Programming Languages and Techniques (CIS120)

Lecture 24

March 18, 2016

The Java ASM

What is the value of ans at the end of this program?

```java
Counter[] a = { new Counter(), new Counter() };
Counter[] b = { a[0], a[1] };
a[0].inc();
b[0].inc();
int ans = a[0].inc();
```

1. 1
2. 2
3. 3
4. 0
5. NullPointerException
6. ArrayIndexOutOfBoundsException

```java
public class Counter {

  private int r;

  public Counter () {
    r = 0;
  }

  public int inc () {
    r = r + 1;
    return r;
  }

}
```

Announcements

- Midterm 2, Tuesday evening, 6:15-8:15 PM
  - Topics on Monday's slides
  - Practice exams on website
  - Sign up for makeup exam ASAP (if necessary)
  - Exam location by last name (same as last time)
    A - Schwartz: MEYH B1
    Shah - Z: DRLB A8

- Review session
  - Sunday March 20th
  - Towne 100
  - 6-8PM

The Java Abstract Stack Machine

Objects, Arrays, and Static Methods

Java Abstract Stack Machine

- Similar to OCaml Abstract Stack Machine
  - 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

- Key differences:
  - Everything, including stack slots, is mutable by default
  - Objects store *what class was used to create them*
  - *Arrays store type information and length*
  - *New component: Class table (coming soon)*

Heap Reference Values

Arrays

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

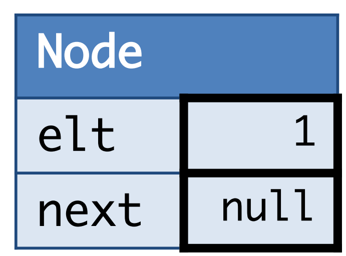
```
int [] a =
    { 0, 0, 7, 0 };
```

length *never* mutable;
elements *always* mutable

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
public/private not tracked by ASM

What does the heap look like at the end of this program?

```
Counter[] a = { new Counter(), new Counter() };
Counter[] b = { a[0], a[1] };
a[0].inc();
b[0].inc();
int ans = a[0].inc();
```

```
public class Counter {

  private int r;

  public Counter () {
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  }

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    r = r + 1;
    return r;
  }

}
```

What does the ASM look like at the end of this program?

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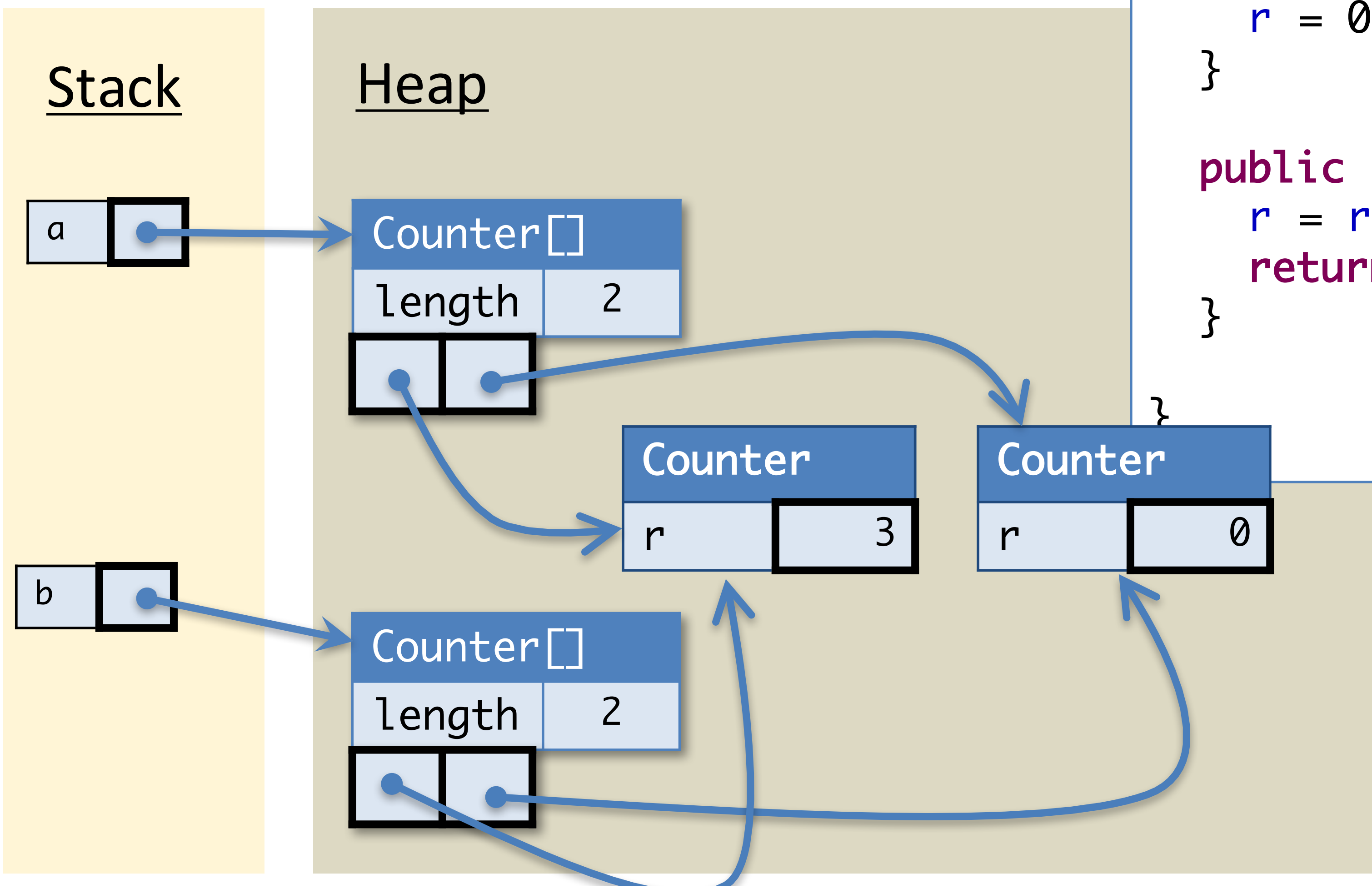
```



Multidimensional Arrays

Multi-Dimensional Arrays

A 2-d array is just an array of arrays...

```
String[][] names = {{"Mr. ", "Mrs. ", "Ms. "},
                    {"Smith", "Jones"}};

System.out.println(names[0][0] + names[1][0]);
    //  --> Mr. Smith
System.out.println(names[0][2] + names[1][1]);
    //  --> Ms. Jones
```

`String[][]` just means `(String[])[]`

`names[1][1]` just means `(names[1])[1]`

More brackets → more dimensions

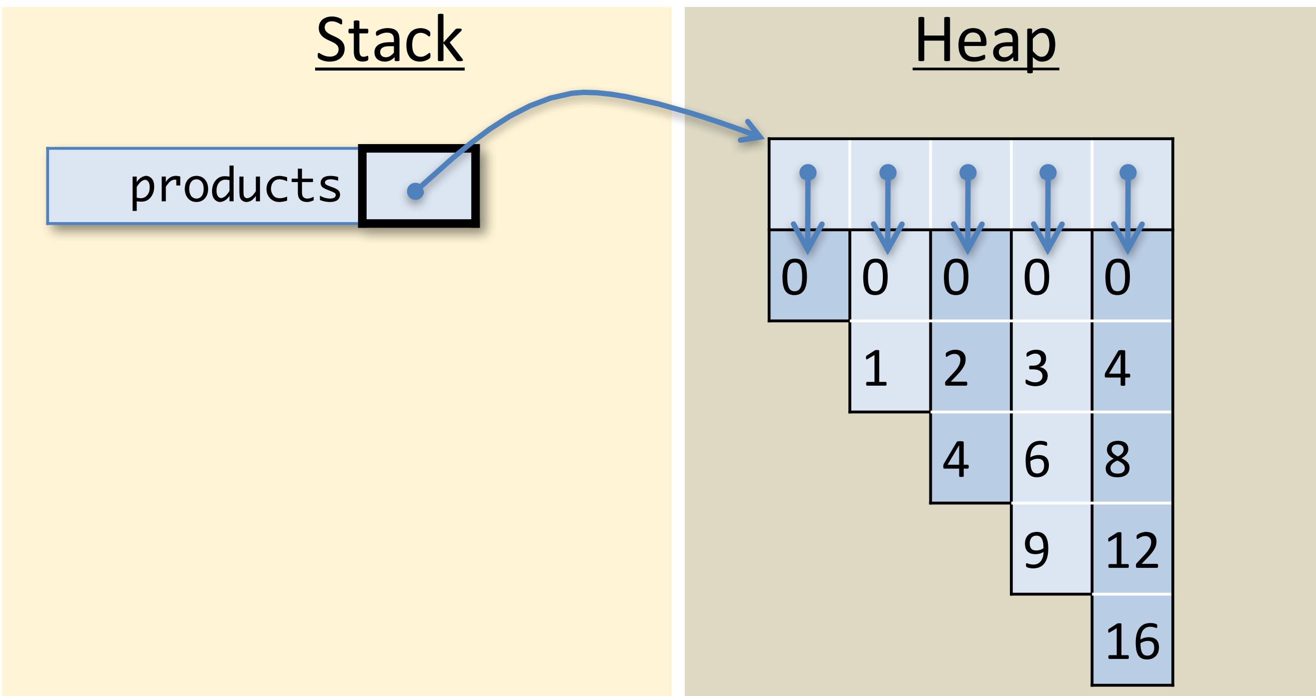
Multi-Dimensional Arrays

```
int[][] products = new int[5][];
for(int col = 0; col < 5; col++) {
   products[col] = new int[col+1];
   for(int row = 0; row <= col; row++) {
      products[col][row] = col * row;
   }
}
```

What does the stack and heap look like on the ASM after running this program?

Multi-Dimensional Arrays

```
int[][] products = new int[5][];
for(int col = 0; col < 5; col++) {
   products[col] = new int[col+1];
   for(int row = 0; row <= col; row++) {
      products[col][row] = col * row;
   }
}
```



Note: This heap picture is simplified – it omits the class identifiers and length fields for all 6 of the arrays depicted. (Contrast with the array shown earlier.)

Note also that orientation doesn't matter on the heap.

Objects on the ASM

What does the following program print?
1 – 9

or 0 for "NullPointerException"

```
public class Node {
  public int elt;
  public Node next;
  public Node(int e0, Node n0) {
    elt  = e0;
    next = n0;
  }
}
public class Test {
  public static void main(String[] args) {
    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  = 9;
    System.out.println(n1.elt);
  }

}
```

Answer: 9

Workspace

Stack

Heap

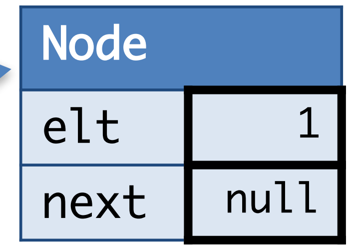
```
Node n1 = new Node(1,null);
Node n2 = new Node(2,n1);
Node n3 = n2;
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 9;
```

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 = 9;
```

Stack

Heap



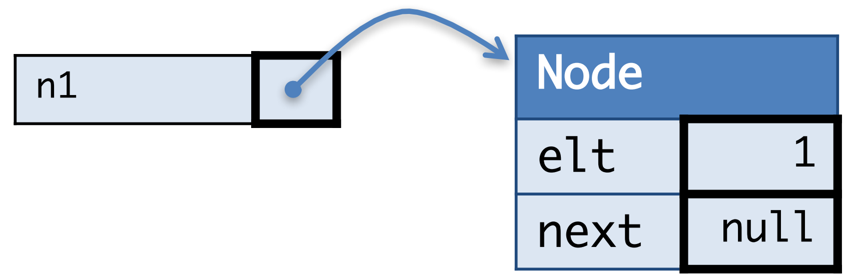
Note: we're skipping details here about how the constructor works. We'll fill them in next week. For now, assume the constructor allocates and initializes the object in one step.

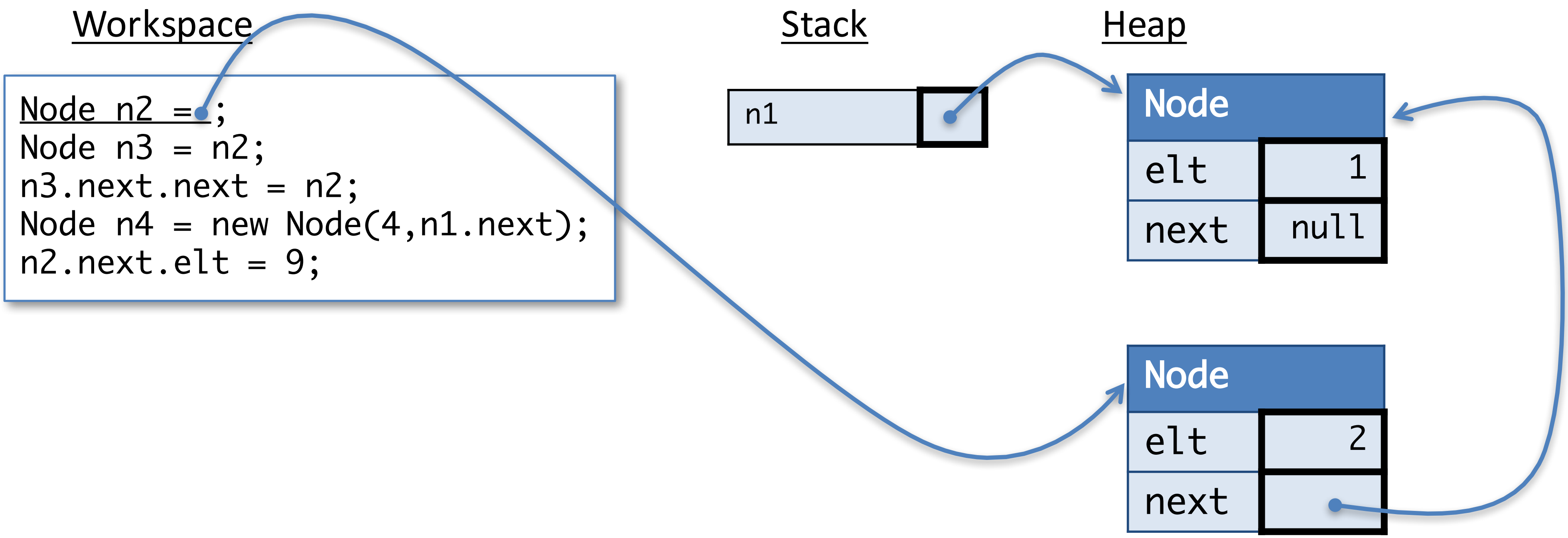
Workspace

```
Node n2 = new Node(2,n1);
Node n3 = n2;
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 9;
```

Stack

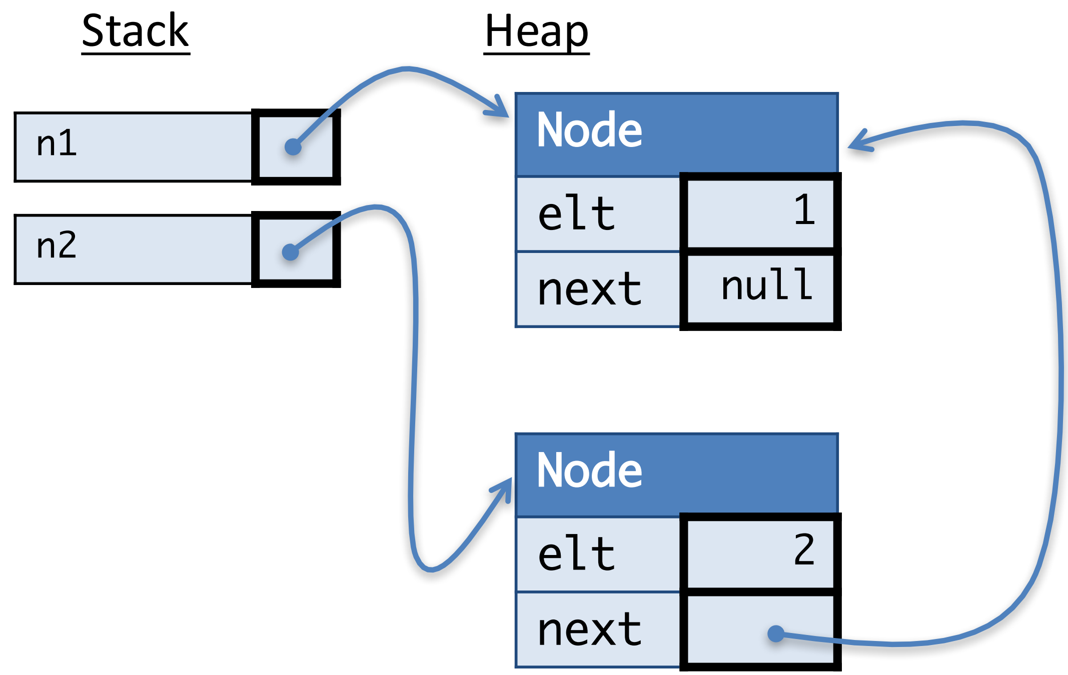
Heap




Workspace
Node n2 = ;
Node n3 = n2;
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 9;
Stack
n1
Heap
Node
elt
1
next
null
Node
elt
2
next

Workspace

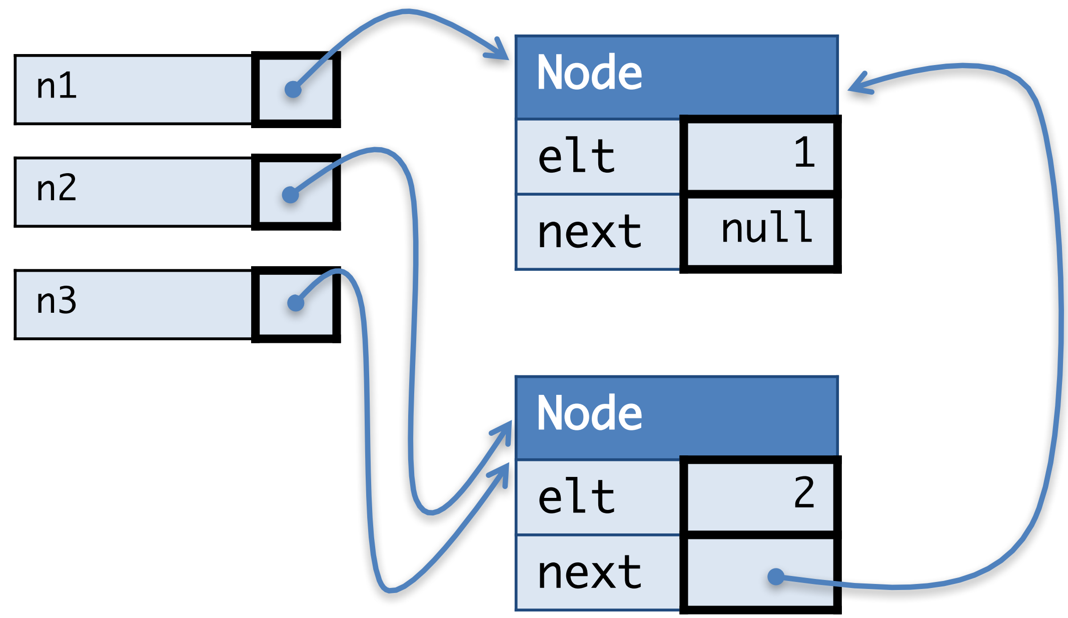
```
Node n3 = n2;
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 9;
```



Workspace

```
n3.next.next = n2;
Node n4 = new Node(4,n1.next);
n2.next.elt = 9;
```

Stack Heap



Workspace

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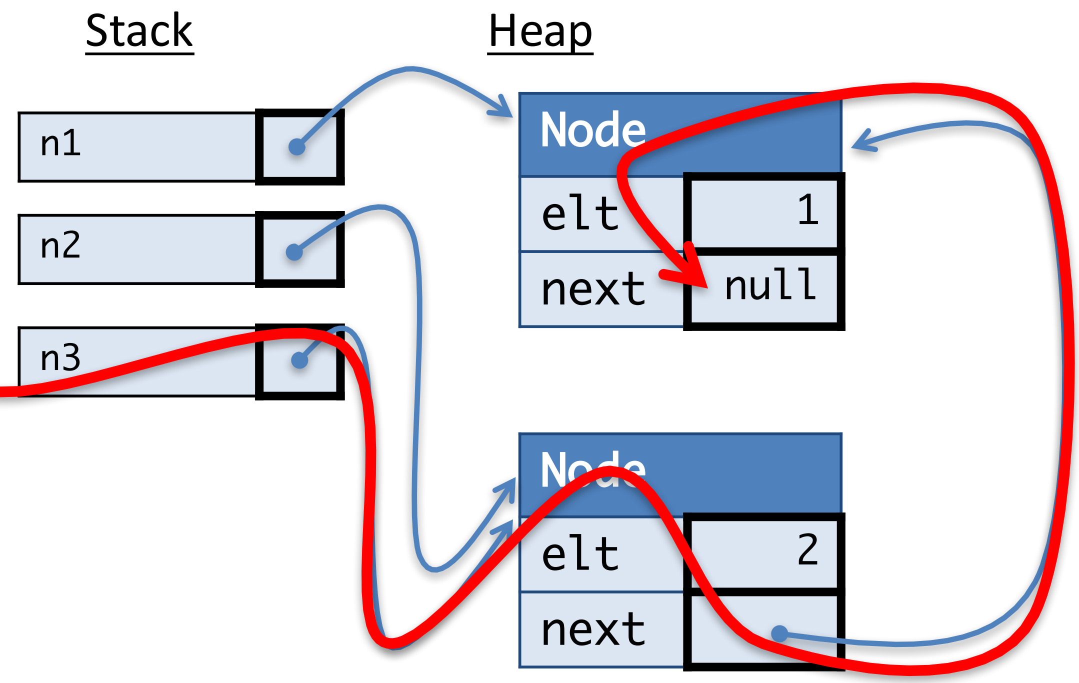

Workspace

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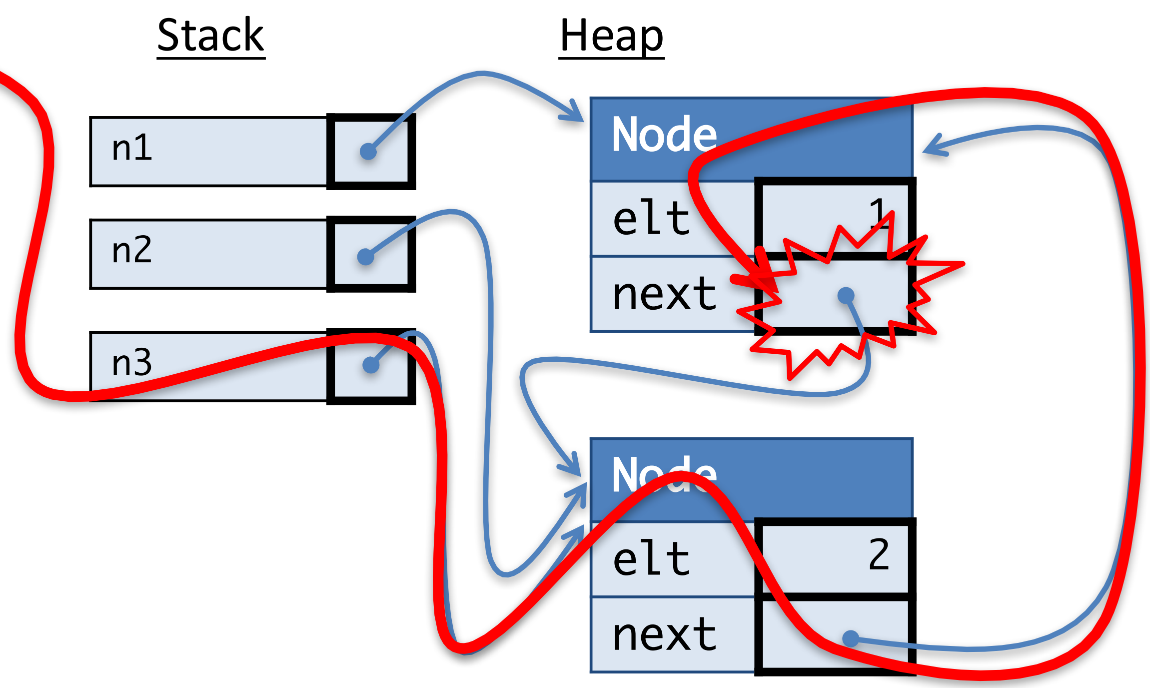

Workspace

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Node n4 = new Node(4,n1.next);
n2.next.elt = 9;
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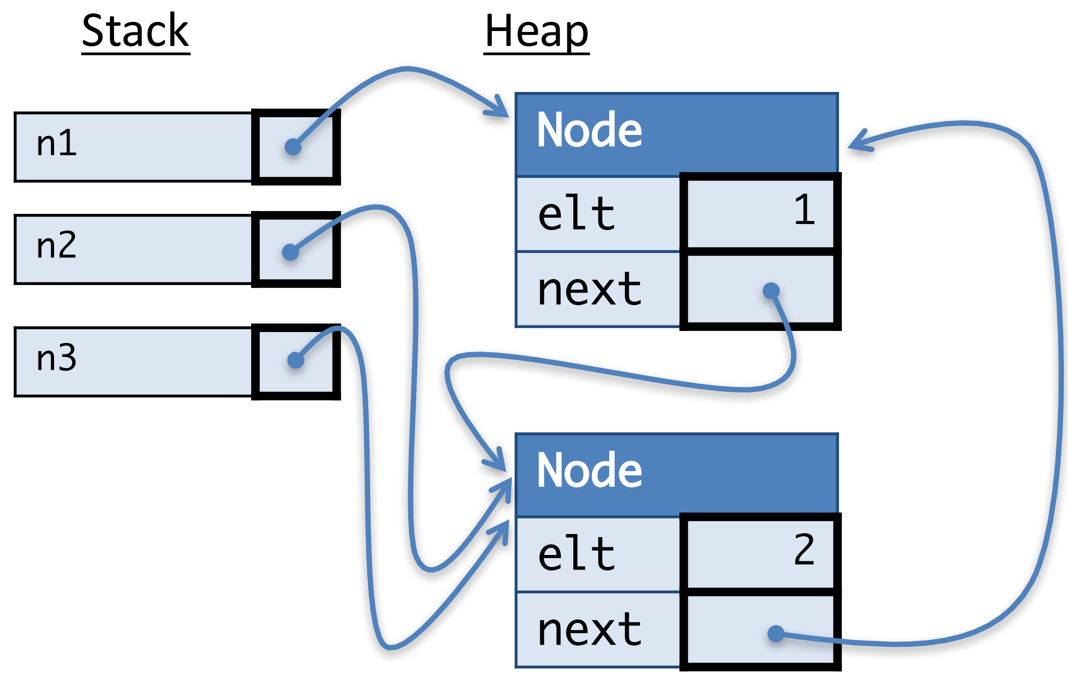
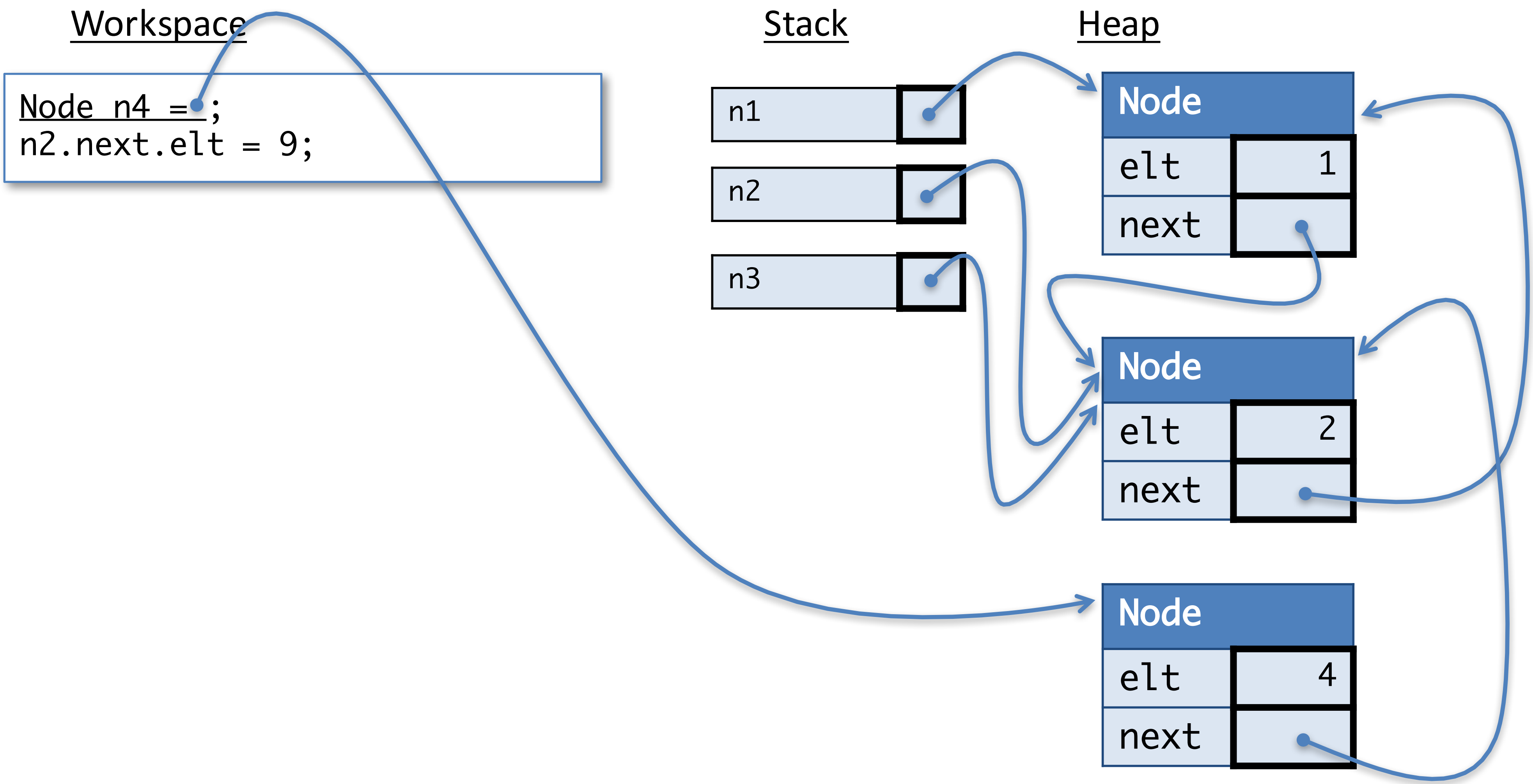
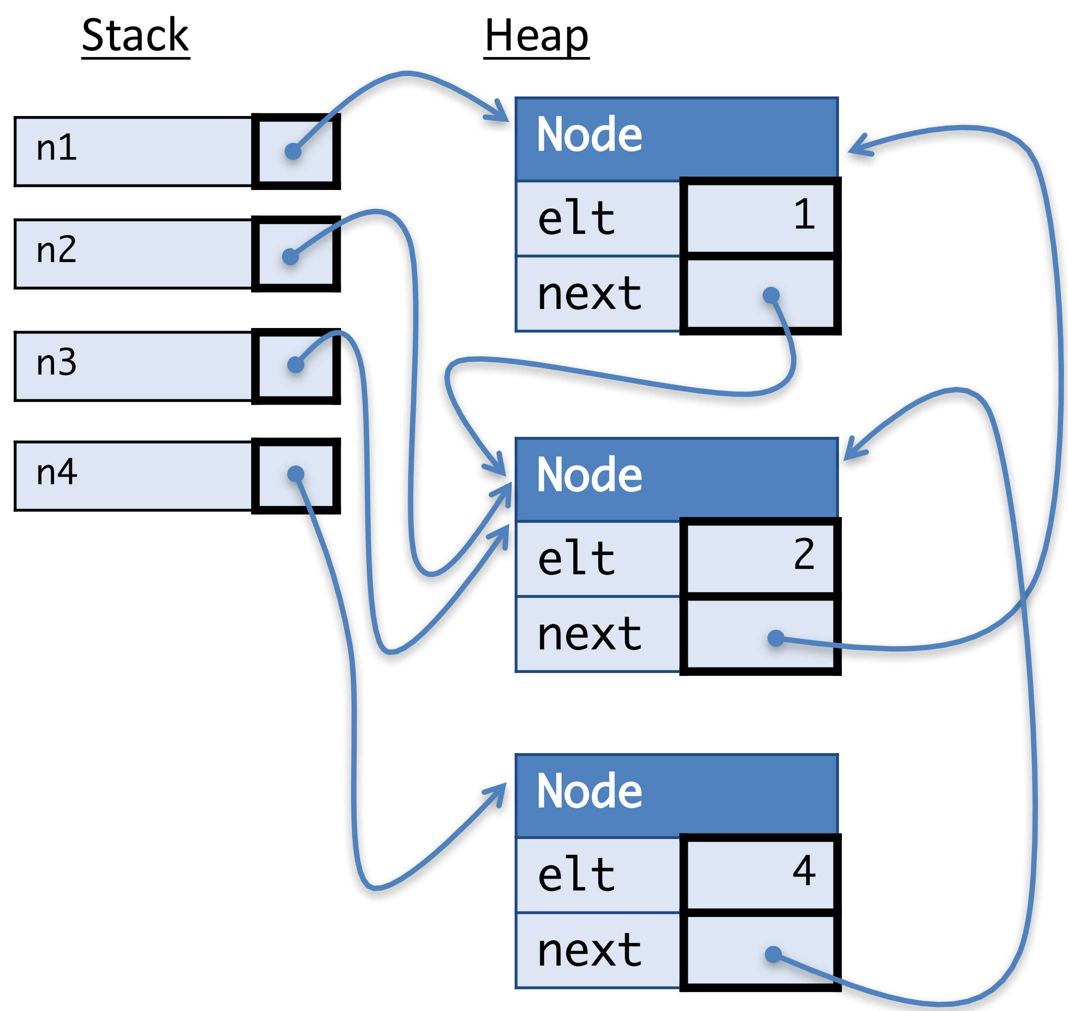
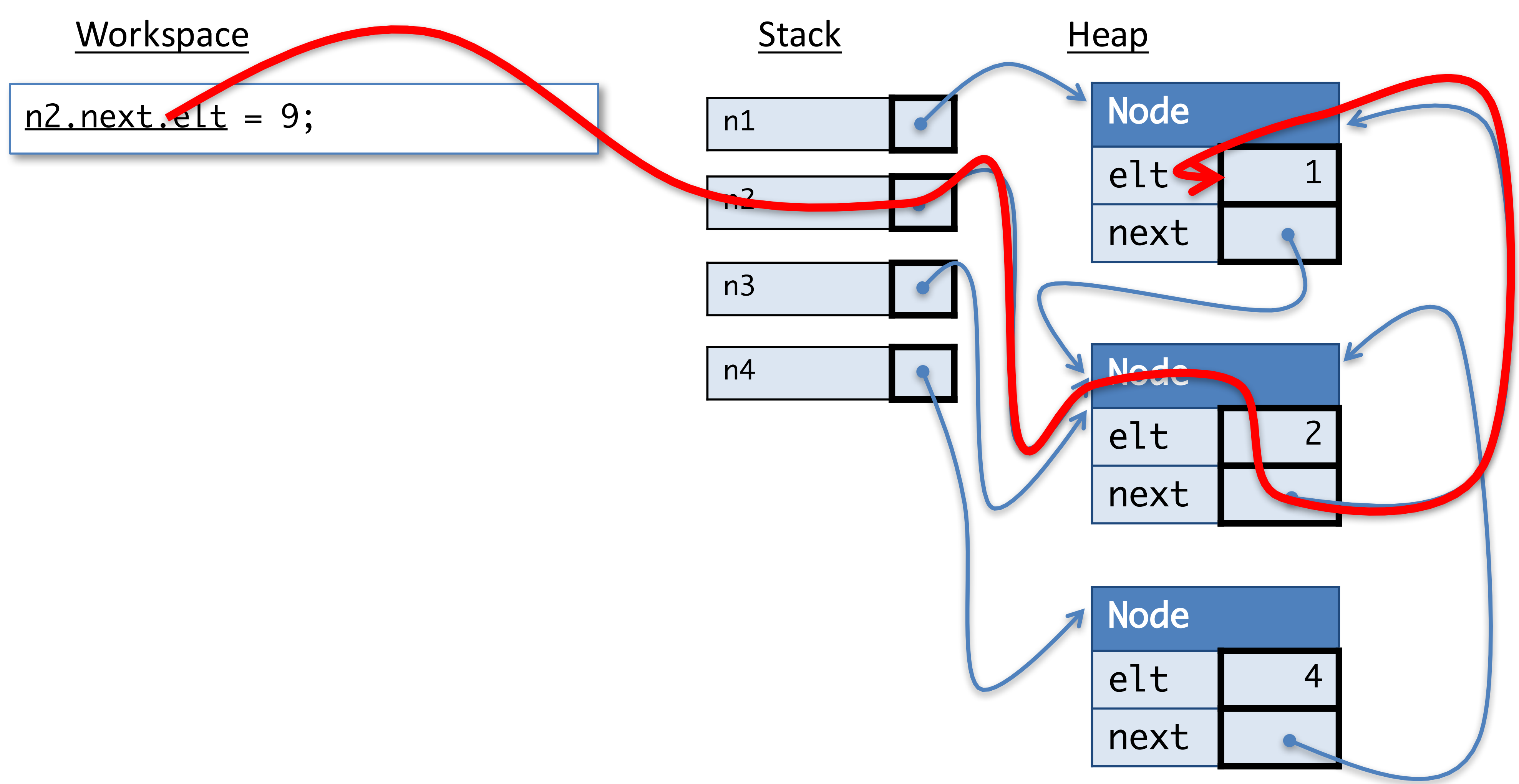



Workspace
Node n4 = ;
n2.next.elt = 9;
Stack
n1
n2
n3
Heap
Node
elt
1
next
Node
elt
2
next
Node
elt
4
next

Workspace

```
n2.next.elt = 9;
```




Workspace
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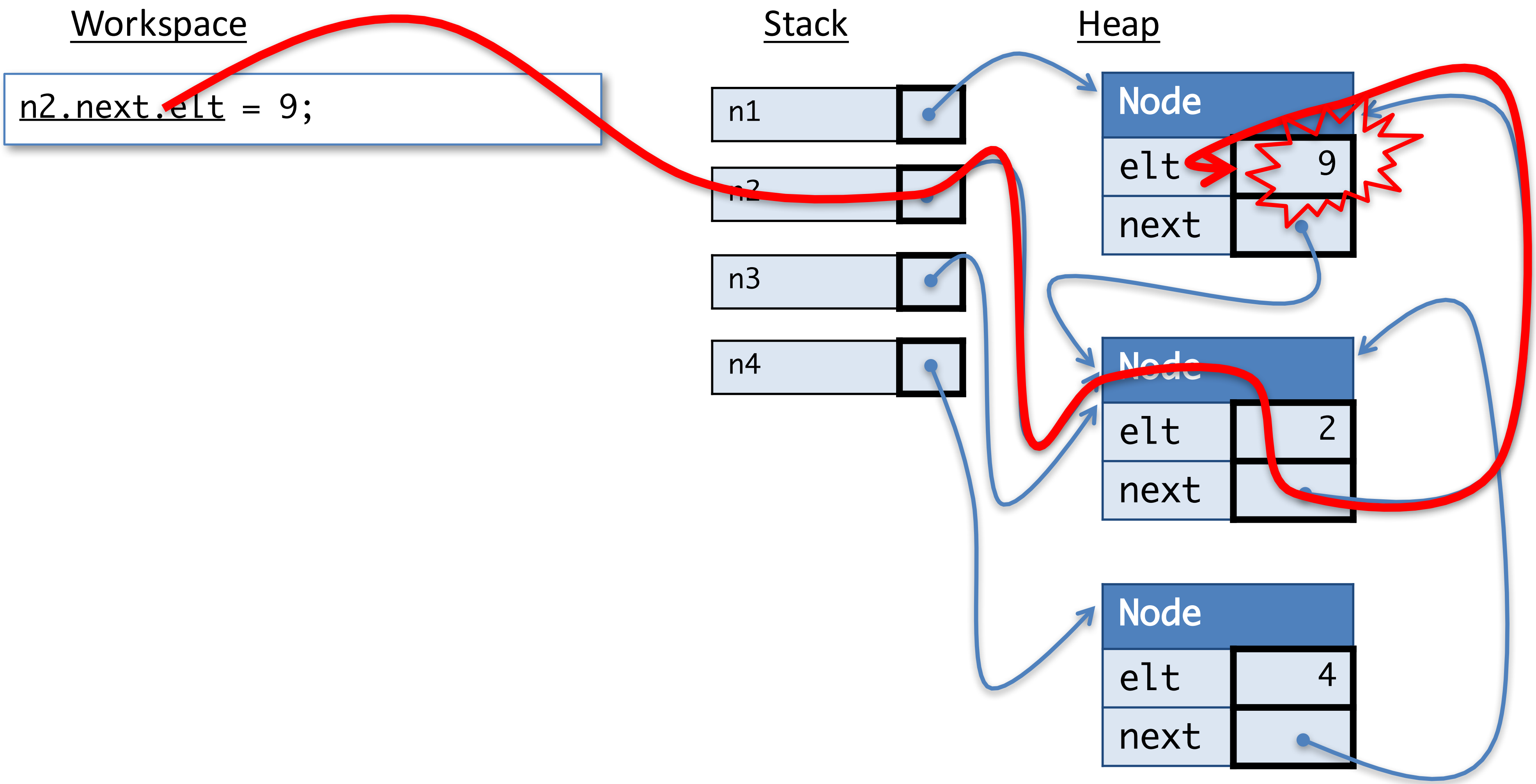
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n1
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Array Examples Demo