# A Bag
# Data Structure

Computer Science 112
Boston University

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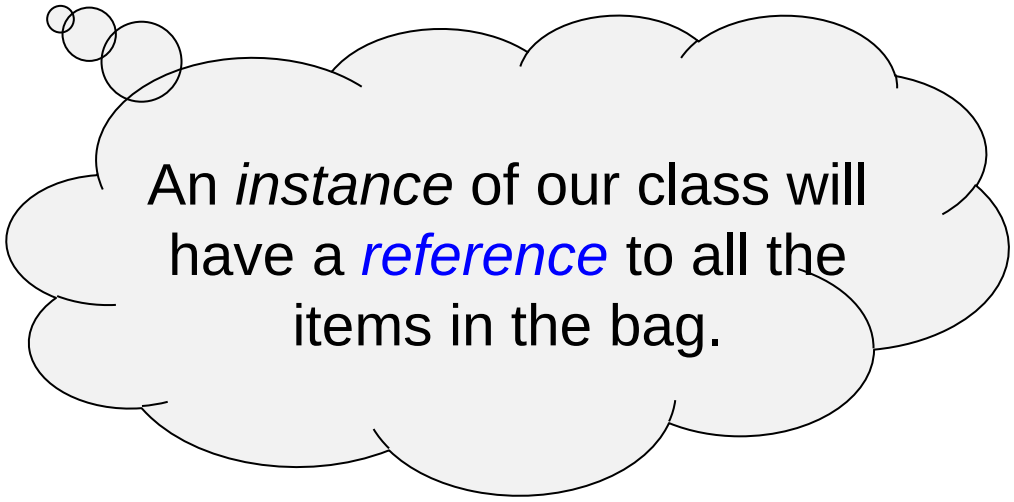
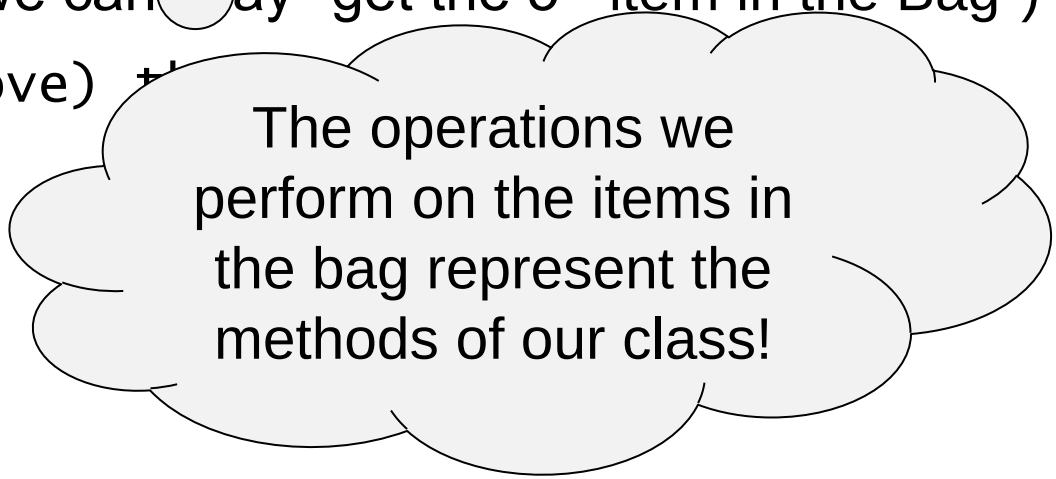
# A Bag Data Structure

- A bag is just a container for a group of data items.
  - analogy: a bag of candy
- The positions of the data items don't matter (unlike a sequence).
  - {3, 2, 10, 6} is equivalent to {2, 3, 6, 10}
- The items do *not* need to be unique (unlike a set).
  - {**7**, 2, 10, **7**, 5} isn't a set, but it is a bag



# A Bag Data Structure

- The operations we want our `Bag` to support:
  - `add` an `item` to the `Bag`
  - `remove` one occurrence of an `item` (if any) from the `Bag`
  - `check` if `a specific item` is in the `Bag`
  - `count the` the number of items in the `Bag`
  - `select` an item at random, without removing it
    - reflects the fact that the items don't have a position (and thus we can't say "get the 5th item in the Bag")
  - `carry (or move) th`



# Storing Items in a Bag Data Structure

## an array of Objects

- We store the items in ….

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public class ArrayBag {

}
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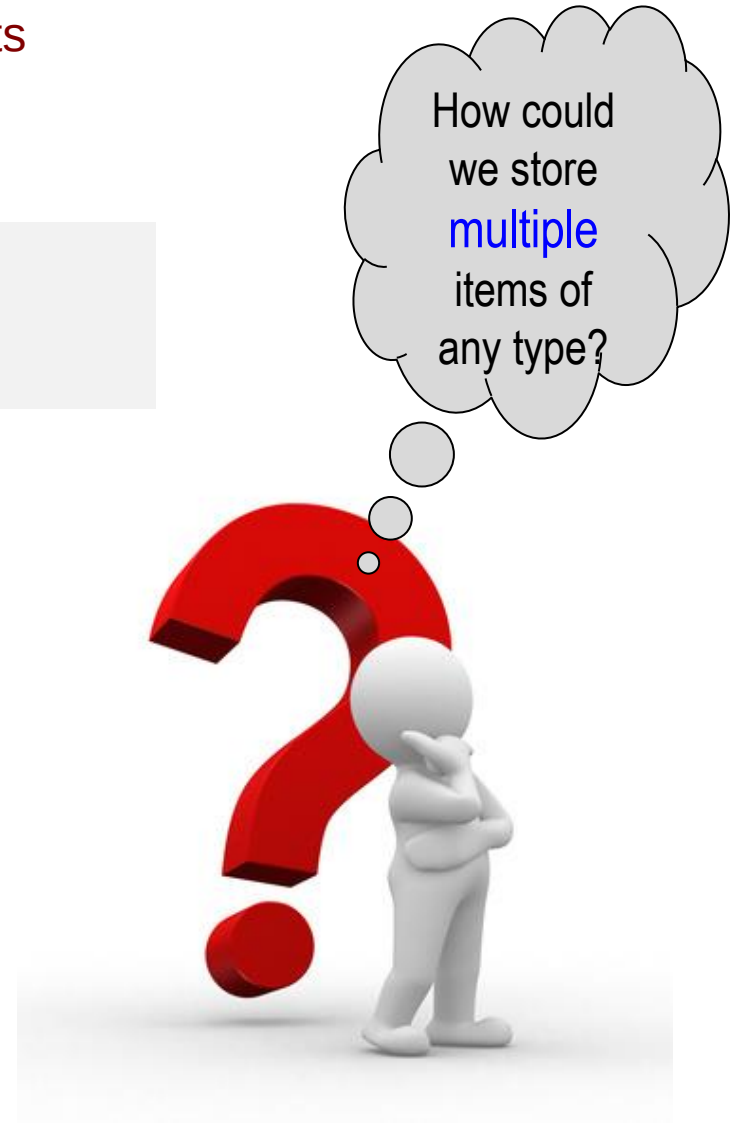

# Storing Items in a Bag Data Structure

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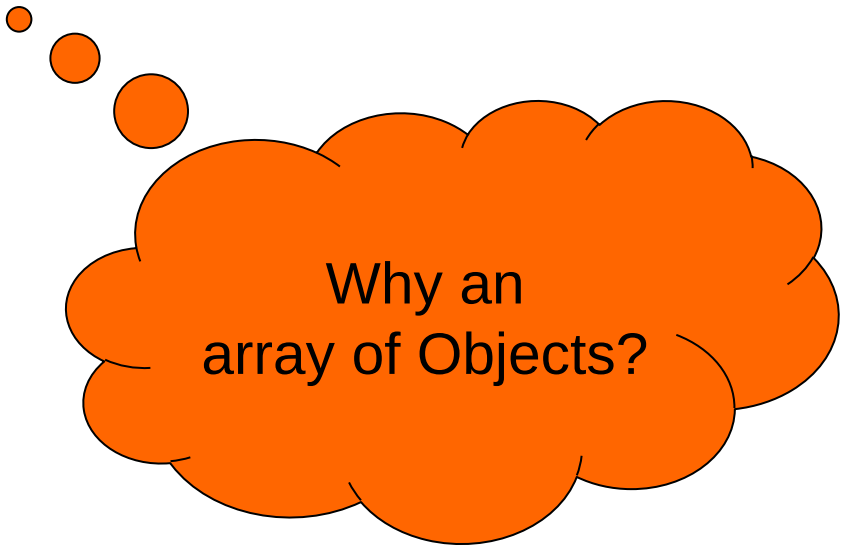

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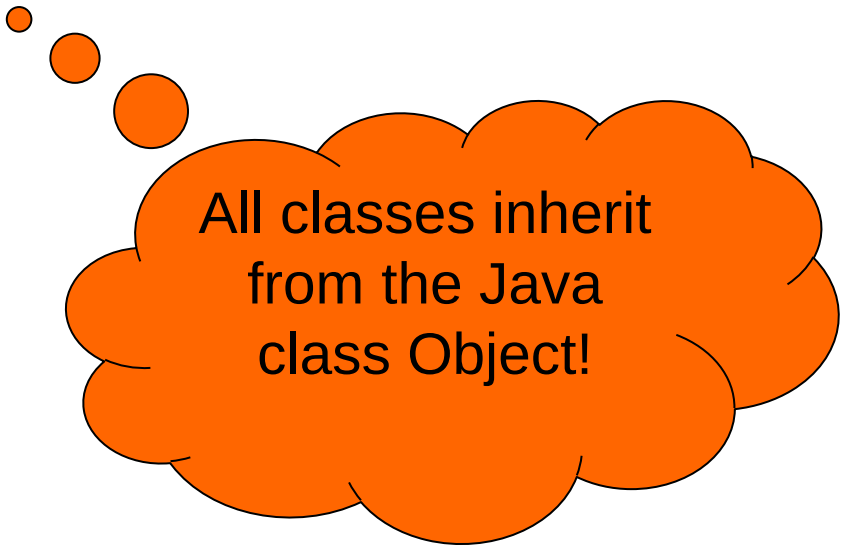


# Storing Items in a Bag Data Structure

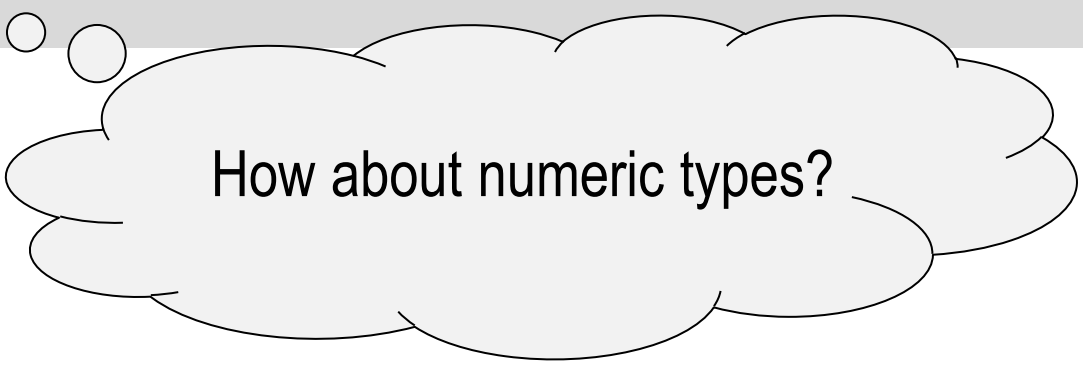
*an array of any object type*

- We store the items in an array of type `Object`.

```
public class ArrayBag {
    private Object[] items;
    private int numItems;
    ...
}
```

- This allows us to store *any* type of object in the `items` array, thanks to the power of polymorphism:

```
ArrayBag bag = new ArrayBag();
bag.add("hello");
bag.add(new Rectangle(20, 30));
```



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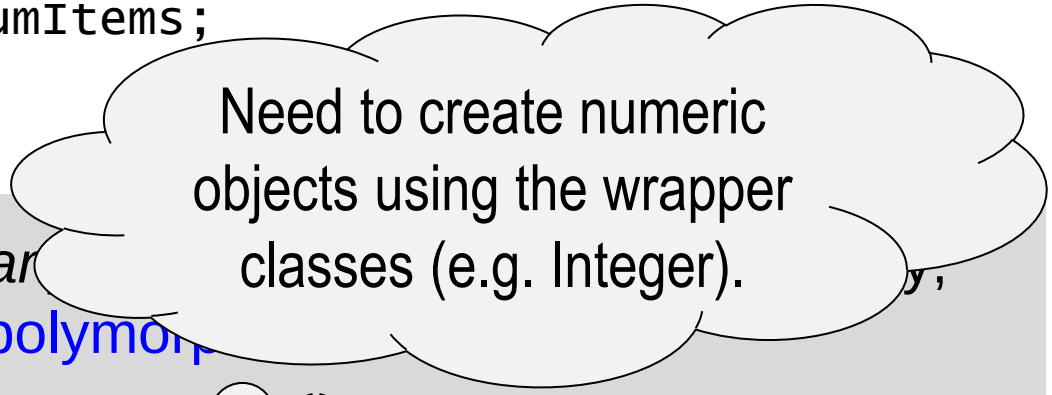


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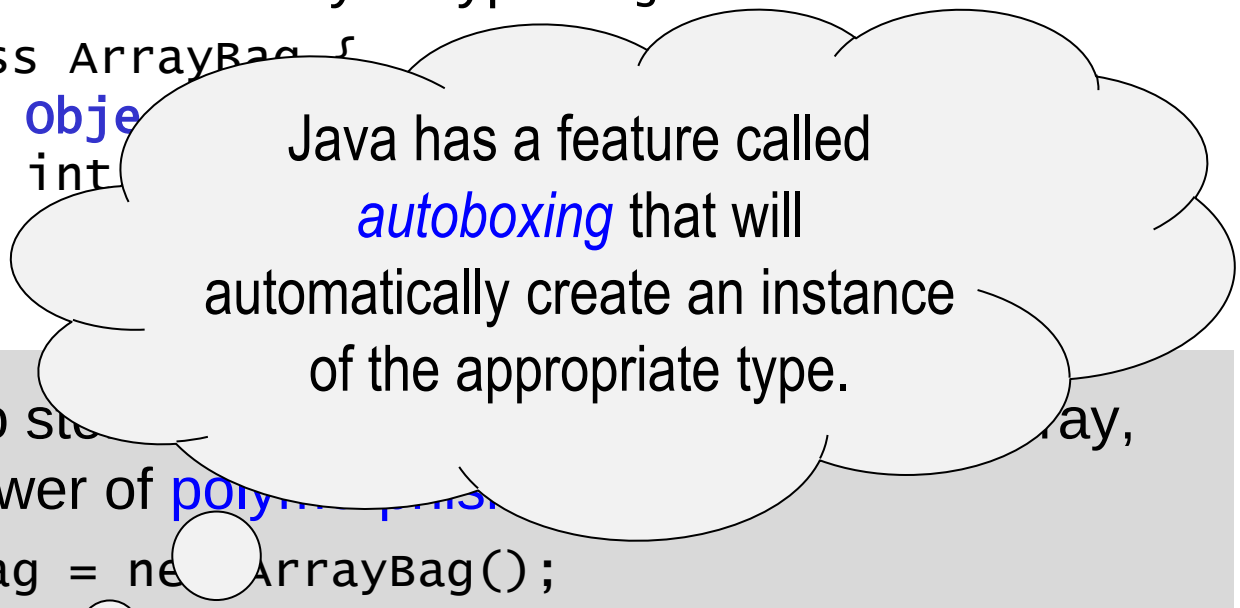


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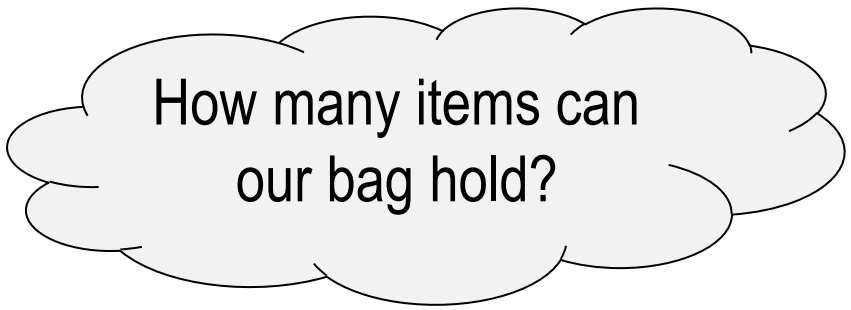

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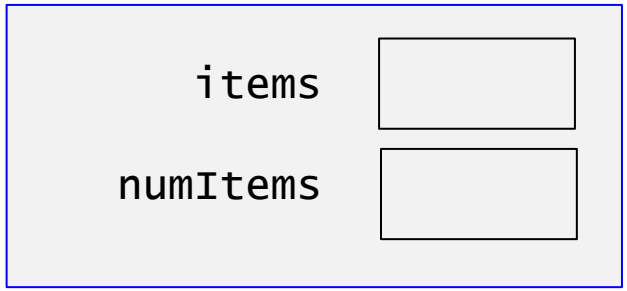



an `ArrayBag` object

# Storing Items in a Bag Data Structure

*an array of any object type*

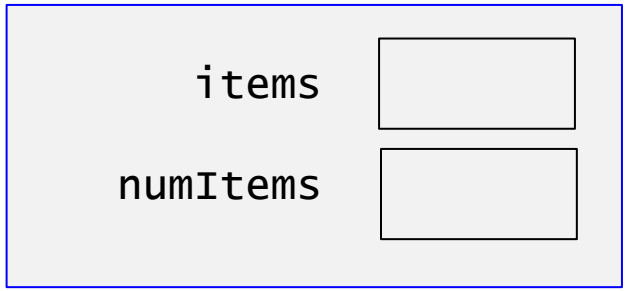
- We store the items in an array of

```
public class ArrayBag
    private Object[]
    private int num
    ...
}
```

Calls a `constructor` to initialize the data members of our object!

- This allows us to store *any* type of object in the `items` array, thanks to the power of polymorphism:

```
ArrayBag bag = new ArrayBag(5);
bag.add("hello");
bag.add(new Rectangle(20, 30));
```

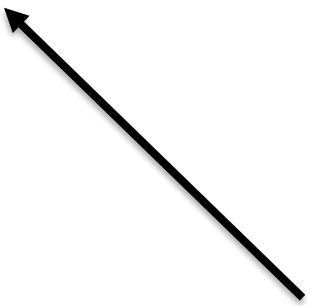



an `ArrayBag` object

# Two Constructors for the ArrayBag Class

```
public class ArrayBag {
    private Object[] items;
    private int numItems;
    public static final int DEFAULT_MAX_SIZE = 50;

    public ArrayBag() {
        this.items = new Object[DEFAULT_MAX_SIZE];
        this.numItems = 0;
    }
    public ArrayBag(int maxSize) {
    ...
}
```



- We can have two different constructors!
  - the parameters must differ in some way
- The first constructor is useful for small bags.
  - creates an array with room for 50 items.

# Two Constructors for the ArrayBag Class

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    private Object[] items;
    private int numItems;
    public static final int DEFAULT_MAX_SIZE = 50;

    public ArrayBag() {
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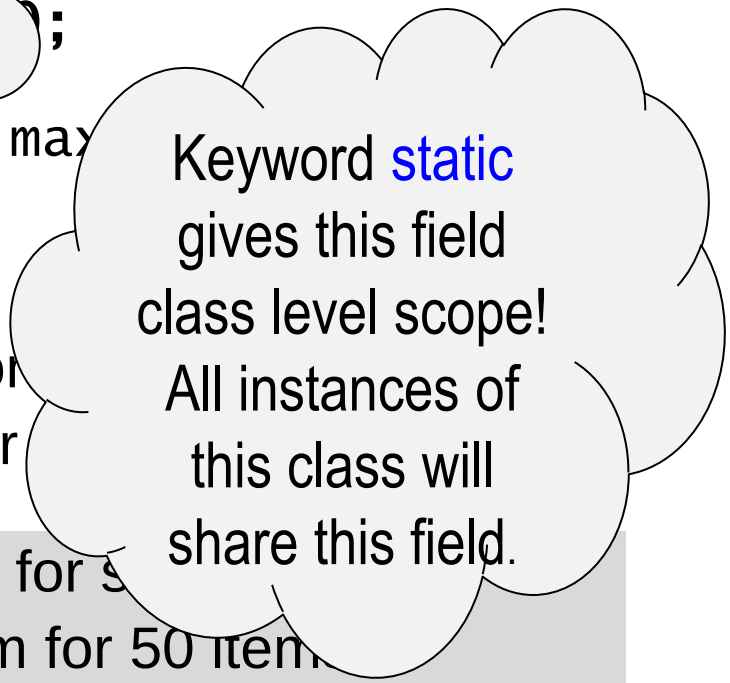
        this.numItems = 0;
    }
    public ArrayBag(int max
    ...
}
```

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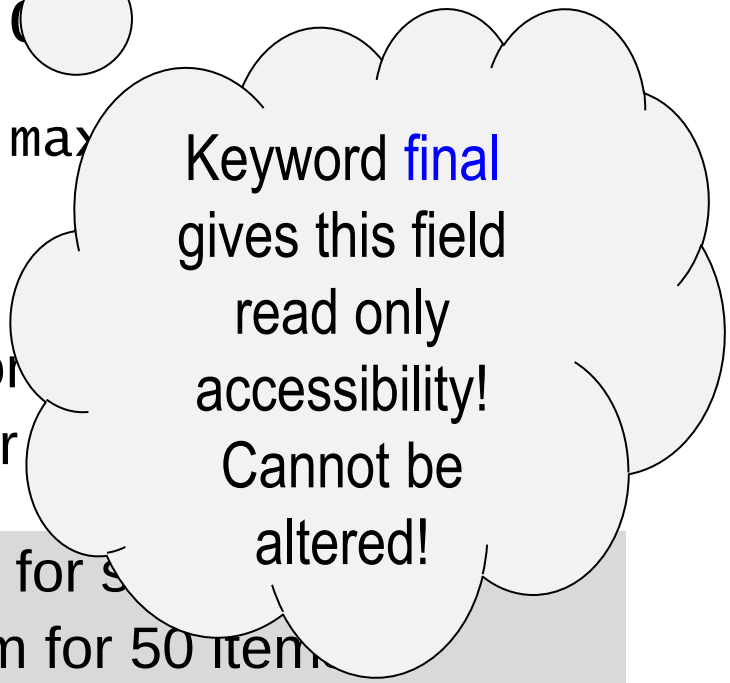


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    public ArrayBag() {
        this.items = new Object[DEFAULT_MAX_SIZE];
        this.numItems = 0;
    }
    public ArrayBag(int maxSize) {
        if (maxSize <= 0) {
            throw new IllegalArgumentException(
              "maxSize must be > 0");
        }
        this.items = new Object[maxSize];
        this.numItems = 0;
    }
    ...
}
```

- If the user inputs an invalid `maxSize`, we throw an exception.

# Two Constructors for the `ArrayBag` Class

```
public class ArrayBag {
    private Object[] items;
    private int numItems;
    public static final int DEF

    public ArrayBag() {
        this.items = new Obje
        this.numItems = 0;
    }
    public ArrayBag(int maxSize) {
        if (maxSize <= 0) {
            throw new IllegalArgumentException(
              "maxSize must be  0");
        }
        this.items = new Object[maxSize];
        this.numItems = 0;
    }
    ...
}
```

We initialize the data member numItems to zero in both cases!

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    }
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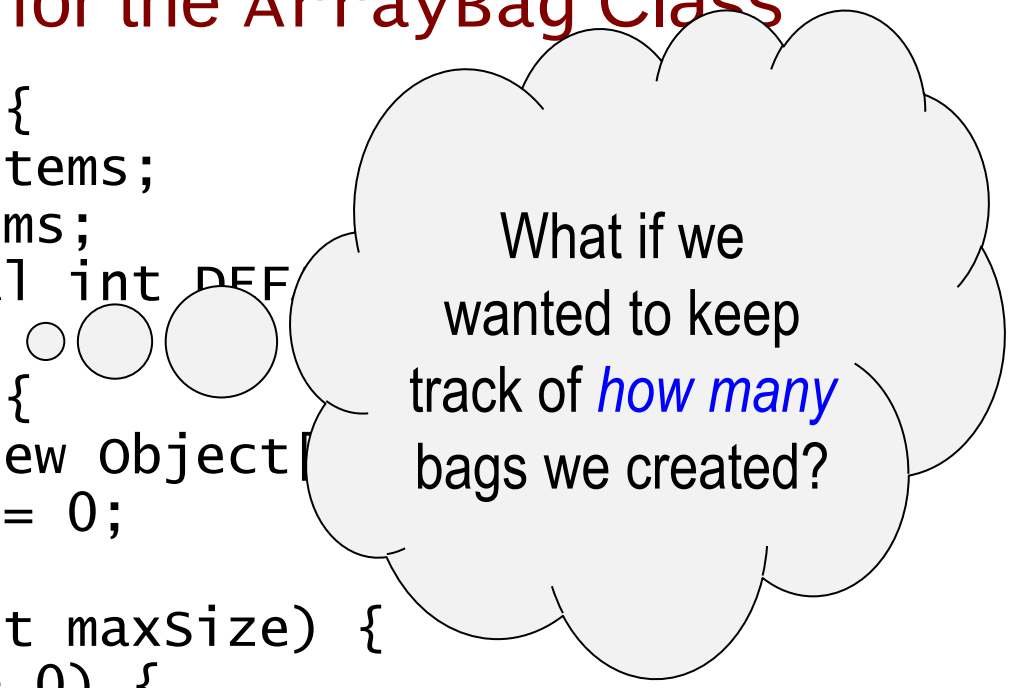


- If the user inputs an invalid `maxSize`, we throw an exception.

# Two Constructors for the `ArrayBag` Class

```
public class ArrayBag {
    private Object[] items;
    private int numItems;
    public static final int DEFAULT_MAX_SIZE = 50;
    private static int numBagsCreated = 0;
    public ArrayBag() {
        this.items = new Object[DEFAULT_MAX_SIZE];
        this.numItems = 0;
    }
    public ArrayBag(int maxSize) {
        if (maxSize <= 0) {
            throw new IllegalArgumentException(
              "maxSize must be positive");
        }
        this.items = new Object[maxSize];
        this.numItems = 0;
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}
```

Note that this `static` member is not declared `final` because ....

- If the user inputs an invalid `maxSize`, we throw an exception.

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    public ArrayBag() {
        this.items = new Object[DEFAULT_MA
        this.numItems = 0;
        numBagsCreated++;
    }
    public ArrayBag(int maxSize) {
        if (maxSize <= 0) {
            throw new IllegalArgumentException(
              "maxSize must be > 0");
        }
        this.items = new Object[maxSize];
        this.numItems = 0;
        numBagsCreated++;
    }
    ...
}
```

Increment the static variable every time that we create an `ArrayBag`.

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public class ArrayBag {
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    private static int numBagsCreated = 0;
    public ArrayBag() {
        // can take advantage of constructor chaining
        // to consolidate the code
        this(DEFAULT_MAX_SIZE);
    }
    public ArrayBag(int maxSize) {
        if (maxSize <= 0) {
            throw new IllegalArgumentException(
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        }
        this.items = new Object[maxSize];
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    p
    }
    ...
}
```

Increment the static variable

Assume I have four different colors: **green**, **blue**, **red**, and **black**.

Let's say I want to enhance the ArrayBag class to:

1. create a bag with a specific color, and
2. keep track of how many bags of each color I created.

What additional fields (data members) do I need to add to my Arraybag class, and what type of fields should they be, static or non-static (i.e. instance)?

# Two Constructors

```
public class ArrayBa
    private Objec
    private int n
    public static
    private static
    public ArrayBa
        this.items = n
    }
    p
    ...
}
```

1. Add an *instance* variable to represent color (i.e. non static).
2. Change the constructor(s) to initialize this instance member, either using a *default* color in the no-arg constructor or by adding a parameter in the custom constructor.

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    p
    ...
}
```

1. Add an int **static** variable, one for each possible color **or**
2. Add an int **static** array where each element of the array represents a color.
3. Change the constructor(s) to update the appropriate *counter* each time a bag is created.

Assume I have four differ… …**black**.

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Now let's say I wanted to add a method that would allow me to change the color of a specific bag. What type of method would that be and what operations would it perform?

- The method should be an instance method because it will be called on a specific bag. Example:

```
ArrayBag bag = new ArrayBag(15, "green");
bag.changeColor( "blue" );
```

- The method should update the instance variable that represents the color of the bag, **and** update the class level counters. *In this example, the number of green bags should decrease by one and the number of blue bags should increase by one.*

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// client
public static void main(String[] args) {
    ArrayBag b1 = new ArrayBag(2);
    ArrayBag b2 = new ArrayBag(4);

    …
}
```

```
// constructor
public ArrayBag(int maxSize) {
   ...  // error-checking
   this.items = new Object[maxSize];
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}
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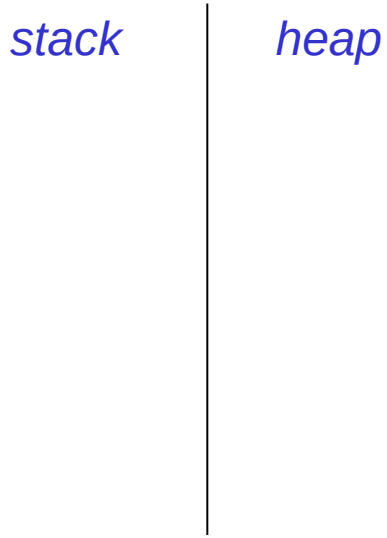

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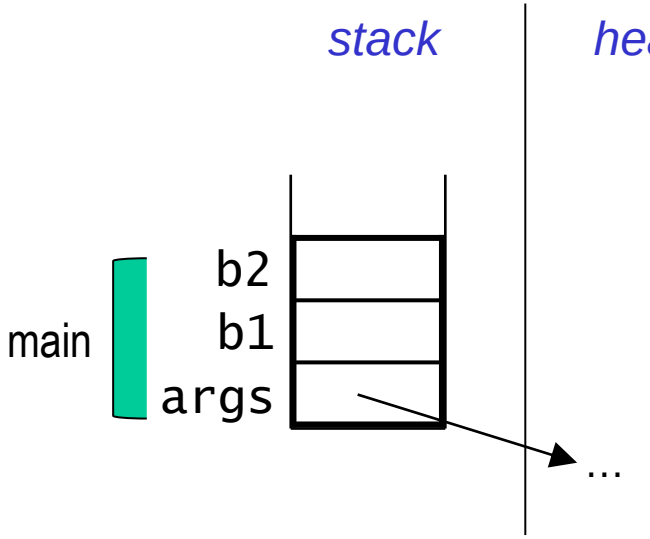

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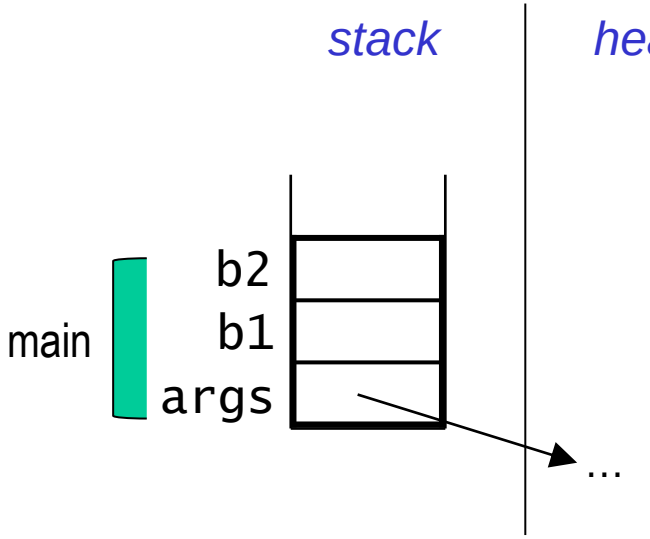

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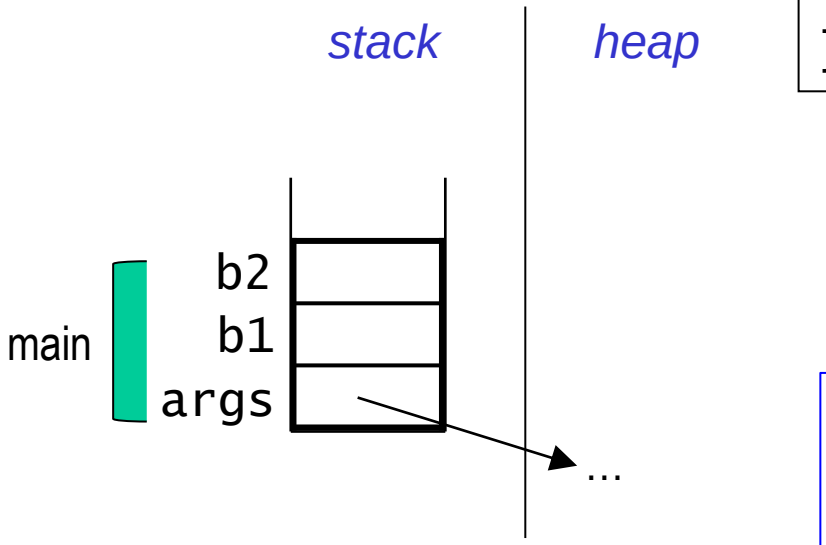


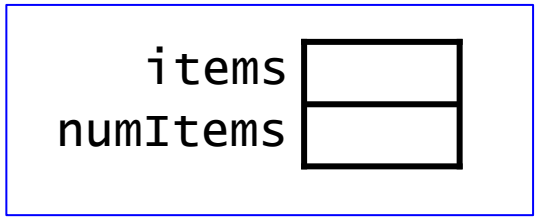

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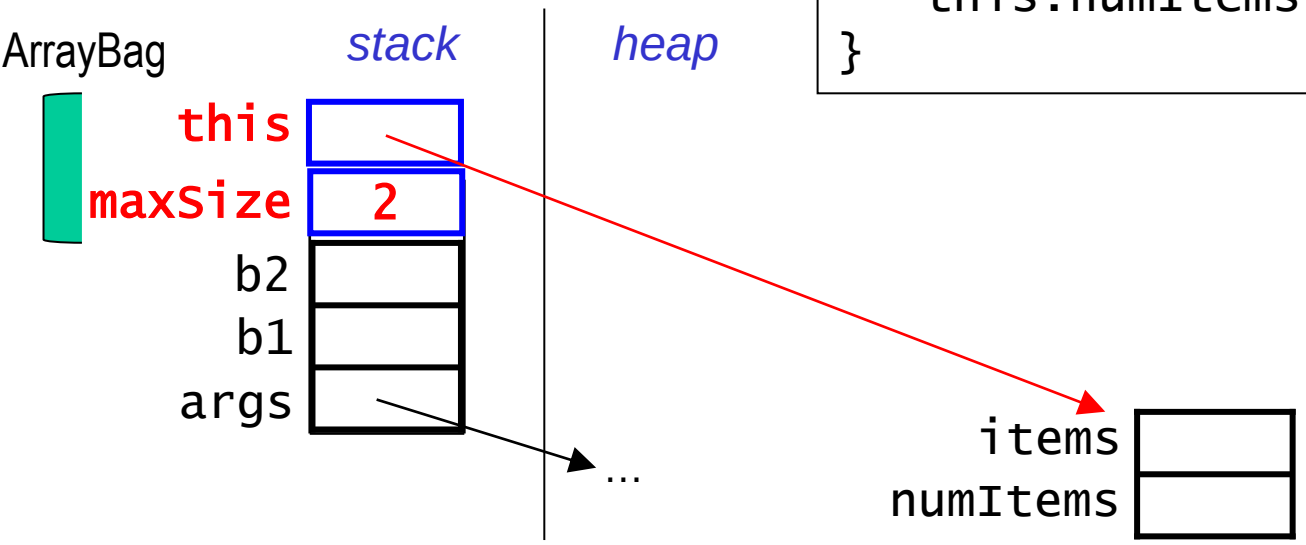


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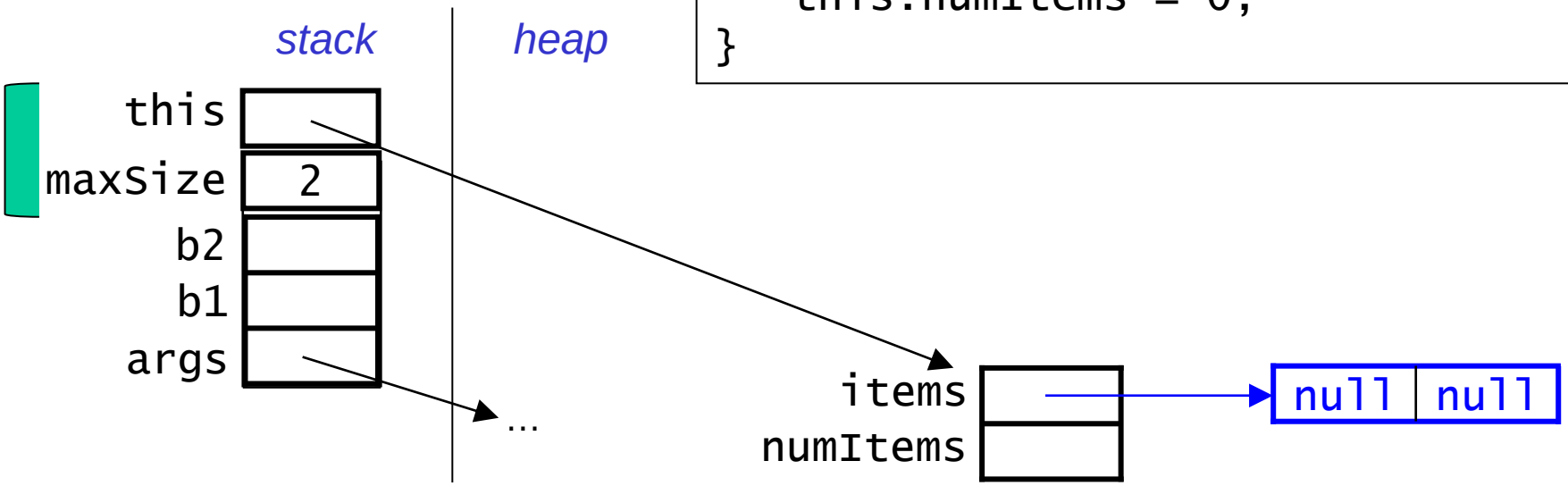


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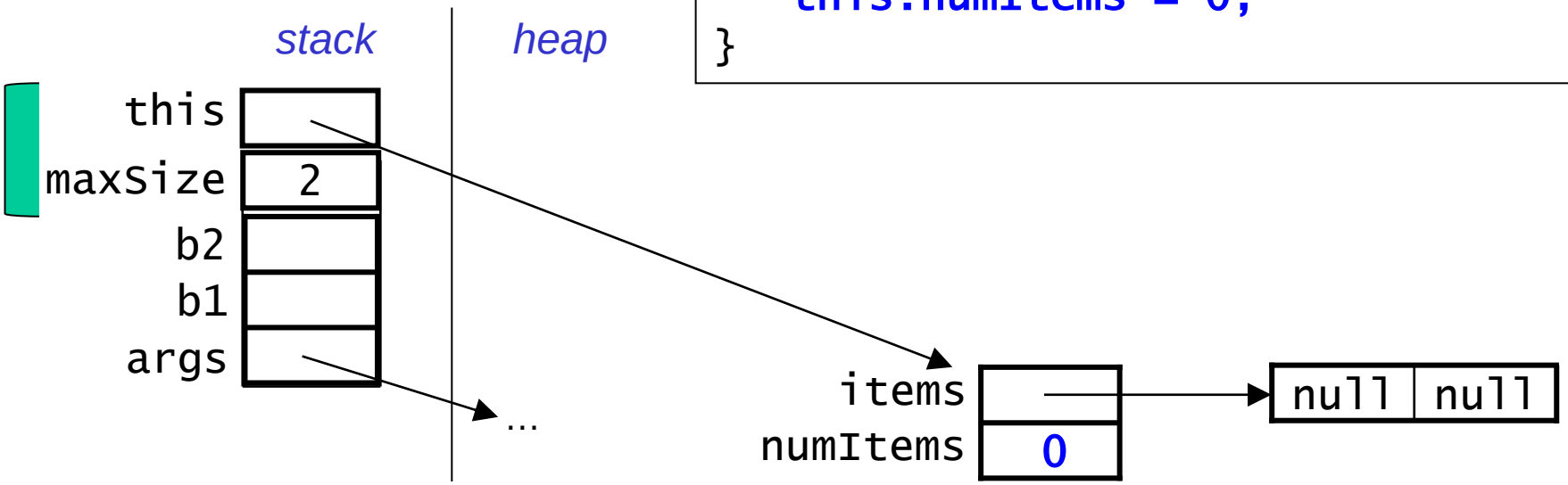


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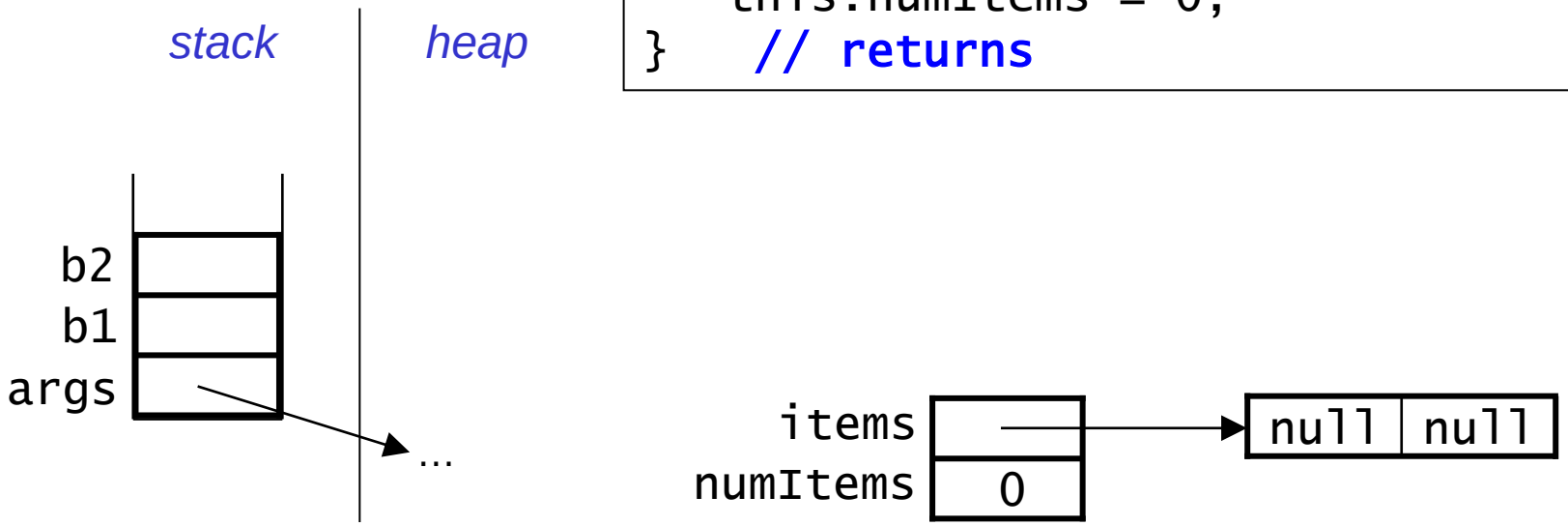

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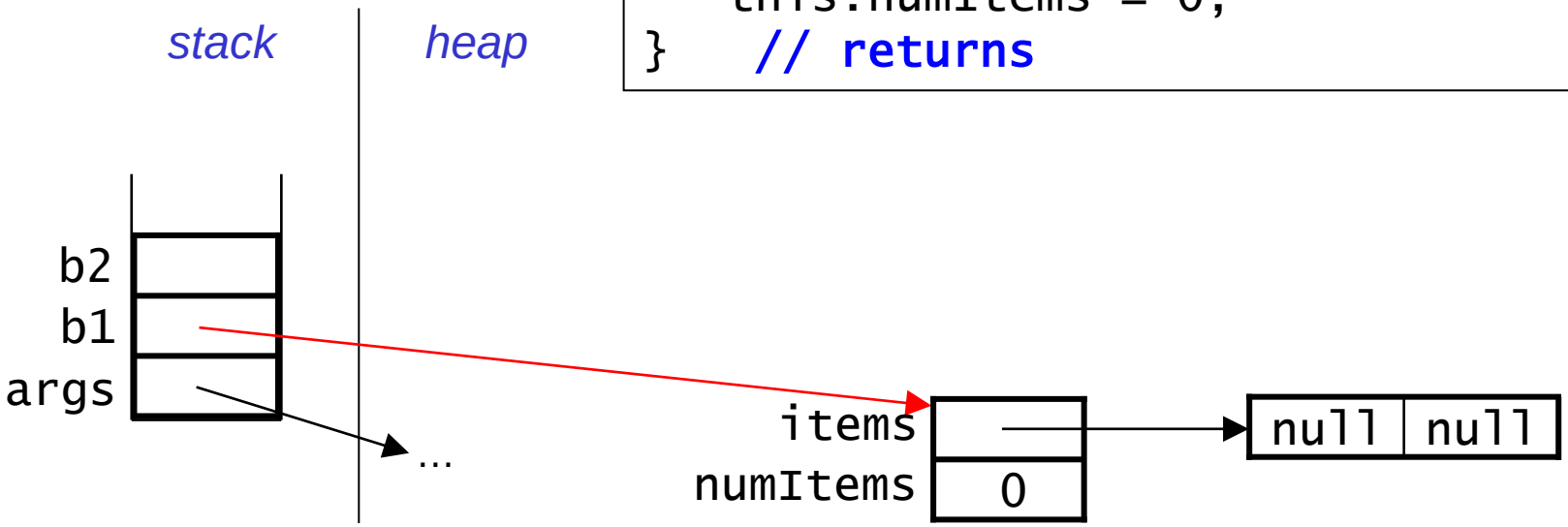

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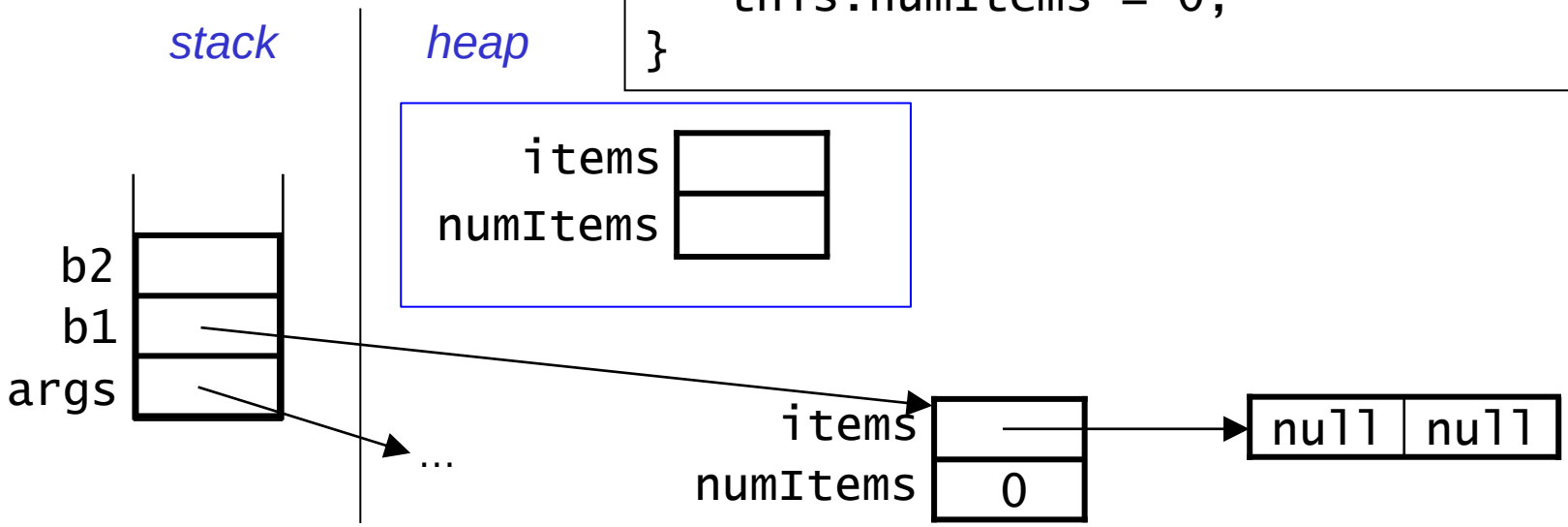

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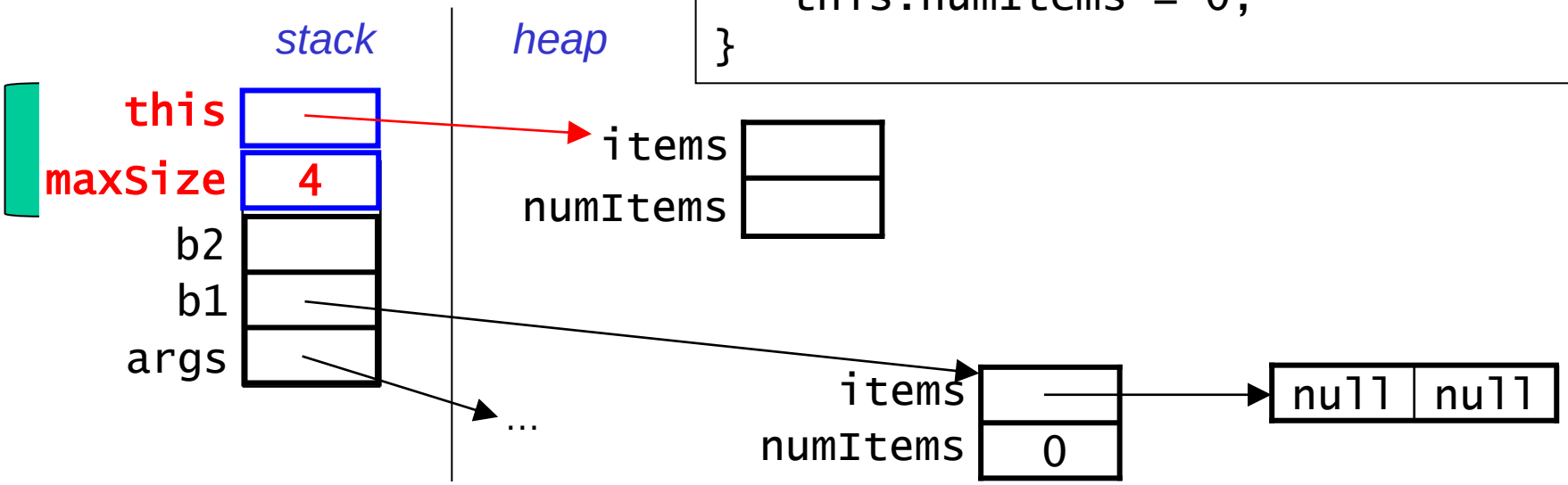


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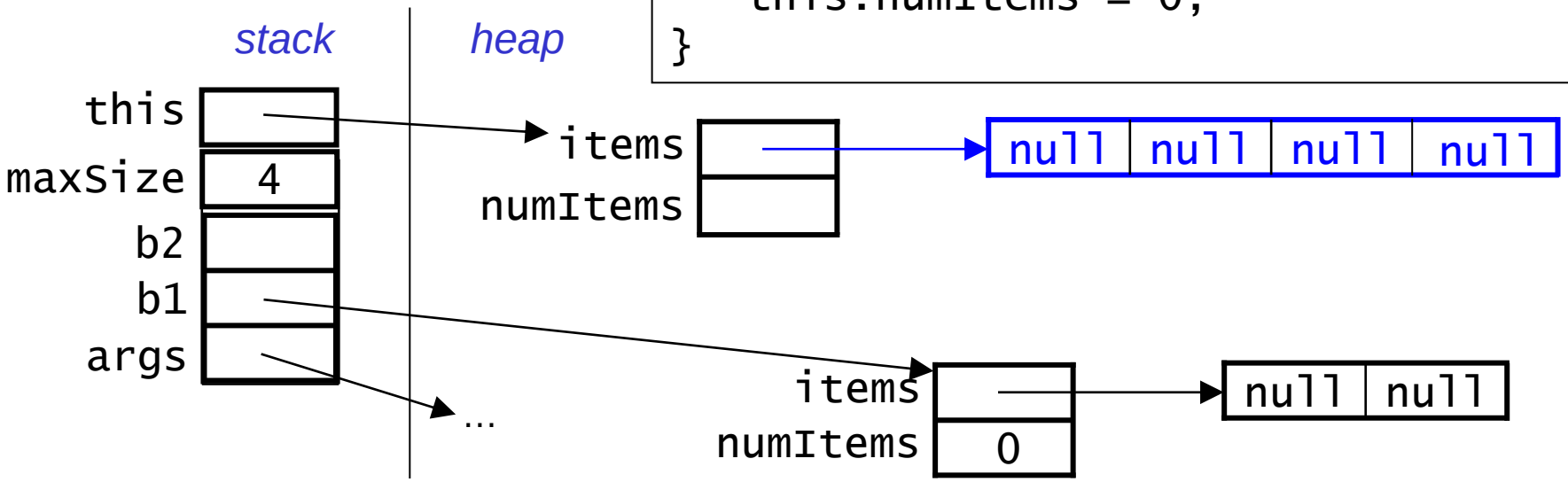


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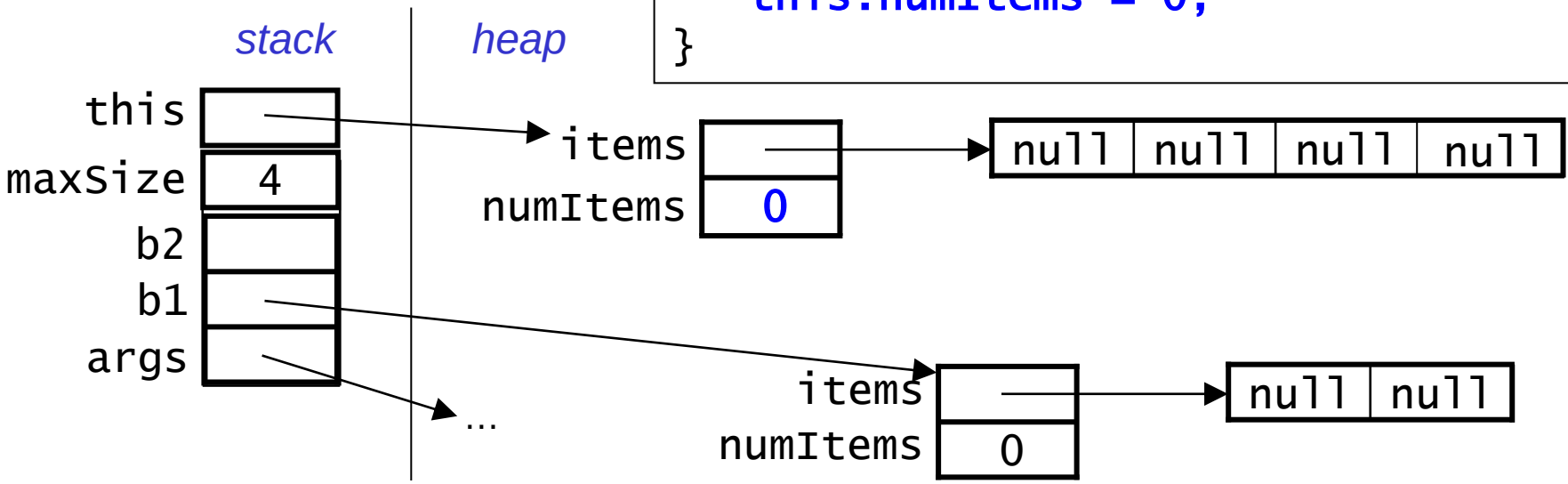


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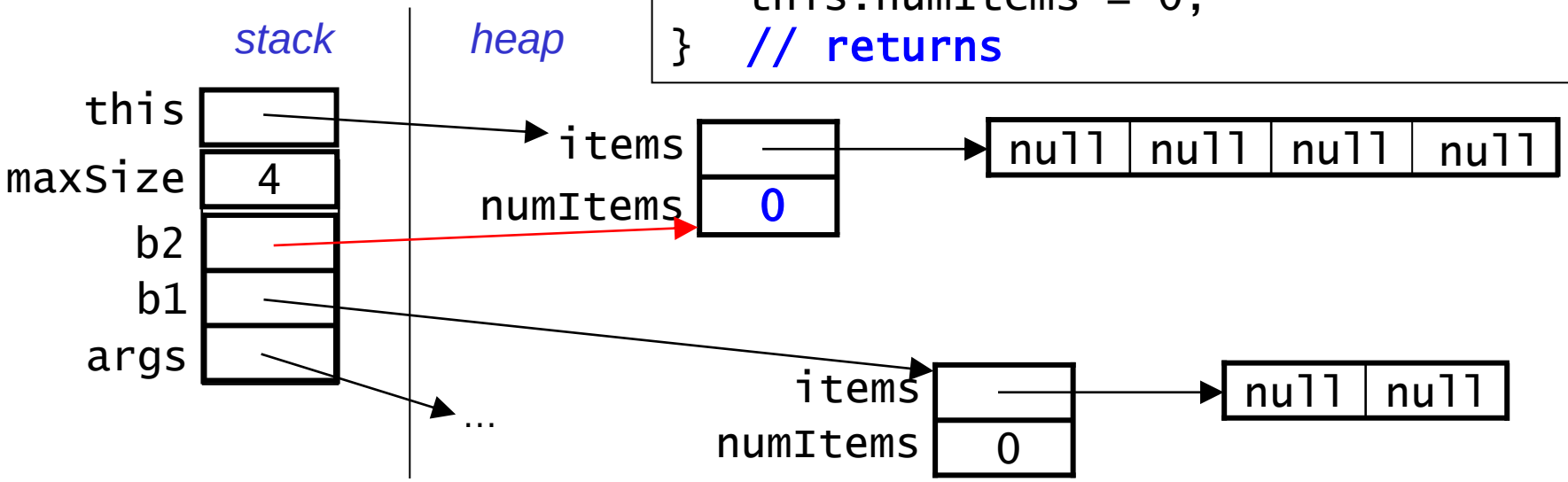


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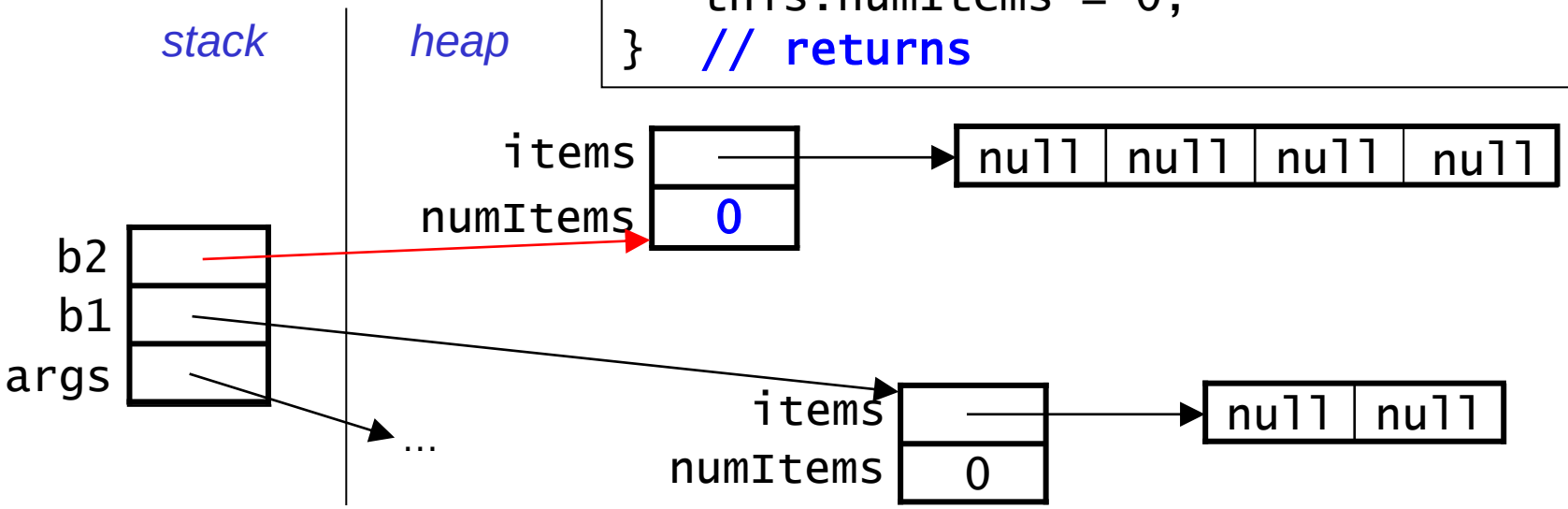


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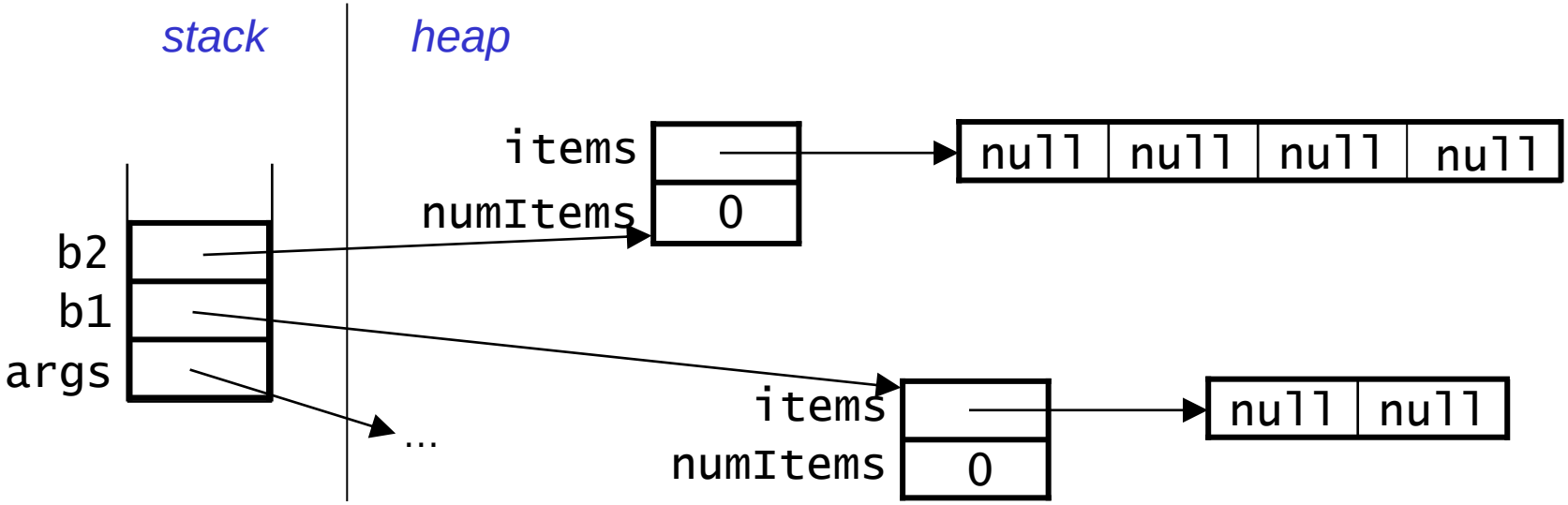

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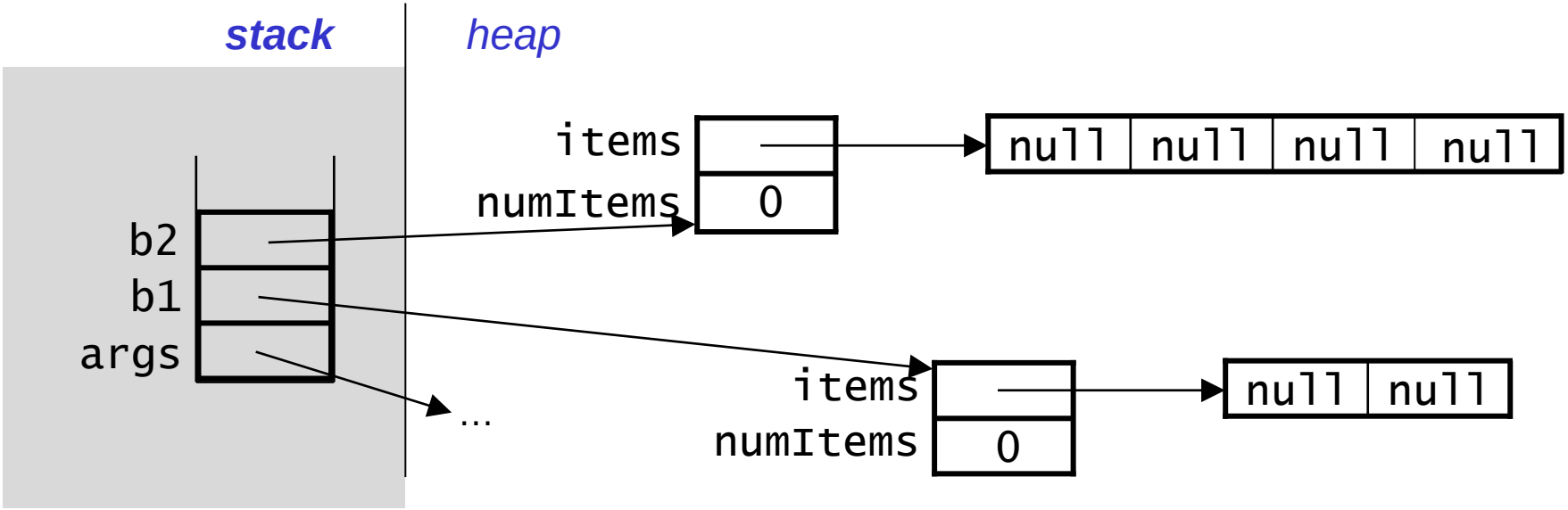

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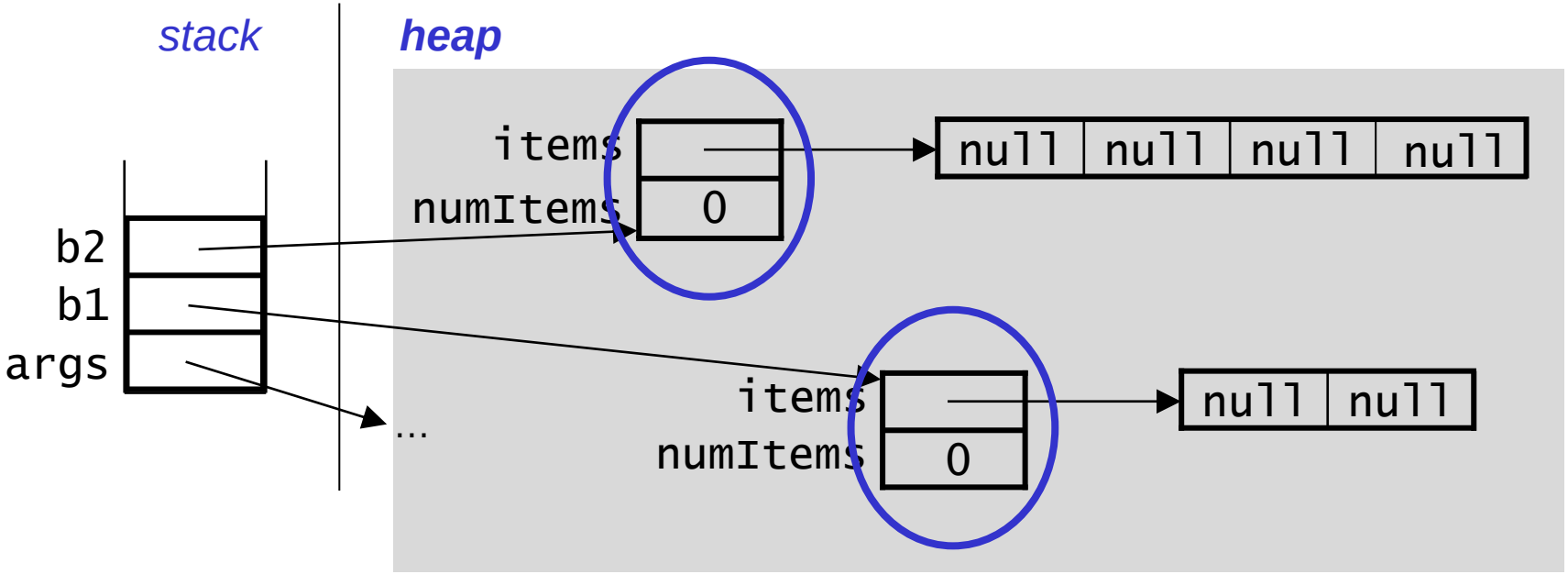

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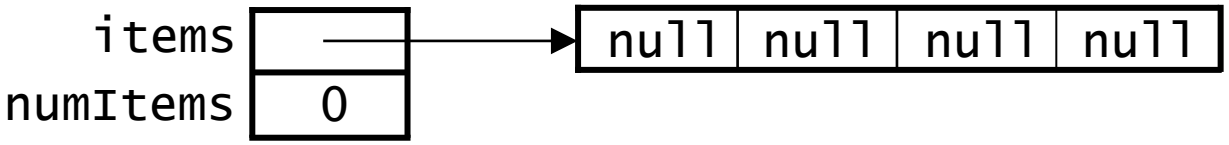

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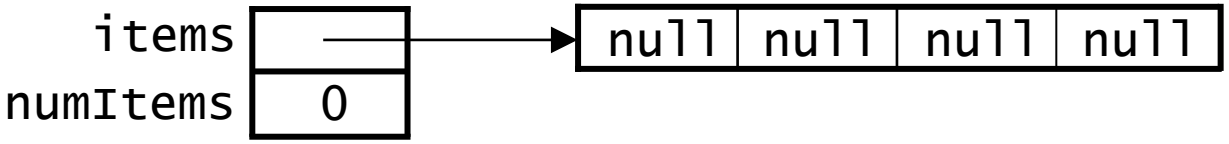


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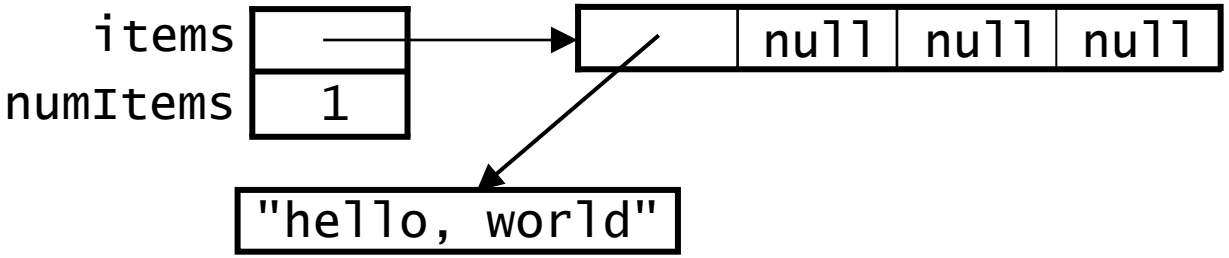

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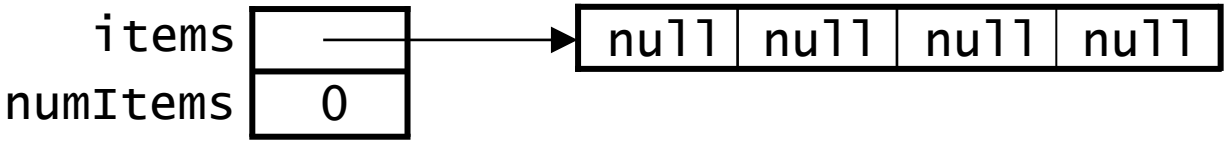


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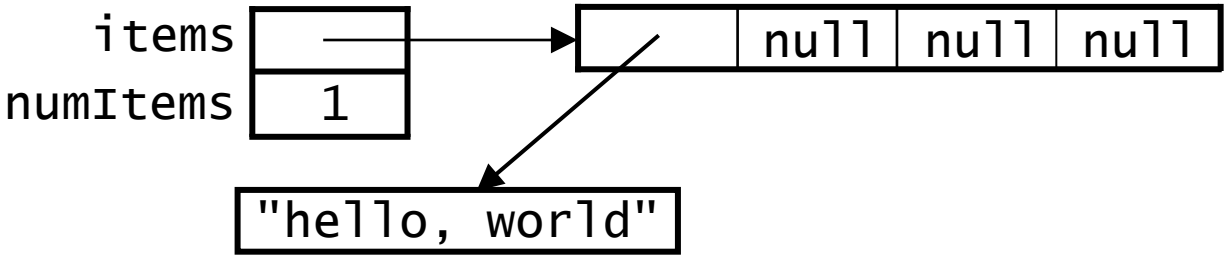
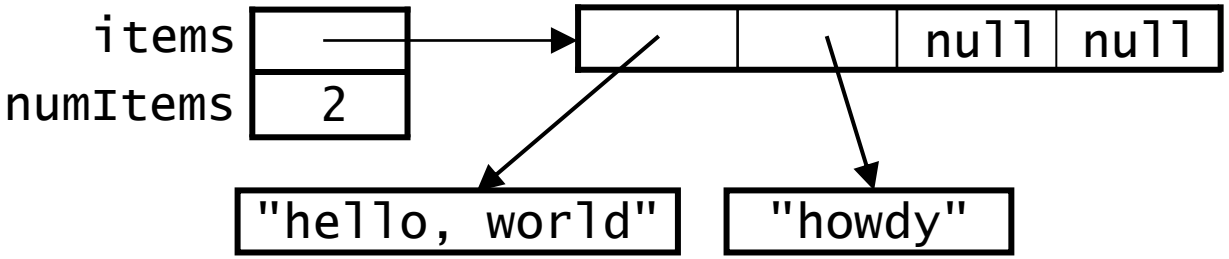



- After adding the second item:



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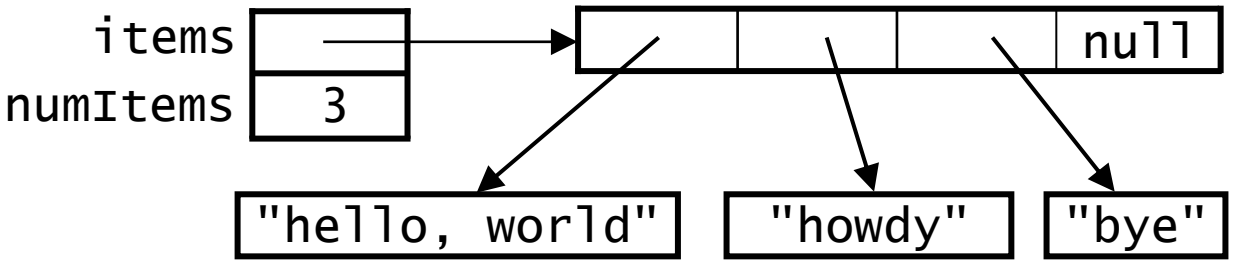
- After adding the third item:



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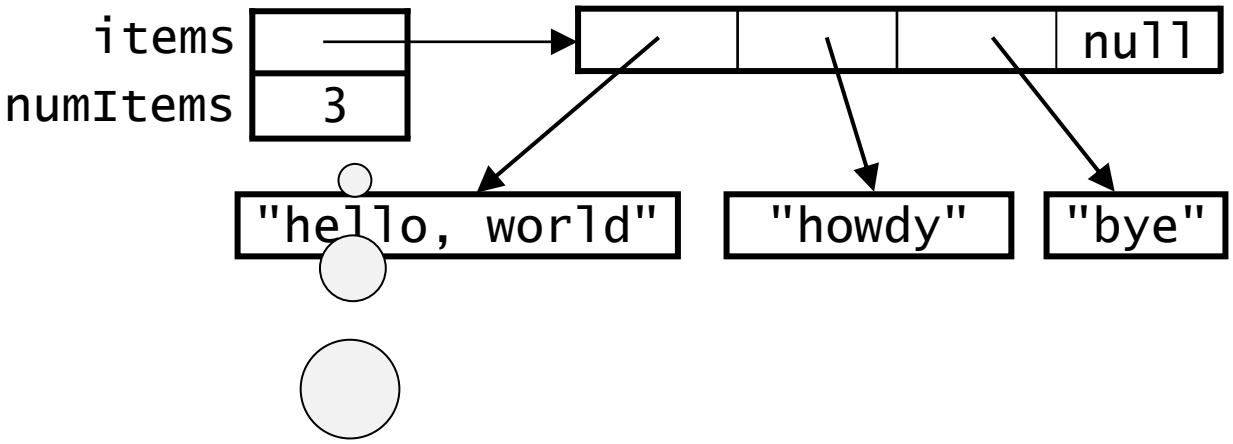


Note the correlation between the *number* of items currently in the bag and the *index* (or offset) we will use to add the next item!

# Adding Items (cont.)

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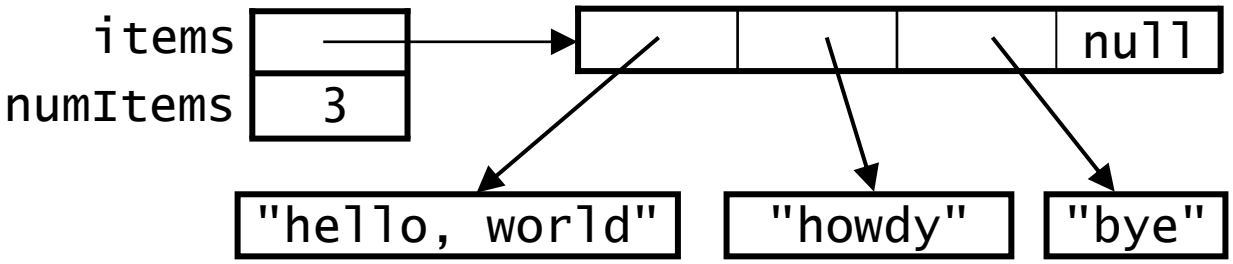


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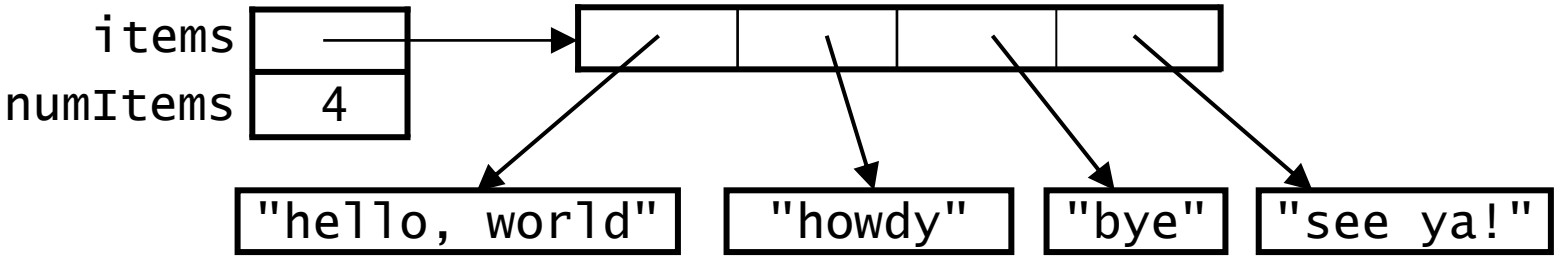

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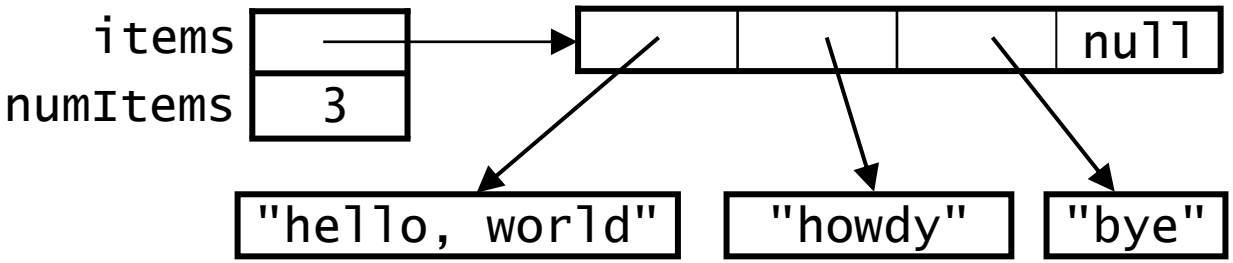


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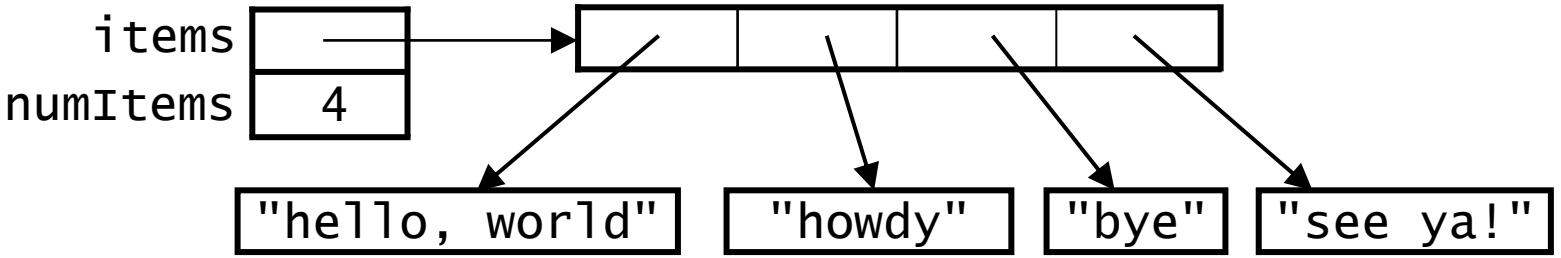


- At this point, the `ArrayBag` is full!
  - We would have to "grow" the array, but for our purposes
  - additional items cannot be added until one is removed

# Adding Items (cont.)

- Af

Assume an array of primitive type `int` is referenced by a variable `items`, the basic steps to grow the array are:

1. Create a new array of a larger size. Example:
   `int[] tmp = new int[items.length *2];`
2. Loop through the array referenced by `items` and assign each element to the array referenced by `tmp`.
3. Reassign the reference (i.e. `items`) to the new array (i.e. `tmp`). Example: `items = tmp;`

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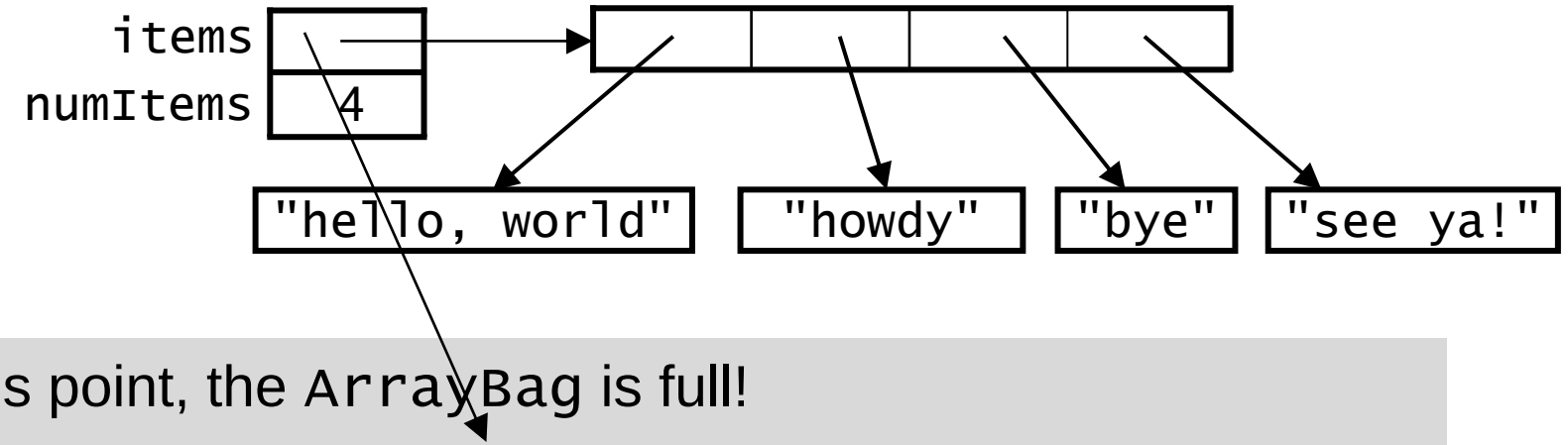


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- takes an object of any type!
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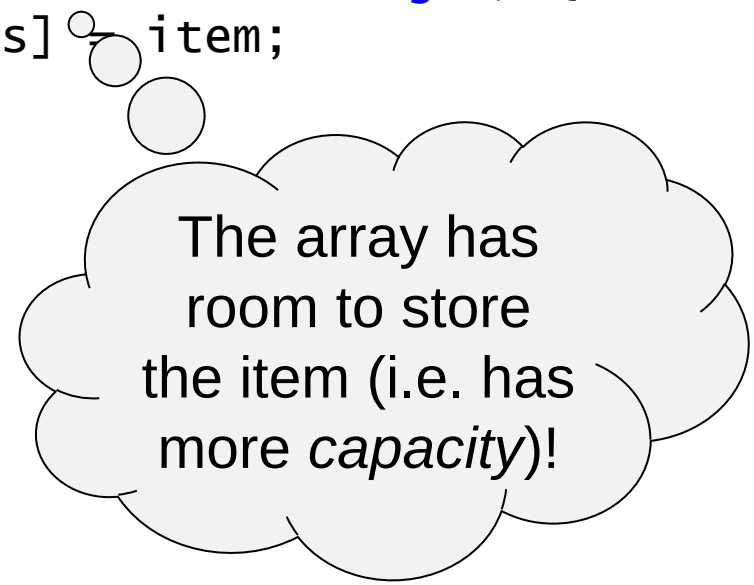

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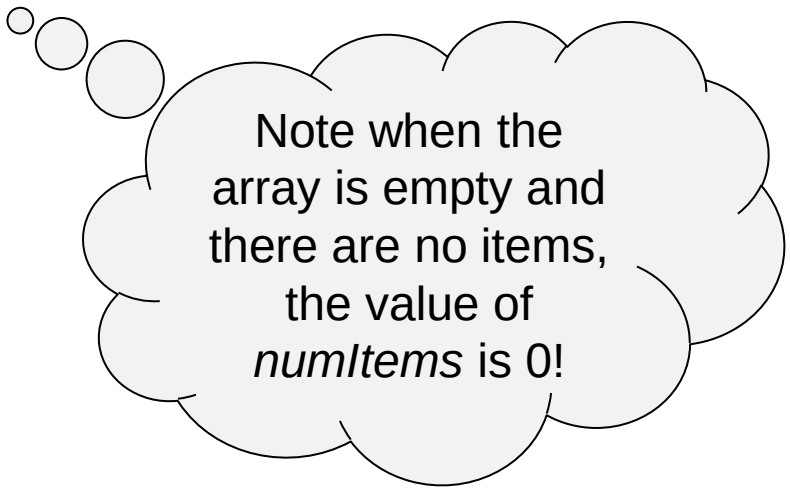

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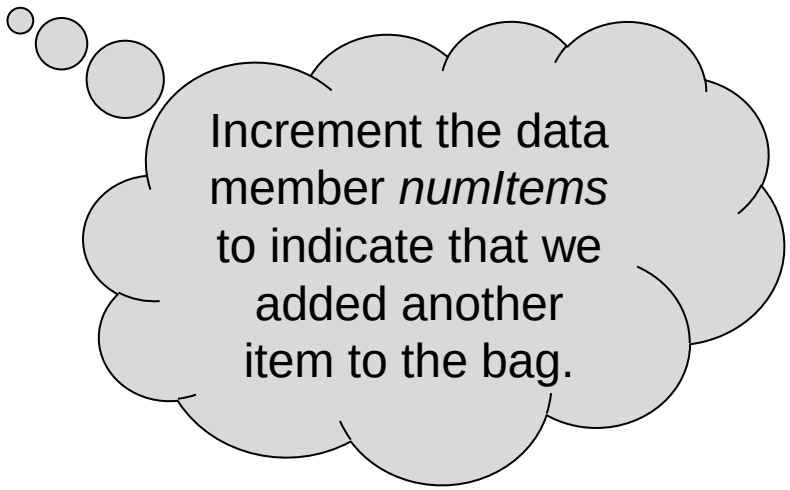

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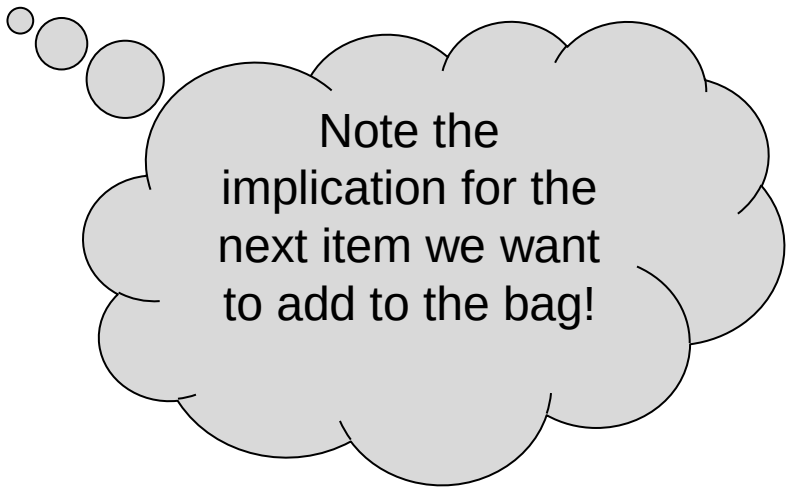

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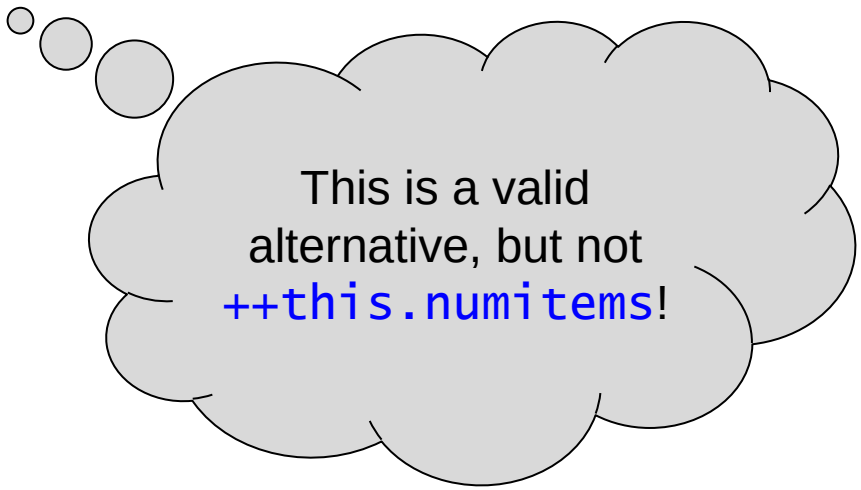

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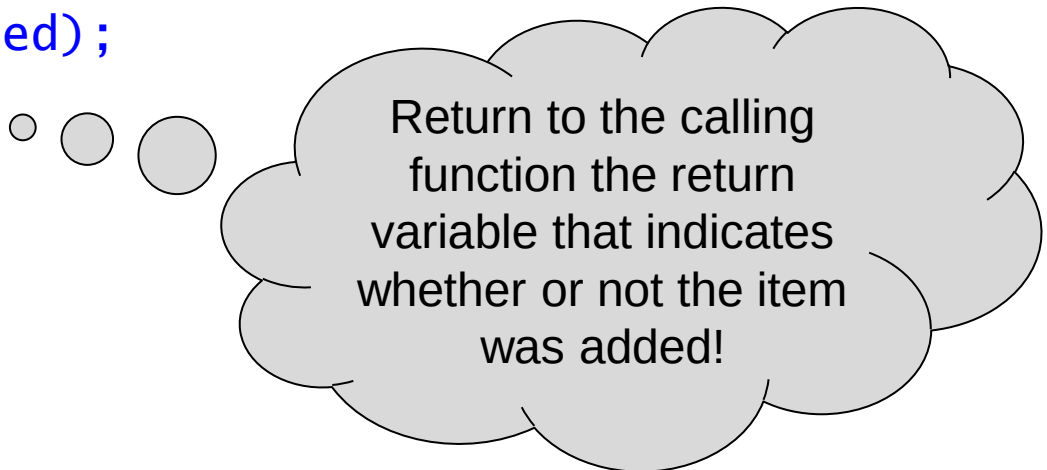
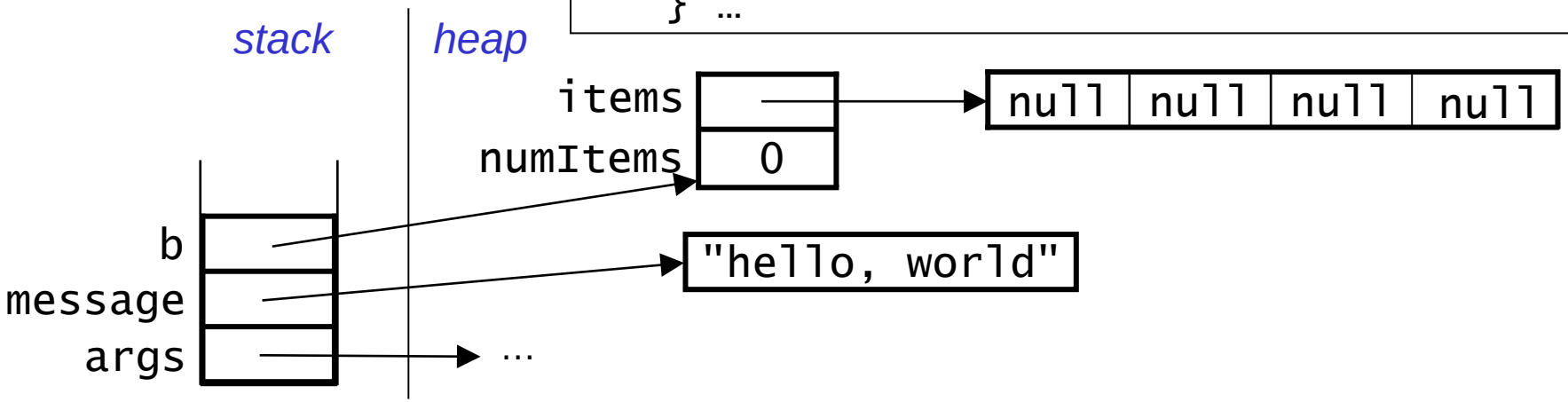


# Example: Adding an Item

```
public static void main(String[] args) {
    String message = "hello, world";
    ArrayBag b = new ArrayBag(4);
    b.add(message);
    …
}
```

```
public boolean add(Object item) {
   …
   else {
        this.items[this.numItems] = item;
        this.numItems++;
        item_added = true;
   } …
```



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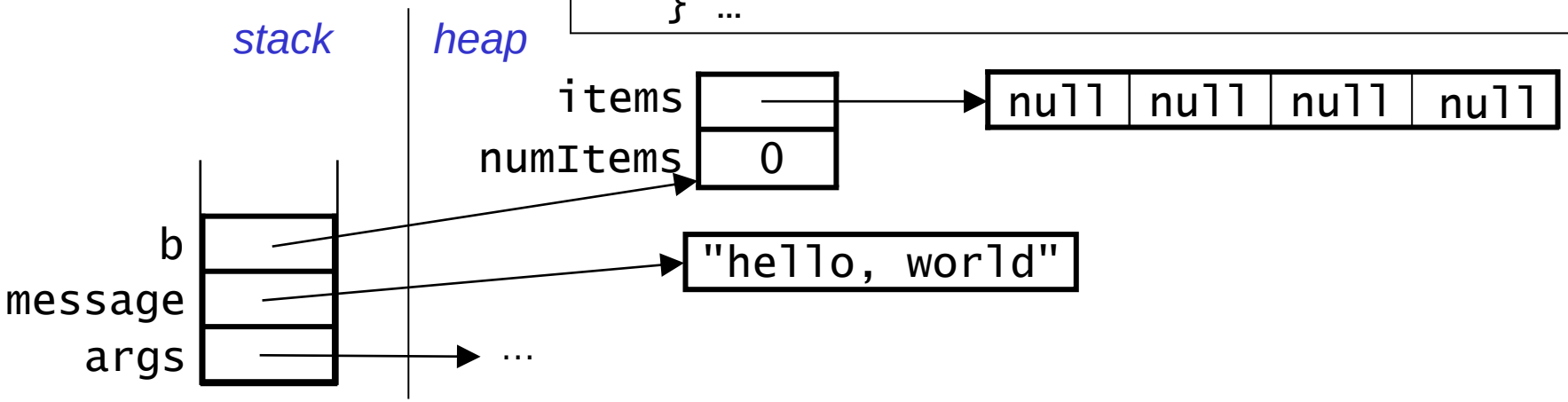

# Example: Adding an Item (cont.)

```
public static void main(String[] args) {
    String message = "hello, world";
    ArrayBag b = new ArrayBag(4);
    b.add(message);
    …
}
```

```
public boolean add(Object item) {
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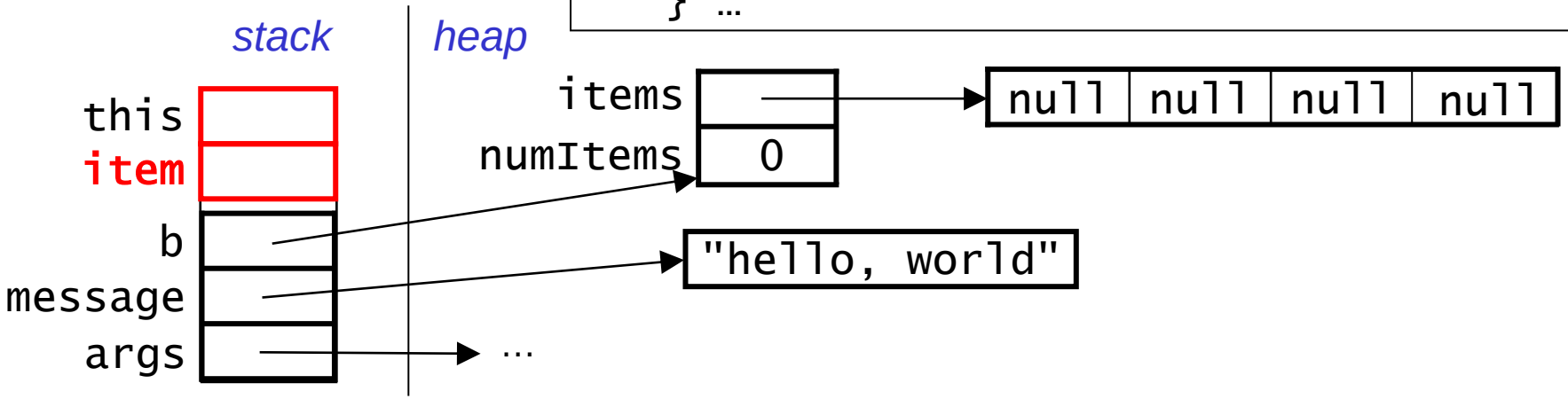
   else {
        this.items[this.numItems] = item;
        this.numItems++;
        item_added = true;
   } …
```




- add's stack frame

Note: We are not showing the return address or local variable `item_added`.

# Example: Adding an Item (cont.)

```
public static void main(String[] args) {
    String message = "hello, world";
    ArrayBag b = new ArrayBag(4);
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    …
}
```

```
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        this.items[this.numItems] = item;
        this.numItems++;
        item_added = true;
    } …
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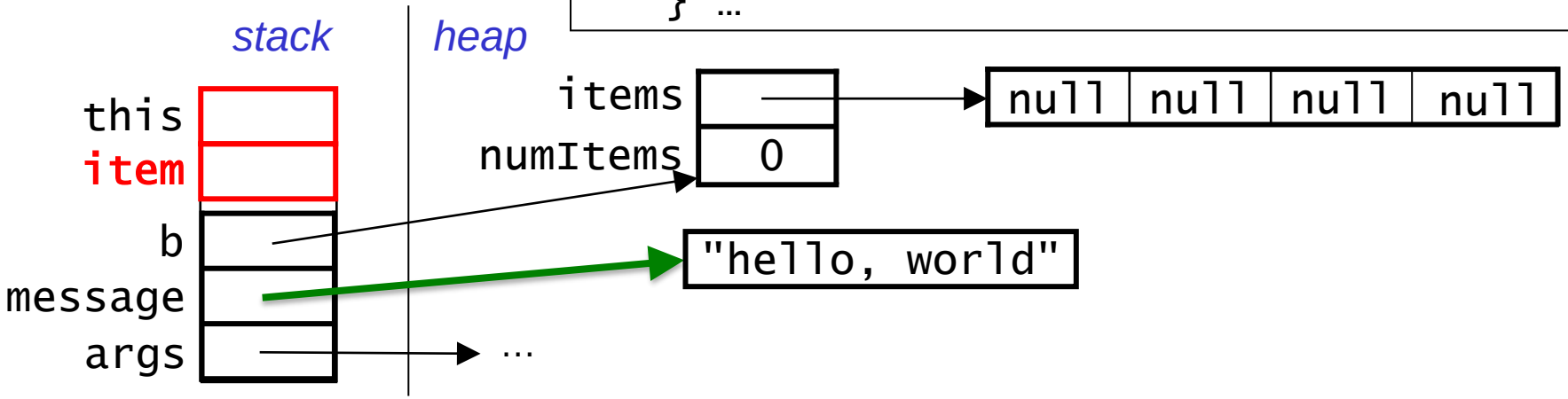


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# Example: Adding an Item (cont.)

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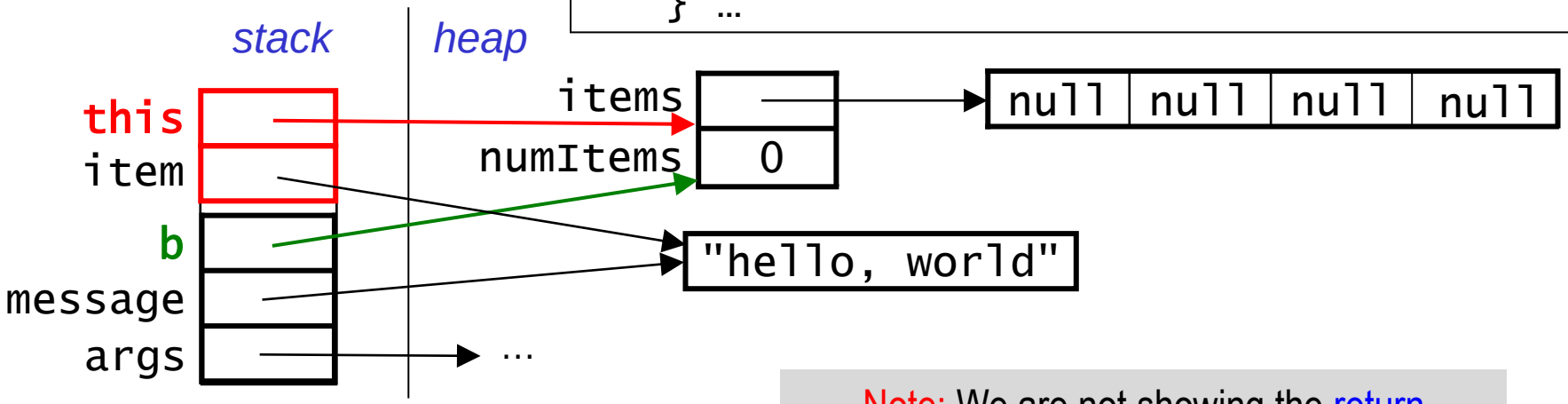


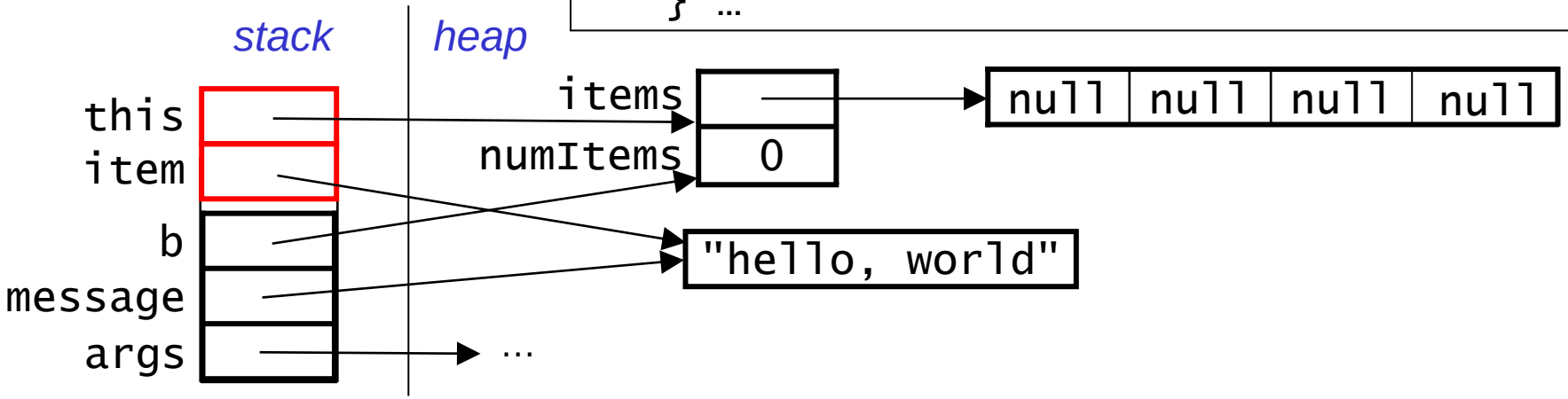

Note: We are not showing the return address or local variable `item_added`.

- add's stack frame includes:
  - `item`, which stores a copy of the reference passed as a param.
  - `this`, which stores a reference to the called `ArrayBag` object

# Example: Adding an Item (cont.)

```
public static void main(String[] args) {
    String message = "hello, world";
    ArrayBag b = new ArrayBag(4);
    b.add(message);
    …
}
```

```
public boolean add(Object item) {
   …
   else {
       this.items[this.numItems] = item;
       this.numItems++;
       item_added = true;
   } …
```




- The method modifies the `items` array and `numItems`.

# Example: Adding an Item (cont.)

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public static void main(String[] args) {
    String message = "hello, world";
    ArrayBag b = new ArrayBag(4);
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    …
}
```

```
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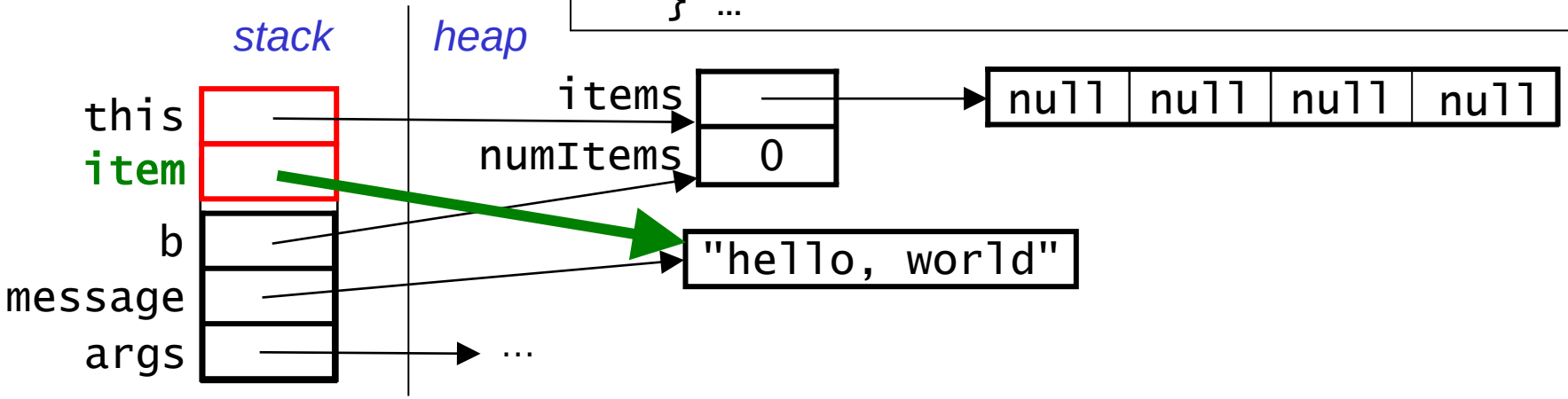
```

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    …
}
```

```
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   else {
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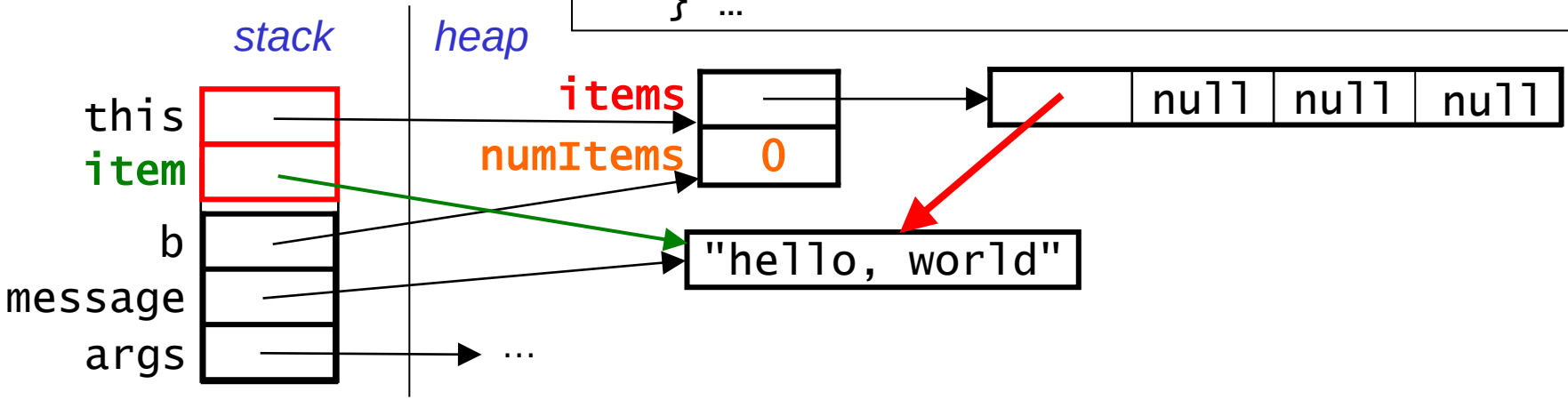
```




- The method modifies the `items` array and `numItems`.

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       this.numItems++;
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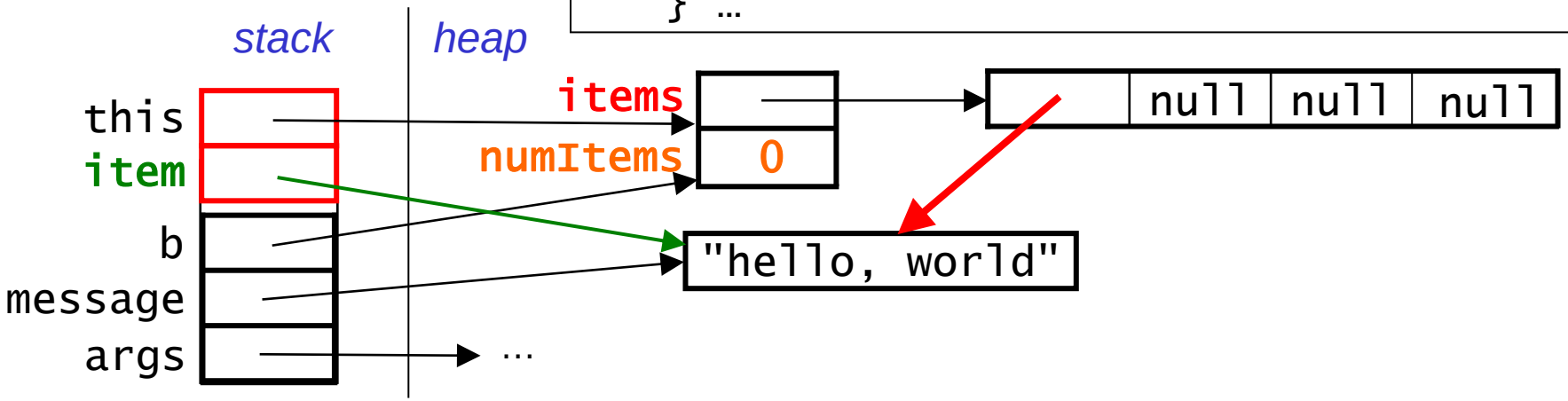


- The method modifies the `items` array and `numItems`.
  - note that the array stores a copy of the *reference* to the item, not a copy of the item itself.

# Example: Adding an Item (cont.)

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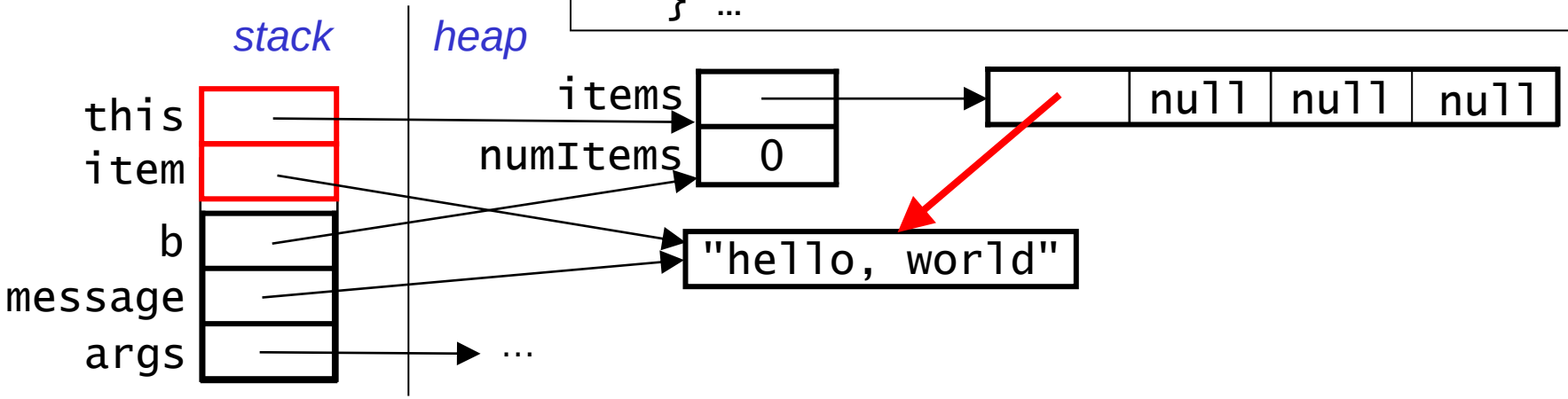
```

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   else {
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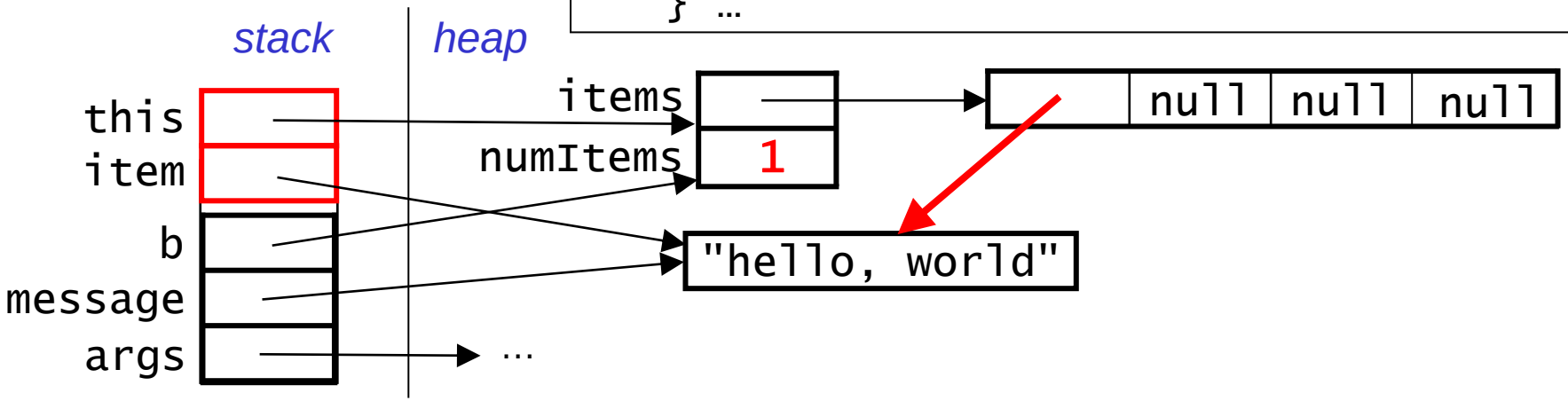
       this.numItems++;
       item_added = true;
   } …
```

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    …
}
```

```
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   …
   else {
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       this.numItems++;
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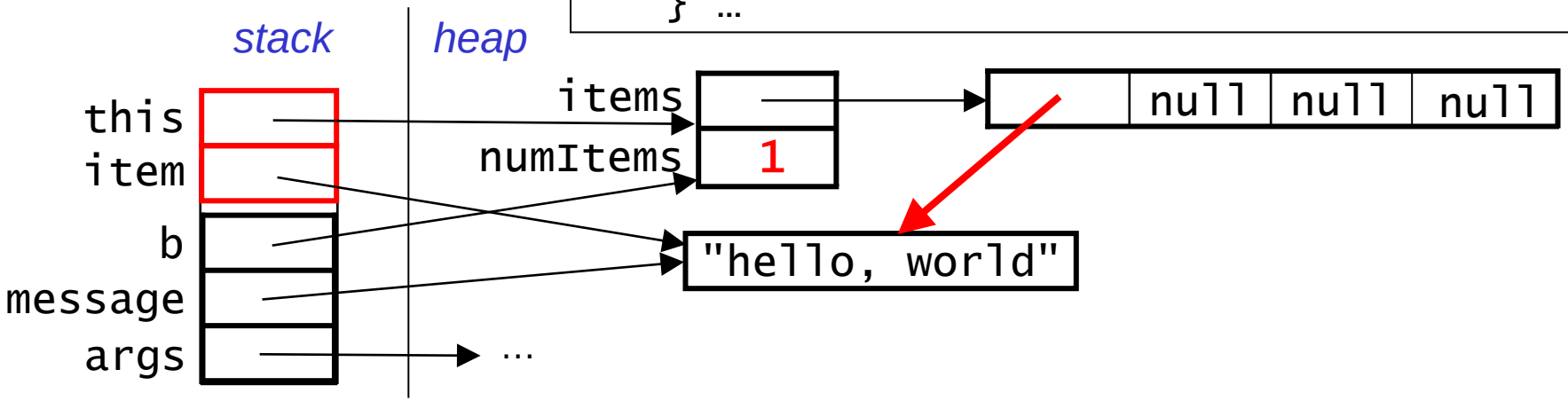
   } …
```

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```

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   else {
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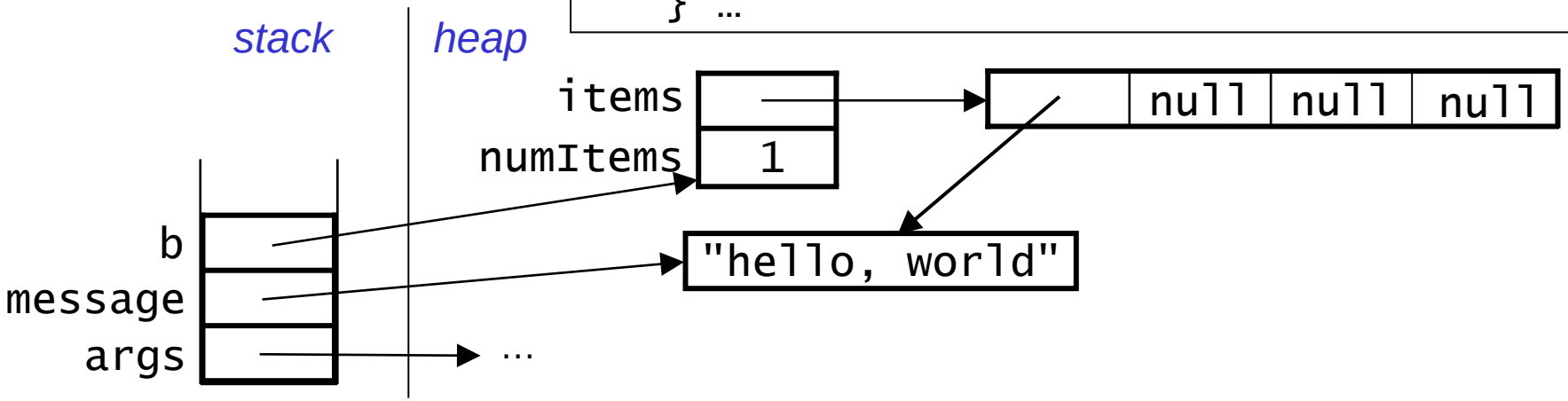
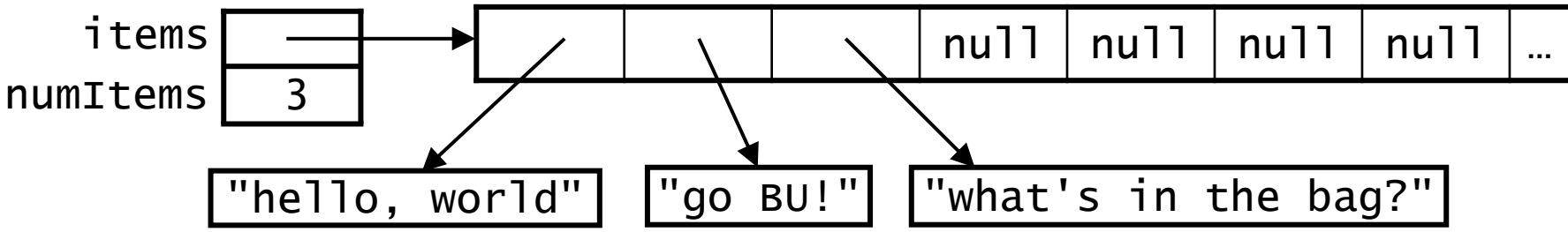
       item_added = true;
   } …
```




- After the method call returns, add's stack frame is removed from the stack.

# Extra Practice: Determining if a Bag Contains an Item



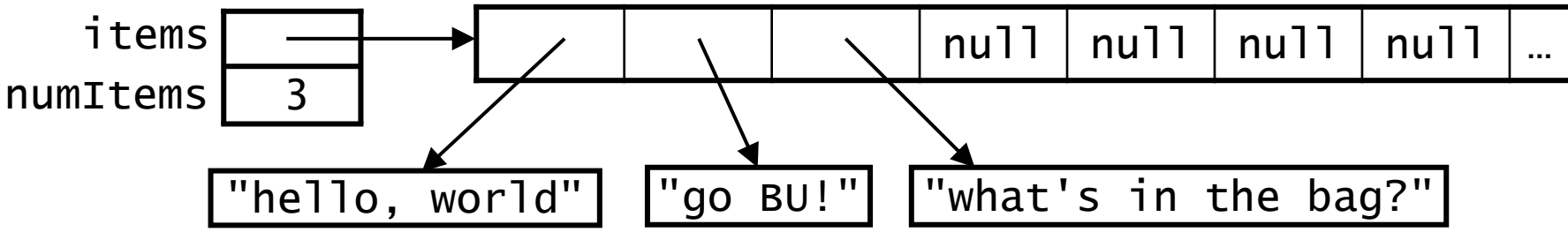

- Let's write the `ArrayBag contains()` method together.
  - should return `true` if an object equal to `item` is found, and `false` otherwise.

```
_____________________ contains(_____________ item) {




}
```

# Extra Practice: Determining if a Bag Contains an Item



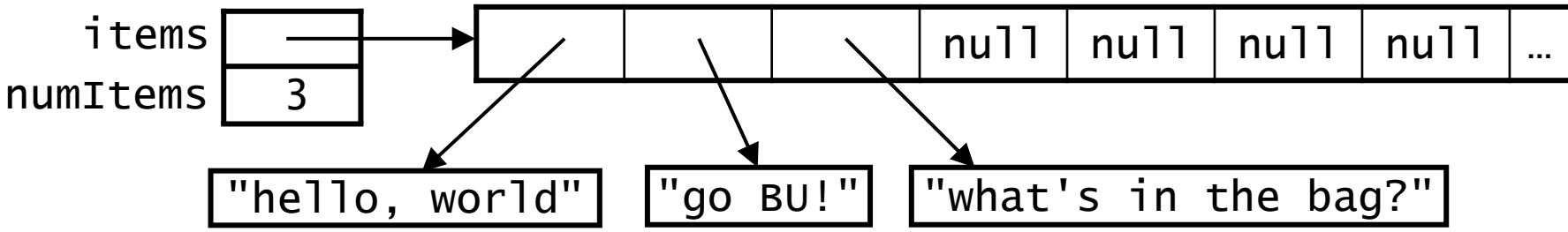

- Let's write the `ArrayBag contains()` method together.
  - should return `true` if an object equal to `item` is found, and `false` otherwise.

```
public boolean contains(_____________ item) {




}
```

# Extra Practice: Determining if a Bag Contains an Item

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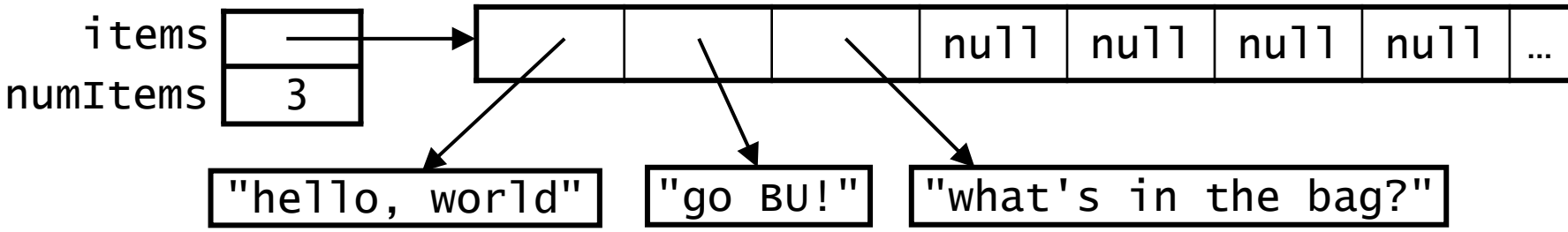
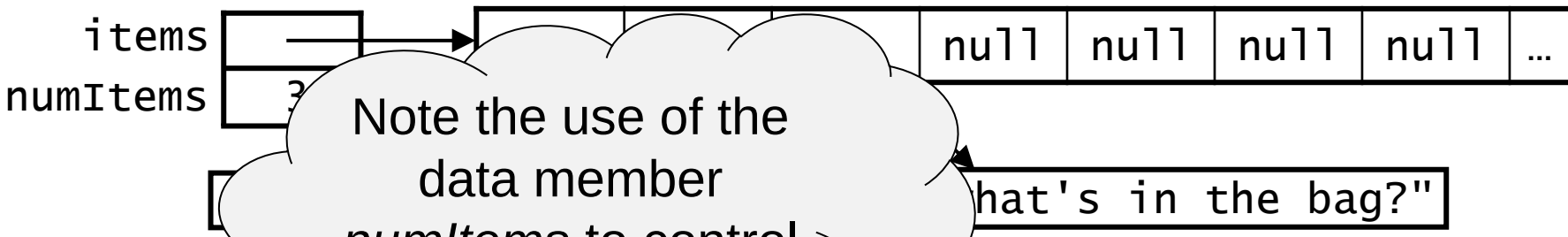



- Let's write the `ArrayBag contains()` method together.
  - should return `true` if an object equal to `item` is found, and `false` otherwise.

```
public boolean contains(Object item) {
    for (int i = 0; i < this.numItems; i++) {
        if (this.items[i].equals(item) {  // not ==
            return true;
        }
    }
    return false;
}
```

# Extra Practice: Determining if a Bag Contains an Item




- Let's write the `contains()` method together.
  - should return `true` if an object equal to `item` is found, and `false` otherwise.

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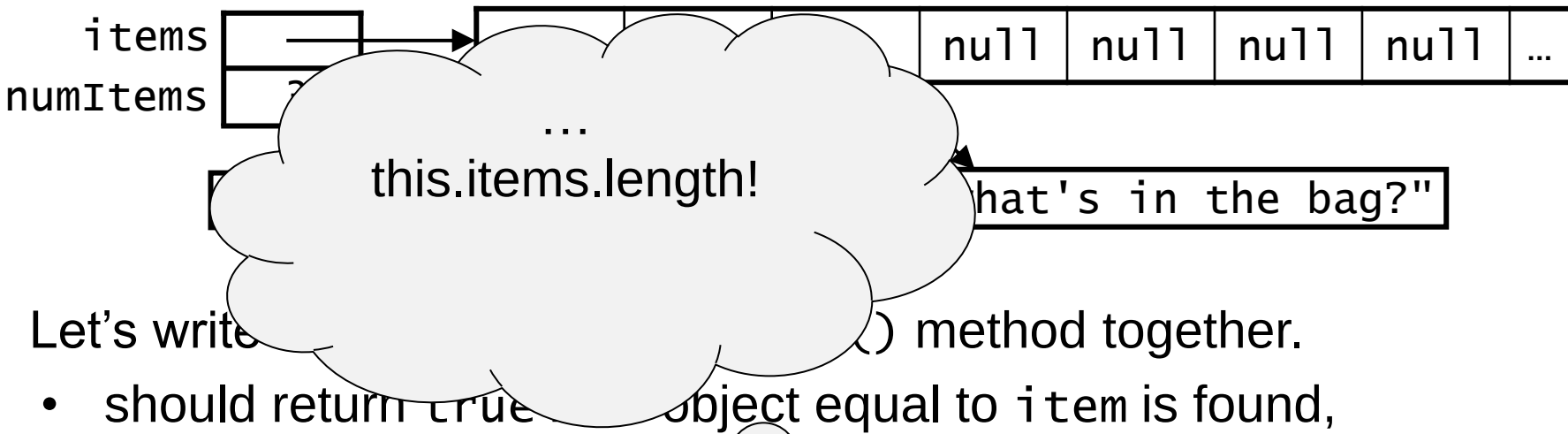
            return true;
        }
    }
    return false;
}
```

# Would this work instead?




- Let's write() method together.
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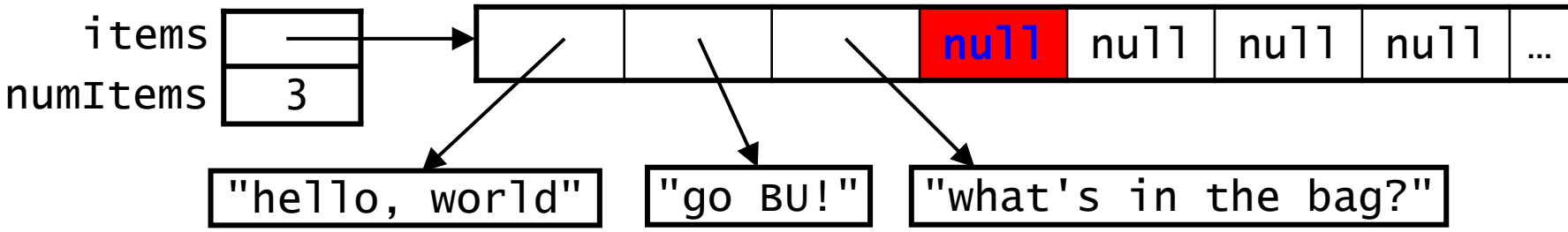
```
public boolean contains(Object item) {
    for (int i = 0; i < this.items.length; i++) {
        if (this.items[i].equals(item) {  // not ==
            return true;
        }
    }
    return false;
}
```

# Would this work instead? *no!*

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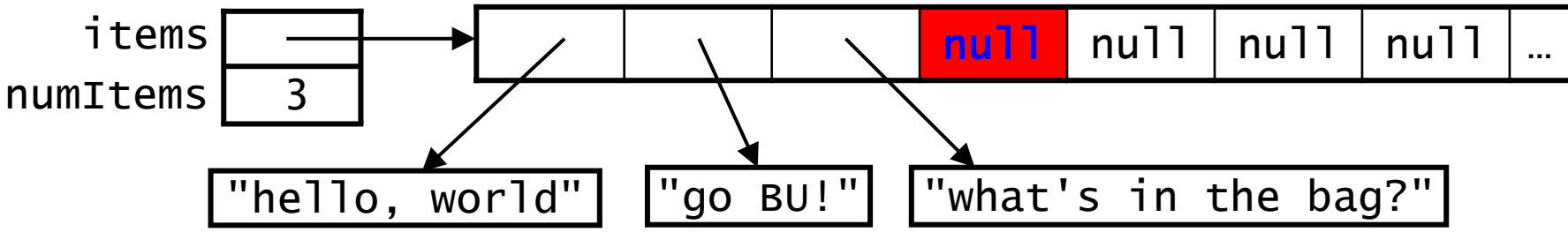
}
```

- will get a `NullPointerException` from first array element that is still `null`
- even if we check for `null`s, it's more efficient to only look at actual items!

# Would this work instead? *no!*

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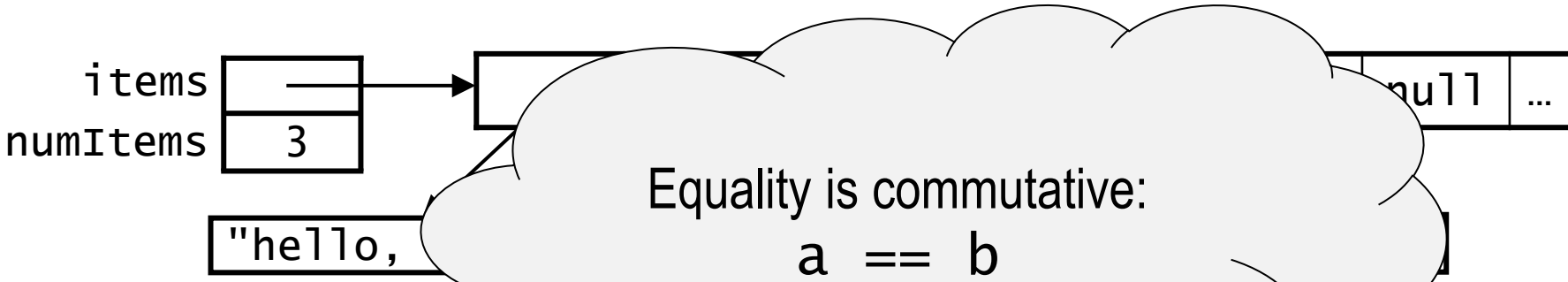


- Let's write the `Array` …
  - should return `true` if an object e… `tem` is found, and `false` otherwise.

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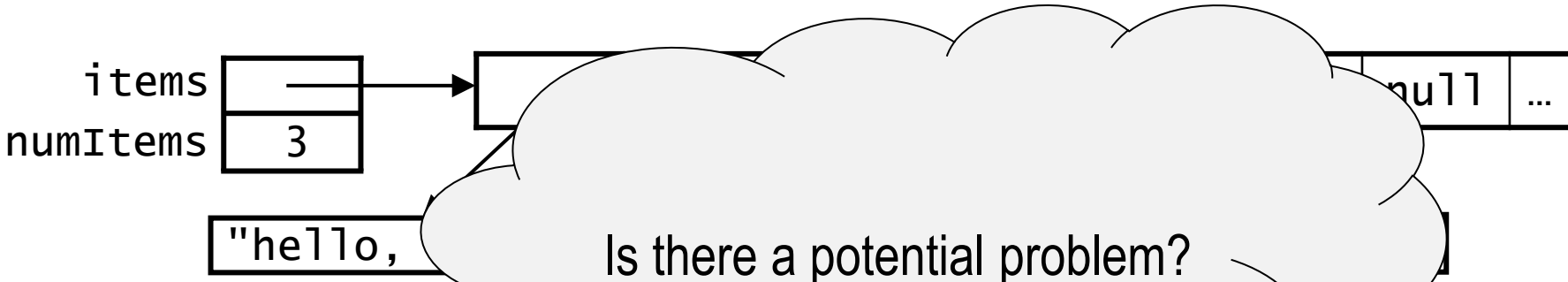


- Let's write the `Array` .
  - should return `true` if an object e em is found, and `false` otherwise.

```
public boolean contains(Object item) {
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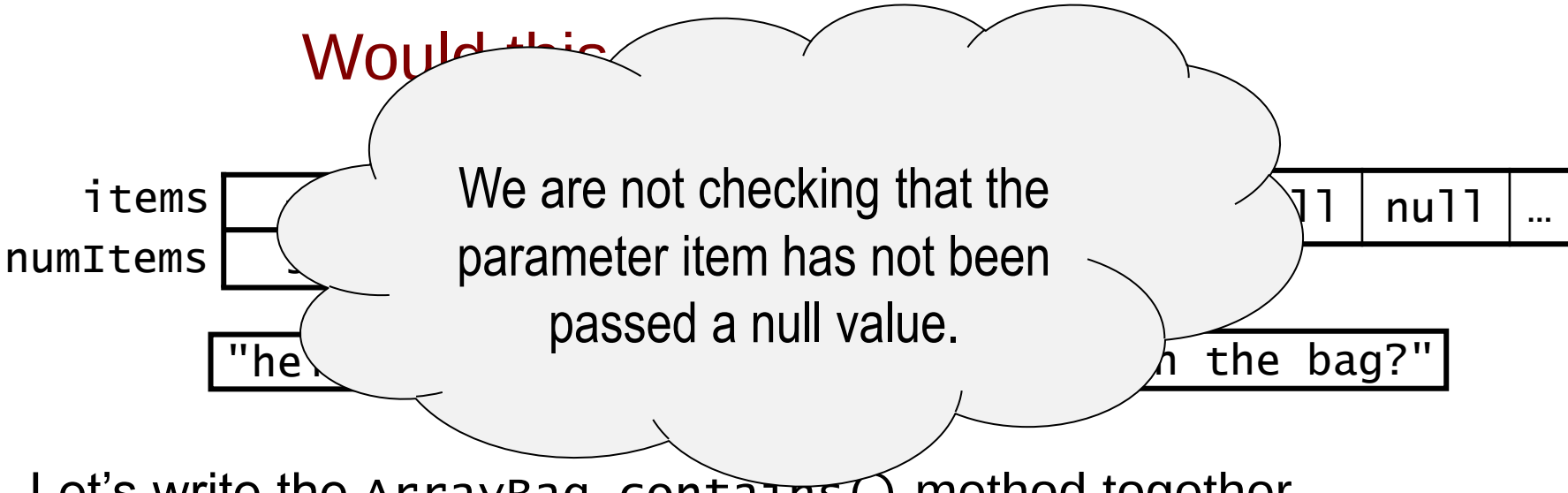


- Let's write the `ArrayBag contains()` method together.
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public boolean contains(Object item) {
    for (int i = 0; i < this.numItems; i++) {
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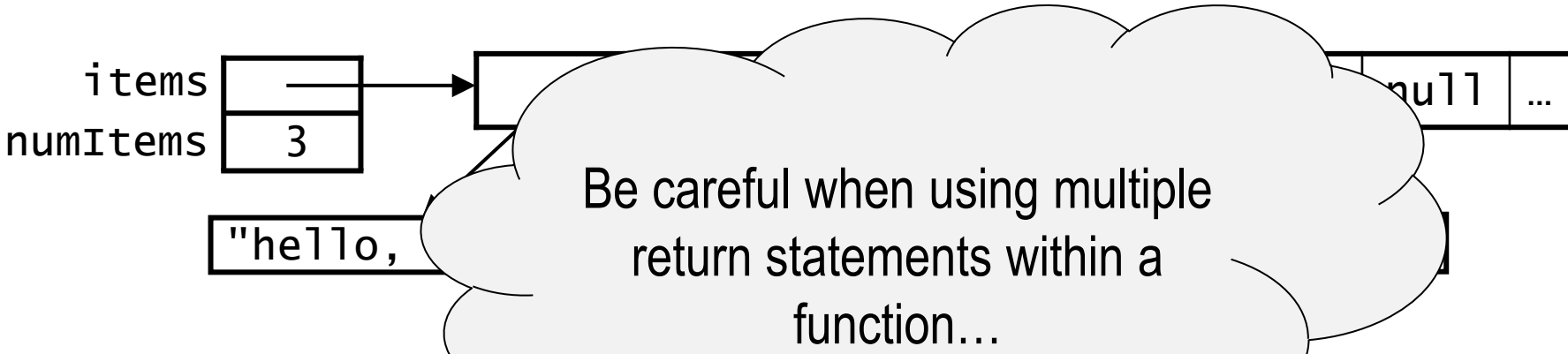
            return true;
        }
    }
    return false;
}
```

- will get a `NullPointerException` because we are calling a method on a null object,

# Would this work instead? *no!*

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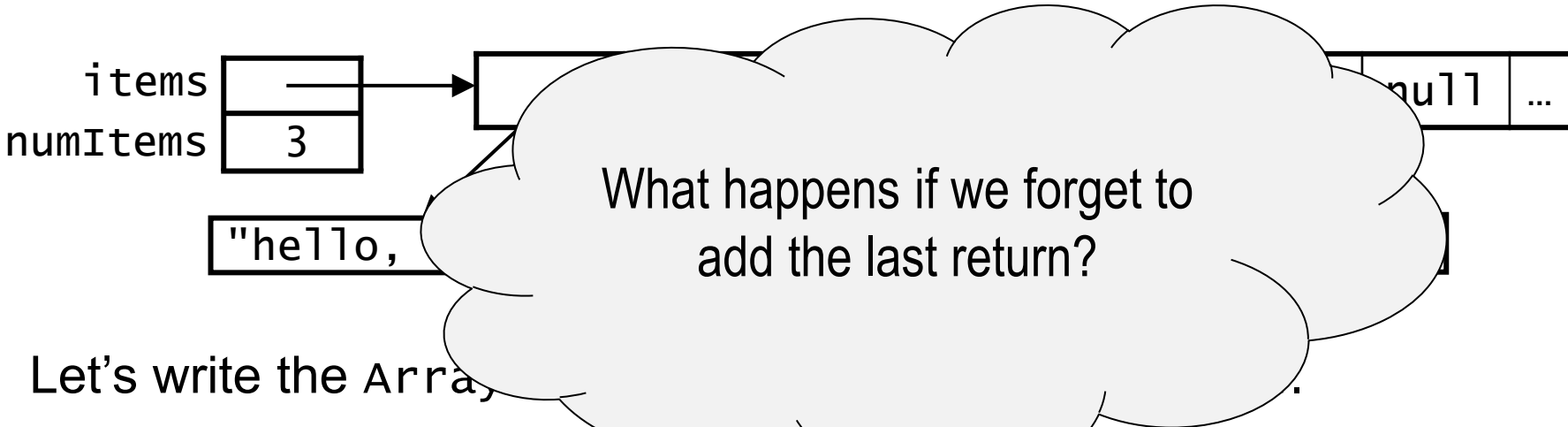


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```

- will get a `NullPointerException` from first array element that is still `null`
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# Another Incorrect `contains()` Method

```
public boolean contains(Object item) {
     for (int i = 0; i < this.numItems; i++) {
          if (this.items[i].equals(item))
               return true;
          else
               return false;
     }
     return false;
}
```

- Why won't this version of the method work in all cases?

- When would it work?

# Another Incorrect `contains()` Method

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     for (int i = 0; i < this.numItems; i++) {
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         else
             return false;
     }
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}
```

- Why won't this version of the method work in all cases? *When the first item of the array is not the item we are looking for, we return false without looking at the remaining items of the array*

- When would it work?

# Another Incorrect `contains()` Method

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     for (int i = 0; i < this.numItems; i++) {
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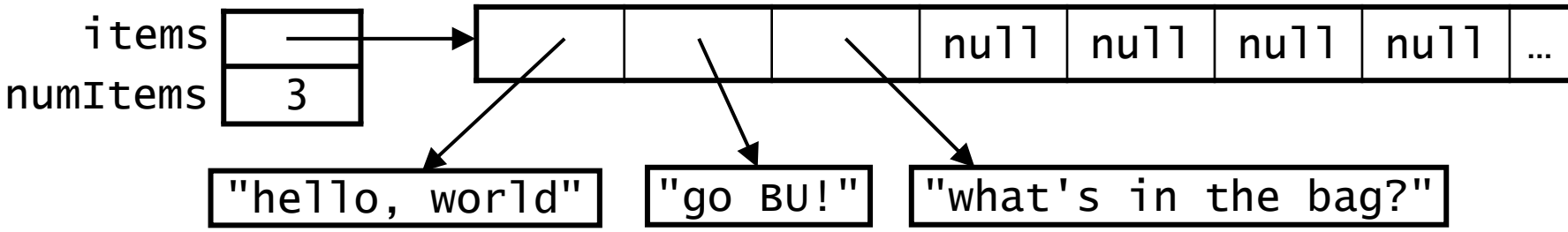
}
```

- Why won't this version of the method work in all cases? *When the first item of the array is not the item we are looking for, we return false without looking at the remaining items of the array*

- When would it work? *If the first item in the array is the item we are looking for.*

# An alternative version…

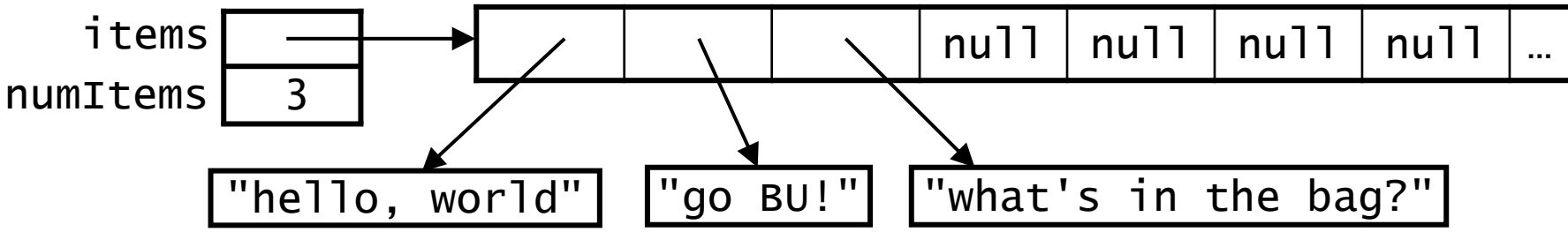



```
public boolean contains(Object item) {

    boolean found = false;

    for (int i = 0; i < this.numItems; i++) {
       if (this.items[i].equals(item)) {  // not ==
          found = true;
          break;
        }
    }
    return found;
}
```

# An alternative version…




```
public boolean contains(Object item) {

    boolean found = false;

    for (int i = 0; i<this.numItems && !found; i++) {
       if (this.items[i].equals(item)) {  // not ==
          found = true;

        }
    }
    return found;
}
```

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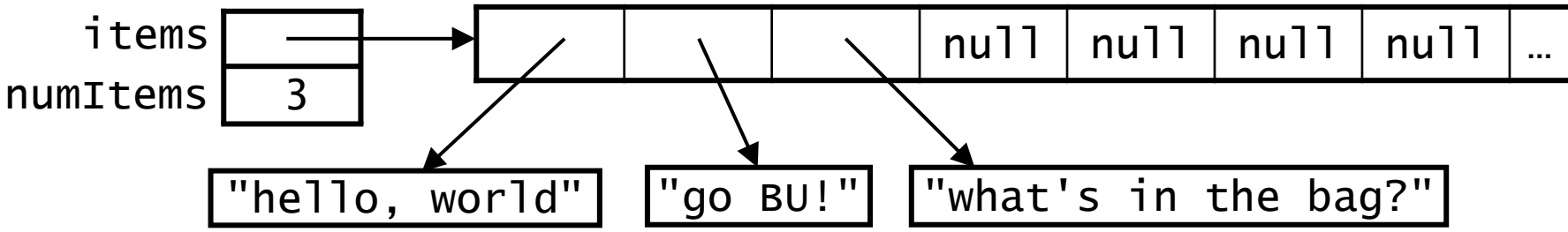


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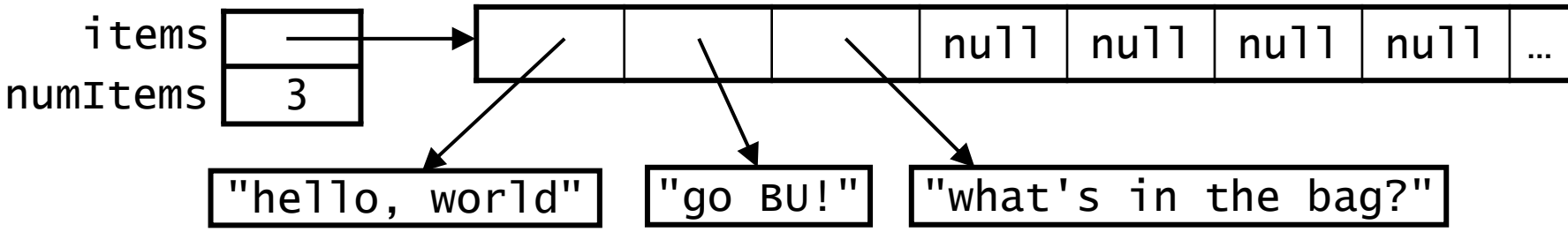


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       } // if
    } // for
    return found;
} // contains
```

Useful strategy for keeping track of brace alignment!

# A Method That Takes Another Bag as a Parameter:

## check that all items in the *other* bag are also items in *this* bag

```
public boolean containsAll(ArrayBag other) {
    boolean is_inthere = true;    // assume we will find
                                  // all items
    if (other == null || other.numItems <= 0)
       // If the array bag that is passed is empty
       // then there is no need to check further
       is_inthere = false;
    else {
       // check that each item in the other bag
       // is contained in this bag.
       for (int i = 0; i < other.numItems; i++) {
          if (!contains(other.items[i])) {
             // an item in the other bag is not in
             // this bag, no need to check further
             is_inthere = false;
             break;
          }
     }
     return (is_inthere);
}
```

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       for (int i = 0; i < other.numItems; i++) {
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             break;
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     return (is_inthere);
}
```

# A Type Mismatch

- Here are the headers of two `ArrayBag` methods:

```
public boolean add(Object item)
public Object grab()
```

- Polymorphism allows us to pass `String` objects into `add()`:

```
ArrayBag stringBag = new ArrayBag();
stringBag.add("hello");
stringBag.add("world");
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```
publi
publ
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- Poly

```
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Recall, *this will perform integer division:*

```
int a = 5;
double result = a / 2;
```

- However, this wi work:

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Recall, *we can explicitly change one of the operands:*

```
int a = 5;
double result = a / 2.0;
```

- However, this wi work:

```
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```

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Recall, *we can also type cast one of the operands!*

```
int a = 5;
double result = (double) a / 2;
```

- However, this wi work:

```
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```

  - the return type of grab( Object
  - Object isn't a subclass of String, so polymorphism doesn't help!

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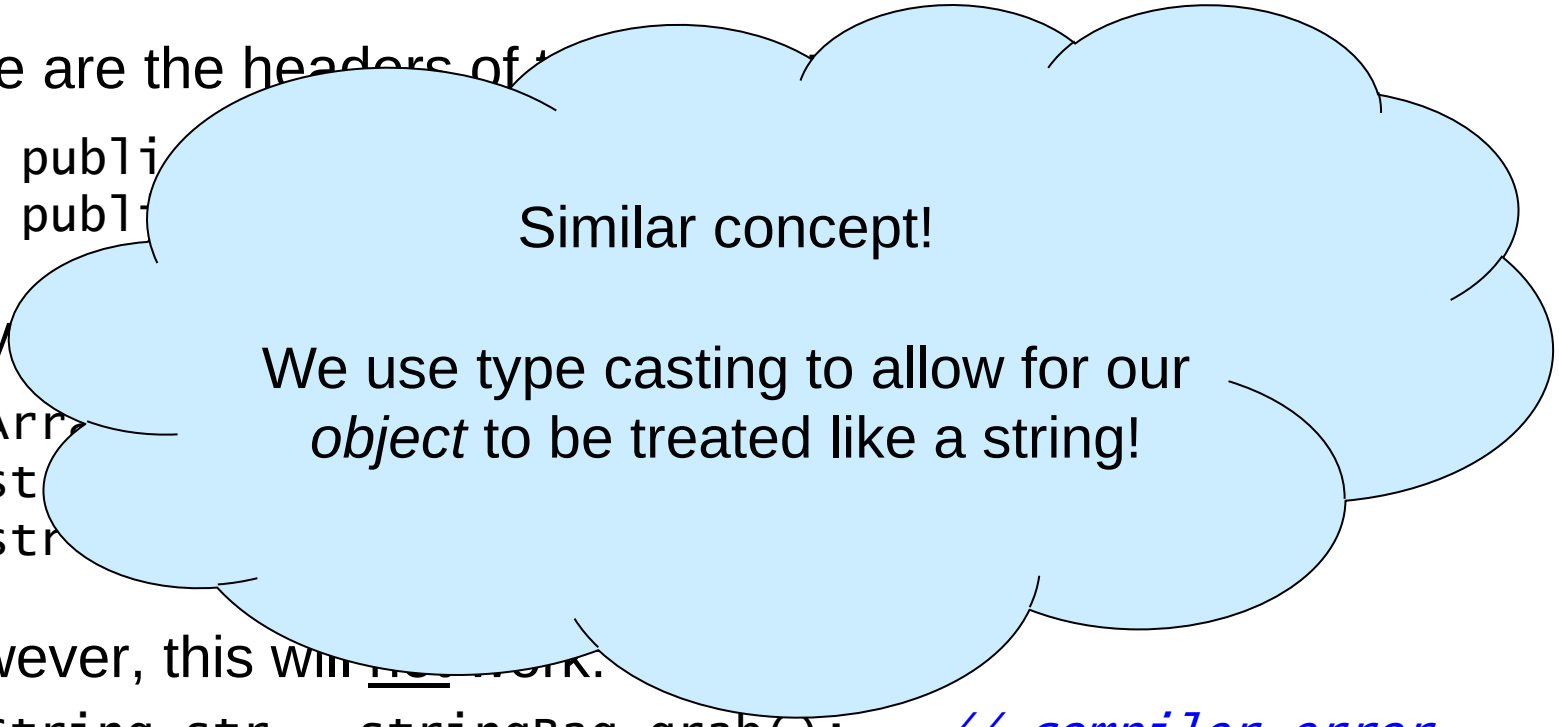


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