The List ADT

Objectives

- Define a list abstract data type
- Examine different classes of lists
- Examine various list implementations
- Compare list implementations

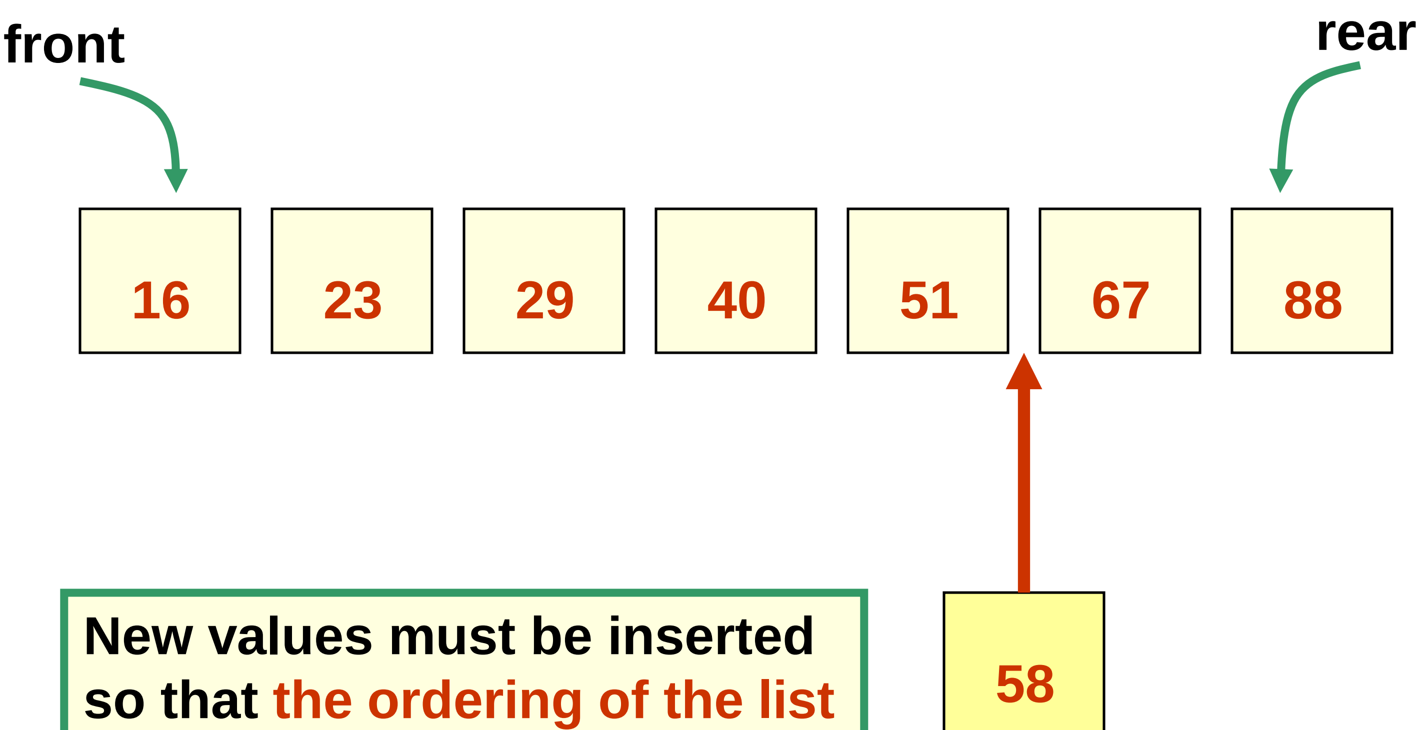
Lists

- A ***list*** is a ***linear*** collection, like a stack and queue, but more flexible: adding and removing elements from a list does *not* have to happen at one end or the other
- We will examine three types of list collections:
  - ***ordered*** lists
  - ***unordered*** lists
  - ***indexed*** lists

Ordered Lists

- ***Ordered list***: Its elements are ordered by some inherent characteristic of the elements
- ***Examples***:
  - Names in alphabetical order
  - Numeric scores in ascending order
- So, the elements themselves determine where they are stored in the list

Conceptual View of an Ordered List

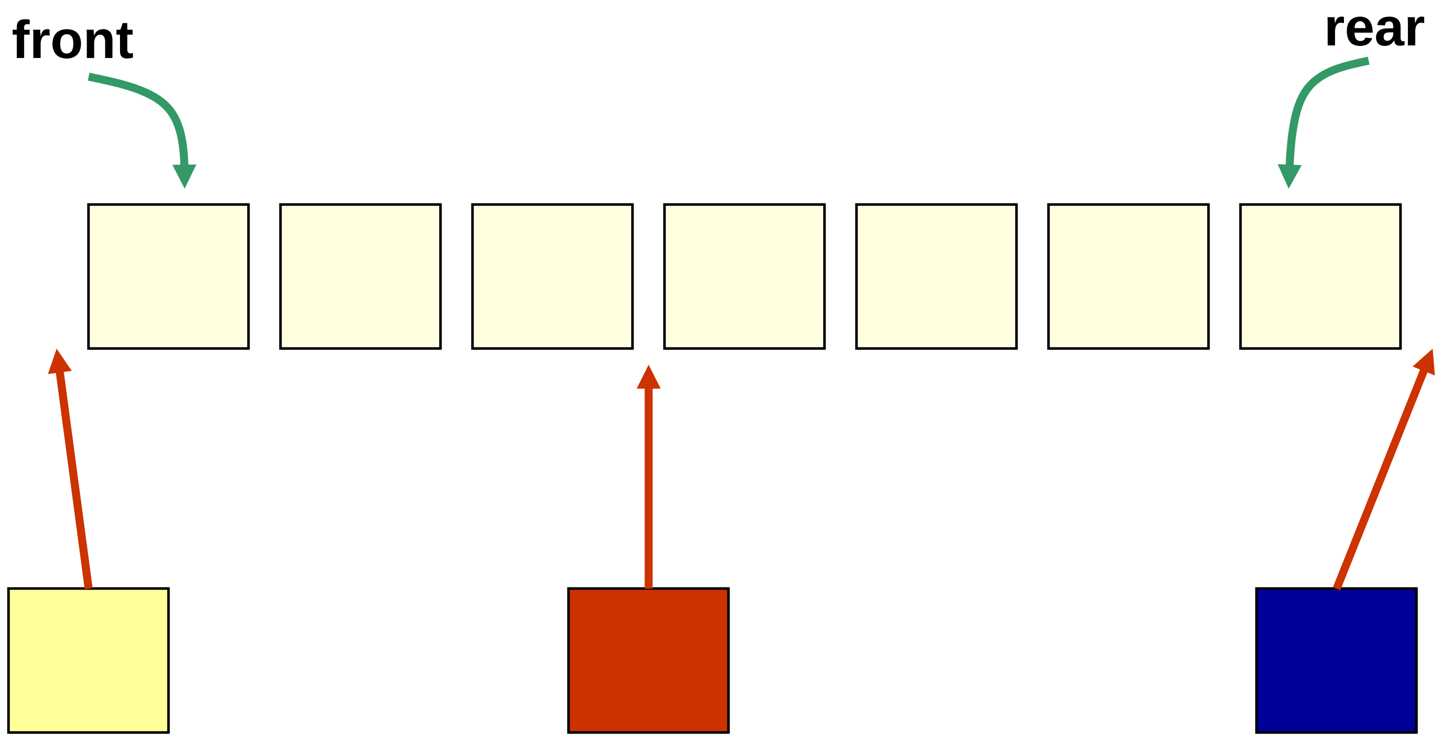


New values must be inserted so that the ordering of the list is maintained

Unordered Lists

- ***Unordered list***: the order of the elements in the list is ***not*** based on a characteristic of the elements, but is determined by the ***user*** of the list
- A new element can be put
  - on the front of the list,
  - or on the rear of the list,
  - or after a particular element already in the list
- ***Examples***: shopping list, to-do list, …

Conceptual View of an Unordered List

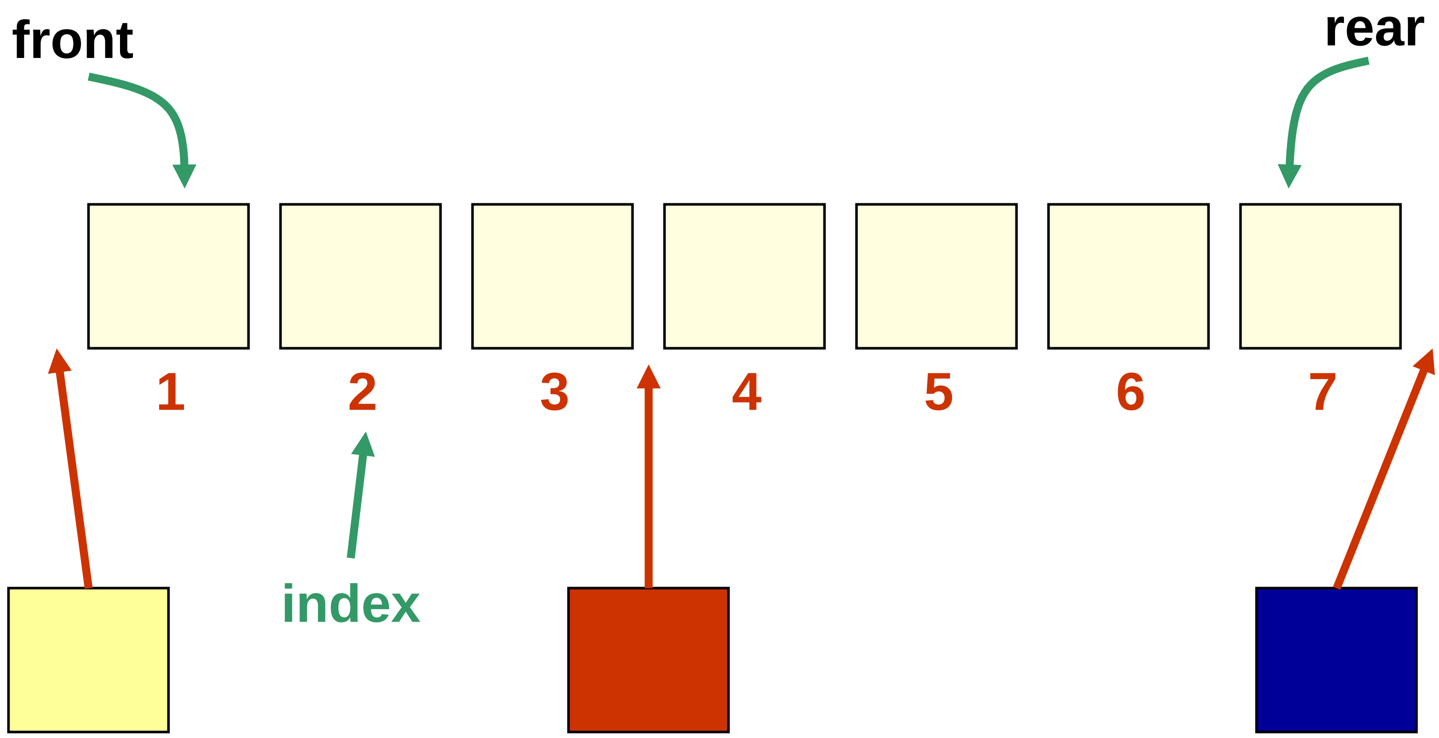


New values can be inserted anywhere in the list

Indexed Lists

- ***Indexed list*:** elements are referenced by their ***numeric position*** in the list, called its ***index***
- It is the position in the list that is important, and the user can determine the order in which the items go in the list
- Every time the list changes, the position (index) of an element may change
- ***Example***: current first-place holder in the bobsled race

Conceptual View of an Indexed List



New values can be inserted at any position in the list

List Operations

- Operations common to *all* list types include:
  - ***Adding/removing*** elements
  - ***Checking the status*** of the list (**isEmpty**, **size**)
  - ***Iterating through*** the elements in the list (more on this later!)
- The key differences between the list types involve the way elements are ***added***

The Common Operations on a List

Operation	Description
removeFirst	Removes the first element from the list
removeLast	Removes the last element from the list
remove	Removes a particular element from the list
first	Gets the element at the front of the list
last	Gets the element at the rear of the list
contains	Determines if a particular element is in the list
isEmpty	Determines whether the list is empty
size	Determines the number of elements in the list
toString	Returns a string representation of the list

Operation Particular to an Ordered List

Operation	Description
add	Adds an element to the list (in the correct place)

Operations Particular to an Unordered List

Operation	Description
addToFront	Adds an element to the front of the list
addToRear	Adds an element to the rear of the list
addAfter	Adds an element after a particular element already in the list

Operations Particular to an Indexed List

Operation	Description
add	Adds an element at a particular index in the list
set	Sets the element at a particular index in the list overwriting any element that was there
get	Returns a reference to the element at the specified index
indexOf	Returns the index of the specified element
remove	Removes and returns the element at a particular index

List Operations

- We use Java interfaces to formally define the lists ADTs
- Note that interfaces can be defined via ***inheritance*** (derived from other interfaces)
  - Define the common list operations in one interface
    - See ***ListADT.java***
  - Derive the thee others from it
    - see ***OrderedListADT.java***
    - see ***UnorderedListADT.java***
    - see ***IndexedListADT.java***

ListADT Interface

```
import java.util.Iterator;
public interface ListADT<T> {

  //  Removes and returns the first element from this list
  public T removeFirst ( );
  //  Removes and returns the last element from this list
  public T removeLast ( );
  //  Removes and returns the specified element from this list
  public T remove (T element);
  //  Returns a reference to the first element on this list
  public T first ( );
  //  Returns a reference to the last element on this list
  public T last ( );
  //  cont'd..
```

```
   // ..cont'd
   // Returns true if this list contains the specified target element
   public boolean contains (T target);
   // Returns true if this list contains no elements
   public boolean isEmpty( );
   // Returns the number of elements in this list
   public int size( );
   // Returns a string representation of this list
   public String toString( );
}
```

OrderedList ADT

```
public interface OrderedListADT<T> extends ListADT<T>
{
  //  Adds the specified element to this list at the proper location
  public void add (T element);
}
```

UnorderedListADT

```
public interface UnorderedListADT<T> extends ListADT<T>
{
  //  Adds the specified element to the front of this list
  public void addToFront (T element);

  //  Adds the specified element to the rear of this list
  public void addToRear (T element);

  //  Adds the specified element after the specified target
  public void addAfter (T element, T target);
}
```

IndexedListADT

```
public interface IndexedListADT<T> extends ListADT<T> {
  //  Inserts the specified element at the specified index
  public void add (int index, T element);
  //  Sets the element at the specified index
  public void set (int index, T element);
  //  Returns a reference to the element at the specified index
  public T get (int index);
  //  Returns the index of the specified element
  public int indexOf (T element);
  //  Removes and returns the element at the specified index
  public T remove (int index);
  }
```

Discussion

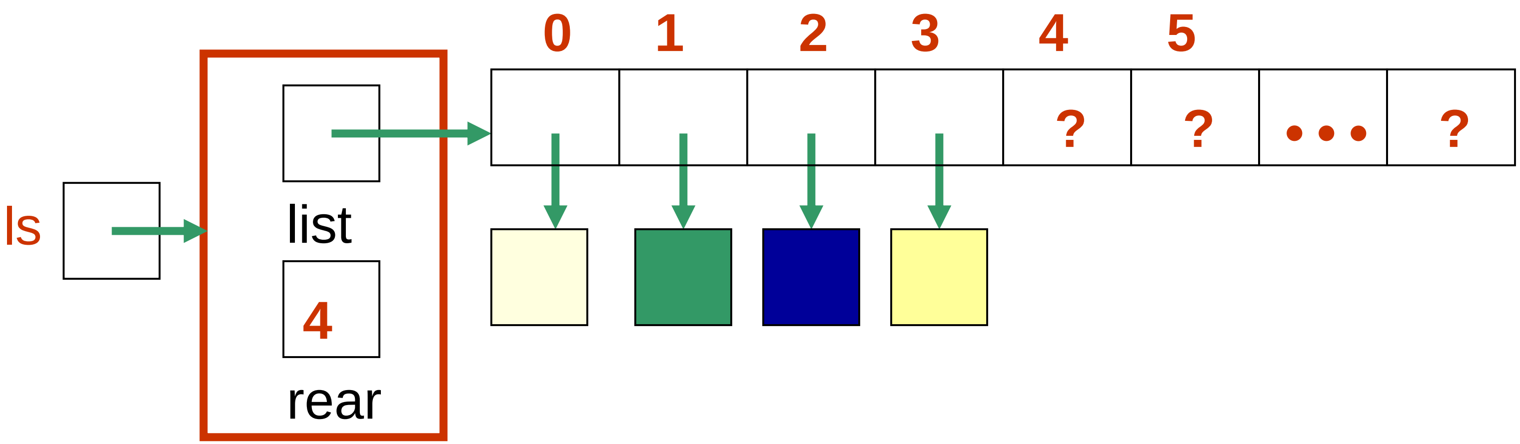
- Note that the remove method in the IndexedList ADT is overloaded
  - Why? Because there is a remove method in the parent ListADT
    - This is *not* overriding, because the parameters are different

List Implementation using Arrays

- Container is an array
- Fix one end of the list at index 0 and shift ***as needed*** when an element is added or removed
- Is a shift needed when an element is added
  - at the front?
  - somewhere in the middle?
  - at the end?
- Is a shift needed when an element is removed
  - from the front?
  - from somewhere in the middle?
  - from the end?

An Array Implementation of a List

An array-based list ls with 4 elements



```java
//-----------------------------------------------------------------
//  Removes and returns the specified element.
//-----------------------------------------------------------------
public T remove (T element) throws ElementNotFoundException
{
   T result;
   int index = find (element);    // uses helper method find
   if (index == NOT_FOUND)
      throw new ElementNotFoundException("list");
   result = list[index];
   rear--;
   // shift the appropriate elements
   for (int scan=index; scan < rear; scan++)
      list[scan] = list[scan+1];
   list[rear] = null;
   return result;
}
```

```
//-----------------------------------------------------------------
//  Returns the array index of the specified element,
//  or the constant NOT_FOUND if it is not found.
//-----------------------------------------------------------------
private int find (T target)
{
   int scan = 0, result = NOT_FOUND;
   boolean found = false;
   if (! isEmpty( ))
      while (! found && scan < rear)
         if (target.equals(list[scan])
            found = true;
         else
            scan++;
   if (found)
      result = scan;
   return result;
}
```

```
//-----------------------------------------------------------------
//  Returns true if this list contains the specified element.
//-----------------------------------------------------------------
public boolean contains (T target)
{
   return (find(target) != NOT_FOUND);
                                        //uses helper method find
}
```

The **Comparable** Interface

- For an ordered list, the *actual* class for the generic type **T** ***must*** have a way of comparing elements so that they can be ordered
  - So, it must implement the **Comparable** interface, ***i.e.*** it must define a method called **compareTo**
- But, the *compiler* does not know whether or not the class that we use to fill in the generic type **T** will have a **compareTo** method

The Comparable Interface

- So, to make the compiler happy:
  - Declare a variable that is of type **Comparable<T>**
  - Convert the variable of type **T** to the variable of type **Comparable<T>**

```
Comparable<T> temp =
                    (Comparable<T>)element;
```

- Note that an object of a class that implements **Comparable** can be referenced by a variable of type **Comparable<T>**

```
//-------------------------------------------------------------
//  Adds the specified Comparable element to the list,
// keeping the elements in sorted order.
//-------------------------------------------------------------
public void add (T element)
{
  if (size( ) == list.length)
    expandCapacity( );
   Comparable<T> temp = (Comparable<T>)element;
  int scan = 0;
  while (scan < rear && temp.compareTo(list[scan]) > 0)
    scan++;
  for (int scan2=rear; scan2 > scan; scan2--)
    list[scan2] = list[scan2-1]

  list[scan] = element;
  rear++;
}
```

List Implementation Using Arrays, Method 2: ***Circular Arrays***

- Recall circular array implementation of queues
- ***Exercise***: implement list operations using a circular array implementation

List Implementation Using Links

- We can implement a ***list*** *collection* with a *linked list* as the container
  - Implementation uses techniques similar to ones we've used for stacks and queues
- We will first examine the **remove** operation for a singly-linked list implementation
- Then we’ll look at the **remove** operation for a a doubly-linked list, for comparison

```
//-------------------------------------------------------------
//  Removes the first instance of the specified element
// from the list, if it is found in the list, and returns a
// reference to it. Throws an ElementNotFoundException
// if the specified element is not found on the list.
//-------------------------------------------------------------
public T remove (T targetElement) throws ElementNotFoundException
{
  if (isEmpty( ))
      throw new ElementNotFoundException ("List");
   boolean found = false;
   LinearNode<T> previous = null
   LinearNode<T> current = front;
   // cont'd..
```

```
while (current != null && !found)
   if (targetElement.equals (current.getElement( )))
      found = true;
   else {
      previous = current;
      current = current.getNext( );
   }
if (!found)  throw new ElementNotFoundException (“No data");

if (size( ) == 1)
   front = rear = null;
else
   if (current.equals (front))
        front = current.getNext( );
   else
   // cont’d
```

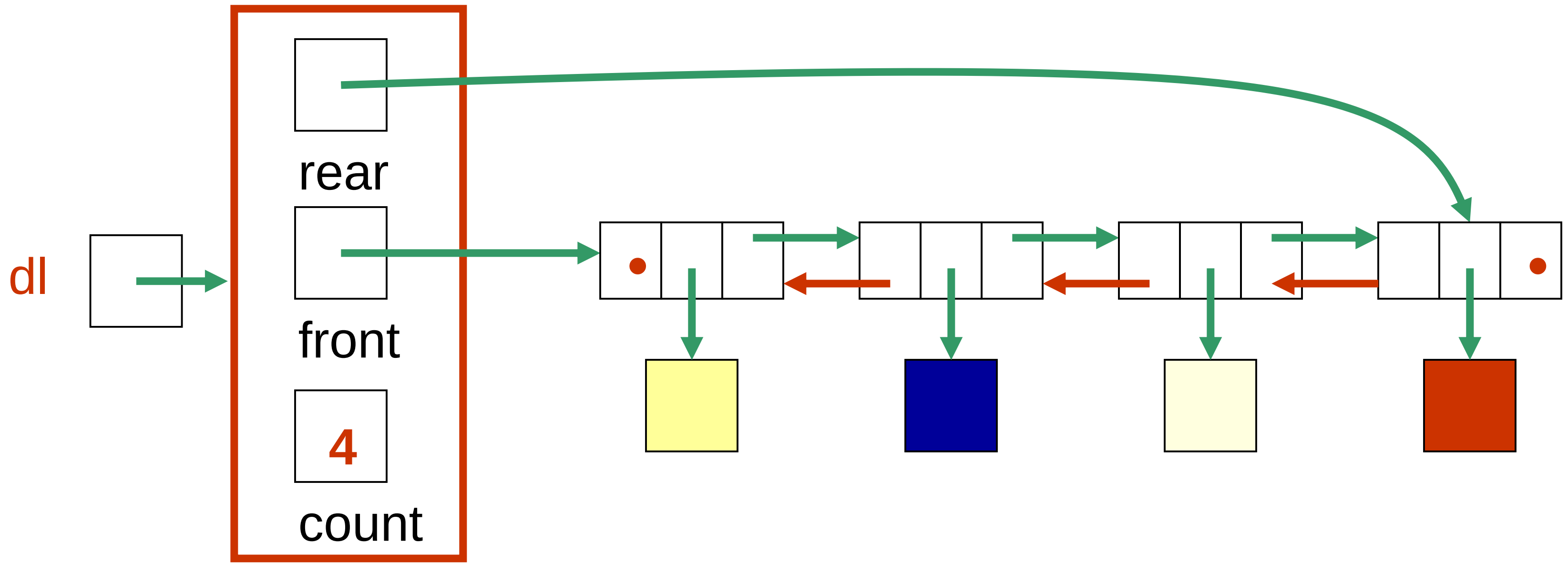
```
      if (current.equals (rear)) {
         rear = previous;
         rear.setNext(null);
      }
      else
         previous.setNext(current.getNext( ));

   count--;
   return current.getElement( );
}
```

Doubly Linked Lists

- A ***doubly linked list*** has ***two*** references in each node:
  - One to the **next** element in the list
  - One to the **previous** element
- This makes moving back and forth in a list easier, and eliminates the need for a **previous** reference in particular algorithms
- ***Disadvantage?*** a bit more overhead when managing the list

Implementation of a Doubly-Linked List

A doubly-linked list dl with 4 elements



- See ***DoubleNode.java***

- We can then implement the **ListADT** using a doubly linked list as the container
- Following our usual convention, this would be called ***DoublyLinkedList.java***

```
public DoubleNode<T> find (T element) {
   DoubleNode<T> current = front;
   while (current != null && !element.equals(current.getElement()))
        current = current.getNext();
   return current;
}
```

```
public T remove (T element) throws ElementNotFoundException {
  DoubleNode<T> node = find (element);
  if (node == null) throw new ElementNotFoundException (“No element");

   if (node == front) {
        front = next;
        if (front != null) front.setPrevious(null);
  }
  else (node.getPrevious()).setNext(node.getNext());

  if (node == rear) {
        rear = node.getPrevious();
        if (rear != null) rear.setNext(null);
  }
  else (node.getNext()).setPrevious(node.getPrevious());

  count--;
  return node.getElement();
}
```

```
//  Adds element to the list,  keeping the list sorted.
public void add (T element) {
   Comparable<T> temp = (Comparable<T>)element;
   DoubleNode<T> newNode = new DoubleNode<T>(element);
   If  (front == null) {
       front = newNode;
       rear = newNode;
   }
   else {
      DoubleNode<T> current = front;
      while (current != null && temp.compareTo(current.getElement() > 0)
            current = current.getNext();
      if (current == null) {
           // Add newNode at the end of the list
           rear.setNext(newNode);
           newNode.setPrev(rear);
           rear = newNode;
      }
```

```
else {  // newNode is not added to the end
      newNode.setNext(current);
      newNode.setPrev(current.getPrev());
      current.setPrev(newNode);
      if (newNode.getPrev() != null)
            newNode.getPrev().setNext(newNode);
      else front = newNode;
  }
  ++count;
}
```

Analysis of List Implementations

- In both array and linked implementations, many operations are similar in efficiency
- Most are **O(1)**, except when shifting or searching need to occur, in which case they are order **O(n)**
  - ***Exercise***: determine the time complexity of each operation
- In particular situations, the frequency of the need for *particular operations* may guide the use of one approach over another