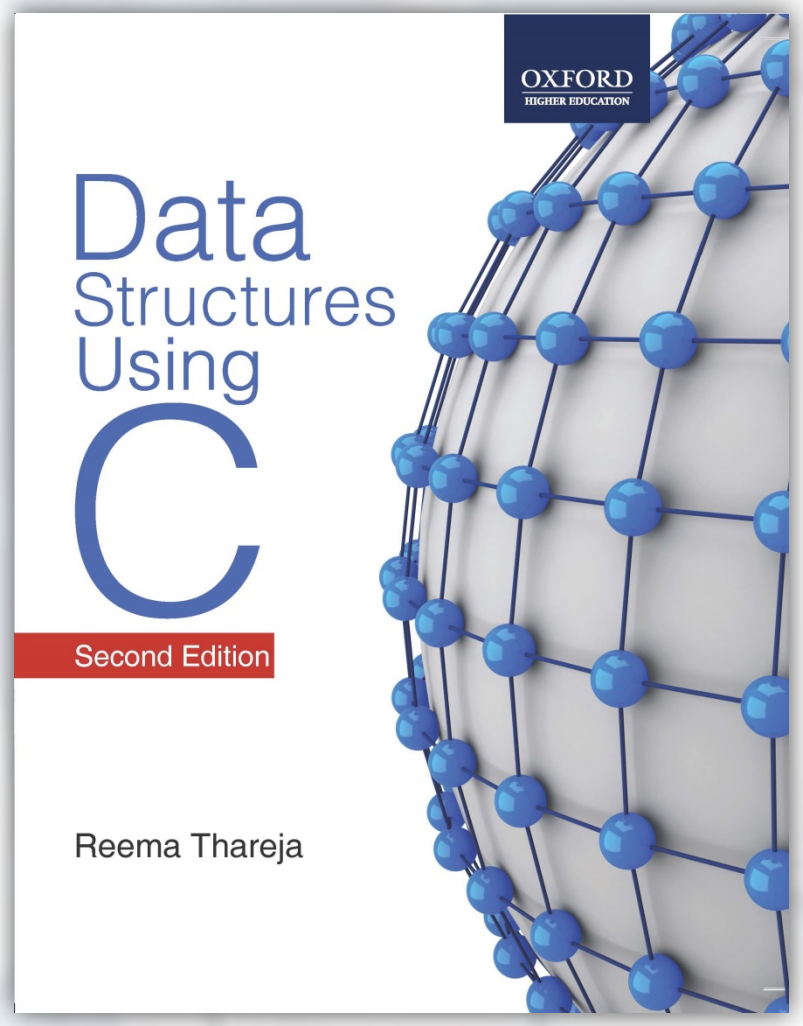

Data Structures Using C, 2e

Reema Thareja

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Chapter 6

Linked Lists

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Introduction

- A linked list is a linear collection of data elements called nodes in which linear representation is given by links from one node to the next node.
- Linked list is a data structure which in turn can be used to implement other data structures. Thus, it acts as building block to implement data structures like stacks, queues and their variations.
- A linked list can be perceived as a train or a sequence of nodes in which each node contains one or more data fields and a pointer to the next node.

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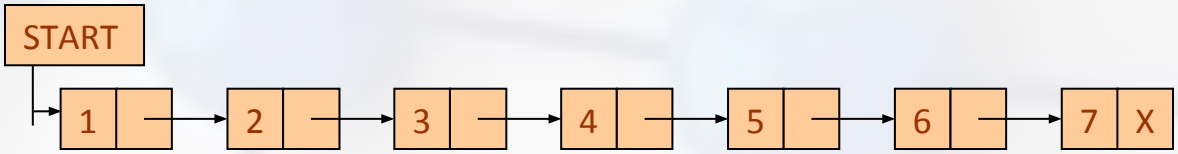
Simple Linked List



- In the above linked list, every node contains two parts - one integer and the other a pointer to the next node.
- The left part of the node which contains data may include a simple data type, an array or a structure.
- The right part of the node contains a pointer to the next node (or address of the next node in sequence).
- The last node will have no next node connected to it, so it will store a special value called NULL.

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Traversing Linked Lists

- We can traverse the entire linked list using a single pointer variable called START.
- The START node contains the address of the first node; the next part of the first node in turn stores the address of its succeeding node.
- Using this technique the individual nodes of the list will form a chain of nodes.
- If START = NULL, this means that the linked list is empty and contains no nodes.
- In C, we can implement a linked list using the following code:

```
struct node
{
    int data;
    struct node *next;
};
```

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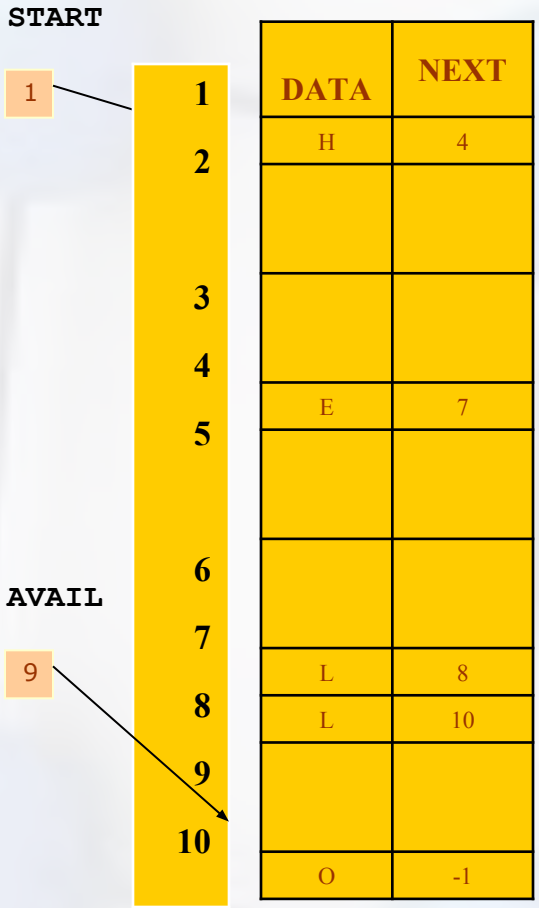
START Pointer

START pointing to the first element of the linked list in memory



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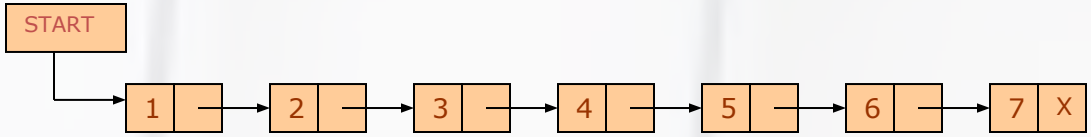
Singly Linked Lists

- A singly linked list is the simplest type of linked list in which every node contains some data and a pointer to the next node of the same data type.




```
ALGORITHM FOR TRAVERSING A LINKED LIST

Step 1: [INITIALIZE] SET PTR = START
Step 2: Repeat Steps 3 and 4 while PTR != NULL
Step 3:         Apply Process to PTR->DATA
Step 4:         SET PTR = PTR->NEXT
        [END OF LOOP]
Step 5: EXIT
```

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Searching a Linked List

```
ALGORITHM TO SEARCH A LINKED LIST

Step 1: [INITIALIZE] SET PTR = START
Step 2: Repeat Step 3 while PTR != NULL
Step 3:         IF VAL = PTR->DATA
                SET POS = PTR
                Go To Step 5
          ELSE
                SET PTR = PTR->NEXT
          [END OF IF]
        [END OF LOOP]
Step 4: SET POS = NULL
Step 5: EXIT
```

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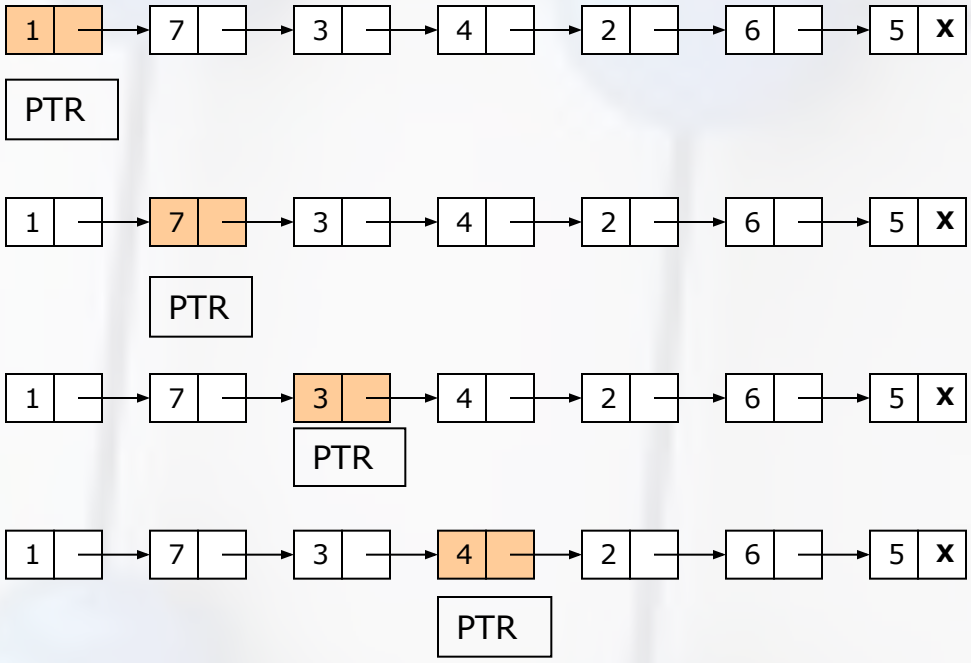
Searching for Val 4 in Linked List



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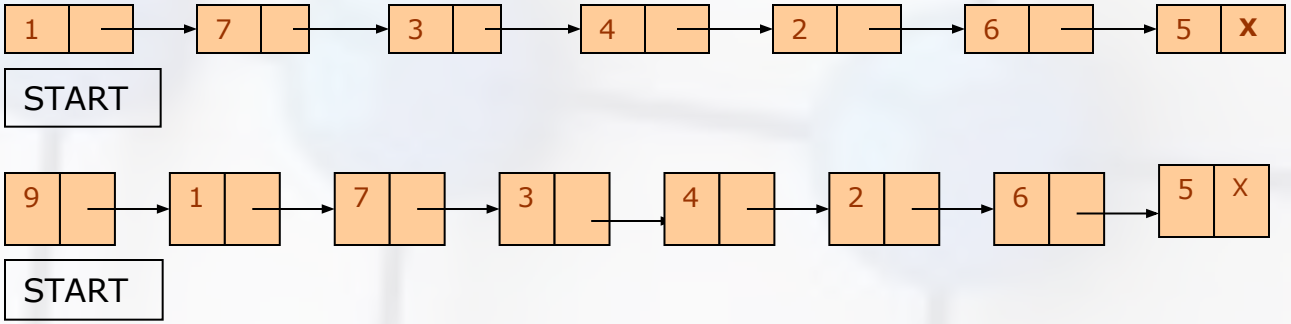
Inserting a Node at the Beginning




```
ALGORITHM TO INSERT A NEW NODE IN THE BEGINNING OF THE LINKED LIST

Step 1: IF AVAIL = NULL, then
          Write OVERFLOW
          Go to Step 7
        [END OF IF]
Step 2: SET New_Node = AVAIL
Step 3: SET AVAIL = AVAIL->NEXT
Step 4: SET New_Node->DATA = VAL
Step 5: SET New_Node->Next = START
Step 6: SET START = New_Node
Step 7: EXIT
```

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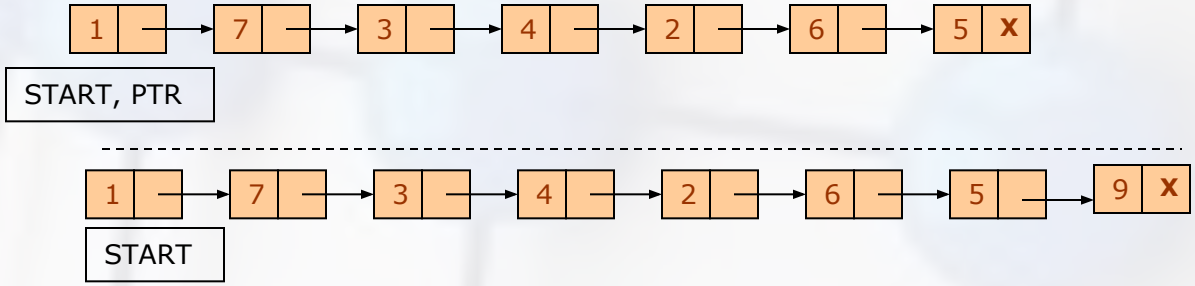
Inserting a Node at the End




```
ALGORITHM TO INSERT A NEW NODE AT THE END OF THE LINKED LIST

Step 1: IF AVAIL = NULL, then
          Write OVERFLOW
          Go to Step 10
     [END OF IF]
Step 2: SET New_Node = AVAIL
Step 3: SET AVAIL = AVAIL->NEXT
Step 4: SET New_Node->DATA = VAL
Step 5: SET New_Node->Next = NULL
Step 6: SET PTR = START
Step 7: Repeat Step 8 while PTR->NEXT != NULL
Step 8:         SET PTR = PTR ->NEXT
        [END OF LOOP]
Step 9: SET PTR->NEXT = New_Node
Step 10: EXIT
```

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Inserting a Node after Node that ahs Value NUM

```
ALGORITHM TO INSERT A NEW NODE AFTER A NODE THAT HAS VALUE NUM

Step 1: IF AVAIL = NULL, then
            Write OVERFLOW
            Go to Step 12
        [END OF IF]
Step 2: SET New_Node = AVAIL
Step 3: SET AVAIL = AVAIL->NEXT
Step 4: SET New_Node->DATA = VAL
Step 5: SET PTR = START
Step 6: SET PREPTR = PTR
Step 7: Repeat Steps 8 and 9 while PREPTR->DATA != NUM
Step 8:             SET PREPTR = PTR
Step 9:             SET PTR = PTR->NEXT
        [END OF LOOP]
Step 10: PREPTR->NEXT = New_Node
Step 11: SET New_Node->NEXT = PTR
Step 12: EXIT
```

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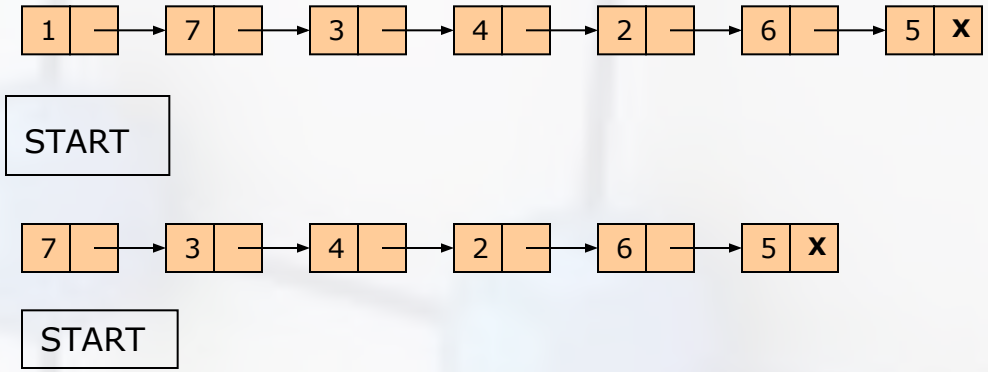
Deleting the First Node

```
Algorithm to delete the first node from the linked list

Step 1: IF START = NULL, then
          Write UNDERFLOW
          Go to Step 5
        [END OF IF]
Step 2: SET PTR = START
Step 3: SET START = START->NEXT
Step 4: FREE PTR
Step 5: EXIT
```



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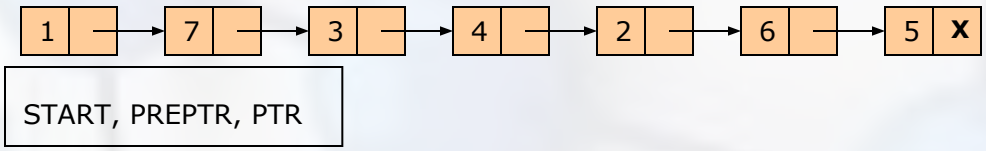
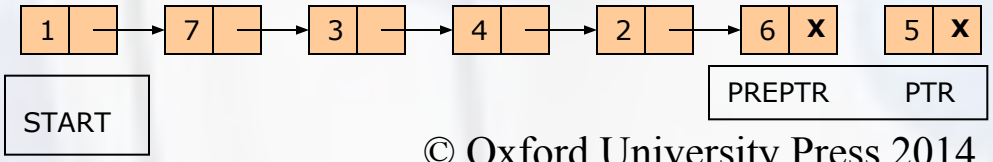
Deleting the Last Node

```
ALGORITHM TO DELETE THE LAST NODE OF THE LINKED LIST

Step 1: IF START = NULL, then
          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
```





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Deleting the Node After a Given Node

```
ALGORITHM TO DELETE THE NODE AFTER A GIVEN NODE FROM THE LINKED LIST

Step 1: IF START = NULL, then
          Write UNDERFLOW
          Go to Step 10
     [END OF IF]
Step 2: SET PTR = START
Step 3: SET PREPTR = PTR
Step 4: Repeat Step 5 and 6 while PRETR->DATA != NUM
Step 5:         SET PREPTR = PTR
Step 6:         SET PTR = PTR->NEXT
     [END OF LOOP]
Step7: SET TEMP = PTR->NEXT
Step 8: SET PREPTR->NEXT = TEMP->NEXT
Step 9: FREE TEMP
Step 10: EXIT
```

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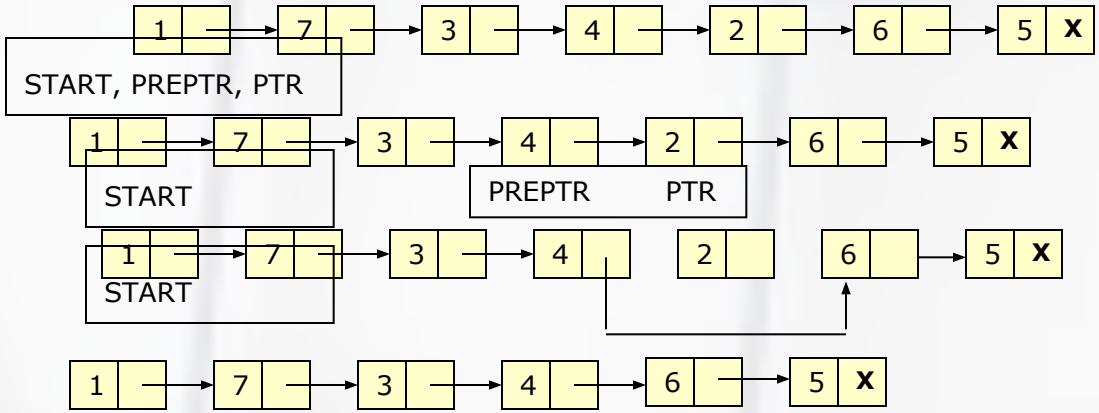
Singly Linked List



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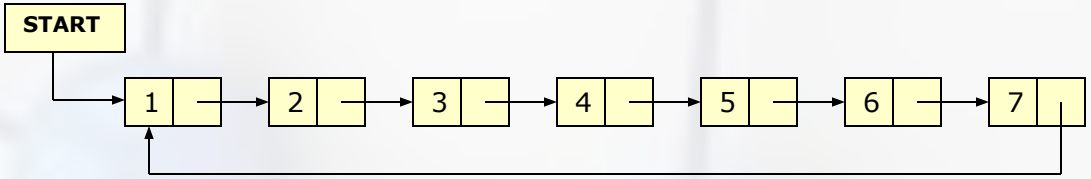
Circular Linked List

- In a circular linked list, the last node contains a pointer to the first node of the list. We can have a circular singly listed list as well as circular doubly linked list. While traversing a circular linked list, we can begin at any node and traverse the list in any direction forward or backward until we reach the same node where we had started. Thus, a circular linked list has no beginning and no ending.



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Circular Linked List

```
Algorithm to insert a new node in the beginning of circular the linked list

Step 1: IF AVAIL = NULL, then
          Write OVERFLOW
          Go to Step 7
     [END OF IF]
Step 2: SET New_Node = AVAIL
Step 3: SET AVAIL = AVAIL->NEXT
Step 4: SET New_Node->DATA = VAL
Step 5: SET PTR = START
Step 6:   Repeat Step 7 while PTR->NEXT != START
Step 7:         PTR = PTR->NEXT
Step 8: SET New_Node->Next = START
Step 8: SET PTR->NEXT = New_Node
Step 6: SET START = New_Node
Step 7: EXIT
```

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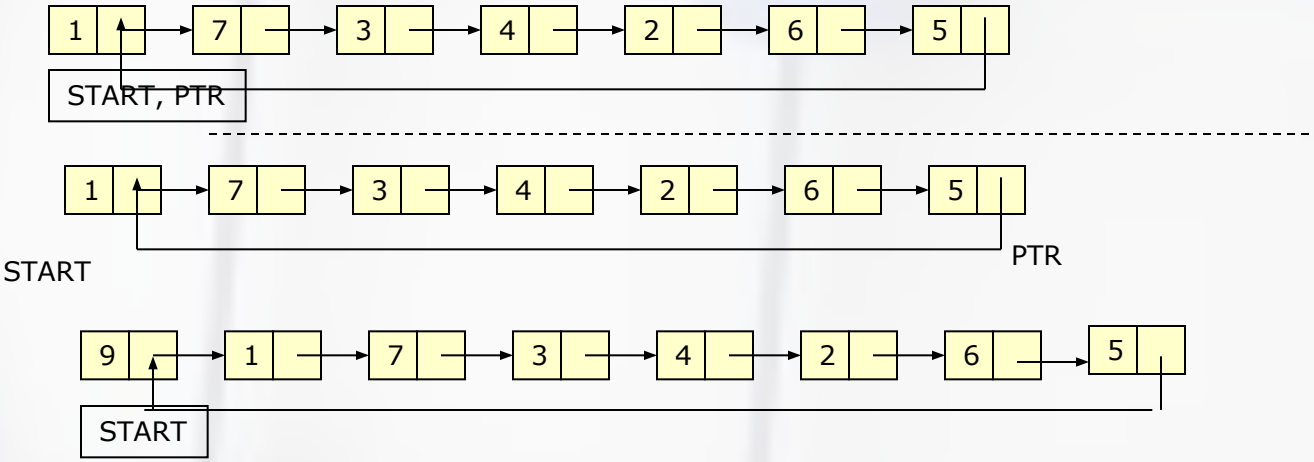
Circular Linked List



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Circular Linked List

```
Algorithm to insert a new node at the end of the circular linked list

Step 1: IF AVAIL = NULL, then
          Write OVERFLOW
          Go to Step 7
     [END OF IF]
Step 2: SET New_Node = AVAIL
Step 3: SET AVAIL = AVAIL->NEXT
Step 4: SET New_Node->DATA = VAL
Step 5: SET New_Node->Next = START
Step 6: SET PTR = START
Step 7: Repeat Step 8 while PTR->NEXT != START
Step 8:         SET PTR = PTR ->NEXT
     [END OF LOOP]
Step 9: SET PTR ->NEXT = New_Node
Step 10: EXIT
```

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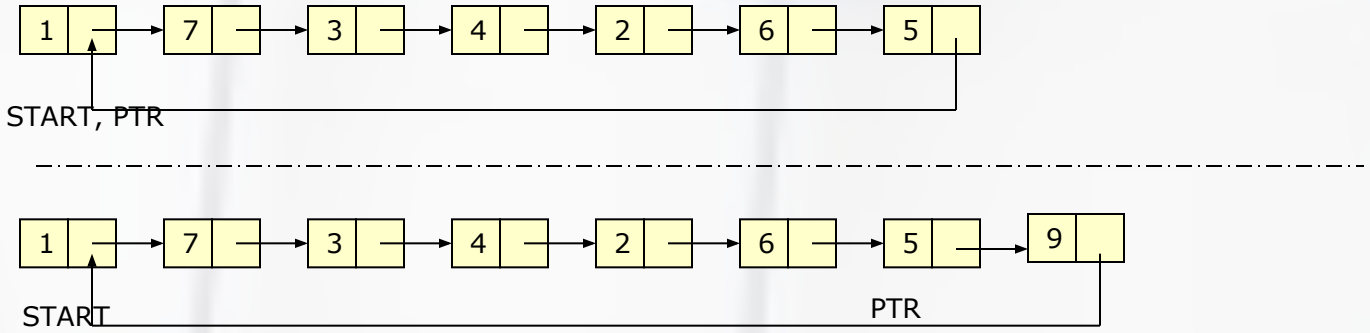
Circular Linked List



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Circular Linked List

```
Algorithm to insert a new node after a node that has value NUM

Step 1: IF AVAIL = NULL, then
          Write OVERFLOW
          Go to Step 12
     [END OF IF]
Step 2: SET New_Node = AVAIL
Step 3: SET AVAIL = AVAIL->NEXT
Step 4: SET New_Node->DATA = VAL
Step 5: SET PTR = START
Step 6: SET PREPTR = PTR
Step 7: Repeat Step 8 and 9 while PTR->DATA != NUM
Step 8:         SET PREPTR = PTR
Step 9:         SET PTR = PTR->NEXT
     [END OF LOOP]
Step 10: PREPTR->NEXT = New_Node
Step 11: SET New_Node->NEXT = PTR
Step 12: EXIT
```

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Circular Linked List

Algorithm to delete the first node from the circular linked list

```
Step 1: IF START = NULL, then
              Write UNDERFLOW
              Go to Step 8
        [END OF IF]
Step 2: SET PTR = START
Step 3: Repeat Step 4 while PTR->NEXT != START
Step 4:              SET PTR = PTR->NEXT
        [END OF IF]
Step 5: SET PTR->NEXT = START->NEXT
Step 6: FREE START
Step 7: SET START = PTR->NEXT
Step 8: EXIT
```

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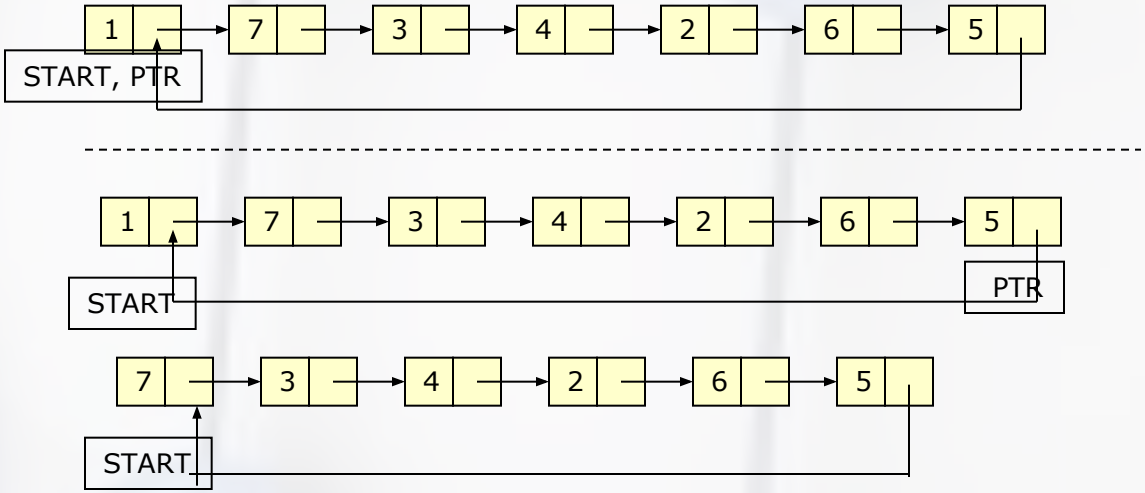
Circular Linked List



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Circular Linked List

```
Algorithm to delete the last node of the circular linked list

Step 1: IF START = NULL, then
          Write UNDERFLOW
          Go to Step 8
     [END OF IF]
Step 2: SET PTR = START
Step 3: Repeat Step 4  while PTR->NEXT != START
Step 4:         SET PREPTR = PTR
Step 5:         SET PTR = PTR->NEXT
     [END OF LOOP]
Step 6: SET PREPTR->NEXT = START
Step 7: FREE PTR
Step 8: EXIT
```

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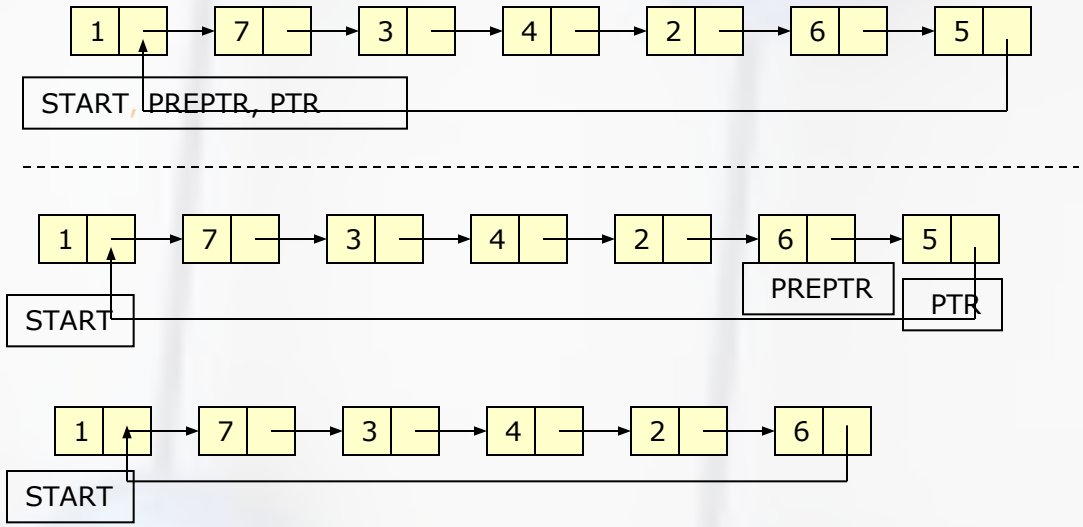
Circular Linked List



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Circular Linked List

Algorithm to delete the node after a given node from the circular linked list

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

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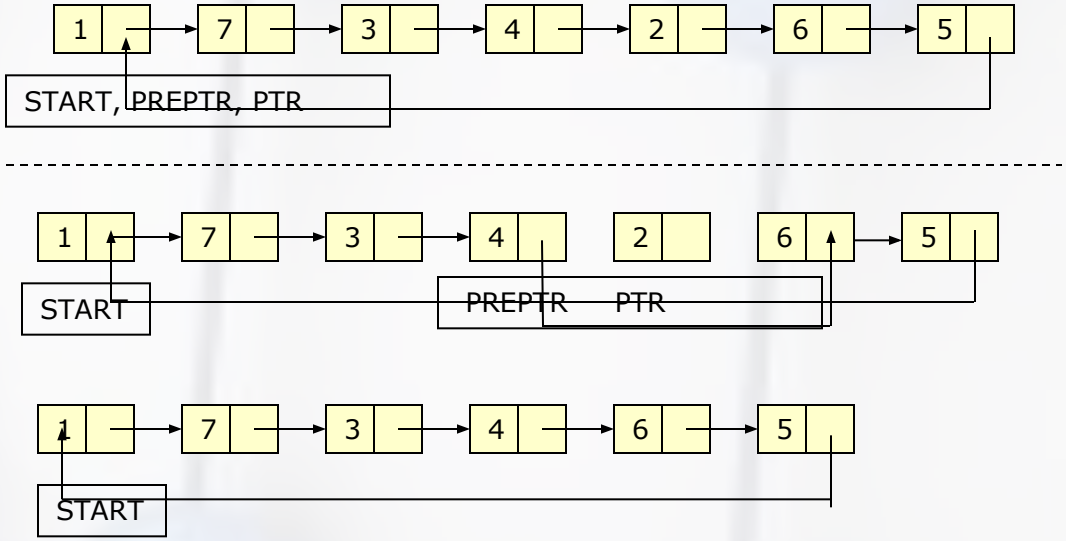
Circular Linked List



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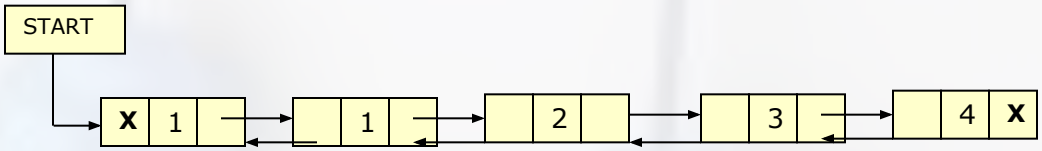
Doubly Linked List

- A doubly linked list or a two way linked list is a more complex type of linked list which contains a pointer to the next as well as previous node in the sequence. Therefore, it consists of three parts and not just two. The three parts are data, a pointer to the next node and a pointer to the previous node



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Doubly Linked List

- In C language, the structure of a doubly linked list is given as,

```
struct node
{    struct node *prev;
     int data;
     struct node *next;
};
```

- The prev field of the first node and the next field of the last node will contain NULL. The prev field is used to store the address of the preceding node. This would enable to traverse the list in the backward direction as well.

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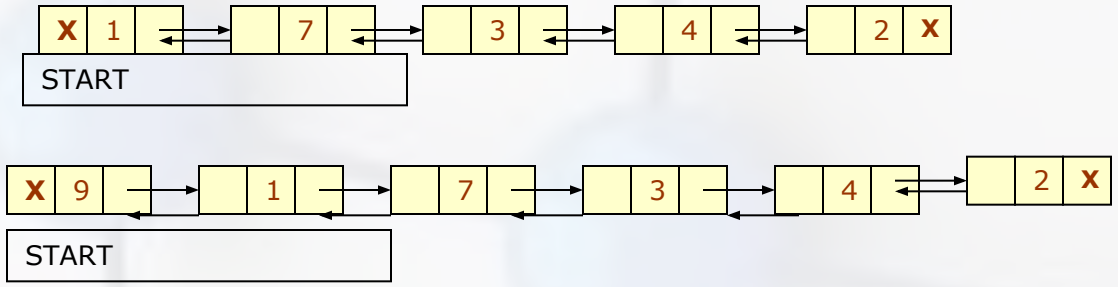
Doubly Linked List

```
Algorithm to insert a new node in the beginning of the doubly linked list

Step 1: IF AVAIL = NULL, then
          Write OVERFLOW
          Go to Step 8
     [END OF IF]
Step 2: SET New_Node = AVAIL
Step 3: SET AVAIL = AVAIL->NEXT
Step 4: SET New_Node->DATA = VAL
Step 5: SET New_Node->PREV = NULL
Step 6: SET New_Node->Next = START
Step 7: SET START = New_Node
Step 8: EXIT
```



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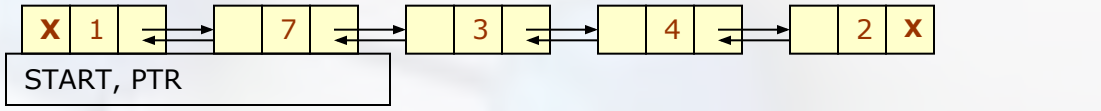
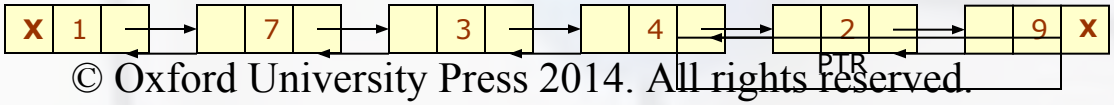
Doubly Linked List

```
Algorithm to insert a new node at the end of the doubly linked list

Step 1: IF AVAIL = NULL, then
          Write OVERFLOW
          Go to Step 11
     [END OF IF]
Step 2: SET New_Node = AVAIL
Step 3: SET AVAIL = AVAIL->NEXT
Step 4: SET New_Node->DATA = VAL
Step 5: SET New_Node->Next = NULL
Step 6: SET PTR = START
Step 7: Repeat Step 8 while PTR->NEXT != NULL
Step 8:         SET PTR = PTR->NEXT
     [END OF LOOP]
Step 9: SET PTR->NEXT = New_Node
Step 10: New_Node->PREV = PTR
Step 11: EXIT
```





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Doubly Linked List

```
Algorithm to insert a new node after a node that has value NUM

Step 1: IF AVAIL = NULL, then
          Write OVERFLOW
          Go to Step 11
     [END OF IF]
Step 2: SET New_Node = AVAIL
Step 3: SET AVAIL = AVAIL->NEXT
Step 4: SET New_Node->DATA = VAL
Step 5: SET PTR = START
Step 6: Repeat Step 8 while PTR->DATA != NUM
Step 7:         SET PTR = PTR->NEXT
     [END OF LOOP]
Step 8: New_Node->NEXT = PTR->NEXT
Step 9: SET New_Node->PREV = PTR
Step 10: SET PTR->NEXT = New_Node
Step 11: EXIT
```

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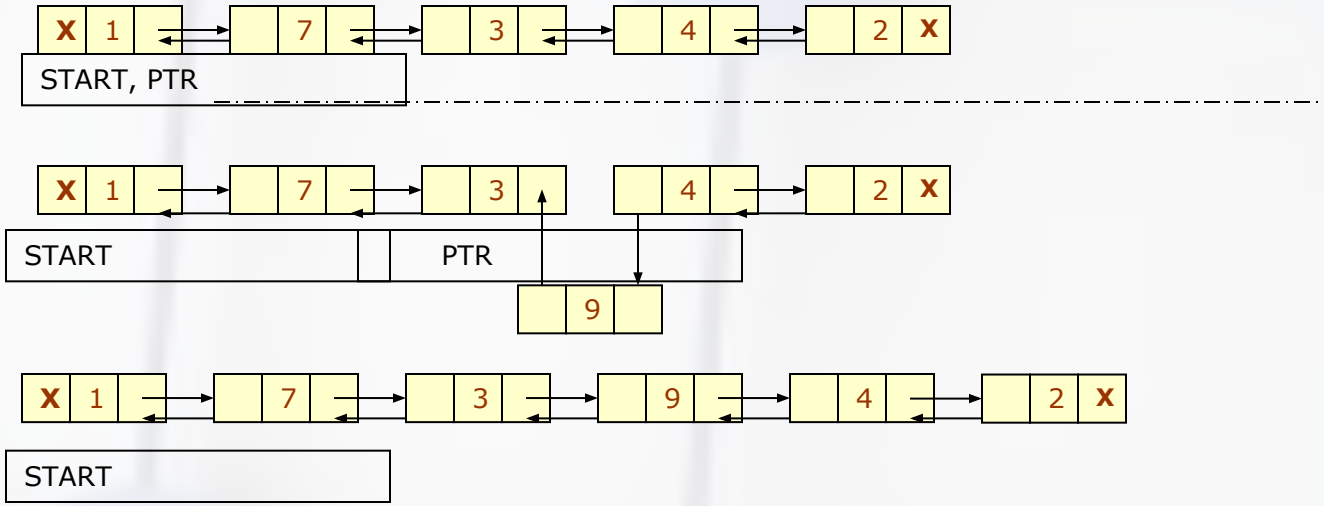
Doubly Linked List



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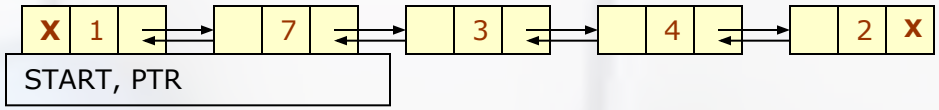
Doubly Linked List

```
Algorithm to delete the first node from the doubly linked list

Step 1: IF START = NULL, then
          Write UNDERFLOW
          Go to Step 6
     [END OF IF]
Step 2: SET PTR = START
Step 3: SET START = START->NEXT
Step 4: SET START->PREV = NULL
Step 5: FREE PTR
Step 6: EXIT
```



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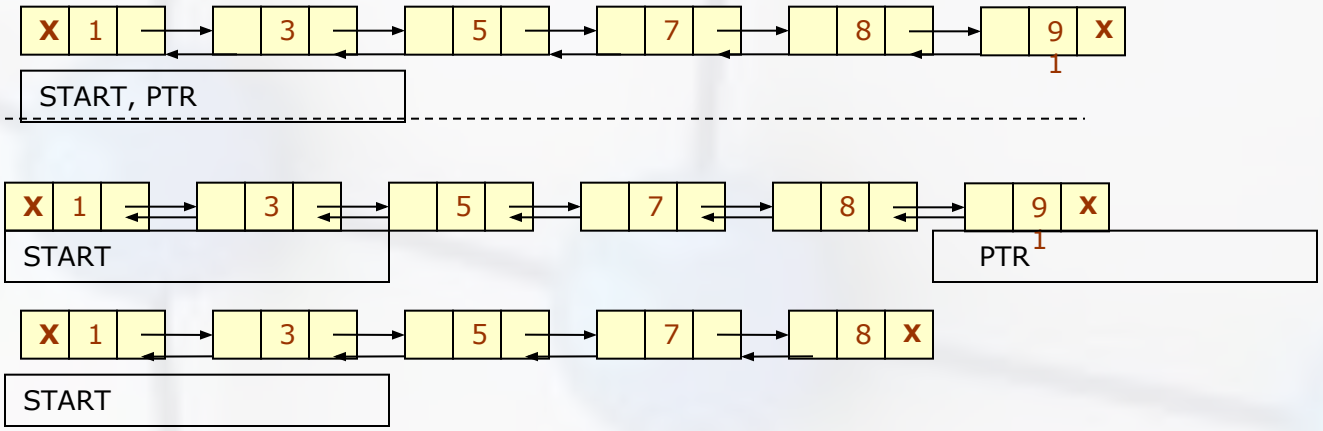
Doubly Linked List

```
Algorithm to delete the last node of the doubly linked list

Step 1: IF START = NULL, then
          Write UNDERFLOW
          Go to Step 7
     [END OF IF]
Step 2: SET PTR = START
Step 3: Repeat Step 4 and 5 while PTR->NEXT != NULL
Step 4:         SET PTR = PTR->NEXT
     [END OF LOOP]
Step 5: SET PTR->PREV->NEXT = NULL
Step 6: FREE PTR
Step 7: EXIT
```



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Doubly Linked List

```
Algorithm to delete the node after a given node from the doubly linked list

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

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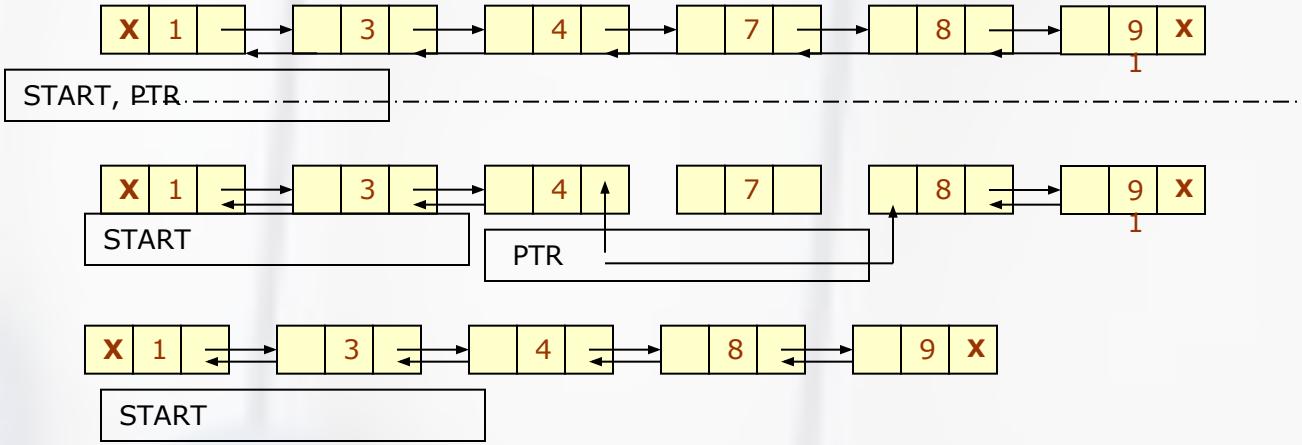
Doubly Linked List



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Circular Doubly Linked List

- A circular doubly linked list or a circular two way linked list is a more complex type of linked list which contains a pointer to the next as well as previous node in the sequence.

- The difference between a doubly linked and a circular doubly linked list is same as that exists between a singly linked list and a circular linked list. The circular doubly linked list does not contain NULL in the previous field of the first node and the next field of the last node. Rather, the next field of the last node stores the address of the first node of the list, i.e; START. Similarly, the previous field of the first field stores the address of the last node.

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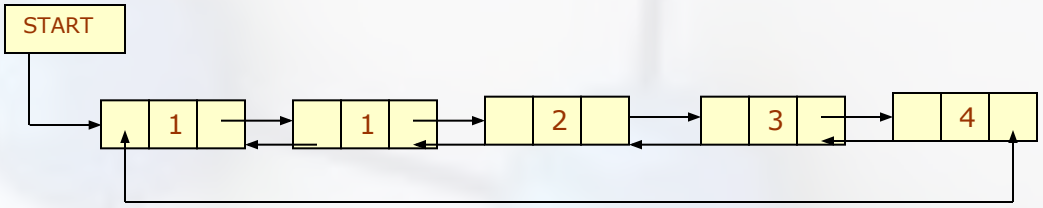
Circular Doubly Linked List

- Since a circular doubly linked list contains three parts in its structure, it calls for more space per node and for more expensive basic operations. However, it provides the ease to manipulate the elements of the list as it maintains pointers to nodes in both the directions . The main advantage of using a circular doubly linked list is that it makes searches twice as efficient.



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Circular Doubly Linked List

Algorithm to insert a new node in the beginning of the circular doubly linked list

```
Step 1: IF AVAIL = NULL, then
            Write OVERFLOW
            Go to Step 12
        [END OF IF]
Step 2: SET New_Node = AVAIL
Step 3: SET AVAIL = AVAIL->NEXT
Step 4: SET New_Node->DATA = VAL
Step 6: SET START->PREV->NEXT = new_node;
Step 7: SET New_Node->PREV = START->PREV;
Step 8: SET START->PREV= new_Node;
Step 9: SET new_node->next = START;
Step 10: SET START = New_Node
Step 11: EXIT
```

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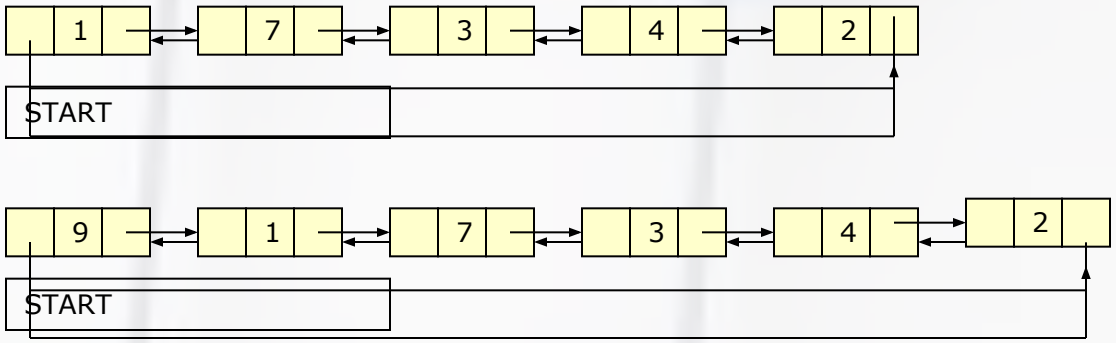
Circular Doubly Linked List



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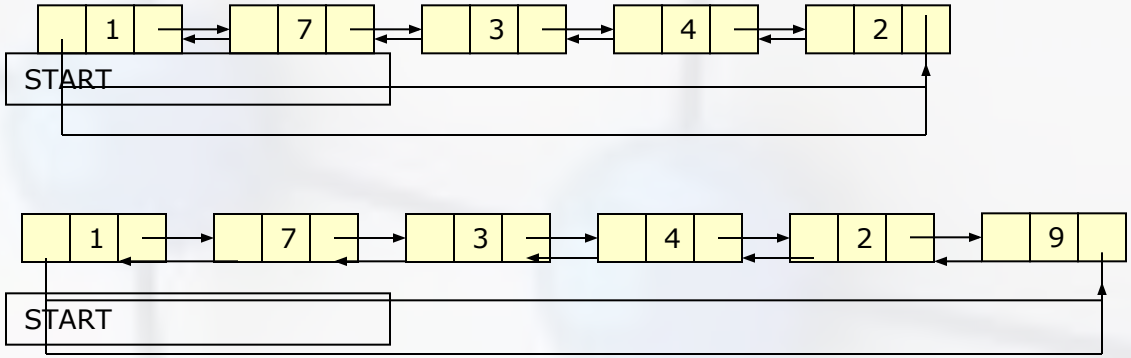
Circular Doubly Linked List

```
Algorithm to insert a new node at the end of the circular doubly linked
list

Step 1: IF AVAIL = NULL, then
          Write OVERFLOW
          Go to Step 11
     [END OF IF]
Step 2: SET New_Node = AVAIL
Step 3: SET AVAIL = AVAIL->NEXT
Step 4: SET New_Node->DATA = VAL
Step 5: SET New_Node->Next = START
Step 6: SET New_Node->PREV = START->PREV
Step 7: EXIT
```



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Circular Doubly Linked List

```
Algorithm to insert a new node after a node that has value NUM

Step 1: IF AVAIL = NULL, then
          Write OVERFLOW
          Go to Step 11
     [END OF IF]
Step 2: SET New_Node = AVAIL
Step 3: SET AVAIL = AVAIL->NEXT
Step 4: SET New_Node->DATA = VAL
Step 5: SET PTR = START
Step 6: Repeat Step 8 while PTR->DATA != NUM
Step 7:         SET PTR = PTR->NEXT
     [END OF LOOP]
Step 8: New_Node->NEXT = PTR->NEXT
Step 9: SET PTR->NEXT->PREV = New_Node
Step 9: SET New_Node->PREV = PTR
Step 10: SET PTR->NEXT = New_Node
Step 11: EXIT
```

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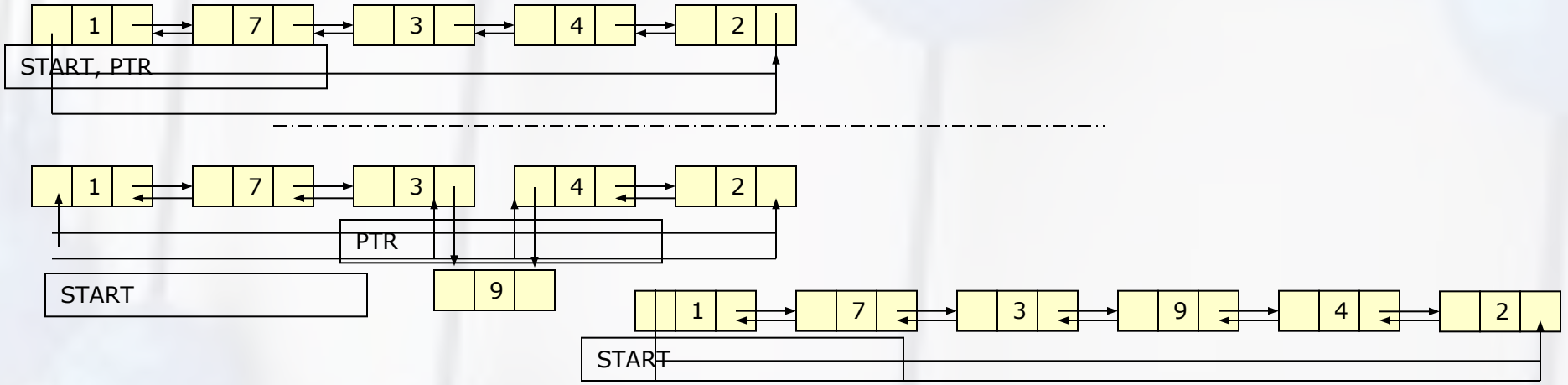
Circular Doubly Linked List



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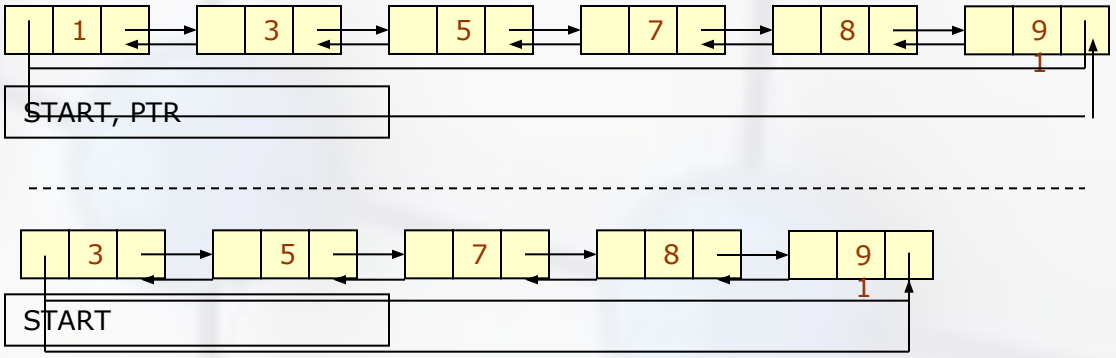
Circular Doubly Linked List

```
Algorithm to delete the first node from the circular doubly linked list

Step 1: IF START = NULL, then
          Write UNDERFLOW
          Go to Step 8
     [END OF IF]
Step 2: SET PTR = START
Step 3: SET PTR->PREV=>NEXT= PTR->NEXT
Step 4: SET PTR->NEXT->PREV = PTR->PREV
Step 5: SET START = START->NEXT
Step 6: FREE PTR
Step 7: EXIT
```



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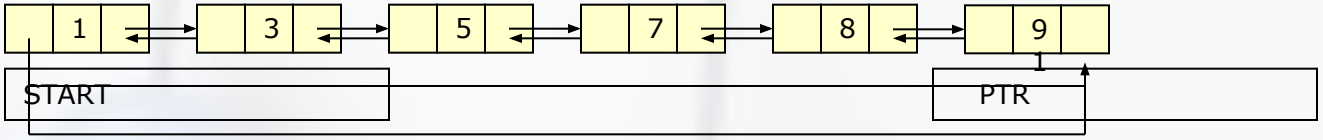
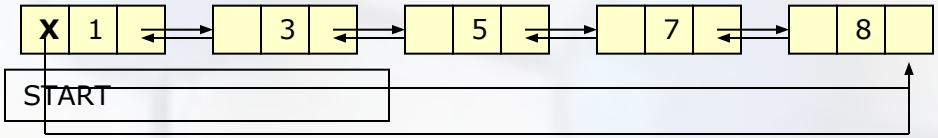
Circular Doubly Linked List

```
Algorithm to delete the last node of the circular doubly linked list

Step 1: IF START = NULL, then
          Write UNDERFLOW
          Go to Step 8
     [END OF IF]
Step 2: SET PTR = START->PREV
Step 5: SET PTR->PREV->NEXT = START
Step 6: SET START->PREV = PTR->PREV
Step 7: FREE PTR
Step 8: EXIT
```





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Circular Doubly Linked List

```
Algorithm to delete the node after a given node from the circular doubly
linked list

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

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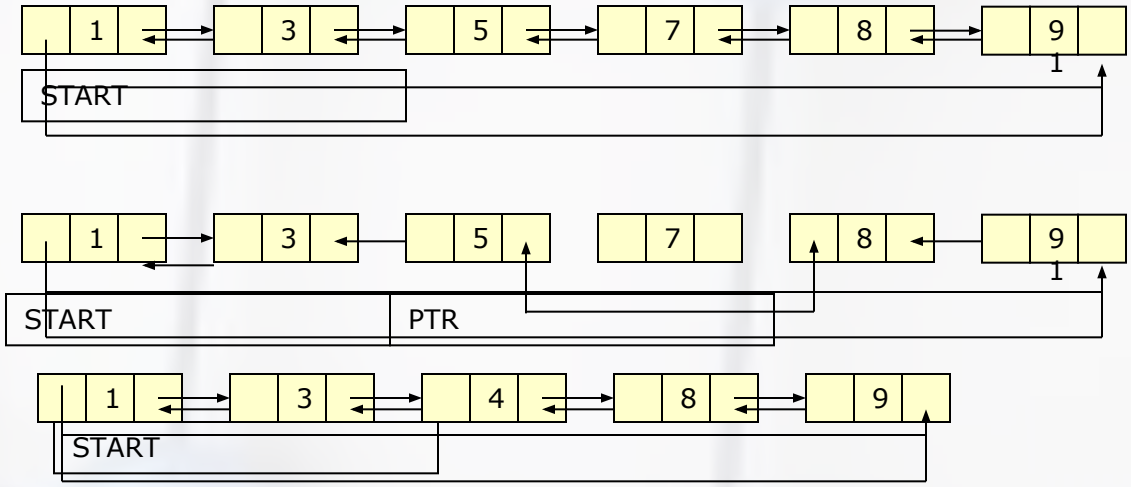
Circular Doubly Linked List



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Circular Doubly Linked List

- A header linked list is a special type of linked list which contains a header node at the beginning of the list. So, in a header linked list START will not point to the first node of the list but START will contain the address of the header node. There are basically two variants of a header linked list-

- Grounded header linked list which stores NULL in the next field of the last node

- Circular header linked list which stores the address of the header node in the next field of the last node. Here, the header node will denote the end of the list.

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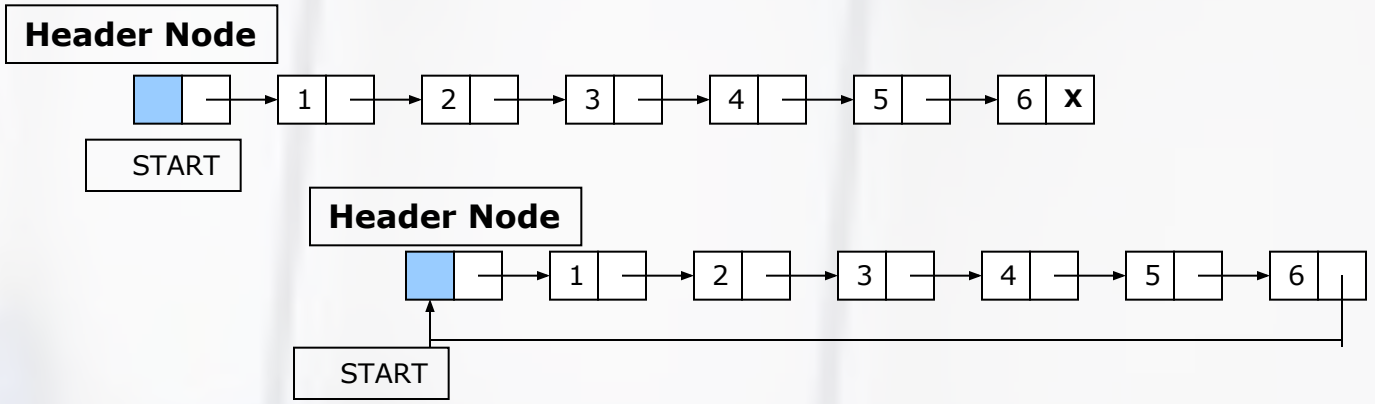
Circular Doubly Linked List



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Circular Doubly Linked List

```
Algorithm to traverse a Circular Header Linked List

Step 1: SET PTR = START->NEXT
Step 2: Repeat Steps 3 and 4 while PTR != START
Step 3:         Apply PROCESS to PTR->DATA
Step 4:         SET PTR = PTR->NEXT
     [END OF LOOP]
Step 5: EXIT
```

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Circular Doubly Linked List

```
Algorithm to insert a new node after a given node

Step 1: IF AVAIL = NULL, then
          Write OVERFLOW
          Go to Step 10
     [END OF IF]
Step 2: SET New_Node = AVAIL
Step 3: SET AVAIL = AVAIL->NEXT
Step 4: SET PTR = START->NEXT
Step 5: SET New_Node->DATA = VAL
Step 6: Repeat step 4 while PTR->DATA != NUM
Step 7:   SET PTR = PTR->NEXT
     [END OF LOOP]
Step 8: New_Node->NEXT = PTR->NEXT
Step 9: SET PTR->NEXT = New_Node
Step 10: EXIT
```

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