Programming Languages and Techniques (CIS120)

Lecture 23

Mar 14, 2012

Java ASM & Encapsulation

Announcements

- HW07 is available on the web
  - Image processing in Java
  - Due tomorrow, March 15th at 11:59:59pm
- HW08 will be available on Friday
  - Due Monday, March 26th at 11:59:59pm
- Midterm 1 regrade deadline on Friday
- Midterm 2 on Friday, March 30th

The Java Abstract Stack Machine

Objects, Arrays and Static Methods

Java Abstract Stack Machine

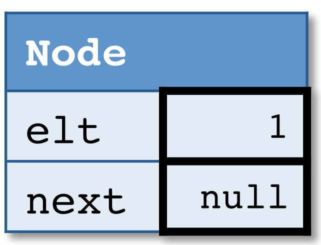
- Similar to OCaml Abstract Stack Machine
  - Distinction between “primitive” and “reference values”
- Workspace
  - Contains the currently executing code
- Stack
  - Remembers the values of local variables and "what to do next" after function/method calls
- Heap
  - Stores reference types: objects and arrays
- Differences:
  - Everything, including stack slots, is mutable by default
  - Special reference value: null
  - Heap objects store *dynamic class information*
  - Code stored in Class Table

Heap Values

Objects

- Name of the class that constructed it
- Values for all of the fields

```
class Node {
    private int elt;
    private Node next;
    …
}
```

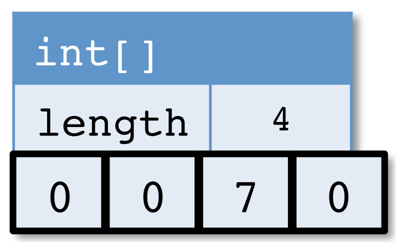


fields may or may not be mutable

Arrays

- Type of values that it stores
- Length
- Values for all of the elements

```
int [] a = { 0, 0, 7, 0 };
```



length *never* mutable
elements *always* mutable

Object Aliasing example

```
public class Node {
  private int elt;
  private Node next;
  public Node(int e0, Node n0) {
    elt  = e0;
    next = n0;
  }

  public static int m() {
    Node n1 = new Node(1,null);
    Node n2 = new Node(2,n1);
    Node n3 = n2;
    n3.next.next = n2;
    Node n4 = new Node(4,n1.next);
    n2.next.elt = 17;
    return n1.elt;
  }
}
```

ASM Example

Workspace

```
Node.m();
```

Stack

Heap

Static method call, similar to OCaml function call:

- Save the workspace to the stack
- Look up method named 'm' in the class table
- Put method parameters on the stack
- Put method body in the workspace

ASM Example

Workspace

```
Node n1 = new Node(1,null);
Node n2 = new Node(2,n1);
Node n3 = n2;
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 17;
return n1.elt;
```

Stack

Heap

We'll omit this in the rest of the example.

ASM Example

Workspace

```
Node n1 = new Node(1,null);
Node n2 = new Node(2,n1);
Node n3 = n2;
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 17;
return n1.elt;
```

Stack

Heap

Note: we're skipping details here about how the constructor works. We'll fill them in next week. For now, assume the constructor allocates and initializes the object in one step.

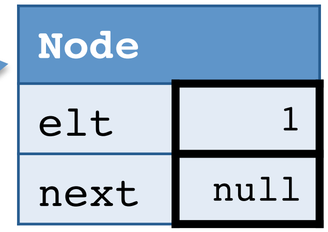
Constructing an Object

Workspace

```
Node n1 = ;
Node n2 = new Node(2,n1);
Node n3 = n2;
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 17;
return n1.elt;
```

Stack

Heap



Local variable definition: as in OCaml,
add to the stack.
Unlike OCaml, the value is mutable.

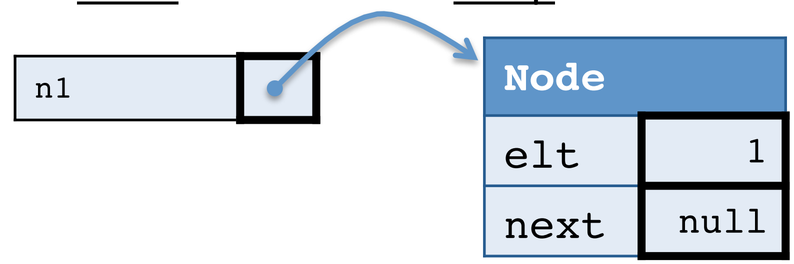
Constructing an Object

Workspace

```
Node n2 = new Node(2,n1);
Node n3 = n2;
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 17;
return n1.elt;
```

Stack

Heap



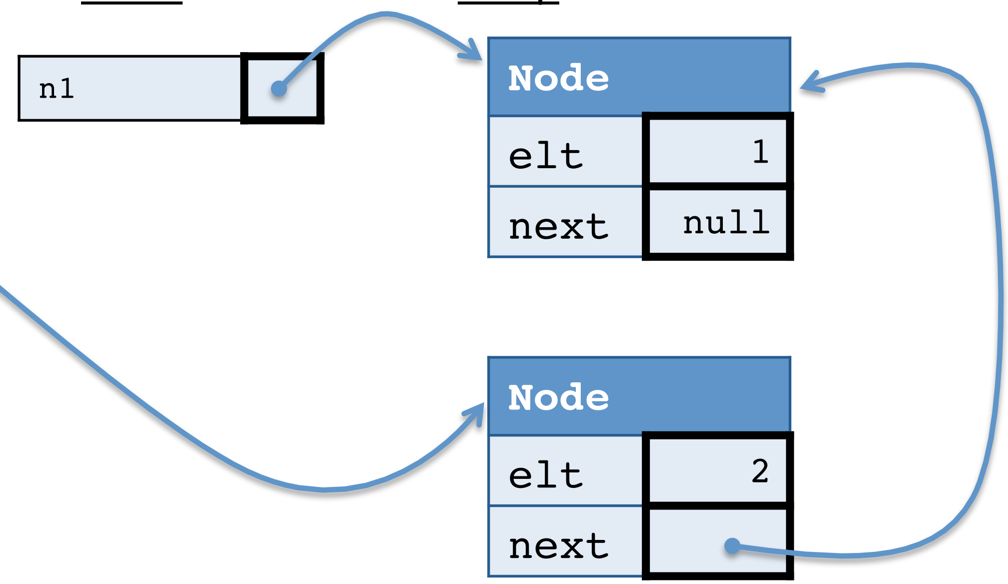
Constructing an Object

Workspace

```
Node n2 = ;
Node n3 = n2;
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 17;
return n1.elt;
```

Stack

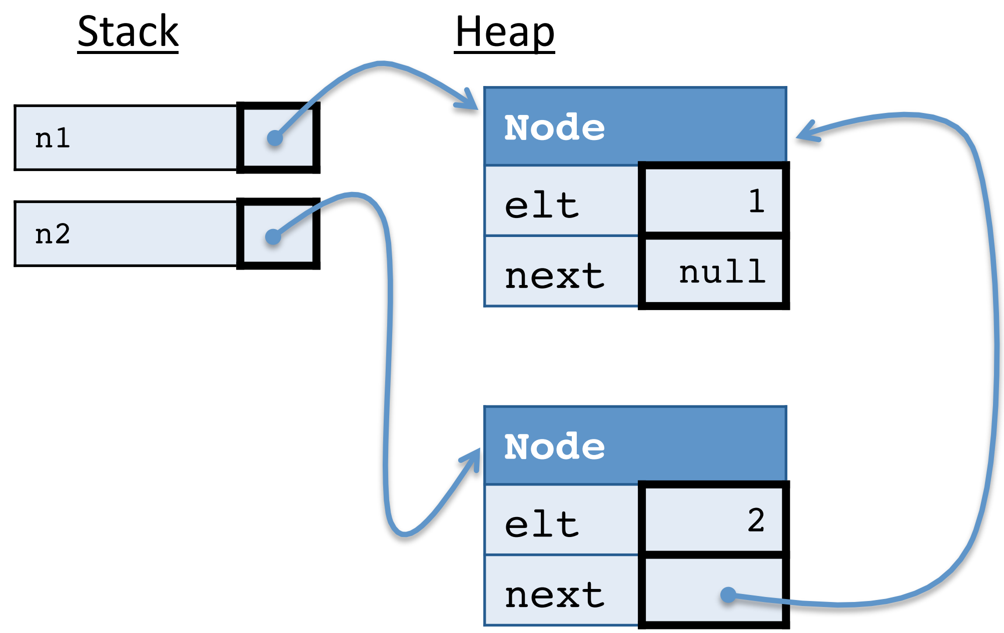
Heap



Constructing an Object

Workspace

```
Node n3 = n2;
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 17;
return n1.elt;
```



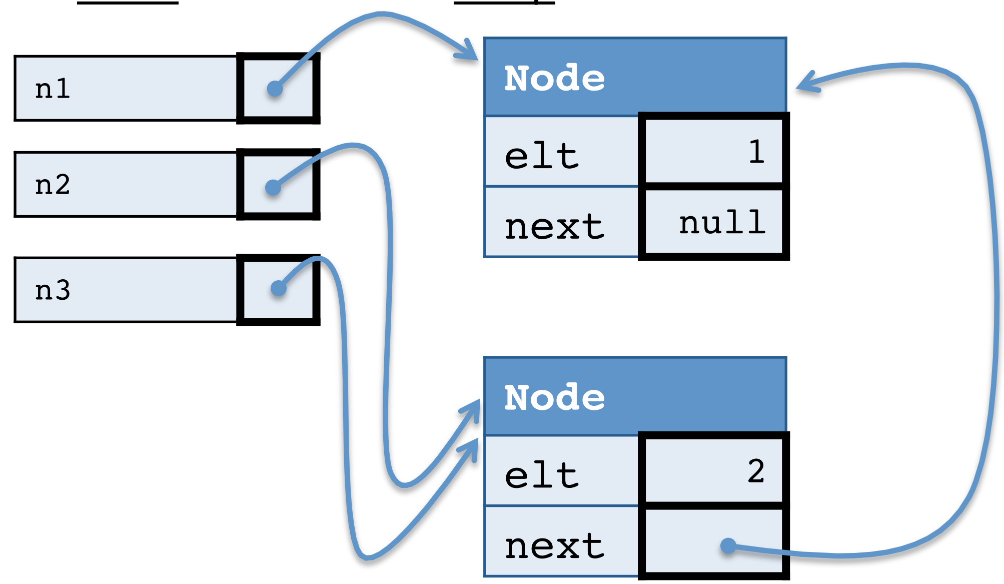
Mutating a field

Workspace

```
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 17;
return n1.elt;
```

Stack

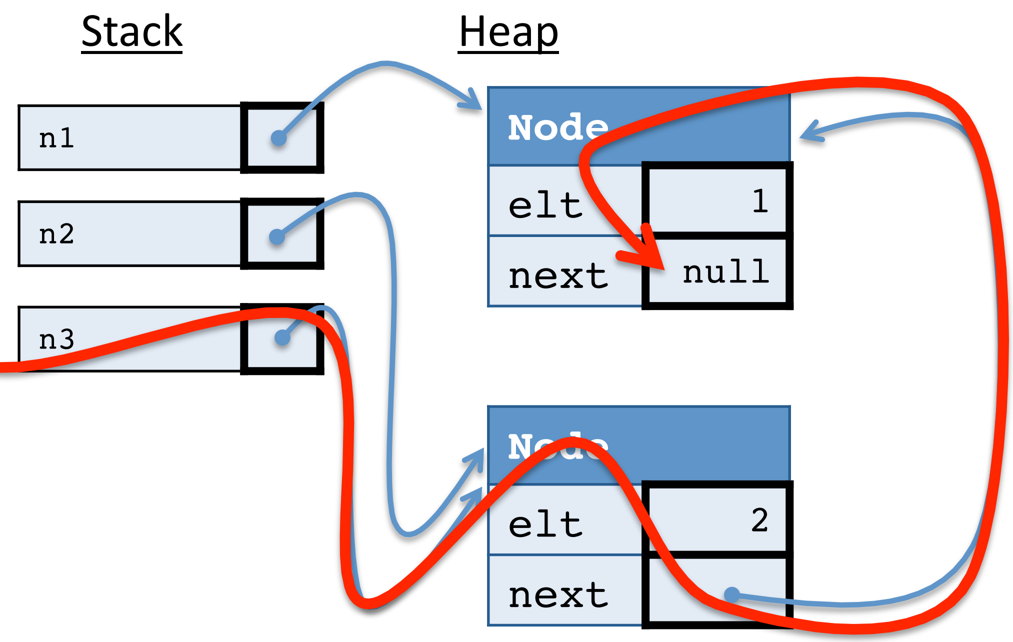
Heap



Mutating a field

Workspace

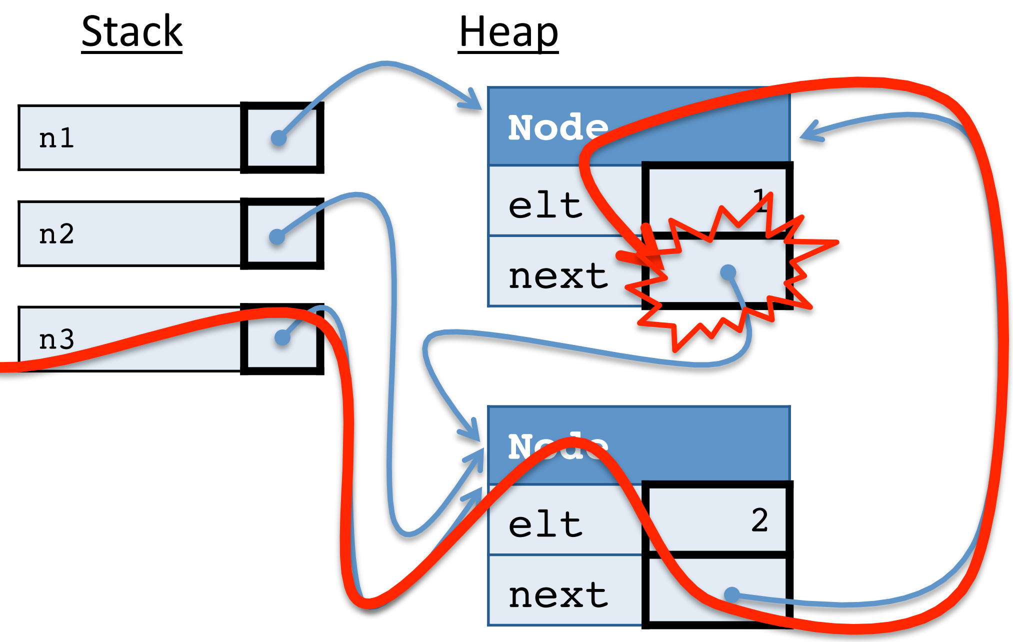
```
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 17;
return n1.elt;
```



Mutating a field

Workspace

```
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 17;
return n1.elt;
```

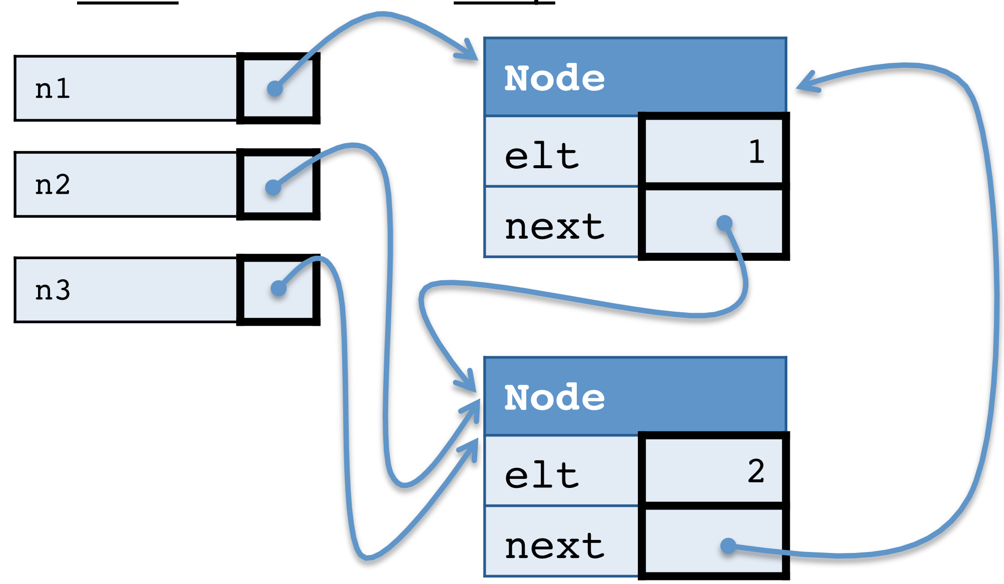


Accessing a field

Workspace

```
Node n4 = new Node(4,n1.next);
n2.next.elt = 17;
return n1.elt;
```

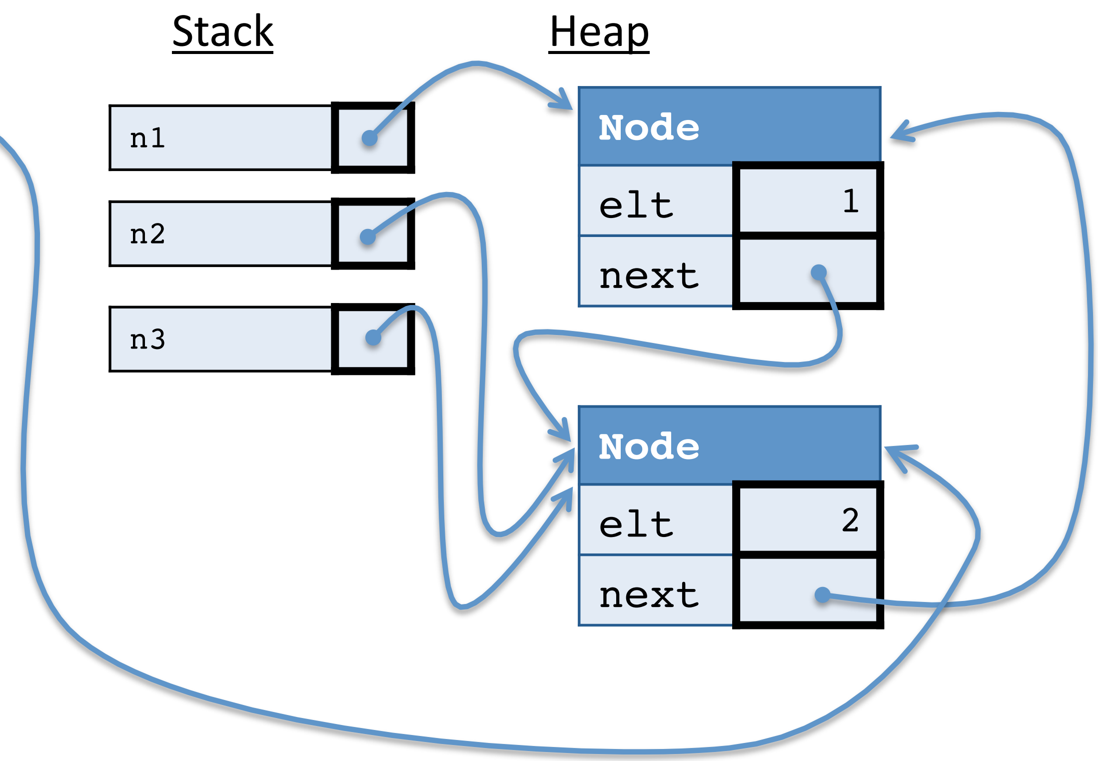
Stack Heap



Constructing an Object

Workspace

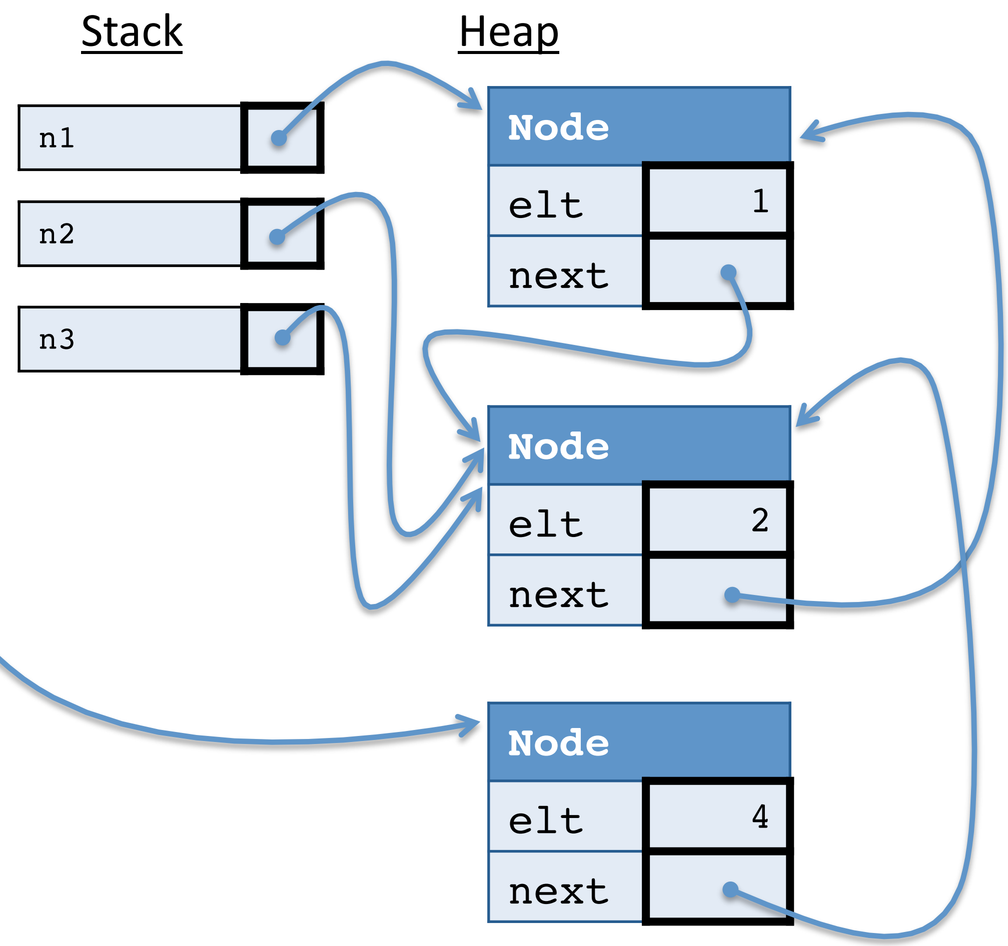
```
Node n4 = new Node(4, );
n2.next.elt = 17;
return n1.elt;
```



Constructing an Object

Workspace

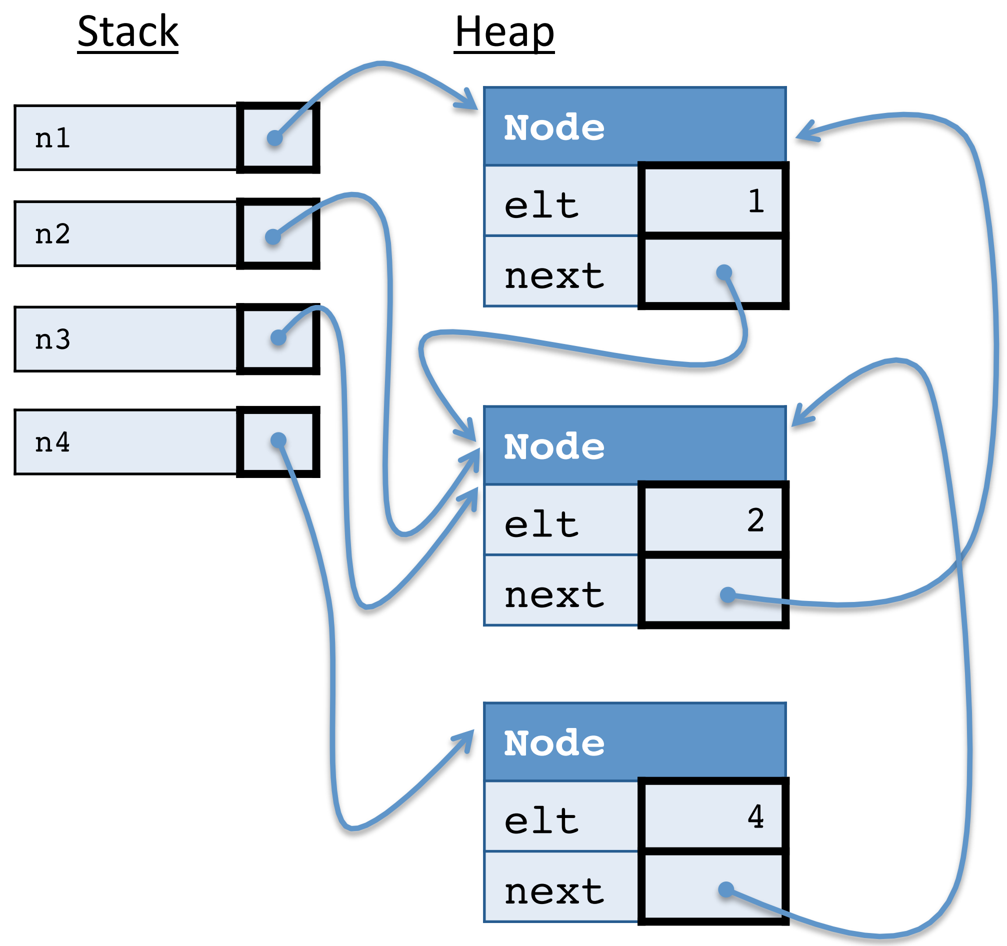
```
Node n4 = ;
n2.next.elt = 17;
return n1.elt;
```



Mutating a field

Workspace

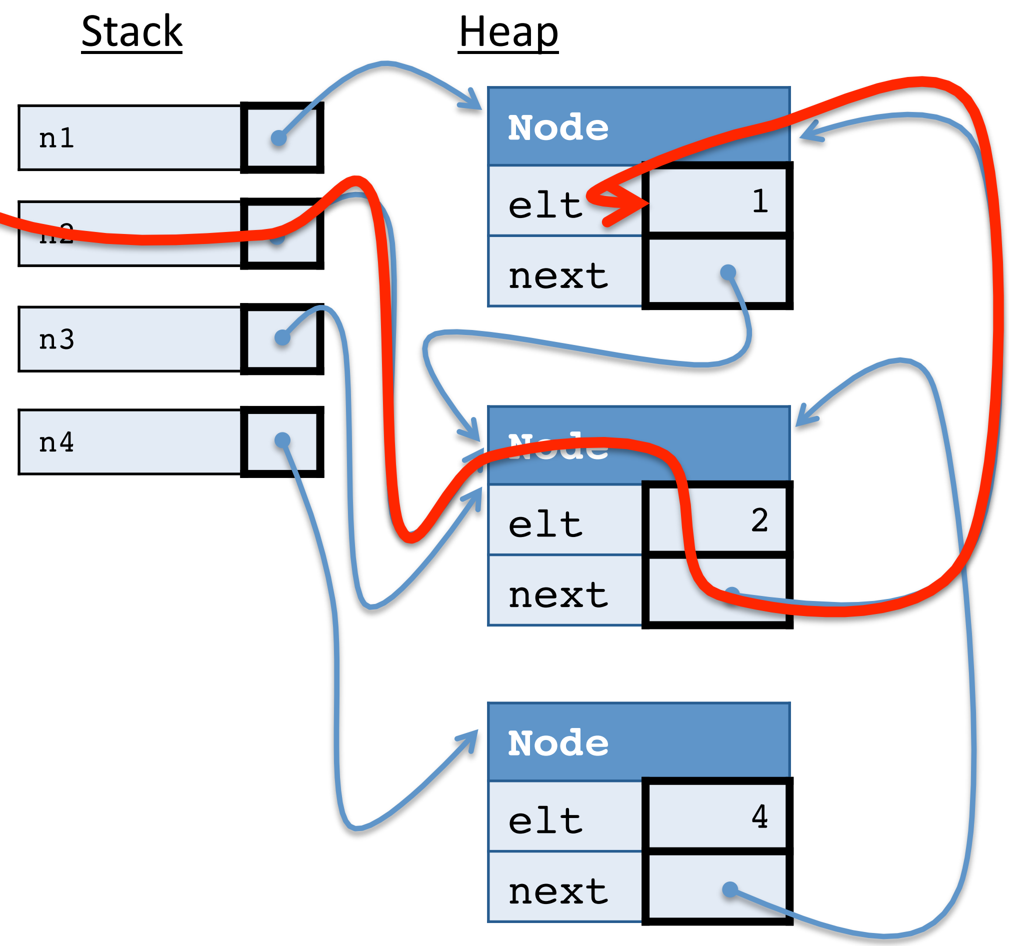
```
n2.next.elt = 17;
return n1.elt;
```



Mutating a field

Workspace

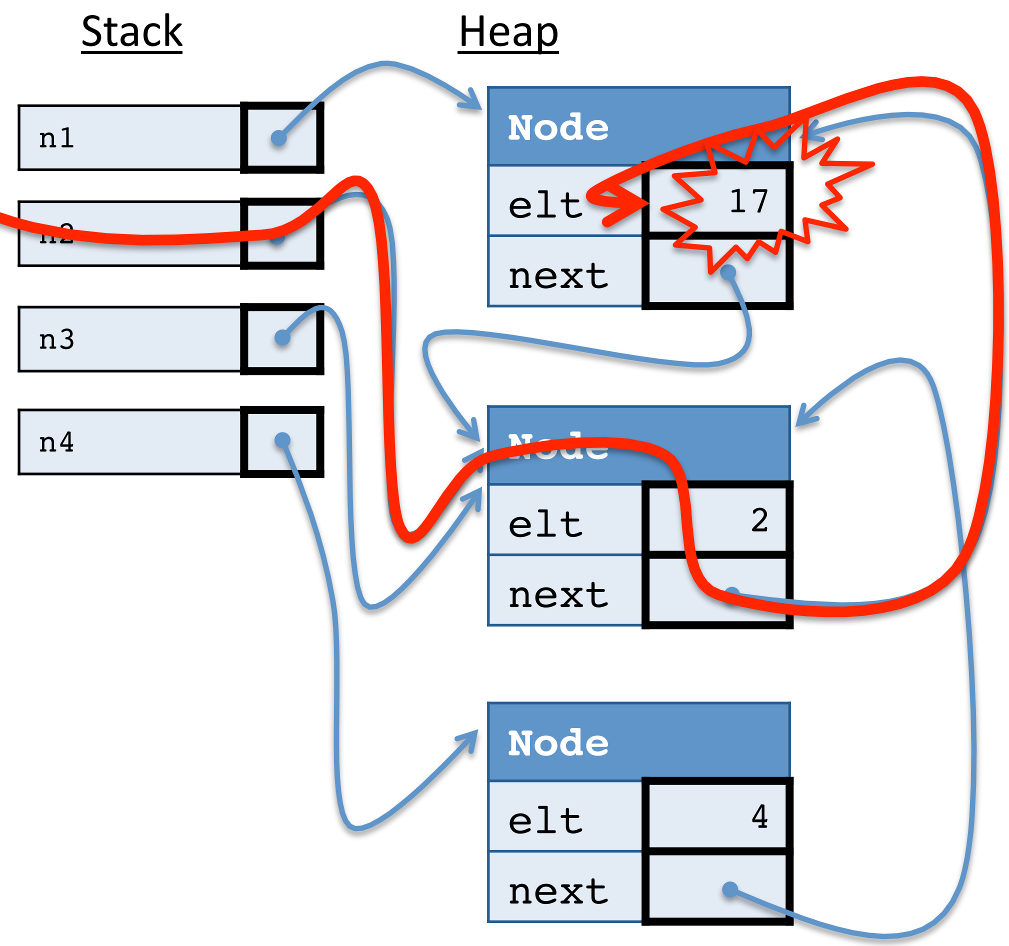
```
n2.next.elt = 17;
return n1.elt;
```



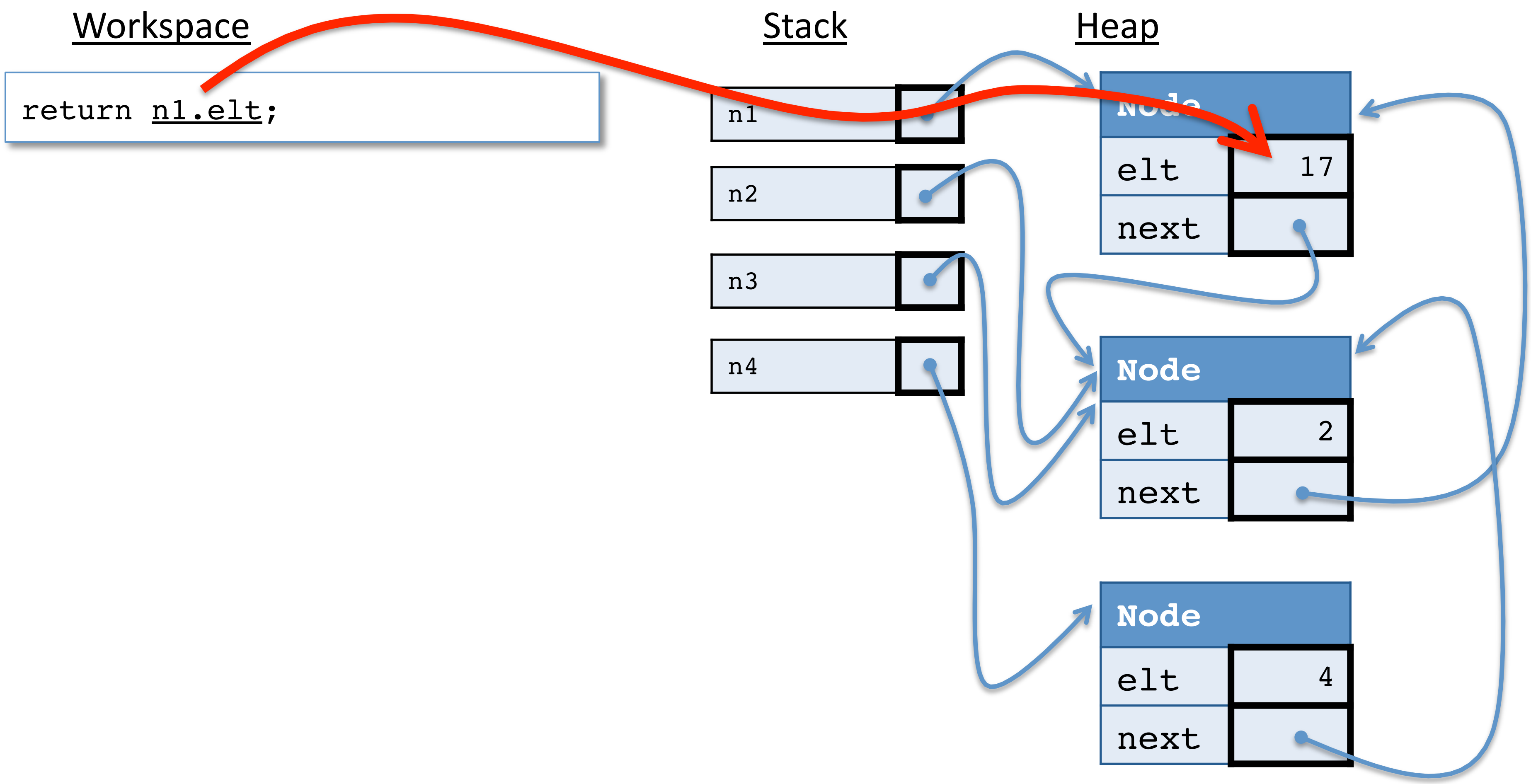
Mutating a field

Workspace

```
n2.next.elt = 17;
return n1.elt;
```



Accessing a field



Design Exercise: Resizable Arrays

Arrays that grow without bound.

Resizable Arrays

Object Invariant: extent is always 1 past the last nonzero value in data
(or 0 if the array is all zeros)

```
public class ResArray {

  /** Constructor, takes no arguments. */
  public ResArray() { … }

  /** Access the array at position i. If position i has not yet
   * been initialized, return 0.
   */
  public int get(int i) { … }

  /** Modify the array at position i to contain the value v. */
  public void set(int i, int v) { … }

  /** Return the extent of the array. */
  public int getExtent() { … }

}
```

ResArray ASM

Workspace

```
ResArray x = new ResArray();
x.set(3,2);
x.set(4,1);
x.set(4,0);
```

Stack

Heap

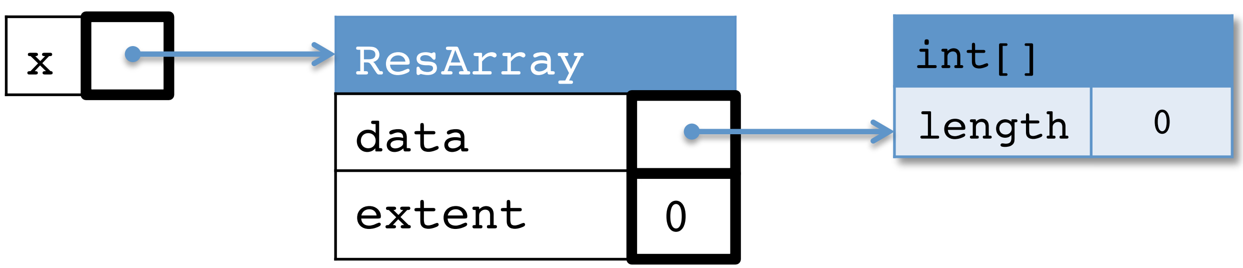
ResArray ASM

Workspace

```
~~ResArray x = new ResArray();~~
x.set(3,2);
x.set(4,1);
x.set(4,0);
```

Stack

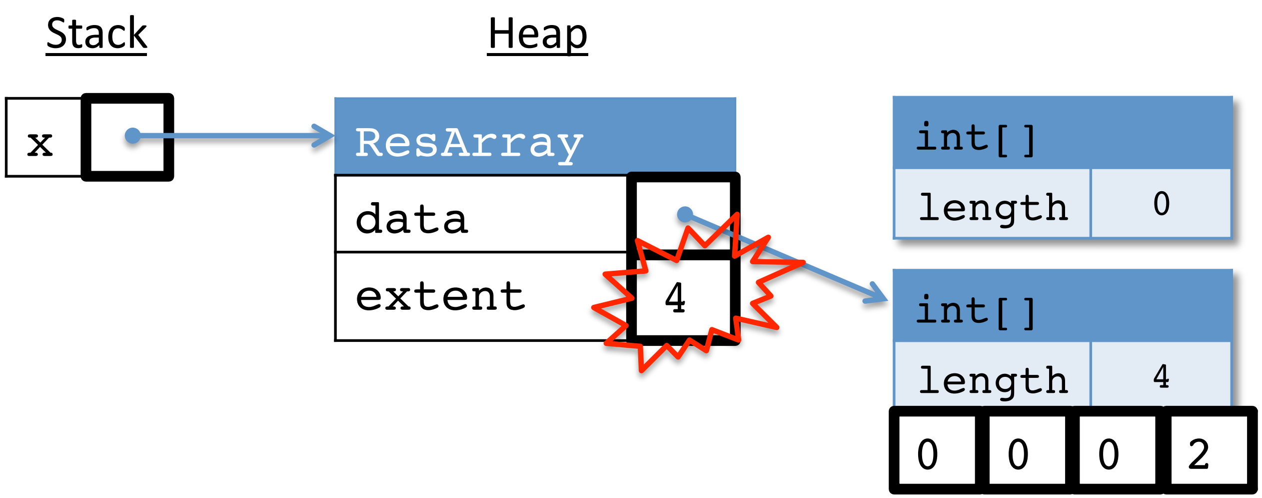
Heap



ResArray ASM

Workspace

```
~~ResArray x = new ResArray();~~
~~x.set(3,2);~~
x.set(4,1);
x.set(4,0);
```



ResArray ASM

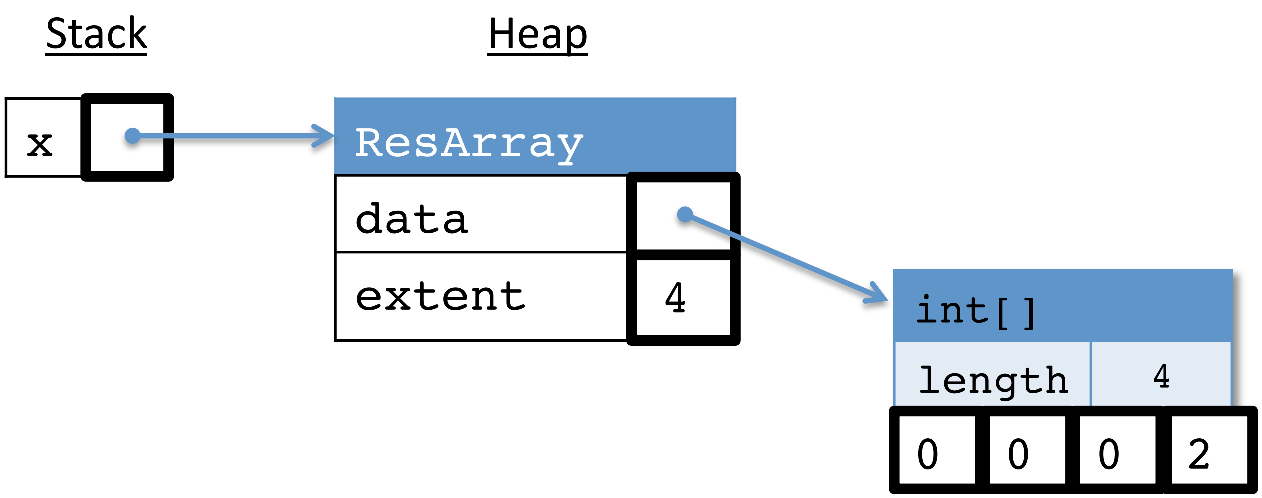
Workspace

~~ResArray x = new ResArray();~~

~~x.set(3,2);~~

x.set(4,1);

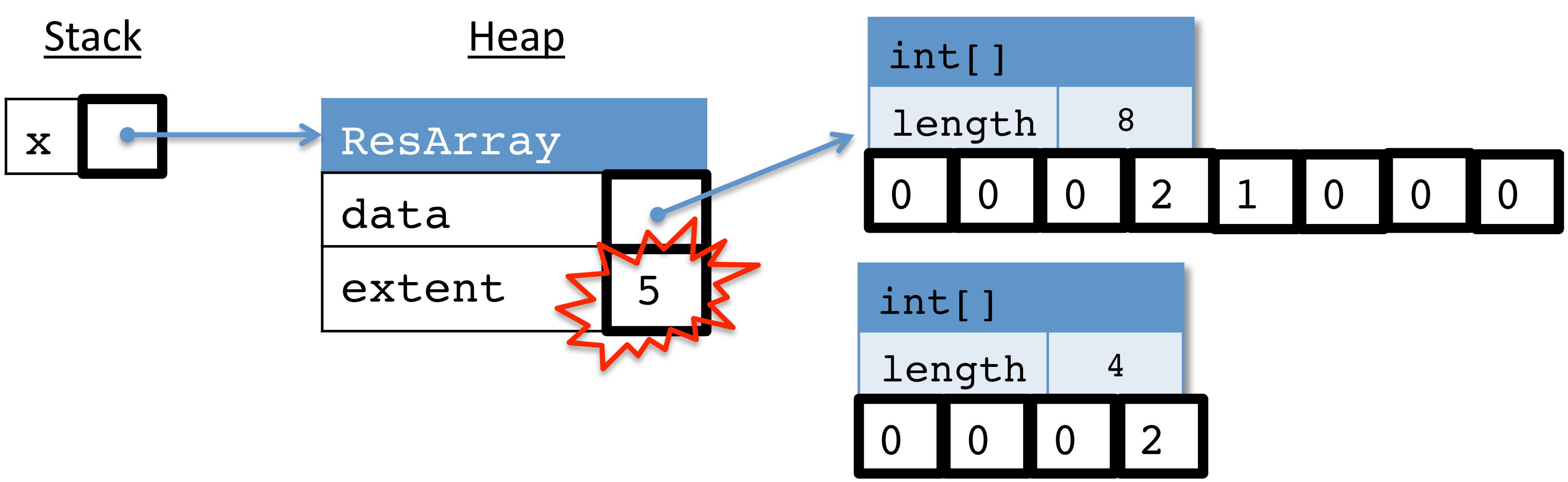
x.set(4,0);



ResArray ASM

Workspace

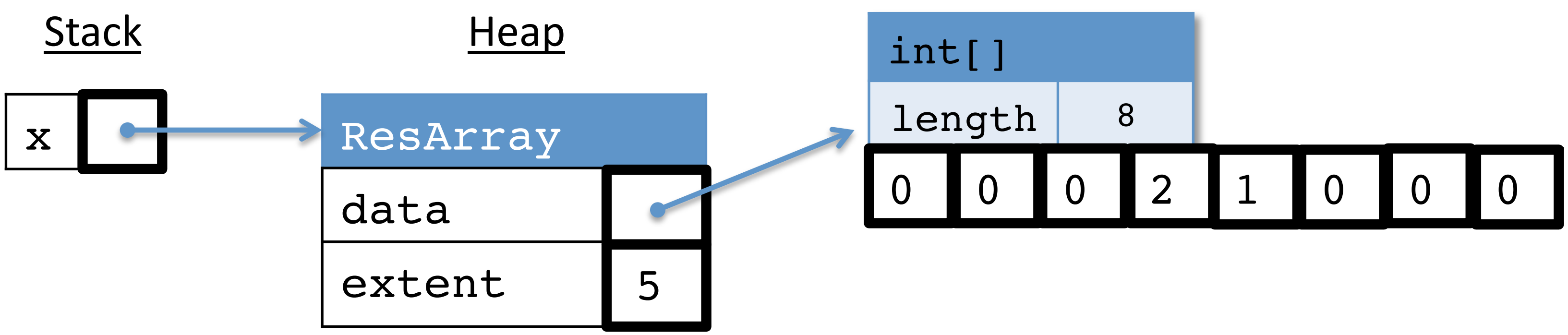
```
~~ResArray x = new ResArray();~~
~~x.set(3,2);~~
~~x.set(4,1);~~
x.set(4,0);
```



ResArray ASM

Workspace

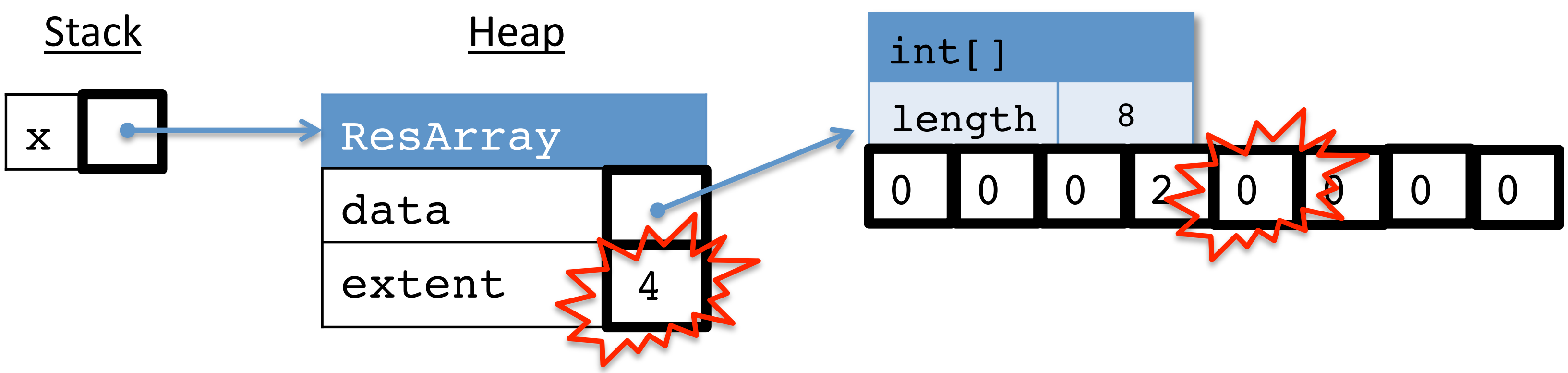
```
~~ResArray x = new ResArray();~~
~~x.set(3,2);~~
~~x.set(4,1);~~
x.set(4,0);
```



ResArray ASM

Workspace

```
~~ResArray x = new ResArray();~~
~~x.set(3,2);~~
~~x.set(4,1);~~
~~x.set(4,0);~~
```



Demo

ResArray.java

ResArrayTest.java

Resizable Arrays

```
public class ResArray {

  /** Constructor, takes no arguments. */
  public ResArray() { … }

  /** Access the array at position i. If position i has not yet
   * been initialized, return 0.
   */
  public int get(int i) { … }

  /** Modify the array at position i to contain the value v. */
  public void set(int i, int v) { … }

  /** Return the extent of the array. */
  public int getExtent() { … }

  /** The smallest prefix of the ResArray
   * that contains all of the nonzero values as a normal array.
   */
  public int[] values() { … }
}
```

Object Invariant: extent is always 1 past the last nonzero value in data
(or 0 if the array is all zeros)

Optimized(???) Values Method

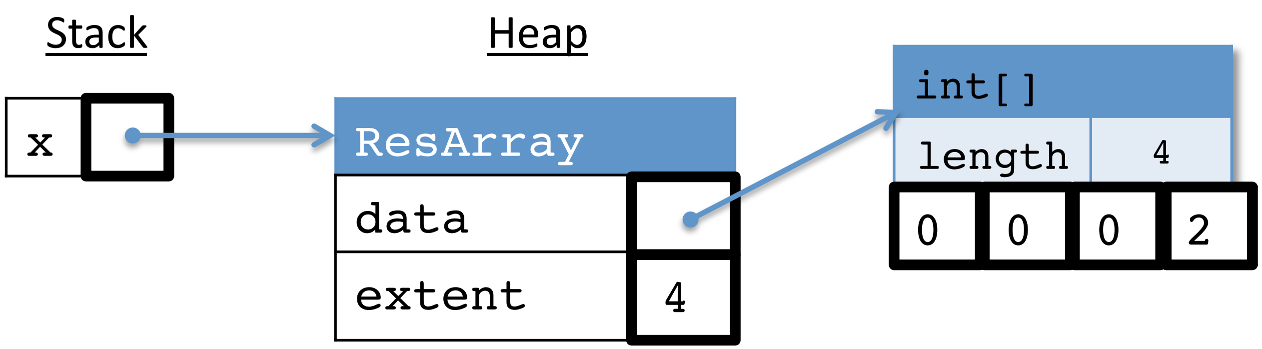
```
public int[] values() {
    int[] values = new int[extent];
    for(int i=0; i<extent; i++) {
        values[i] = data[i];
    }
    return values;
}
```

```
public int[] values() {
    if (data.length == extent) {
        return data;
    }
    int[] values = new int[extent];
    for(int i=0; i<extent; i++) {
        values[i] = data[i];
    }
    return values;
}
```

ResArray ASM

Workspace

```
ResArray x = new ResArray();
x.set(3,2);
int[] y = x.values();
y[3] = 0;
```



ResArray ASM

Workspace

```
~~ResArray x = new ResArray();~~
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y[3] = 0;
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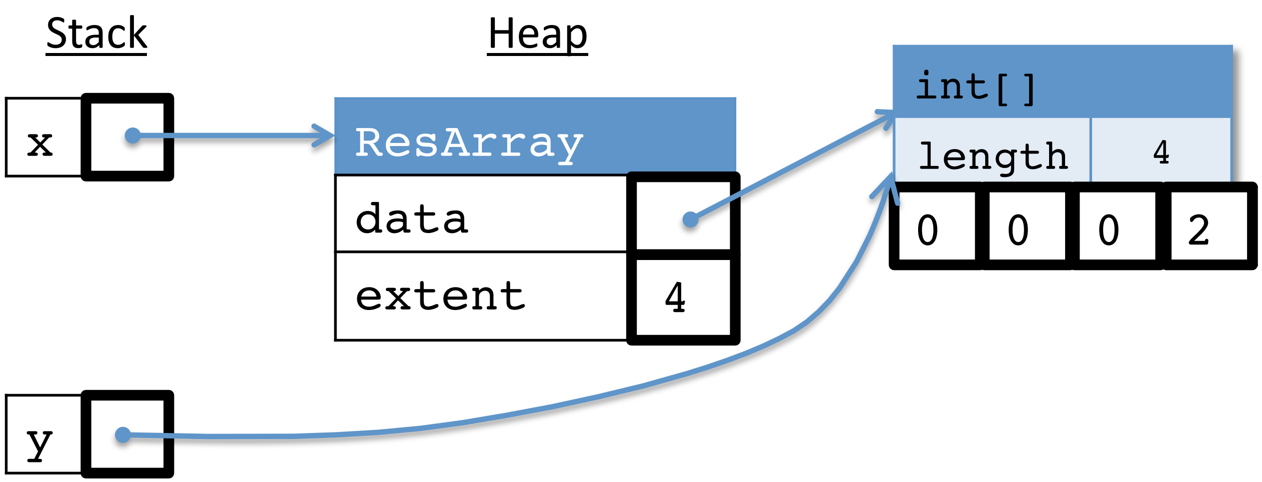

ResArray ASM

Workspace

```
ResArray x = new ResArray();
x.set(3,2);
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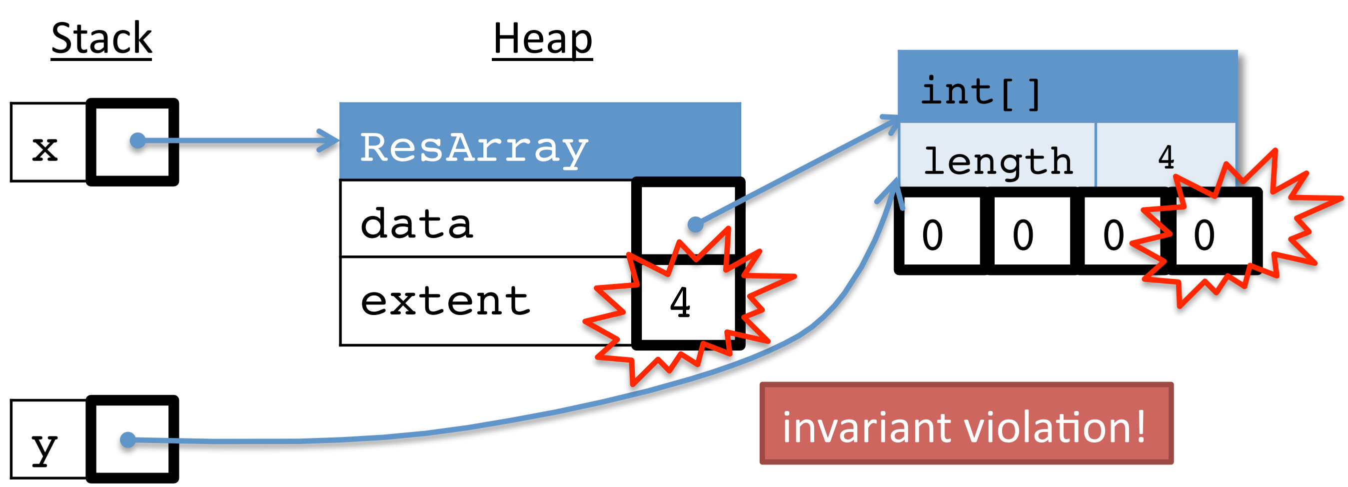

Object encapsulation

- All modification to the state of the object must be done using the object's own methods.
- Use encapsulation to preserve invariants about the state of the object.
- Enforce encapsulation by not returning aliases. Make a COPY of a data structure if necessary.

Mutable Queue ML Interface

```
module type QUEUE =
sig
  (* type of the data structure *)
  type 'a queue

  (* Make a new, empty queue *)
  val create : unit -> 'a queue

  (* Add a value to the end of the queue *)
  val enq : 'a -> 'a queue -> unit

  (* Remove the front value and return it (if any) *)
  val deq : 'a queue -> ‘a

  (* Determine if the queue is empty *)
  val is_empty : ‘a queue -> bool

  (* Remove the first occurrence of the value. *)
  val remove : 'a -> 'a queue -> unit
end
```