

# Linked List

# Array Limitations

What are the limitations of an array, as a data structure?

1. Fixed size
2. Physically stored in consecutive memory locations
3. To insert or delete items, may need to shift data

# List Overview

## 1. Basic operations of linked lists

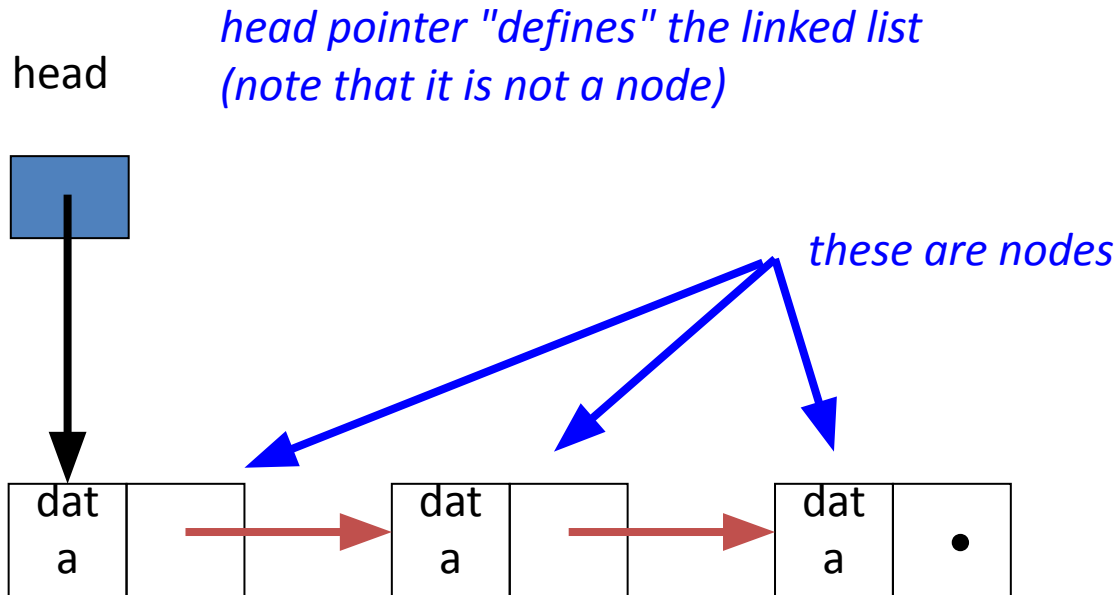
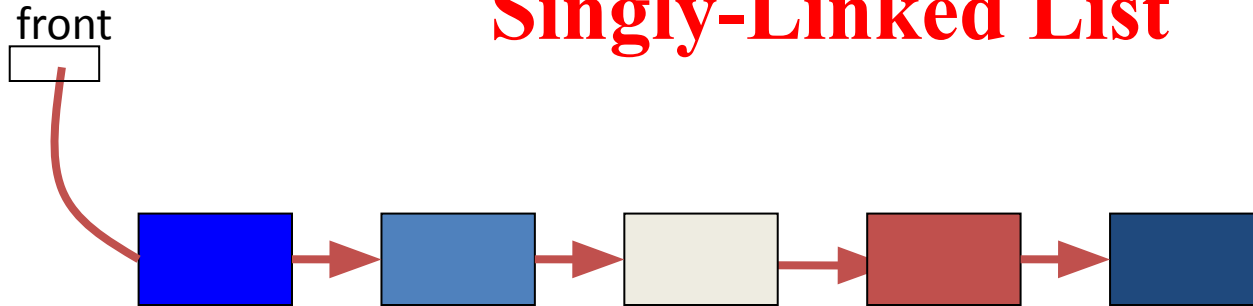
Insert, find, delete, print, etc.

## 2. Variations of linked lists

1. Linear Linked list
2. Circular linked lists
3. Doubly linked lists

# Conceptual Diagram

## Singly-Linked List



# Advantages of Linked Lists

- The items do *not* have to be stored in consecutive memory locations: the successor can be anywhere physically
  - can insert and delete items without shifting data
  - can increase the size of the data structure easily
- Linked lists can grow *dynamically* (i.e. at run time) – the amount of memory space allocated can grow and shrink as needed

# Disadvantages of Linked Lists

- A linked list will use more memory storage than arrays. It has more memory for an additional linked field or next pointer field.
- Arrays elements can be randomly accessed by giving the appropriate index, while linked list elements cannot randomly accessed.
- Binary search cannot be applied in a linked list.
- A linked list takes more time in traversing of elements.

# Nodes

- A linked list is an ordered sequence of items called *nodes*
  - A node is the basic unit of representation in a linked list
- A *node* in a *singly linked list* consists of two fields:
  - A *data* portion
  - A *link (pointer)* to the *next* node in the structure
- The first item (node) in the linked list is accessed via a *front* or *head* pointer
  - The linked list is defined by its head (this is its starting point)

# Linked List Operations

Following are linked list operations:

□ *Add* an item to the linked list

□ *Delete* an item from the linked list

- *Add* an item to the linked list
  - We have 3 situations to consider:
    - insert a node *at the front*
    - insert a node *in the middle*( at particular position)
    - insert a node *at the end*
- *Delete* an item from the linked list
  - We have 3 situations to consider:
    - delete the node *at the front*
    - delete any *interior* node
    - delete the *last* node



## A Simple Linked List Class

We use two classes: **Node** and **List**

Declare `Node` class for the nodes

- `data`: `int`-type data in this example
- `next`: a pointer to the next node in the list

```
class Node {  
public:  
    int info;        // data  
    Node* next;      // pointer to next  
};
```

# A Simple Linked List Class

Declare List, which contains

- head: a pointer to the first node in the list.  
Since the list is empty initially, head is set to NULL
- Operations on List

```
class List {  
public:  
    List(void) {head = NULL;}    // constructor  
    ~List(void);                // destructor  
  
private:  
    Node* head;  
};
```

# A Simple Linked List Class

## Operations of List

- **IsEmpty**: determine whether or not the list is empty
- **InsertNode**: insert a new node at a particular position
- **FindNode**: find a node with a given value
- **DeleteNode**: delete a node with a given value
- **DisplayList**: print all the nodes in the list

## Inserting a new node

- Possible cases of InsertNode
  1. Insert into an empty list
  2. Insert in front
  3. Insert at back
  4. Insert in middle
- But, in fact, only need to handle two cases
  - Insert as the first node (Case 1 and Case 2)
  - Insert in the middle or at the end of the list (Case 3 and Case 4)

# Insertion at the Start

It is just a 2-step algorithm which is performed as follows

Assume

- **node** points to the new node to be inserted
- **front** points to the first node of the linked list

1. Make the new node point to the first node  
(i.e. the node that **front** points to)
2. Make front point to the new node  
(i.e the node that node points to)

# Inserting a Node at the Front

node



**node** points to the new node to be inserted,  
**front** points to the first node of the linked list

front



node



front

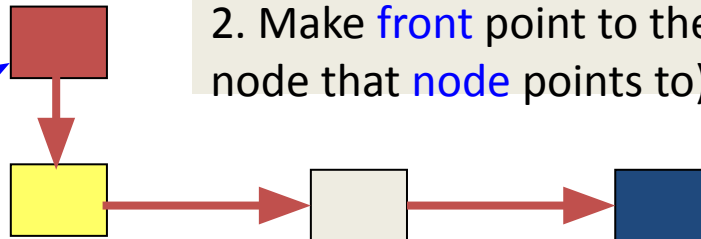


1. Make the new node point to the first node (i.e. the node that **front** points to)

node



front



2. Make **front** point to the new node (i.e the node that **node** points to)

# Algorithm

```
void insert_beg(int val)  
{ node *temp=new node;  
    temp->info=val;  
    if(head==NULL)  
        { head=temp;  
        temp->next=NULL}  
    else  
        temp->next=head;  
        head=temp; }  
}
```

# Insertion at the End

```
void Insert_End(int val)  
{ node *temp=new node;  
  temp->info=val;  
  temp->next=NULL;  
  if(head==NULL)  
  {  
    temp->next= NULL  
    head=temp;  
  }
```

```
else { Node *cur =new Node();  
  cur=head;  
  while(cur->next!=NULL)  
  {  
    cur=cur->next;  
  }  
  cur->next=temp;  
}
```



# Insertion at Particular Position

In this case, a new node is inserted between two consecutive nodes.

Here, We call one node as *current* and the other as *previous*

Now the new node can be inserted between the previous and current node by just performing two steps:

1. Pass the address of the new node in the next field of the previous node.
2. Pass the address of the current node in the next field of the new node.

**OVERFLOW.** Overflow is a condition that occurs when we try to **create a node** but there is not a sufficient memory available.

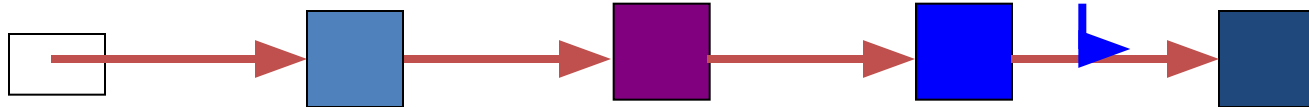
# Inserting a Node in the Middle

Let's insert the new node after the *third* node in the linked list

node



front



1. Locate the node *preceding the insertion point*, since it will have to be modified (make *current* point to it)

node



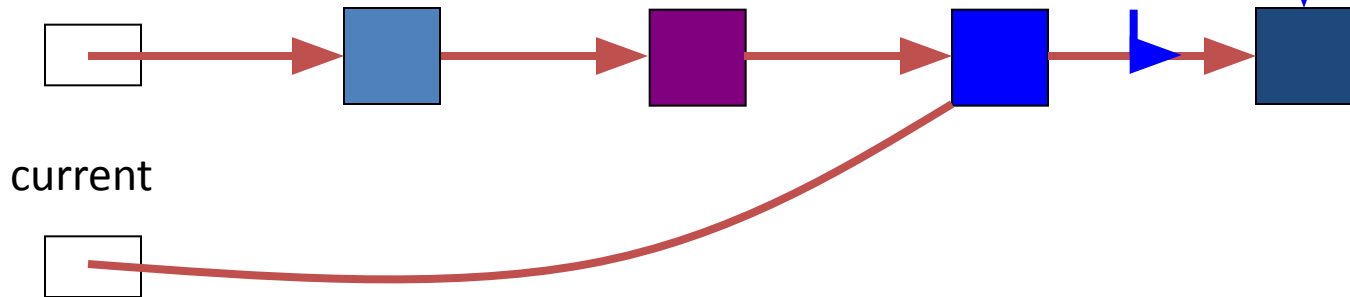
front



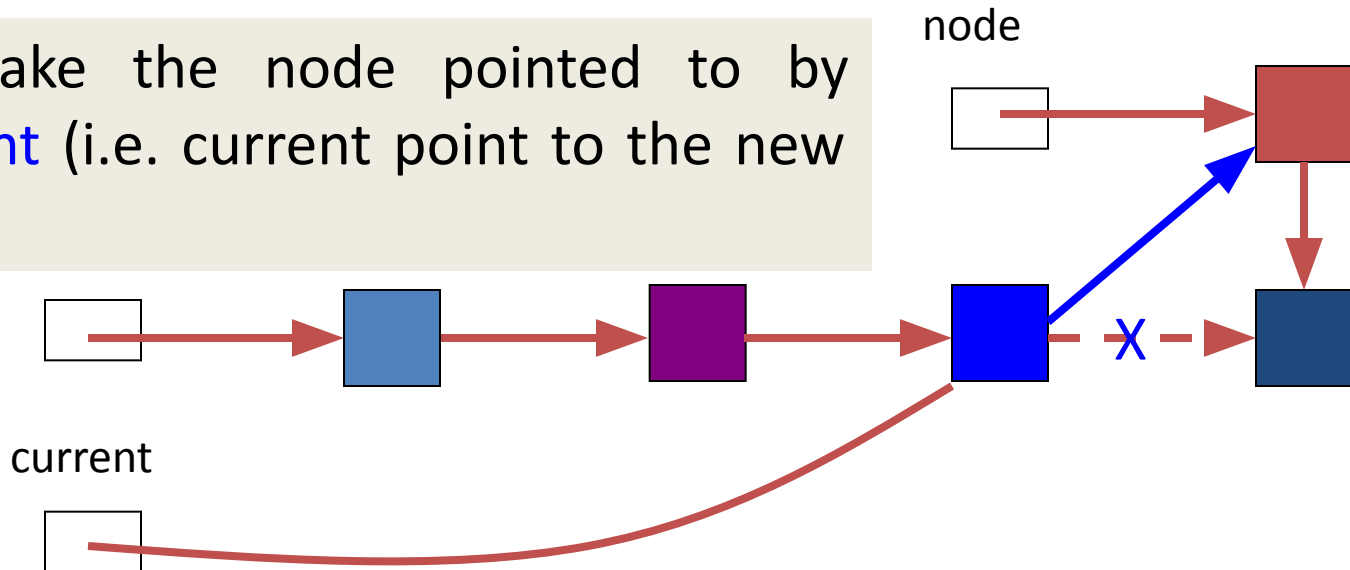
current



2. Make the new node point to the node after the insertion point (i.e. the node pointed to by the node that **current** points to)



3. Make the node pointed to by **current** (i.e. current point to the new node)



# Algorithm

```
void insert_position(int pos, int val)  
{  
    node *pre;  
    node *cur;  
    node *temp=new node;  
    temp->data=val;  
    cur=head;  
    for(int i=1;i<pos;i++)  
        { pre=cur; cur=cur->next; }  
    pre->next=temp;  
    temp->next=cur; }
```

## Algorithm--Insertion after a specific value

```
void insert_specificValue(int sp_val, int data)  
{  
    node *pre;  
    node *cur;  
    node *temp=new node;  
    temp->data=data;  
    cur=head;  
    while (cur->data!= sp_val)  
        { pre=cur; cur=cur->next; }  
    temp->next=cur;  
    pre->next=temp;  
}
```

## Comparison --- Insertion in between two nodes

```
void insert_position(int pos, int val)
```

```
{  node *pre;
    node *cur;
    node *temp=new node;
    temp->data=val;
    cur=head;
```

```
    for(int i=1;i<pos;i++)
```

```
        { pre=cur; cur=cur->next; }
    pre->next=temp;
    temp->next=cur; }
```

```
void insert_specificValue(int sp_val, int data)
```

```
{  node *pre;
    node *cur;
    node *temp=new node;
    temp->data=data;
    cur=head;
```

```
    while (cur->data!= sp_val)
```

```
        { pre=cur; cur=cur->next; }
    temp->next=cur;
    pre->next=temp;
}
```

# Deleting a Node from a Linked List

We will consider three cases and then see how deletion is done in each case.

Case 1: The first node is deleted.

Case 2: The last node is deleted.

Case 3: The node after a given node is deleted.

## UNDERFLOW.

A condition that occurs when we try to **delete a node from an empty linked list**

This happens when **Head = NULL** or when there are no more nodes to delete.

Note that when we delete a node from a linked list, we actually have to free the memory occupied by that node. The memory is returned to the free pool so that it can be used to store other programs and data.

# Deleting the First Node from a Linked List

To delete a node from the beginning of the list, then the following changes will be done in the linked list

**Step 1:** check if the linked list exists or not.

**If Head = NULL**, then there are **no nodes in the list** and the control is transferred to the last statement of the algorithm. (UNDERFLOW)

**Step 2:** However, if there are nodes in the linked list,

A pointer **variable PTR is set to point to the first node** of the list.

(i.e. initialize PTR with Head that stores the address of the first node )

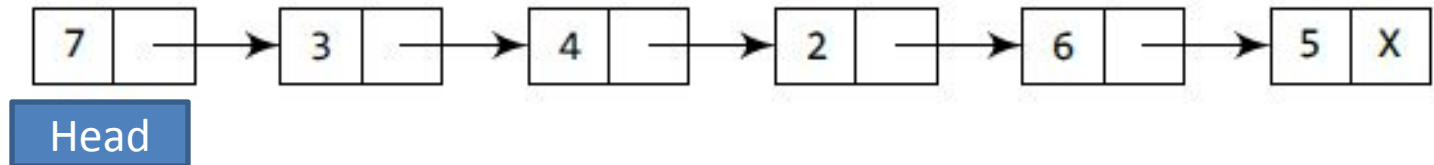
**Step 3:** Head is made to point to the next node in sequence

**Step 4: Finally**, the memory occupied by the node pointed by PTR (initially the first node of the list) is freed and returned to the free pool.





Make **Head** to point to the next node in sequence.



## Deleting the First Node

```
if (head==NULL)
    cout<<"Underflow"<<endl;
else
    node *ptr;
    ptr = head;
    head=head->next;
    delete ptr;
```

# Deleting the Last Node from a Linked List

Following steps will be required

**Step 1:** check if the linked list exists or not.

**If Head = NULL**, then there are **no nodes in the list** and the control is transferred to the last statement of the algorithm. (UNDERFLOW)

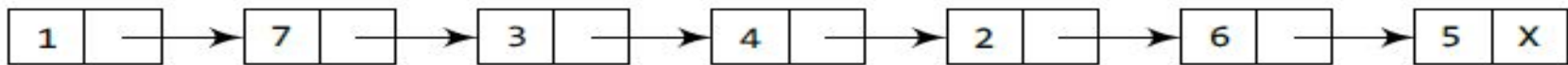
**Step 2:** take a pointer variable **PTR** and initialize it with **head**.

That is, PTR now points to the first node of the linked list.

**Step 3:** take another pointer variable **PREPTR**

In the while loop, we take another pointer variable **PREPTR** such that it always points to one node before the **PTR**.

Once we reach the last node and the second last node, we set the NEXT pointer of the second last node to NULL, so that it now becomes the (new) last node of the linked list. The memory of the previous last node is freed and returned back to the free pool.



START

Take pointer variables PTR and PREPTR which initially point to START.

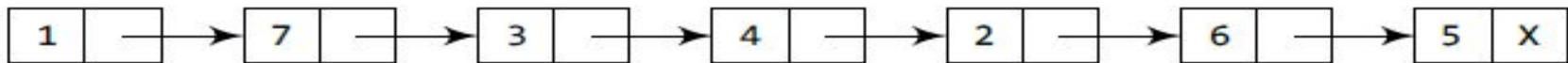


START

PREPTR

PTR

Move PTR and PREPTR such that NEXT part of PTR = NULL. PREPTR always points to the node just before the node pointed by PTR.

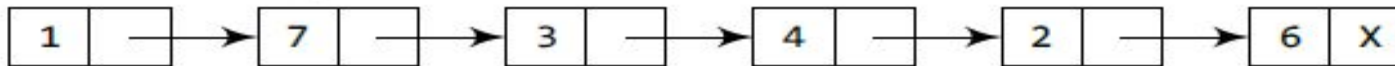


START

PREPTR

PTR

Set the NEXT part of PREPTR node to NULL.



Step 1: IF START = NULL

Write UNDERFLOW

Go to Step 8

[END OF IF]

Step 2: SET PTR = START

Step 3: Repeat Steps 4 and 5 while PTR → NEXT != NULL

Step 4: SET PREPTR = PTR

Step 5: SET PTR = PTR → NEXT

[END OF LOOP]

Step 6: SET PREPTR → NEXT = NULL

Step 7: FREE PTR

Step 8: EXIT

**NOTE: Here START means Head.**

# Deleting the Specific Node in a Linked List

Then the following changes will be done in the linked list:

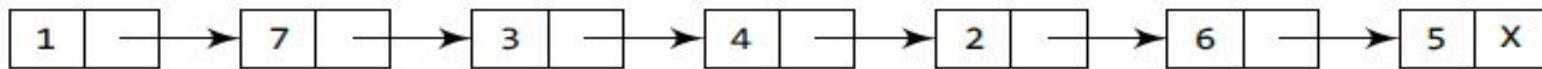
**Step 1:** check if the linked list exists or not.

If **START = NULL**, it signifies that there are no nodes in the list and the control is transferred to the last statement of the algorithm.

**Step 2:** we take a pointer variable **PTR** and initialize it with **START**.

That is, PTR now points to the first node of the linked list. In the while loop, we take another pointer variable **PREPTR** such that it always points to one node before the PTR.

Once we reach the node containing VAL and the node succeeding it, we set the next pointer of the node containing VAL to the address contained in next field of the node preceeding it. The memory of the node succeeding the given node is freed and returned back to the free pool.



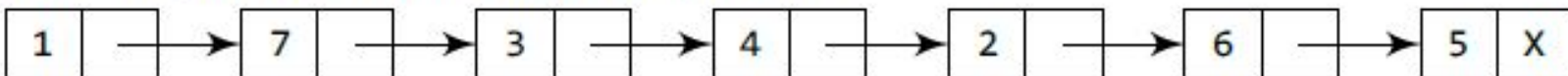
START

Take pointer variables PTR and PREPTR which initially point to START.

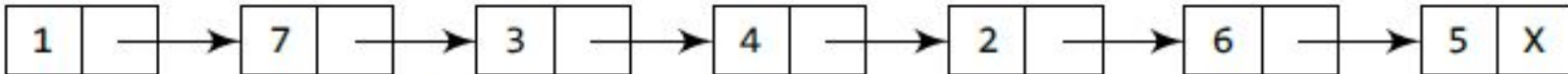


START  
PREPTR  
PTR

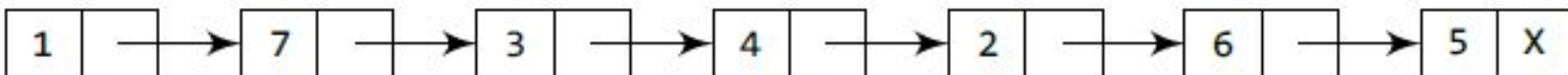
Move PREPTR and PTR such that PREPTR points to the node containing VAL and PTR points to the succeeding node.



START          PREPTR          PTR

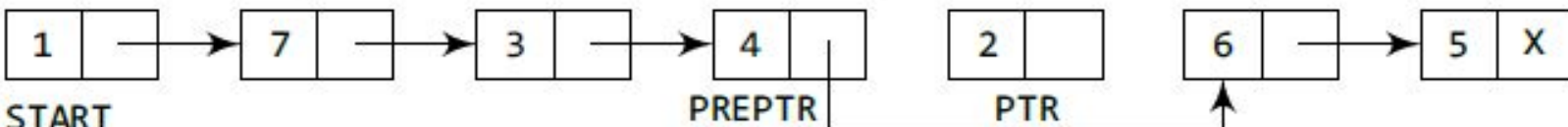


START                  PREPTR          PTR

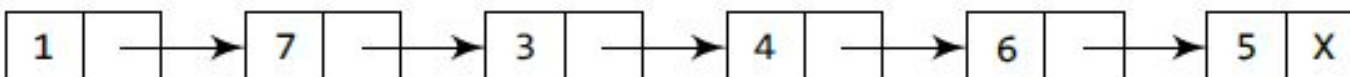


START                          PREPTR          PTR

Set the NEXT part of PREPTR to the NEXT part of PTR.



START



START

## Algorithm: Deleting the Specific Node

```
Step 1: IF START = NULL
        Write UNDERFLOW
        Go to Step 10
    [END OF IF]
Step 2: SET PTR = START
Step 3: SET PREPTR = PTR
Step 4: Repeat Steps 5 and 6 while PREPTR->DATA != NUM
Step 5:     SET PREPTR = PTR
Step 6:     SET PTR = PTR->NEXT
    [END OF LOOP]
Step 7: SET TEMP = PTR
Step 8: SET PREPTR->NEXT = PTR->NEXT
Step 9: FREE TEMP
Step 10: EXIT
```