CSE 143X

Accelerated Computer Programming I/II

Linked Lists I

Outline

1. Learn how `LinkedIntList` is implemented

2. Learn about the different cases to deal with for `LinkedLists`

Outline

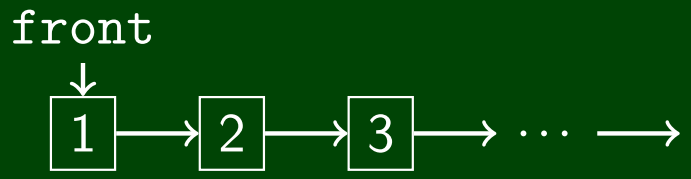
1. Learn how `LinkedIntList` is implemented

2. Learn about the different cases to deal with for `LinkedLists`

- 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`!

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 + "]";
}
```

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 + "]";
}
```

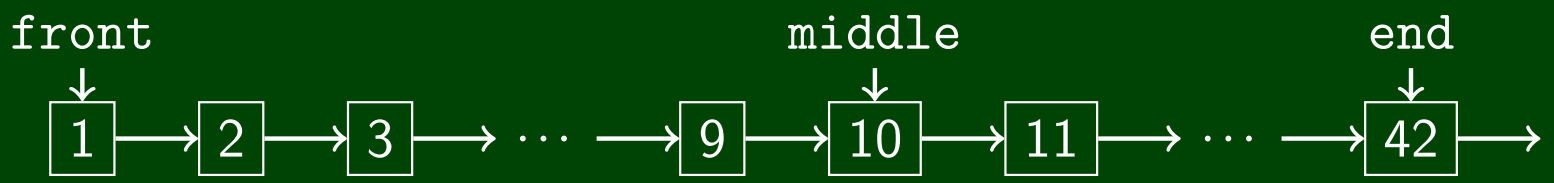
Outline

1. Learn how `LinkedIntList` is implemented

2. Learn about the different cases to deal with for `LinkedLists`

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)

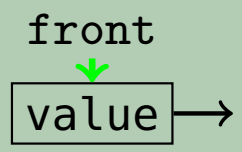
Cases to consider:

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

Add To An Empty List

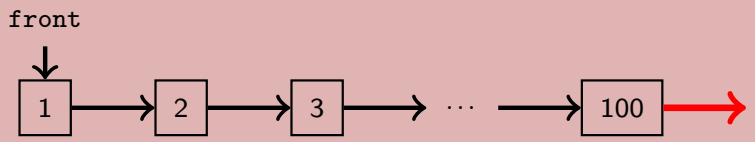
What does an empty list look like?


```
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  }
```

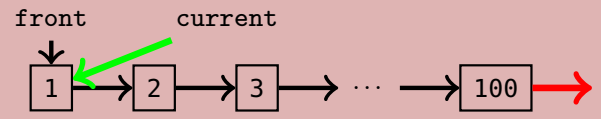


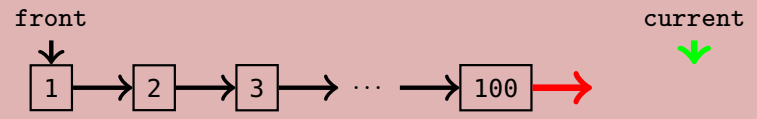
Add To A Non-Empty List

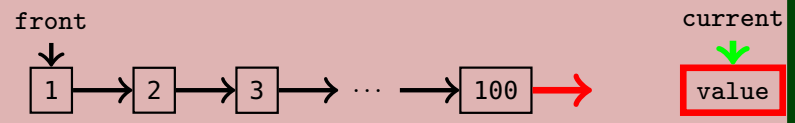
Consider a non-empty list:




```
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
```

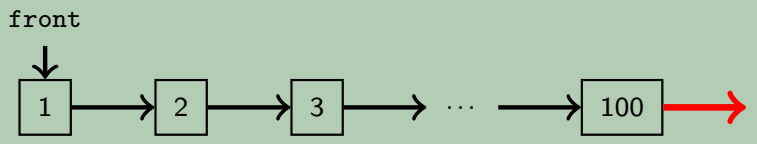




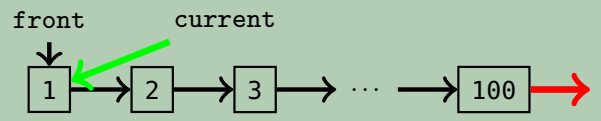


Add To A Non-Empty List (Fixed)

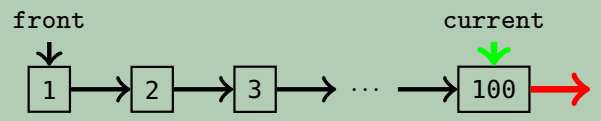
Consider a non-empty list:



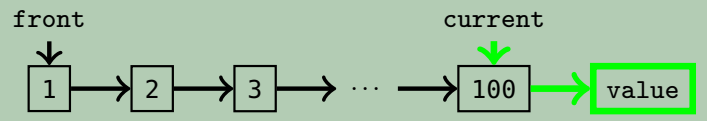

```
1  /* Idea: We want to change the red arrow.
2           Loop until we're at the node before the last node */
3  ListNode current = this.front;
```




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



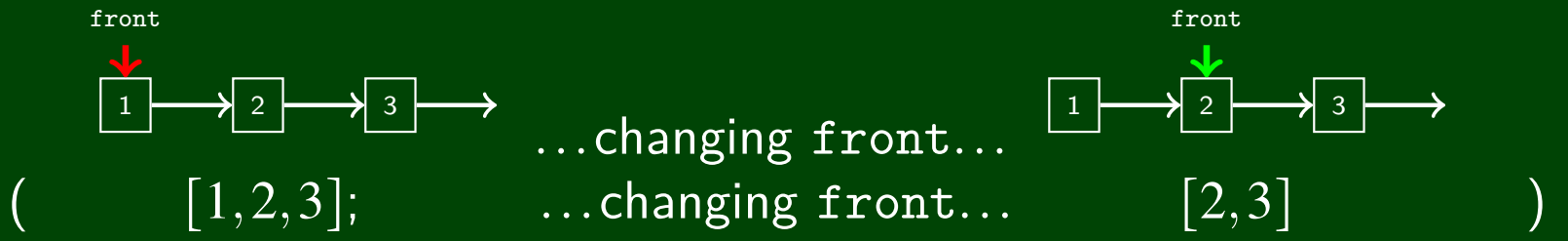

```
8
9  current.next = new ListNode(value);
```



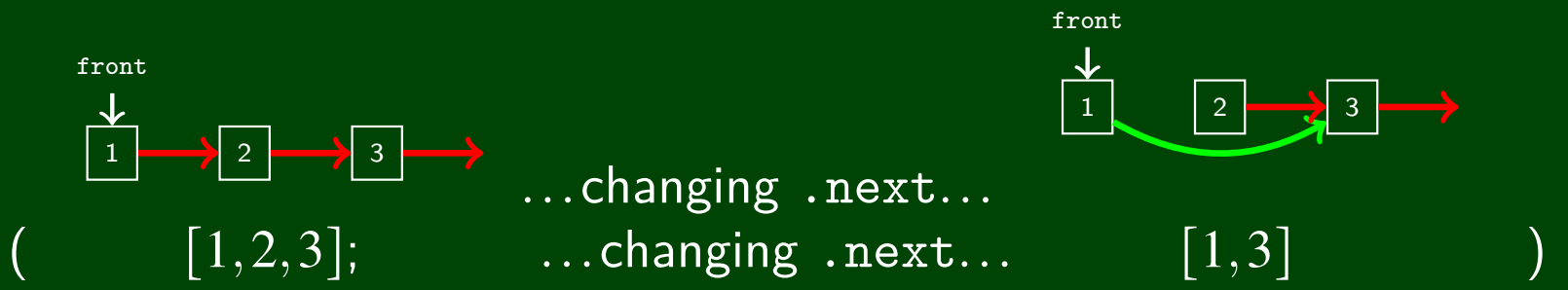

```
10
```

There are only two ways to modify a LinkedList:

- Change front

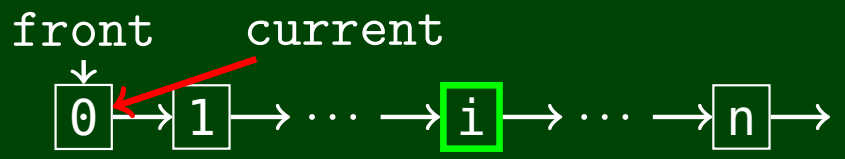


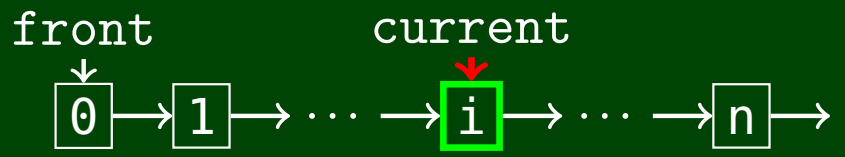
- Change current.next for some ListNode, current



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.
  - 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.

CSE 143X

Accelerated Computer Programming I/II

Linked Lists II

What Are We Doing. . . ?

We're building an alternative data structure to an `ArrayList` with different efficiencies.

Today's Main Goals:

- Get more familiarity with `LinkedLists`
- Write more `LinkedList` methods
- Learn how to "protect" against `NullPointerExceptions`

Outline

1. Get more familiarity with changing `LinkedLists`
2. Write more methods in the `LinkedList` class
3. Protecting Against `NullPointerExceptions`

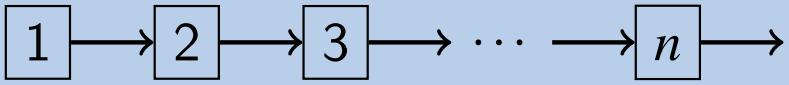
A New `LinkedList` Constructor

New Constructor

Create a constructor

```
public LinkedIntList(int n)
```

which creates the following `LinkedIntList`, when given n:



What kind of loop should we use?

A `for` loop, because we have numbers we want to put in the list.

What cases should we worry about?

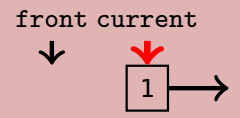
We're creating the list; so, there aren't really "cases".

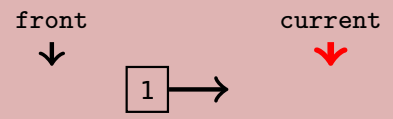
A New `LinkedList` Constructor

First Attempt

```
1  public LinkedList(int n) {
2
3
4     ListNode current = this.front;
5
6     for (int i = 1; i <= n; i++) {
7        current = new ListNode(i);
8
9        current = current.next;
10
11    }
12 }
```

```
/* Current State */
```





Remember, to edit a `LinkedList`, we **MUST** edit one of the following:

- `front`, or
- `node.next` (for some `ListNode node`)

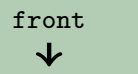
In our code above, we edit `current`, which is neither.

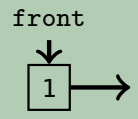
A New LinkedList Constructor

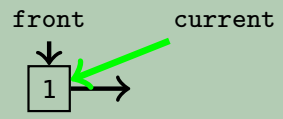
Second Attempt

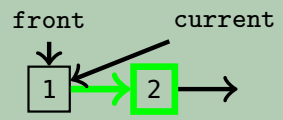
```
1  public LinkedList(int n) {
2
3     if (n > 0) {
4        //n is at least 1...
5        this.front = new ListNode(1);
6
7        ListNode current = this.front;
8
9        for (int i = 1; i <= n; i++) {
10          current.next = new ListNode(i);
11
12          current = current.next;
13
14       }
15    }
16 }
```

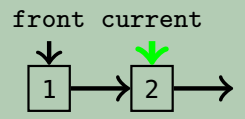
/* Current State */









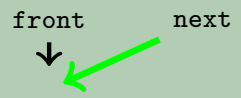


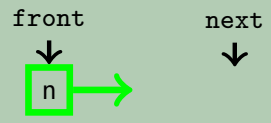
A New `LinkedList` Constructor: Another Solution

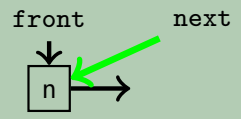
This other solution works by going backwards. Before, we were editing the `next` fields. Here, we edit the `front` field instead:

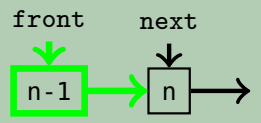
Different Solution!

```
1  public LinkedList(int n) {
2                                                  /* Current State */
3        for (int i = n; i > 0; i--) {
4           ListNode next = this.front;
5
6           this.front = new ListNode(i, next);
7
8        } /* Second time through the loop (for demo)... */
9           //ListNode next = this.front;
10
11          //this.front = new ListNode(i, next);
12
13 }
```







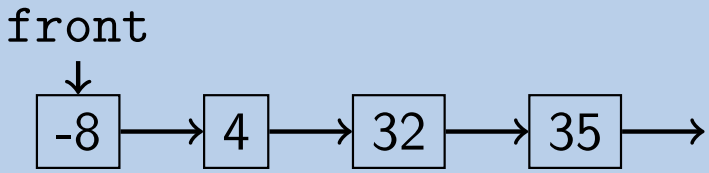


Outline

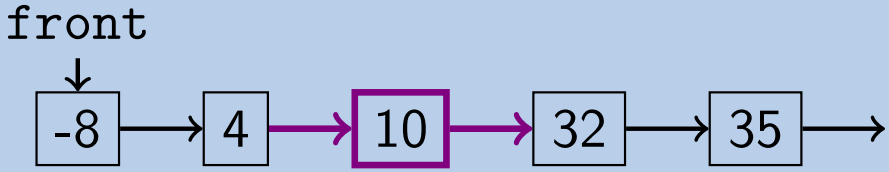
1. Get more familiarity with changing `LinkedLists`
2. Write more methods in the `LinkedList` class
3. Protecting Against `NullPointerExceptions`

addSorted

Write a method `addSorted(int value)` that adds `value` to a sorted `LinkedIntList` and **keeps it sorted**. For example, if we call `addSorted(10)` on the following `LinkedIntList`,



We would get:

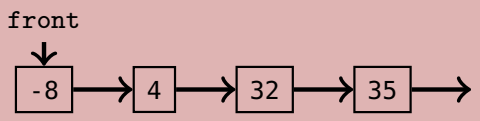


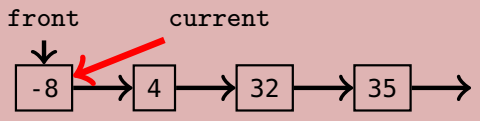
As always, we should approach this by considering the separate cases (and then drawing pictures):

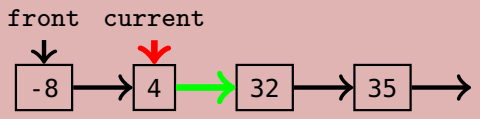
- We're supposed to insert at the front
- We're supposed to insert in the middle
- We're supposed to insert at the back

An Incorrect Solution

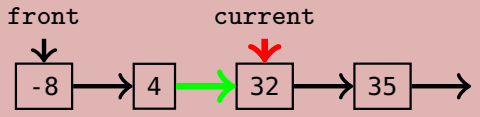
```
1  public void addSorted(int value) { //Say value = 10...
2
3     ListNode current = this.front;
4
5     while (current.data < value) {
6        current = current.next;
7
8     }
9
10
11 }
```







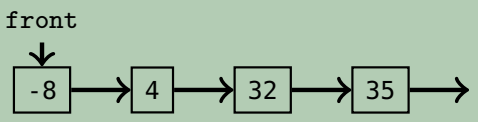
...the while loop continues...

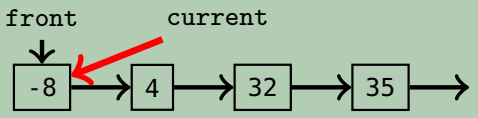


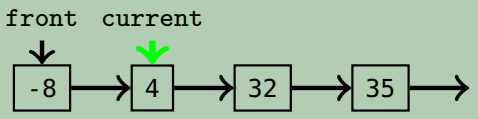
Uh Oh! We went too far! We needed the `next` field BEFORE us.

Fixing the Problem

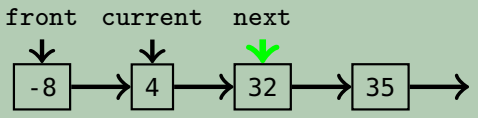
```
1  public void addSorted(int value) { //Say value = 10...
2
3     ListNode current = this.front;
4
5     while (current.next.data < value) {
6        current = current.next;
7
8     }
9
10    ListNode next = current.next;
11
12    current.next = new ListNode(value, next);
13
14 }
```

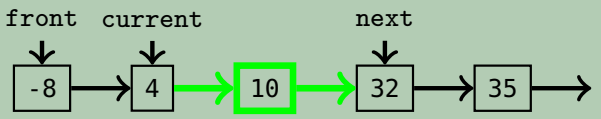






...the while loop STOPS now...

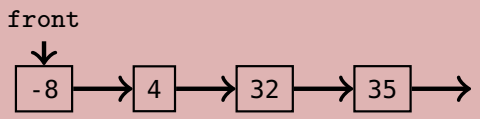


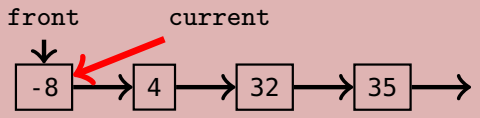


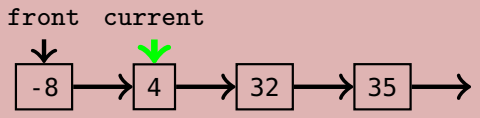
Does this cover all the cases?

Adding At The End?

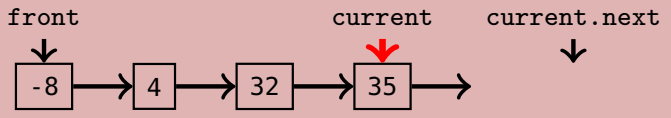
```
1  public void addSorted(int value) { //Say value = 40...
2
3     ListNode current = this.front;
4
5     while (current.next.data < value) {
6        current = current.next;
7
8     }
9
10
11                                  ...AND IT KEEPS ON GOING...
12                          current.next.data → NullPointerException!!!
13 }
```







...the while loop continues...



We fell off the end of the `LinkedList`.
Idea: Make sure `current.next` exists.

Adding At The End?

```
public void addSorted(int value) {
   ListNode current = this.front;
   /* If we are making a check for current.next, we must
    * be sure that current is not null. */
   while (current.next.data < value) {
      /* Since we want to keep on going here,
       * the check must be made in the while loop.
      current = current.next;
   }
}
```

A Fix?

```
public void addSorted(int value) {
   ListNode current = this.front;
   /* The extra check here is useless...we've already checked
    * current.next by the time we get to it. */
   while (current.next.data < value && current.next != null) {
      current = current.next;
   }
}
```

A Real Fix!

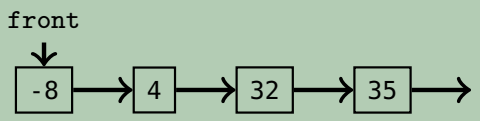
```
public void addSorted(int value) {
   ListNode current = this.front;
   while (current.next != null && current.next.data < value) {
      current = current.next;
   }
}
```

Case: Beginning

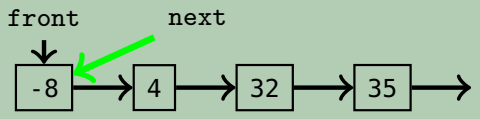
Our current code only sets `current` to a new `ListNode`. Importantly, this never updates `front`; so, we lose the new node.

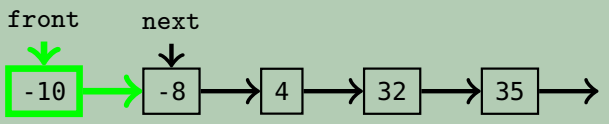
Adding At The Beginning?

```
1  public void addSorted(int value) { //Say value = -10...
2
3     if (value < front.data) {
4        ListNode next = front;
5
6        front = new ListNode(value, next);
7
8     }
9     else {
10       ...
11    }
12 }
```



$-10 < -8 \rightarrow$ `true`





Have we covered all of our cases now?

Outline

1. Get more familiarity with changing `LinkedLists`
2. Write more methods in the `LinkedList` class
3. Protecting Against `NullPointerExceptions`

With `LinkedList` code, every time we make a test (`if`, `while`, etc.), we need to make sure we're protected. Our current code is:

Working Code?

```
1  public void addSorted(int value) {
2     if (value < front.data) {
3        ListNode next = front;
4        front = new ListNode(value, next);
5     }
6     else {
7        while (current.next != null && current.next.data < value) {
8           current = current.next;
9        }
10
11       ListNode next = current.next;
12       current.next = new ListNode(value, next);
13    }
14 }
```

We're "protected" if we **know** we won't get a `NullPointerException` when trying the test. So, consider our tests:

- `value < front.data`
- `current.next != null && current.next.data < value`

So, Are We Protected?

Nope! What happens if `front == null`? We try to get the value of `front.data`, and get a `NullPointerException`. The fix:

Working Code!

```
1  public void addSorted(int value) {
2     if (front == null || value < front.data) {
3        ListNode next = front;
4        front = new ListNode(value, next);
5     }
6     else {
7        while (current.next != null && current.next.data < value) {
8           current = current.next;
9        }
10
11       ListNode next = current.next;
12       current.next = new ListNode(value, next);
13    }
14 }
```

Helpfully, this fix actually handles the empty list case correctly!

Some `LinkedList` Tips!

- Make sure to try all the cases:
  - Empty List
  - Front of Non-empty List
  - Middle of Non-empty List
  - Back of Non-empty List
- To Edit a `LinkedList`, the **assignment** must look like:
  - `this.front = <something>;`, or
  - `node.next = <something>;` (for some `ListNode node` in the list)
- Protect All Of Your Conditionals! Make sure that nothing can accidentally be `null`.
- When protecting your conditionals, make sure the less complicated check goes first.