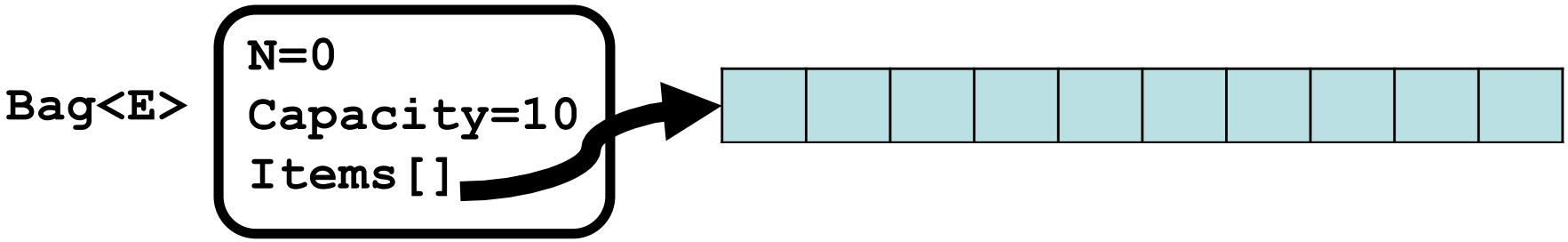
# CMSC 132: Object-Oriented Programming II

## Linked Lists

# Array based Bag

- We implemented the Bag using arrays




- Resizing the bag:
  - Create an array with different size
  - Copy everything from old array to the new array
  - Items references the new array.
  - Old array is garbage.

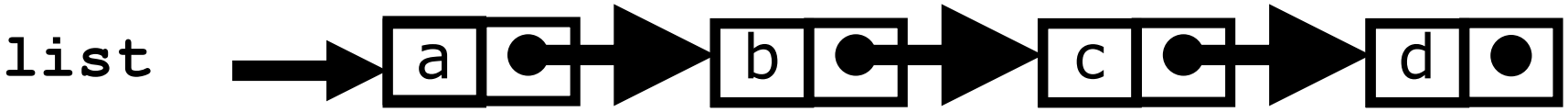
# Arrays

- Advantages:
  - Good cache performance
  - Random access using index

- Disadvantages
  - Static data structure. Size is fixed.
    - if we allocate more memory than requirement then the memory space will be wasted.
    - if we allocate less memory than requirement, then it will create problem
  - Insert/Delete is costly

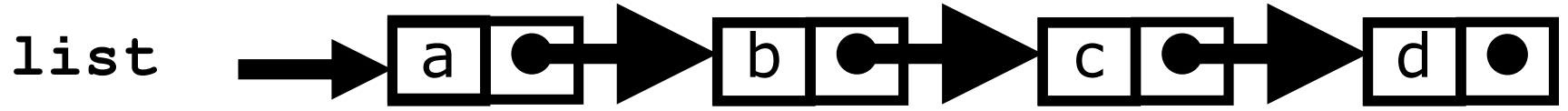
# Linked list

- 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

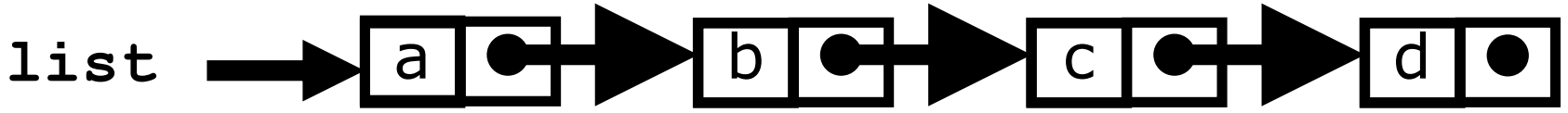



```
class Node<E> {
  E data;
  Node<E> next;

  Node(E item){
     data = item;
  }

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

# Linked List Node

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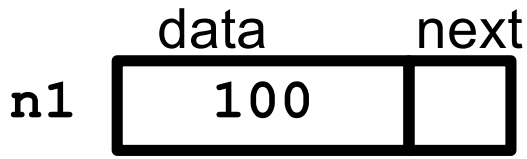
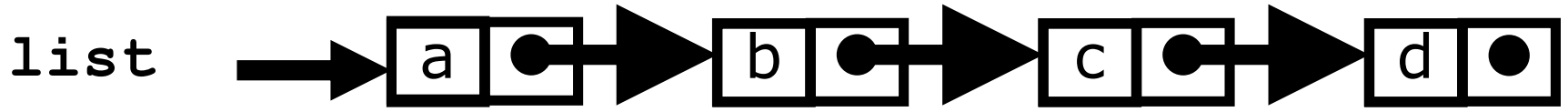
```




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

# Linked List Node

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  Node(E item){
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  Node(E item, Node r){
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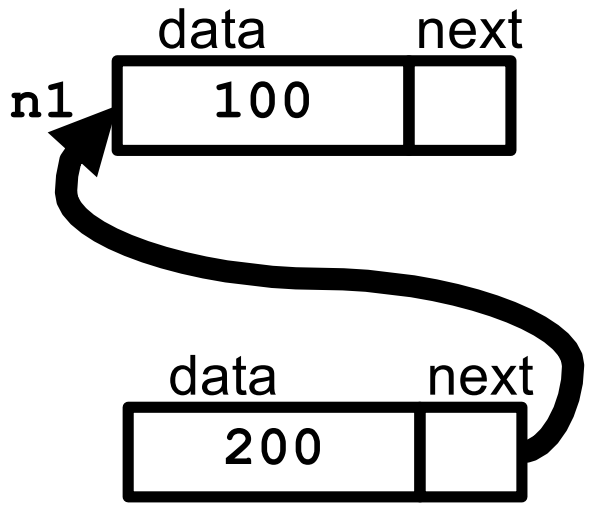
}
```

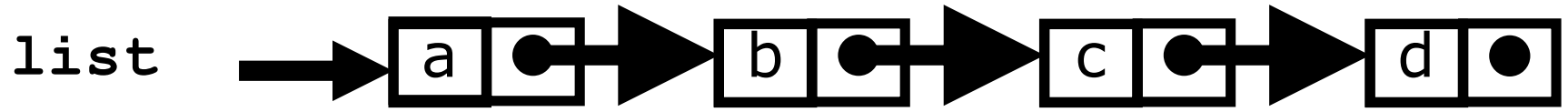



```
Node<Integer> n2 = new Node(200,n1);
```

# 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:**

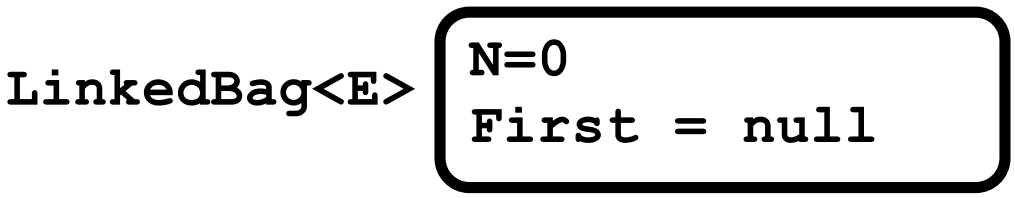
```
Node<String> n3 = new Node("c",new Node("d"));

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;
  }
}
```



# 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

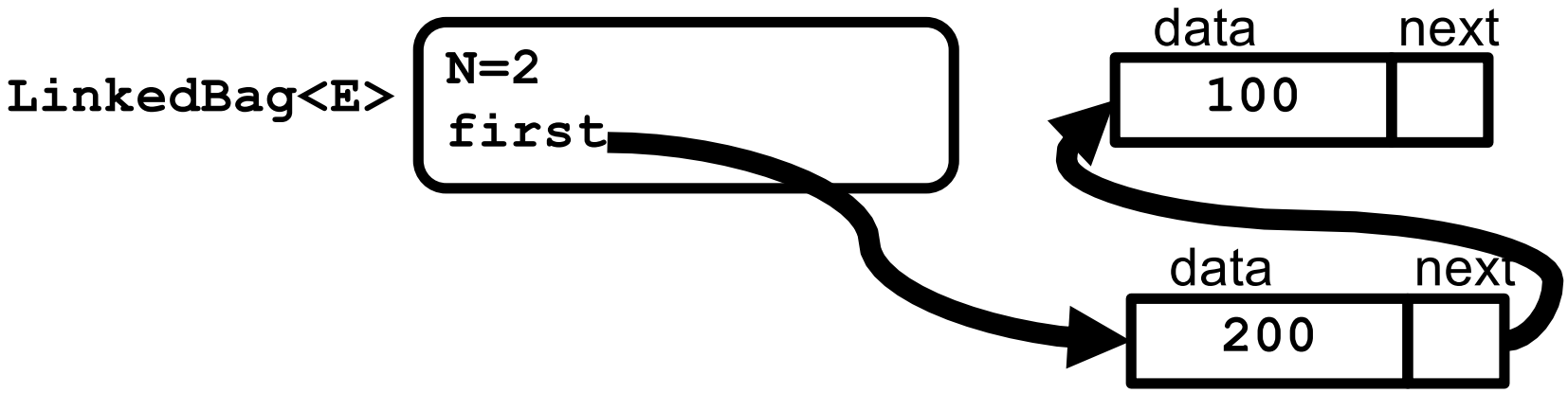
# Insert

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


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

# Insert

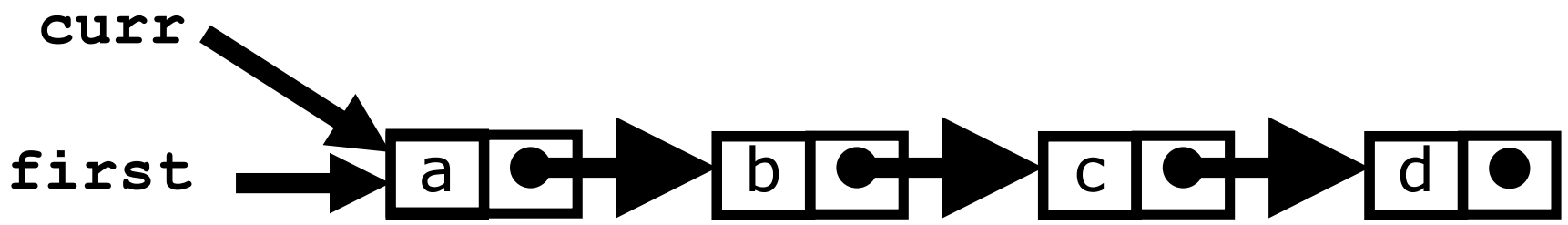
```
public void insert(E item){
   first = new Node<E>(item, first);
   N++;
}
```




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

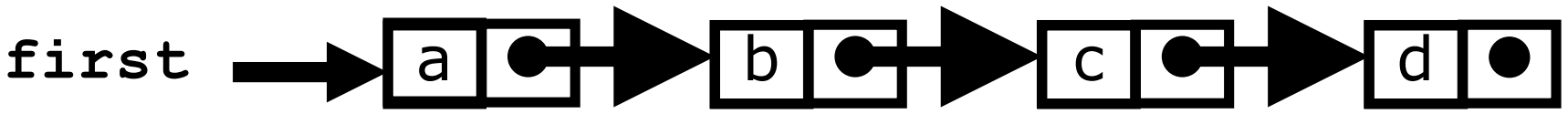
# Traversing a Linked List

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



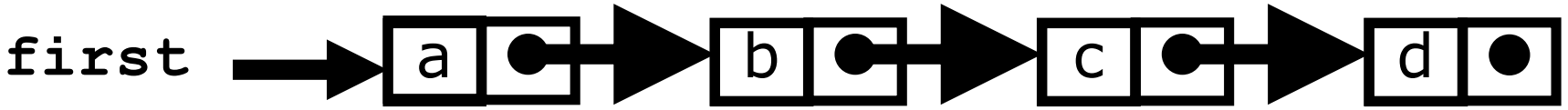
# Traversing a Linked List Recursively

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

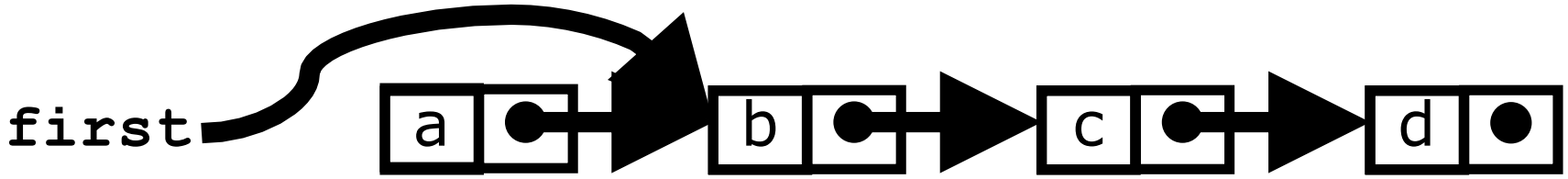


# Deleting a node

**Delete the first node**

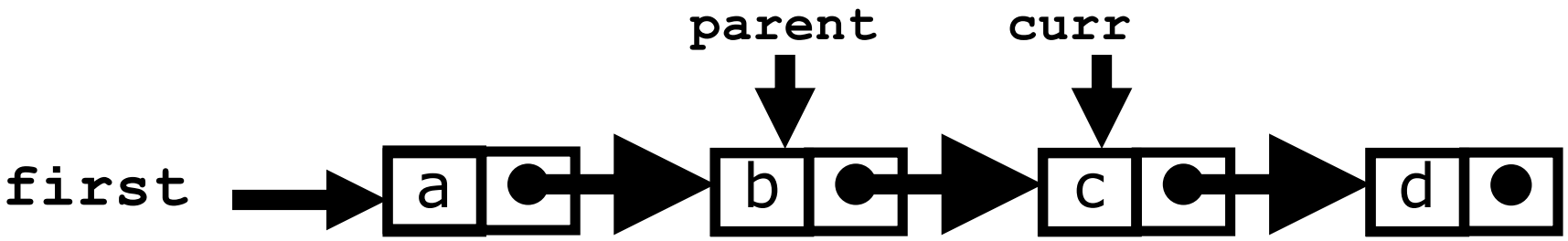



```
first = first.next
```

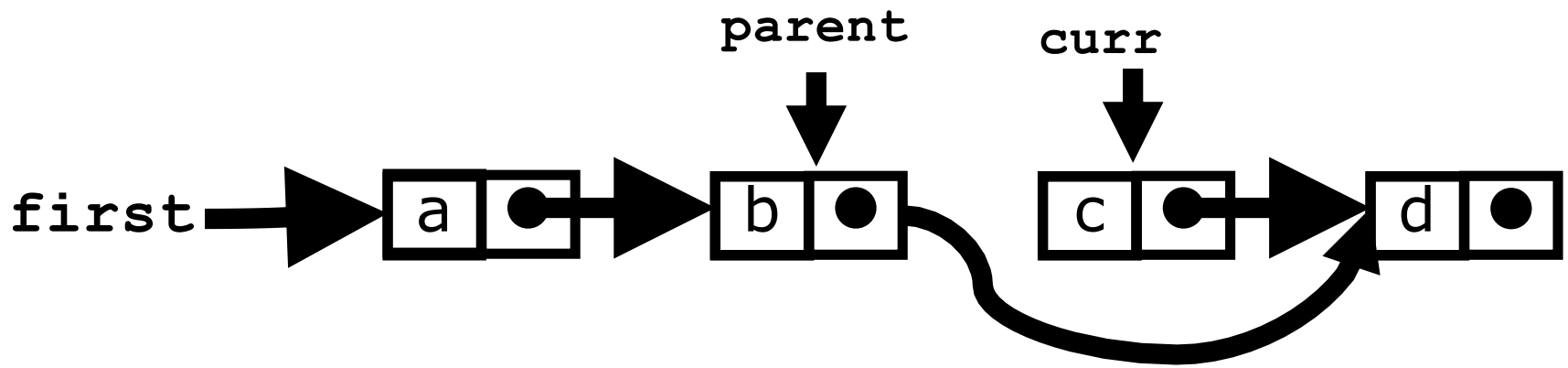


# Deleting a node

**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
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C. Not used in a linked list
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# 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:

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A. Prints all nodes of linked lists
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C. Prints alternate nodes of Linked List
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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

# Quiz 3:

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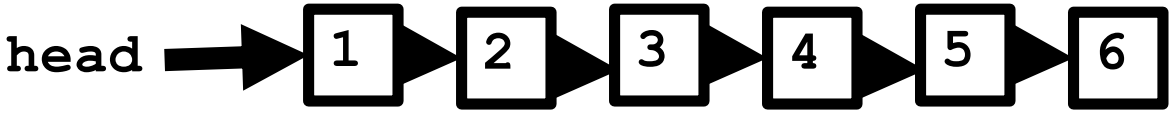
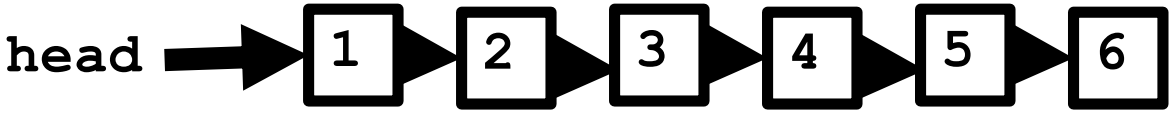
# Quiz 4: What is the output of foo?




```
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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}
```

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