Java **`LinkedList`** class; Iterators

- Introduction to linked lists
  - comparison with arrays
- Useful LinkedList methods
- Traversing a LinkedList: iterators
- ListIterator methods
- Using an iterator to…
  - examine elements
  - modify elements
  - insert elements
  - remove elements

Announcements

- Lab 8 has been published; includes advanced preparation. (uses LinkedList class)
- PA3 has been published.

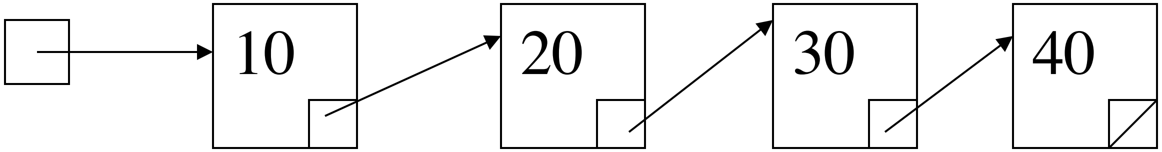
Review

- Want to store a collection of things (elements).
- All elements are the same type
- Want random access to elements
- Can use an array (or ArrayList):

0	1	2	3	4	5			
10	20	30	40					. . .

Introduction

- Alternate: linked list
  - Only use as much space as you need at a time.
  - Can insert and delete from middle without shifting values left or right by one.
  - However *no* random access based on location. E.g., get element at position **`k`** is not constant time:
    - has to traverse to element **`k`**



Linked list implementations

- Will discuss code for writing our own linked lists later this semester (using C++)
- Java (and C++) has a LinkedList class:

```
LinkedList<ElementType>
```

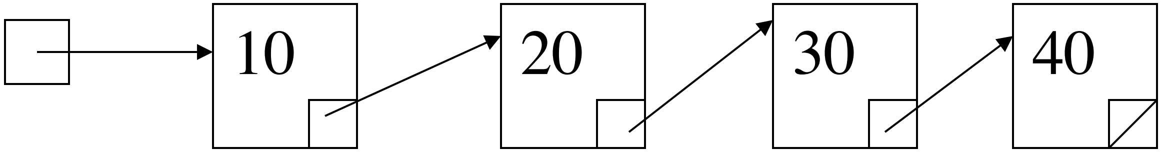
- has some of the same methods as **`ArrayList`**
- but, WARNING, some of them run slower. E.g.,

```
list.get(i)
list.set(i, newVal)
```

Using ArrayList methods with LinkedLists

```
void printList(LinkedList<Integer> list) {
  for (int i = 0; i < list.size(); i++) {
    System.out.println(list.get(i));
  }
}
```

- What is the big-O time to run this code?



Using ArrayList methods with LinkedLists

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

- A bad way to traverse a linked list.

- Generally avoid using the methods that take an index: e.g., add(i, object), remove(i), set(i, object)

Putting elements in a LinkedList

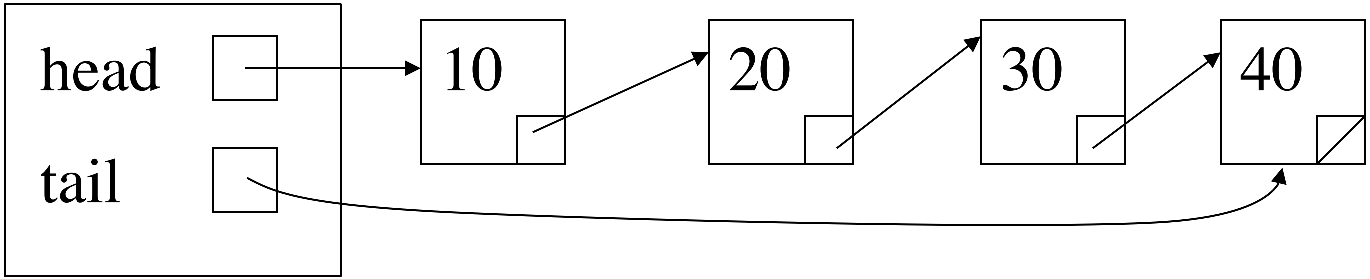
- Create an empty list:

```
LinkedList<Integer> list = new LinkedList<Integer>();
```

- Put some stuff in the list:

```
list.add(10);
list.add(20);
list.add(30);
list.add(40);
```

- Adding to the end (or beginning) is efficient: O(1)
- Internally uses a "tail" pointer (or equivalent)



Other LinkedList methods

- Operations that access the beginning or end are efficient:

```
// suppose list contains :
        [Anne, Sally, George, Carol]

list.addFirst("Gaga");

list.getFirst()   // returns Gaga

list.getLast()    // returns Carol

list.removeFirst();   // removes Gaga

list.removeLast();    // removes Carol
```

So, how *do* we traverse a LinkedList?

- Recall: **`for`** loop with **`get(i)`** is a bad idea.
- Have to use a **`ListIterator`** object
- Associate it with a particular list
- Abstracts the idea of some position in the list
- We can also use it to add or remove from the middle.

ListIterator

- Iterator interface is similar to **`Scanner`**:

  `next()`

  `hasNext()`
- Guard calls to **`next()`** with a call to **`hasNext()`** so you don't go past the end of the list
- To get an iterator positioned at the start of **`list`**:

```
ListIterator<String> iter = list.listIterator();
```

ListIterator

- Iterator points between two elements.
- 5 possible positions for iterator on the following list:

```
[Anne, Sally, George, Carol]
```

Traversing with a **`ListIterator`**

```
// print out all the elements of the list:
ListIterator<String> iter = list.listIterator();
while (iter.hasNext()) {
   String word = iter.next();
   System.out.println(word);
}
```

`next()`: returns the element after iter position and advances iter beyond that element

Suppose **`list`** contains:

```
        [Anne, Sally, George, Carol]
```

`next()` changes state of iterator

- Want to print out all values >=60
- Suppose list contains:

  `[33, 94, 56, 59]`
- What is the output of the following code:

```
ListIterator<Integer> iter = list.listIterator();
while (iter.hasNext()) {
   if (iter.next() >= 60) {
      System.out.println(iter.next());
   }
}
```

Let's write a non-buggy version…

```
ListIterator<Integer> iter = list.listIterator();
```

modifying elements using iterator

Suppose list contains:

```
          [33, 94, 86, 59]
```

- Adds 10 points to everyone's score?

```
ListIterator<Integer> iter = list.listIterator();
while (iter.hasNext()) {
   int current = iter.next();
   current += 10;
}
```

- How to modify the values in the list?

modifying elements using iterator (cont.)

- How to modify the values actually in the list?

```
iter.set(newValue)
```

replaces the element last returned by **`next()`**

- Suppose list contains:

```
        [33, 94, 86, 59]
```

- Add 10 points to everyone's score:

```
ListIterator<Integer> iter = list.listIterator();
while (iter.hasNext()) {
   int current = iter.next();
   iter.set(current+10);
}
```

Lists containing mutable objects

- We've modified the object reference (only way to change an immutable object), using **`set`**
- Could modify contents of a mutable object instead by using a mutator.
- Translate all Points in a list (mutable objects):

```
ListIterator<Point> iter = list.listIterator();
while (iter.hasNext()) {
    Point current = iter.next();
    current.translate(10, 20);
}
```

ArrayLists containing mutable objects

- (Review) Similarly with ArrayList:
- Translate all Points in an ArrayList:

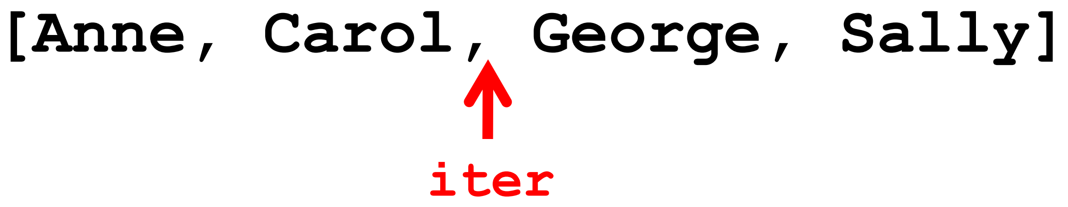
```
ArrayList<Point> pointList = . . .;
for (int i = 0; i < pointList.size(); i++) {
   Point current = pointList.get(i);
   current.translate(10, 20);
}
```

Inserting/removing from the middle of the list

- Review: more efficient than with array, don't have to shift a bunch of elements.
- Still would have to traverse to get to the correct place to insert/remove.
- Use the *iterator* **`add`** / **`remove`** methods

ListIterator **`add`** method

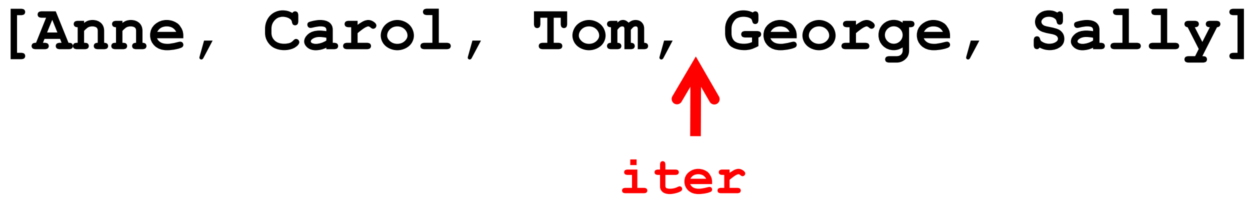
- Recall **`iter`** is positioned between two values.



```
[Anne, Carol, George, Sally]
              iter
```

- **`iter.add(newValue)`**

  inserts **`newValue`** at that position
- after operation, iterator is positioned after **`newValue`**
- Suppose **`newValue = "Tom"`**



```
[Anne, Carol, Tom, George, Sally]
                   iter
```

Example of using add

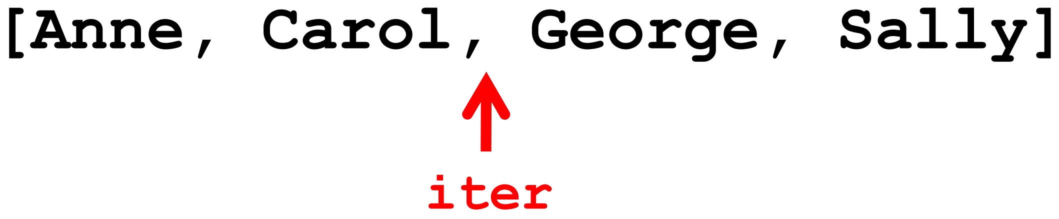
Duplicate all the values in a list:

```
list before = [Anne, Carol, George]
list after =
        [Anne, Anne, Carol, Carol, George, George]

public static void dupe(LinkedList<String> list) {
```

ListIterator **`remove`** method

- Recall **`iter`** is positioned between two values.

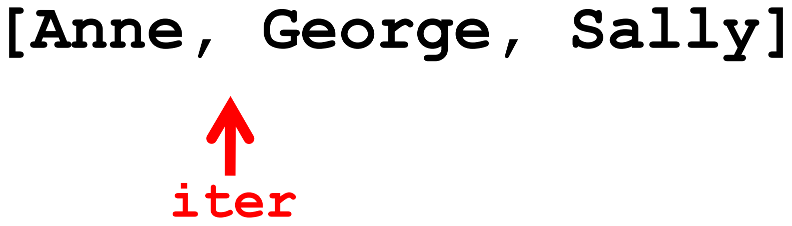


```
[Anne, Carol, George, Sally]
            ↑
           iter
```

- **`iter.remove()`**

removes the element that was returned by the last call to **`next()`**

- after operation, iterator is positioned where the old value used to be



```
[Anne, George, Sally]
     ↑
    iter
```

Example of using **`remove`**

Remove all values below a threshold (e.g., 60)

```
list before = [93, 86, 57, 59, 100]
list after = [93, 86, 100]

void removeLT(LinkedList<Integer> list,
              int threshold) {
```

More on LinkedLists

- There are more **`LinkedList`** and **`ListIterator`** methods that may be useful for lab 8.
  - E.g., you can also iterate backwards over a list.
- Remember: avoid using the LinkedList methods that take an **`index`** as a param in a loop.
  - Note: if index is **`0`** or **`size()-1`** it's ok, because optimizes those cases with head and tail pointer (O(1))
- Use online documentation for more information.