04-09-2023

Module 2.0

Linear Data Structure: Linked List

04-09-2023

Memory Allocation & Deallocation for Linked List

Memory Allocation

There are two types of Memory Allocation

- **Compile Time or Static Allocation**
- **Runtime or Dynamic Allocation**

Compile Time or Static Allocation

- Memory allocated to the program element
  - **at the start of the program.**
- Memory allocated
  - **is fixed and determined by the compiler at compile time.**

- **Eg- float a[5]** ,

allocation of 20 bytes to the array, i.e. 5*4 bytes

Compile Time or Static Allocation

- **Inefficient Use of Memory-**
  - **Can cause under utilization of memory in case of over allocation**
    - That is if you store less number of elements than the number for elements which you have declared memory.
    - Rest of the memory is wasted, as it is not available to other applications.

Compile Time or Static Allocation

- **Inefficient Use of Memory-**
  - **Can cause Overflow in case of under allocation**
    - For float a[5];
    - No bound checking in C for array boundaries, if you are entering more than fives values,
    - It will not give error but when these extra element will be accessed, the values will not be available.

Compile Time or Static Allocation

- **No reusability of allocated memory**
- **Difficult to guess the exact size of the data at the time of writing the program**

Runtime or Dynamic Allocation

- **All Linked Data Structures are preferably implemented through dynamic memory allocation.**
- Dynamic data structures provide flexibility in **adding, deleting or rearranging data objects at run time.**
- Managed in C through a set of library functions:
  - malloc()
  - Calloc()
  - free()
  - Realloc()

Runtime or Dynamic Allocation

- Memory space required by Variables is **calculated and allocated during execution**
- Get Required chunk of memory at Run time or As the need arises
- Best Suited –
  - **When we do not know the memory requirement in advance**, which is the case in most of the real life problems.

Runtime or Dynamic Allocation

- **Efficient use of Memory**
  - Additional Space can be allocated at run time.
  - Unwanted Space can be released at run time.

- **Reusability of Memory space**

The malloc() fn

- **Allocates a block of memory in bytes**
- The user should **explicitly give the block size** needed.

The malloc() fn

- **Request to the RAM of the system to allocate memory**,
  - If request is granted returns a pointer to the first block of the memory
  - If it fails, it returns NULL

The malloc() fn

- **The type of pointer is Void, i.e. we can assign it any type of pointer.**
- Available in header file alloc.h or stdlib.h

The mallloc() fn

- Syntax-

ptr_var=(type_cast*)malloc(size)

The mallloc() fn

- **Syntax-**

  ptr_var=(type_cast*)malloc(size)

- ptr_var = name of pointer that holds the starting address of allocated memory block
- type_cast* = is the data type into which the returned pointer is to be converted
- Size = size of allocated memory block in bytes

The mallloc() fn

Eg-

```
int *ptr;
ptr=(int *)malloc(10*sizeof(int));
```

The mallloc() fn

Eg-

```
int *ptr;
ptr=(int *)malloc(10*sizeof(int));
```

- Size of int=2bytes
- So 20 bytes are allocated,
- Void pointer is casted into int and assigned to ptr

The mallloc() fn

Eg-

```
char *ptr;
ptr=(char *)malloc(10*sizeof(char));
```

The mallloc() fn- Usage in Linked List

Eg-

```
struct student;
{
        int roll_no;
        char name[30];
        float percentage;
};
struct student *st_ptr;
st_ptr=(struct student *)malloc(10*sizeof(struct student));
```

The callloc() fn

- Similar to malloc
  - It neds two arguments as against one argument in malloc() fn

Eg-

```
int *ptr;
ptr=(int *)calloc(10,2));
```

1st argument=no of elements

2nd argument=size of data type in bytes

The callloc() fn

- Available in header file alloc.h or stdlib.h

Malloc() vs calloc() fn

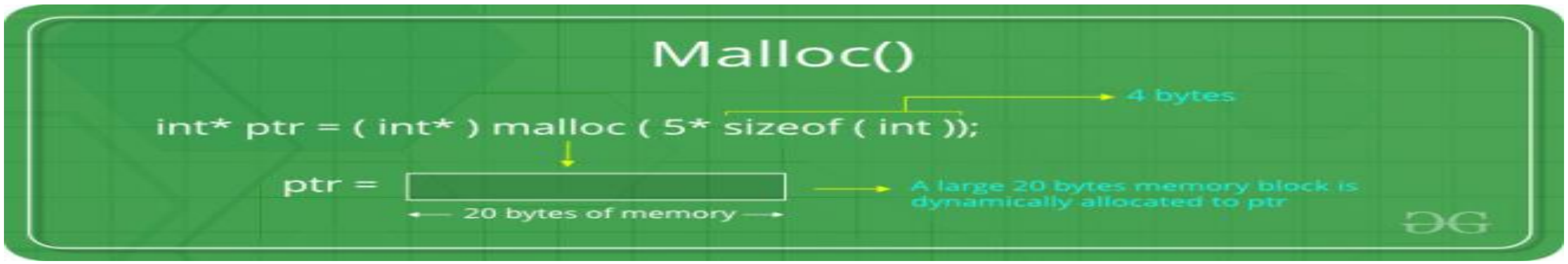
Initialization:

- malloc() doesn't initialize the allocated memory.
  - If we try to access the content of memory block(before initializing) then we'll get segmentation fault error(or garbage values).
- calloc() allocates the memory and also initializes the allocated memory block to zero.
  - If we try to access the content of these blocks then we'll get 0.

Malloc() vs calloc() fn

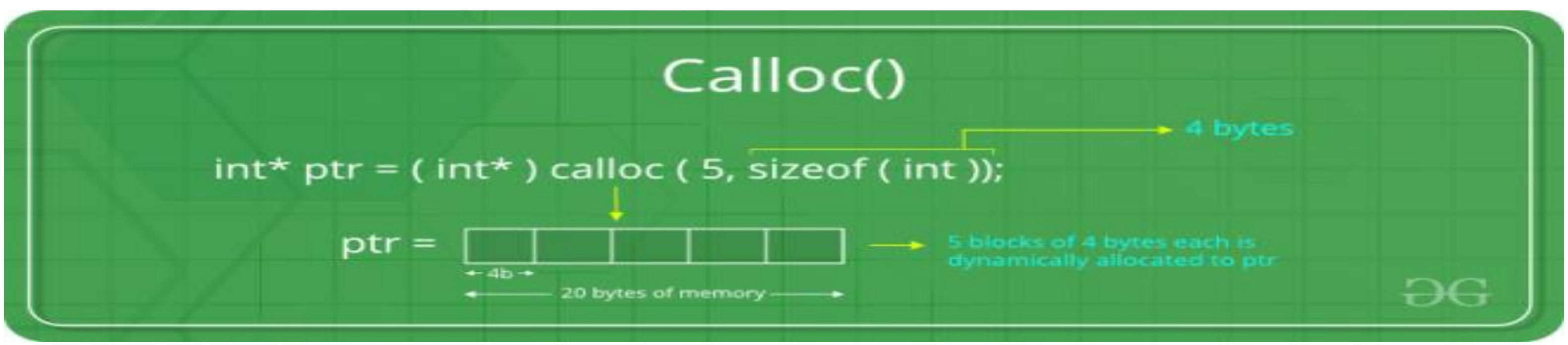
Malloc

- allocate a single large block of memory with the specified size.



Calloc

- allocate multiple blocks of memory
- dynamically allocate the specified number of blocks of memory of the specified type.



The free() fn

- Used to deallocate the previously allocated memory using malloc or calloc() fn

- **Syntax-**

  free(ptr_var);

- ptr_var is the pointer in which the address of the allocated memory block is assigned.

- Returns the allocated memory to the system RAM..

What happens when you don’t free memory after using malloc()

What happens when you don't free memory after using malloc()

- The memory allocated using malloc() is not de-allocated on its own.
- So, "free()" method is used to de-allocate the memory.
- But the free() method is not compulsory to use.

What happens when you don’t free memory after using malloc()

- If free() is not used in a program
  - the memory allocated using malloc() will be de-allocated
  - after completion of the execution of the program
  - (included program execution time is relatively small and the program ends normally).

What happens when you don’t free memory after using malloc()

- Still, there are some important reasons to free() after using malloc():

1) **Use of free after malloc is a good practice of programming.**
2) **There are some programs like a digital clock, a listener that runs in the background for a long time and there are also such programs which allocate memory periodically.**

What happens when you don't free memory after using malloc()

- Still, there are some important reasons to free() after using malloc():

  - In these cases, even small chunks of storage add up and create a problem.
  - Thus our usable space decreases.
  - **This is also called "memory leak".**
  - It may also happen that our system goes out of memory if the de-allocation of memory does not take place at the right time.

Memory Leak ?

- A memory leak is a type of resource leak
- that occurs when a computer program incorrectly manages memory allocations
- in a way that memory which is no longer needed is not released

The realloc() fn

- To resize the size of memory block, which is already allocated using malloc.
- Used in two situations:
  - **If the allocated memory is insufficient for current application**
  - **If the allocated memory is much more than what is required by the current application**

The realloc() fn

- Syntax-

  ptr_var=realloc(ptr_var,new_size);

- ptr_var is the pointer holding the starting address of already allocated memory block.

- Available inn header file<stdlib.h>

- **Can resize memory allocated previously through malloc/calloc only.**

Eg of mallloc() fn

```
#include <stdio.h>
#include <string.h>
#include <stdlib.h>

int main()
{
   char *mem_allocation;
   mem_allocation = (char *) malloc( 20 * sizeof(char) );

   if( mem_allocation == NULL )
   {
      printf("Couldn't able to allocate requested memory\n");
   }
   else
   {
     strcpy( mem_allocation,"fresh2refresh.com");
   }
```

Eg of mallloc() fn

```
printf("Dynamically allocated memory content  : "%s\n",
mem_allocation );
    mem_allocation=realloc(mem_allocation,100*sizeof(char));
    if( mem_allocation == NULL )
    {
        printf("Couldn't able to allocate requested memory\n");
    }
    else
    {
        strcpy( mem_allocation,"space is extended upto 100
characters");
    }
    printf("Resized memory : %s\n", mem_allocation );
    free(mem_allocation);
}
```

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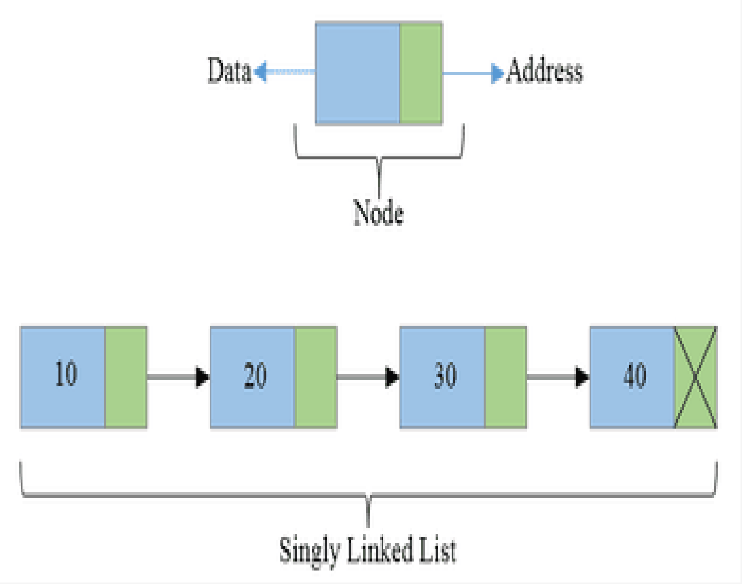
Linked List

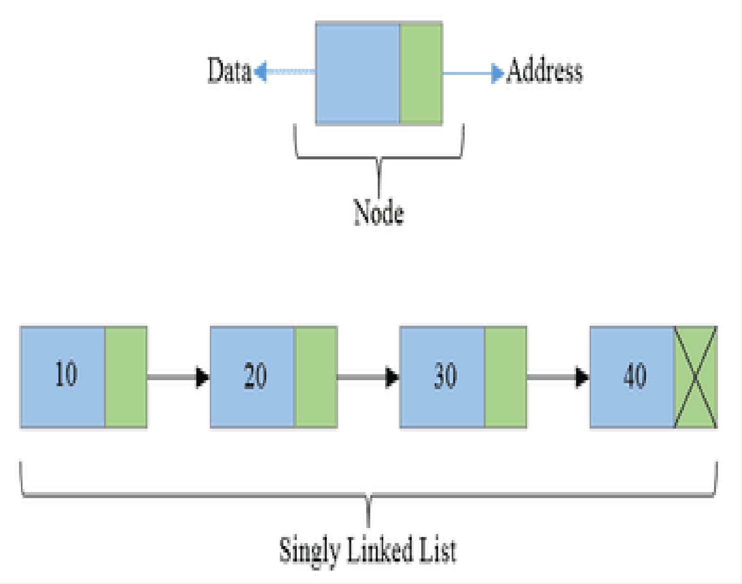
Linked Lists

- **Linear Collection of data elements called Nodes**
- **Linear order is given by means of pointers.**



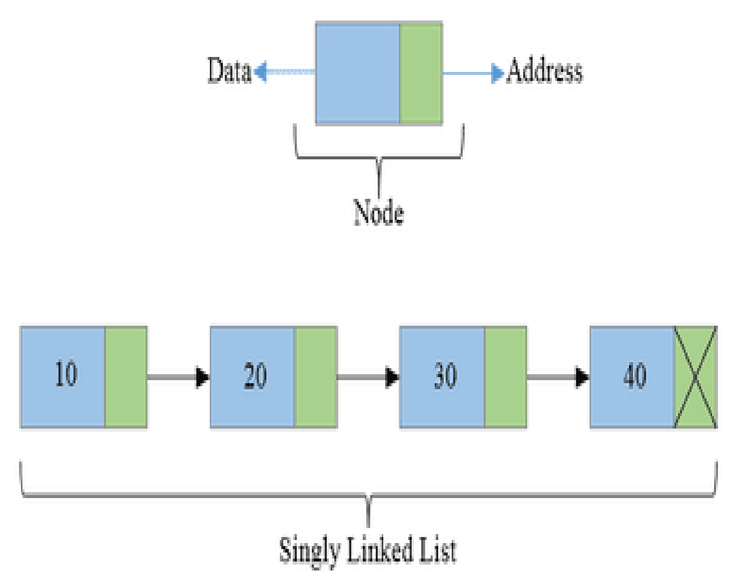
Linked Lists

- **Each node may be divided into atleast two fields for :**
  - **Storing Data**
  - **Storing Address of next element.**



Linked Lists

- **The Last node's Address field contains Null rather than a valid address.**
- **It's a NULL Pointer and indicates the end of the list.**



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Comparison between Array and Linked List

Advantages of Arrays

- Simple to use and define
- Supported by almost all programming languages
- **Constant access time**
  - Array element can be accessed a[i]
- Mapping by compiler
  - Compiler maps a[i] to its physical location in memory.
  - **This mapping is carried out in constant time, irrespective of which element is accessed**

Disadvantages of Arrays

Arrays suffer from some severe limitations

- **Static Data Structure-**
  - **Size of an array is defined at the time of programming**
- **Insertion and Deletion is time consuming**
- Requires Contiguous memory

Advantages of Linked List

- **Linked are Dynamic Data Structures**
  - Grow and shrink during execution of the program
- **Efficient Memory Utilization**
  - As memory is not preallocated.
  - Memory can be allocated whenever required and deallocated when not needed.
- **Insertion and deletions are easier and efficient**
  - Provide flexibility in inserting a data item at a specified position and deletion of a data item from the given position
- **Many complex applications can be easily carried out with linked lists**

Disadvantages of Linked List

- Access to an arbitary data item is little bit cumbersome and also time consuming

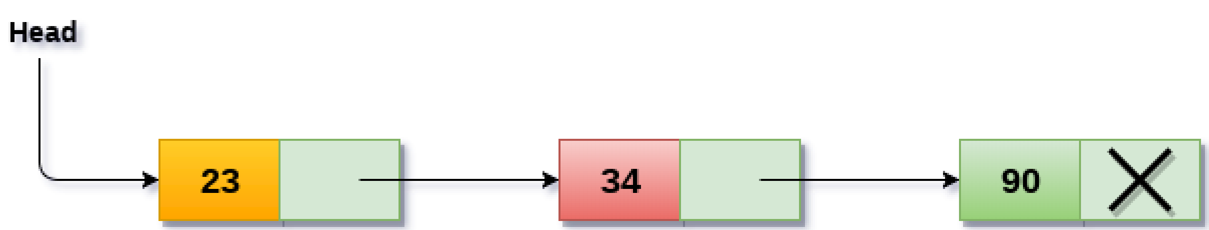
- **More memory**
  - If the number of fields are more, then more memory space is needed.

Types of Linked List

- Singly Linked List
- Doubly Linked List
- Circular Linked List

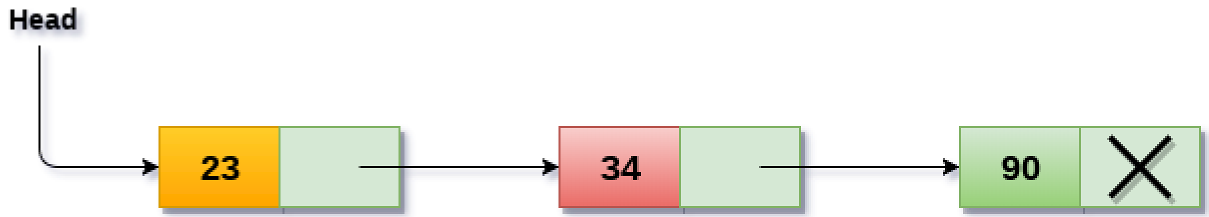
Singly Linked List

- All nodes are linked in sequential manner
- Linear Linked List
- One way chain
- It has beginning and end



Singly Linked List

- Problem-
  - The predecessor of a node cannot be accessed from the current node.
  - This can be overcome in doubly linked list.

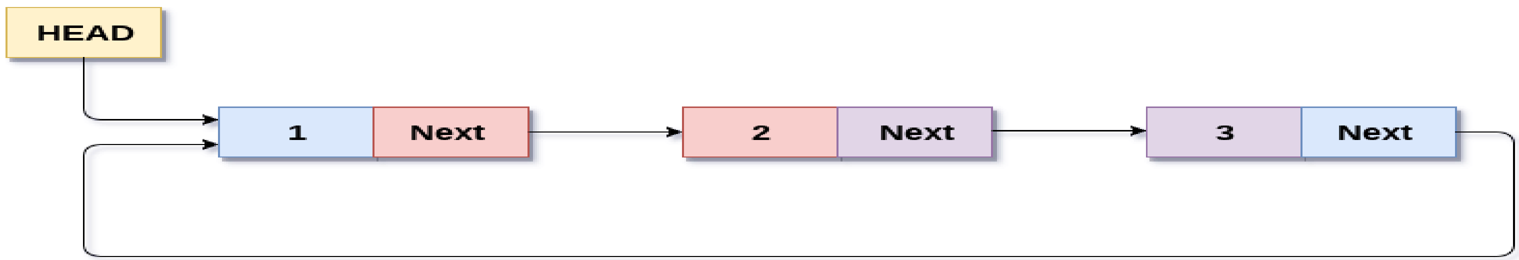


Doubly Linked List

- Linked List holds two pointer fields
- Addresses of next as well as preceding elements are linked with current node.
- This helps to traverse in both Forward or Backward direction

Circular Linked List

- The first and last elements are adjacent.
- A linked list can be made circular by
  - Storing the address of the first node in the link field of the last node.



Circular Singly Linked List

Linked List Operations

- Creation
- Insertion
- Deletion
- Traversal
- Searching

Implementation of Linked Lists

- Structures in C are used to define a node
- Address of a successor node can be stored in a pointer type variable

Linked Lists

Struct Basics

Struct Syntax

Struct examples

Pointer to structure

Sample Programs for Pointer to structures

Initialization of Pointers to Structures

Linked Lists

```
struct node
{
    int info;
    struct node *link;
}
```

Information field

Pointer that points to the structure itself,
Thus Linked List.

Singly Linked List

Creation of a new node

```
struct node{
            type1 member1;
            type2 member2;
            ......................
            ......................
            struct node *link;
        };
```

Info part

```
struct node
{
    int info;
    struct node *link;
};
```


```
struct node *start = NULL;
```

Creation of a new node

New node=temp

```
struct node *tmp;
tmp= (struct node *) malloc(sizeof(struct node));
tmp->info=data;
tmp->link=NULL;
```

Creating a Linked List

```
create_list(int data)
{
        struct node *q,*tmp;
        tmp= (struct node *) malloc(sizeof(struct node));
        tmp->info=data;
        tmp->link=NULL;

        if(start==NULL)
        /*If list is empty, the new node becomes the start*/

        {       start=tmp;
        }
        else
        {   /*Element inserted at the end */
/*Otherwise, traverse to the end of the list and append the new node*/
                q=start;
                while(q->link!=NULL)
                        q=q->link;
                q->link=tmp;
        }
}/*End of create_list()*/
```

Explanation-

```
if(start==NULL) /*If list is empty */
        {
        start=tmp;
        }
```

The code handles the insertion of a new node into the linked list. If the list is empty, the new node becomes the start.

Explanation-

```
else
        {       /*Element inserted at the end */
                q=start;
        while(q->link!=NULL)
                q=q->link;
                q->link=tmp;
        }
```

If the list is not empty, the new node is inserted at the end of the list by traversing to the last node and updating its link to point to the new node.

Traversing a Linked List

- Visit the node and print the data value

Traversing a Linked List

- Assign the Value of start to another pointer say q

```
struct node *q=start;
```

- Now q also points to the first element of linked list.

- For processing the next element, we assign the address of the next element to the pointer q as-

```
q=q->link;
```

- Traverse each element of the Linked list through this assignment until pointer q has NULL address, which is link part of last element.

```
while(q!=NULL)
 {
        q=q->link;
 }
```

Explanation-

```
while(q!=NULL)
  {
        q=q->link;
  }
```

The link field of the current node (pointed to by q) holds the memory address of the next node in the list.

Explanation-

Algorithm for Traversing a Linked List

Step 1:[INITIALIZE] SET PTR=START

Step 2: Repeat Steps 3 and 4 while PTR!=NULL
Step 3: Print PTR->INFO

Step 4: Set PTR=PTR->LINK

[End of Loop]
Step 5 :EXIT

Algorithm for Counting the number of elements in a Linked List

Step 1:[INITIALIZE] SET COUNT=0

Step 2:[INITIALIZE] SET PTR=START

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

Step 4: Set COUNT=COUNT +1

Step 5: Set PTR=PTR->LINK

[End of Loop]

Step 6:Print COUNT

Step 7:EXIT

Searching a Linked List

- First traverse the linked list
- While traversing compare the info part of each element with the given element

Searching a Linked List

```
search(int data)
{
        struct node *ptr = start;
        int pos = 1;
        while(ptr!=NULL)
        {
                if(ptr->info==data)
                {
                        printf("Item %d found at position %d\n",data,pos);
                        return;
                }
                ptr = ptr->link;
                pos++;
        }
        if(ptr == NULL)
                printf("Item %d not found in list\n",data);
}/*End of search()*/
```

Algorithm for Searching a Linked List

Step 1:[INITIALIZE] SET POSITION=1

Step 2:[INITIALIZE] SET PTR=START

Step 3: Repeat Steps 4 while PTR!=NULL

Step 4: If DATA=PTR->INFO

Print POSITION

Exit

[End of If]

Set PTR=PTR->LINK

Set POSITION=POSITION +1

[End of Loop]

Step 5:If PTR=NULL

Print Search Unsuccessful

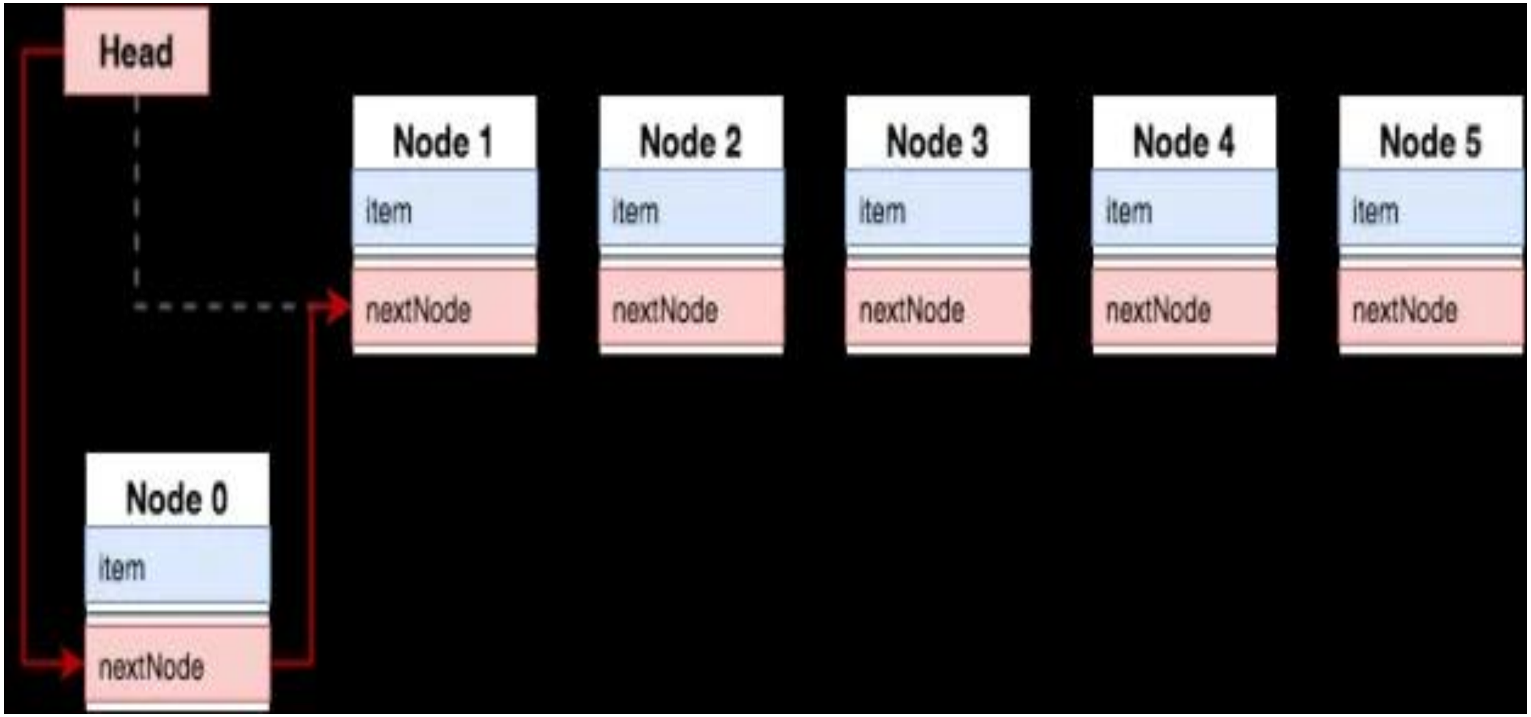
[End of If]

Step 6: Exit

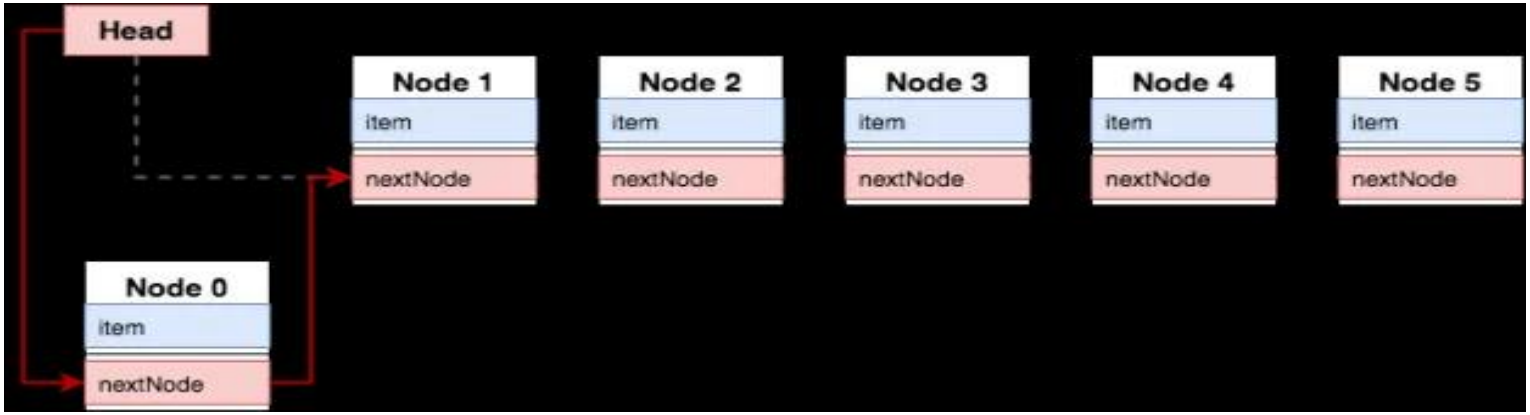
Insertion into a Linked List

- Insertion is possible in two ways:
  - Insertion at Beginning
  - Insertion in Between

Case 1- Insertion at Beginning



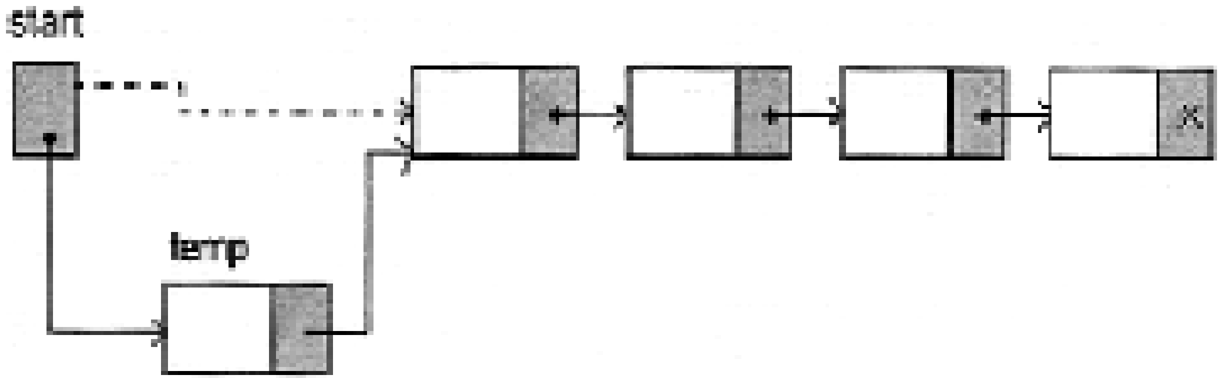
Case 1- Insertion at Beginning



CREATE THE NEW NODE,
CONNECT NEW NODE TO THE OLD FIRST NODE
CONNECT THE START POINTER TO THE NEW NODE,

……

Case 1- Insertion at Beginning



?

Case 1- Insertion at Beginning

- Lets say tmp is the pointer which points to the node that has to be inserted
- Assign data to the new node

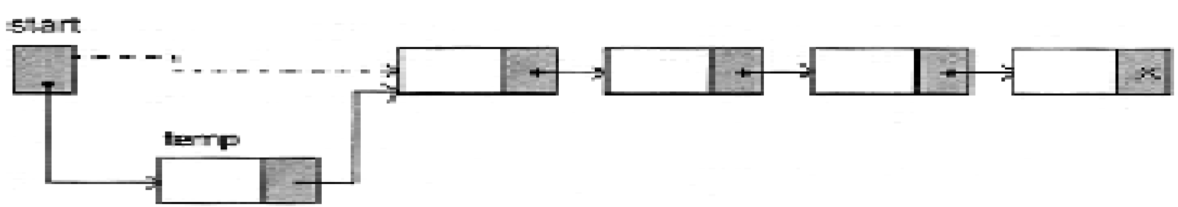
tmp->info=data;

- Start points to the first element of linked list
- Assign the value of start to the link part of the inserted node as

tmp->link=start;

- Now inserted node points beginning of the linked list.
- To make the newly inserted node the first node of the linked list:

start=temp



Algorithm for Insertion at Beginning in a Linked List

- **First check whether Memory is available for the new node.**
- **If the memory has exhausted then an Overflow message is printed**
- **Else We allocate memory for the new node**

Algorithm for Insertion at Beginning in a Linked List

Step 1:If AVAIL=NULL Then

WRITE OVERFLOW

Go to Step 7

[End of If]

Step 2: Set TEMP=AVAIL

Step 3: Set AVAIL=AVAIL->LINK

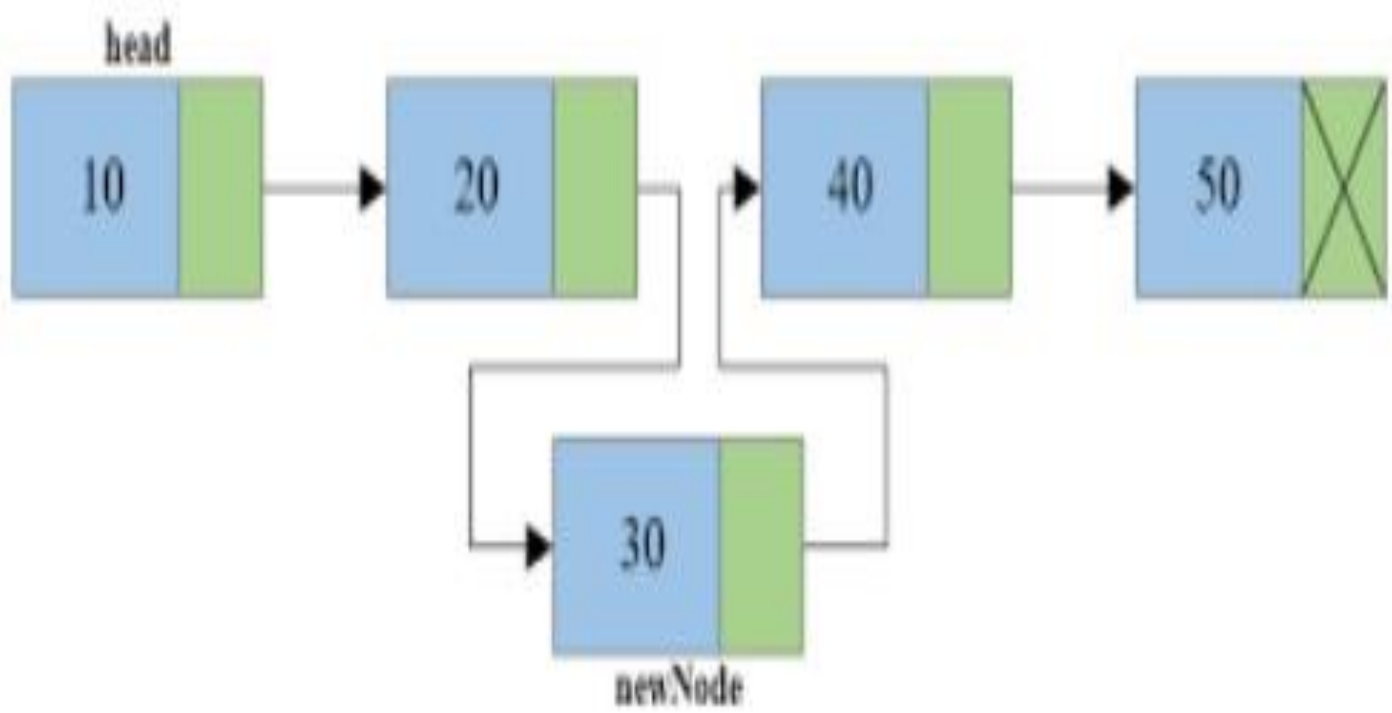
Step 4: Set TEMP->INFO=DATA

Step 5: Set TEMP->LINK=START

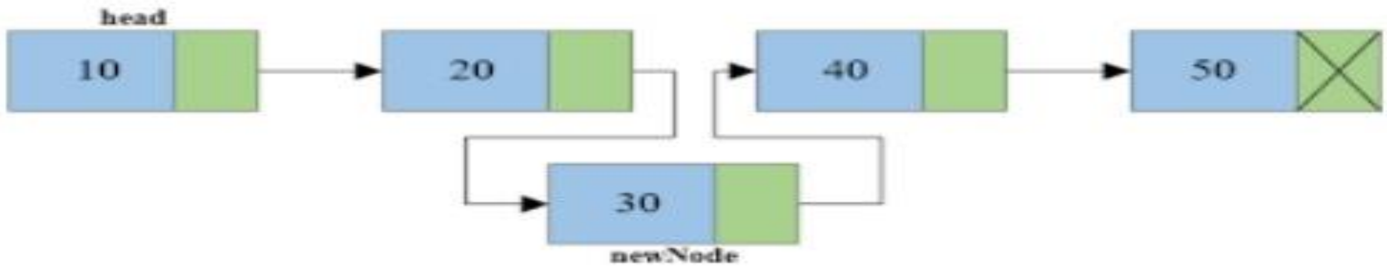
Step 6 : Set START=TEMP

Step 7 :EXIT

Case 2- Insertion in Between



Case 2- Insertion in Between



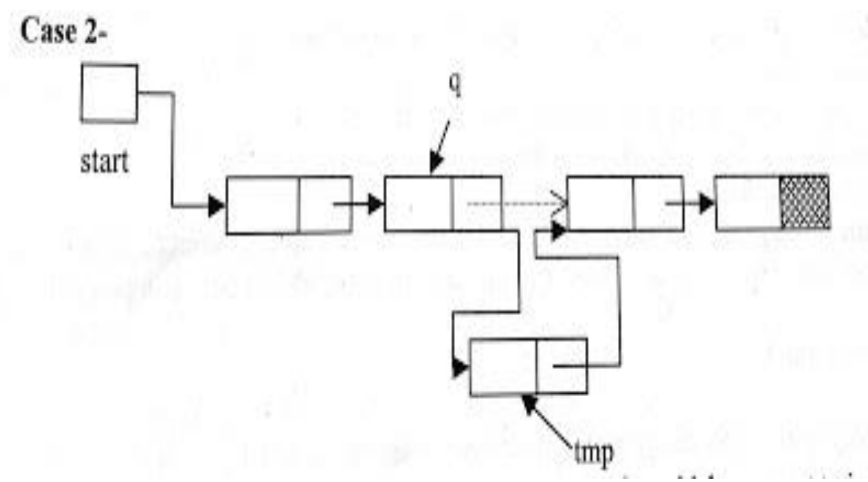
CREATE THE NEW NODE ,
CONNECT THE NEW NODE TO THE NEXT NODE
CONNECT THE PREVIOUS TO THE NEW NODE,

……

Case 2- Insertion in Between

- First we traverse the linked list for obtaining the node after which we want to insert the element

```
q=start;
for(i=0;i<pos-1;i++)
    {
        q=q->link;
        if(q==NULL)
        {
            printf("There are less than %d elements",pos);
            return;
        }
    }/*End of for*/
```



Explanation-

```
q=start;
for(i=0;i<pos-1;i++)
        {
                q=q->link;
                if(q==NULL)
                {
                        printf("There are less than %d elements",pos);
                        return;
                }
        }/*End of for*/
```

Explanation-

Algorithm for Insertion in Between

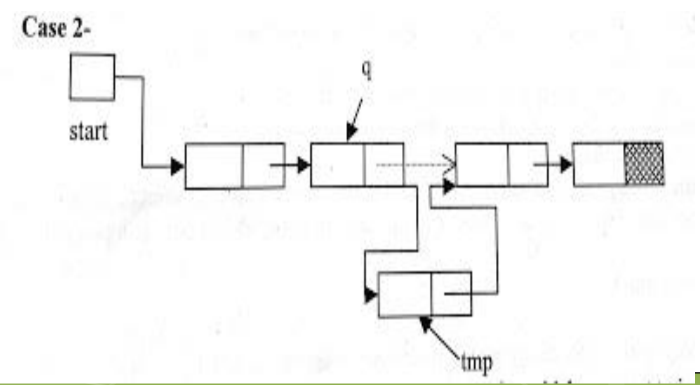
Step 1:If AVAIL=NULL Then
WRITE OVERFLOW
Go to Step 13
[End of If]
Step 2: Set TEMP=AVAIL
Step 3: Set AVAIL=AVAIL->LINK
Step 4: Set TEMP->INFO=DATA
Step 5: Set TEMP->LINK=NULL
Step 6 : Read POSITION from User
Step 7 : Set Q=START
Step 8 : Set I=0
Step 9 : Repeat step 10 till I<POS-1
Step 10: Set Q=Q->LINK
If Q=NULL
Print Less Number of Elements
Exit
[End of If]
SET I=I+1
[End of Loop]
Step 11:Set TEMP->LINK=Q->LINK
Step 12:Set Q->LINK=TEMP
Step 13:Exit

```
q=start;
for(i=0;i<pos-1;i++)
    {
        q=q->link;

    if(q==NULL)
        {

    printf("There are less than %d elements",pos);

    return;
        }
    }/*End of for*/
```



Case 2- Insertion in Between

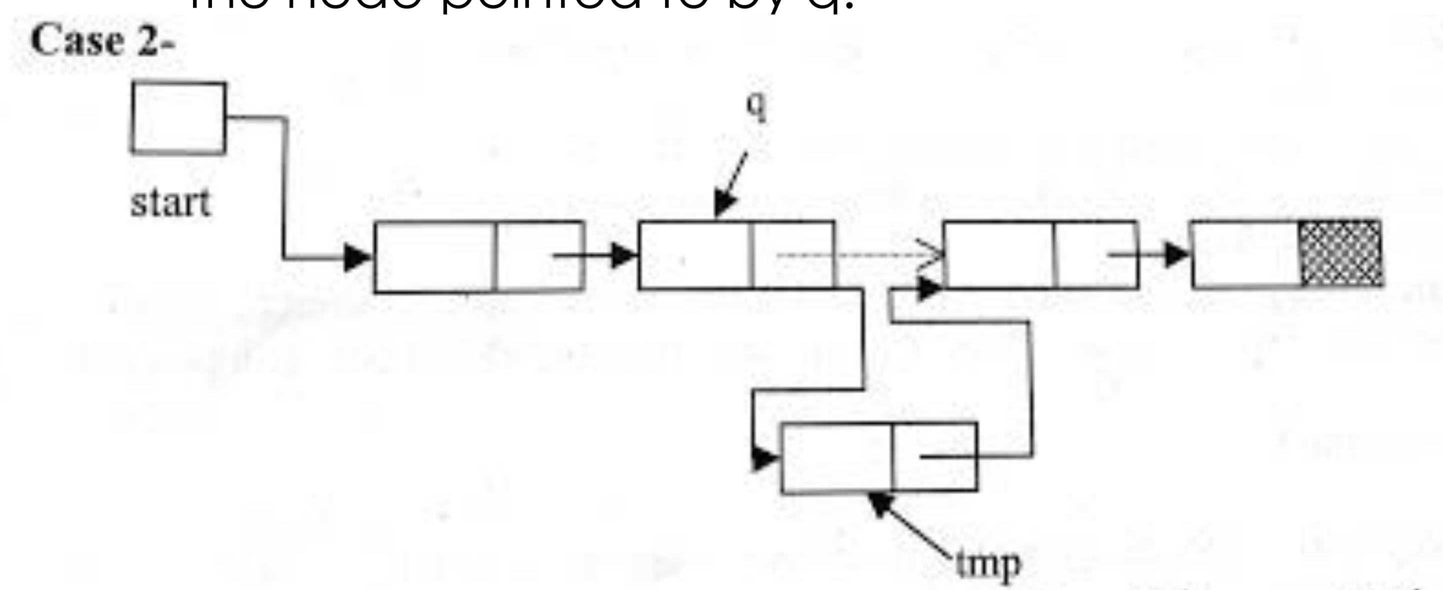
- Then we add the new node by adjusting address fields

  tmp->info=data;

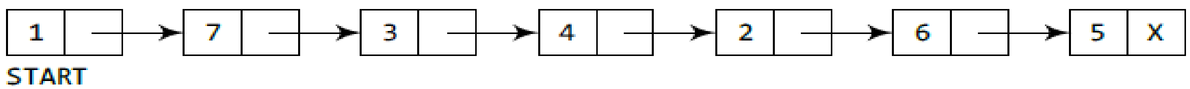
  tmp->link=q->link;

  the tmp node point to the node that comes after it in the list.

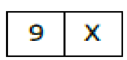
  q->link=tmp;// inserts the tmp node into the list after the node pointed to by q.



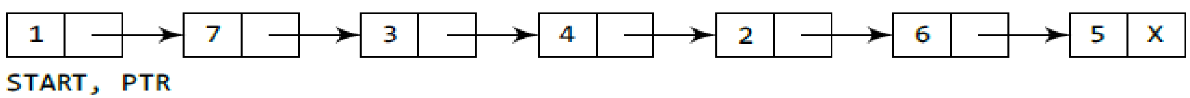
Case 2- Insertion in Between



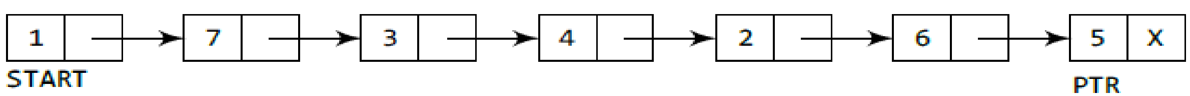
Allocate memory for the new node and initialize its DATA part to 9 and NEXT part to NULL.



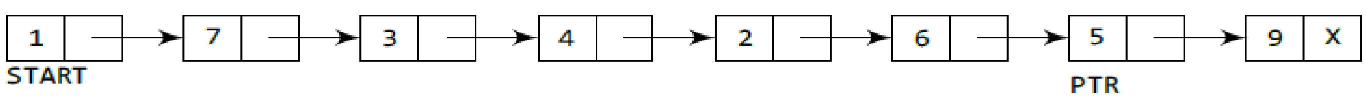
Take a pointer variable PTR which points to START.



Move PTR so that it points to the last node of the list.



Add the new node after the node pointed by PTR. This is done by storing the address of the new node in the NEXT part of PTR.



Case 2- Insertion at the end

- **Without Using Position ?**
- **At the end?**

Algorithm for Insertion at the end of a Linked List

Step 1: If AVAIL=NULL Then

WRITE OVERFLOW

Go to Step 10

[End of If]

Step 2: Set TEMP=AVAIL

Step 3: Set AVAIL=AVAIL->LINK

Step 4: Set TEMP->INFO=DATA

Step 5: Set TEMP->LINK=NULL

Step 6 : Set Q=START

Step 7 : Repeat step 8 while PTR->LINK!=NULL

Step 8: SET Q=Q->LINK

[End of Loop]

Step 9 : SET Q->LINK=TEMP

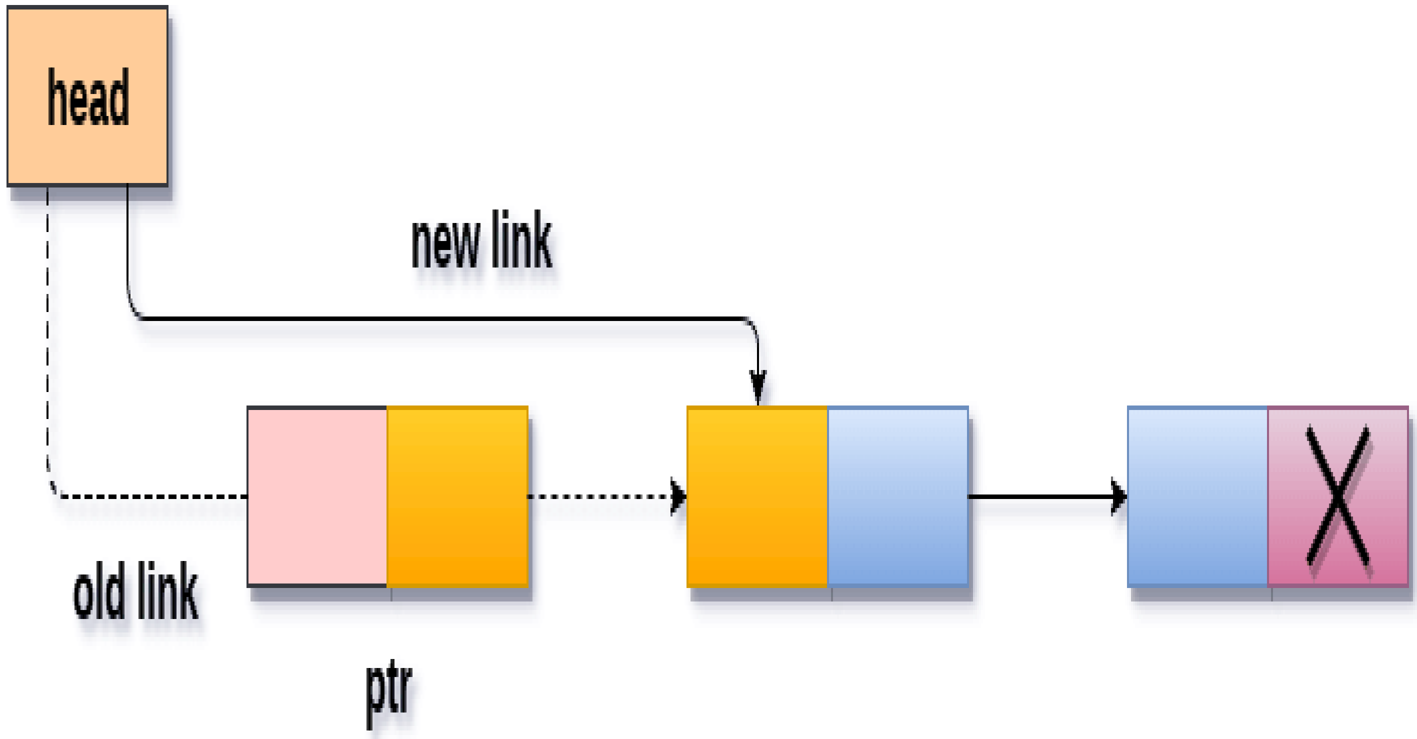
Step 10 : EXIT

Deletion from a Linked List

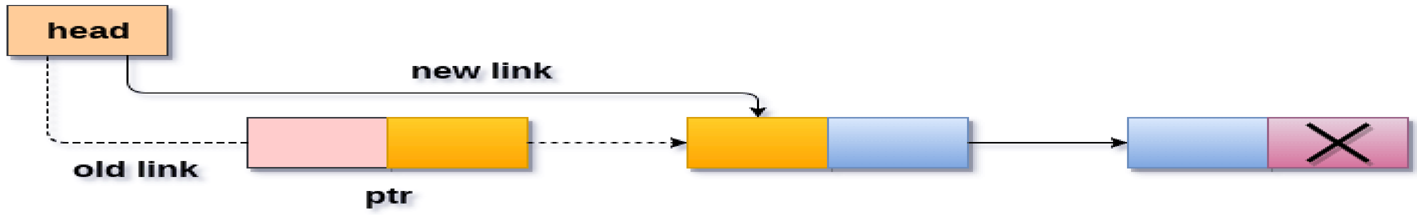
- For deleting the node from a linked list, first we traverse the linked list and compare with each element.

- After finding the element there may be two cases for deletion-
  - **Deletion in beginning**
  - **Deletion in between**

Deletion in beginning



Deletion in beginning



CONNECT
START POINTER TO THE SECOND NODE……
DELETE THE FIRST NODE

Deletion in beginning

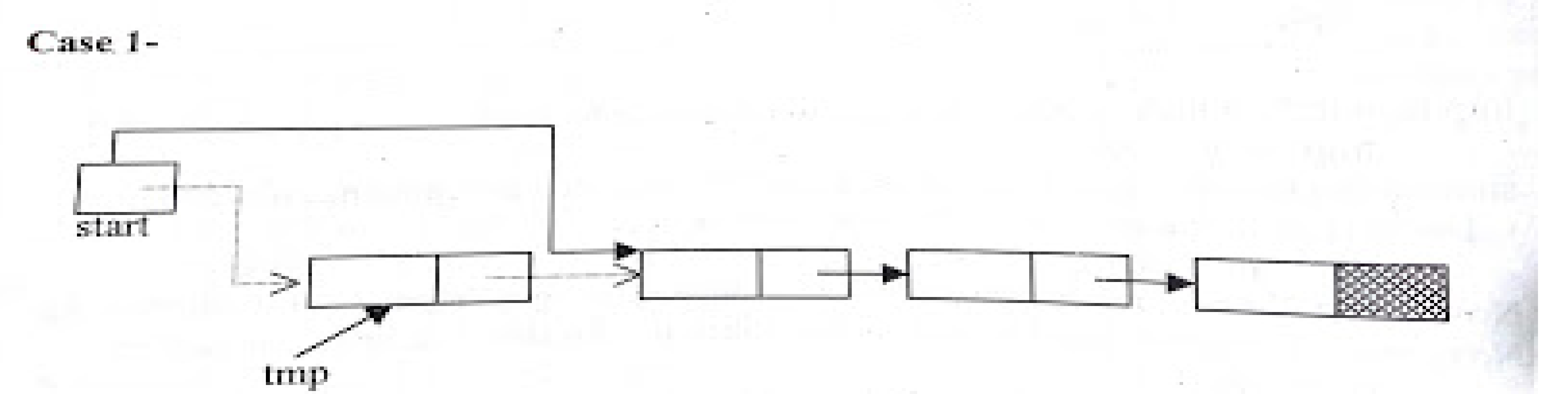
- Start points to the first element of linked list.
- If element to be deleted is the first element of linked list then we assign the value of start to tmp as-

  tmp = start;

- So tmp points to the first node which has to be deleted.
- Now assign the link part of the deleted node to start as-

  start=start->link;

- **Since start points to the first element of linked list, so start->link will point to the second element of linked list.**
- Now we should free the element to be deleted which is pointed by tmp. **free(tmp);**



Algorithm for Deletion in the beginning of the Linked List

Step 1:If START=NULL

Step 2: Write UNDERFLOW

Step 3: Go to Step 7

[End of If]

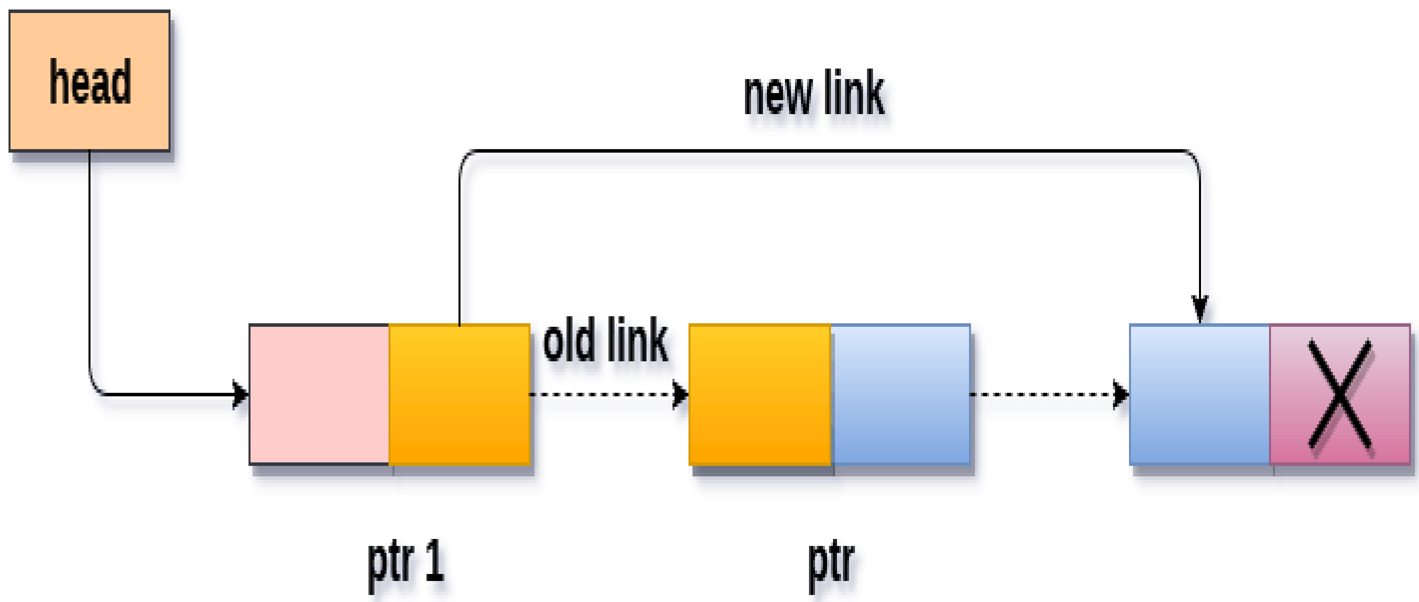
Step 4:Set TEMP=START

Step 5:Set START=START->LINK

Step 6:FREE TEMP

Step 7:EXIT

Deletion in between



Deletion a node from specified position

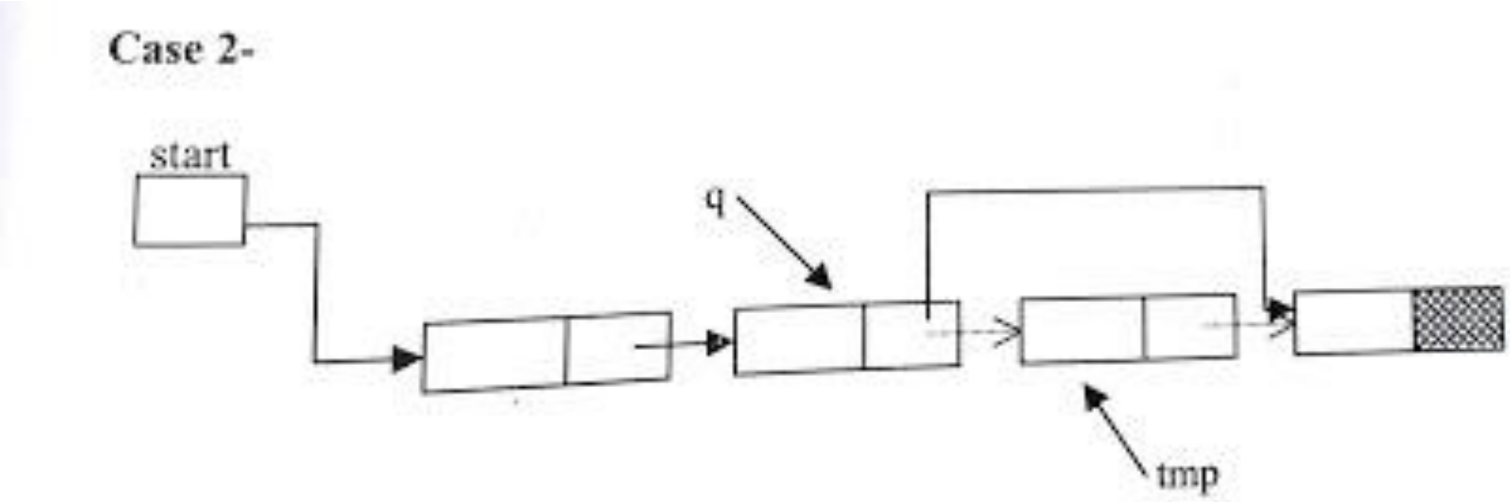
Deletion in between

DELETE THE NODE AND CONNECT THE PREVIOUS AND THE NEXT NODE……

Deletion in between

- If the element is other than the first element of linked list then
  - **we give the link part of the deleted node to the link part of the previous node.**
  - This can be as-

```
tmp =q->link;
q->link = tmp->link;
free(tmp);
```



Deletion at the end

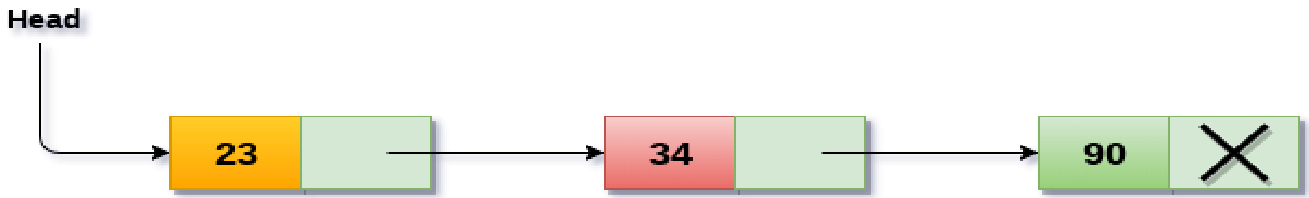
- If node to be deleted is last node of linked list then statement 2 will be as-

```
tmp =q->link;
q->link = NULL;
free(tmp);
```

Circular Linked List

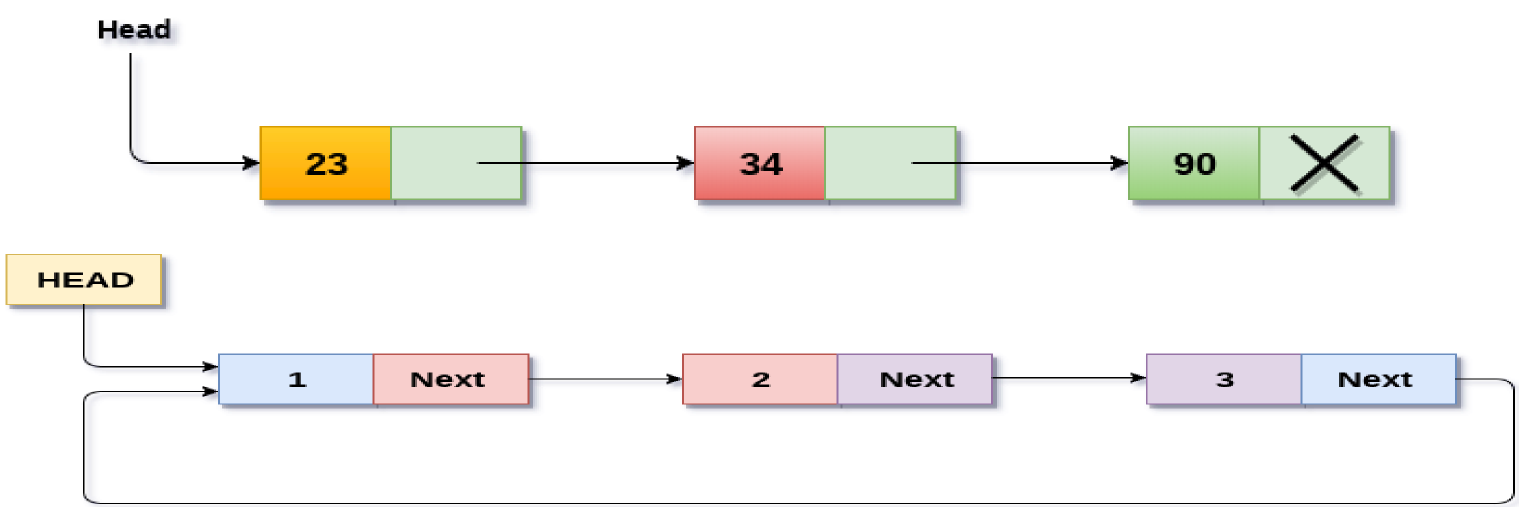
Why Circular?

- In a singly linked list,
  - **If we are at any node in the middle of the list, then it is not possible to access nodes that precede the given node.**
  - This problem can be solved by slightly altering the structure of singly linked list.



How?

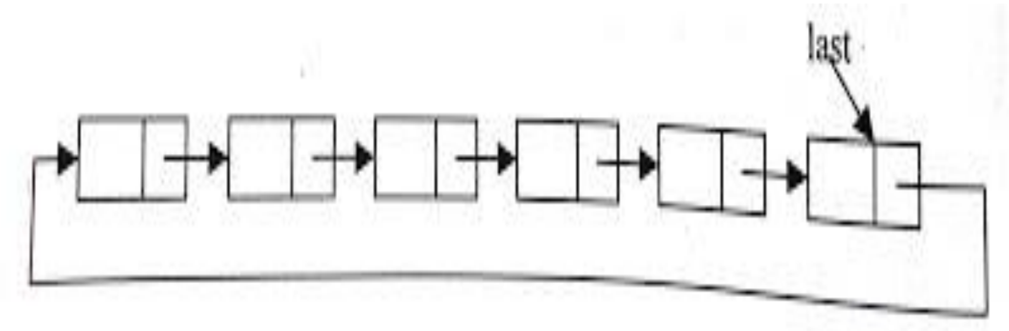
- In a singly linked list, next part (pointer to next node) of the last node is NULL,
  - if we utilize this link to point to the first node then we can reach preceding nodes.



Circular Singly Linked List

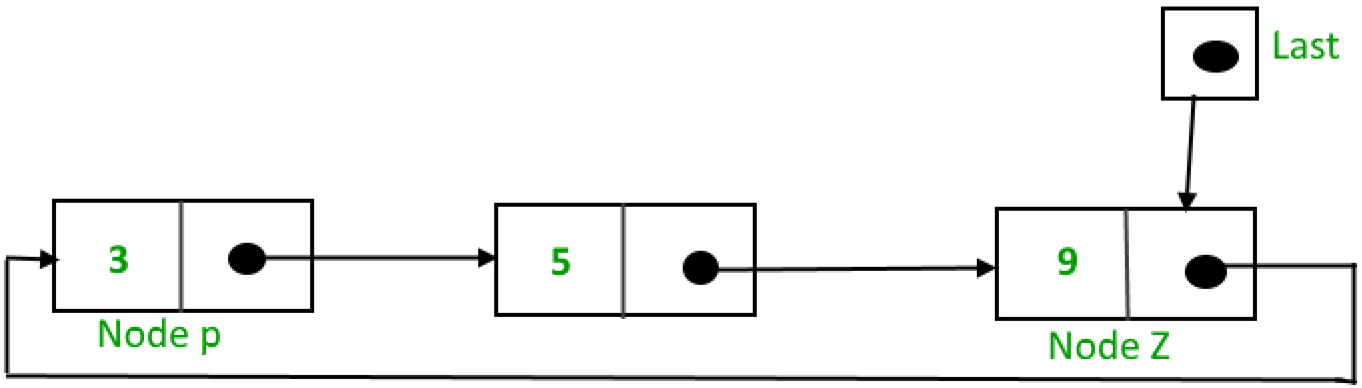
Implementation of circular linked list

- Creation of circular linked list is same as single linked list.
- **Last node will always point to first node instead of NULL.**



Implementation of circular linked list

- One pointer last,
  - which points to last node of list and link part of this node points to the first node of list.



Advantages of a Circular linked list

- In circular linked list, **we can easily traverse to its previous node**, which is not possible in singly linked list.

- **Entire list can be traversed from any node.**
  - If we are at a node, then we can go to any node. But in linear linked list it is not possible to go to previous node.

Advantages of a Circular linked list

- In Single Linked List, for insertion at the end, the whole list has to be traversed.
- In Circular Linked list,
  - **with pointer to the last node there won't be any need to traverse the whole list.**
  - So insertion in the begging or at the end takes constant time irrespective of the length of the list i.e O(1).
  - **It saves time when we have to go to the first node from the last node.**
    - **It can be done in single step because there is no need to traverse the in between nodes**

Disadvantages of Circular linked list

- Circular list are complex
  - as compared to singly linked lists.

- **Reversing of circular list is a complex**
  - **as compared to singly or doubly lists.**

- If not traversed carefully,
  - then we could end up in an infinite loop.

Insertion into a circular linked list :-

Insertion in a circular linked list may be possible in two ways-

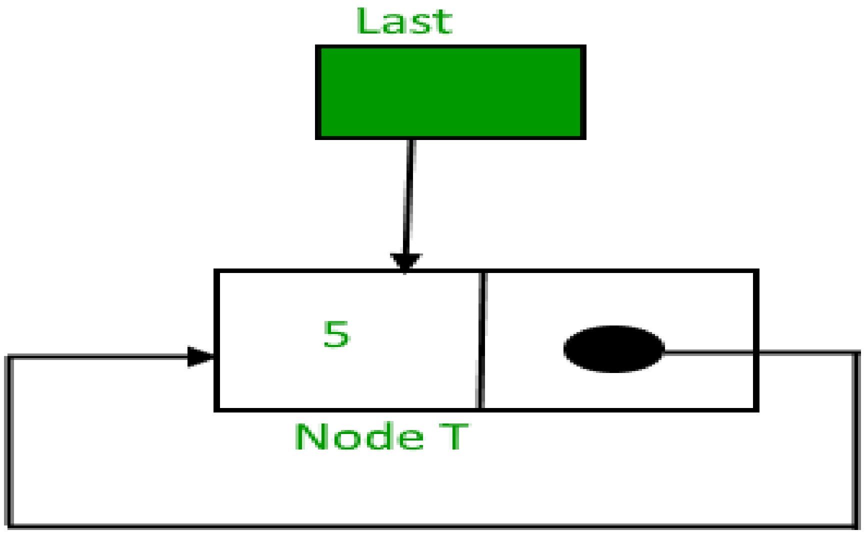
- ***Insertion in an empty list***
- **Insertion at the end of the list**
- ***Insertion at beginning***
- ***Insertion in between***

Insertion in an empty list

New element can be added as-

- *If linked list is empty:*

If (last==NULL)
{
last=tmp;
tmp->link=last
}



Insertion at the end of circular linked list

- *If linked list is not empty:*

Insertion at the end of the list

{

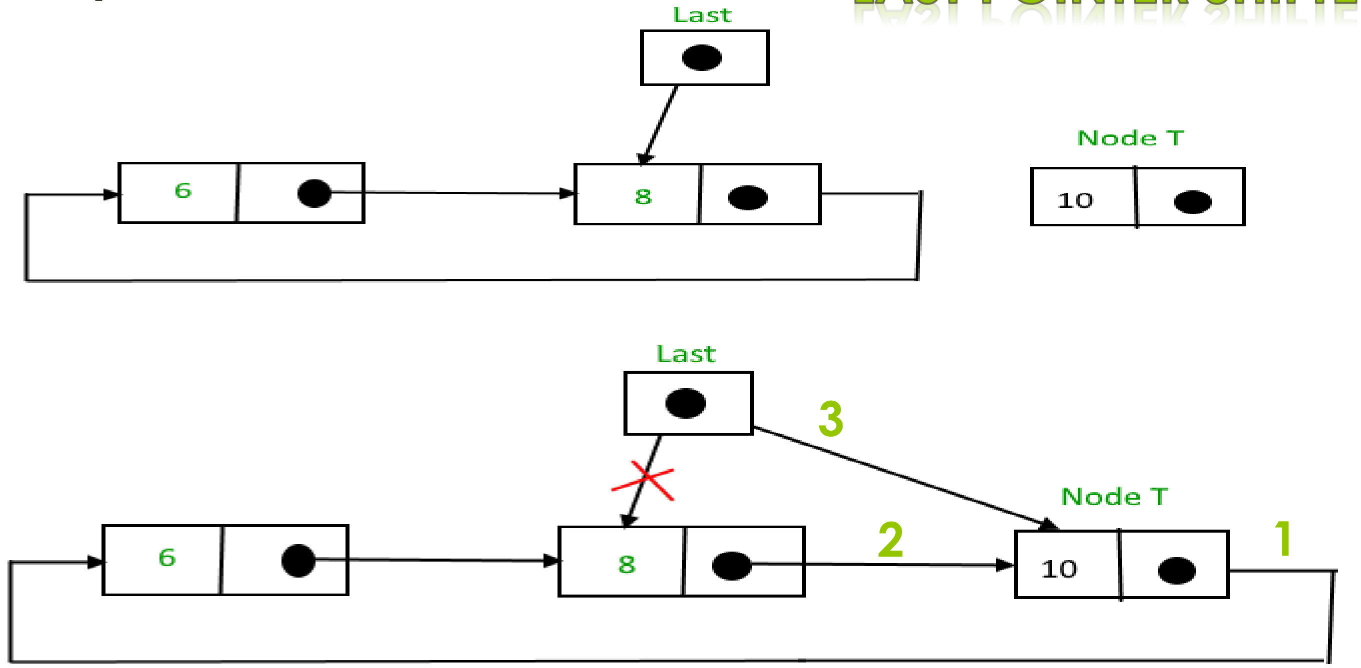
tmp->link = last->link; /* added at the end of list*/

last->link = tmp;

last = tmp;

}

LAST POINTER SHIFTED



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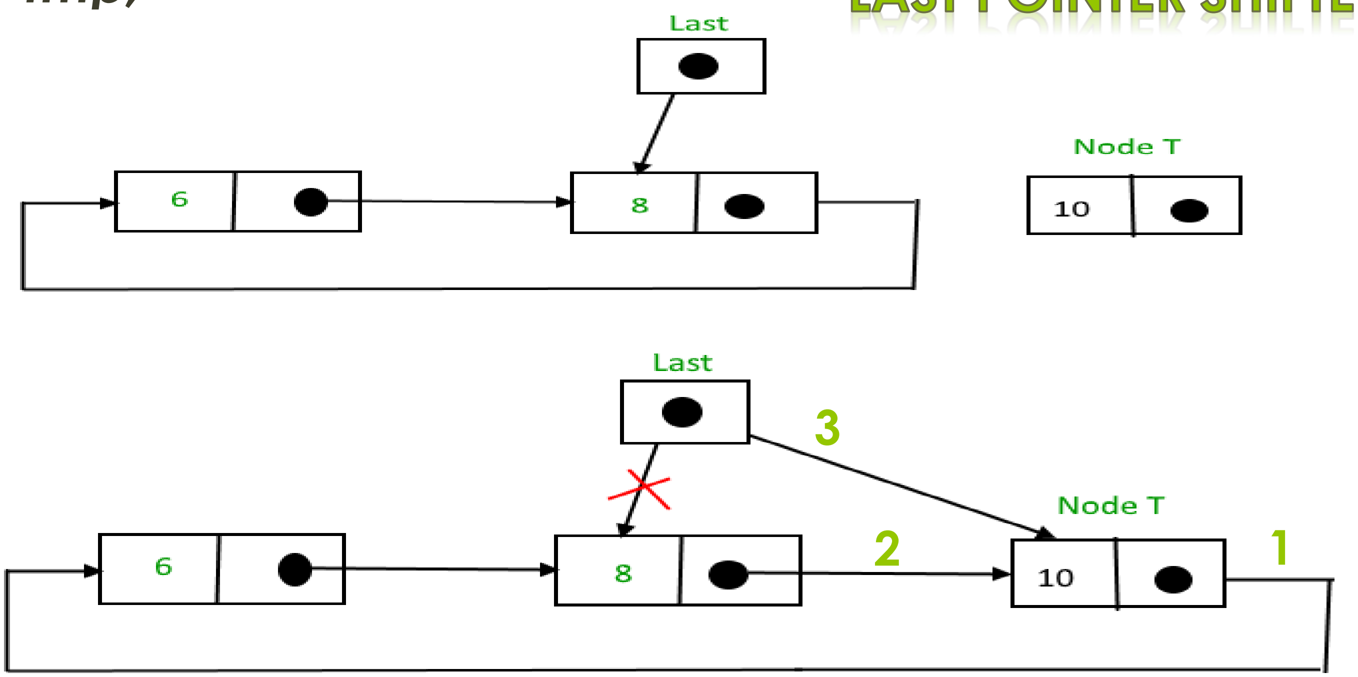


Insertion at the beginning of circular linked list

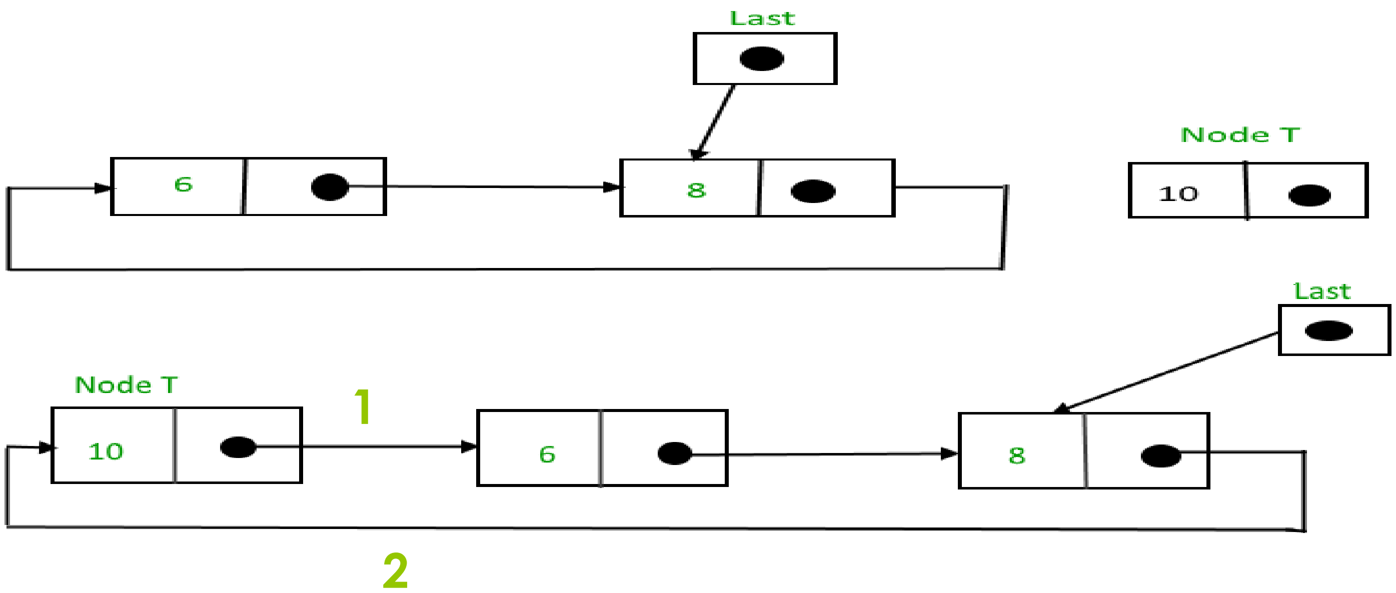
- *If linked list is not empty:*

Insertion at the beginning of the list

Follow these step:

1. Create a node, say tmp.
2. Make tmp-> next = last -> next.
3. last -> next = tmp.

LAST POINTER NOT SHIFTED !!



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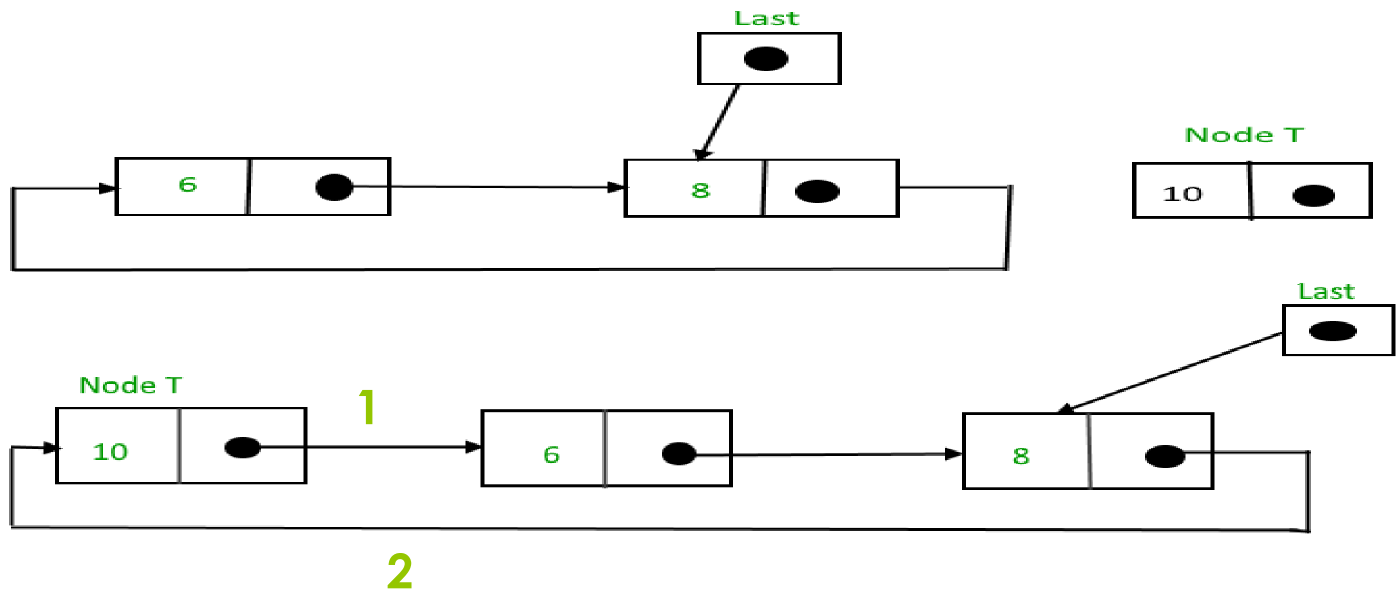


Insertion in between of circular linked list

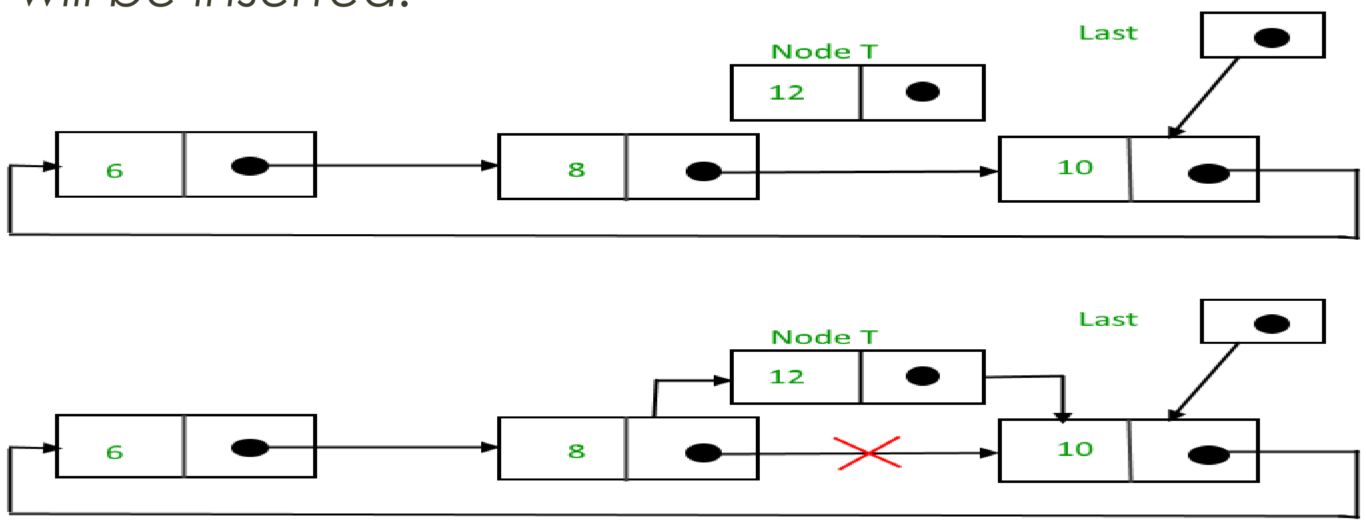
- Insertion in between is same as in single linked list. This can be as-

tmp->link = q->link;

tmp->info = num;

q->link =tmp;

- Here q points to the node after which new node will be inserted.



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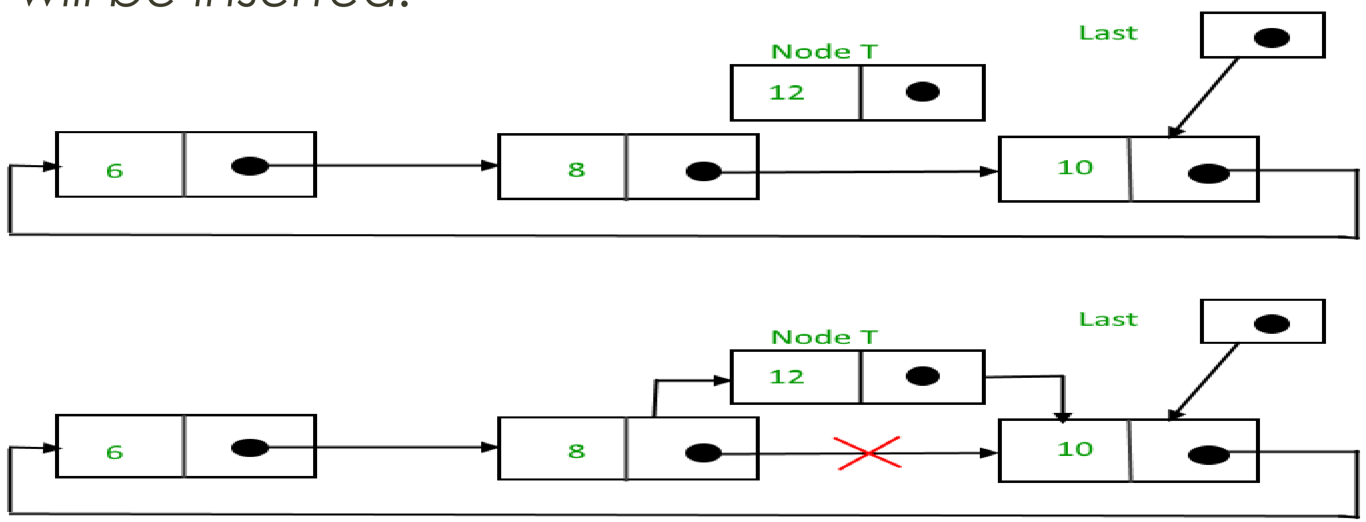

Creation of CLL

```
create_list(int num)
{
        struct node *q,*tmp;
        tmp= malloc(sizeof(struct node));
        tmp->info = num;

        if(last == NULL)
        {
                last = tmp;
                tmp->link = last;
        }
        else
        {
                tmp->link = last->link; /*added at the end of list*/
                last->link = tmp;
                last = tmp;
        }
}/*End of create_list( )*/
```