# Stack and Queue

# Stack and Queue

- Data structures with specific purposes
  - Restricted features
- All operations are very efficient
  - Inefficient operations are not allowed
- We'll see a stack and queue using linked lists
- *Scala has builtin Stack and Queue classes

# Stack

- LIFO
  - Last in First out
  - The last element pushed onto the stack is the first element to be popped off the stack
- Only the element on the top of the stack can be accessed

# Stack Methods

- Push
  - Add an element to the top of the stack
- Pop
  - Remove the top element of the stack

# Stack Implementation

- Implement a Stack class by wrapping a linked list
- Stack uses the linked list and adapts its methods to implement push and pop

```
class Stack[A] {

  var top: LinkedListNode[A] = null

  def push(a: A): Unit = {
    this.top = new LinkedListNode[A](a, this.top)
  }

  def pop(): A = {
    val toReturn = this.top.value
    this.top = this.top.next
    toReturn
  }

}
```

# Stack Usage

- Create a new empty Stack
- Call push to add an element to the top
- Call pop to remove an element
- Same exact usage when using Scala's builtin Stack

```
val stack = new Stack[Int]()
stack.push(3)
stack.push(7)
stack.push(2)
stack.push(-5)

val element = stack.pop()
```

# Stack Usage

- We can use Scala's list as a Stack
  - The preferred way to use the concept of a stack in practice

```
@deprecated("Stack is an inelegant and potentially poorly-performing wrapper around List.
             Use List instead: stack push x becomes x :: list; stack.pop is list.tail.", "2.11.0")
class Stack[+A] protected (protected val elems: List[A])
```

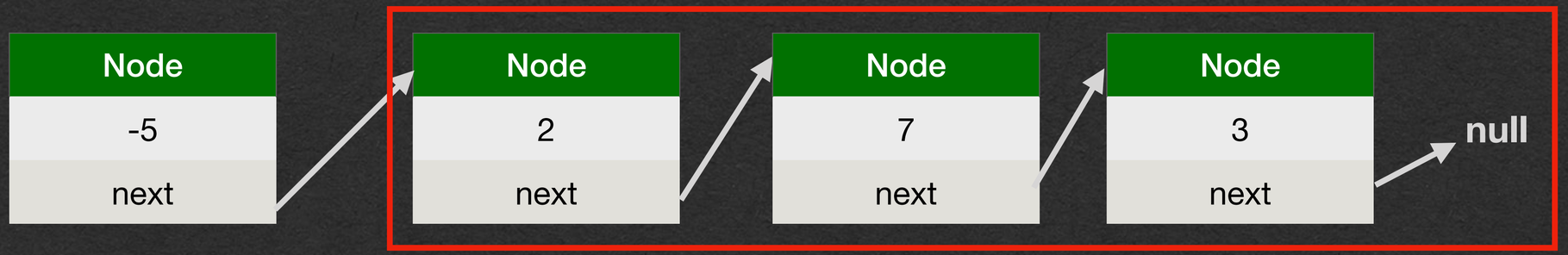
- This is very efficient!
- But wait.. doesn't this create a new list each time an element is pushed or popped since List is immutable?
  - No.. well, kind of

```
var stack = List[Int]()
stack = 3 :: stack
stack = 7 :: stack
stack = 2 :: stack
stack = -5 :: stack

val element = stack.head
stack = stack.tail
```

# Stack Usage

- Before -5 is pushed, the stack is equal to nodes in the red box
- After pushing -5, the red box is unchanged
- A new List **is** returned, but it reuses the old List
  - No need to recreate the entire List

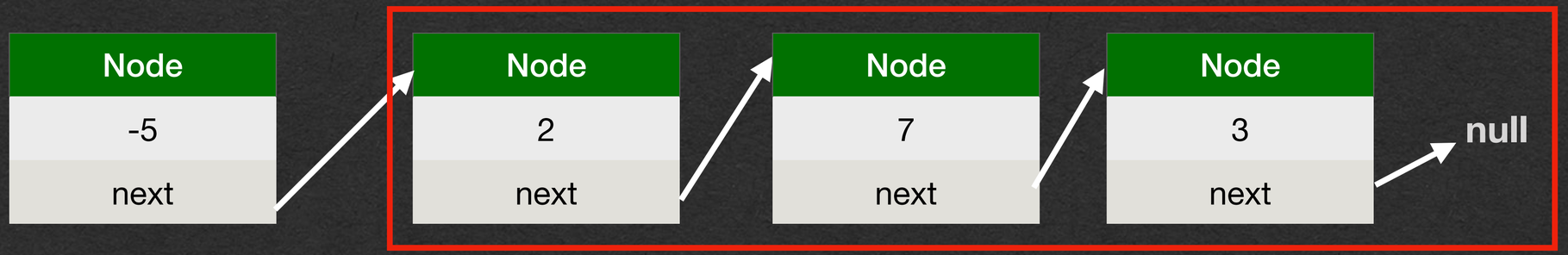
```
var stack = List[Int]()
stack = 3 :: stack
stack = 7 :: stack
stack = 2 :: stack
stack = -5 :: stack

val element = stack.head
stack = stack.drop(1)
```



# Stack Usage

- Same efficiency when -5 is popped
- The red box never changed, but we update the reference stored in the stack variable
- Other parts of the program can share parts of a List without having their changes affect each other

```
var stack = List[Int]()
stack = 3 :: stack
stack = 7 :: stack
stack = 2 :: stack
stack = -5 :: stack

val element = stack.head
stack = stack.drop(1)
```



# Queue

- FIFO
  - First in First out
  - The first element enqueued into the queue is the first element to be dequeued out of the queue
- Elements can only be added to the end of the queue
- Only the element at the front of the queue can be accessed

# Queue Methods

- Enqueue
  - Add an element to the end of the queue
- Dequeue
  - Remove the front element in the queue

# Queue Implementation

- Implement a Queue class by wrapping a linked list
- Queue needs a reference to the first and last element

```
class Queue[A] {

  var front: LinkedListNode[A] = null
  var back: LinkedListNode[A] = null

  def enqueue(a: A): Unit = {
    if (back == null) {
      this.back = new LinkedListNode[A](a, null)
      this.front = this.back
    } else {
      this.back.next = new LinkedListNode[A](a, null)
      this.back = this.back.next
    }
  }

  def dequeue(): A = {
    val toReturn = this.front.value
    this.front = this.front.next
    if(this.front == null){
      this.back = null
    }
    toReturn
  }

}
```

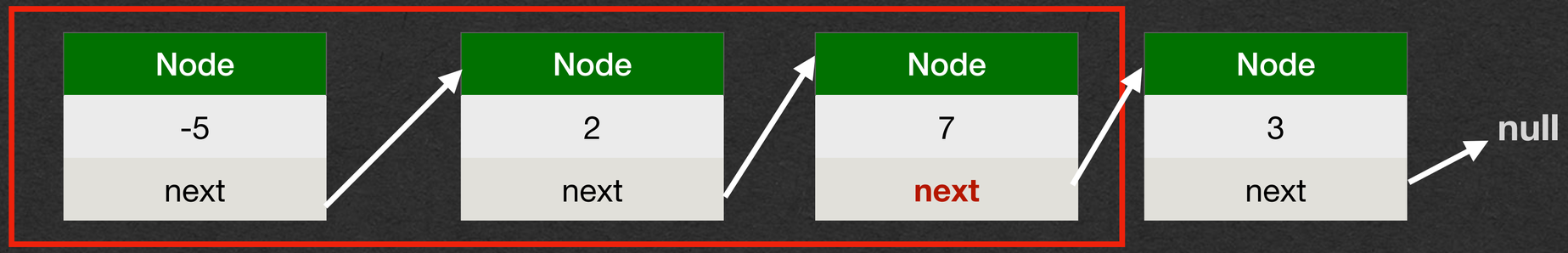
# Queue Usage

- Create a new empty Queue
- Call enqueue to add an element to the back
- Call dequeue to remove the element at the front
- Same exact usage when using Scala's builtin Queue
  - [based on mutable List just like our implementation]

```
val queue = new Queue[Int]()
queue.enqueue(3)
queue.enqueue(7)
queue.enqueue(2)
queue.enqueue(-5)

val element = queue.dequeue()
```

# Queue Usage

- No efficient way to use an immutable List as a queue
- To enqueue 3 the list in the red box must change
  - The next reference of the node containing 7 has to be updated
  - This List cannot be [should not be] used by other parts of the program since the List is changing

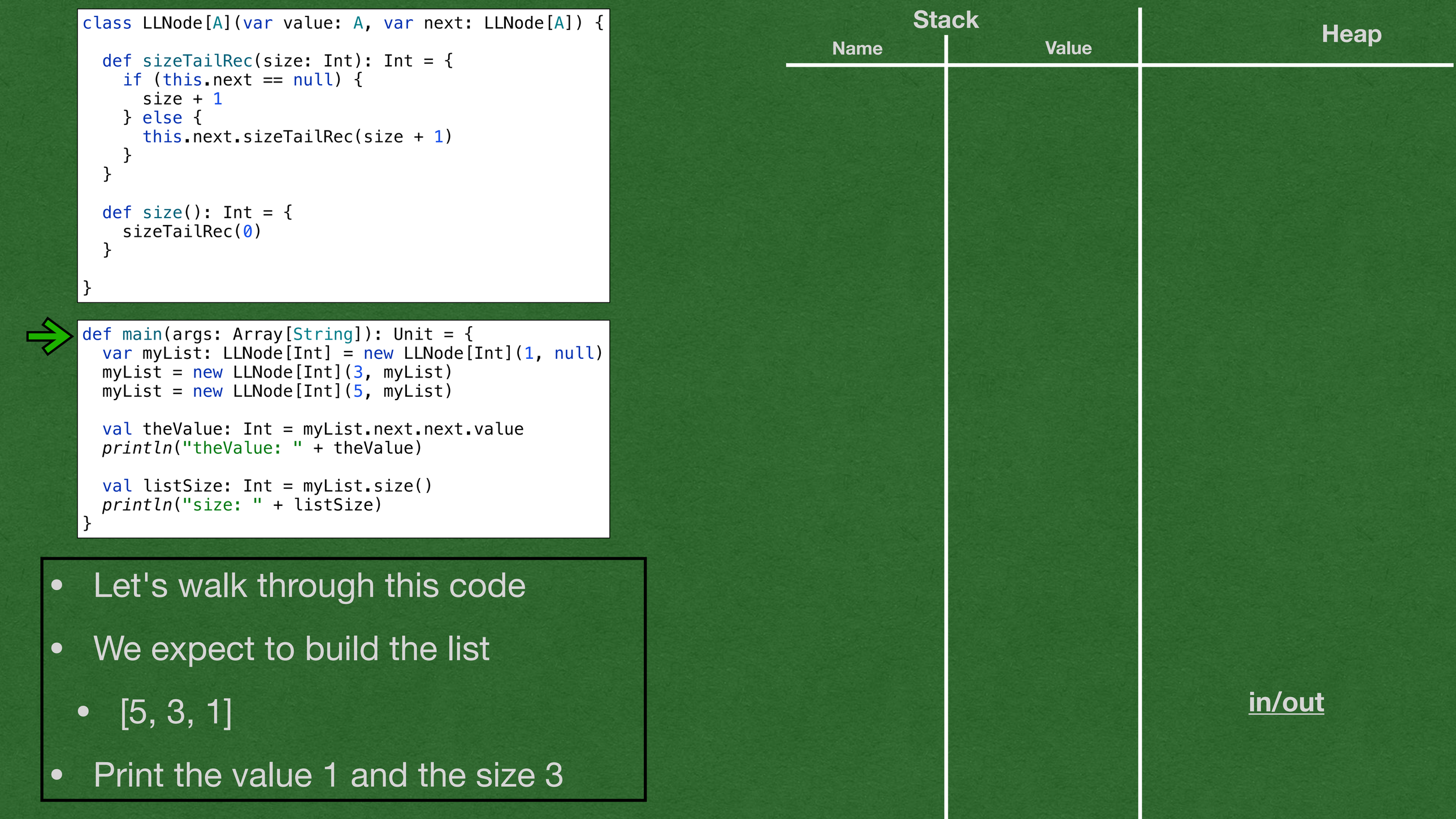


# Memory Diagram

```
class LLNode[A](var value: A, var next: LLNode[A]) {

  def sizeTailRec(size: Int): Int = {
    if (this.next == null) {
      size + 1
    } else {
      this.next.sizeTailRec(size + 1)
    }
  }

  def size(): Int = {
    sizeTailRec(0)
  }

}
```

```
def main(args: Array[String]): Unit = {
  var myList: LLNode[Int] = new LLNode[Int](1, null)
  myList = new LLNode[Int](3, myList)
  myList = new LLNode[Int](5, myList)

  val theValue: Int = myList.next.next.value
  println("theValue: " + theValue)

  val listSize: Int = myList.size()
  println("size: " + listSize)
}
```

- Let's walk through this code
- We expect to build the list
  - [5, 3, 1]
- Print the value 1 and the size 3



```
class LLNode[A](var value: A, var next: LLNode[A]) {

  def sizeTailRec(size: Int): Int = {
    if (this.next == null) {
      size + 1
    } else {
      this.next.sizeTailRec(size + 1)
    }
  }

  def size(): Int = {
    sizeTailRec(0)
  }

}
```

```
def main(args: Array[String]): Unit = {
  var myList: LLNode[Int] = new LLNode[Int](1, null)
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  myList = new LLNode[Int](5, myList)

  val theValue: Int = myList.next.next.value
  println("theValue: " + theValue)

  val listSize: Int = myList.size()
  println("size: " + listSize)
}
```
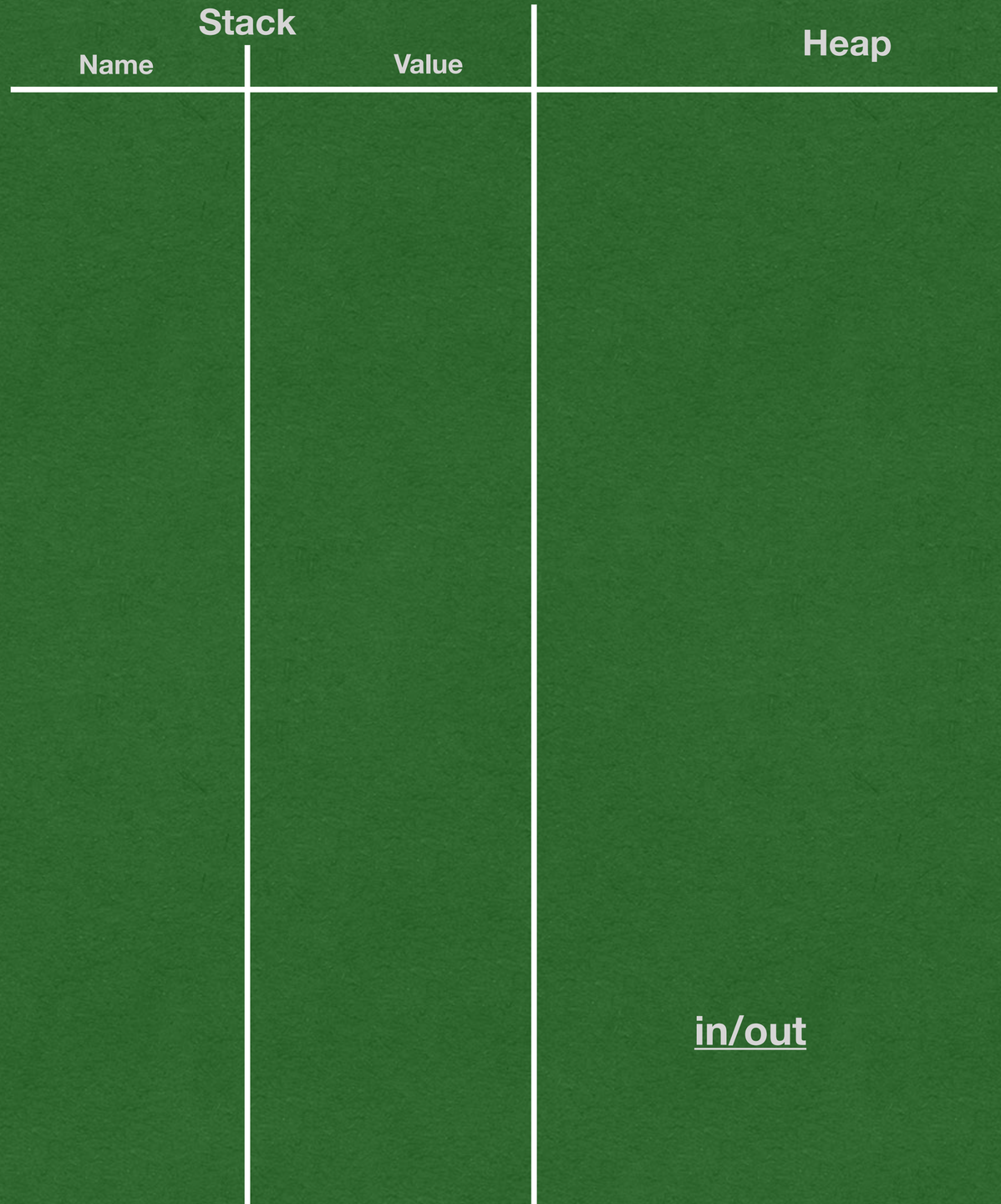

- We saw constructing the linked list last time
- We'll skip the details here



```scala
class LLNode[A](var value: A, var next: LLNode[A]) {

  def sizeTailRec(size: Int): Int = {
    if (this.next == null) {
      size + 1
    } else {
      this.next.sizeTailRec(size + 1)
    }
  }

  def size(): Int = {
    sizeTailRec(0)
  }

}
```

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def main(args: Array[String]): Unit = {
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  myList = new LLNode[Int](5, myList)

  val theValue: Int = myList.next.next.value
  println("theValue: " + theValue)

  val listSize: Int = myList.size()
  println("size: " + listSize)
}
```


- myList now refers to a node containing 5, which refers to a node containing 3, which refers to a node containing 1, which refers to null
- The list is (5, 3, 1)

in/out

```scala
class LLNode[A](var value: A, var next: LLNode[A]) {

  def sizeTailRec(size: Int): Int = {
    if (this.next == null) {
      size + 1
    } else {
      this.next.sizeTailRec(size + 1)
    }
  }

  def size(): Int = {
    sizeTailRec(0)
  }

}
```

```scala
def main(args: Array[String]): Unit = {
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  myList = new LLNode[Int](5, myList)

  val theValue: Int = myList.next.next.value
  println("theValue: " + theValue)

  val listSize: Int = myList.size()
  println("size: " + listSize)
}
```

- Follow the references in next
- Find the value 1

```scala
class LLNode[A](var value: A, var next: LLNode[A]) {

  def sizeTailRec(size: Int): Int = {
    if (this.next == null) {
      size + 1
    } else {
      this.next.sizeTailRec(size + 1)
    }
  }

  def size(): Int = {
    sizeTailRec(0)
  }

}
```

```scala
def main(args: Array[String]): Unit = {
  var myList: LLNode[Int] = new LLNode[Int](1, null)
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  val theValue: Int = myList.next.next.value
  println("theValue: " + theValue)

  val listSize: Int = myList.size()
  println("size: " + listSize)
}
```
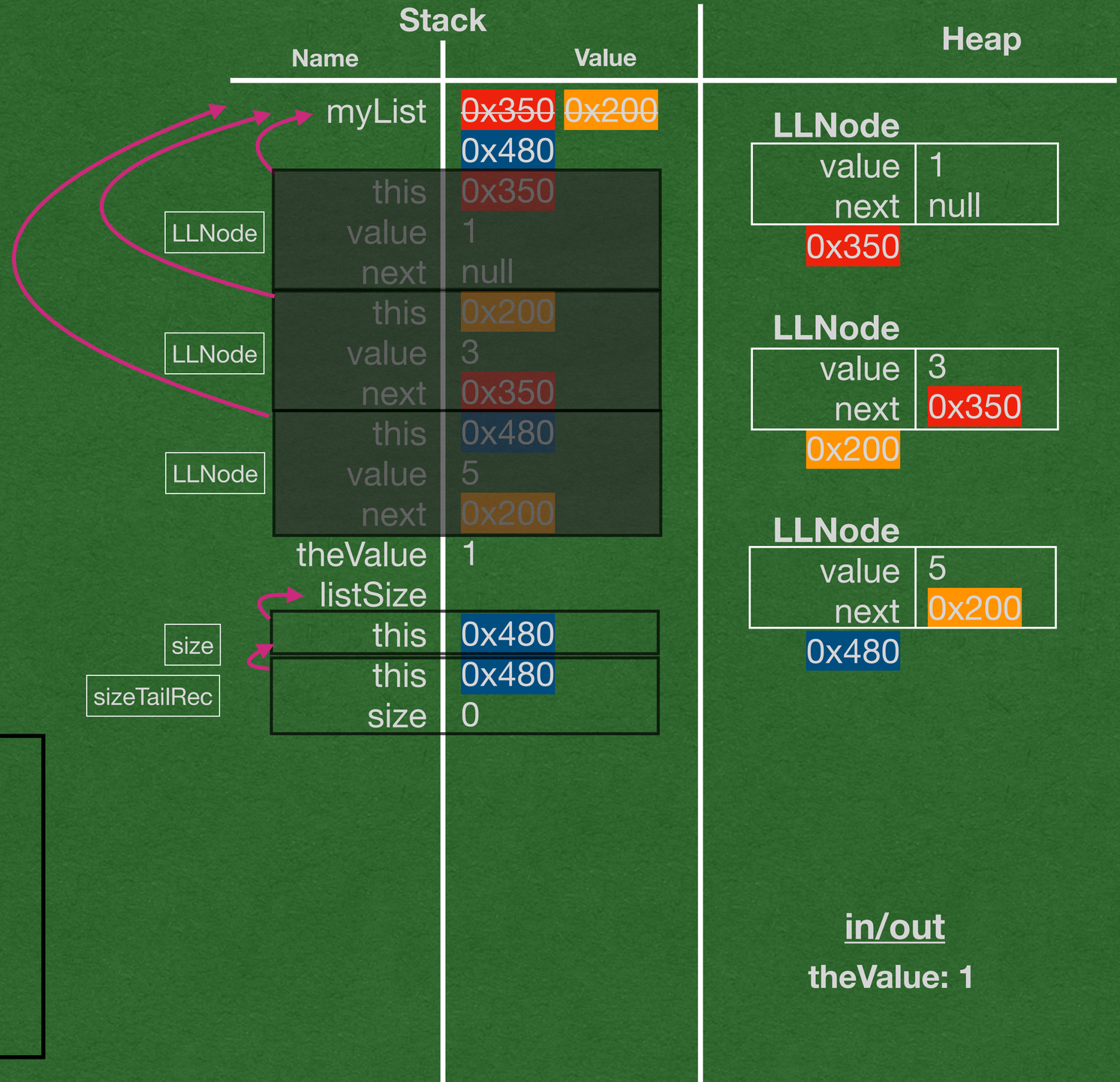

- It's time for recursion!



```scala
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  def sizeTailRec(size: Int): Int = {
    if (this.next == null) {
      size + 1
    } else {
      this.next.sizeTailRec(size + 1)
    }
  }

  def size(): Int = {
    sizeTailRec(0)
  }

}
```

```scala
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  var myList: LLNode[Int] = new LLNode[Int](1, null)
  myList = new LLNode[Int](3, myList)
  myList = new LLNode[Int](5, myList)

  val theValue: Int = myList.next.next.value
  println("theValue: " + theValue)

  val listSize: Int = myList.size()
  println("size: " + listSize)
}
```
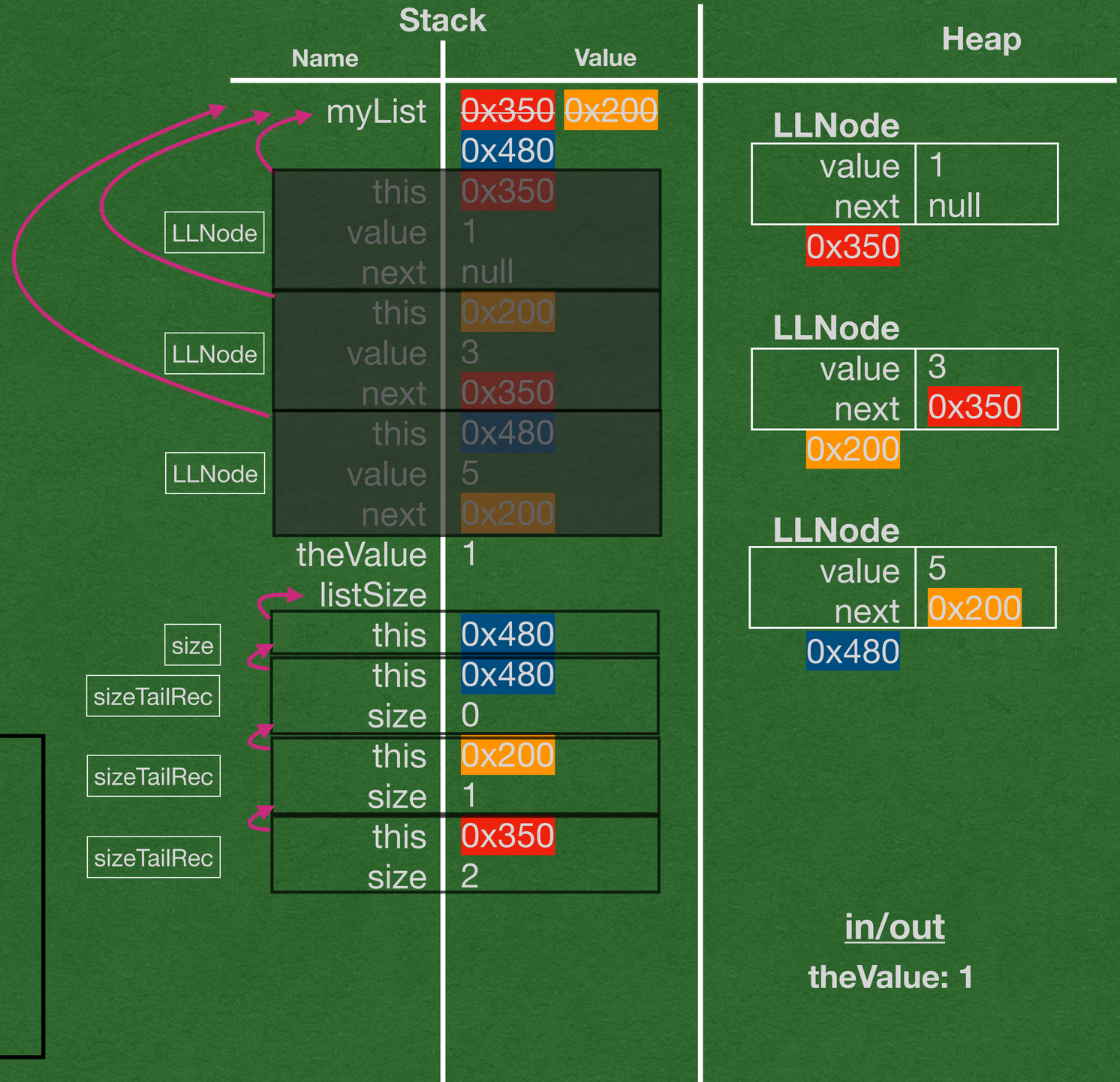

- Keep making calls until we reach the base case



```scala
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  def sizeTailRec(size: Int): Int = {
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      this.next.sizeTailRec(size + 1)
    }
  }

  def size(): Int = {
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  }

}
```

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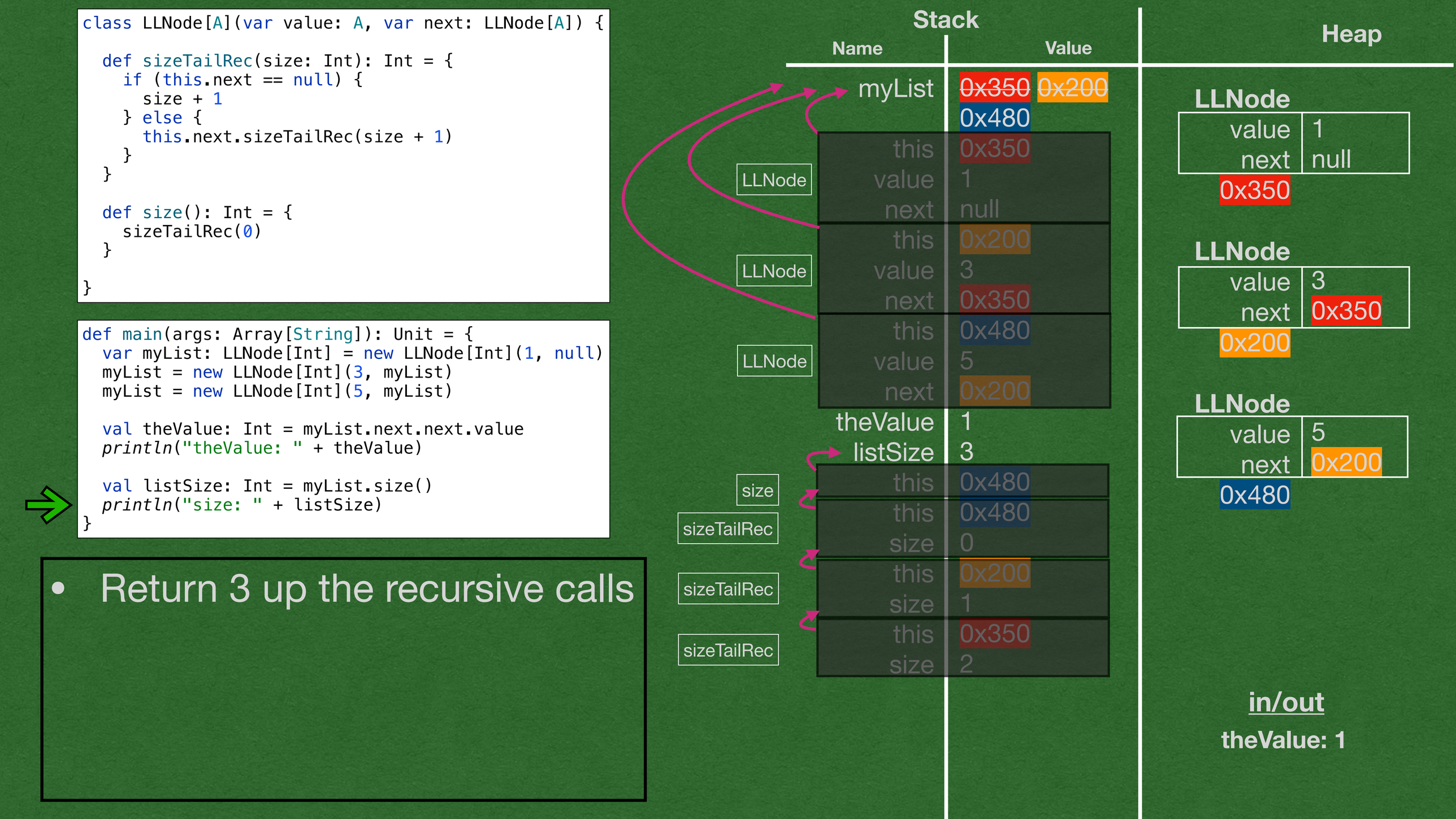
  myList = new LLNode[Int](5, myList)

  val theValue: Int = myList.next.next.value
  println("theValue: " + theValue)

  val listSize: Int = myList.size()
  println("size: " + listSize)
}
```

- Return 3 up the recursive calls



```scala
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  def sizeTailRec(size: Int): Int = {
    if (this.next == null) {
      size + 1
    } else {
      this.next.sizeTailRec(size + 1)
    }
  }

  def size(): Int = {
    sizeTailRec(0)
  }

}
```

```scala
def main(args: Array[String]): Unit = {
  var myList: LLNode[Int] = new LLNode[Int](1, null)
  myList = new LLNode[Int](3, myList)
  myList = new LLNode[Int](5, myList)

  val theValue: Int = myList.next.next.value
  println("theValue: " + theValue)

  val listSize: Int = myList.size()
  println("size: " + listSize)
}
```

- Print 3 to the screen