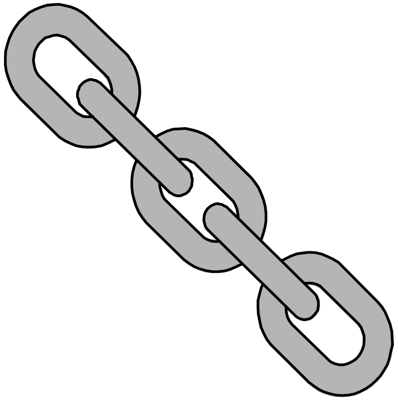


Linked Lists

Read Chapter 4

Questions

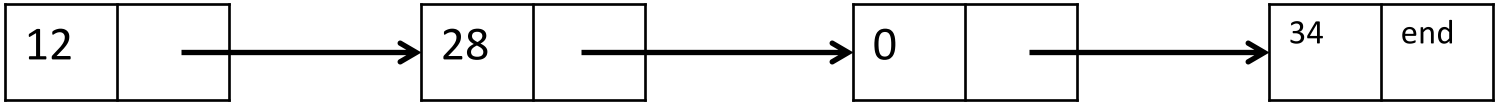
- Given a singly linked list, devise a time- and space-efficient algorithm to find the *m*th-to-last element of the list. Implement your algorithm, taking care to handle relevant error conditions. Define *m*th to last such that m=0, the last element of the list is returned.
- You are given a linked list that is either NULL-terminated (acyclic), or ends in a cycle (cyclic), write a function that takes a pointer to the head of a list and determines if the list is cyclic or acyclic. Your function should return 0 if the list is acyclic and 1 if it is cyclic. You may not modify the list in any way.

Linked list

- Singly linked list
- Doubly linked list
  - With dummy nodes
- Circularly linked list

Linked List

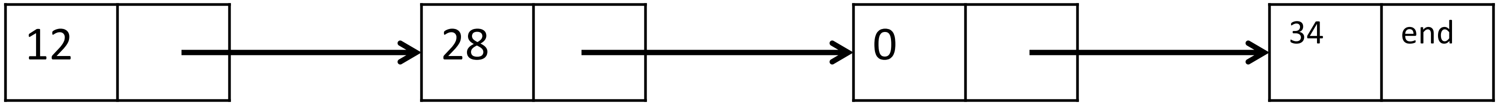
- Linked List
  - A sequence of elements arranged one after another
  - Each element connected to the next by a “link”
- Node
  - Element
  - Link to the next element
  - Last node



Declarations for Linked Lists

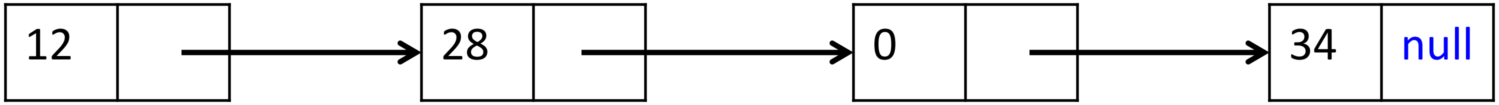
- Each node in the linked list is a class, as shown here.

```
public class IntNode
{
     private int data;
     private IntNode link;
     ...
}
```



List end

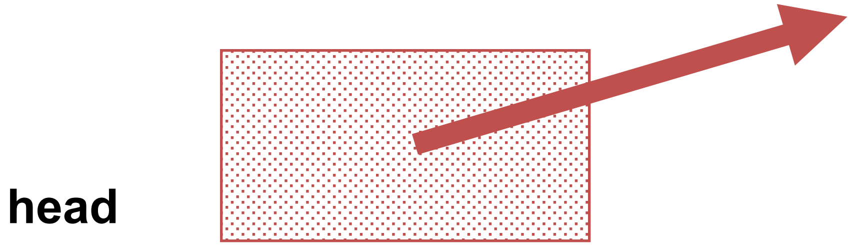
- null reference used as the final node of a linked list



How to access a linked list?

Declarations for Linked Lists

- A program can keep track of the front node by using an IntNode reference variable **head**.
  - Notice that head is not an IntNode -- it is a reference to an IntNode.

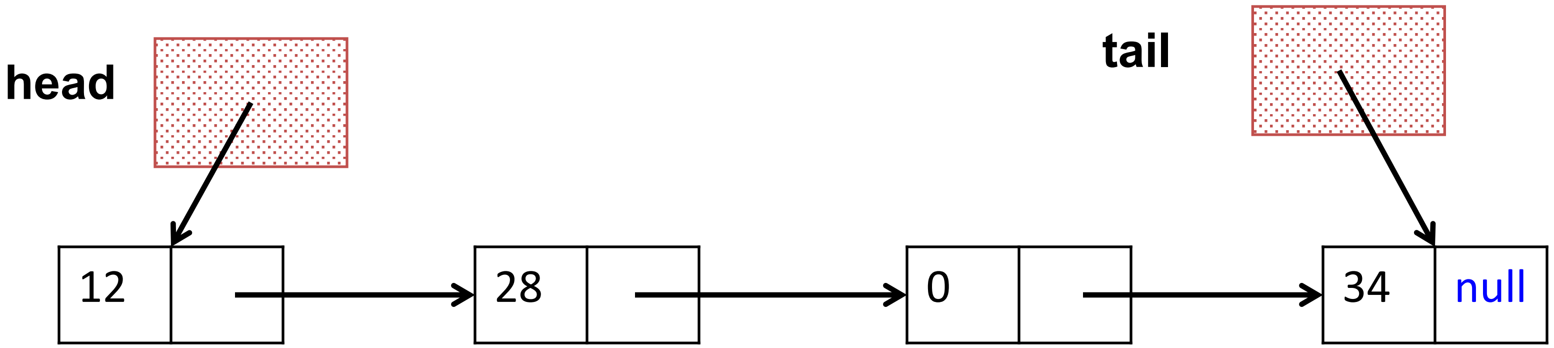


Declarations for Linked Lists

- A program can keep track of the front node by using an IntNode reference variable **head**.
  - Notice that head is not an IntNode -- it is a reference to an IntNode.
- We represent the empty list by storing **null** in the head reference.

Declarations for Linked Lists

- A program can keep track of
  - the front node by using an IntNode reference variable **head**.
  - the last node by using an IntNode reference variable **tail**.



IntNode

Members

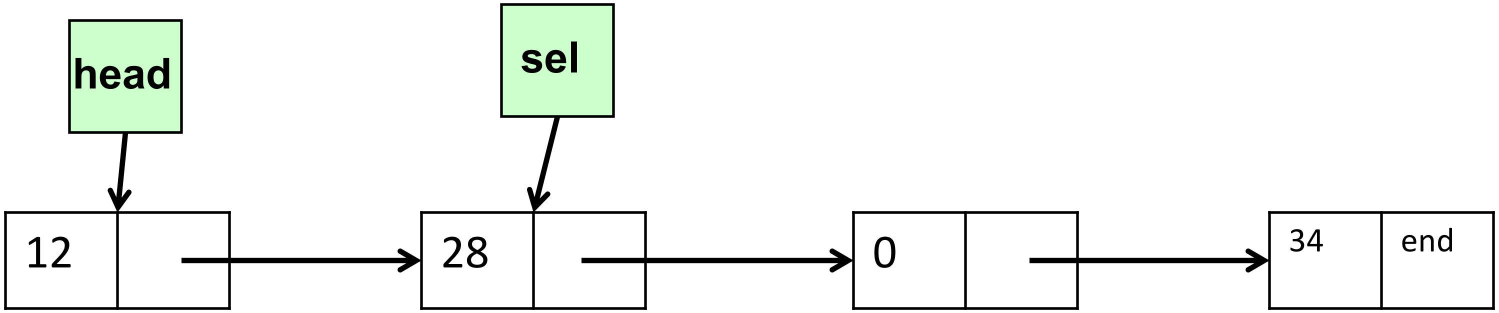
- 2 instance variables
  - int data
  - IntNode link
- Constructor
  - No argument constructor.
  - public IntNode(int initialData, IntNode initialLink)
- Methods
  - public int getData()
  - public IntNode getLink()
  - public void setData(int newData)
  - public void setLink(IntNode newLink)

Members

- Methods
  - public void addNodeAfter(int e)
  - public void removeNodeAfter()

addNodeAfter

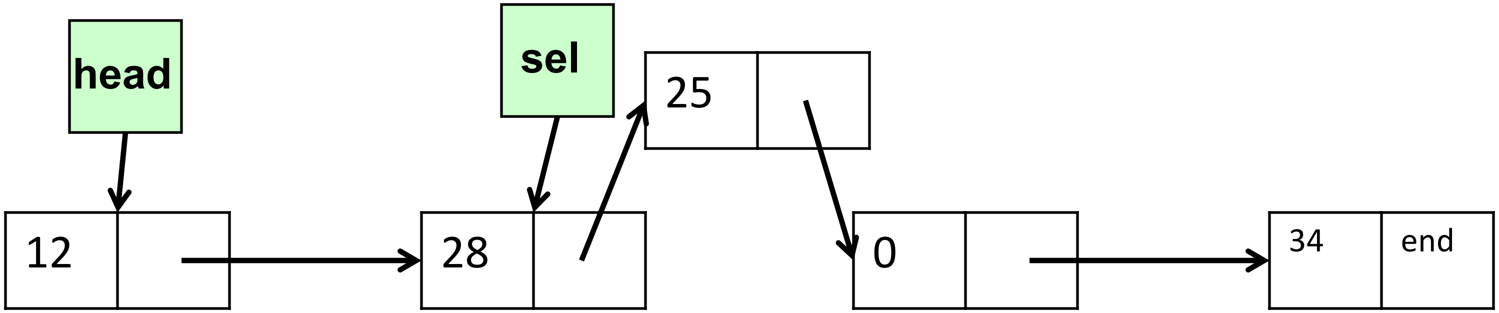
- Add a node with element 25 after the “sel” node



addNodeAfter

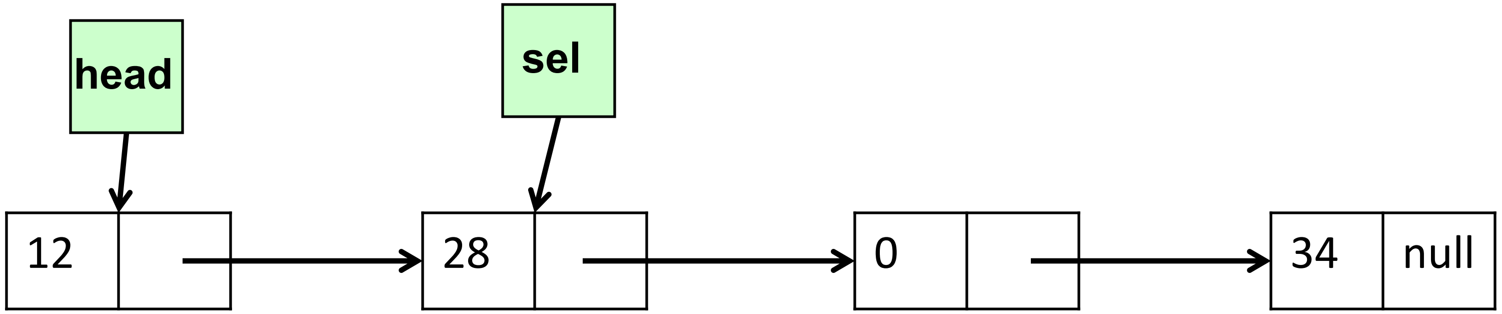
- link =   new IntNode(25,link);

- What if the selected node is the tail of a list?



removeNodeAfter

- Remove the node after the node with value 28

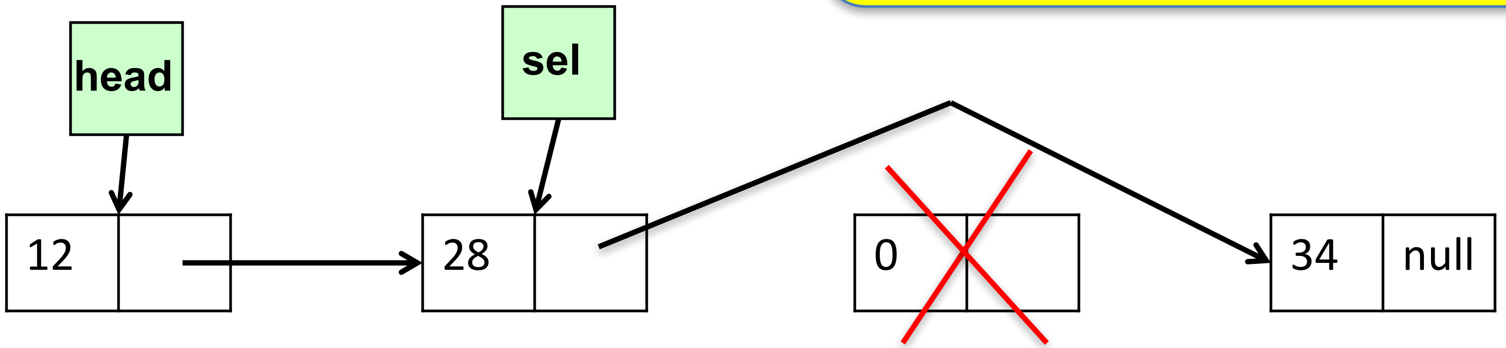


removeNodeAfter

- Remove the node after the node with value 28

sel = the node with value 28
sel.removeNodeAfter()

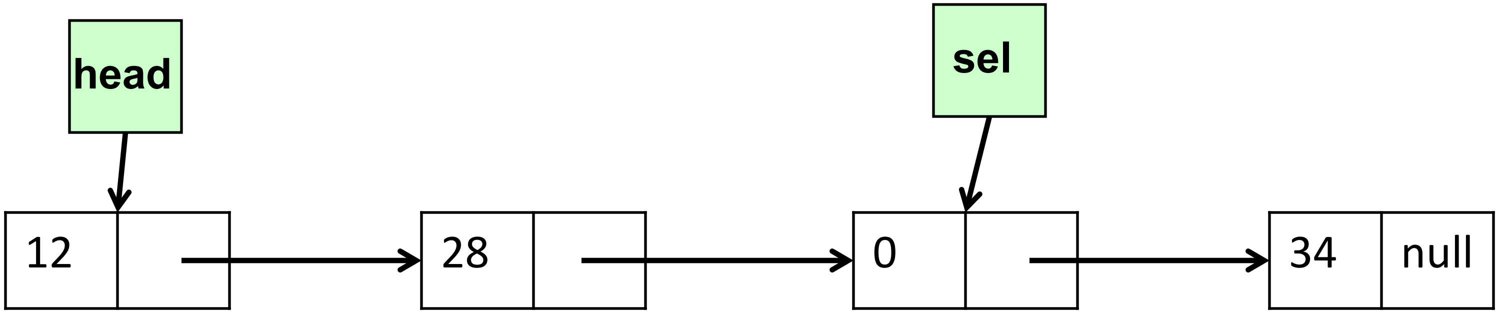
link = sel.getLink().getLink();
Or
link = sel.link.link;



removeNodeAfter

- Special case: remove the last node

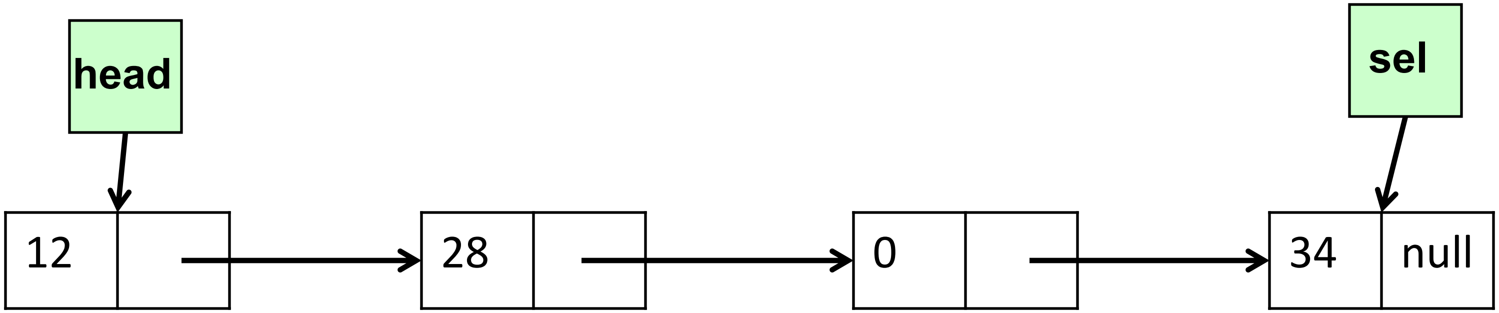
link = node with value 34;
link.link is null;



removeNodeAfter

- Special case: tail node activate this method?

Precondition: link!=null



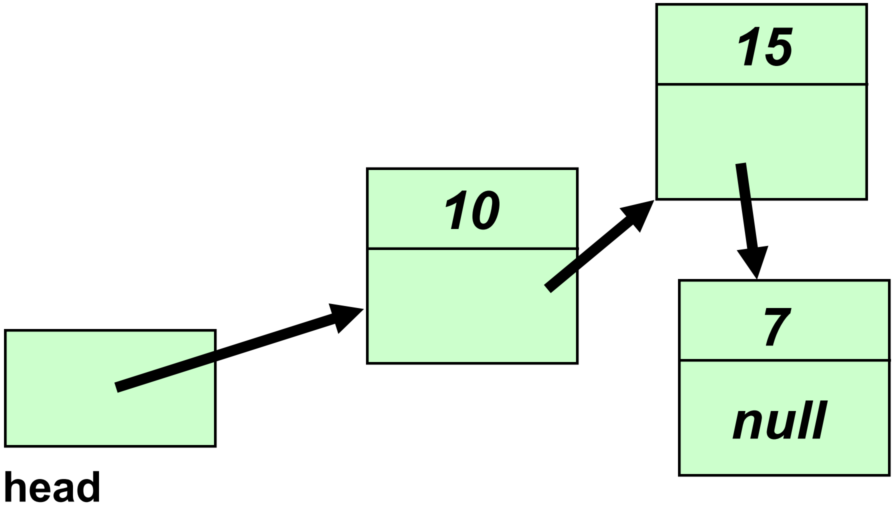
LinkedList

LinkedList

```
public class LinkedList{
    private IntNode head=null;

    public void addFromFront(int e)
    public void removeHead();
}
```

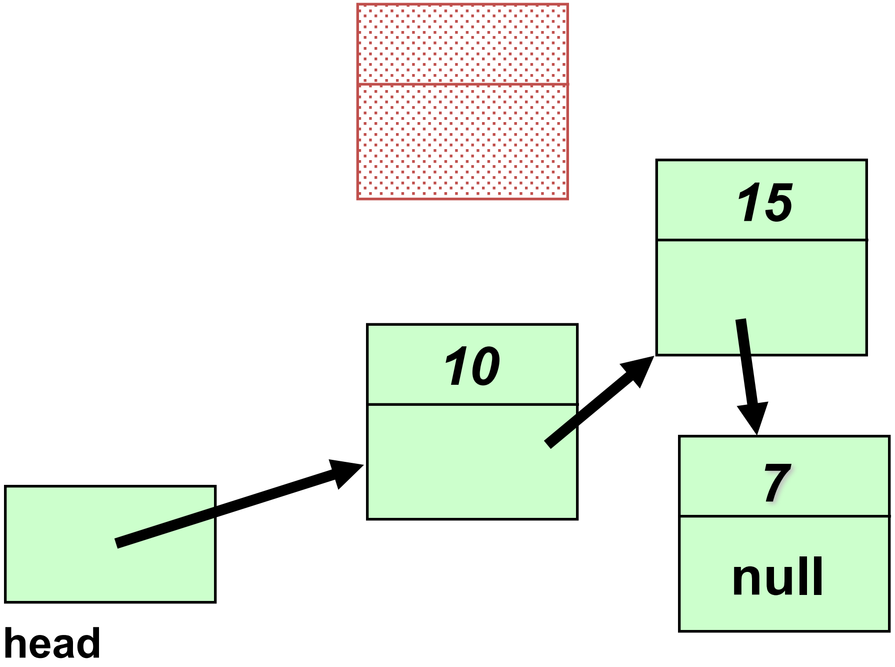
Inserting an IntNode at the Front

We want to add a new entry, 13, to the **front** of the linked list shown here.



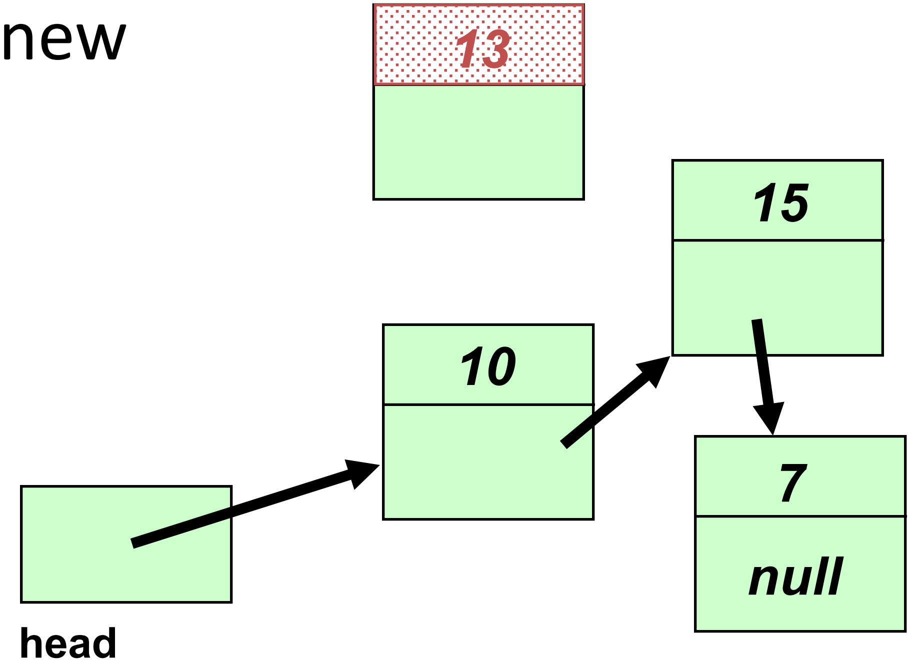
Inserting an IntNode at the Front

1. Create a new node...



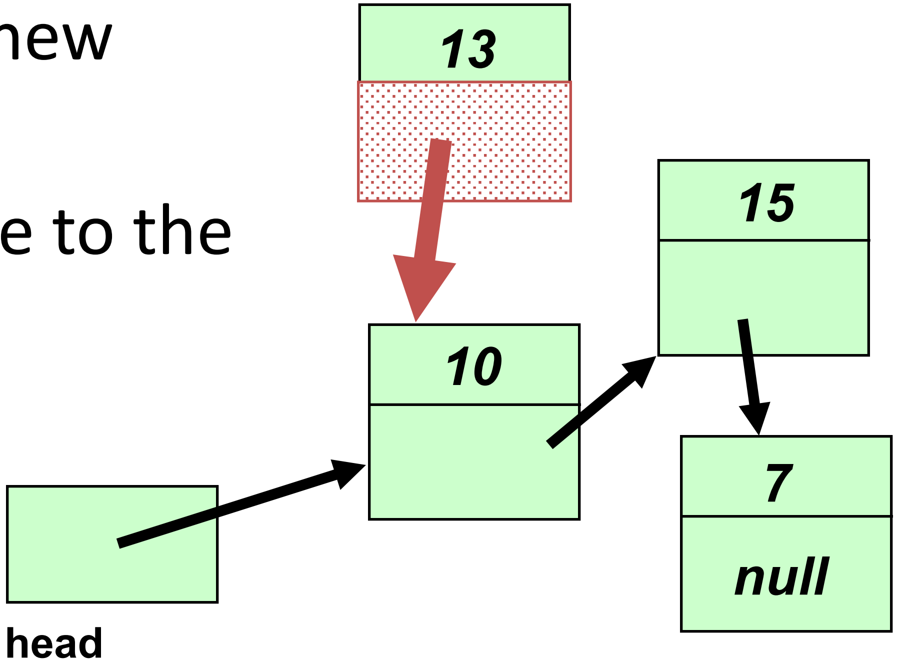
Inserting an IntNode at the Front

1. Create a new node...
2. Place the data in the new node's data field.



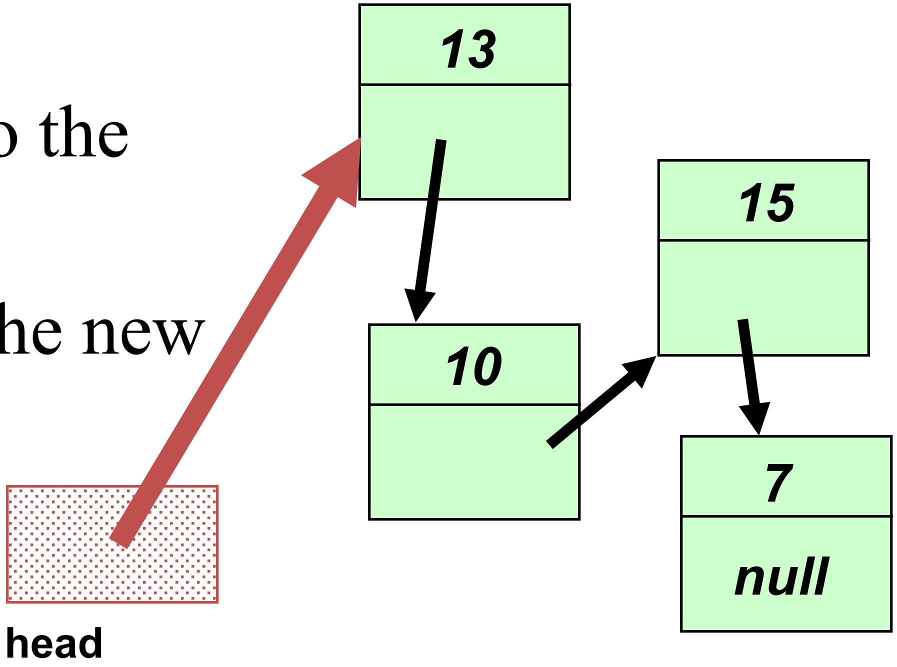
Inserting an IntNode at the Front

1. Create a new node...
2. Place the data in the new node's data field....
3. Connect the new node to the front of the list.



Inserting an IntNode at the Front

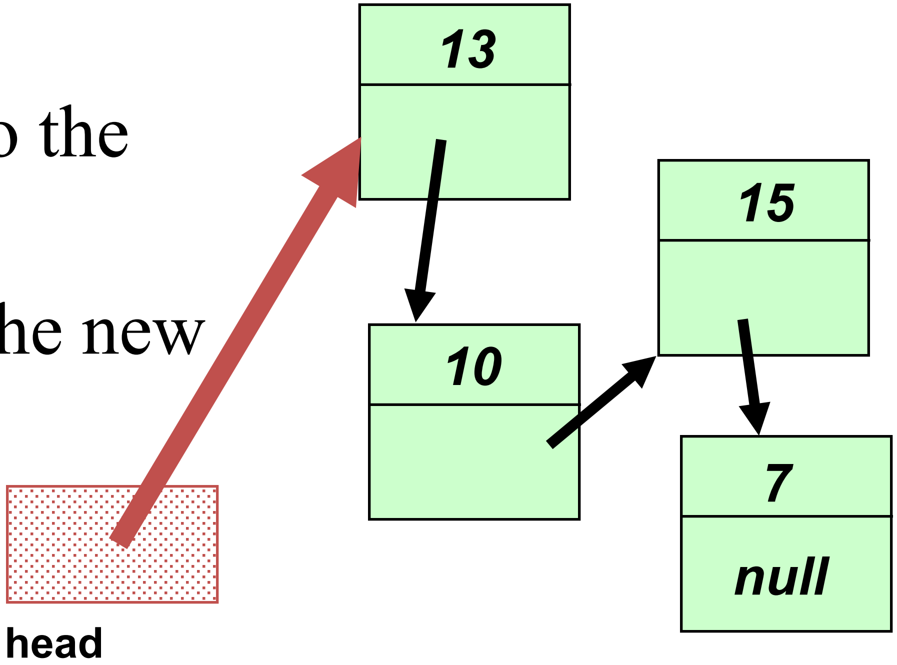
1. Create a new node...
2. Place the data in the new node's data field....
3. Connect the new node to the front of the list.
4. Make the head refer to the new head of the linked list.



Inserting an IntNode at the Front

```
head = new IntNode(13, head);
```

1. Create a new node...
2. Place the data in the new node's data field....
3. Connect the new node to the front of the list.
4. Make the head refer to the new head of the linked list.

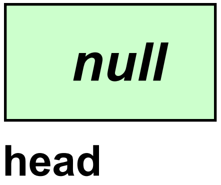


Inserting an IntNode at the Front

```
public IntNode(int initialData, IntNode initialLink)
{
    data = initialEntry;
    link = initialLink;
}
```

Suppose head is null and we execute the assignment shown here:

```
head = new IntNode(13, head);
```



null

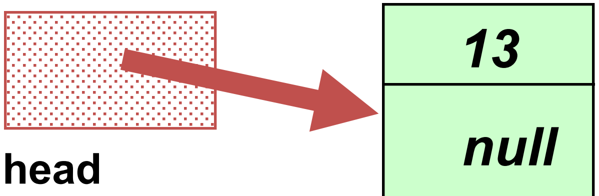
head

Inserting an IntNode at the Front

```
public IntNode(int initialData, IntNode initialLink)
{
    data = initialEntry;
    link = initialLink;
}
```

When the statement finishes, the linked list has one node, containing 13.

```
head = new IntNode(13, head);
```



Caution!

- Always make sure that your linked list methods work correctly with an **empty list**.

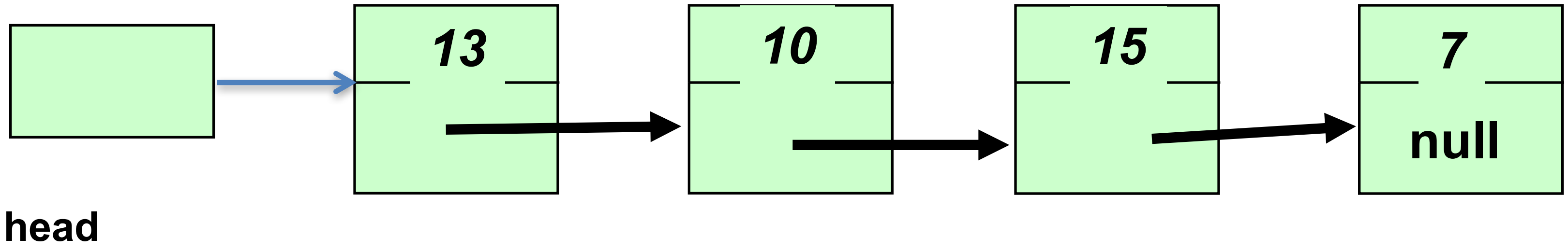
Pseudocode for Removing IntNodes

- A technique for removing a node from the front of a list,
- A technique for removing a node from elsewhere.

Removing the Head IntNode

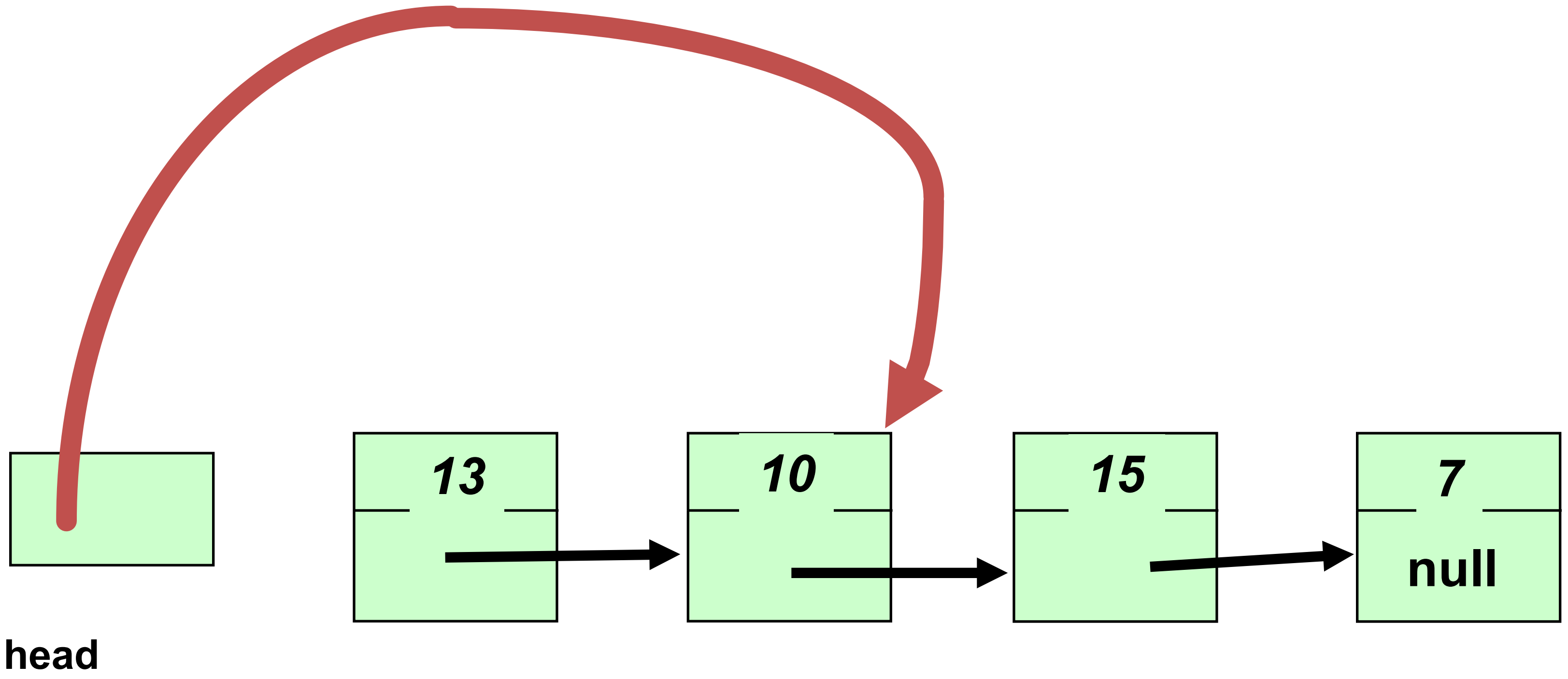
head = head.link;

Draw the change that this statement will make to the linked list.



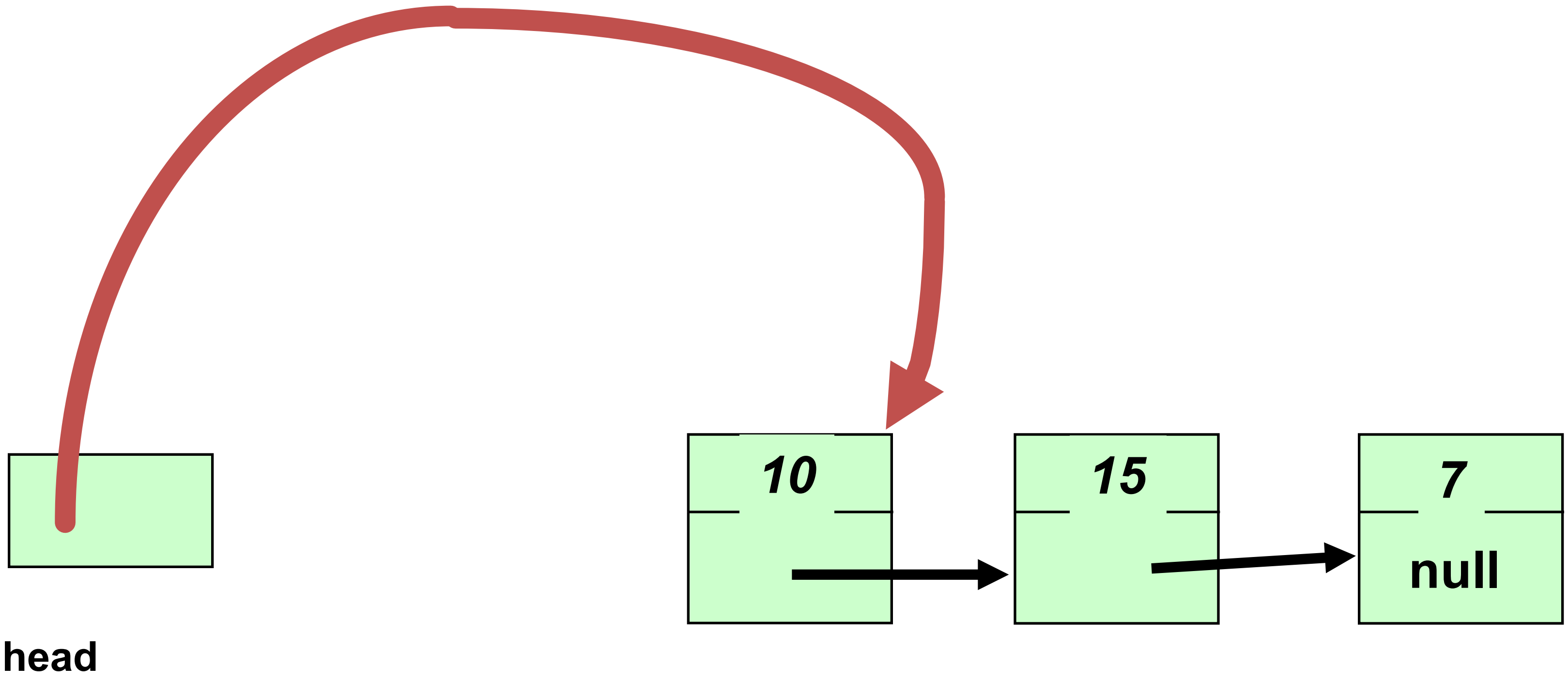
Removing the Head IntNode

```
head = head.link;
```



Removing the Head IntNode

- Here’s what the linked list looks like after the removal finishes.



Special case

- What if a linked list contains only one node?

Use LinkedList

Method - listLength

```
//a method in IntNode
public static int listLength(IntNode head)
{
    int answer = 0
    for(IntNode cursor = head; cursor!=null; cursor=cursor.link)
    {
        answer++;
    }
    return answer;
}
```

listLength

```
//a method in LinkedList
public int listLength()
{
    return IntNode.listLength(head);
}
```

Methods -listSearch

```
//a method in IntNode
public static IntNode listSearch(IntNode head, int target)
{
    IntNode answer = null;
    for(IntNode cursor=head; cursor!=null; cursor = cursor.link){
        if(cursor.data==target){
            answer = cursor;
            break;
        }
    }
    return answer;
}
```

Method-listPosition

```
//a method in IntNode
//pos starts from 1
public static IntNode listPosition(IntNode head, int pos)
{
    int index = 1;
    IntNode cursor=head;
    for(; (cursor!=null)&&(index<pos); index++){
        cursor = cursor.link;
    }
    return cursor;
}
```

findMiddle

- Special cases
- List has 0 elements? pos = 0
- List has 1 element? pos =1
- List has 2 elements? pos=2
- List has 3 elements? Pos=2
- Any rule?
- How to declare it in IntNode and in LinkedList?

Method-listCopy

```
public static IntNode listCopy(IntNode source) {
    IntNode copyHead;
    IntNode copyTail;

    // Handle the special case of the empty list.
    if (source == null) return null;

    // Make the first node for the newly created list.
    copyHead = new IntNode(source.data, null);
    copyTail = copyHead;

    // Make the rest of the nodes for the newly created list.
    while (source.link != null) {
      source = source.link;
      copyTail.addNodeAfter(source.data);
      copyTail = copyTail.link;
    }

    // Return the head reference for the new list.
    return copyHead;
  }
```

Remove example

```
public int removeNumber (int x){
    int num = 0;
    //(1) special process, if the starting nodes contain x
    while(head!=null && head.getData()==x){     head = head.getLink(); num++;}
    if(head==null) return num;
    //(2) Normal case: x exists in other parts of the list
    //    now head.getData for sure is not x
    IntNode preCursor = head;
    IntNode cursor = preCursor.getLink();
    while(cursor!=null){
        if(cursor.getData() ==x){//remove
            preCursor.setLink(cursor.getLink());
            num++;
            cursor = cursor.getLink();
        }else{//moves cursor, not remove
            preCursor = cursor;
            cursor = cursor.getLink();
        }
    }
    return num;
}
```

Summary of LinkedList

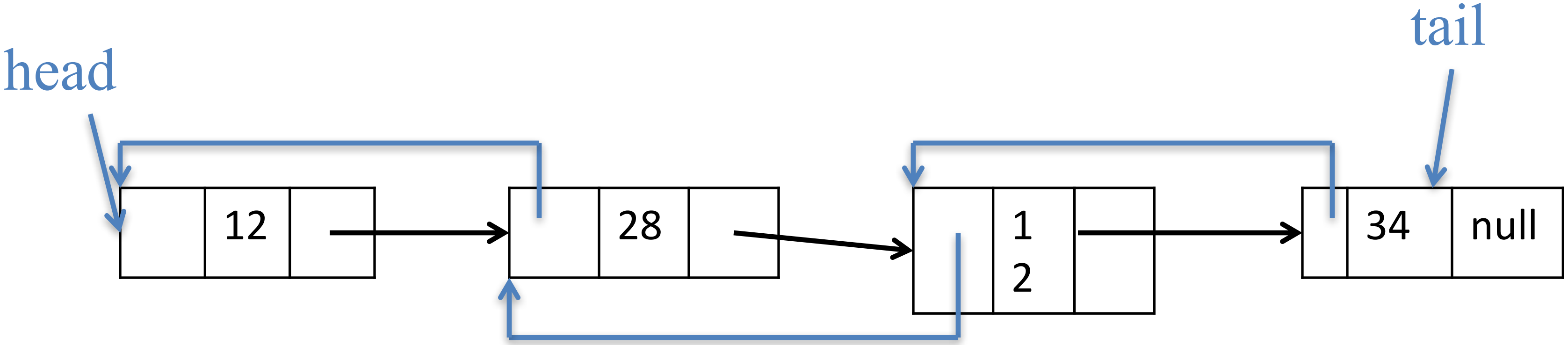
- IntNode
    - Instance variable
    - Constructor
    - Methods
        - Accessor/Modification methods
        - Static methods
            - addNodeAfter
            - removeNodeAfter
            - listLength, listSearch,listPosition
            - listCopy

Linked list

- Singly linked list
- Doubly linked list
  - With dummy nodes
- Circularly linked list

Doubly Linked List

- Doubly Linked List
- Node
  - Element
  - Link to the next/previous element



Doubly Linked List

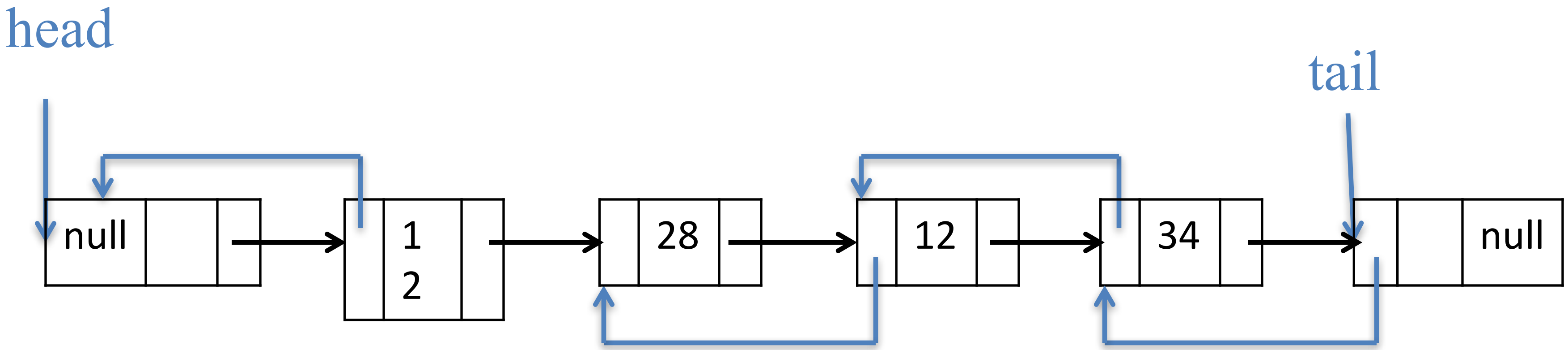
```
public class DLinkedList {
        private DIntNode head;
        private DIntNode tail;
        private int manyItems;

        public DLinkedList( )
        {
            head = tail = null;
            manyItems = 0;
        }
}
```

Doubly Linked List with Dummy Nodes

```
public class DLinkedList {
        private DIntNode head;
        private DIntNode tail;
        private int manyItems;

        public DoublyLinkedListDummy( ){
            head = new DIntNode();
            tail = new DIntNode();
            head.setNext(tail);
            tail.setPrev(head);
            manyItems = 0;
      }
}
```

Outline

- DoublyLinkedList with dummy head and tail



```
public void addAfter(DIntNode v, int element)
{
        DIntNode newNode = new DIntNode(element,null,null);
        //(1) Make newNode's prev link point to v
        newNode.setPrev(v);
        //(2)Make newNode's next link point to w
        DIntNode vNext = v.getNext();
        newNode.setNext(v.getNext());
        //(3) Make vNext's prev link point to newNode
        vNext.setPrev(newNode);
        //(4)Make v's next link point to newNode
        v.setNext(newNode);

        //Update many items
        manyItems++;
}
```

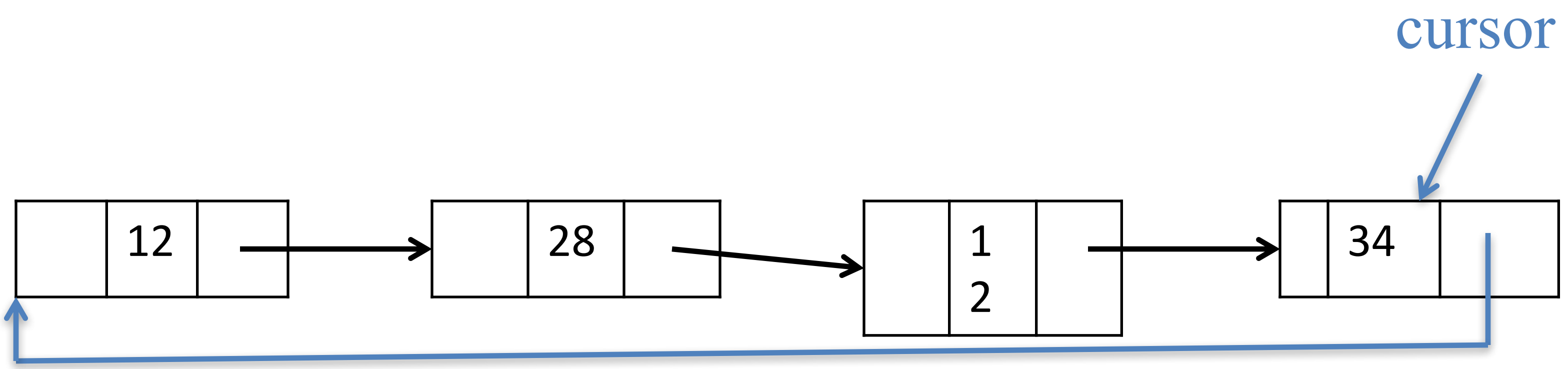
```
public boolean remove(DIntNode v)
 {
        //Pseudo-codes
        //Special consideration
        DIntNode vPrev = v.getPrev();
        DIntNode vNext = v.getNext();

        //Make vNext's prev link point to vPrev
       vNext.setPrev(vPrev);

        //Make vPrev's next link point to vNext
       vPrev.setNext(vNext);

        //Update many items
       manyItems--;
        return true;
}
```

Linked list

- Singly linked list
- Doubly linked list
  - With dummy nodes
- Circularly linked list

Circularly Linked List

- Circularly Linked List
- IntNode
  - Element
  - Link to the next element



cursor
12
28
1
2
34