UNIT 2

Syllabus: Singly Linked List, Doubly Linked List, Circular Linked List, Representing Stack with Linked List, Representing Queue with Linked List.

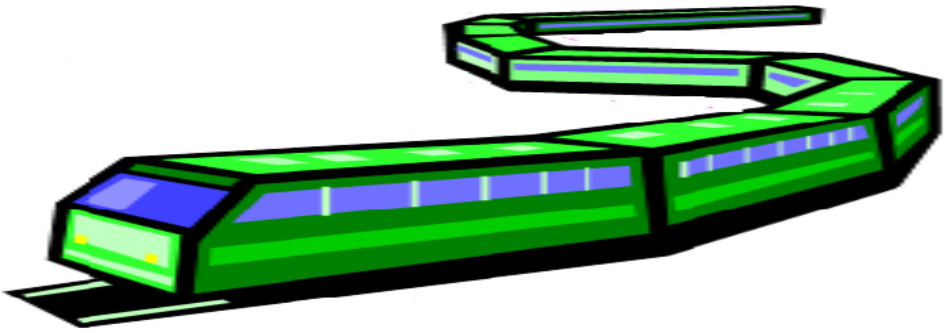
Arrays:

- In **array**, elements are stored in consecutive memory locations.
- To occupy the adjacent space, block of memory that is required for the array should be allocated beforehand.
- Once memory is allocated, it cannot be extended any more. So that array is called the **static data structure**.
- Wastage of memory is more in arrays.
- Array has fixed size
- But, **Linked list** is a dynamic data structure; it is able to grow in size as needed.

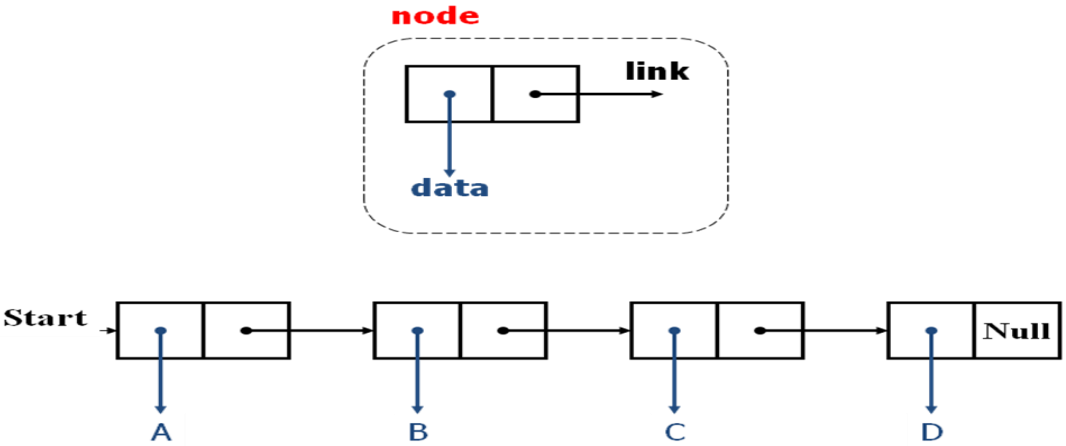
What is Linked List?

- A linked list is a linear collection of homogeneous data elements, called **nodes,** where linear order is maintained by means of links or pointers.
- **Each node has two parts:**
  - The first part contains the **data** (information of the element) and
  - The second part contains the **address of the next node** (link /next pointer field) in the list.
  - Data part of the link can be an integer, a character, a String or an object of any kind.

Example1:



Example2:



Linked Lists:

- Linear collection of self-referential structures, called *nodes,* connected by pointer *links.*
- Accessed via a pointer to the first node of the list.
- Subsequent nodes are accessed via the link-pointer member stored in each node.
- Link pointer in the **last node is set to null** to mark the end of list.
- Data stored dynamically – each node is created as necessary.
- Length of a list can increase or decrease.
- Becomes full only when the system has insufficient memory to satisfy dynamic storage allocation requests.

Types of linked lists:

Singly linked list:

- Begins with a pointer to the first node
- Terminates with a null pointer
- Only traversed in one direction

Circular, singly linked list

- Pointer in the last node points back to the first node

Doubly linked list

- Two "start pointers"- first element and last element
- Each node has a forward pointer and a backward pointer
- Allows traversals both forwards and backwards

Circular, doubly linked list

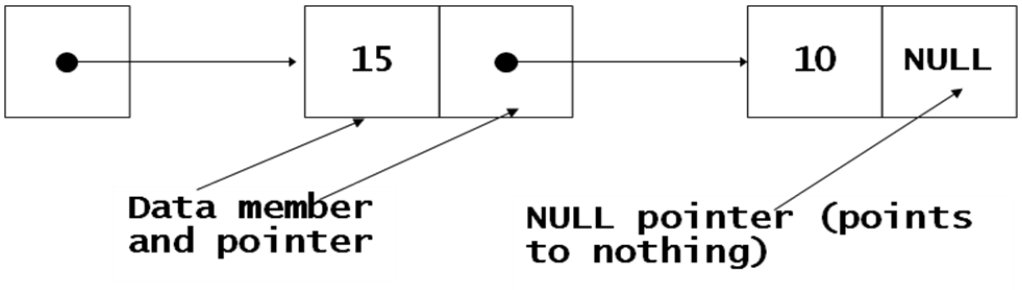
- Forward pointer of the last node points to the first node and backward pointer of the first node points to the last node

Dynamic Memory Allocation: Obtain and release memory during execution.

- **malloc**
  - Takes number of bytes to allocate
  - Use **sizeof** to determine the size of an object
  - Returns pointer of type **void ***
  - A **void *** pointer may be assigned to any pointer
  - If no memory available, returns **NULL.**
    Syntax: newPtr = malloc(sizeof(struct node));
- **free**
  - Deallocates memory allocated by **malloc**
  - Takes a pointer as an argument
    Syntax: free (newPtr);

Self-Referential Structures:

- Self-referential structures
  - Structure that contains a pointer to a structure of the same type.
  - Can be linked together to form useful data structures such as lists, queues, stacks and trees
  - Terminated with a **NULL** pointer.
- Two self-referential structure objects linked together.



Singly linked list operations:

- **Insertion:**
  - Insertion of a node at the front
  - Insertion of a node at any position in the list
  - Insertion of a node at the end
- **Deletion:**
  - Deletion at front
  - Deletion at any position
  - Deletion at end
- **Display:**
  - Displaying/Traversing the elements of a list

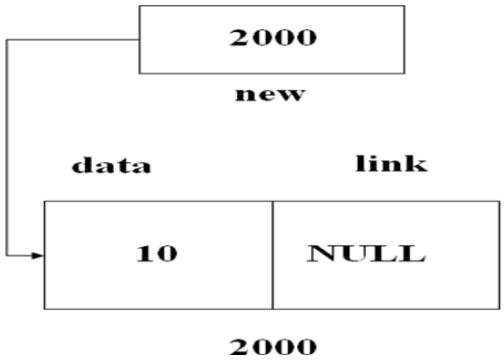
Singly linked lists:

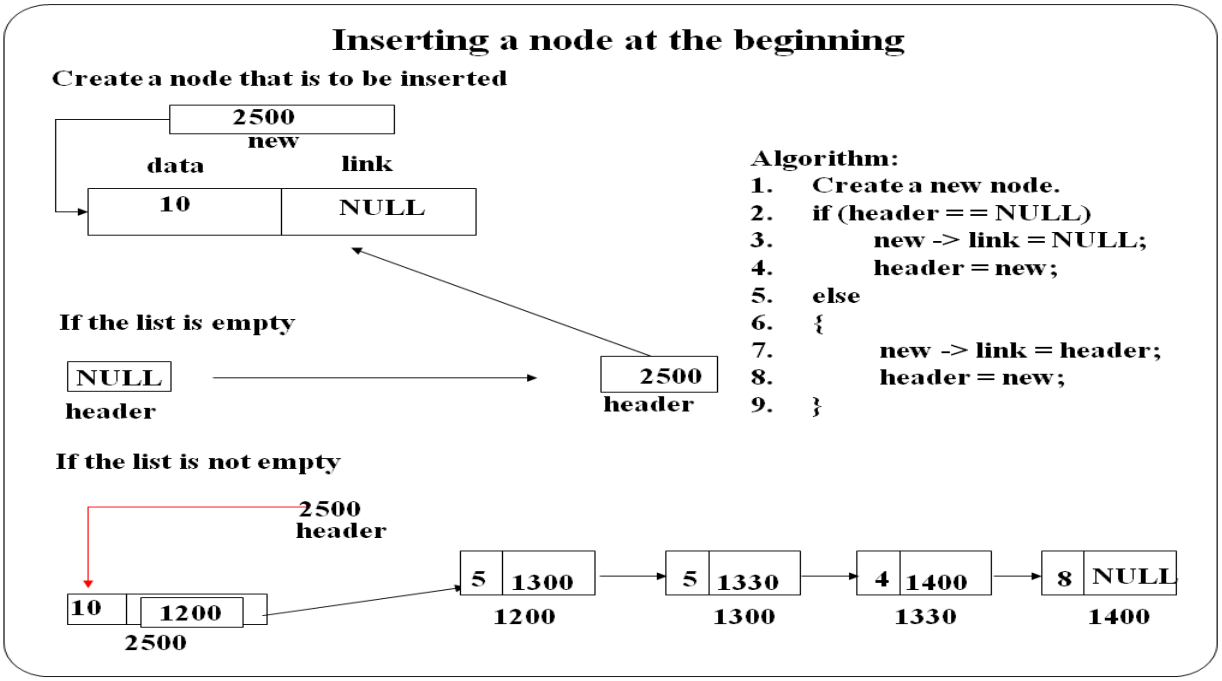
Node Structure:

```
struct node
{
        int data;
        struct node *link;
}*new, *ptr, *header, *ptr1;
```

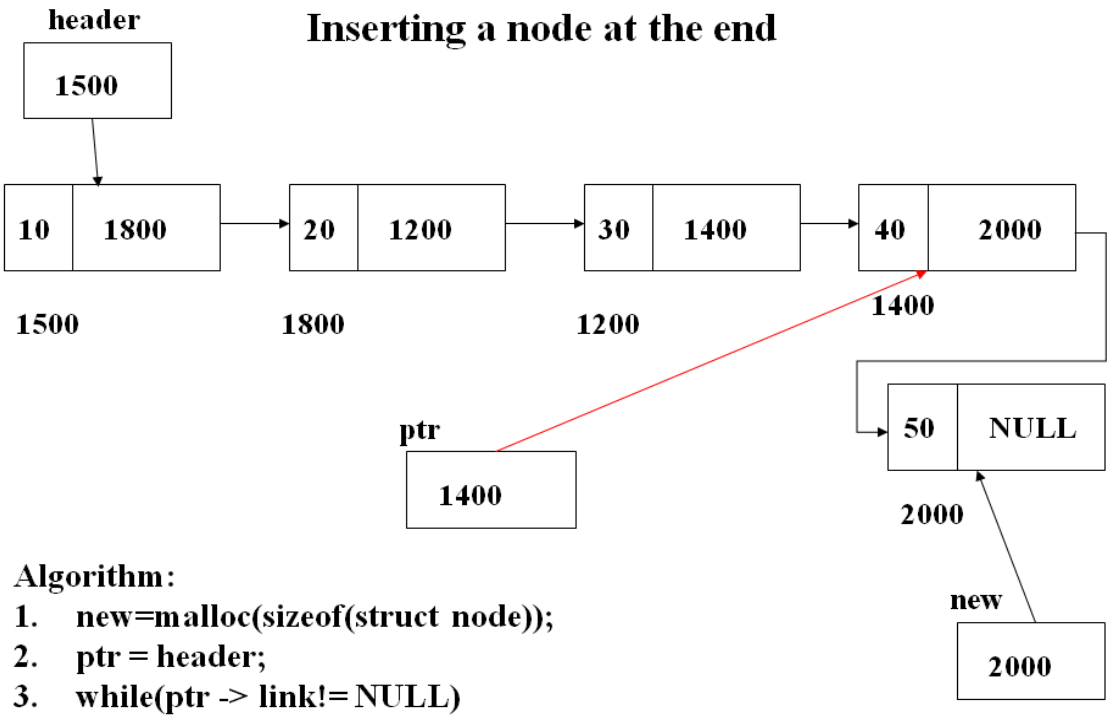
Creating a node:

```
new = malloc (sizeof(struct node));
new -> data = 10;
new -> link = NULL;
```





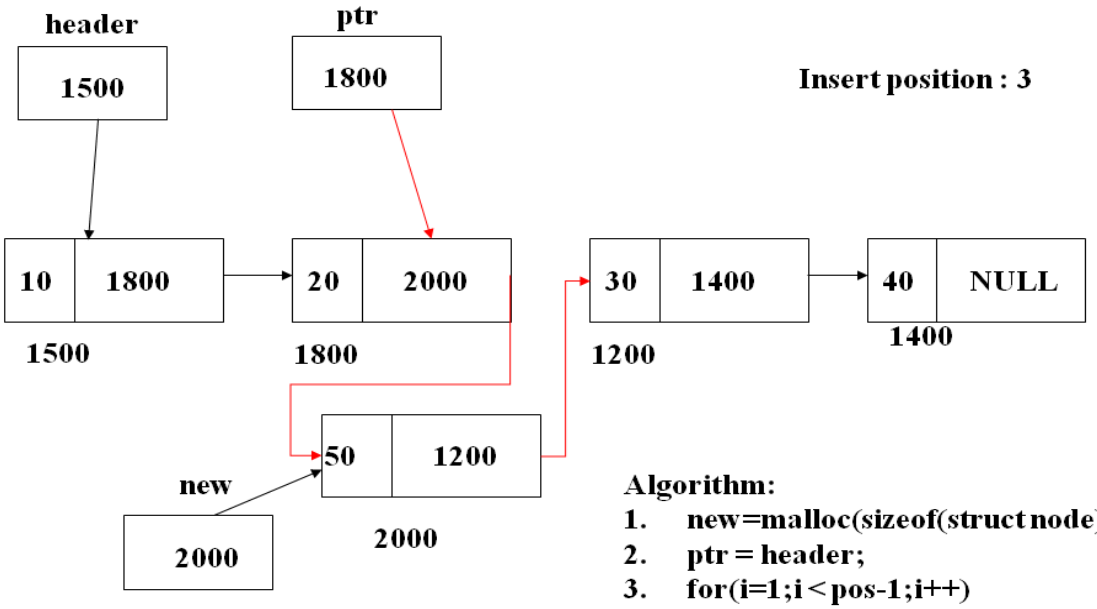
Inserting a node at the end



Algorithm:

1. new=malloc(sizeof(struct node));
2. ptr = header;
3. while(ptr -> link!= NULL)
4. ptr = ptr -> link;
5. new -> link = NULL;
6. ptr -> link = new;

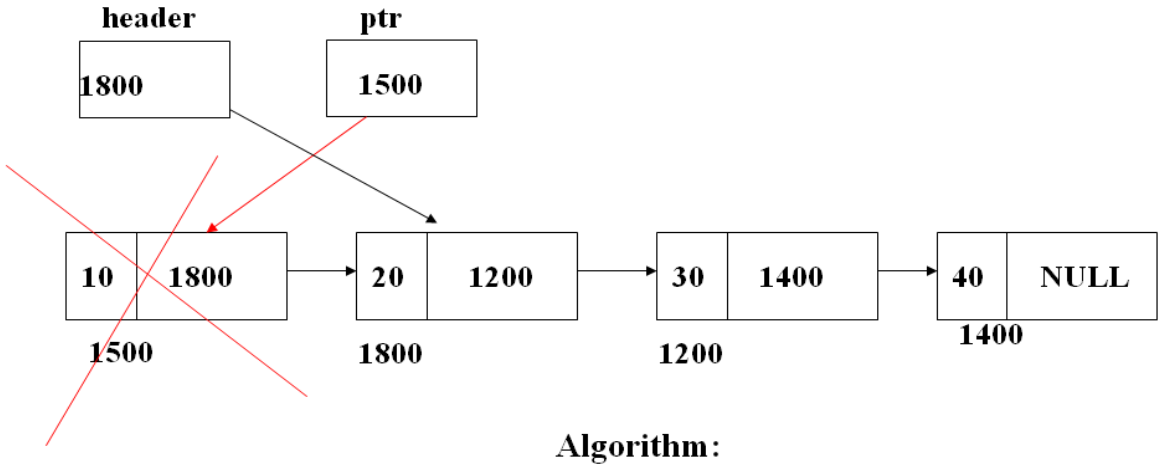
Inserting a node at the given position



Algorithm:

1. new=malloc(sizeof(struct node));
2. ptr = header;
3. for(i=1;i<pos-1;i++)
4. ptr = ptr -> link;
5. new -> link = ptr -> link;
6. ptr -> link = new;

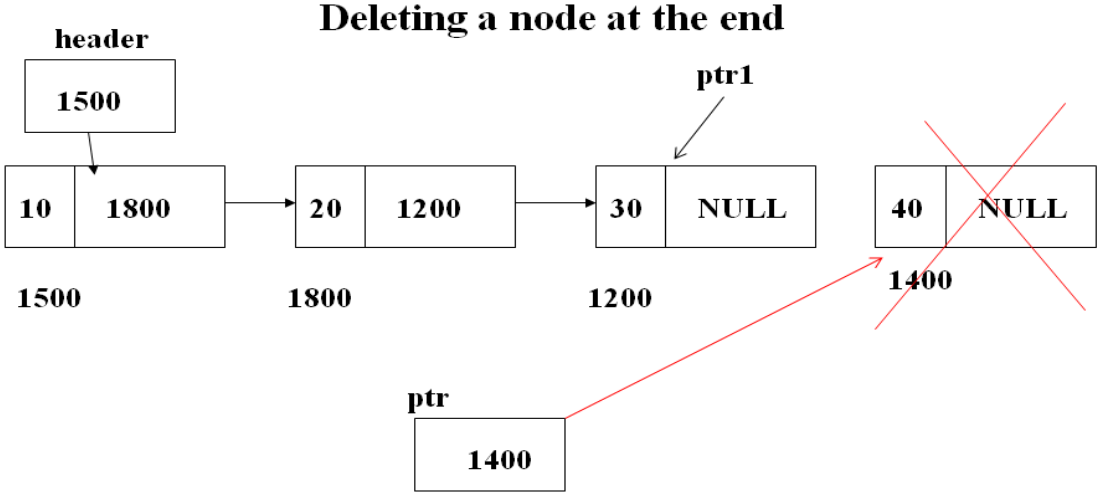
Deleting a node at the beginning



Algorithm:

```
1.  if (header = = NULL)
2.        print  "List is Empty";
3.  else
4.  {
5.        ptr = header;
6.        header = header -> link;
7.        free(ptr);
8.  }
```

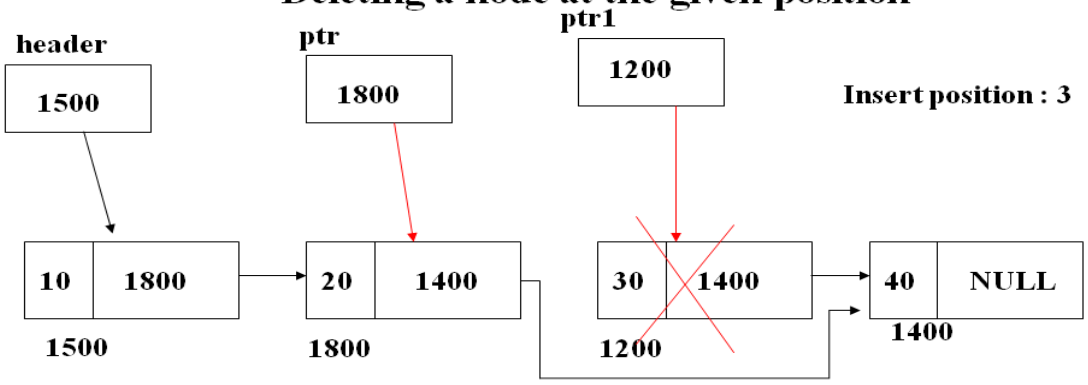
Deleting a node at the end



Algorithm:

```
1.  ptr = header;
2.  while(ptr -> link != NULL)
3.        ptr1=ptr;
4.        ptr = ptr -> link;
5.  ptr1 -> link = NULL;
6.  free(ptr);
```

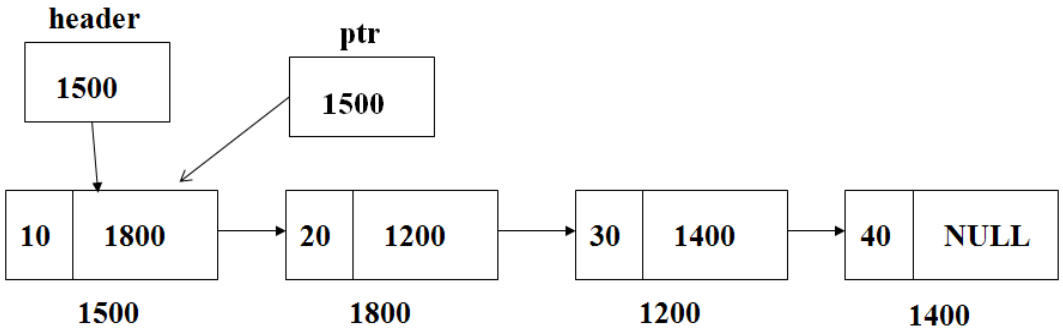
Deleting a node at the given position



Algorithm:

1. ptr = header ;
2. for(i=1;i<pos-1;i++)
3. ptr = ptr -> link;
4. ptr1 = ptr -> link;
5. ptr -> link = ptr1-> link;
6. free(ptr1);

Traversing an elements of a list



Algorithm:

1. if(header = = NULL)
2. print "List is empty";
3. else
4. for (ptr = header ; ptr != NULL ; ptr = ptr -> link)
5. print "ptr->data";

```
/*Single Linked List Program*/
#include<stdio.h>   #include<malloc.h>   #include<conio.h>   #include<stdlib.h>
void traverse();    void deletion();    void insertion();    int choice,i,pos,item;
struct node
{
        int data;
        struct node *link;
}*header,*ptr,*ptr1,*new;
void main()
{
        header=NULL;
        ptr=header;
        printf("****Menu****\n");
        printf("\n 1.Insertion\n 2.Deletion\n 3.Traverse\n 4.Search\n 4.Exit\n");
        while(1)
        {
            printf("\nEnter ur choice: ");
            scanf("%d",&choice);
            switch(choice)
            {
                    case 1: insertion();
                            break;
                    case 2: deletion();
                            break;
                    case 3: traverse();
                            break;
                    case 4: exit(0);
                    default:        printf("\nWrong choice");
            }/*end of switch*/
        }/*end of while*/
}/*end of main*/
void insertion()
{
        new=malloc(sizeof(struct node));
        printf("\nEnter the item to be inserted: ");
        scanf("%d",&item);
        new->data=item;
        if(header==NULL)
        {
            new->link=NULL;
            header=new;
        }/*end of if*/
        else
        {
            printf("\nEnter the place to insert the item: ");
            printf("1.Start\n 2.Middle\n 3.End\n");
            scanf("%d",&choice);
            if(choice==1)
            {
                    new->link=header;
                    header=new;
            }
```

```
            if(choice==2) {
                    ptr=header;
                    printf("\nEnter the position to place an item: ");
                    scanf("%d",&pos);
                    for(i=1;i<pos-1;i++)
                            ptr=ptr->link;
                    new->link=ptr->link;
                    ptr->link=new;
            }

            if(choice==3) {
                    ptr=header;
                    while(ptr->link!=NULL)
                            ptr=ptr->link;
                    new->link=NULL;
                    ptr->link=new;
            }
        }/*end of else*/
}/*end of insertion*/

void deletion()
{
        ptr=header;
        if(header==NULL)
        {
            printf("\nThe list is empty");
        }
        else
        {
            printf("\n1.Start \n2.Middle \n3.End");
            printf("\nEnter the place to delete the element from list:\n");
            scanf("%d",&choice);

            if(choice==1)
            {
                    printf("\nThe deleted item from the list is: %d",ptr->data);
                    header=header->link;
            }

            if(choice==2)
            {
            printf("\nEnter the position to delete the element from the list");
                    scanf("%d",&pos);
                    for(i=0;i<pos-1;i++)
                    {
                            ptr1=ptr;
                            ptr=ptr->link;
                    }
                    printf("\nThe deleted element is: %d",ptr->data);
                    ptr1->link=ptr->link;
            }
```

```
        if(choice==3)     {
                while(ptr->link!=NULL)
                {
                        ptr1=ptr;
                        ptr=ptr->link;
                }//while
        printf("\nThe deleted element from the list is: %d",ptr->data);
                ptr1->link=NULL;
           }
        }/*end of else*/
}/*end of deletion*/

void traverse()
{
           if(header==NULL)
           printf("List is empty\n");
        else
        {
           printf("\nThe elements in the list are: ");
           for(ptr=header;ptr!=NULL;ptr=ptr->link)
                printf("  %d",ptr->data);
        }
}/*end of traverse */
```

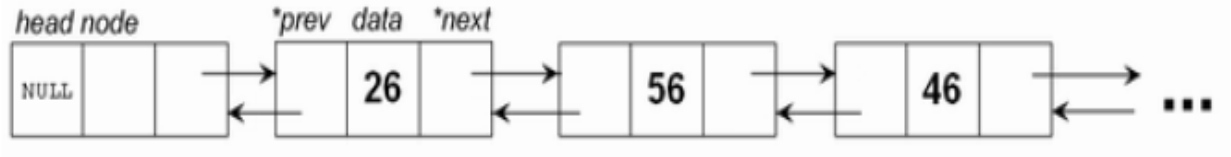
Doubly linked list:

- In a singly linked list one can move from the header node to any node in one direction only (left-right).
- A doubly linked list is a two-way list because one can move in either direction. That is, either from left to right or from right to left.
- It maintains two links or pointer. Hence it is called as doubly linked list.
- Where, DATA field - stores the element or data, PREV- contains the address of its previous node, NEXT- contains the address of its next node.

Structure of the node:

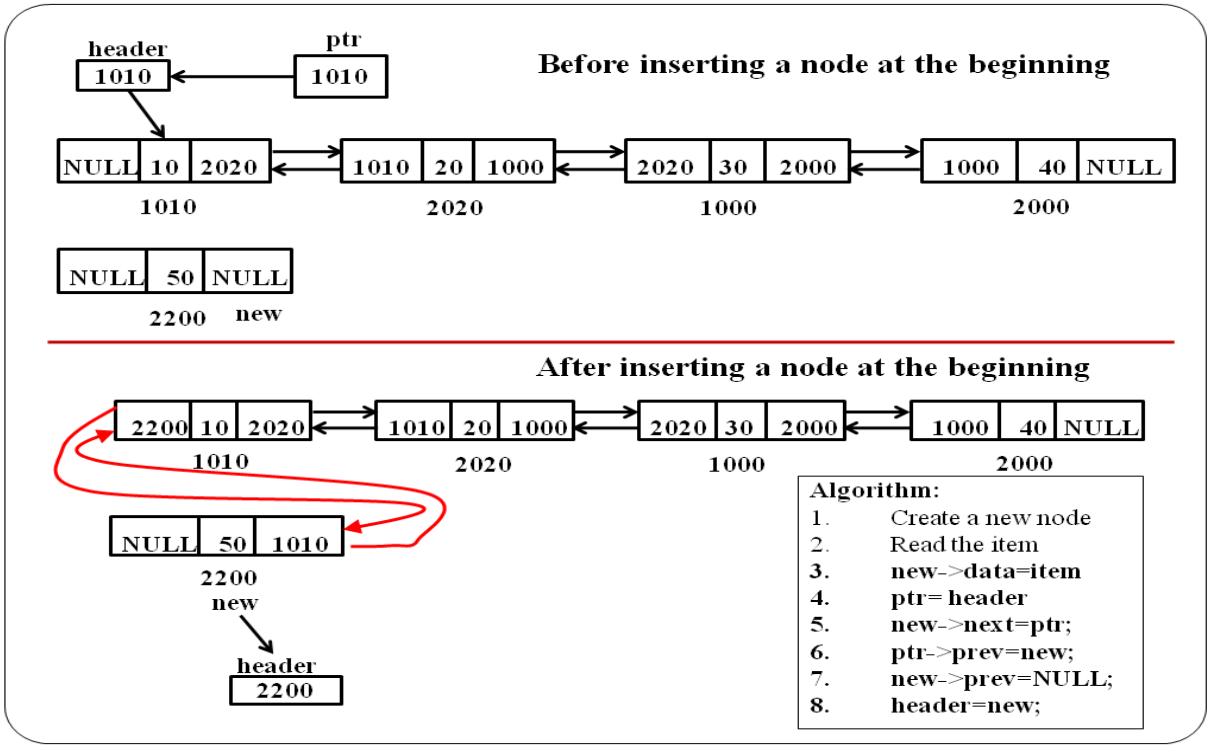
Structure of the node

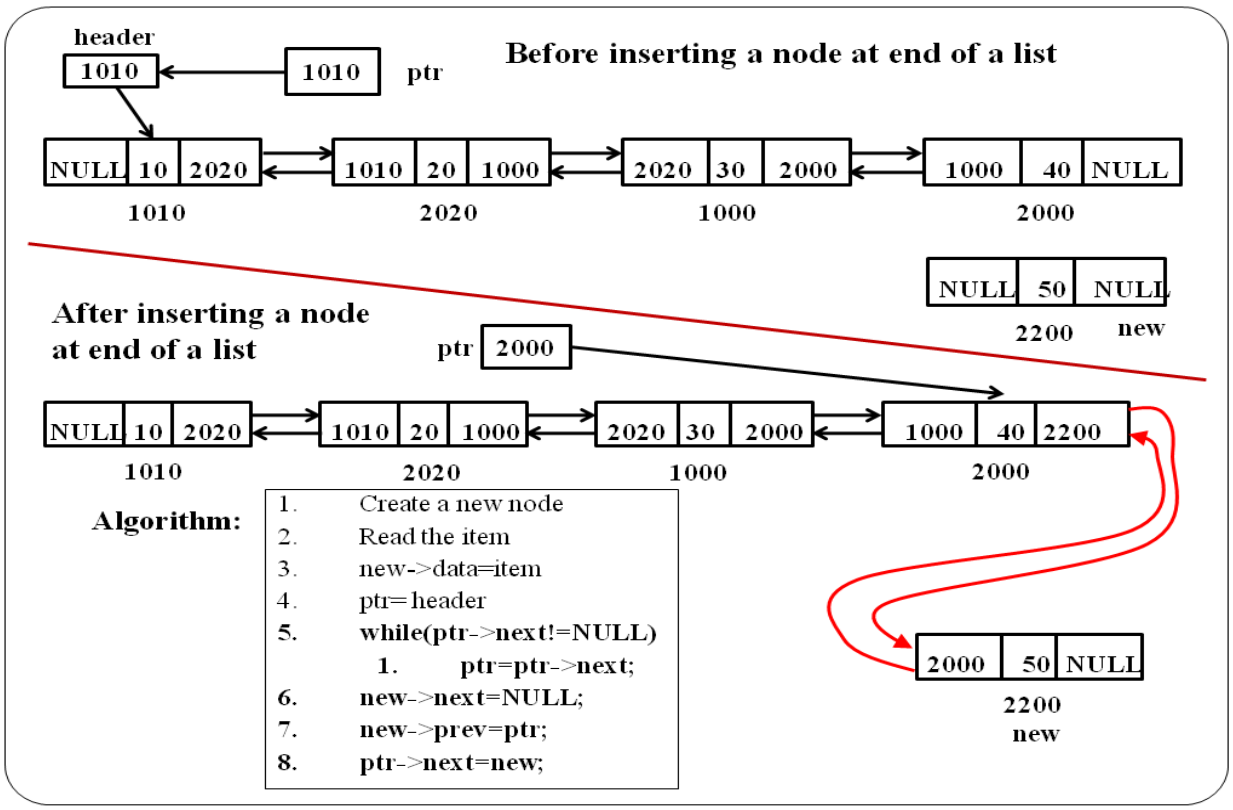
An example of a doubly linked list



Singly linked list operations:

- **Insertion:** Insertion of a node at the front
  Insertion of a node at any position in the list
  Insertion of a node at the end
- **Deletion:** Deletion at front
  Deletion at any position
  Deletion at end
- **Display:** Displaying/Traversing the elements of a list

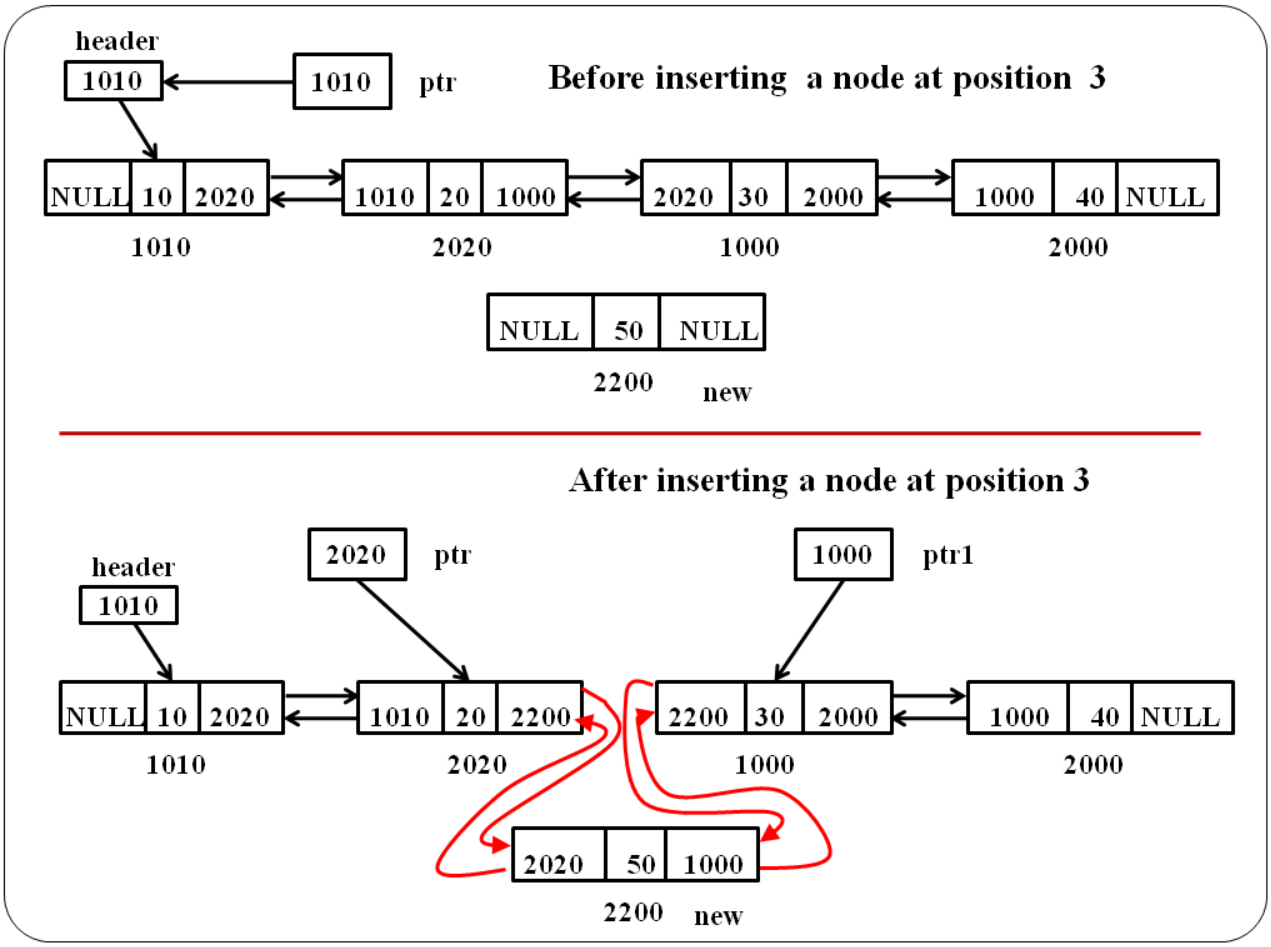


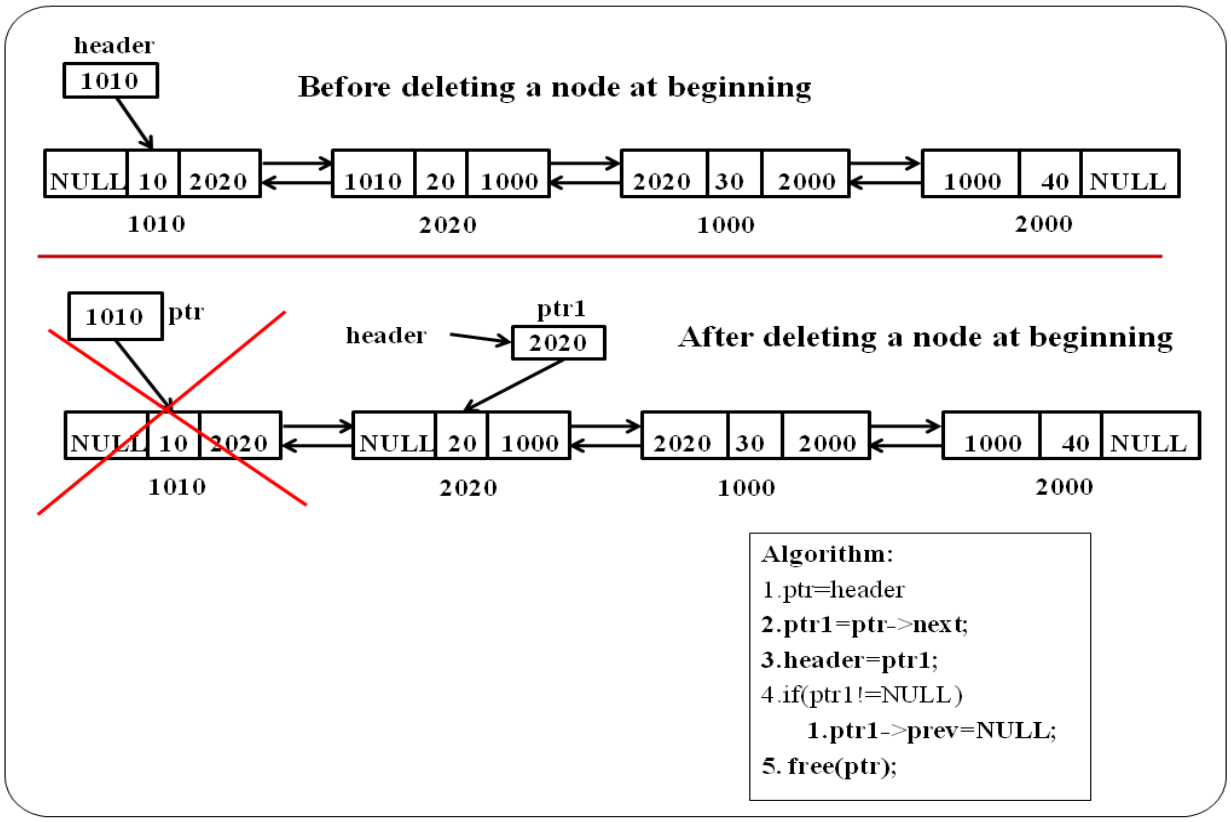


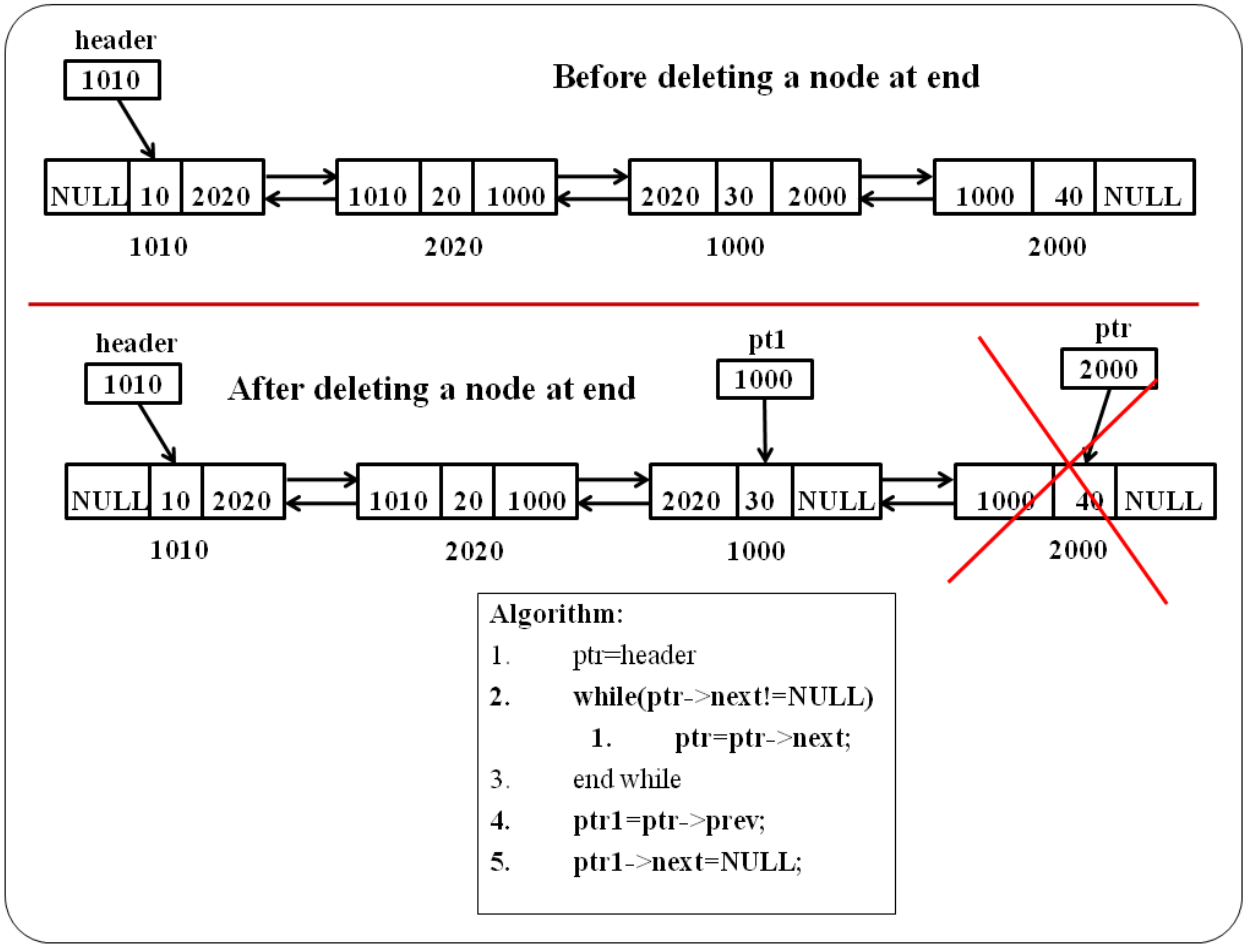
Insertion of a node at any position in the list:

Algorithm:

1. create a node new
2. read item
3. new->data=item
4. ptr=header;
5. Read the position where the element is to be inserted
6. for(i=1;i<pos-1;i++)
   - 6.1 ptr=ptr->next;
7. if(ptr->next = = NULL)
   - 7.1 new->next = NULL;
   - 7.2 new->prev=ptr;
   - 7.3 ptr->next=new;
8. else
   - 8.1 ptr1=ptr->next;
   - 8.2 new->next=ptr1;
   - 8.3 ptr1->prev=new;
   - 8.4 new->prev=ptr;
   - 8.5 ptr->next=new;
9. end



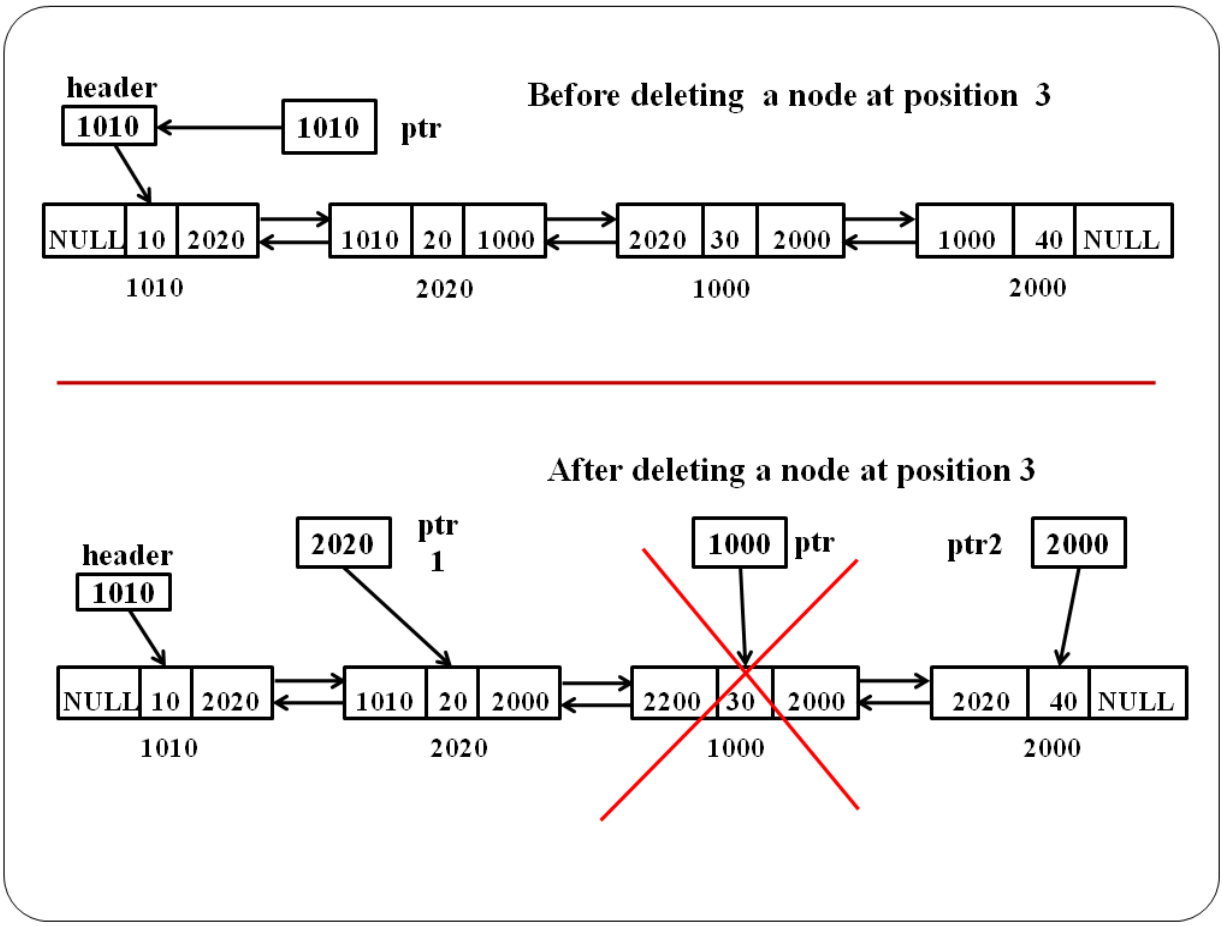

header
1010
Before deleting a node at beginning
NULL 10 2020
1010 20 1000
2020 30 2000
1000 40 NULL
1010
2020
1000
2000
1010 ptr
header
ptr1
2020
After deleting a node at beginning
NULL 10 2020
NULL 20 1000
2020 30 2000
1000 40 NULL
1010
2020
1000
2000
Algorithm:
1.ptr=header
2.ptr1=ptr->next;
3.header=ptr1;
4.if(ptr1!=NULL)
1.ptr1->prev=NULL;
5. free(ptr);


header
1010
Before deleting a node at end
NULL 10 2020
1010 20 1000
2020 30 2000
1000 40 NULL
1010
2020
1000
2000
header
1010
After deleting a node at end
pt1
1000
ptr
2000
NULL 10 2020
1010 20 1000
2020 30 NULL
1000 40 NULL
1010
2020
1000
2000
Algorithm:
1. ptr=header
2. while(ptr->next!=NULL)
1. ptr=ptr->next;
3. end while
4. ptr1=ptr->prev;
5. ptr1->next=NULL;

Deletion at any position:

Algorithm:

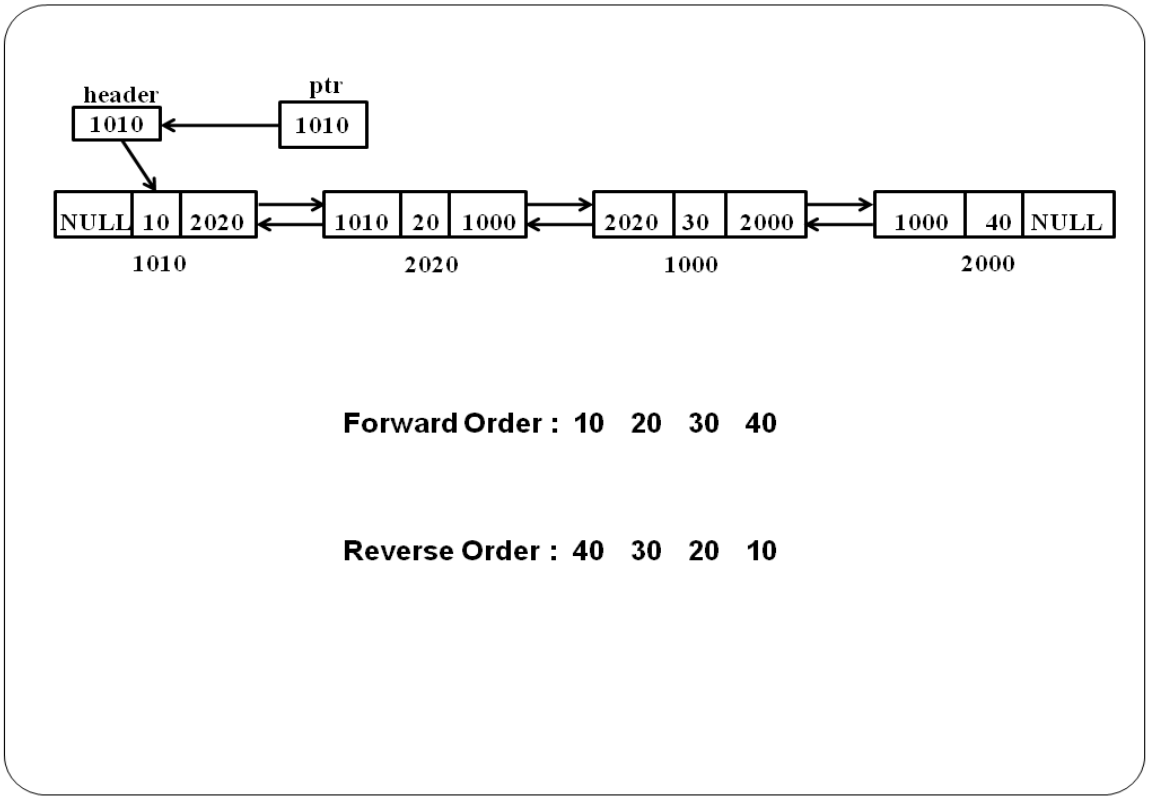
1. ptr=header;
2. **while(ptr->next!=NULL)**
   - **1.for(i=0;i<pos-1;i++)**
     - 1. ptr=ptr->next;
   - **2.if(i = = pos-1)**
     - 1. break;
3. end while
4. **if(ptr = = header)**
   - //if the deleted item is first node
   - 4.1 ptr1=ptr->next;
   - 4.2 ptr1->prev=NULL;
   - 4.3 header=ptr1;
   - 4.4 end if
5. **else**
   - 5.1 ptr1=ptr->prev;
   - 5.2 ptr2=ptr->next;
   - 5.3 ptr1->next=ptr2;
   - 5.4 ptr2->prev=ptr1;
6. end else
7. end if



Displaying elements of a list:

Algorithm:

1. ptr=header;
2. if(header = = NULL)
    1. printf("The list is empty\n");
3. **else**
    1. print “The elements in farword order: “
    2. **while(ptr!=NULL)**
        1. print “ptr->data”;
        2. if(ptr->next = = NULL)
            1. break;
        3. ptr=ptr->next;
    3. print “The elements in reverse order: “
    4. **while(ptr!=header)**
        1. if(ptr->next = = NULL)
            1. print “ptr->data”;
        2. else
            1. print “ptr->data”;
            2. ptr=ptr->prev;
            3. print “ptr->data”;
    3.end else
4. end else



```
/*Double Linked List Program*/
#include<stdio.h>    #include<conio.h>    #include<malloc.h>
void insertion();    void deletion();    void traverse();
int i,pos,item,choice;
struct node
{
        int data;
        struct node *next;
        struct node *prev;
}*new,*header,*ptr,*ptr1,*ptr2;
void main()
{
        clrscr();
        header=NULL;
        printf(" ***** MENU ****");
        printf("\n1.Insertion \n2.Deletion \n3.Traverse \n4.Exit\n");
        while(1)
        {
                printf("\n\nEnter your choice: ");
                scanf("%d",&choice);
                switch(choice)
                {
                        case 1: insertion();
                                        break;
                        case 2: deletion();
                                        break;
                        case 3: traverse();
                                        break;
                        case 4: exit();
                        default: printf("\nWrong choice");
                }/* end of switch */
        }/* end of while */
}/* end of main */

void insertion()
{
        ptr=header;
        new=malloc(sizeof(struct node));
        printf("\nEnter the item to be inserted: ");
        scanf("%d",&item);
        new->data=item;
        if(header==NULL)
        {
                new->prev=NULL;
                new->next=NULL;
                header=new;
        }
        else
        {
                printf("\nSelect the place:");
                printf("\n1.Start \n2.Middle \n3.End\n");
                scanf("%d",&choice);
```

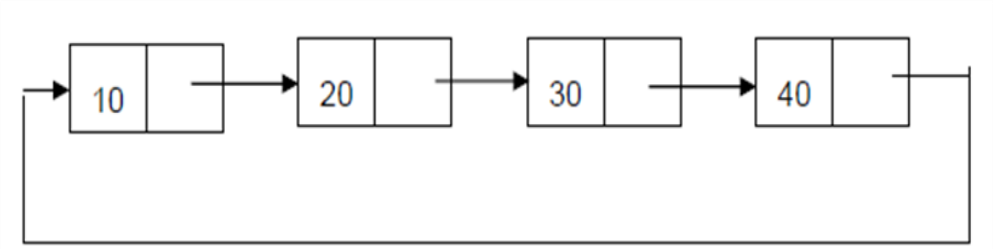
```
            if(choice==1) {
                  new->next=ptr;
                  ptr->prev=new;
                  new->prev=NULL;
                  header=new;
            }/* choice1 */
            if(choice==2) {
                  printf("\nEnter the position to place the new element: ");
                  scanf("%d",&pos);
                  for(i=1;i<pos-1;i++)
                        ptr=ptr->next;
                        if(ptr->next==NULL)
                        {
                              new->next=NULL;
                              new->prev=ptr;
                              ptr->next=new;
                        }
                        else
                        {
                              ptr1=ptr->next;
                              new->next=ptr1;
                              ptr1->prev=new;
                              new->prev=ptr;
                              ptr->next=new;
                        }
            }/* choice2 */
            if(choice==3) {
                  while(ptr->next!=NULL)
                        ptr=ptr->next;
                  new->next=NULL;
                  new->prev=ptr;
                  ptr->next=new;
            }
      }/* end of else */
}/* end of insertion */
void deletion()
{
      ptr=header;
      if(header==NULL)
            printf("The list is empty\n");
      else
      {
            printf("\Select the place:");
            printf("\n1.Start \n2.Middle \n3.End\n");
            scanf("%d",&choice);
            if(choice==1) {
                  printf("\nThe deleted item is: %d",ptr->data);
                  ptr1=ptr->next;
                  header=ptr1;
                  if(ptr1!=NULL)
                        ptr1->prev=NULL;
            }/* choice1 */
```

```
        if(choice==2) {
                printf("\nEnter the position to delete the element: ");
                scanf("%d",&pos);
                while(ptr->next!=NULL)
                {
                        for(i=0;i<pos-1;i++)
                                ptr=ptr->next;
                        if(i==pos-1)
                                break;
                }//while
                printf("\n\nThe deleted node is: %d",ptr->data);
                if(ptr==header)//deleted item is starting node
                {
                        ptr1=ptr->next;
                        ptr1->prev=NULL;
                        header=ptr1;
                }//if
                else
                {
                        ptr1=ptr->prev;
                        ptr2=ptr->next;
                        ptr1->next=ptr2;
                        ptr2->prev=ptr1;
                }
        }/* choice2 */
    }/* end of else */
    if(choice==3) {
        while(ptr->next!=NULL)
                ptr=ptr->next;
        printf("\n\nThe deleted node is: %d",ptr->data);
        ptr1=ptr->prev;
        ptr1->next=NULL;
    }/* choice3 */
}/*end of deletion */

void traverse()
{
    ptr=header;
    if(header==NULL)
        printf("The list is empty\n");
    else
    {
        printf("\n\nThe elements in farword order: ");
        while(ptr!=NULL)    {
                printf("  %d",ptr->data);
                if(ptr->next==NULL)
                {
                        break;
                }
                ptr=ptr->next;
        }/* end of while */
        printf("\n\nThe elements in reverse order: ");
```

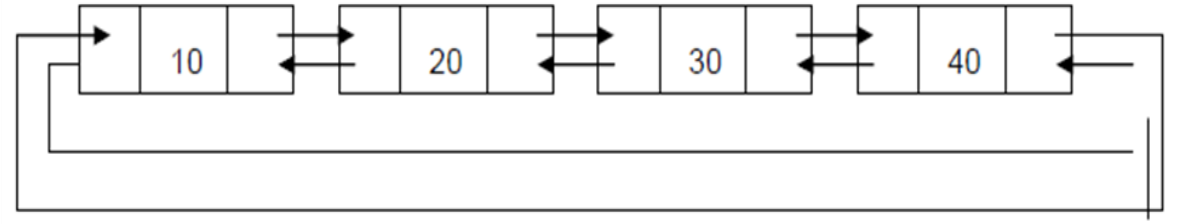
```
                while(ptr!=header)   {
                        if(ptr->next==NULL)
                                printf("  %d",ptr->data);
                        else
                                printf("  %d",ptr->data);
                        ptr=ptr->prev;
                }/* end of while */
                printf("  %d",ptr->data);
        }/* end of else */
}/* end of traverse() */
```

Circular linked list:

- The linked list where the last node points the header node is called circular linked list.



Circular singly linked list



Circular doubly linked list

/* Write a c program to implement circular linked list*/

```
#include<stdio.h>
#include<conio.h>
#include<malloc.h>
#include<stdlib.h>
int choice,i,item;

struct node
{
        int data;
        struct node *link;
}*front,*rear,*new,*ptr1,*ptr;

main()
{
        clrscr();
        front=rear=NULL;
        printf("\n select menu\n");
        while(1)
        {
                printf("\n1.Enqueue \n2.Dequeue \n3.Display \n4.Exit");
                printf("\nEnter ur choice: ");
                scanf("%d",&choice);
                switch(choice)
                {
                        case 1: enqueue();
                                        break;
                        case 2: dequeue();
                                        break;
                        case 3: display();
                                        break;
                        case 4: exit(0);
                        default: printf("\nWrong choice.");
                }/*end of switch*/
        }/*end of while*/
}/*end of main*/

int enqueue()
{
        new=malloc(sizeof(struct node));
        printf("\nEnter the item: ");
        scanf("%d",&item);
        new->data=item;
        if(front==NULL)
                front=new;
        else
                rear->link=new;
                rear=new;
                rear->link=front;
                return;
}/*end of enqueue()*/
```

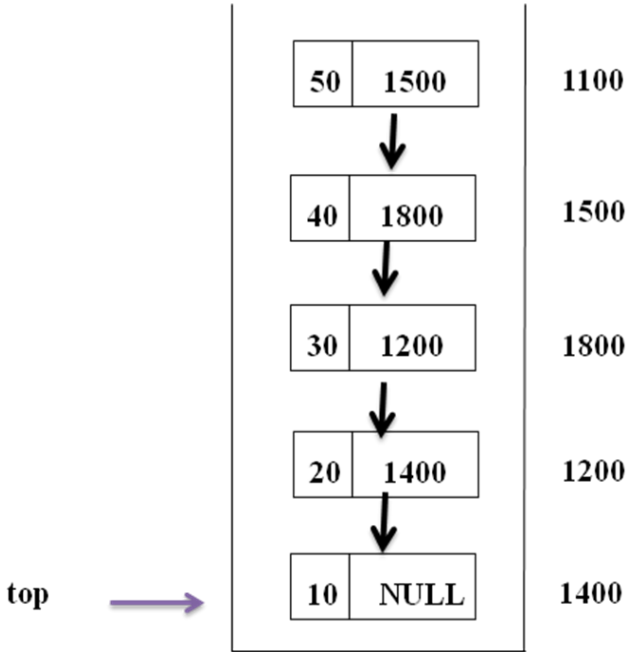
```
dequeue()
{
        if(front==NULL)
                printf("\nThe circular list is empty.");
        else
        if(front==rear)
        {
                printf("\nThe deleted element is: %d",front->data);
                front=rear=NULL;
        }
        else
        {
                printf("\nThe deleted element is: %d",front->data);
                front=front->link;
                rear->link=front;
        }
        return;
}/*end of dequeue*/

display()
{
        ptr=front;
        ptr1=NULL;
        if(front==NULL)
                printf("\nThe circular list is empty.");
        else
        {
                printf("\nElements in the list are: ");
                while(ptr!=ptr1)
                {
                        printf("  %d",ptr->data);
                        ptr=ptr->link;
                        ptr1=front;
                }/*end of while*/
                return;
        }/*end of else*/
}/*end of display*/
```

Representing Stack with Linked List:

- Disadvantage of using an array to implement a stack or queue is the wastage of space.
- Implementing stacks as linked lists provides a feasibility on the number of nodes by dynamically growing stacks, as a linked list is a dynamic data structure.
- The stack can grow or shrink as the program demands it to.
- A variable **top** always points to top element of the stack.
- top = NULL specifies stack is empty.

Example:

- The following list consists of five cells, each of which holds a data object and a link to another cell.
- A variable, **top**, holds the address of the first cell in the list.



/* Write a c program to implement stack using linked list */

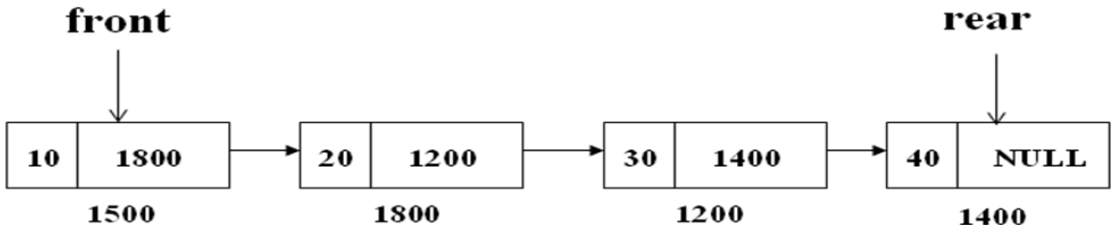
```
#include<stdio.h>   #include<conio.h>   #include<malloc.h>   #include<stdlib.h>
int push();         int count();          int pop();            int display();
int choice,i,item;
struct node
{
                    int data;
                    struct node *link;
}*top,*new,*ptr;
main()
{
                    top=NULL;
                    printf("\n***Select Menu***\n");
                    while(1)
                    {
                     printf("\n1.Push \n2.Pop \n3.Display \n4.Exit\n5.Count");
                     printf("\n\nEnter ur choice: ");
                     scanf("%d",&choice);
                     switch(choice)
                     {
                              case 1: push();
                                      break;
                              case 2: pop();
                                      break;
                              case 3: display();
                                      break;
                              case 4: exit(0);
                              case 5: count();
                                      break;
                              default: printf("\nWrong choice");
                     }/* end of switch */
                    }/* end of while */
}/* end of main */
```

```
int push()
{
                    new=malloc(sizeof(struct node));
                    printf("\nEnter the item: ");
                    scanf("%d",&item);
                    new->data=item;
                    if(top==NULL)
                    {
                     new->link=NULL;
                    }
                    else
                    {
                     new->link=top;
                    }
                    top=new;
                    return;
}/* end of insertion */


int pop()
{
                    if(top==NULL)
                    {
                     printf("\n\nStack is empty");
                     return;
                    }//if
                    else
                    {
                     printf("\n\nThe deleted element is: %d",top->data);
                     top=top->link;
                    }
                    return;
}/* end of pop() */


int display()
{
                    ptr=top;
                    if(top==NULL)
                    {
                     printf("\nThe list is empty");
                     return;
                    }
                    printf("\nThe elements in the stact are: ");
                    while(ptr!=NULL)
                    {
                              printf("\n %d",ptr->data);
                              ptr=ptr->link;
                    }/* end of while */
                    return;
}/* end of display() */
```

```
int count()
{
                    int count=1;
                    ptr=top;
                    if(top==NULL)
                    {
                     printf("\nThe list is empty");
                     return;
                    }
                    while(ptr->link!=NULL)
                    {
                     ++count;
                     ptr=ptr->link;
                    }
                    printf("\n\nThe number of elements in the stack are: %d",count);
                    return;
}/* end of count */
```

Representing Queue with Linked List:

- New items are added to the end of the list.
- Removing an item from the queue will be done from the front.
- A pictorial representation of a queue being implemented as a linked list is given below.



- The variables **front** points to the front item in the queue and **rear** points to the last item in the queue.

/*write a c program to implement queue using linked list*/

```
#include<stdio.h>    #include<conio.h>    #include<malloc.h>    #include<stdlib.h>
int choice,i,item;
struct node  {
                    int data;
                    struct node *link;
}*front,*rear,*new,*ptr;
main()
{
                    front=NULL;
                    rear=NULL;
                    clrscr();
                    printf("\n\n MENU");
                    printf("\n1.Enqueue \n2.Dequeue \n3.Display \n4.Exit");
                    while(1)
                    {
                     printf("\nEnter your choice: ");
                     scanf("%d",&choice);
```

```
                    switch(choice)  {
                            case 1:enqueue();       break;
                            case 2:dequeue();       break;
                            case 3:display();       break;
                            case 4:exit(0);
                            default:printf("\nwrong choice");
                     }/*end of switch */
                    }/*end of while */
}/*end of main */
int enqueue()  {
                    new=malloc(sizeof(struct node));
                    printf("\nenter the item");
                    scanf("%d",&item);
                    new->data=item;
                    new->link=NULL;
                    if(front==NULL)
                    {
                     front=new;
                    }
                    else
                    {
                     rear->link=new;
                    }
                    rear=new;
                    return;
}/*end of enqueue */
dequeue()  {
                    if(front==NULL)
                     printf("\nThe list is empty");
                    else
                    if(front==rear)           /*list has single element*/
                    {
                     printf("\nThe deleted element is: %d",front->data);
                     front=rear=NULL;
                    }
                    else
                    {
                     printf("\nThe deleted element is: %d",front->data);
                     front=front->link;
                    }
                    return;
}/*end ofdequeue*/
display()   {
                    if(front==NULL)
                     printf("\nThe list is emtpy");
                    else
                    {
                     for(ptr=front;ptr!=NULL;ptr=ptr->link)
                            printf("    %d",ptr->data);
                    }
                    return;
}/* end of display */
```