Linked Lists

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CS 2401 (Fall 2010)

Elementary Data Structures and Algorithms

Motivation

- Suppose I have an array: 1,4,10,19,6
- I want to insert a 7 between the 4 and the 10
- What do I need to do?

Linked Lists
aka “Reference-Based Lists”

- Linked list
  - List of items, called nodes
  - The order of the nodes is determined by the address, called the link, stored in each node
- Every node (except the last node) contains the address of the next node
- Components of a node
  - Data: stores the relevant information
  - Link: stores the address of the next node

Linked Lists (continued)

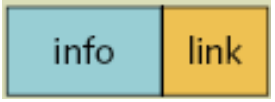


Figure 16-1 Structure of a node

Figure 16-2 Linked list

- Head or first
  - Holds the address of the first node in the list
- The info part of the node can be either a value of a primitive type or a reference to an object

Linked Lists (continued)

- Class `Node`
  - Represents nodes on a list
  - It has two instance variables
    - `info` (of type `int`, but it can be any other type)
    - `link` (of type `Node`)

```
public class Node {
    public int info;
    public Node link;
}
```

Linked List: Some Properties

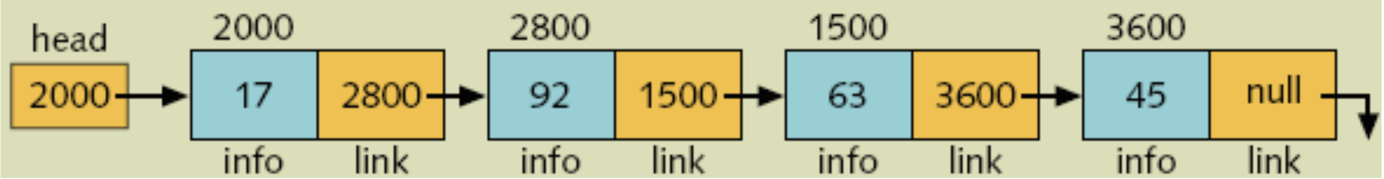
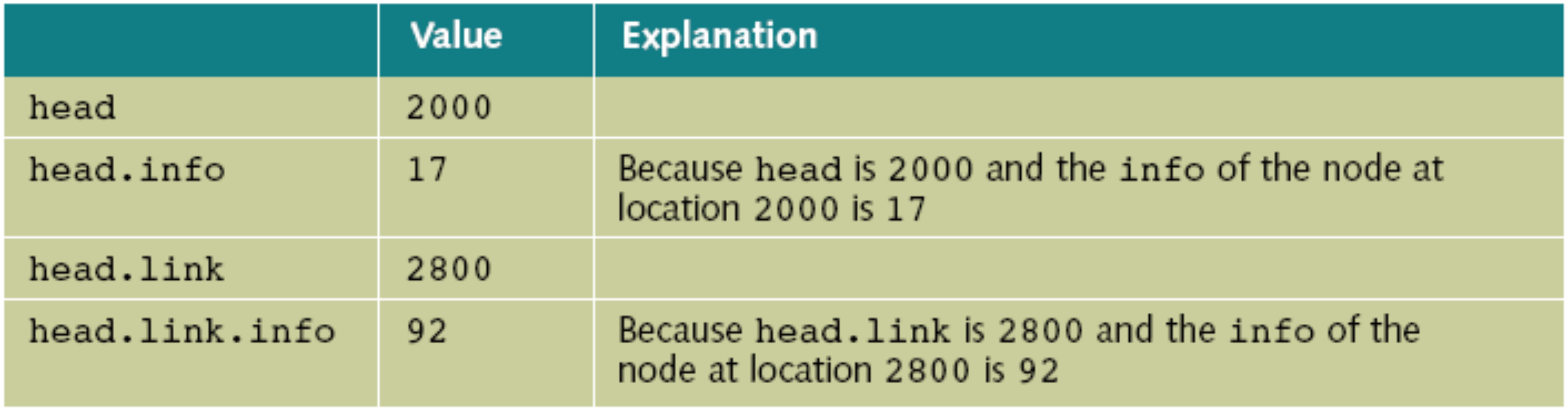


Figure 16-4 Linked list with four nodes

Table 16-1 Values of `head` and some of the nodes of the linked list in Figure 16-4



	Value	Explanation
`head`	`2000`	
`head.info`	`17`	Because `head` is `2000` and the `info` of the node at location `2000` is `17`
`head.link`	`2800`	
`head.link.info`	`92`	Because `head.link` is `2800` and the `info` of the node at location `2800` is `92`

Linked List: Some Properties

- Now consider the statement `current = head;`

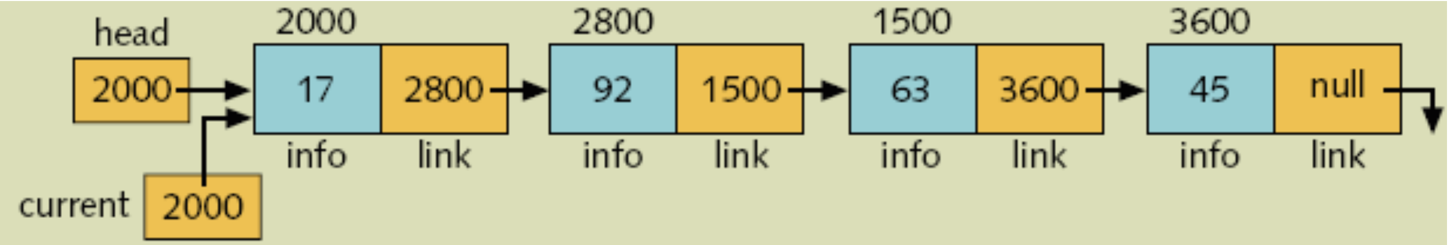
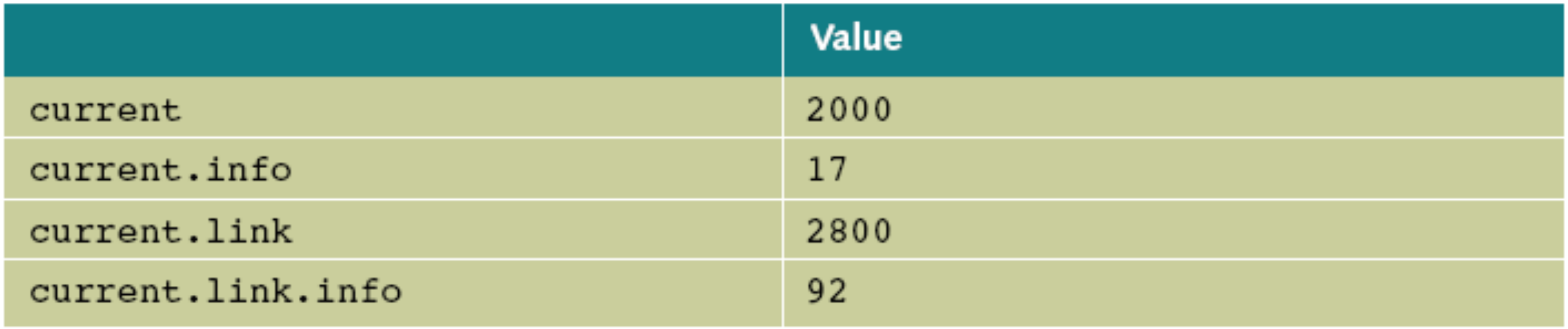


Figure 16-5 Linked list after `current = head;` executes

Table 16-2 Values of `current` and some of the nodes of the linked list in Figure 16-5



	Value
`current`	`2000`
`current.info`	`17`
`current.link`	`2800`
`current.link.info`	`92`

Linked List: Some Properties

- Now consider the statement

```
current = current.link;
```

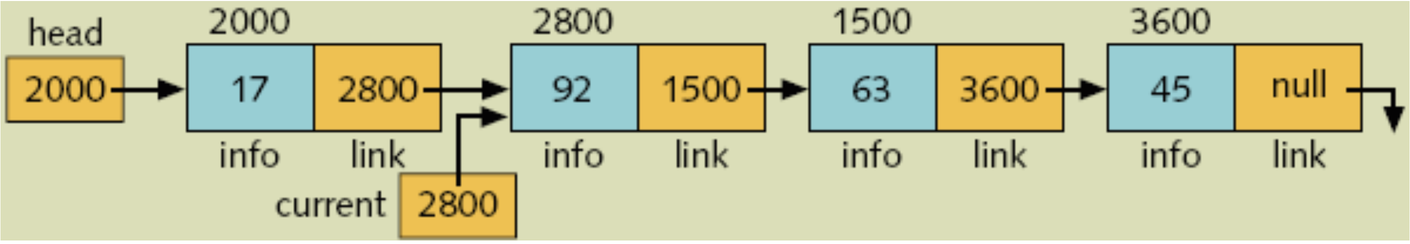
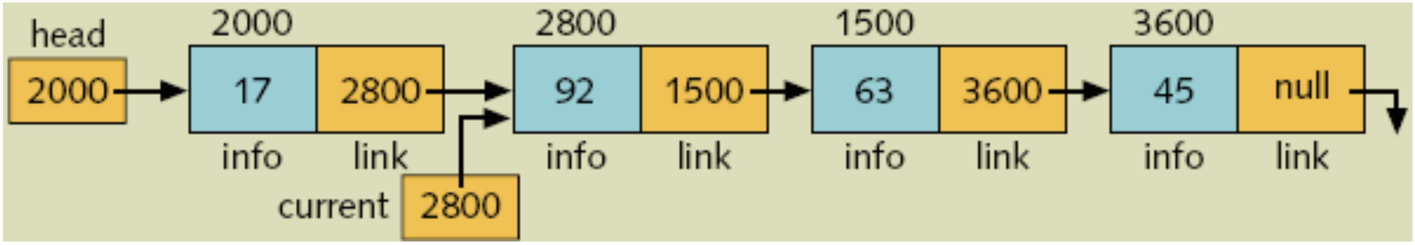


Figure 16-6 List after the statement `current = current.link;`

Table 16-3 Values of `current` and some of the nodes of the linked list in Figure 16-6

	Value
`current`	2800
`current.info`	92
`current.link`	1500
`current.link.info`	63

Linked List: Some Properties



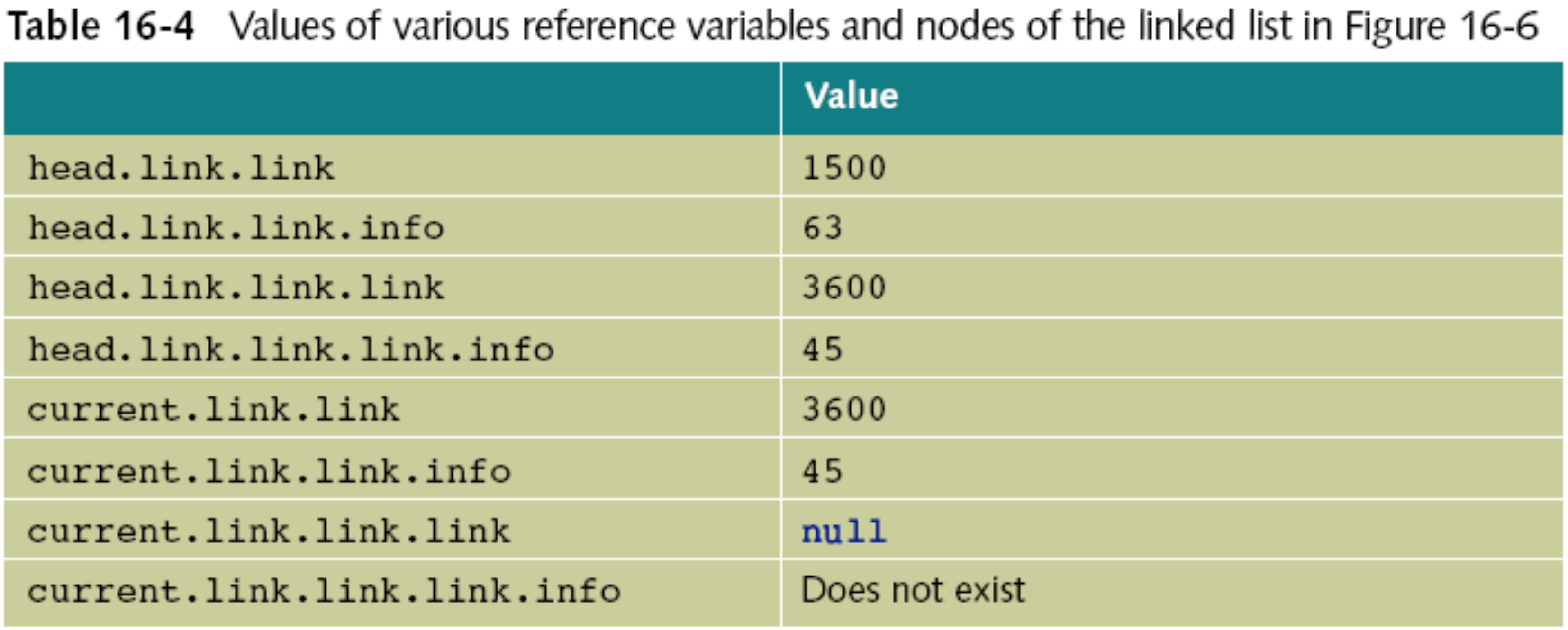


Table 16-4 Values of various reference variables and nodes of the linked list in Figure 16-6

	Value
`head.link.link`	`1500`
`head.link.link.info`	`63`
`head.link.link.link`	`3600`
`head.link.link.link.info`	`45`
`current.link.link`	`3600`
`current.link.link.info`	`45`
`current.link.link.link`	`null`
`current.link.link.link.info`	Does not exist

Traversing a Linked List

- Basic operations of a linked list that require the link to be traversed
  - Search the list for an item
  - Insert an item in the list
  - Delete an item from the list
- You cannot use `head` to traverse the list
  - You would lose the nodes of the list
  - Use another reference variable of the same type as `head`: `current`

Traversing a Linked List

- The following code traverses the list

```
current = head;
while (current != null) {
      //Process current
    current = current.link;
}
```

Exercise

- Write code to print out the data stored in each node in a linked list

```
current = head;
while (current != null)
{
    System.out.println(current.info + “ “);
    current = current.link;
}
```

Exercise

- Write code to set the data in the 5th node to be 10

```
current = head;
cnt = 0;
while (cnt < 4 && current != null) {
    current = current.link;
}
if (current != null) {
  current.info = 10;
}
```

Insertion

- Consider the following linked list

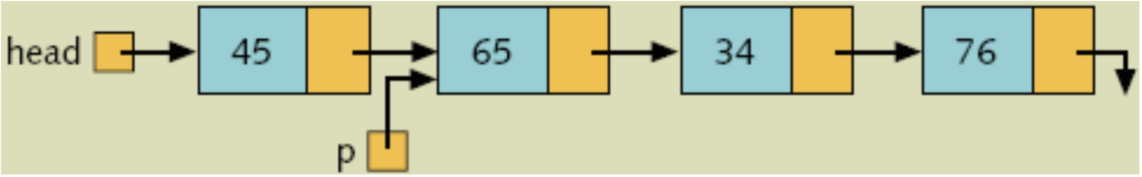


Figure 16-7 Linked list before item insertion

- You want to create a new node with `info 50` and insert it after `p`

Insertion

- The following statements create and store 50 in the info field of a new node

```
Node newNode = new Node();    //create newNode
newNode.info = 50;        //store 50 in the new node
```

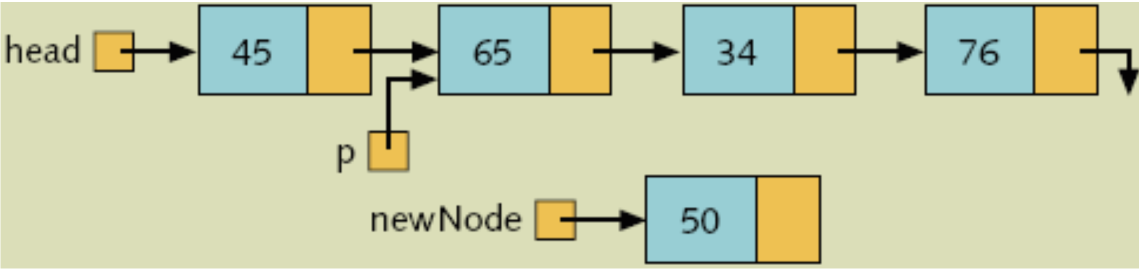


Figure 16-8 Create newNode and store 50 in it

Insertion

- The following statements insert the node in the linked list at the required place

```
newNode.link = p.link;
p.link = newNode;
```

- The sequence of statements to insert the node is very important

Insertion (continued)

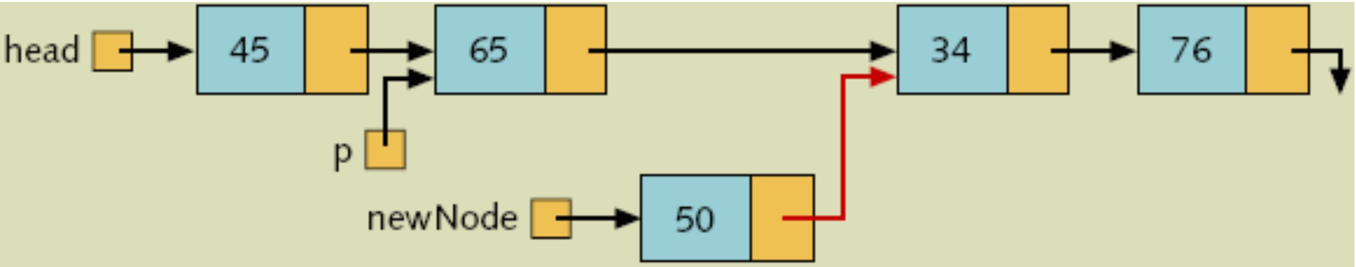


Figure 16-9 List after the statement `newNode.link = p.link;` executes

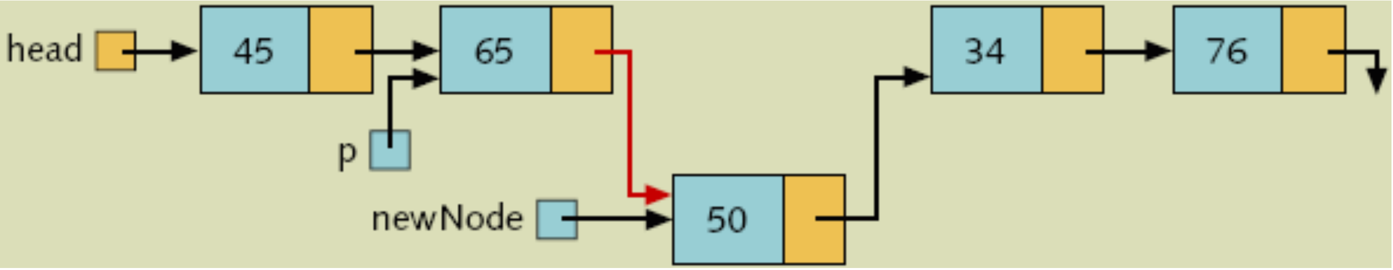


Figure 16-10 List after the statement `p.link = newNode;` executes

Deletion

- Consider the following linked list

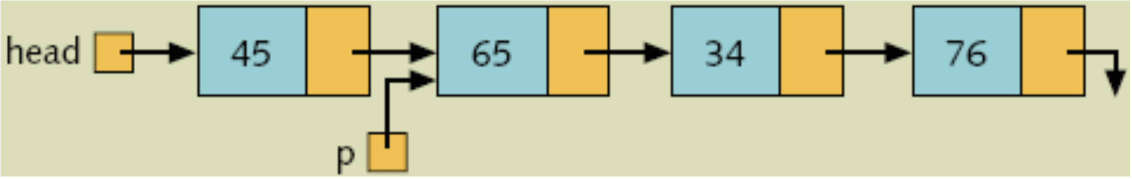


Figure 16-15 Node to be deleted is with `info 34`

- You want to delete node with `info 34`

Deletion (continued)

- The following statement removes the nodes from the list

```
p.link = p.link.link
```

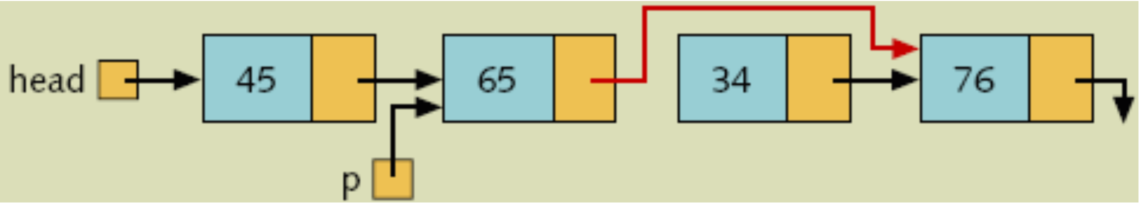


Figure 16-16 List after the statement `p.link = p.link.link;` executes

Deletion (continued)

- Previous statement removed the node
  - However, the memory may still be occupied by this node
- System's automatic garbage collector reclaims memory occupied by unreferenced nodes
  - Use `System.gc();` to run the garbage collector

Building a Linked List

- You can build a list in two ways: forward or backward
- Forward manner
  - A new node is always inserted at the end of the linked list
- Backward manner
  - A new node is always inserted at the beginning of the linked list

Building a Linked List Forward

- You need three reference variables
  - One to point to the front of the list
    - Cannot be moved
  - One to point to the last node of the list
  - One to create the new node
- Next two slides show the code for creating a linked list forward

Building a Linked List Forward (continued)

```
Node buildListForward()
{
    Node first, newNode, last;
    int num;
    System.out.println(“Enter integers ending with -999:”);
    num = console.nextInt();
    first = null;
    while (num != -999)
    {
        newNode = new Node();
        newNode.info = num;
        newNode.link = null;
```

Building a Linked List Forward (continued)

```
    if (first == null)
        {
            first = newNode;
            last = newNode;
        }
    else
        {
            last.link = newNode;
            last = newNode;
        }
        num = console.nextInt();
    }//end while
    return first;
}//end buildListForward
```

Building a Linked List Backward

- You only need two reference variables
  - One to point to the front of the list
    - Changes each time a new node is inserted
  - One to create the new node
- Next slide shows the code for creating a linked list backward

Building a Linked List Backward (continued)

```
Node buildListBackward()
{
    Node first, newNode;
    int num;
    System.out.println(“Enter integers ending with -999:”);
    num = console.nextInt();
    first = null;
    while (num != -999)
    {
        newNode = new Node();     //create a node
        newNode.info = num;       //store the data in newNode
        newNode.link = first;     //put newNode at the beginning of the list
        first = newNode;          //update the head of the list,
        num = console.nextInt();  //get the next number
    }
    return first;
}//end buildListBackward
```

Exercise

- Write code to take in an array of ints and returns the head reference to a linked list of the ints

```
public Node createLinkedList(int[] a) {







}
```

- Write code to take in an array of ints and returns the head reference to a linked list of the ints

```
public Node createLinkedList(int[] a) {
  Node head = new Node();
  head.info = a[length-1];
  head.link = null;

  for (int i = a.length-2; i >=0; i--) {
    Node n = new Node();
    n.info = a[i];
    n.link = head.link;
    head = n;
  }
  return head;
}
```

Linked Lists

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Elementary Data Structures and Algorithms

Abstract Data Types (ADT)

- A set of data
- A set of operations that can be done on the data

- In Java, implemented using interfaces
  - Methods are abstract
  - Cannot create and instance of an ADT
  - Need a concrete implementation
  - Can be multiple implementations!

Example: Lists

- A list is an ordered sequence of elements of a single type of data
- There are multiple ways to implement lists
  - Array-Based lists (Vectors)
  - Reference-Based lists (Linked Lists)

Using an ADT

```
public int sum(List<Integer> myList){
  int tempSum = myList.get(0);
  for (int i=1; i <= myList.size(); i++) {
    tempSum+= myList.get(i);
  }
  return tempSum;
}

List<Integer> myList = new Vector<Integer>();
l.add(3);
l.add(5);

System.out.println(sum(myList));
```

To use a Linked List Instead…

```
public int sum(List<Integer> myList){
  int tempSum = myList.get(0);
  for (int i=1; i <= myList.size(); i++) {
    tempSum+= myList.get(i);
  }
  return tempSum;
}

List<Integer> myList = new LinkedList<Integer>();
l.add(3);
l.add(5);

System.out.println(sum(myList));
```

Linked List Iterators

- An iterator is an object that produces each element of a collection one element at a time
- An iterator has at least two methods: `hasNext` and `next`
- `hasNext`
  - Determines whether there is a next element in the collection
- `next`
  - Gives access to the next element in the list

Iterators in Java: Typical Example

```
List<Integer> tmp = new Vector<Integer>();
tmp.add(7);
tmp.add(4);

Iterator itr = tmp.iterator();
while(itr.hasNext()) {
  int num = itr.next();
  System.out.println(num);
}
```

Doubly Linked Lists

- Linked list in which every node has a next pointer and a back pointer
- A doubly linked list can be traversed in either direction

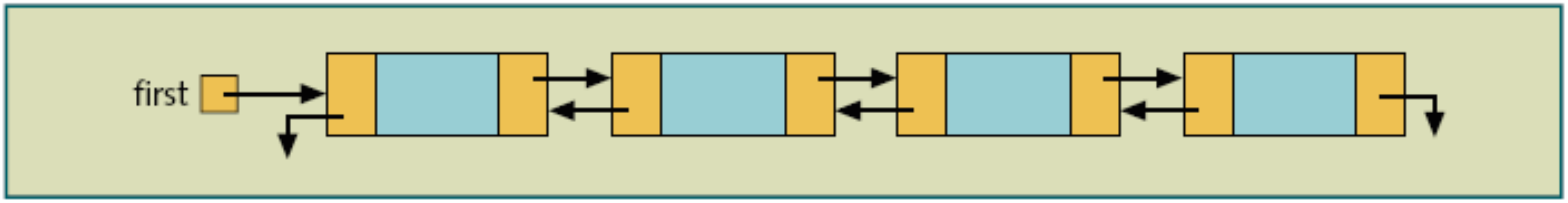

Figure 16-48 Doubly linked list

Doubly Linked List Nodes

- Class `DoublyLinkedListNode`

```
public class DoublyLinkedListNode<T> implements Cloneable
{
    T info;
    DoublyLinkedListNode<T> next;
    DoublyLinkedListNode<T> back;

    //place constructors and methods here
}
```

reversePrint List

- Doubly Linked lists make certain things easier…

```
public void reversePrint()
{
    DoublyLinkedListNode<T> current; //reference variable to
                                     //traverse the list
    current = last;  //set current to point to the last node
    while (current != null)
    {
        System.out.print(current.info + “  ”);
        current = current.back;
    }
}
```

Circular Linked Lists

- A linked list in which the last node points to the first node
- It is convenient to make `first` point to the last node

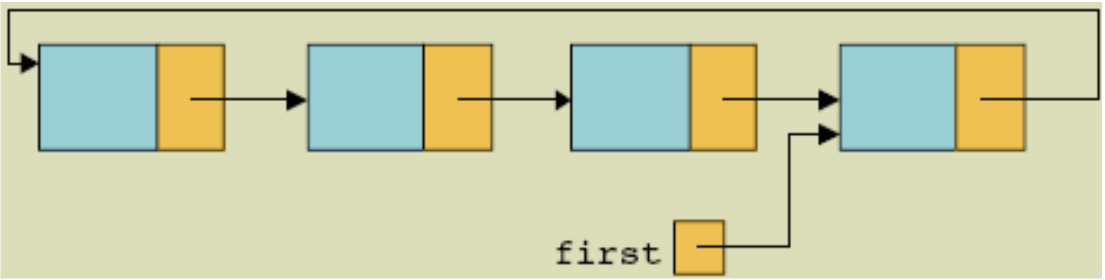

Figure 16-56 Circular linked list with more than one node

Exercise

- Write a method swap(List myList, i, j) that interchanges the elements in positions i and j

```
public void swap(List myList,int i, int j){
       int itemp = myList.get(i);
       int jtemp = myList.get(j);

       myList.remove(i);
       myList.add(i,jtemp);

       myList.remove(j);
       myList.add(j,itemp);
}
```

What happens if we first remove both elements, and then add both?

Exercise

- Write a **recursive** method to determine whether a linked list is sorted in descending order or not (return a boolean)

```
boolean isSorted(Node A){
      if (A == null | a.link == null) {
            return true;
      }
      if (a.info > a.link.info) {
        return false;
      }
      return isSorted(A.link);
}
```