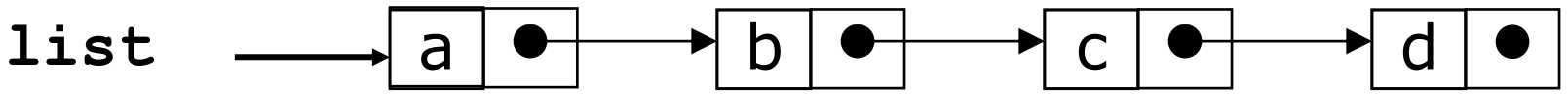
CMSC 132: Object-Oriented Programming II

Linked Lists

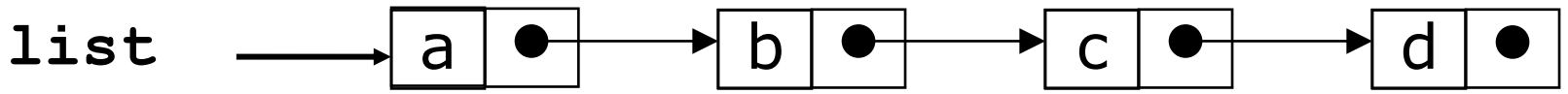
Linked list

- A linked list is a linear data structure, in which the elements are not stored at contiguous memory locations.
- A linked list consists of:
  - A sequence of **nodes**



- Each node contains a value and a link (pointer or reference) to some other node
- The last node contains a null link

Linked List Node

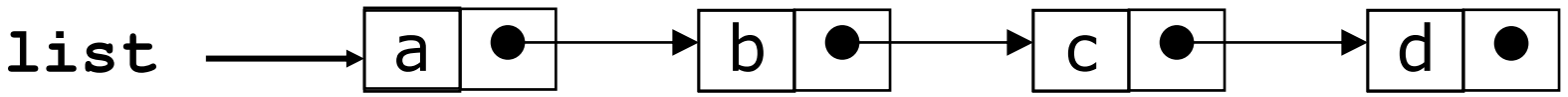



```
class Node<E> {
  E data;
  Node<E> next;

  Node(E item){
     data = item;
  }

  Node(E item, Node r){
     data = item;
     next = r;
  }
}
```

Linked List Node

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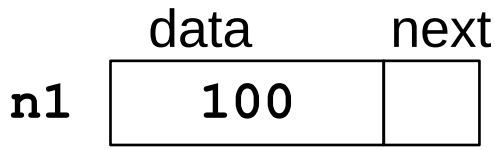
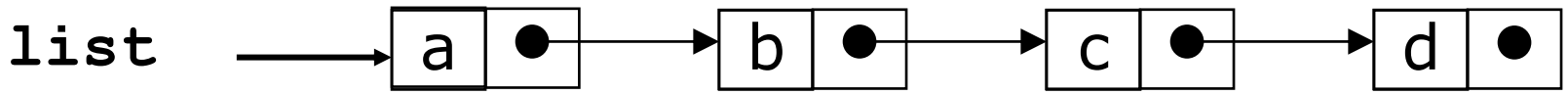



```
Node<Integer> n1 = new Node(100);
```

Linked List Node

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  E data;
  Node<E> next;

  Node(E item){
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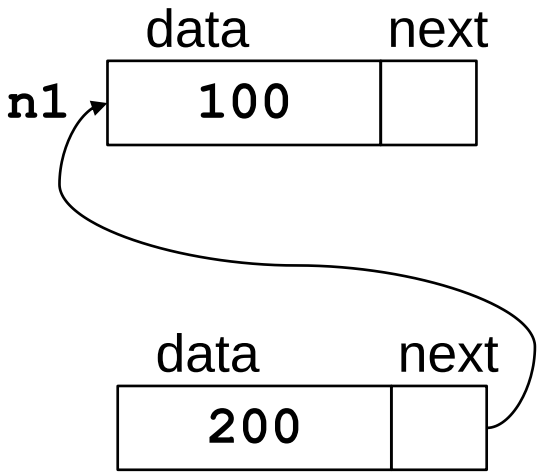
  }

  Node(E item, Node r){
     data = item;
     next = r;
  }
}
```

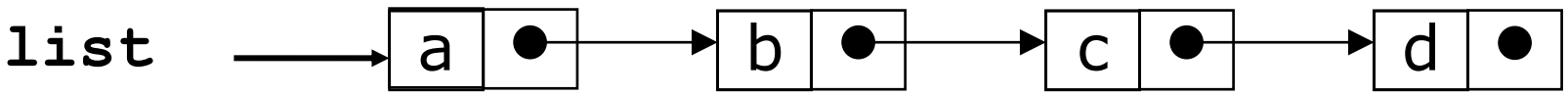



```
Node<Integer> n2 = new Node(200,n1);
```

More terminology

- A node's successor is the next node in the sequence
  - The last node has no successor
- A node's predecessor is the previous node in the sequence
  - The first node has no predecessor
- A list's length is the number of elements in it
  - A list may be empty (contain no elements)

Creating a Linked List




```
Node<String> list = new Node<>("a");
Node<String> n2 = new Node<>("b");
list.next = n2;
```

- **If successor exists:**

```
Node<String> n3 = new Node("c",new Node("d"));

N2.next = n3
```

Implement the Bag using Linked List

```
public class LinkedBag<E>{
  private int N;  //number of items in the bag
  private Node<E> first;    //beginning of bag

  private class Node<E> {
     private E data;
     private Node<E> next;
     Node(E item){
      data = item;
  }
}
```

LinkedBag<E>

```
N=0
First = null
```

Insert

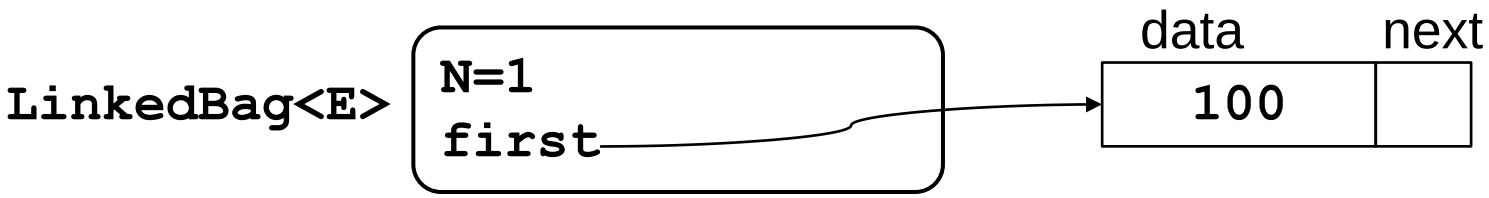
Insert the item as the first node:

```
public void insert(E item){
   first = new Node<>(item, first);
   N++;
}
```

- No capacity limit
- No need to resize

Insert

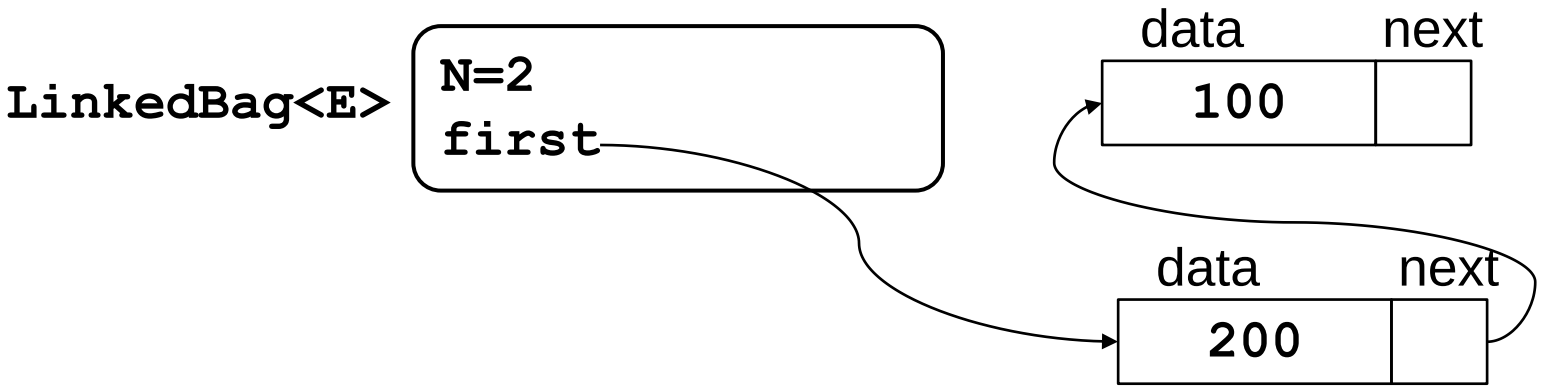
```
public void insert(E item){
   first = new Node<E>(item, first);
   N++;
}
```




```
LinkedBag<Integer> bag = new LinkedBag();
bag.insert(100);
```

Insert

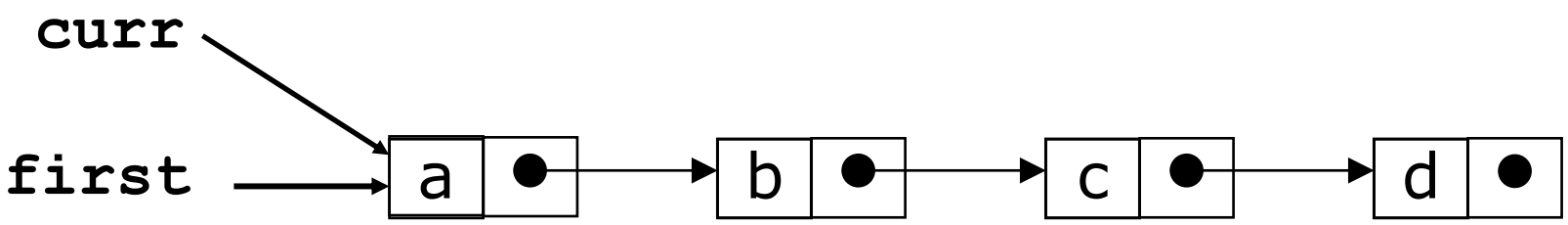
```
public void insert(E item){
   first = new Node<E>(item, first);
   N++;
}
```




```
LinkedBag<Integer> bag = new LinkedBag();
bag.insert(100);
bag.insert(200);
```

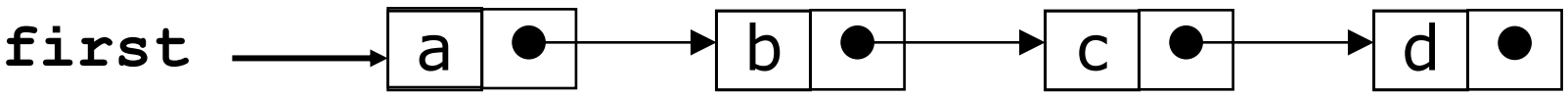
Traversing a Linked List

```
public void print() {
  Node<E> curr = first;
  While(curr != null){
    System.out.print(curr.data + ",");
    curr = curr.succ;
  }
}
```



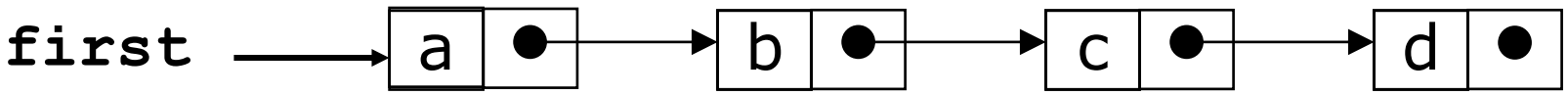
Traversing a Linked List Recursively

```
private void print(Node r) {
  if(r == null) return;
  System.out.print(r.data + ",");
  print(r.next);  //recursive call
}
```

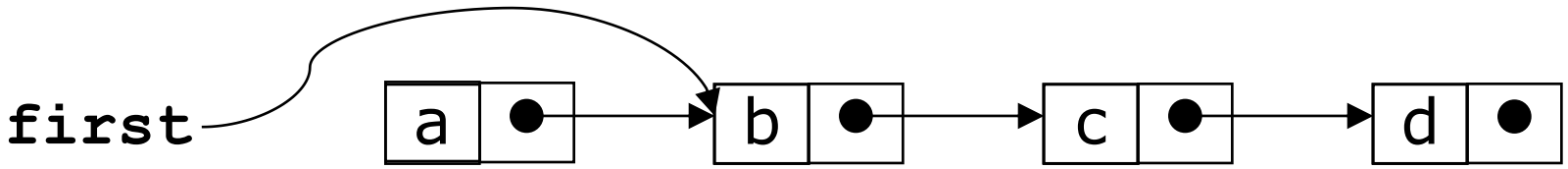


Deleting a node

Delete the first node

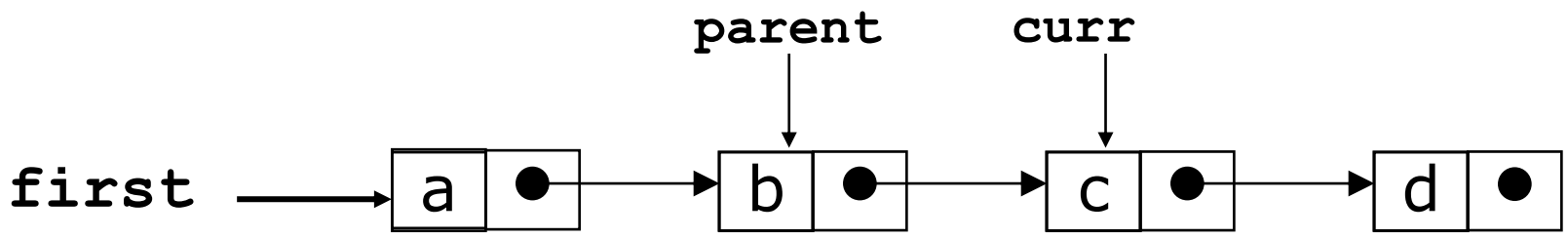



```
first = first.next
```

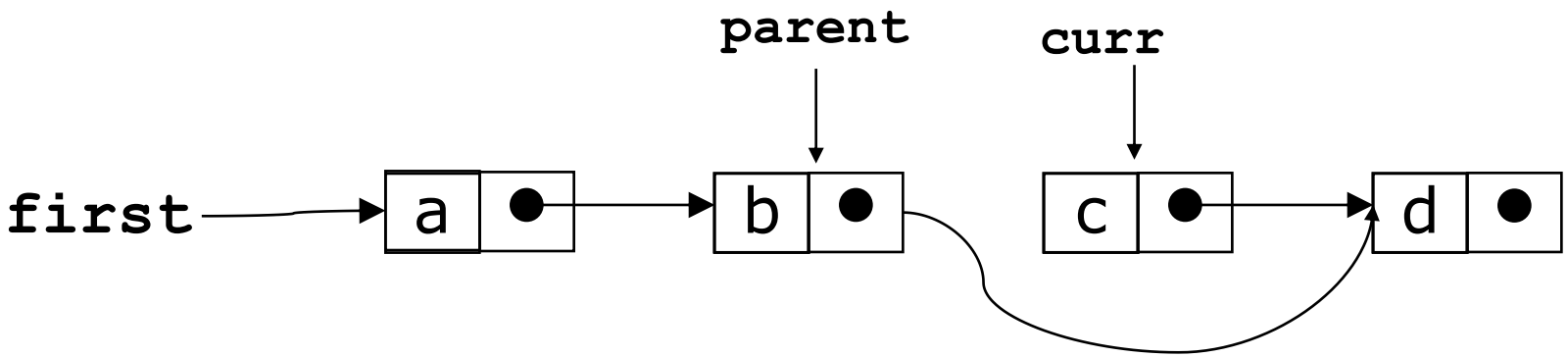


Deleting a node

Delete the node “c”




```
parent.next = curr.next;
```



Deleting a node

```
public boolean remove(E item){
  if(isEmpty()) throw new NoSuchElementException();
  if(item == null) return false;
  if(first.data.equals(item)){
    first = first.next;    return true;
  }
  Node<E> parent = first;
  Node<E> current = first.next;
  while(current != null){
    if(current.data.equals(item)){
      parent.next = current.next;
      return true;
    }
    parent = current;
    current = current.next;
  }
  return false;
}
```

Deleting a Node Recursively

```
public void remove_rec(E item){
  first = remove_rec(first, item);
}

private Node<E> remove_rec(Node<E> r, E item){
  if( r == null) return null;
  if(r.data.equals(item)){
    return r.next;
  }
  r.next = remove_rec(r.next, item);
  return r;
}
```

Quiz 1:

What is a Node used for in a linked list?

A. To store the information and the link to the next item
B. To check for the end of the list
C. Not used in a linked list
D. To check for the beginning of the list

Quiz 1:

What is a Node used for in a linked list?

A. To store the information and the link to the next item
B. To check for the end of the list
C. Not used in a linked list
D. To check for the beginning of the list

Quiz 2:

What does the following function do for a given Linked List with first node as head?

```
void foo(Node head){
  if(head == null) return;
    foo(head.next);
    print(head.data);
}
```

A. Prints all nodes of linked lists
B. Prints all nodes of linked list in reverse order
C. Prints alternate nodes of Linked List
D. Prints alternate nodes in reverse order

Quiz 2:

What does the following function do for a given Linked List with first node as head?

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void foo(Node head){
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Quiz 3:

Which of the following points is/are true about Linked List data structure when it is compared with array

A. Arrays have better cache locality.
B. Easy to insert and delete elements in Linked List
C. Random access is not allowed in Linked Lists
D. All of the above

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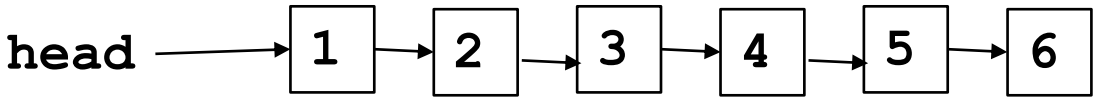
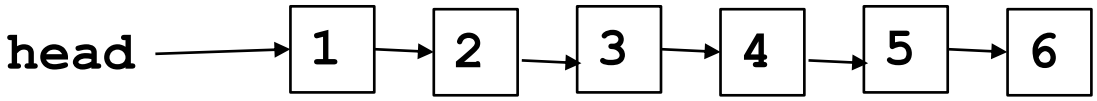
Quiz 4: What is the output of foo?




```
void foo(Node head){
  if(head == null) return;
  print(head.data);
  if(head.next != null)
    foo(head.next.next);
  print(head.data);
}
```

A. 1 4 6 6 4 1
B. 1 3 5 1 3 5
C. 1 2 3 5
D. 1 3 5 5 3 1

Quiz 4: What is the output of foo?

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   if(head.next != null)
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}
```

A. 1 4 6 6 4 1
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