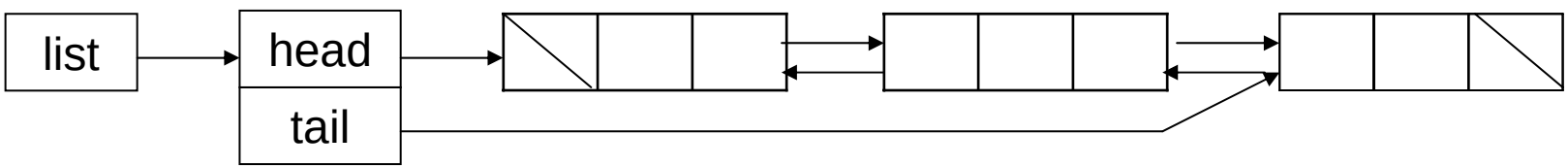
Doubly Linked Lists

- Representation
- Space Analysis
- Creation and Insertion
- Traversal
- Deletion

Representation

```
public class DoublyLinkedList{
   protected Element head, tail;
   //. . .
   public class Element {
      Object data; Element next, previous;

      Element(Object obj, Element next, Element previous){
         data = obj; this.next = next;
         this.previous = previous;
      }
      public Object getData(){return data;}
      public Element getNext(){return next;}
      public Element getPrevious(){return previous;}
      // . . .
  }
}
```



Doubly Linked Lists : Space Analysis

- The space requirements of our representation of the doubly linked lists is as follows:

  S(n) = sizeof(DoublyLinkedList) + n sizeof(DoublyLinkedList.Element)

  = 2 sizeof(DoublyLinkedList.Element ref) + n [sizeof(Object ref)

  + 2 sizeof(DoublyLinkedList.Element ref)]

  = (2n + 2) sizeof(DoublyLinkedList.Element ref) + n sizeof(Object ref)

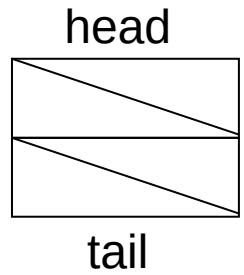
Required space	Explanation
sizeof(DoublyLinkedList)	The list reference has two fields: ***head*** (type: *Element*) and ***tail*** (type: *Element*) = 2 sizeof(DoublyLinkedList.Element ref)
n sizeof(DoublyLinkedList.Element)	The list has n elements of type ***Element***. Each element has three fields-- ***previous*** (type *Element*), ***data*** (type *Object*), and ***next*** (type *Element*)

List Creation and Insertion

- An empty doubly linked list is created as follows:

  DoublyLinkedList list = new DoublyLinkedList();

b)



- Like singly link list, once Created, elements can be inserted into the list using either the `append` or `prepend` methods

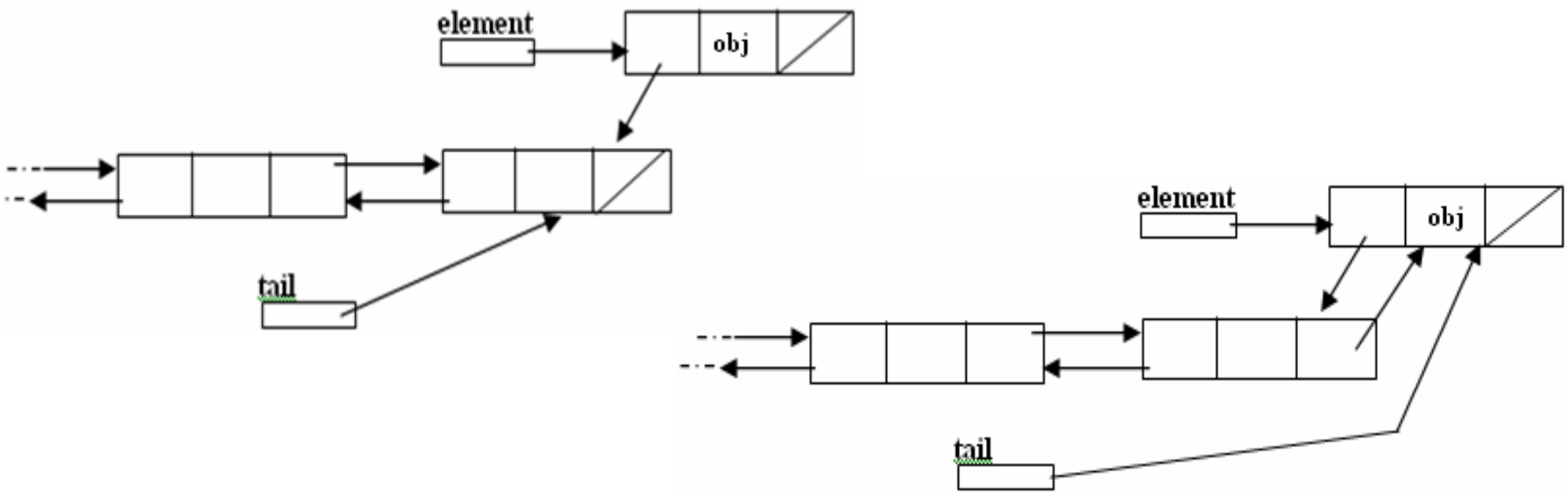
```
for (int k = 0; k < 10; k++)
    list.append(new Int(k));
```

- Also if we have reference to a node (an element), we can use `insertAfter` or `InsertBefore` of the Element class..

Insertion at the end (append)

```
public void append(Object obj){
   Element element = new Element(obj, null, tail);
   if(head == null)
      head = tail = element;
   else {
      tail.next = element;
      tail = element;
   }
}
```

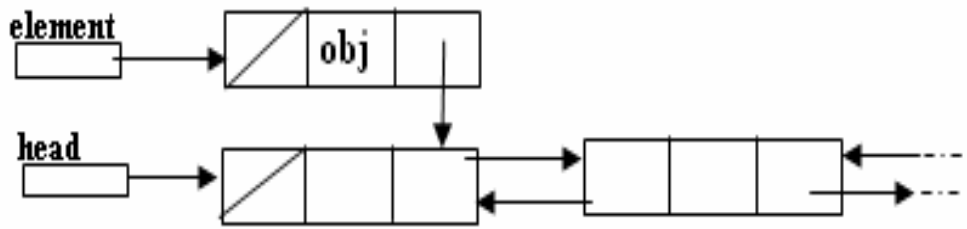
Complexity is O(1)

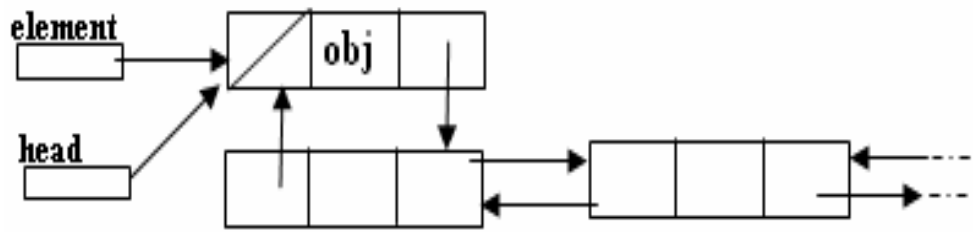


Insertion at the beginning (prepend)

```
public void prepend(Object obj){
   Element element = new Element(obj, head, null);
   if(head == null)
      head = tail = element;
   else {
      head.previous = element;
      head = element;
   }
}
```

Complexity is O(1)



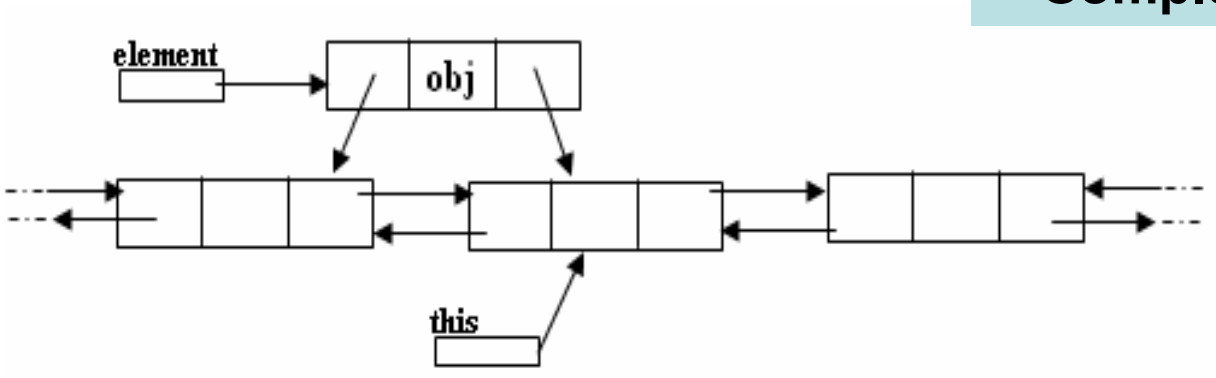


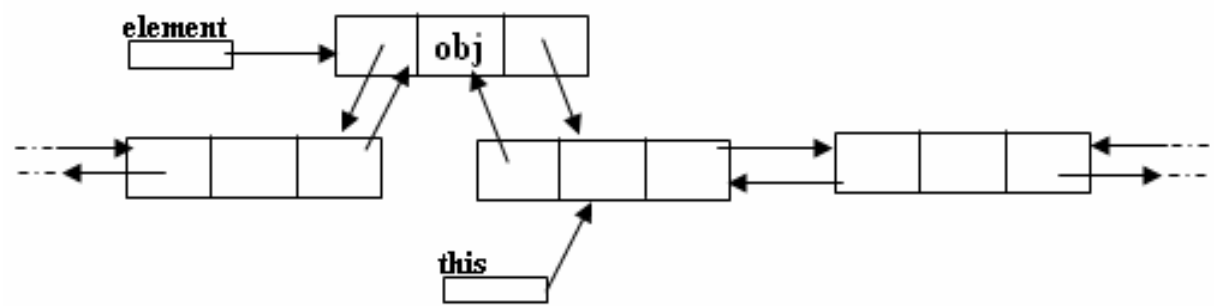
Insertion before an element

- **Inserting before the current node (this) that is neither the first nor the last node:**

```
Element element = new Element(obj, this, this.previous);
this.previous.next = element;
this.previous = element;
```

Complexity is O(1)





Traversal

For DoublyLinked list, traversal can be done in either direction. Forward, starting from head, or backward starting from tail.

```
Element e = head;
while (e != null) {
  //do something
   e = e.next;
}
```

```
Element e = tail;
while (e != null) {
  //do something
   e = e.previous;
}
```

Example: Count the number of nodes in a linked list.

```
public int countNodes(){
   int count = 0;
   Element e = head;
   while(e != null){
      count++;
      e = e.next;
   }
   return count;
}
```

Complexity is O(n)

Traversal

Example: The following computes the sum of the last n nodes:

```
public int sumLastNnodes(int n){
   if(n <= 0)
      throw new IllegalArgumentException("Wrong: " + n);
   if(head == null)
       throw new ListEmptyException();

   int count = 0, sum = 0;
   Element e = tail;
   while(e != null && count < n){
      sum += ((Integer)e.data).intValue();
      count++;
      e = e.previous;
   }
   if(count < n)
      throw new IllegalArgumentException("No. of nodes < "+n);
   return sum;
 }
```

Complexity is O(n)

Deletion

- To delete an element, we use either the `extract` method of DoublyLinkedList or that of the Element inner class.

```
public void extract(Object obj){
    Element element = head;
    while((element != null) && (!element.data.equals(obj)))
        element = element.next;

    if(element == null)
          throw new IllegalArgumentException("item not found");
    if(element == head) {
          head = element.next;
          if(element.next != null)
               element.next.previous = null;
    }else{
          element.previous.next = element.next;
          if(element.next != null)
               element.next.previous = element.previous;
   }
   if(element == tail)
        tail = element.previous;
}
```

Complexity is O(n)

Exercises

- For the DoublyLinkedList class, Implement each of the following methods and state its complexity.
  - String toString()
  - Element find(Object obj)
  - void ExtractLast()
  - void ExtractFirst()
  - void ExtractLastN(int n)
- For the DoublyLinkedList.Element inner class, implement each of the following methods and state its complexity.
  - void insertBefore()
  - void insertAfter()
  - void extract()
- What are the methods of DoublyLinkedList and its Element inner class are more efficient than those of MyLinkedList class?