Storage Strategies: Dynamic Linking

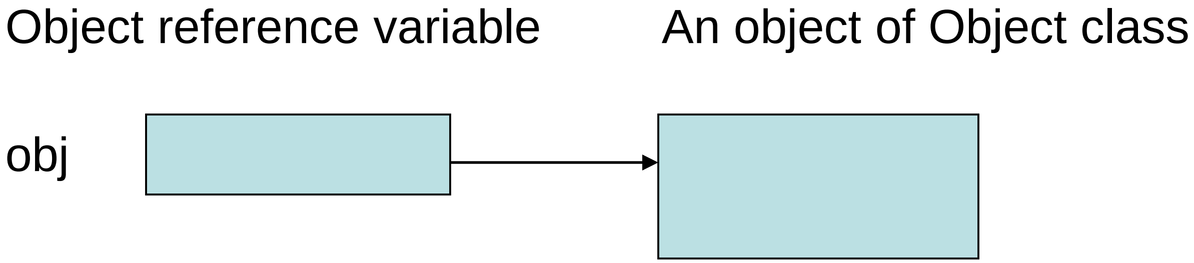
- References as Links
- Data Encapsulation and Linking
- Linked Lists
- Singly Linked Lists
- Doubly Linked Lists
- Reading: L&C 4.1-4.3, 4.6, 7.4

References as Links

- A *linked structure* is a data structure that uses object reference variables to create links between objects
- Declaring an object reference variable

```
Object obj = new Object();
```

- A diagram of an object reference variable



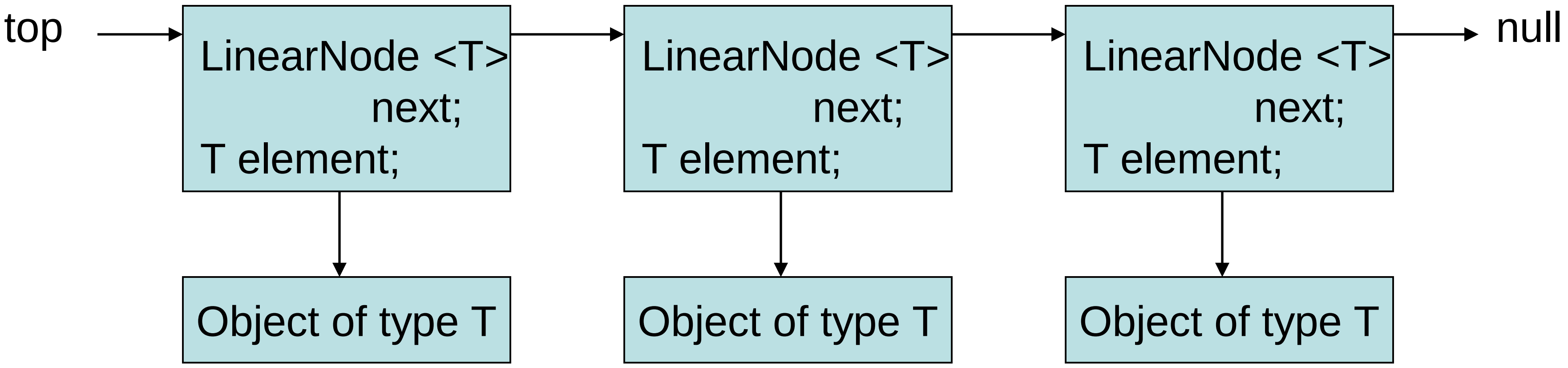
Object reference variable

An object of Object class

obj

Data Encapsulation and Linking

- It is desirable to have a generic link class that can be used to link any type of objects of any class encapsulating the “real” data
- Class LinearNode<T> does that this way



Data Encapsulation and Linking

- A *self-referential* (or *recursive)* LinearNode<T> object has a reference to another LinearNode<T> object

```
public class LinearNode<T>
{
  // attributes of the data in an element object
  private T element             // encapsulated element
  // link (or pointer) to another LinearNode object
  private LinearNode<T> next; // next item in list

  // constructor
  public LinearNode(T element)
  {
    this.element = element;   // encapsulate element
    next = null;              // set the link to null
  }
```

Data Encapsulation and Linking

```
// accessor and mutator methods
public void setNext(LinearNode<T> next)
  {
    this.next = next;
  }
public LinearNode<T> getNext()
  {
    return next;
  }
public T getElement()
  {
    return element;
  }
}// end class LinearNode<T>
```

Data Encapsulation and Linking

- Unlike an array which has a fixed size, a linked list is considered to be a *dynamic* memory structure
- The amount of memory used grows and shrinks as objects are added to the list or deleted from the list
- The Java compiler and virtual machine allocate memory for each object as it is created (via the new operator) and free memory as each object is garbage collected

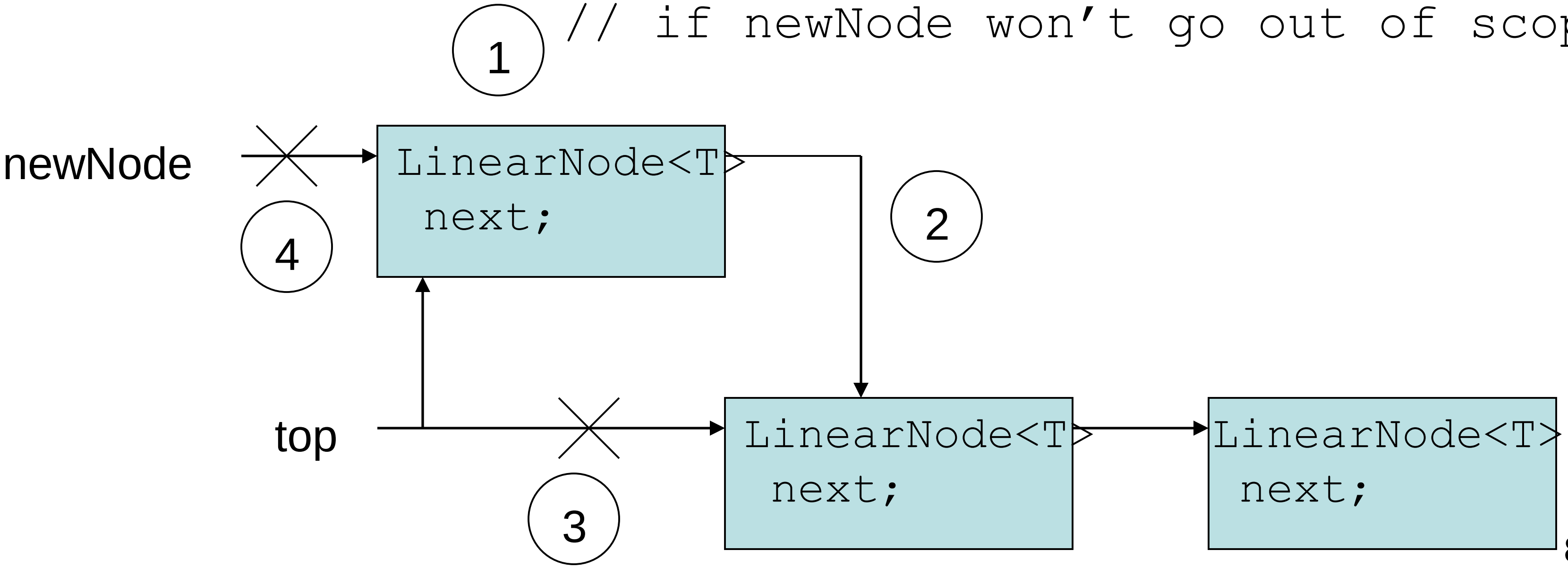
Managing Singly Linked Lists

- Can insert a new LinearNode in two places:
  - At the front
  - In the middle or at the end
- Can delete a LinearNode in two places:
  - At the front
  - In the middle or at the end
- The order in which references are changed is crucial to maintaining linked list integrity

Inserting Objects in a Linked List

- Create new LinearNode object and link at top

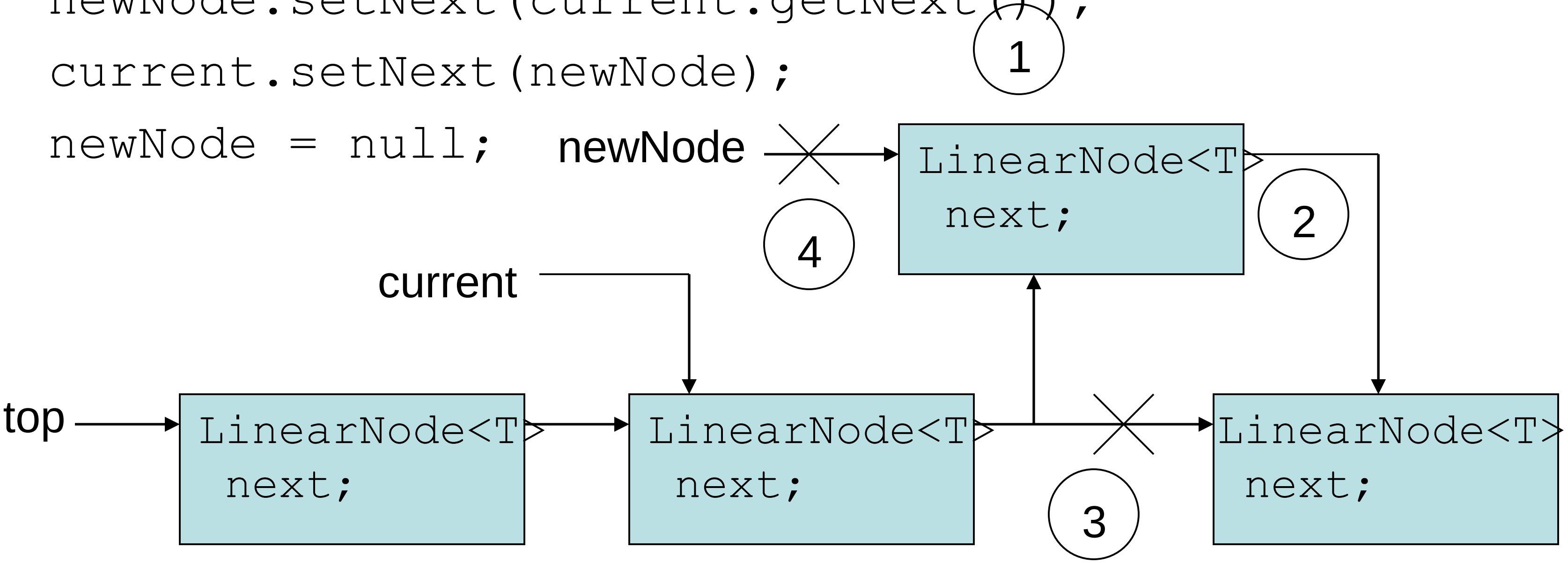
```
LinearNode<T> newNode = new LinearNode<T>(element);
newNode.setNext(top);
top = newNode;
newNode = null; // may be needed for stale reference
                // if newNode won't go out of scope
```



Inserting Objects in a Linked List

- Create new LinearNode object
- Link after current LinearNode object (current could be at the end)

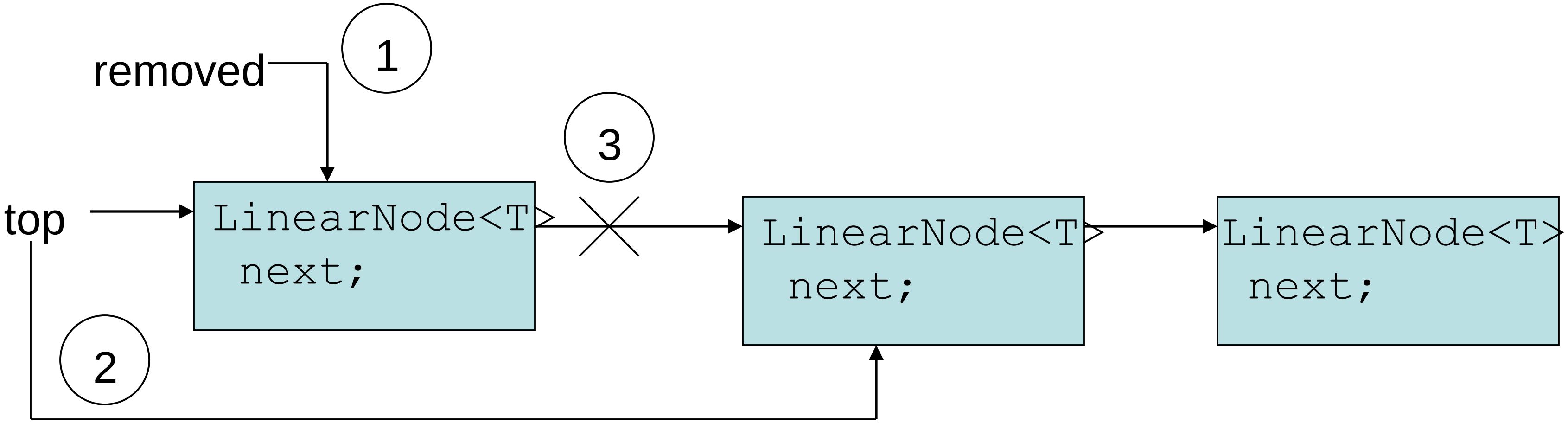
```
LinearNode<T> newNode = new LinearNode<T>(element);
newNode.setNext(current.getNext());
current.setNext(newNode);
newNode = null;
```



Removing Objects from a Linked List

- Remove LinearNode object at front

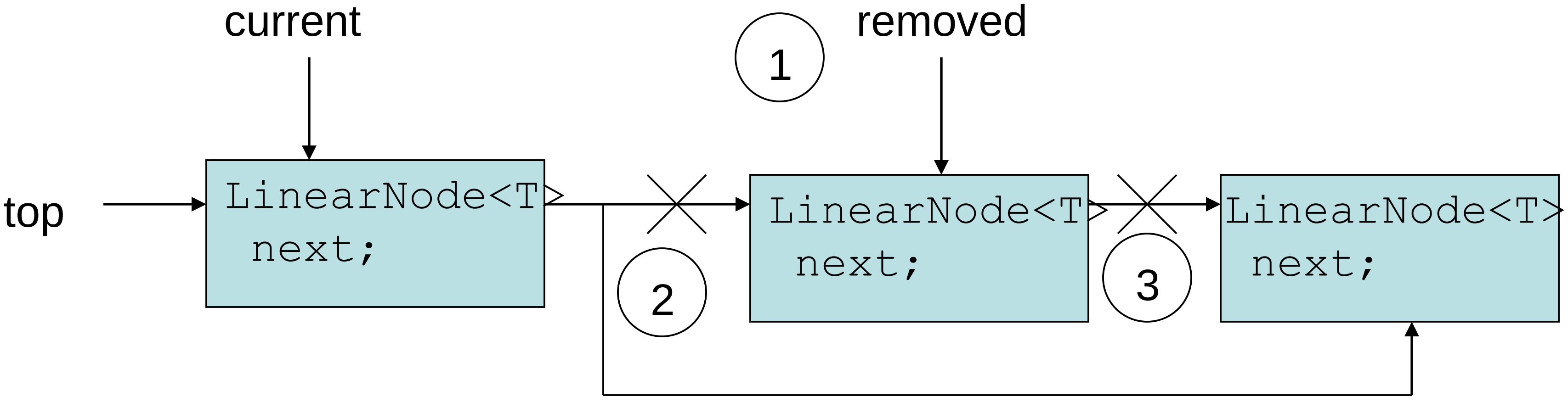
```
LinearNode<T> removed = top;
top = top.getNext());
removed.setNext(null);  // remove stale reference
```



Removing Objects from a Linked List

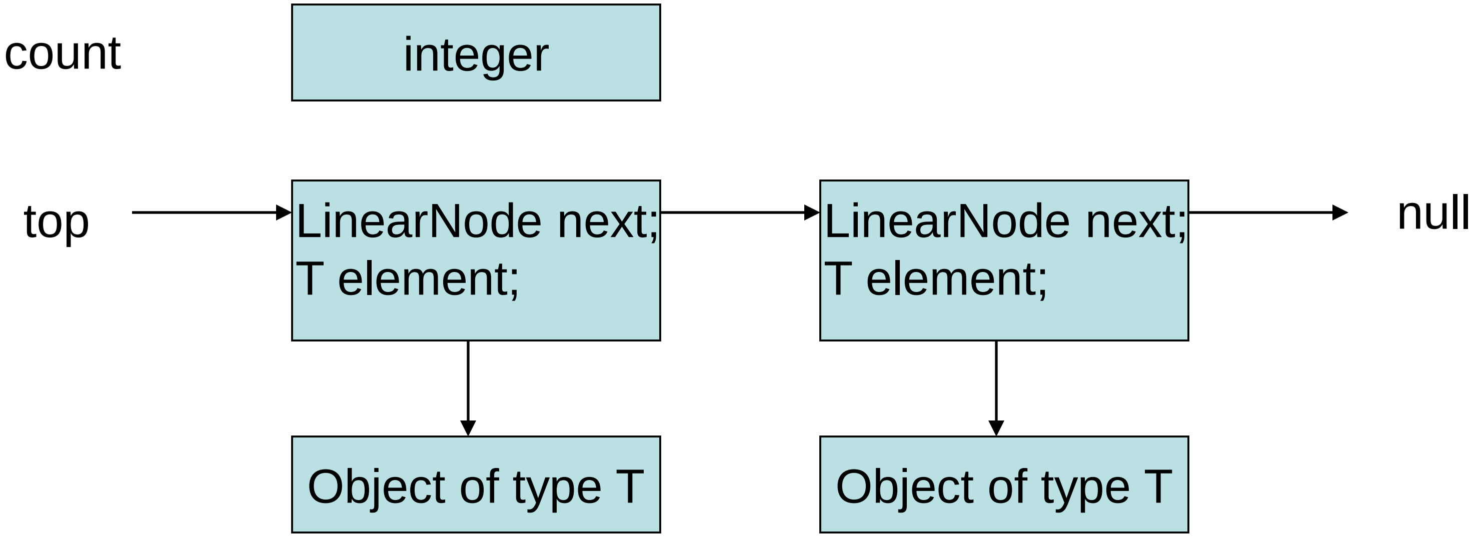
- Remove LinearNode after current LinearNode object (removed object could be at end)

```
LinearNode<T> removed = current.getNext();
current.setNext(removed.getNext());
removed.setNext(null);  // remove stale reference
```



Linked Stack Implementation

- We can use the LinearNode class to implement a Stack using linking
- We use the attribute name “top” to have a meaning consistent with a stack



Linked Stack Implementation

- push – O(1)

```
public void push (T element)
{
  LinearNode<T> temp = new LinearNode<T>(element);
  temp.setNext(top);
  top = temp;
  count++;
}
```

- Note difference between the LinkedStack push method and ArrayStack push method

Linked Stack Implementation

- pop – O(1)

```
public T pop () throws EmptyStackException
{
  if (isEmpty())  throw new EmptyStackException();
  T result = top.getElement();
  top = top.getNext();  // LinearNode is garbage now
  count--;
  return result;
}
```

- Note difference between the LinkedStack pop method and ArrayStack pop method

LinkedStack Implementation

- Notice that we don’t need an expandCapacity method in our LinkedStack implementation
  - The “new” operator called in the push method automatically allocates the memory for each LinearNode object when it is needed
  - When the reference to the LinearNode at top is overwritten in the pop method, the JVM garbage collector will release the memory for the now unneeded LinearNode

StackIterator Definition/Attributes

- Class Definition/Attribute Declarations (implemented as an inner class)

```
private class StackIterator<T>
               implements Iterator<T>
{
   private T current;
```

- Constructor:

```
public StackIterator()
{
  current = top;  // start at top for LIFO
}
```

StackIterator Methods

- hasNext – O(1)

```
public boolean hasNext()
{
  return current != null;
}
```

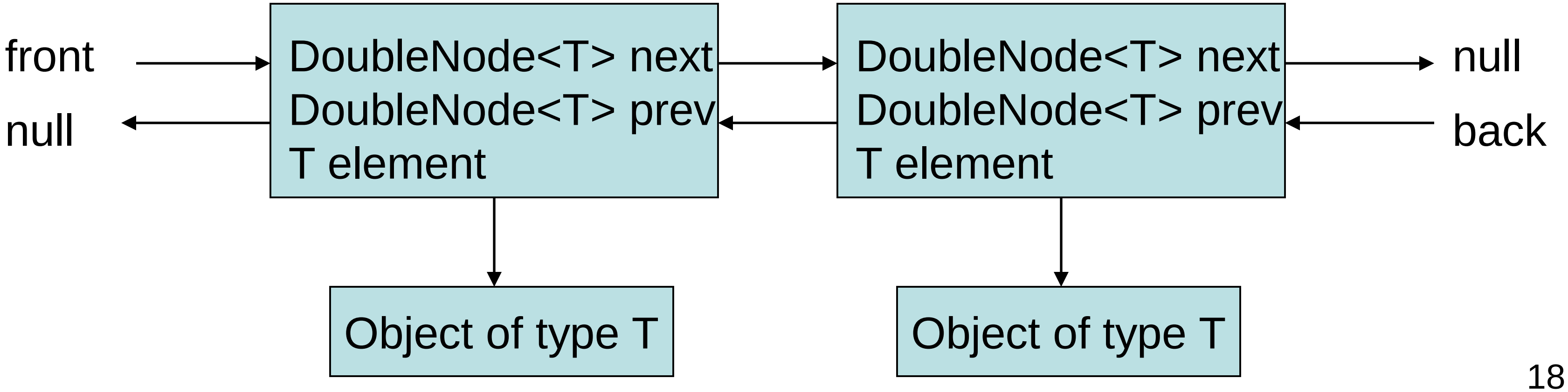
- next – O(1)

```
public T next()
{
  if (!hasNext())
     throw new NoSuchElementException();
  T result = current.getElement();
  current = current.getNext();
  return ;
}
```

Doubly Linked Lists

- Each DoubleNode object has a reference to next DoubleNode and previous DoubleNode

```
public class DoubleNode<T>
{
  private DoubleNode<T> next;
  private DoubleNode<T> prev;
  private T element;
```



Doubly Linked Lists

- To add a DoubleNode object to the list, your code must set the DoubleNode `next` and `prev` variables in both the new node and its adjacent neighbors
- To delete a DoubleNode object from the list, your code must bypass the DoubleNode `next` and `prev` variables in both neighbors adjacent to the removed node and may need to set its two stale references to `null`

Traversing Linked Lists

- We can use “for” or “while” loops to traverse a linked list or a doubly linked list - examples:

```
for(LinearNode<T> node = front; node != null;
  node = node.getNext()) {  . . . }


for(DoubleNode<T> node = back; node != null;
  node = node.getPrev()) {  . . . }


LinearNode<T> node = front;  // or DoubleNode back
while(node != null)
  { . . .
    node = node.getNext();   // or Doublenode prev
  }
```