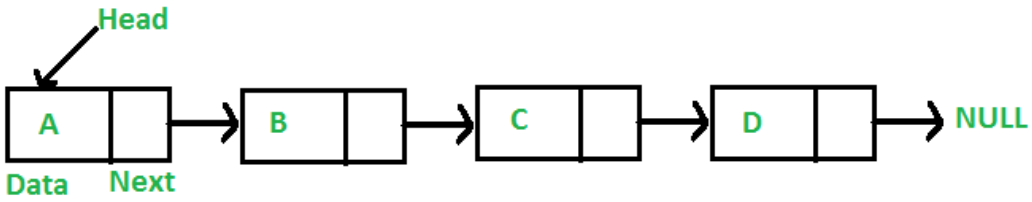
Linked Lists

A linked list is a linear data structure, in which the elements are not stored at contiguous memory locations. The elements in a linked list are linked using pointers as shown in the below image:



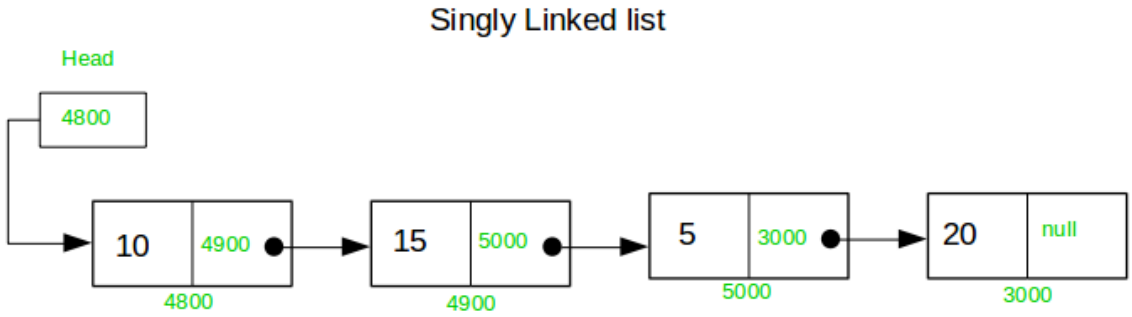
In simple words, a linked list consists of nodes where each node contains a data field and a reference(link) to the next node in the list.

Types of Linked Lists:

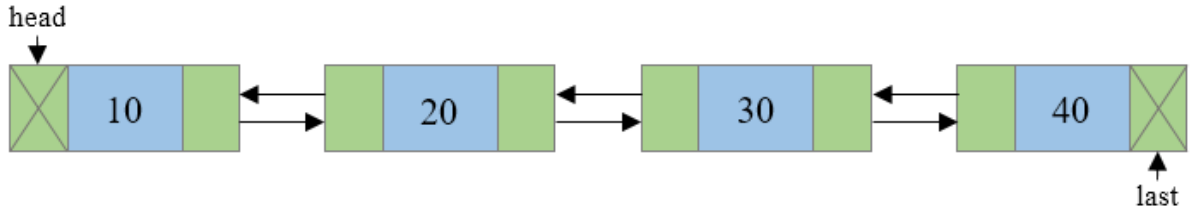
Basically we can put linked lists into the following four items:

1. Single Linked List.
2. Double Linked List.
3. Circular Linked List.
4. Circular Double Linked List.

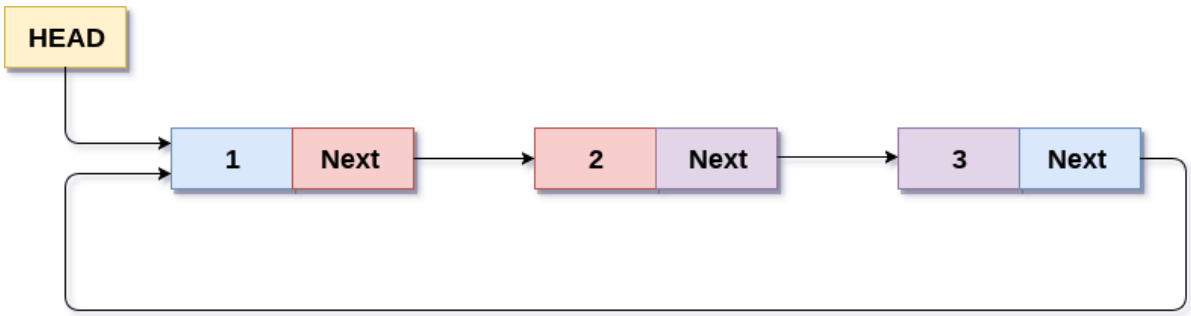
A single linked list is one in which all nodes are linked together in some sequential manner. Hence, it is also called as linear linked list.



A double linked list is one in which all nodes are linked together by multiple links which helps in accessing both the successor node (next node) and predecessor node (previous node) from any arbitrary node within the list. Therefore each node in a double linked list has two link fields (pointers) to point to the left node (previous) and the right node (next). This helps to traverse in forward direction and backward direction.



A circular linked list is one, which has no beginning and no end. A single linked list can be made a circular linked list by simply storing address of the very first node in the link field of the last node.



Circular Singly Linked List

A circular double linked list is one, which has both the successor pointer and predecessor pointer in the circular manner.

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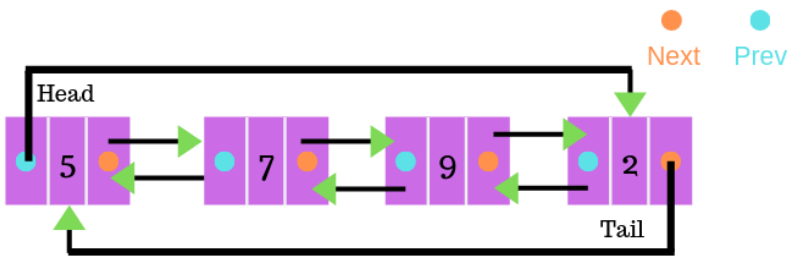

Circular Doubly linked list

Operations on Single Linked List

The following operations are performed on a Single Linked List

- **Insertion**
- **Deletion**
- **Display**

Before we implement actual operations, first we need to set up an empty list. First, perform the following steps before implementing actual operations.

- **Step 1 -** Include all the **header files** which are used in the program.
- **Step 2 -** Declare all the **user defined functions**.
- **Step 3 -** Define a **Node** structure with two members **data** and **next**
- **Step 4 -** Define a Node pointer **'head'** and set it to **NULL**.
- **Step 5 -** Implement the main method by displaying operations menu and make suitable function calls in the main method to perform user selected operation.

```
struct Node
{
int data;
struct Node
*next;}*head =
NULL;
```

Insertion

In a single linked list, the insertion operation can be performed in three ways. They are as follows...

1. Inserting At Beginning of the list
2. Inserting At End of the list
3. Inserting At Specific location in the list

Inserting At Beginning of the list

We can use the following steps to insert a new node at beginning of the single linked list...

- **Step 1 -** Create a **newNode** with given value.
- **Step 2 -** Check whether list is **Empty** (**head == NULL**)
- **Step 3 -** If it is **Empty** then, set **newNode→next = NULL** and **head = newNode**.
- **Step 4 -** If it is **Not Empty** then, set **newNode→next = head** and **head = newNode**.

```
void insertAtBeginning(int value)
{
  struct Node *newNode;
  newNode = (struct Node*)malloc(sizeof(struct Node));
  newNode->data = value;
  if(head == NULL)
  {
    newNode->next = NULL;
    head = newNode;
  }
  else
  {
    newNode->next = head;
    head = newNode;
  }
  printf("\nOne node inserted!!!\n");
}
```

Inserting At End of the list

We can use the following steps to insert a new node at end of the single linked list...

- **Step 1 -** Create a **newNode** with given value and **newNode → next** as **NULL**.
- **Step 2 -** Check whether list is **Empty** (**head == NULL**).
- **Step 3 -** If it is **Empty** then, set **head = newNode**.
- **Step 4 -** If it is **Not Empty** then, define a node pointer **temp** and initialize with **head**.
- **Step 5 -** Keep moving the **temp** to its next node until it reaches to the last node in the list (until **temp → next** is equal to **NULL**).
- **Step 6 -** Set **temp → next = newNode**.

```
void insertAtEnd(int value)
{
  struct Node *newNode;
  newNode = (struct Node*)malloc(sizeof(struct Node));
  newNode->data = value;
  newNode->next = NULL;
  if(head == NULL)
      head = newNode;
  else
  {
    struct Node *temp = head;
    while(temp->next != NULL)
              {temp = temp->next;}
    temp->next = newNode;
    newNode->next= NULL;
  }
  printf("\nOne node inserted!!!\n");
}
```

Inserting At Specific location in the list (After a Node)

We can use the following steps to insert a new node after a node in the single linked list...

- **Step 1 -** Create a **newNode** with given value.
- **Step 2 -** Check whether list is **Empty** (**head == NULL**)
- **Step 3 -** If it is **Empty** then, set **newNode → next = NULL** and **head = newNode**.
- **Step 4 -** If it is **Not Empty** then, define a node pointer **temp** and initialize with **head**.
- **Step 5 -** Keep moving the **temp** to its next node until it reaches to the node after which we want to insert the newNode (until **temp1 → data** is equal to **location**, here location is the node value after which we want to insert the newNode).
- **Step 6 -** Every time check whether **temp** is reached to last node or not. If it is reached to last node then display **'Given node is not found in the list!!! Insertion not possible!!!'** and terminate the function. Otherwise move the **temp** to next node.
- **Step 7 -** Finally, Set '**newNode → next = temp → next**' and '**temp → next = newNode**'

Deletion

In a single linked list, the deletion operation can be performed in three ways. They are as follows...

1. Deleting from Beginning of the list
2. Deleting from End of the list
3. Deleting a Specific Node

Deleting from Beginning of the list

We can use the following steps to delete a node from beginning of the single linked list...

- **Step 1 -** Check whether list is **Empty** (**head == NULL**)
- **Step 2 -** If it is **Empty** then, display **'List is Empty!!! Deletion is not possible'** and terminate the function.
- **Step 3 -** If it is **Not Empty** then, define a Node pointer **'temp'** and initialize with **head**.
- **Step 4 -** Check whether list is having only one node (**temp → next == NULL**)
- **Step 5 -** If it is **TRUE** then set **head = NULL** and delete **temp** (Setting **Empty** list conditions)
- **Step 6 -** If it is **FALSE** then set **head = temp → next**, and delete **temp**.

```
void removeBeginning()
{
  if(head == NULL)
      printf("\n\nList is Empty!!!");
  else
  {
    struct Node *temp = head;
    if(head->next == NULL)
    {
       head = NULL;
       free(temp);
    }
    else
    {
      head = temp->next;
      free(temp);
      printf("\nOne node deleted!!!\n\n");
```

```
        }
      }
    }
```

Deleting from End of the list

We can use the following steps to delete a node from end of the single linked list...

- **Step 1 -** Check whether list is **Empty** (**head == NULL**)
- **Step 2 -** If it is **Empty** then, display **'List is Empty!!! Deletion is not possible'** and terminate the function.
- **Step 3 -** If it is **Not Empty** then, define two Node pointers **'temp1'** and **'temp2'** and initialize **'temp1'** with **head**.
- **Step 4 -** Check whether list has only one Node (**temp1 → next == NULL**)
- **Step 5 -** If it is **TRUE**. Then, set **head = NULL** and delete **temp1**. And terminate the function. (Setting **Empty** list condition)
- **Step 6 -** If it is **FALSE**. Then, set **'temp2 = temp1 '** and move **temp1** to its next node. Repeat the same until it reaches to the last node in the list. (until **temp1 → next == NULL**)
- **Step 7 -** Finally, Set **temp2 → next = NULL** and delete **temp1**.

```
void removeEnd()
{
  if(head == NULL)
  {
    printf("\nList is Empty!!!\n");
  }
  else
  {
    struct Node *temp1 = head,*temp2;
    if(head->next == NULL)
      head = NULL;
    else
    {
      while(temp1->next != NULL)
      {
        temp2 = temp1;
```

```
            temp1 = temp1->next;
        }
        temp2->next = NULL;
    }
    free(temp1);
    printf("\nOne node deleted!!!\n\n");
  }
}
```

Deleting a Specific Node from the list

We can use the following steps to delete a specific node from the single linked list...

- **Step 1 -** Check whether list is **Empty** (**head** == **NULL**)
- **Step 2 -** If it is **Empty** then, display **'List is Empty!!! Deletion is not possible'** and terminate the function.
- **Step 3 -** If it is **Not Empty** then, define two Node pointers **'temp1'** and **'temp2'** and initialize **'temp1'** with **head**.
- **Step 4 -** Keep moving the **temp1** until it reaches to the exact node to be deleted or to the last node. And every time set **'temp2 = temp1'** before moving the **'temp1'** to its next node.
- **Step 5 -** If it is reached to the last node then display **'Given node not found in the list! Deletion not possible!!!'**. And terminate the function.
- **Step 6 -** If it is reached to the exact node which we want to delete, then check whether list is having only one node or not
- **Step 7 -** If list has only one node and that is the node to be deleted, then set **head** = **NULL** and delete **temp1** (**free(temp1)**).
- **Step 8 -** If list contains multiple nodes, then check whether **temp1** is the first node in the list (**temp1 == head**).
- **Step 9 -** If **temp1** is the first node then move the **head** to the next node (**head = head → next**) and delete **temp1**.
- **Step 10 -** If **temp1** is not first node then check whether it is last node in the list (**temp1 → next == NULL**).
- **Step 11 -** If **temp1** is last node then set **temp2 → next** = **NULL** and delete **temp1** (**free(temp1)**).
- **Step 12 -** If **temp1** is not first node and not last node then set **temp2 → next** = **temp1 → next** and delete **temp1** (**free(temp1)**).

```
void removeSpecific(int delValue)
```

```
{
  struct Node *temp1 = head, *temp2;
  while(temp1->data != delValue)
  {
   if(temp1 -> next == NULL){
      printf("\nGiven node not found in the list!!!");
      goto functionEnd;
   }
   temp2 = temp1;
   temp1 = temp1 -> next;
  }
  temp2 -> next = temp1 -> next;
  free(temp1);
  printf("\nOne node deleted!!!\n\n");
  functionEnd:
}
```

Displaying a Single Linked List

We can use the following steps to display the elements of a single linked list...

- **Step 1 -** Check whether list is **Empty** (**head == NULL**)
- **Step 2 -** If it is **Empty** then, display **'List is Empty!!!'** and terminate the function.
- **Step 3 -** If it is **Not Empty** then, define a Node pointer **'temp'** and initialize with **head**.
- **Step 4 -** Keep displaying **temp → data** with an arrow (**--->**) until **temp** reaches to the last node
- **Step 5 -** Finally display **temp → data** with arrow pointing to **NULL** (**temp → data ---> NULL**).

```
void display()
{
  if(head == NULL)
  {
    printf("\nList is Empty\n");
  }
  else
```

```
    {
      struct Node *temp = head;
      printf("\n\nList elements are - \n");
      while(temp->next != NULL)
      {
         printf("%d --->",temp->data);
         temp = temp->next;
      }
      printf("%d --->NULL",temp->data);
    }
}
```