Linked List

Lecture Question

Task: Write reduce for our linked list

- Write a method in the week8.linkedlist.LinkedListNode class (from the repo) named reduce that:
  - Takes a function of type (A, A) => A
  - Returns A
  - Combines all the elements of the list into a single value by applying the provided function to all elements
    - You may assume the function is commutative
  - If the list has size 1, return that element without calling the provided function

Example:
If head stores a reference to the List(4, 6, 2)

```
head.reduce((a: Int, b: Int) => a + b) == 12
```

Recall - Array

- Sequential
  - One continuous block of memory
  - Random access based on memory address
    - address = first_address + (element_size * index)
- Fixed Size
  - Since memory adjacent to the block may be used
  - Efficient when you know how many elements you'll need to store

Array

Program Stack	
Main Frame	name:myArray, value:1503

Program Heap	
1503	myArray[0]
…	myArray[1]
…	myArray[2]
…	myArray[3]
[used by another program]	

- Arrays are stored on the heap
- Pointer to index 0 goes on the stack
- add index * sizeOfElement to 1503 to find each element
    - This is called random access

Recall - Linked List

- Sequential
  - Spread across memory
  - Each element knows the memory address of the next element
    - Follow the addresses to find each element
- Variable Size
  - Store new element anywhere in memory
  - New element stores address of the first element

Linked List

Program Stack	
Main Frame	name:myList, value:506

Program Heap	
506	name:value, value:5
...	name:next, value:795

Program Heap	
795	name:value, value:3
...	name:next, value:416

Program Heap	
416	name:value, value:1
...	name:next, value:null

- myList stores a list containing: [5,3,1]
- Last link stores null
  - We say the list is "null terminated"
  - When we read a value of null we know we reached the end of the list

Linked List

Program Stack	
Main Frame	name:myList, value:506

Program Heap	
506	name:value, value:5
...	name:next, value:795

Program Heap	
795	name:value, value:3
...	name:next, value:416

Program Heap	
416	name:value, value:1
...	name:next, value:null

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

}
```

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

- We create our own linked list class by defining a node
  - A node represents one "link" in the list
- The list itself is a reference to the first/head node
- Note: This is a **mutable** list

Linked List Algorithms

- We know the structure of a linked list
- How do we operate on these lists?
- We would like to:
  - Find the size of a list
  - Print all the elements of a list
  - Access elements by location
  - Add/remove elements
  - Find a specific value

Size

- Navigate through the entire list until the next reference is null
  - Count the number of nodes visited
- Could use a loop. Recursive example shown

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

To String

- Same as size, but accumulate the values as strings instead of counting the number of nodes
- Recursion makes it easier to manage our commas
    - ", " is only appended if it's not the last element

```
override def toString: String = {
  if (this.next == null) {
    this.value.toString
  }else {
    this.value.toString + ", " + this.next.toString
  }
}
```

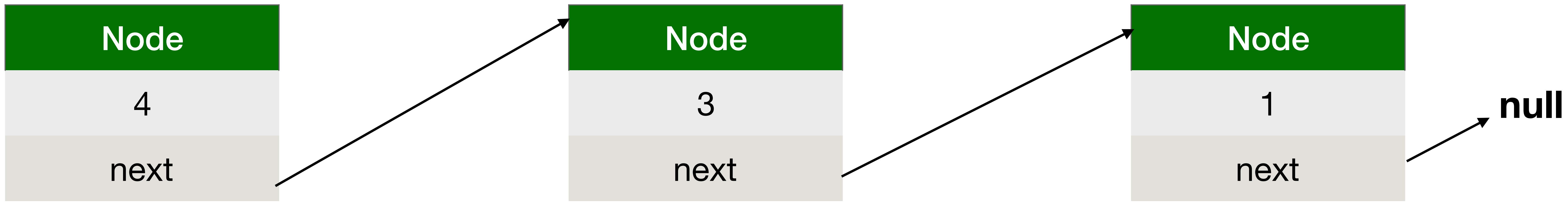
Access Element by Location

- Simulates array access
- Take an "index" and advance through the list that many times
- MUCH slower than array access
  - Calls next n times - O(n) runtime
  - ex. apply(4) is the same as this.next.next.next.next

```
def apply(i: Int): LinkedListNode[A] = {
  if (i == 0) {
    this
  } else {
    this.next.apply(i - 1)
  }
}
```

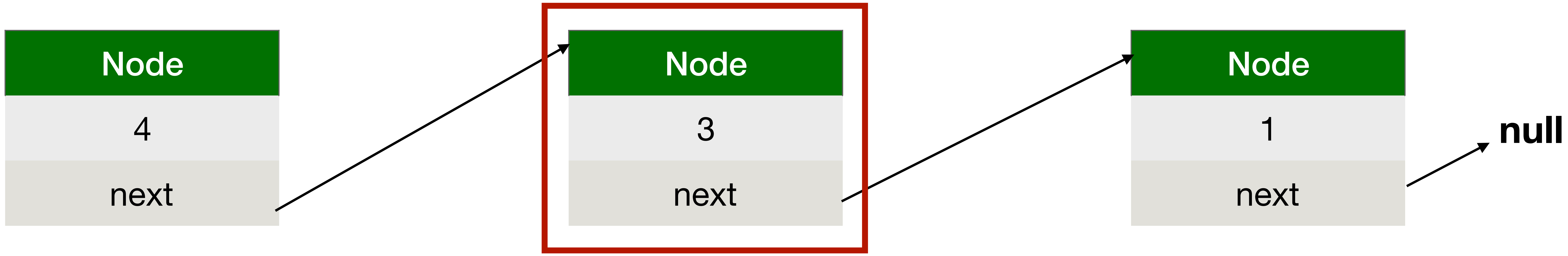
Add an Element

- To add an element we first need a reference to the node before the location of the new element
- Update the next reference of this node
- Want to add 2 in this list after 3



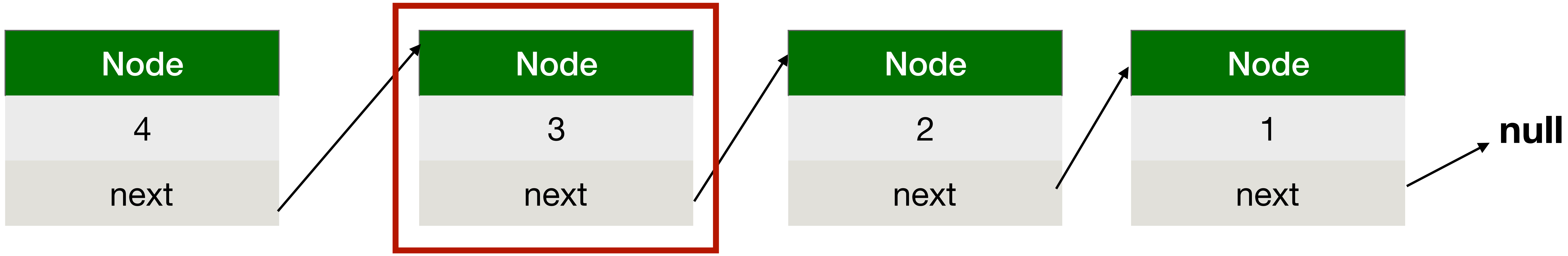
Add an Element

- Need reference to the node containing 3



Add an Element

- Need reference to the node containing 3
- Create the new node with next equal to this node's next
- This node's next is set to the new node



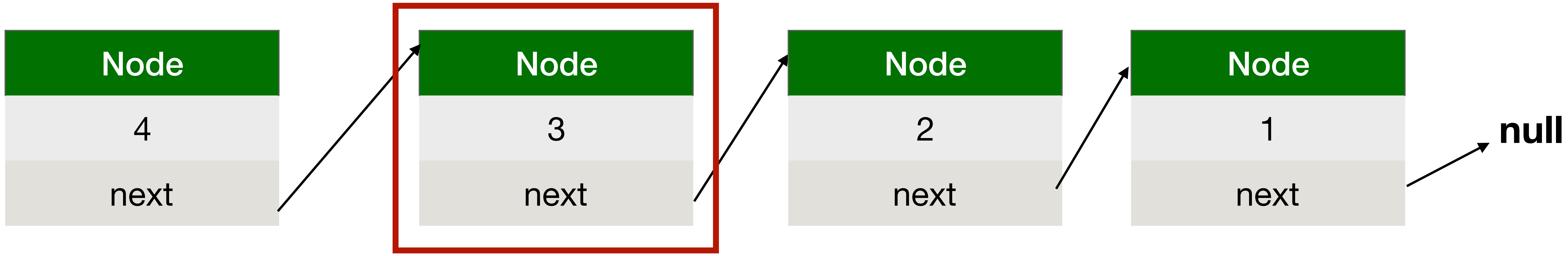
Add an Element

- Need reference to the node containing 3
- Create the new node with next equal to this node's next
- This node's next is set to the new node

```
def insert(element: A): Unit = {
  this.next = new LinkedListNode[A](element, this.next)
}
```

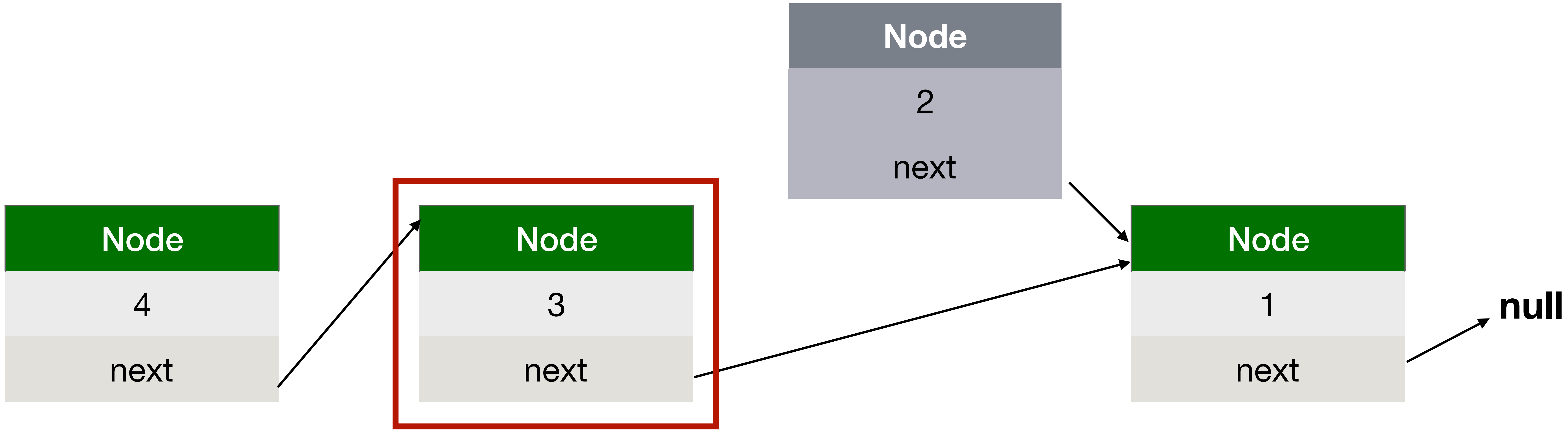
Delete a Node

- Want to delete the node containing 2
- Need a reference to the previous node



Delete a Node

- Update that node's next to bypass the deleted node
  - Don't have to update deleted node
  - The list no longer refers to this node



Delete a Node

- Update that node's next to bypass the deleted node
    - Don't have to update deleted node
    - The list no longer refers to this node

```
def deleteAfter(): Unit = {
  this.next = this.next.next
}
```

Find a Value

- Navigate through the list one node at a time
  - Check if the node contains the value
  - If it doesn't, move to the next node
  - If the end of the list is reached, the list does not contain the element

```
def find(toFind: A): LinkedListNode[A] = {
  if (this.value == toFind) {
    this
  } else if (this.next == null) {
    null
  } else {
    this.next.find(toFind)
  }
}
```

Find - Recursion v. Iteration

```
def findIterative(toFind: A): LinkedListNode[A] = {
  var node = this
  while (node != null) {
    if (node.value == toFind) {
      return node
    }
    node = node.next
  }
  null
}
```

```
def find(toFind: A): LinkedListNode[A] = {
  if (this.value == toFind) {
    this
  } else if (this.next == null) {
    null
  } else {
    this.next.find(toFind)
  }
}
```

ForEach

- Call a function on each node of the list

```
def foreach(f: A => Unit): Unit = {
  f(this.value)
  if(this.next != null) {
    this.next.foreach(f)
  }
}
```

Map Usage

- Recall the map method for builtin List
- Used to transform every element in a list

```
val numbers: List[Int] = List(1, 2, 3, 4, 5, 6, 7, 8, 9, 10)
val numbersSquared = numbers.map((n: Int) => n * n)
println(numbersSquared)
```

List(1, 4, 9, 16, 25, 36, 49, 64, 81, 100)

Map

- Apply a function to each element of the list
  - Return a new list containing the return values of the function

```scala
def map(f: A => A): LinkedListNode[A] = {
  val newValue = f(this.value)
  if (this.next == null) {
    new LinkedListNode[A](newValue, null)
  } else {
    new LinkedListNode[A](newValue, this.next.map(f))
  }
}
```

Map - Change Type

- Can change the type of the returned list with a second type parameter
- A could be equal to B if you don't want to change the type
- Example: You want to divide a list of Ints by 2 and have to return a list of Doubles to avoid truncation

```
def map[B](f: A => B): LinkedListNode[B] = {
  val newValue = f(this.value)
  if (this.next == null) {
    new LinkedListNode[B](newValue, null)
  } else {
    new LinkedListNode[B](newValue, this.next.map(f))
  }
}
```

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