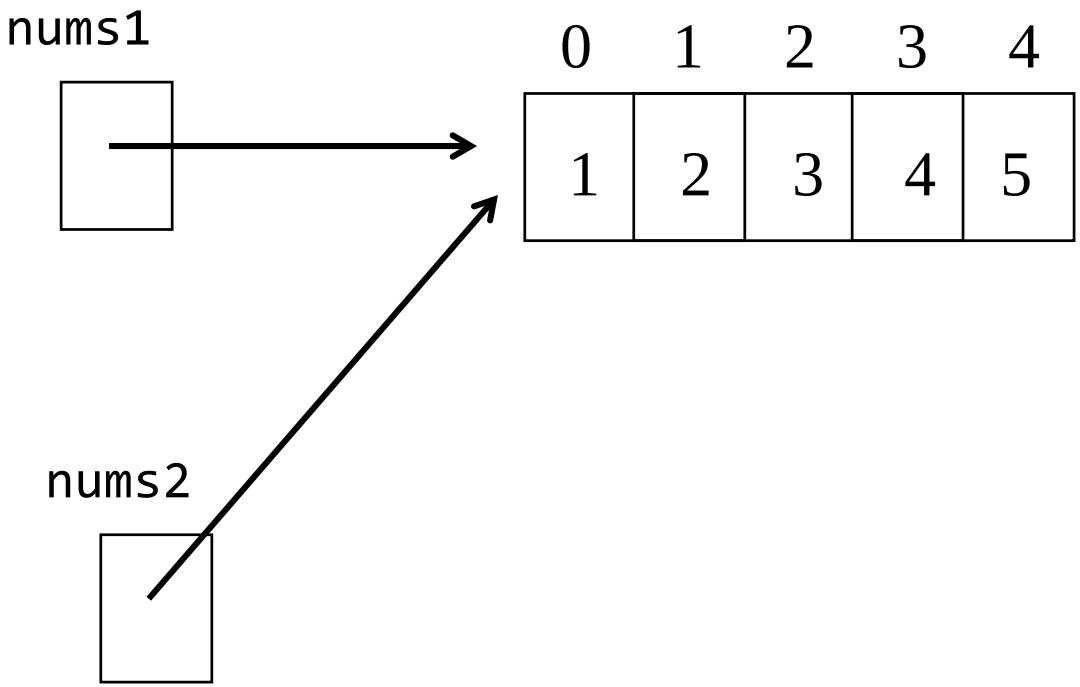
- What is stored in `nums1[0]` after this code?

```
int[] nums1 = {1, 2, 3, 4, 5};
int[] nums2 = nums1;
nums2[0] = 99;
```

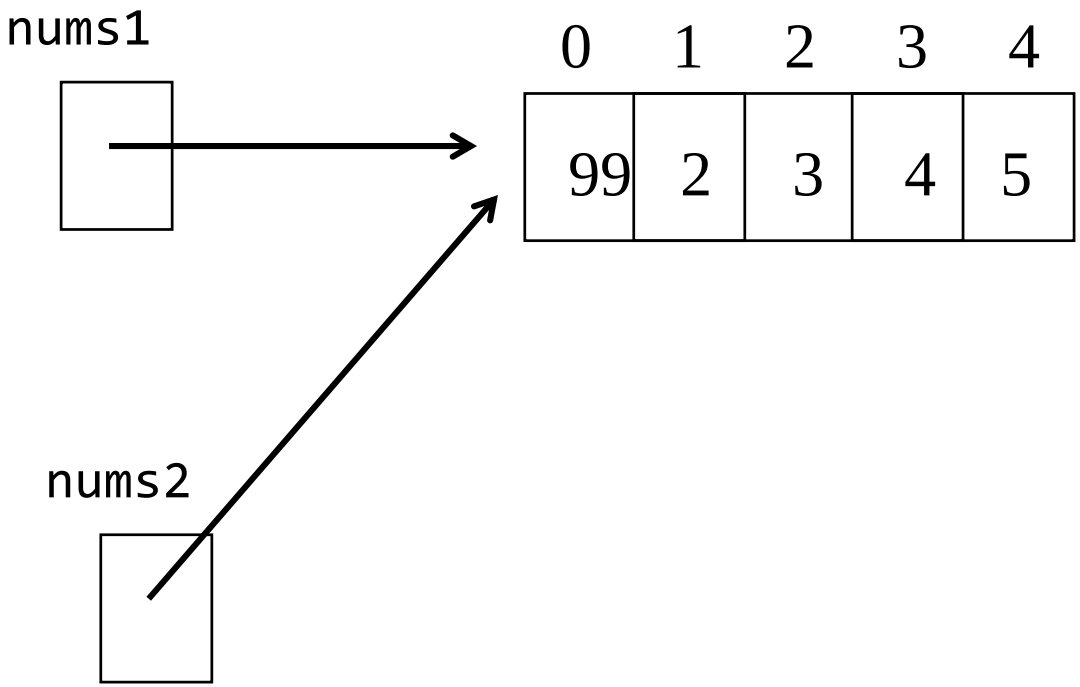
Arrays as Objects



Arrays as Objects



Arrays as Objects



Copying Arrays

- What is stored in `nums1[0]` after this code?

```
int[] nums1 = {1, 2, 3, 4, 5};
int[] nums2 = nums1;
nums2[0] = 99;
```

- 99 is stored there!
  - `nums1` and `nums2` aliases of each other.
  - Changes to one will affect changes to the other.
- To only affect one of these arrays, we need to make a *copy*:
  - Create a whole new array
  - Copy over *each* element in the array

Array Size Revisited

- You cannot make an array bigger.
- You *can* create a *new, bigger* array and make your array reference point to it.
  - You need to manually copy over the data.

Copying an array

```
int[] nums = {1, 2, 3};
```

original array

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

bigger, empty array

```
for(int i=0; i<nums.length; i++) {
  moreNums[i] = nums[i];
}
```

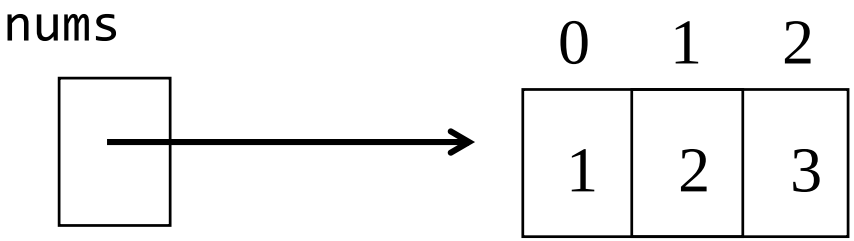
copy the old array contents into the new array

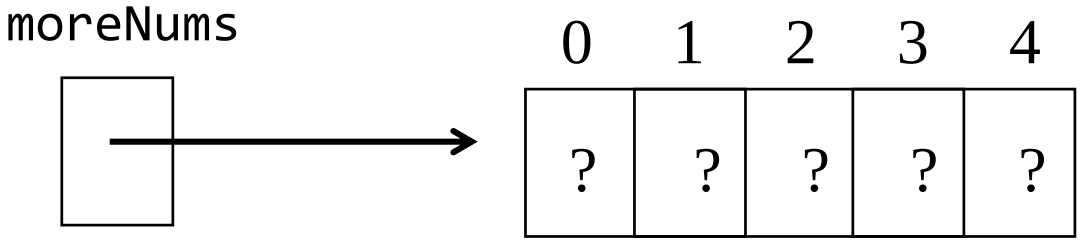
```
nums = moreNums;
```

point the reference to the new array

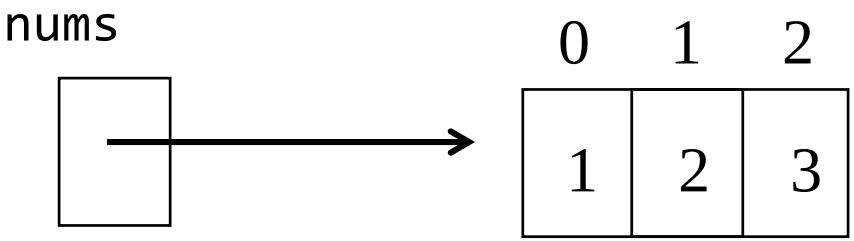
the old “nums” memory location is lost and those contents are garbage collected

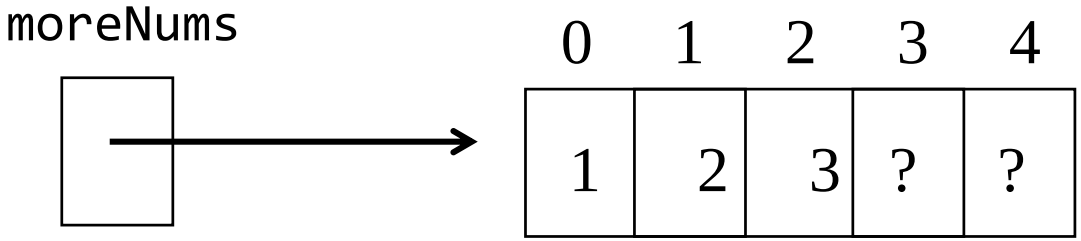
Arrays as Objects



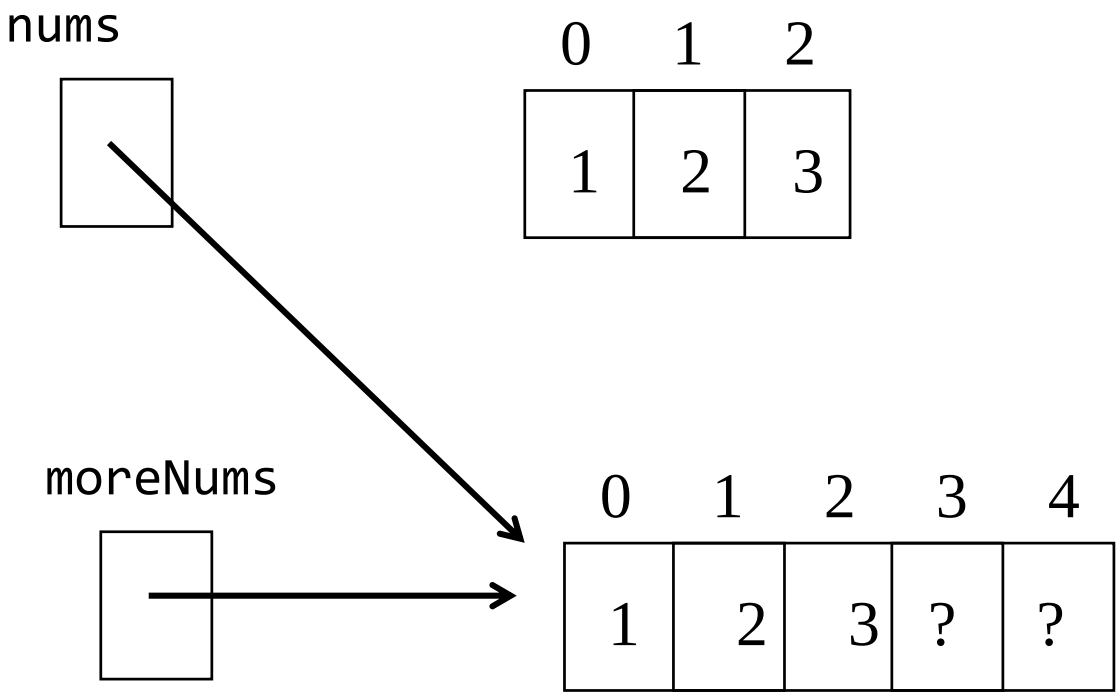


Arrays as Objects





Arrays as Objects



Arrays as Parameters

- An entire array can be passed as a parameter to a method.
- Like any other object, the value is passed.
  - The value is the *reference* to the data in the array.
  - So, the formal and actual parameters (the two array references) become *aliases* of each other.
- This means that changing an array element within the method will also change that element in the original copy of the array.
- Review the example code.

USING AN ARRAY TO IMPLEMENT A BAG

BagInterface

- A bag is an unordered organization of items.
- Bags allow you to add items, remove an item, test if an item is in the bag, and determine the size of the bag.
- Bags allow duplicate values.

Implementing a Bag

- We will now write a class to implement a bag.
- We need a data structure behind the scenes to store the elements in the bag.
  - An array
  - Linked nodes
  - A List!
  - Could be many other ways…
- We get to decide.

Using an Array to Implement a Bag

- In any class, the instance data variables describe objects of that class.
  - private!
- For a bag, we'll use two variables:

  T[] bag; // hold the items

  int numberOfEntries; // how many items
- The constructor will initialize these variables.

Overloading Constructors

- We often provide more than one constructor.
  - This allows different ways to set up an object.
  - Best practice is to invoke one constructor from the others when the “this” keyword whenever possible.
  - Usually, this means putting the code in the constructor that takes the most parameters and invoking that constructor from the others sending along parameters and/or default values.
- For the bag class, we can initialize the array based on a size sent by the user or using a default size.

Creating a Generic Array

- Generics were added in Java 5 and sometimes the code to work with arrays and generics can get strange.
- Unfortunately, we cannot do this:
  - T[] bag = new T[size];
- The syntax instead is this:

```
T[] genericArray = (T[]) new Object[size];
```

The Bag vs the Array

- In Java, all variables have a type.
- When you create an object of type ArrayBag, its type is ArrayBag.
- Each ArrayBag object has an array as part of what describes it.
  - The array is private and behind the scenes!
  - The array is used to implement the bag.

The Bag vs the Array

```
BagInterface<Integer> numberBag =
        new ArrayBag<Integer>();
```

numberBag :

- declared type is BagInterface
- actual type is ArrayBag

numberBag.bag type:

- declared and actual type is an array []
- cannot be accessed outside the class!
- inside the class, access “bag” or “this.bag”
  - inside the class, “this” is an ArrayBag object; “this.bag” is an array

The Bag vs the Array

- The array cannot be resized.
  - In the add method, you can see that if the array is full, you cannot add any more elements to the bag.
  - By using a traditional array as our behind the scenes data structure, we've also made our bag fixed in size.

The Bag vs the Array

- Bags are unordered!
  - But our array is linear and does have an order!
- Inside the class, we can use the ordered array. But the outward-facing bag remains unordered.

Adding and Removing

- Adding is straightforward.
  - Check if there is room and then add to the end of the array.
  - No shifting required- very efficient! O(1)
- Removing
  - remove(): the interface doesn't specify what element to remove, so we can decide
    - If we remove the last element, no shifting is required!
  - remove(T): find and remove the specified element
    - Since the bag is unordered, we don't need to shift elements to keep them in order!
    - We can just swap the last element into the place of the removed element! This is more efficient than shifting.
- Make sure to update both the array and numberOfEntries!

Private Helper Methods

- When implementing an ADT, you'll often write private methods to help you manipulate the behind the scenes data structure.
- If you ever start to write code more than once or (gasp!) copy/paste code, stop!
  - It's almost always best to put this code inside a method and invoke it rather than duplicate code.

ResizeableArrayBag

- A second class also uses an array to represent the bag, but allows the array to grow as needed.
  - This means the bag is not fixed in size!
  - Behind the scenes, when we need to make the array bigger, we create a bigger array, copy the contents, and update the instance data variable.

ResizeableArrayBag Design Choices

- We will need to change the add method so that if the array is full, we can expand it.

- Do any other methods need to change?
- Do you notice a lot of repeated code?

USING AN ARRAY TO IMPLEMENT A LIST

List

- A list is an ordered, indexed organization of items.
- Lists allow you to add items, remove items, and retrieve items.

Implementing a List

- We need a data structure behind the scenes to store the elements in the list.
  - An array
  - Linked nodes
  - Another kind of List!
  - Could be many other ways…
- We get to decide.

Using an Array to Implement a List

- For a list, we'll use two variables:

  T[] list; // hold the items

  int numberOfEntries; // how many items
- The constructor will initialize these variables.

The List vs the Array

```
ListInterface<Integer> numberList =
        new AList<Integer>();
```

numberList :

- declared type is ListInterface<Integer
- actual type is AList<Integer

numberList.list type:

- declared and actual type is an array []
- cannot be accessed outside the class!
- inside the class, access “list” or “this.list”
  - inside the class, “this” is an AList object; “this.list” is an array

Adding and Removing

- Adding
  - add(T): add to the end
  - add(int, T): add at a specific position- shifting will be required!
- Removing
  - remove(int): order matters, so shifting is required!
- Make sure to update both the array and numberOfEntries!

ListInterface Design Choices

- Should the list be fixed in size or expandable?
- ListInterface elements start at position 1.
  - Where should we store things in our list array?
- Private helper methods
  - We'll be shifting in multiple places…
  - We'll need to often check if indices are valid

List and ArrayList

- The Java standard library provides a class that implements the List interface using an array behind the scenes- ArrayList
  - Expandable
  - Efficient!

Programming to the Interface

- It’s often best to declare the type to be the most general type you need.

- List<Integer> numberList = new ArrayList<>();

DEVELOPER PERSPECTIVE

Writing Code as the Developer

- What behind-the-scenes data structures and other variables do I need to represent my ADT?
- How will I respond to unusual conditions?
- Check that I am:
  - Following the specifications described in the interface
  - Being consistent within my own code
  - Documenting design decisions
  - Reducing repeated code

Respond to Unusual Conditions

- You have to account for a user not acting as you intend!
  - Removing from an empty bag
  - Adding to a full list
- You can:
  - Ignore it (not good!)
  - Return a value to indicate a problem (null, -1, false, etc.)
  - Throw an exception
- Sometimes these are specified by the interface, so you must follow that.