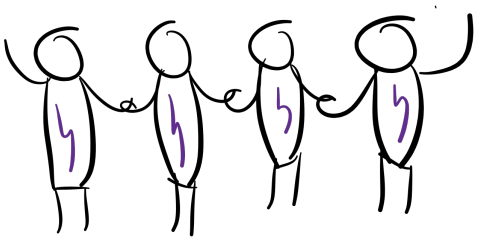
CSE 143X

Accelerated Computer Programming I/II

List Nodes



More Than Arrays

- So far, the only "real data structure" we've seen is **arrays**
- What are some limitations of arrays?
  - You need to know the size before declaration
  - Adding/removing can be annoying
  - They have no methods
- This is where the idea of a **list** comes in

Today's Goals

- Get familiar with the idea of "references" (things that point to objects)
- Define and explore **ListNode**
- Learn about `null`
- Practice modifying linked lists
- Get familiar with matching up code and pictures of linked lists

Memory

Consider the following two documents in a text editor:

- A normal book
- A "choose your own adventure" book

What happens to the page numbers when we...

- Find the last page
- Add a new page in the middle of the book
- Add a new page at the end of the book

Books as Data Structures

- Arrays are stored in memory like a normal book; it's **contiguous**, and **random-access**
- For the next three lectures, we'll discuss the data structure equivalent to a "choose your own adventure" book

Mystery


```
1  int[] a1 = new int[2];
2  a1.x = 8;
3  a1.y = 3;
4  int[] a2 = new int[2];
5  a2.x = 100;
6
7  int[] a3 = a2;
8  a2 = a1;
9  a2.x = 5;
10 a1.y = 2;
11 System.out.println("A: " + a1.x + ", " + a1.y);
12 System.out.println("B: " + a2.x + ", " + a2.y);
13 System.out.println("C: " + a3.x + ", " + a3.y);
```

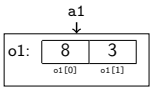
What does this code print?

OUTPUT

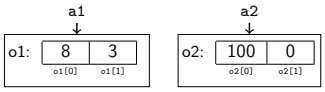
```
>> A: 5, 2
>> B: 5, 2
>> C: 100, 0
```

Mystery Explained 5

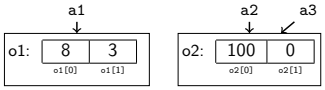
```
1 int[] a1 = new int[2]; //o1
2 a1.x = 8;
3 a1.y = 3;
```




```
4 int[] a2 = new int[2]; //o2
5 a2.x = 100;
```

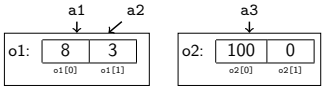



```
6 int[] a3 = a2;
```

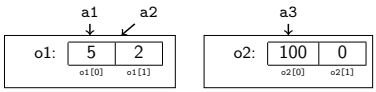


Mystery Explained (cont.) 6

```
7 a2 = a1;
```




```
8 a2.x = 5;
9 a1.y = 2;
```



What's Going On?

- The keyword **new** creates an actual new object to point to (o1, o2).
- All the other variables just point to objects that were created with new (a1,a2,a3).

ListNode 7

ListNode Class

```
1 public class ListNode {
2    int data;
3    ListNode next;
4 }
```

A ListNode is:

The **box** represents data, and the **arrow** represents next.

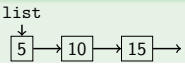
Since next is of ListNode type, the arrow can either point to nothing (null) or another ListNode.

ListNode 8

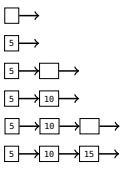
ListNode Class

```
1 public class ListNode {
2    int data;
3    ListNode next;
4 }
```

How can we use code to make this list?




```
1 ListNode list = new ListNode();
2 list.data = 5;
3 list.next = new ListNode();
4 list.next.data = 10;
5 list.next.next = new ListNode();
6 list.next.next.data = 15;
```

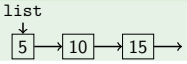


ListNode 9

ListNode Class

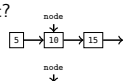
```
1 public class ListNode {
2    int data;
3    ListNode next;
4 }
```

How can we use code to make this list?

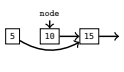


What does this code do to our list?

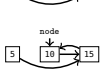
```
1 ListNode node = list.next;
```




```
2 list.next = list.next.next;
```




```
3 list.next.next = node;
```

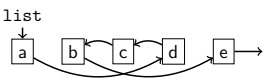


This isn't quite

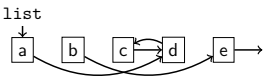
What's wrong?

Working With Linked Lists 10

```
list.next.next.next = list.next;
```



The code sets **the arrow** coming out of c to **the node** d.

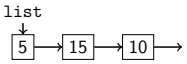


The **left side** of the assignment is **an arrow**.

The **right side** of the assignment is **a node**.

Dereferencing

When we call `.next`, we follow an **arrow** in the list. What happens if we have this list:



And we call the following code:

```
1 System.out.println(list.next.next.next);
```

Or this code:

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

The first one prints `null`. The second throws a `NullPointerException`.

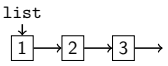
`null` means "end of the list"!

Constructors!


```
1  public class ListNode {
2     int data;
3     ListNode next;
4
5     public ListNode(int data) {
6        this(data, null);
7     }
8
9     public ListNode(int data, ListNode next) {
10       this.data = data;
11       this.next = next;
12    }
13 }
```

What list does this code make?

```
ListNode list = new ListNode(1, null);
list.next = new ListNode(2, null);
list.next.next = new ListNode(3, null);
```



Can we do this without ever using `.next`?

```
ListNode list = new ListNode(1, new ListNode(2, new ListNode(3, null)));
```

CSE 143x

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

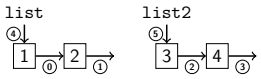
Does That Make Sense? 1

Quick Note: When I say "does that make sense?"...

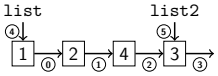
- If it does make sense, yell "yes"
- Otherwise, say nothing.

Another `ListNode` Example 2

Before:



After:



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

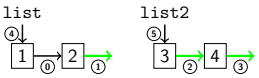
There are FOUR. Each box is a `ListNode`.

How many references to `ListNodes` are there?

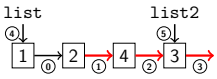
There are SIX. Every arrow is a reference to a `ListNode`.

Another `ListNode` Example (Solution) 3

Before:

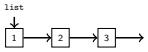


After:




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

Printing a `LinkedList` 4

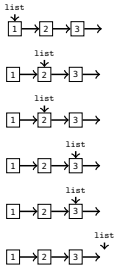


Printing a LinkedList Manually

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

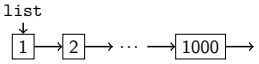
Now, note that we can use a variable to keep track of where we are:

```
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 **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 }
```

`LinkedIntList`

- 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`!