CSE 143

Computer Programming II

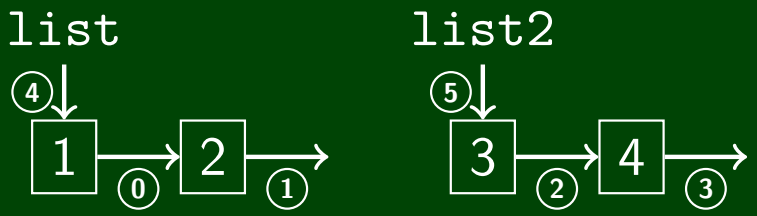
Linked Lists I

Outline

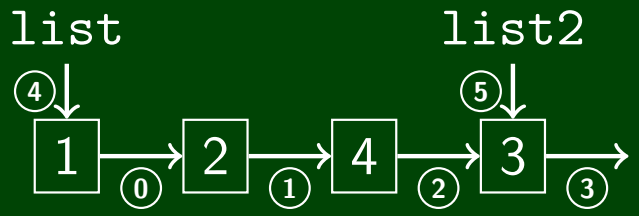
1. Get more familiar with `ListNodes`
2. Learn how to run through the values of a `LinkedList`
3. Learn how `LinkedIntList` is implemented
4. Learn about the different cases to deal with for `LinkedLists`

Another `ListNode` Example

Before:



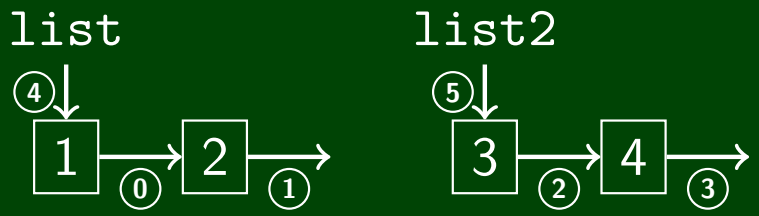
After:



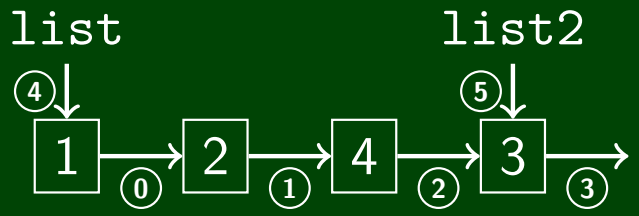
How many `ListNodes` are there in the before picture?

Another `ListNode` Example

Before:



After:

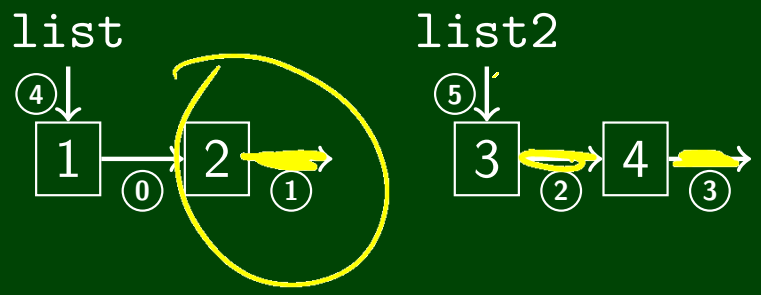


How many `ListNodes` are there in the before picture?

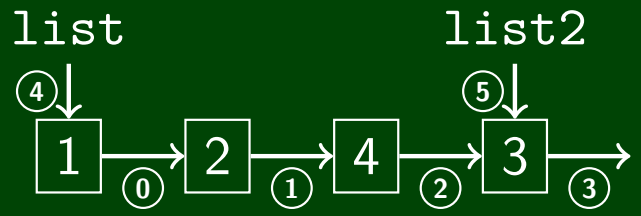
There are FOUR. Each box is a `ListNode`.

Another `ListNode` Example

Before:



After:



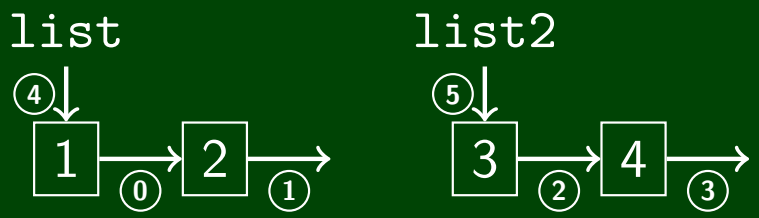
How many `ListNodes` are there in the before picture?

There are FOUR. Each box is a `ListNode`.

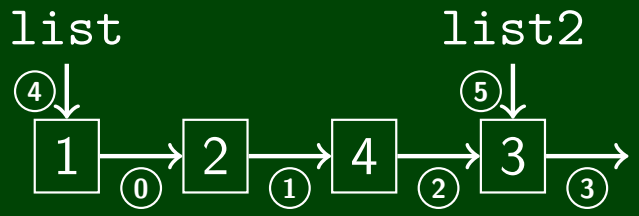
How many references to `ListNodes` are there?

Another `ListNode` Example

Before:



After:



How many `ListNodes` are there in the before picture?

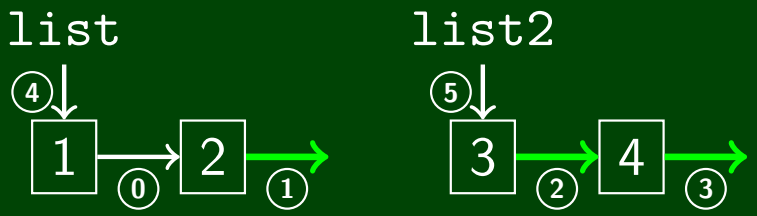
There are FOUR. Each box is a `ListNode`.

How many references to `ListNodes` are there?

There are SIX. Every arrow is a reference to a `ListNode`.

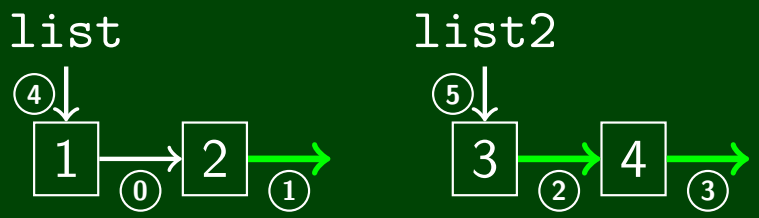
Another `ListNode` Example (Solution)

Before:

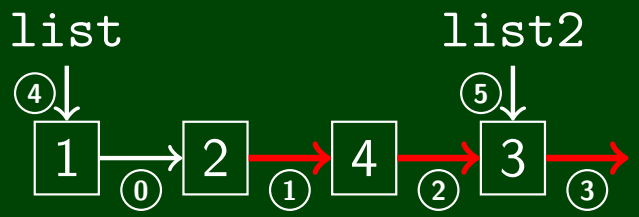


Another `ListNode` Example (Solution)

Before:

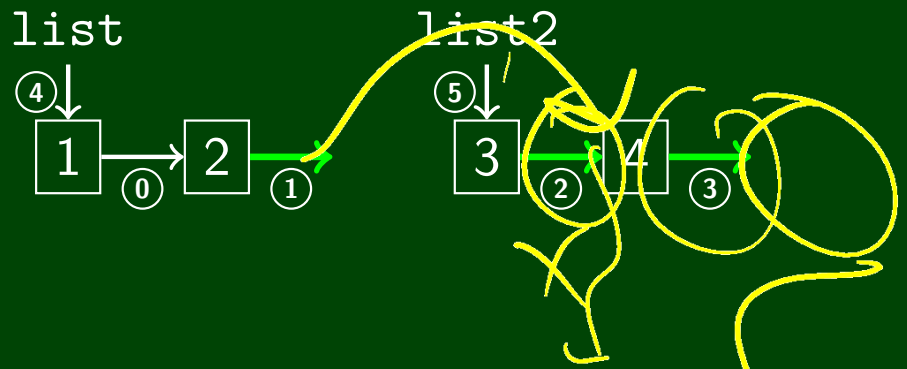


After:

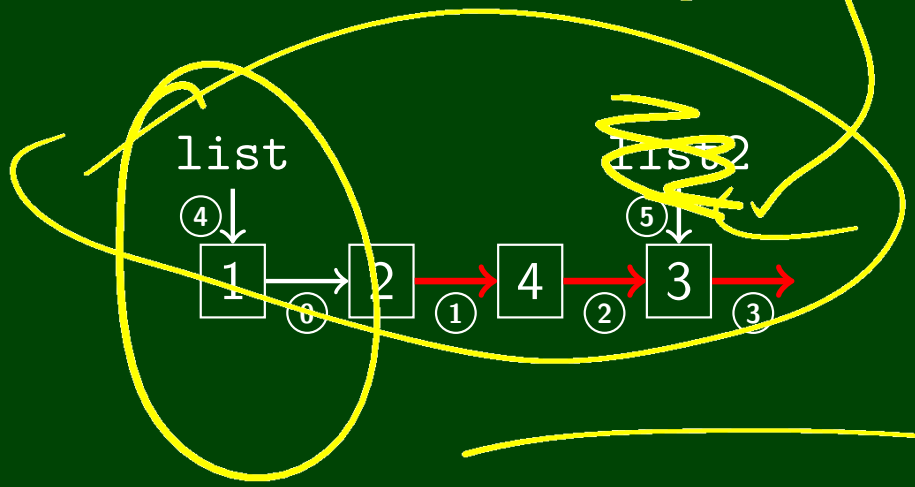


Another `ListNode` Example (Solution)

Before:

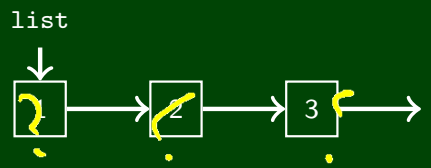


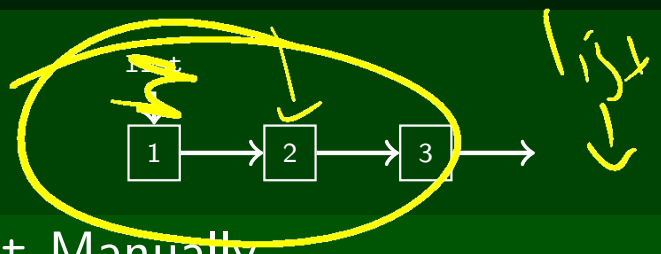
After:




```
1  list.next.next = list2.next
2  list2.next.next = list2;
3  list2.next = null;
```

Printing a `LinkedList`



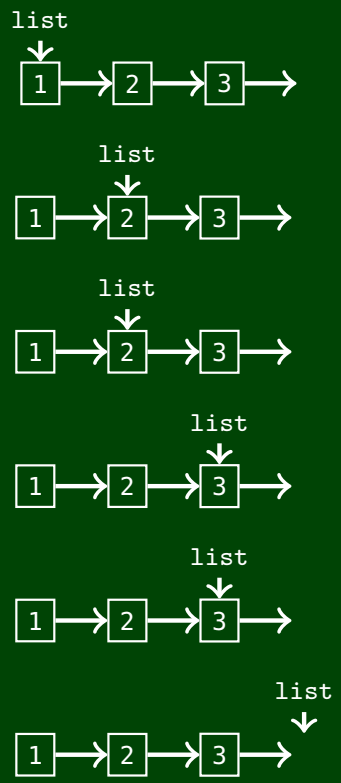


Printing a LinkedList Manually

```
1 System.out.println(list.data);
2 System.out.println(list.next.data);
3 System.out.println(list.next.next.data);
```

Now, note that we can use a variable to keep track of where we are:

```
1 System.out.println(list.data);
2 list = list.next;
3 System.out.println(list.data);
4 list = list.next;
5 System.out.println(list.data);
6 list = list.next;
```



Printing a `LinkedList`: Better Version

What if our list has 1000 nodes? That would be horrible to write.

Printing a `LinkedList`: Better Version

What if our list has 1000 nodes? That would be horrible to write.

Printing a **BIG** `LinkedList`

```
1 while (list != null) {
2   System.out.println(list.data);
3   list = list.next;
4 }
```

But that destroys the list; so, use a temporary variable instead:

Printing a **BIG** `LinkedList` Correctly

```
1 ListNode current = list
2 while (current != null) {
3   System.out.println(current.data);
4   current = current.next;
5 }
```

We can use for loops in a similar way to with ArrayLists to run through LinkedLists!

Traversing an ArrayList

```
for (int i = 0; i < arrayList.size(); i++) {
   System.out.println(arrayList.get(i));
}
```

Traversing an LinkedList

```
for (ListNode current = linkedList; current != null; current = current.next) {
   System.out.println(current.data);
}
```

Description	ArrayList Code	LinkedList Code
Go to front of list	`int i = 0;`	`ListNode current = list;`
Test for more elements	`i < list.size()`	`current != null`
Current value	`list.get(i)`	`current.data`
Go to next element	`i++;`	`current = current.next;`

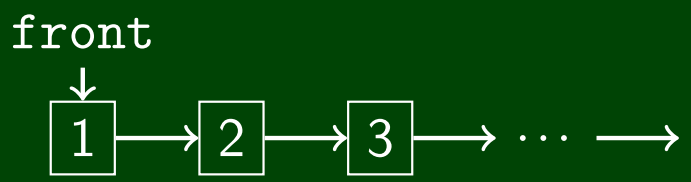
- No generics (only stores ints)
- Fewer methods: `add`(value), `add`(index, value), `get`(index), `set`(index, value), `size`(), `isEmpty`(), `remove`(index), `indexOf`(value), `contains`(value), `toString`()
- This is the same idea as when we implemented `ArrayIntList`!

`LinkedIntList` Fields

What fields does our `LinkedIntList` need?

What fields does our LinkedIntList need?

A reference to the front of the list



LinkedIntList v1

```
1  public class LinkedIntList {
2     private ListNode front;
3
4     public LinkedIntList() {
                                          front
                                            ↓
5        front = null;
6     }
7
8     ...
9  }
```

Buggy toString()

```
public String toString() {
   String result = "[";

   ListNode current = this.front;
   while (current != null) {
      result += current.data + ", ";
      current = current.next;
   }

   return result + "]";
}
```

Buggy toString()

```
public String toString() {
   String result = "[";

   ListNode current = this.front;
   while (current != null) {
      result += current.data + ", ";
      current = current.next;
   }

   return result + "]";
}
```

Our toString() puts a trailing comma. Fix it by stopping one early:

Fixed toString()

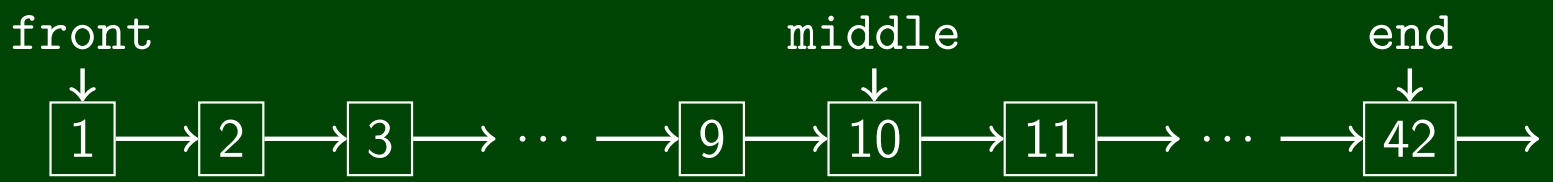
```
public String toString() {
   String result = "[";

   ListNode current = this.front;
   while (current != null && current.next != null) {
      result += current.data + ", ";
      current = current.next;
   }
   if (current != null) {
      result += current.data;
   }

   return result + "]";
}
```

Writing a LinkedList Method

1. Identify cases to consider...
   - Front/Empty
   - Middle
   - End
2. Draw pictures for each case
3. Write each case separately



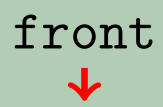
LinkedIntList add() (Empty Case)

Cases to consider:

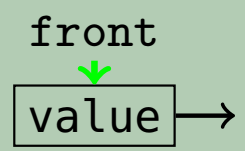
- Add to empty list
- Add to non-empty list

Add To An Empty List

What does an empty list look like?

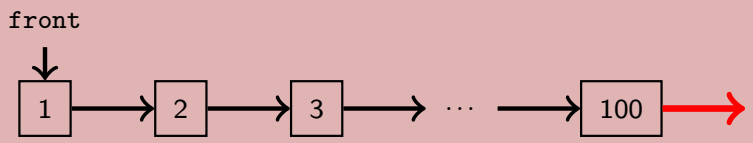



```
1  public void add(int value) {
2     /* If the list is empty... */
3     if (this.front == null) {
4        this.front = new ListNode(value);
5
6     }
7     /* Other Cases ... */
8  }
```

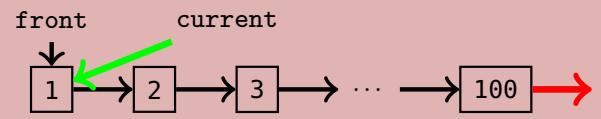


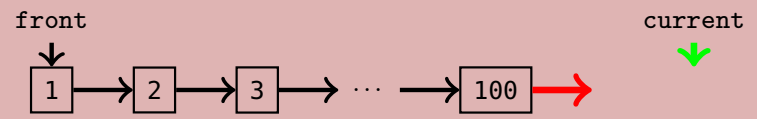
Add To A Non-Empty List

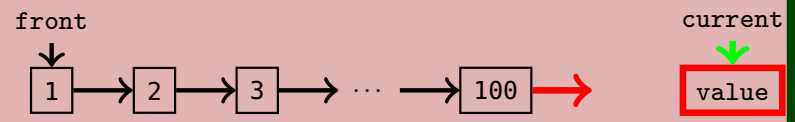
Consider a non-empty list:




```
1  /* Idea: We want to change the red arrow.
2           Loop until we're at the last node. */
3  ListNode current = this.front;
4
5  while (current != null) {
6     current = current.next;
7  }
8
9  current = new ListNode(value);
10
```

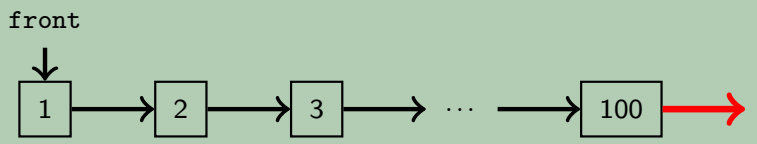




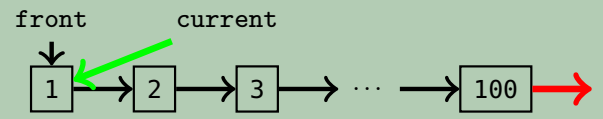


Add To A Non-Empty List (Fixed)

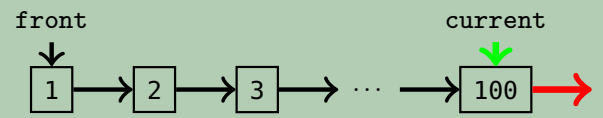
Consider a non-empty list:



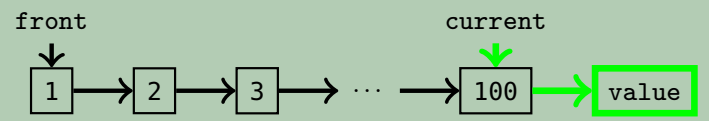

```
1  /* Idea: We want to change the red arrow.
2           Loop until we're at the node before the last node */
3  ListNode current = this.front;
```




```
4
5  while (current.next != null) {
6     current = current.next;
7  }
```



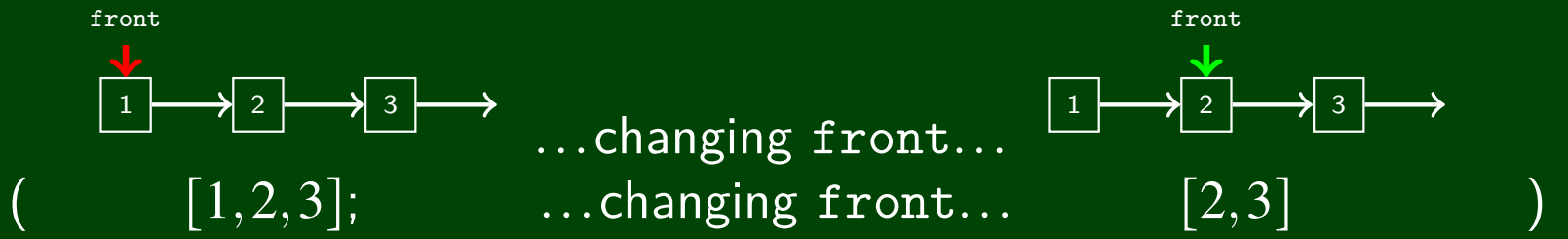

```
8
9  current.next = new ListNode(value);
```



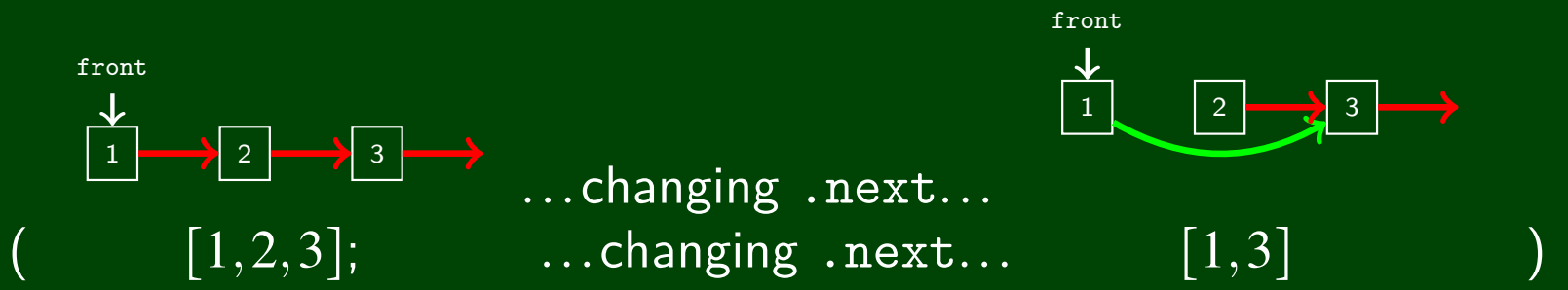

```
10
```

There are only two ways to modify a LinkedList:

- Change front

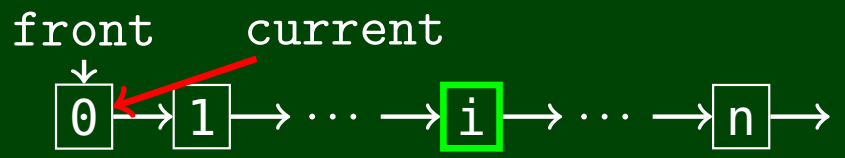


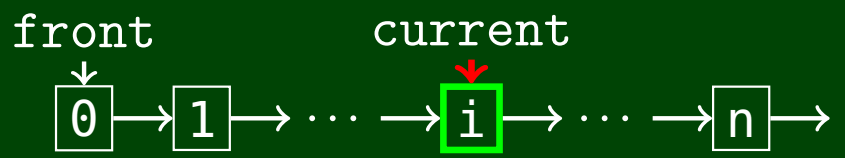
- Change current.next for some ListNode, current



Settting "current" does NOTHING!

```
1  // pre: 0 <= index < size
2  // post: Returns the value in the list at index
3  public int get(int index) {
4     ListNode current = front;
5
6     for (int i = 0; i < index; i++) {
7        current = current.next;
8     }
9
10    return current.data;
11 }
```





Some `LinkedList` Tips!

- Be able to deal with before-and-after `ListNode` pictures
- Know how to loop through a `LinkedList`
  - Use a `while` loop.
  - Don't forget to create a `ListNode current` variable so we don't destroy the original list.
  - Don't forget to update the `current` variable.
- Understand differences and similiarities between `ArrayList` and `LinkedList`
  - They both have the same functionality (`add`,`remove`, etc.)
  - But they're **implemented** differently (array vs. `ListNodes`)
- With `LinkedLists`, you often have to stop **one node before the one you want**.
- DO NOT start coding `LinkedList` problems without drawing pictures first.