CSE 143
Lecture 6

Linked List Basics

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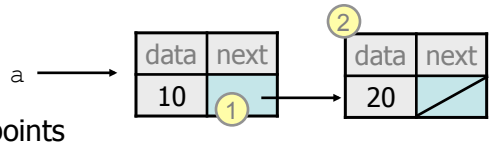
http://www.cs.washington.edu/143/

References vs. objects

variable = **value**;

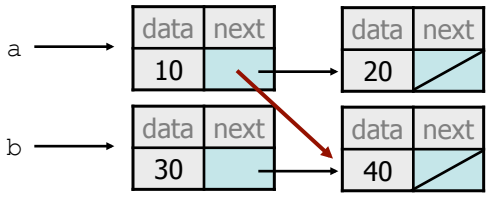
a *variable* (left side of =) is an arrow (the base of an arrow)
a *value* (right side of =) is an object (a box; what an arrow points at)

- For the list at right:
  - `a.next` = **value**;
    means to adjust where (1) points
  - **variable** = `a.next;`
    means to make **variable** point at (2)



Reassigning references

- when you say:
  - `a.next = b.next;`
- you are saying:
  - "Make the *variable* `a.next` refer to the same *value* as `b.next`."
  - Or, "Make `a.next` point to the same place that `b.next` points."



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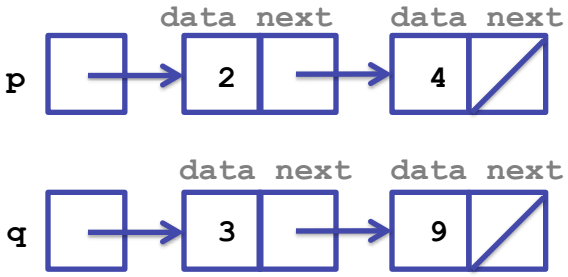
Basic Linked List Questions

- Suppose you have two variables of type **`ListNode`** named **`p`** and **`q`**. Consider the following situation:



- How many variables of type **`ListNode`** are there?
- How many **`ListNode`** objects are there?

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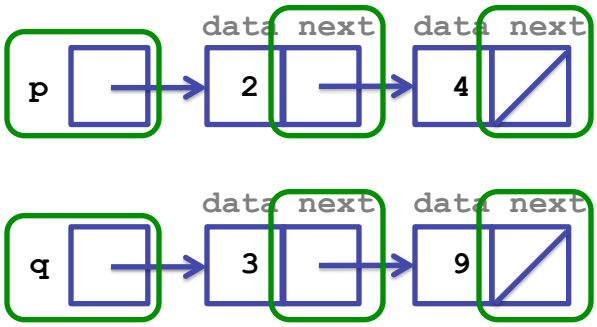
Basic Linked List Questions

- How many variables of type `ListNode` are there?
  - **6, circled in green**



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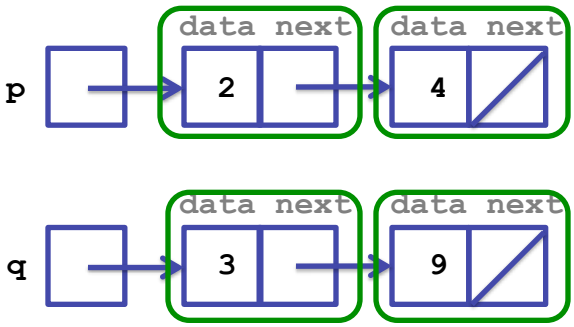
Basic Linked List Questions

- How many `ListNode` objects are there?
  - **4, circled in green**



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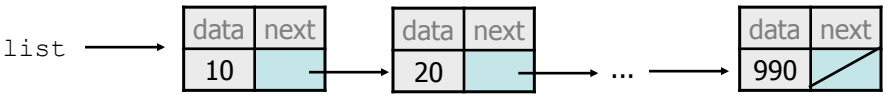
Linked node question

- Suppose we have a long chain of list nodes:



  - We don't know exactly how long the chain is.

- How would we print the data values in all the nodes?

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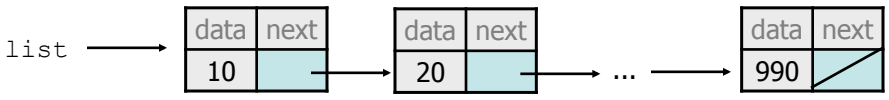
Algorithm pseudocode

- Start at the **front** of the list.
- While (there are more nodes to print):
  - Print the current node's **data**.
  - Go to the **next** node.

- How do we walk through the nodes of the list?

```
list = list.next;    // is this a good idea?
```



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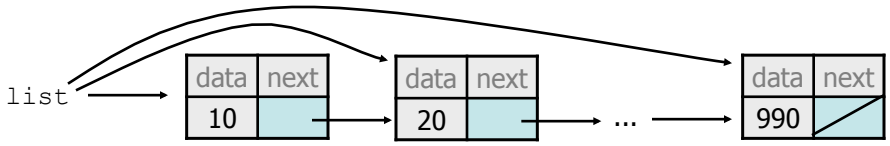
Traversing a list?

- One (bad) way to print every value in the list:

```
while (list != null) {
    System.out.println(list.data);
    list = list.next;     // move to next node
}
```

  - What's wrong with this approach?
    - (It loses the linked list as it prints it!)



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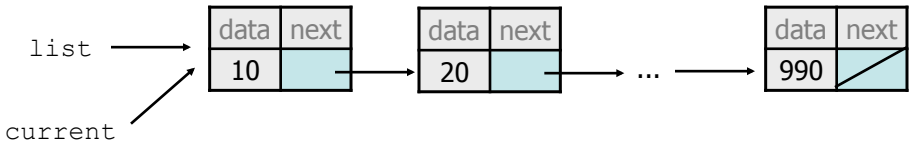
A `current` reference

- Don't change `list`. Make another variable, and change that.
  - A `ListNode` variable is NOT a `ListNode` object

```
ListNode current = list;
```



- What happens to the picture above when we write:

```
current = current.next;
```

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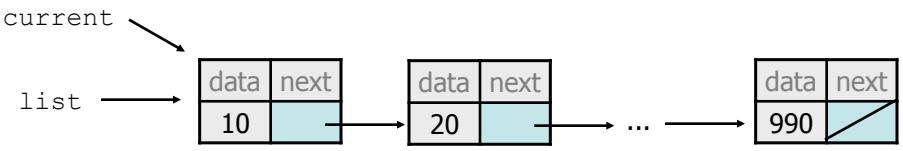
Traversing a list correctly

- The correct way to print every value in the list:

```
ListNode current = list;
while (current != null) {
    System.out.println(current.data);
    current = current.next;  // move to next node
}
```


  - Changing `current` does not damage the list.



Linked list vs. array

- Algorithm to print list values:

```
ListNode front = ...;

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

- Similar to array code:

```
int[] a = ...;

int i = 0;
while (i < a.length) {
    System.out.println(a[i]);
    i++;
}
```

Relationship to Array Code

- A table explaining this relationship:

Description	Array Code	Linked List Code
go to front of list	`int i = 0;`	`ListNode current = front;`
continue?	`i < size`	`current != null`
get current value	`elementData[i]`	`current.data`
go to next element	`i++;`	`current = current.next;`

- This may be helpful if you are comfortable with arrays

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For Loops

- Of course, we usually write the array code in a for loop:

```
for (int i = 0; i < size; i++) {
    System.out.println(elementData[i]);
}
```

- And we can still do this with the linked list code:

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

- Whether you use a for loop or a while loop to traverse the linked list is up to you.

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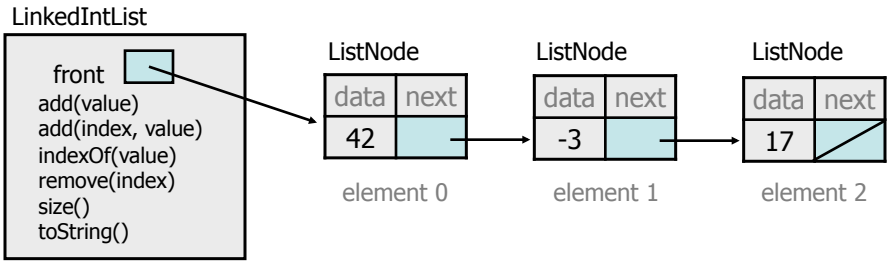
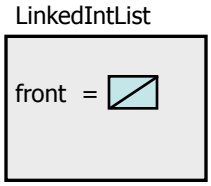
A `LinkedIntList` class

- Let's write a collection class named `LinkedIntList`.
  - Has the same methods as `ArrayIntList`:
    - `add`, `add`, `get`, `indexOf`, `remove`, `size`, `toString`
  - The list is internally implemented as a chain of linked nodes
    - The `LinkedIntList` keeps a reference to its `front` as a field
    - `null` is the end of the list; a `null` front signifies an empty list



`LinkedIntList` class v1

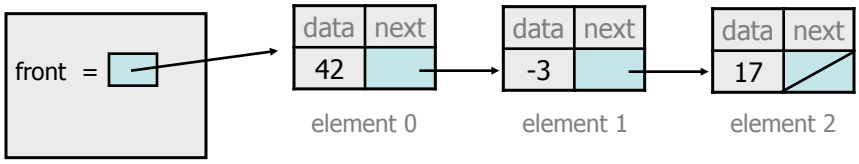
```
public class LinkedIntList {
    private ListNode front;

    public LinkedIntList() {
        front = null;
    }

    methods go here

}
```



Implementing `add`

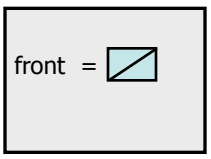
```
// Adds the given value to the end of the list.
public void add(int value) {
    ...
}
```

- How do we add a new node to the end of a list?
- Does it matter what the list's contents are before the add?

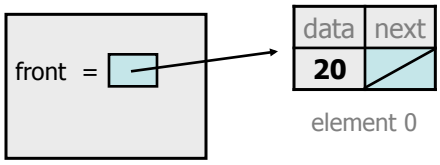


Adding to an empty list

- Before adding 20:



After:



- We must create a new node and attach it to the list.

The `add` method, 1st try

```
// Adds the given value to the end of the list.
public void add(int value) {
    if (front == null) {
        // adding to an empty list
        front = new ListNode(value);
    } else {
        // adding to the end of an existing list

        ...

    }
}
```

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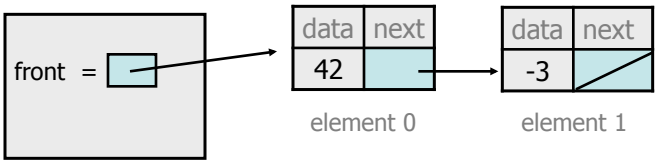
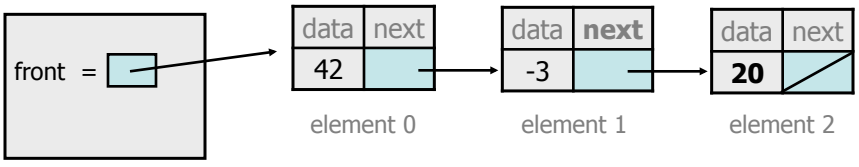
Adding to non-empty list

- Before adding value 20 to end of list:



- After:



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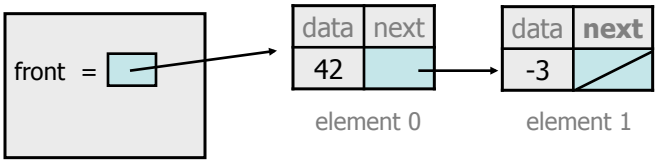
Don't fall off the edge!

- To add/remove from a list, you must modify the `next` reference of the node *before* the place you want to change.



  - Where should `current` be pointing, to add 20 at the end?
  - What loop test will stop us at this place in the list?

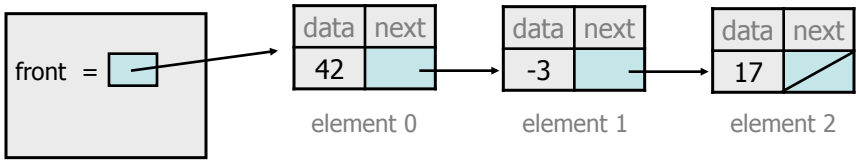
The `add` method

```
// Adds the given value to the end of the list.
public void add(int value) {
    if (front == null) {
        // adding to an empty list
        front = new ListNode(value);
    } else {
        // adding to the end of an existing list
        ListNode current = front;
        while (current.next != null) {
            current = current.next;
        }
        current.next = new ListNode(value);
    }
}
```

Implementing `get`

```
// Returns value in list at given index.
public int get(int index) {
    ...
}
```

– Exercise: Implement the `get` method.



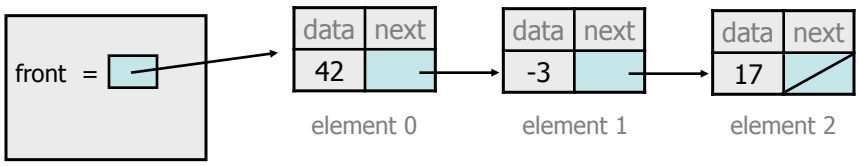
The `get` method

```
// Returns value in list at given index.
// Precondition: 0 <= index < size()
public int get(int index) {
    ListNode current = front;
    for (int i = 0; i < index; i++) {
        current = current.next;
    }
    return current.data;
}
```

Implementing add (2)

```
// Inserts the given value at the given index.
public void add(int index, int value) {
    ...
}
```

– Exercise: Implement the two-parameter `add` method.



The add method (2)

```
// Inserts the given value at the given index.
// Precondition: 0 <= index <= size()
public void add(int index, int value) {
    if (index == 0) {
        // adding to an empty list
        front = new ListNode(value, front);
    } else {
        // inserting into an existing list
        ListNode current = front;
        for (int i = 0; i < index - 1; i++) {
            current = current.next;
        }
        current.next = new ListNode(value,
                                    current.next);
    }
}
```