Data Structures and Algorithms

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Lecture 03: Link List

Definition - List

- A list is a collection of items that has a particular order
    - It can have an arbitrary length
    - Objects / elements can be inserted or removed at arbitrary locations in the list
    - A list can be traversed in order one item at a time

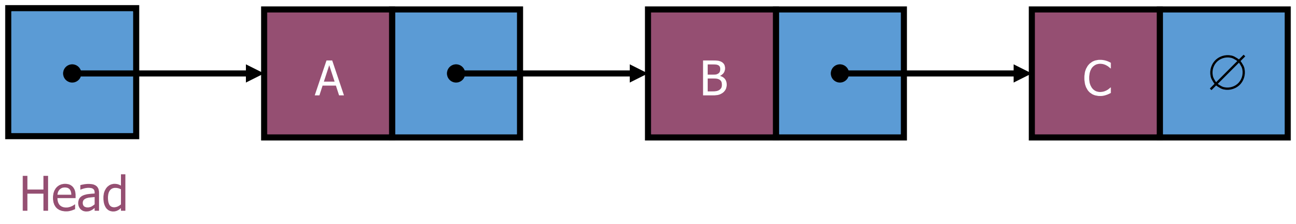
List Overview

- Linked lists
  - Abstract data type (ADT)
- Basic operations of linked lists
  - Insert, find, delete, print, etc.
- Variations of linked lists
  - Singly linked lists
  - Circular linked lists
  - Doubly linked lists
  - Circular doubly linked list

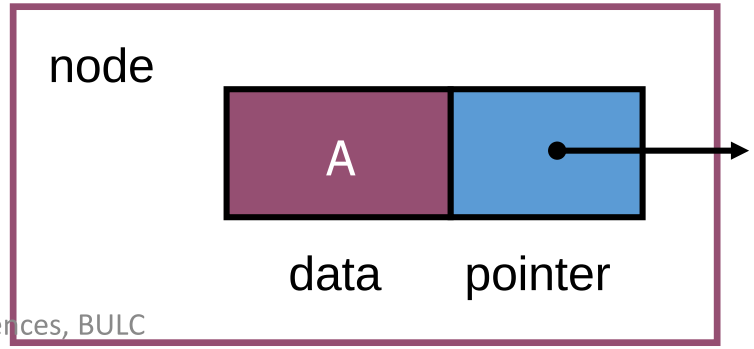
Linked List Terminologies

- **Traversal of List**
  - Means to visit every element or node in the list beginning from first to last.
- **Predecessor and Successor**
  - In the list of elements, for any location n, (n-1) is predecessor and (n+1) is successor.
  - In other words, for any location n in the list, the left element is predecessor and the right element is successor.
  - Also, the first element does not have predecessor and the last element does not have successor.

Linked Lists



- A *linked list* is a series of connected *nodes*
- Each node contains at least
  - A piece of data (any type)
  - Pointer to the next node in the list
- *Head*: pointer to the first node
- The last node points to `NULL`



Lists – Another perspective

A list is a linear collection of varying length of homogeneous components.

Homogeneous: All components are of the same type.

Linear: Components are ordered in a line (hence called Linear linked lists).

Arrays are lists..

Arrays Vs Lists

- Arrays are lists that have a fixed size in memory.
- The programmer must keep track of the length of the array
- No matter how many elements of the array are used in a program, the array has the same amount of allocated space.
- Array elements are stored in successive memory locations. Also, order of elements stored in array is same logically and physically.

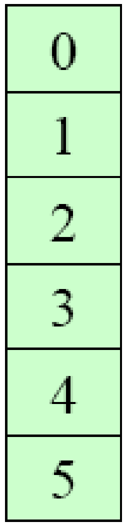
Arrays Vs Lists

- A linked list takes up only as much space in memory as is needed for the length of the list.
- The list expands or contracts as you add or delete elements.
- In linked list the elements are not stored in successive memory location
- Elements can be added to (or deleted from) either end, or added to (or deleted from)the middle of the list.

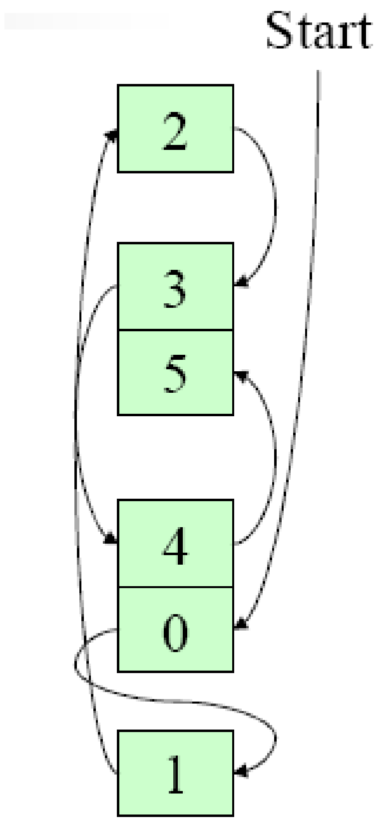
Array versus Linked Lists

- Linked lists are more complex to code and manage than arrays, but they have some distinct advantages.
  - **Dynamic**: a linked list can easily grow and shrink in size.
    - We don’t need to know how many nodes will be in the list. They are created in memory as needed.
    - In contrast, the size of a C++ array is fixed at compilation time.
  - **Easy and fast insertions and deletions**
    - To insert or delete an element in an array, we need to copy to temporary variables to make room for new elements or close the gap caused by deleted elements.
    - With a linked list, no need to move other nodes. Only need to reset some pointers.

An Array



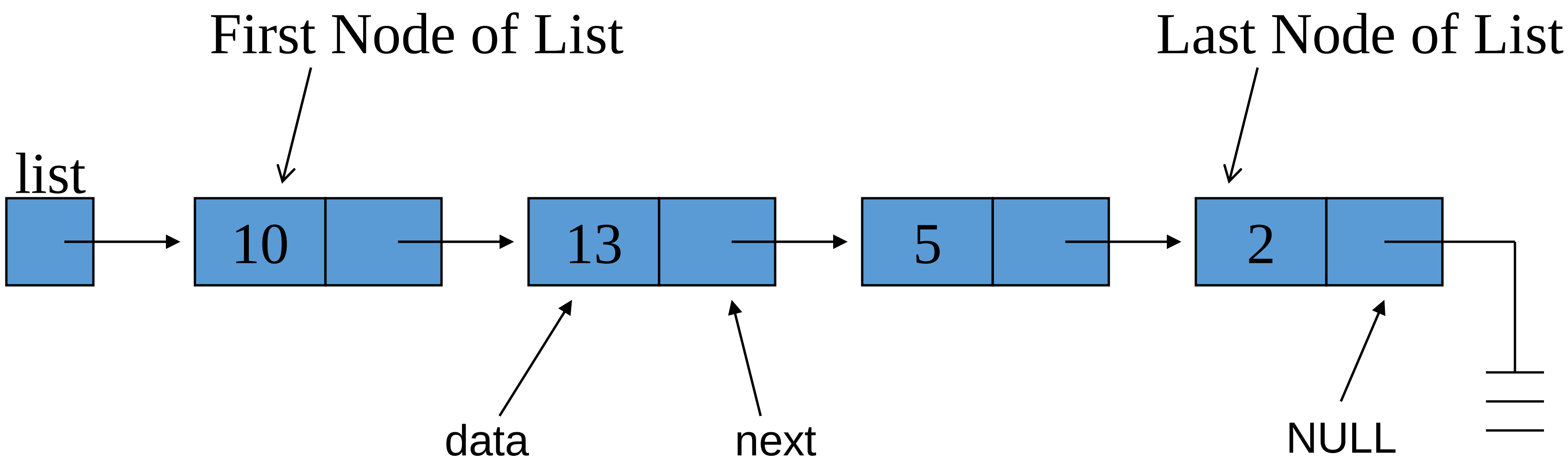
A Linked List



Basic Operations of Linked List

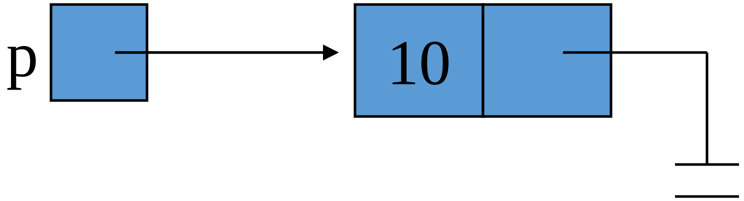
- Operations of `Linked List`
  - `IsEmpty`: determine whether or not the list is empty
  - `InsertNode`: insert a new node at a particular position
  - `FindNode`: find a node with a given value
  - `DeleteNode`: delete a node with a given value
  - `DisplayList`: print all the nodes in the list

An integer linked list



Creating a List node

```
struct Node {
        int data;               // data in node
        Node *next;             // Pointer to next node
};

Node *p;
p = new Node;
p - > data = 10;
p - > next = NULL;
```



The NULL pointer

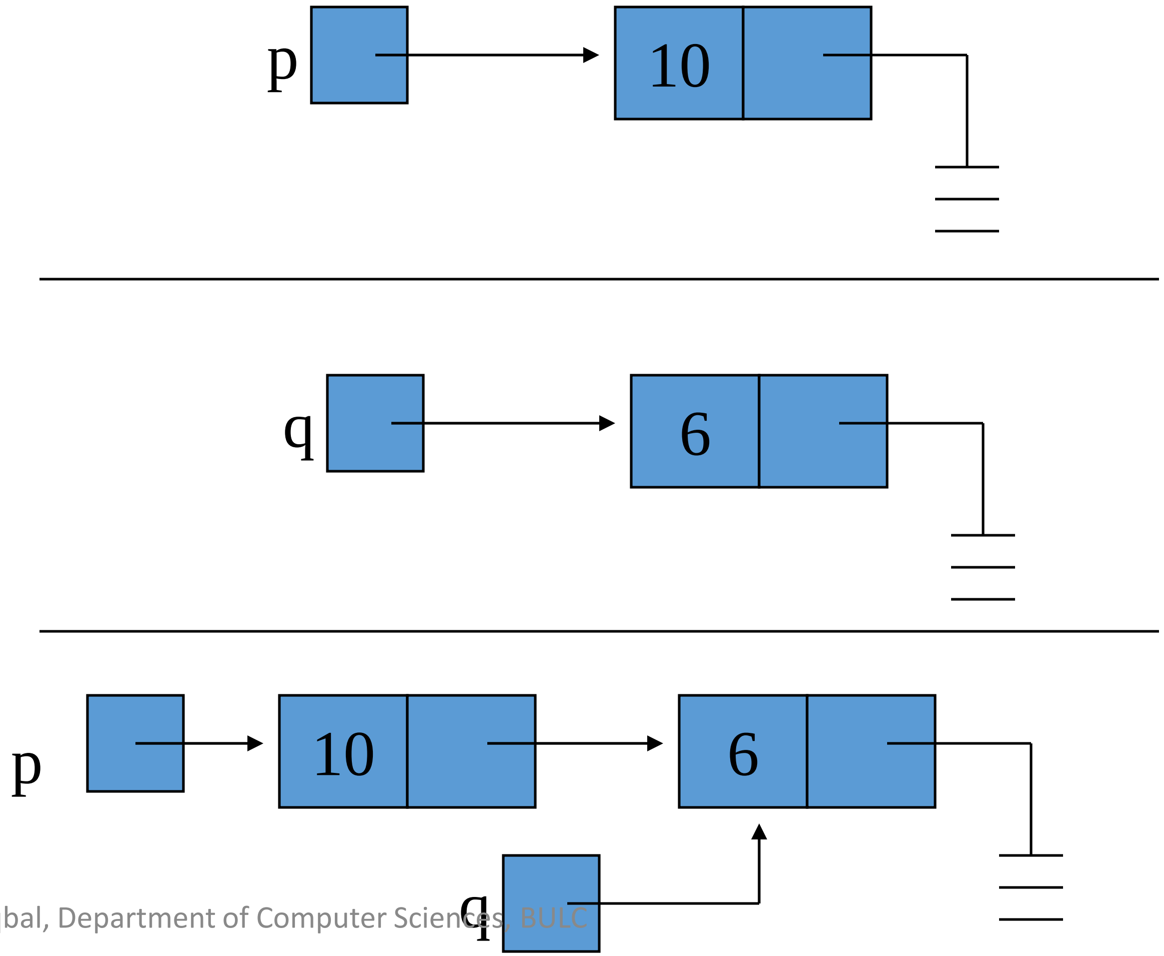
NULL is a special pointer value that does not reference any memory cell.

If a pointer is not currently in use, it should be set to NULL so that one can determine that it is not pointing to a valid address:

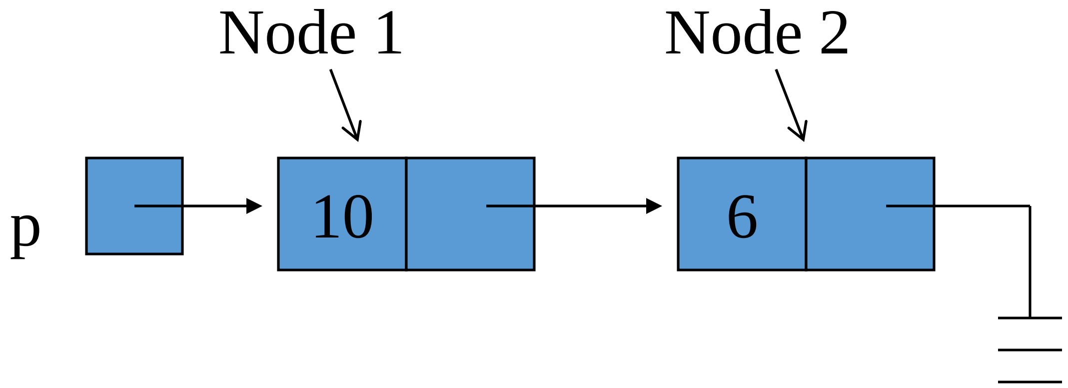
```
int *p;
p = NULL;
```

Adding a node to a list

```
Node *p, *q;

p = new Node;
p - > data = 10;
p - > next = NULL;

q = new Node;
q - > data = 6;
q - > next = NULL;

p - > next = q;
```



Accessing List Data



Expression	Value
p	Pointer to first node (head)
p - > data	10
p - > next	Pointer to next node
p - > next - > data	6
p - > next - > next	NULL pointer

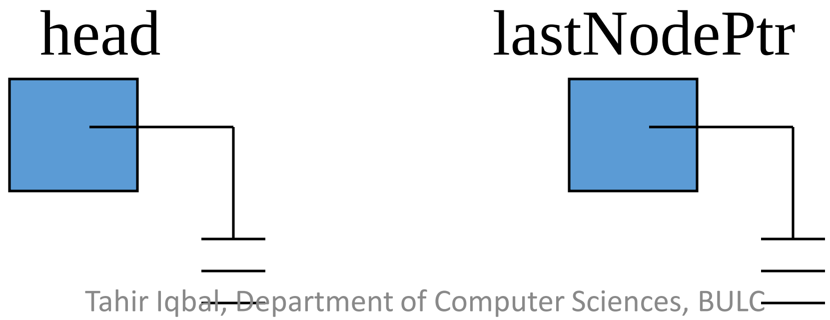
Linked List

```
struct List{
        int item;
        List * next;
};

List * head = NULL;

void insert(int x){
   List * temp = new List;
   temp->item = x;
   if (head== NULL){
      temp->next = NULL;
      head = temp;
   }
   else{
      temp->next=head;
      head = temp;
   }
}
```

```
void delete(){
   Node * temp = head;
   if (head == NULL){
      return;
   }
   else{
      head = head->next;
      delete temp;
   }
}

void main(){
      insert(10);
      insert (20);
      insert (40);
      delete();
}
```

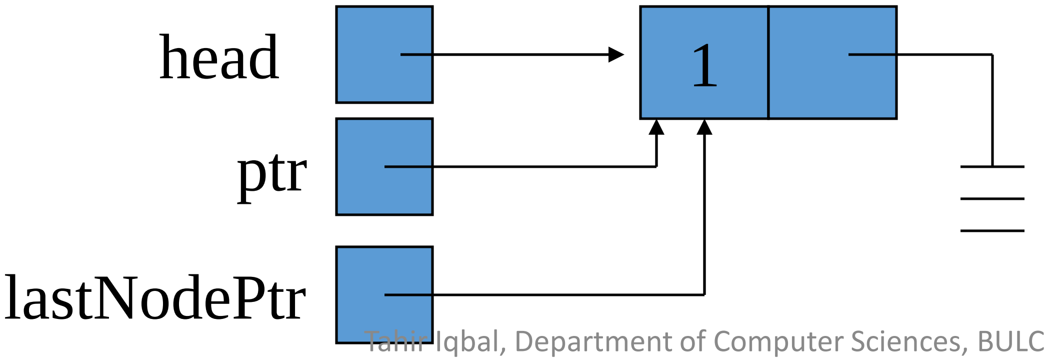
Building a list from 1 to n

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

Node *head = NULL;                    // pointer to the list head
Node *lastNodePtr = NULL;             // pointer to last node in list
```



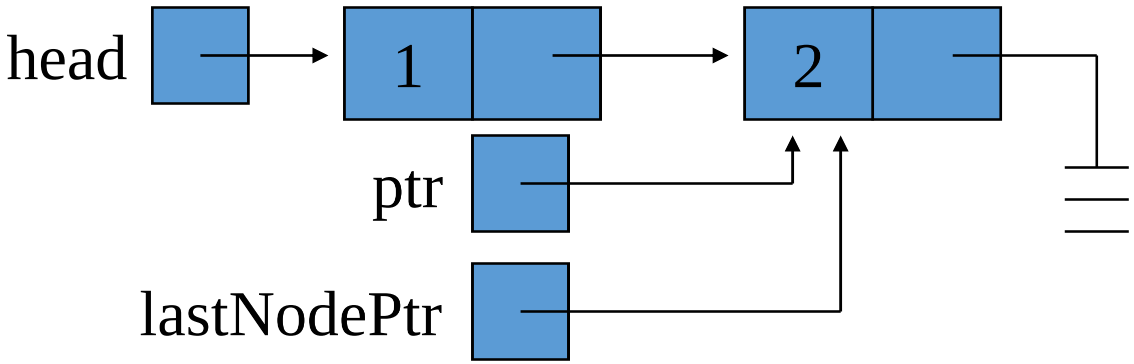
Creating the first node

```
Node *ptr;                 // declare a pointer to Node
ptr = new Node;               // create a new Node
ptr - > data = 1;
ptr - > next = NULL;

head = ptr;                // new node is first
lastNodePtr = ptr;     // and last node in list
```

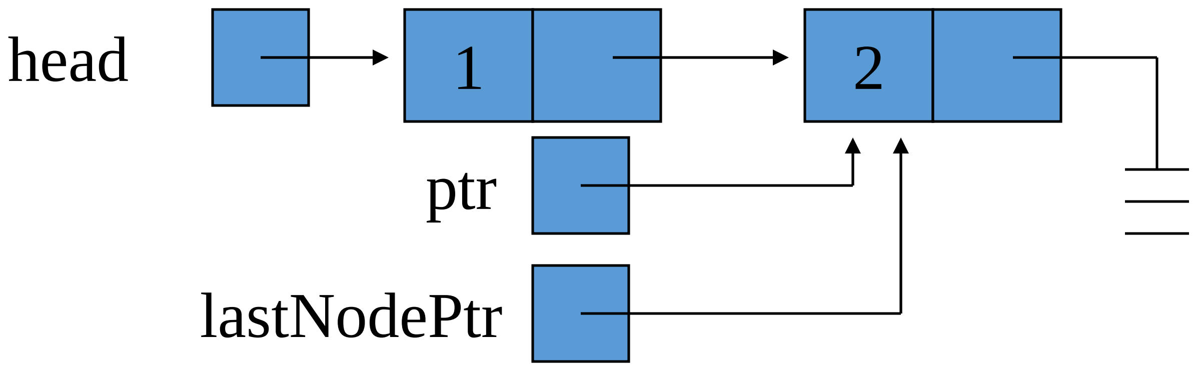


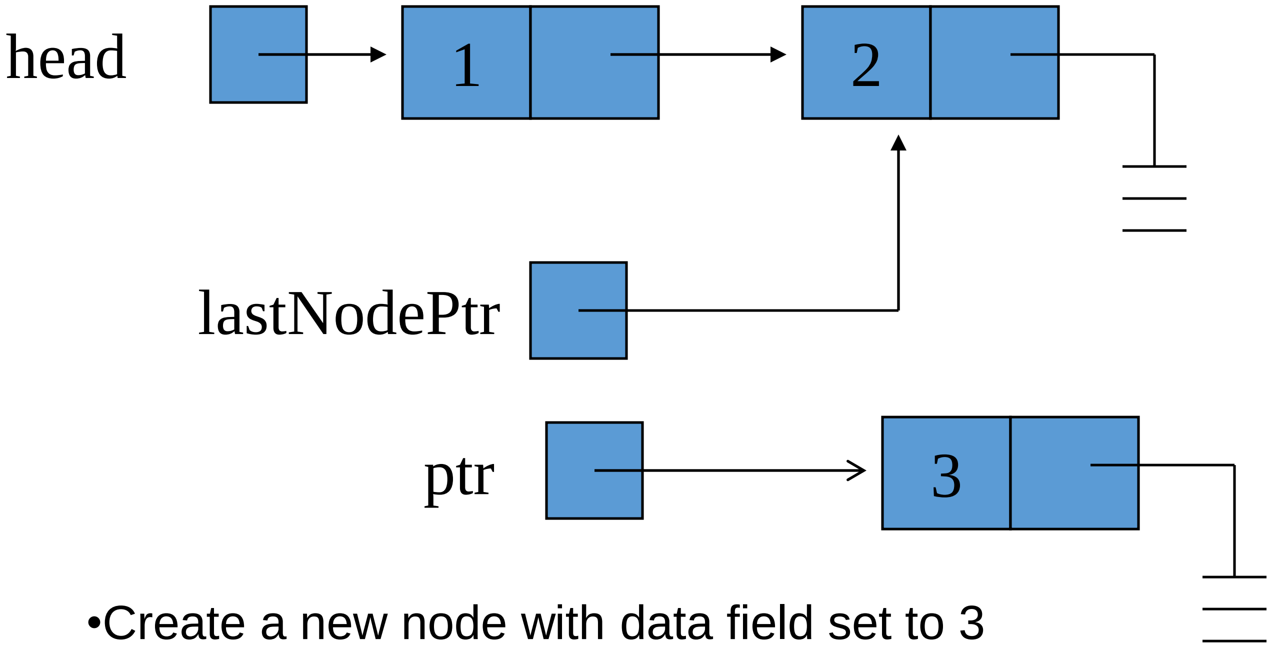
Adding more nodes

```
for (int i = 2; i < = n; i ++ ) {
        ptr = new Node;                    //create new node
        ptr - > data = i;
        ptr - > next = NULL;
        lastNodePtr - > next = ptr;  // order is
        lastNodePtr = ptr;               // important
}
```

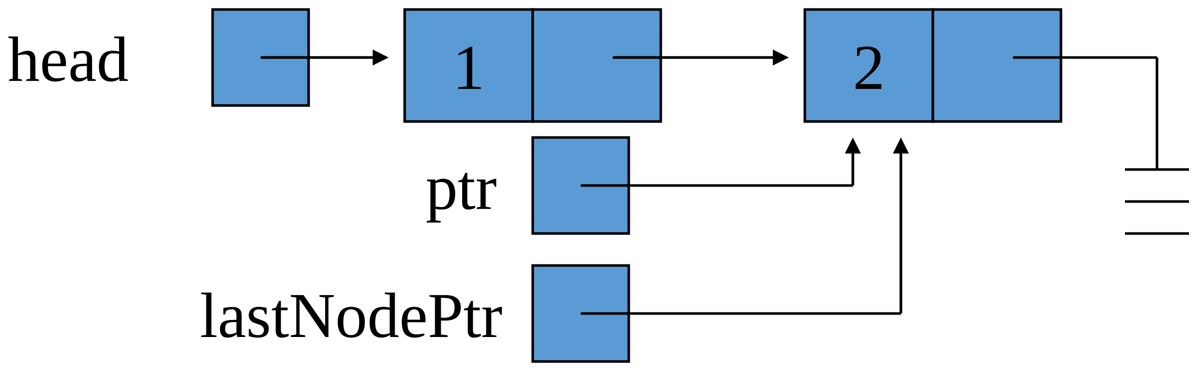


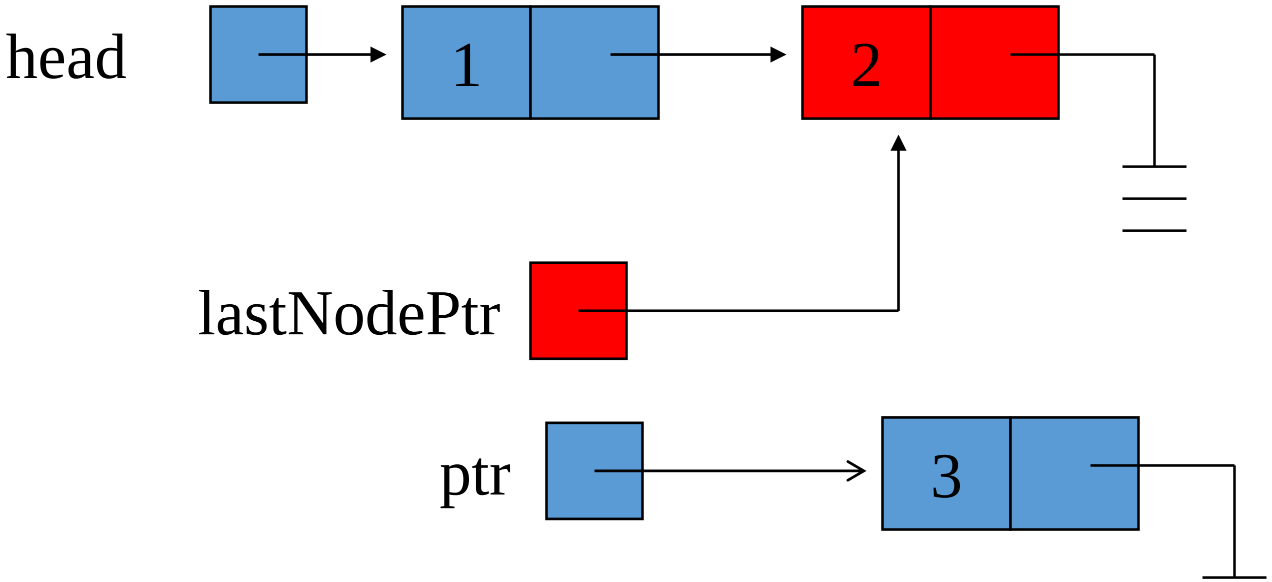
Initially



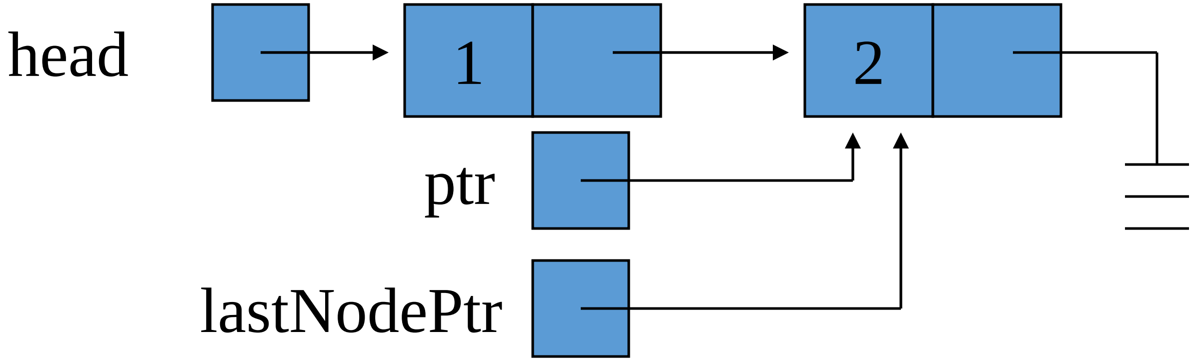


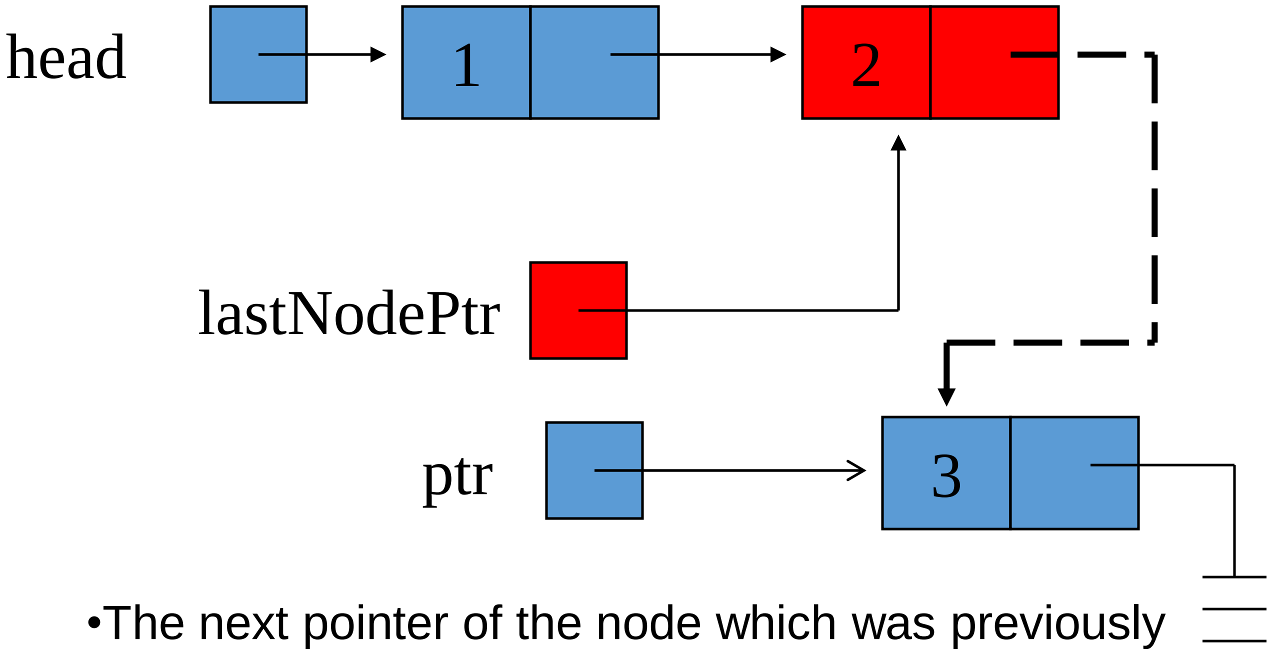
- Create a new node with data field set to 3
- Its next pointer should point to NULL



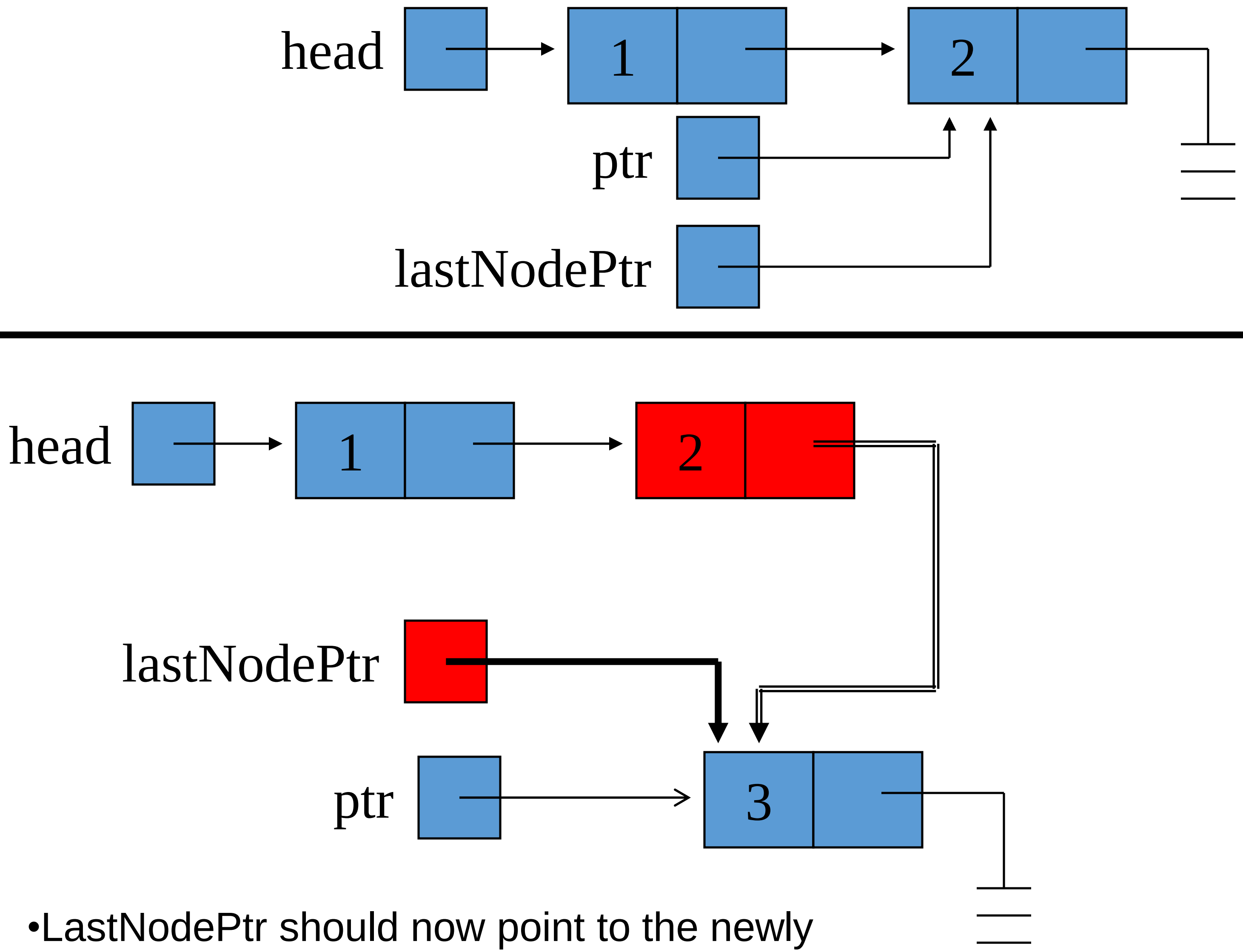


- The next pointer of the node which was previously last should now point to newly created node "lastNodePtr->next=ptr"



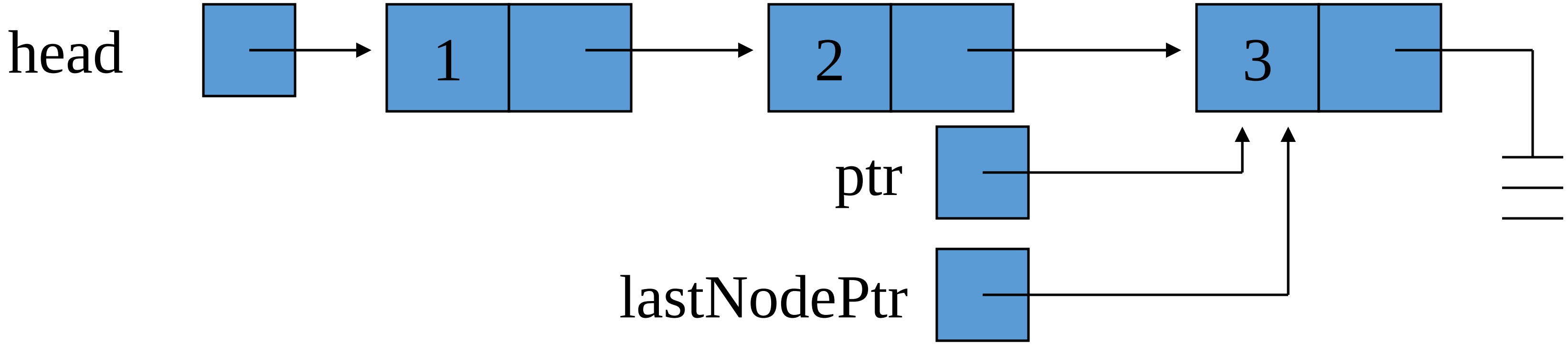


- The next pointer of the node which was previously last should now point to newly created node "lastNodePtr->next=ptr"
- LastNodePtr should now point to the newly created Node "lastNodePtr = ptr;"



- LastNodePtr should now point to the newly created Node “lastNodePtr = ptr;”

Re-arranging the view



The items in this list are arranged in the form of Queue.

Deleting a Node from end of list

```
if(head != NULL)
  head = head - > next;
```

Queue

```
struct Queue{
  int data;
  Queue * next;
}
Queue * front=NULL;
Queue * rear=NULL;
void main(){
  // switch statement
  Enqueue(10);
  Enqueue(23);
  Enqueue(33);
  Dequeue();
}
```

```
void Enqueue(int x){
  Queue * newNode = new Queue;
  newNode->data = x;
  newNode->next = NULL;
  if(rear == NULL){
     front = rear = newNode;

  }
  else{
     rear->next = newNode;
     rear = newNode;
  }
}
```

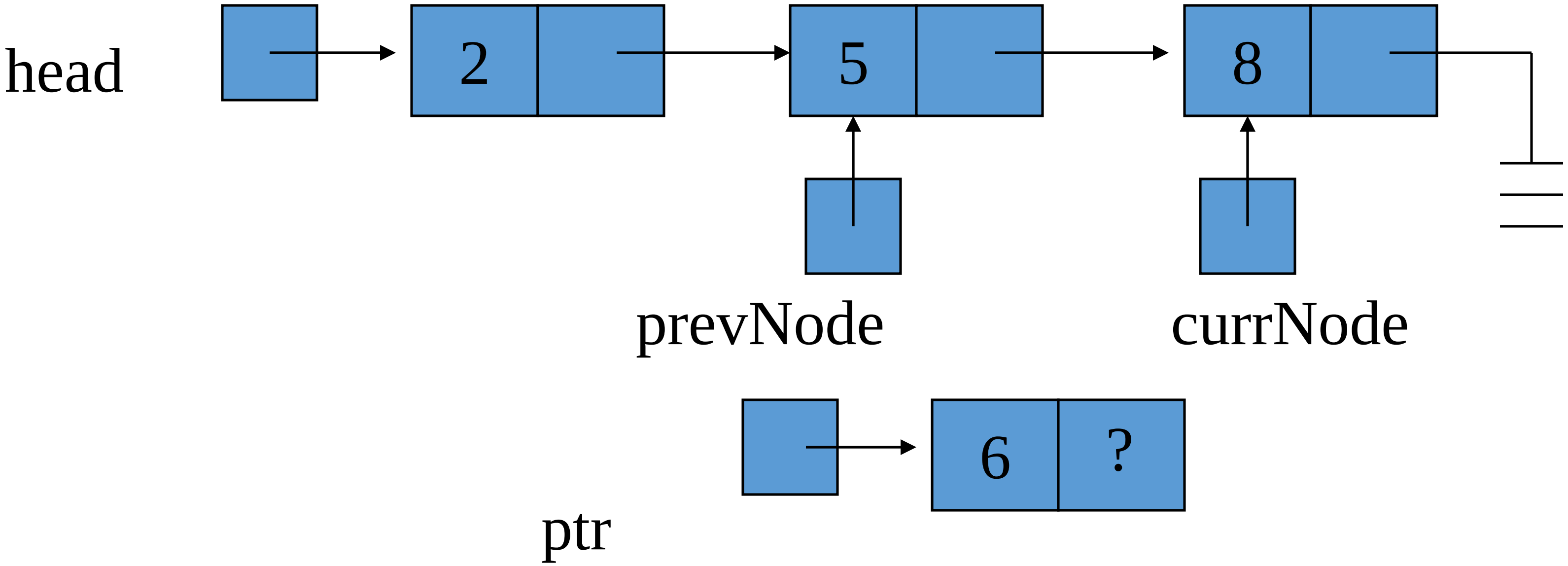
Queue

```
void Dequeue(){
  Queue * temp = first;
  if(front == NULL){
    cout<<"Queue Empty";
  }
  elseif(front == rear){
    cout<<"Item deleted";
    front = rear = NULL;
    delete temp;
  }
  else{
    cout<<"Item deleted";
    front = front->next;
    delete temp;
}
```

Traversing through the list

```
Node * currNode;
currNode = head;
while (currNode != NULL)
{
  cout<< currNode->data;
  currNode = currNode->next;
}
```

Inserting a node in a list



Determine where you want to insert a node. Suppose we want to insert in ascending order.

Create a new node:

```
Node *ptr;
ptr = new Node;
ptr - > data = 6;
```

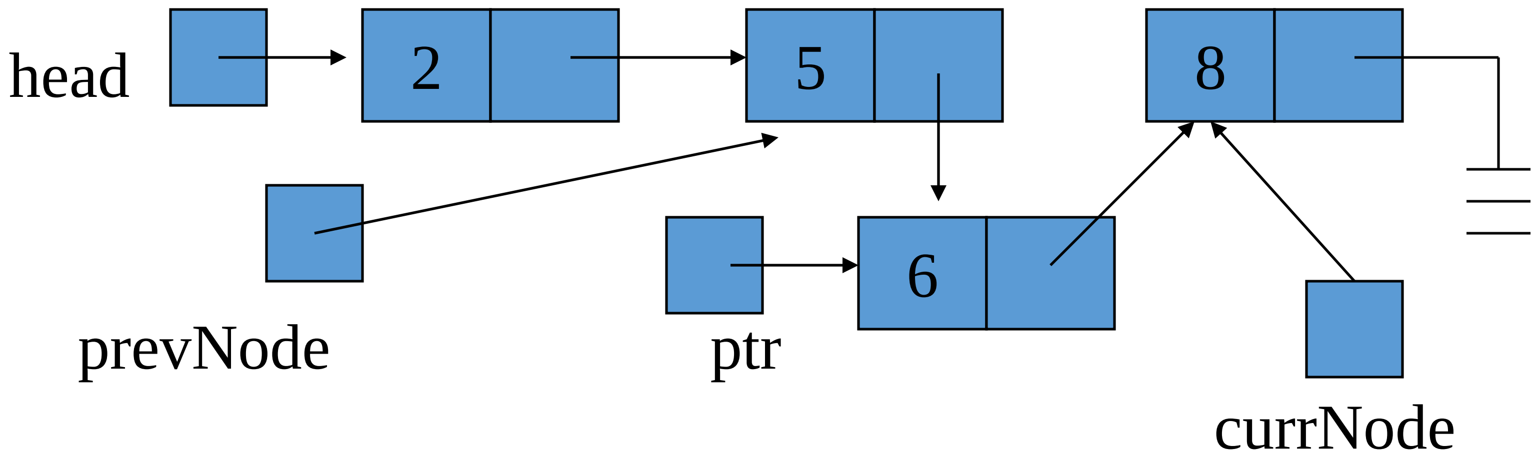
```
Node *ptr, *currNode, *prevNode ;
prevNode = head;
ptr = new Node;
ptr->data = 6;
ptr->next = NULL;
currNode = head->next;
while (currNode->data   <    ptr->data)
{
            prevNode = currNode;
            currNode = currNode->next;
}
```

Note:

when this loop terminates **prevNode** and **currNode** are at a place where insertion will take place. Only the “LINKS” or pointers of the list need to be adjusted in case of insert.

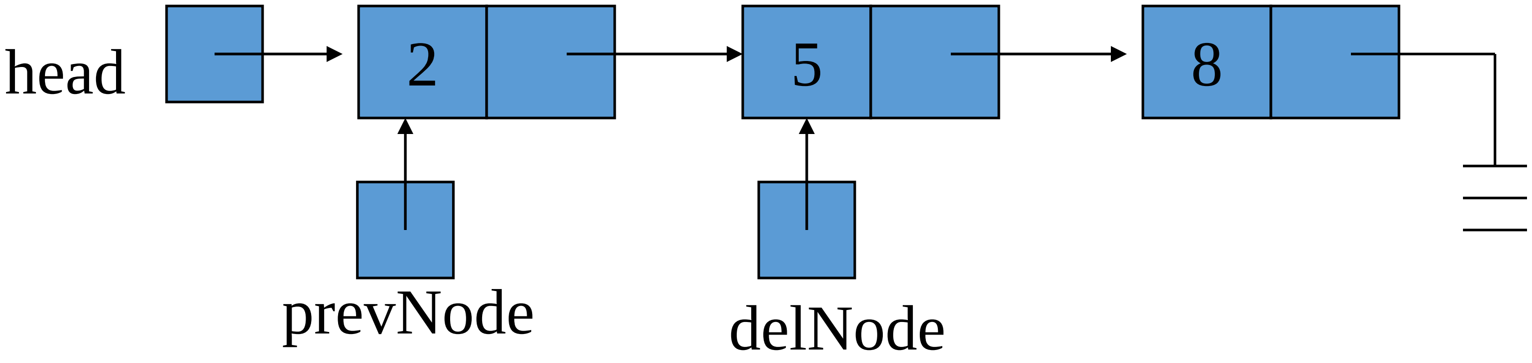
List after node insert

Now The new link has been added in the linked list



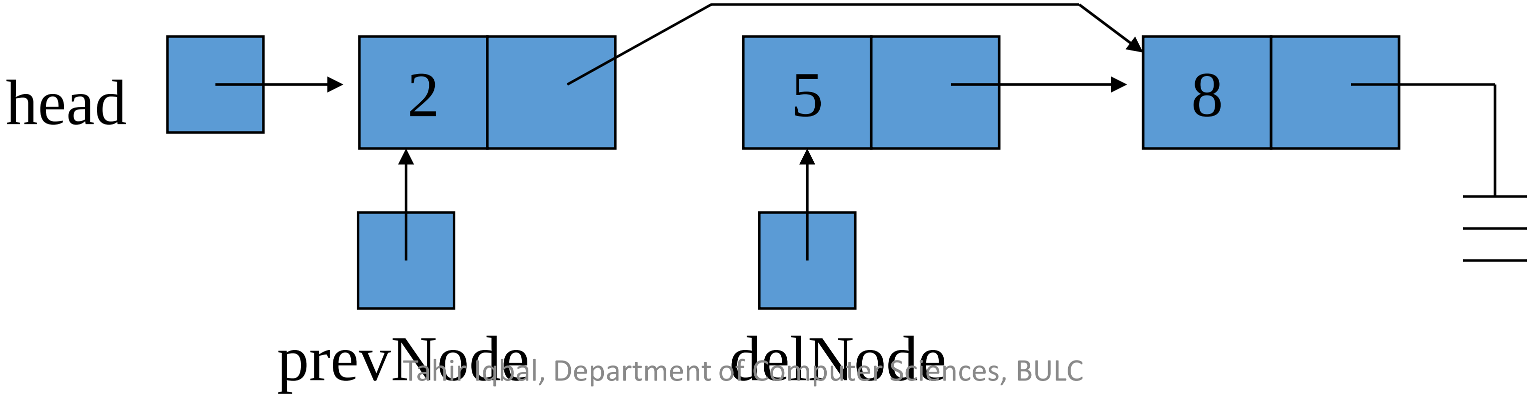
In this implementation we have used two temporary pointers during insert procedure. Can we insert a node using only one pointer!

Deleting a node from a list



Step 1: Use a pointer that traverse through the list and finds the previous node of the desired node to be deleted.

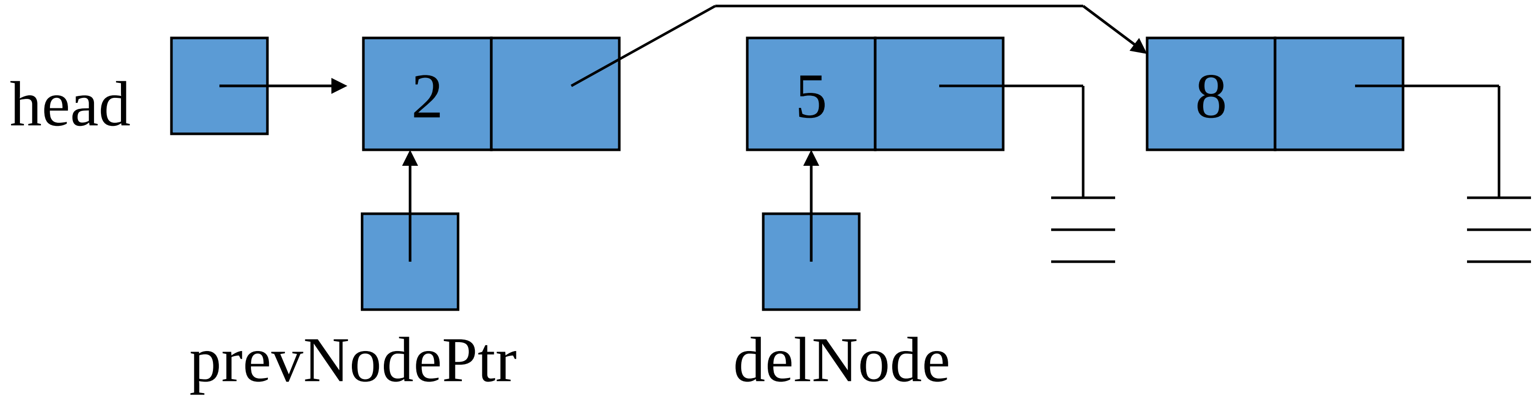
prevNode - > next = delNode - > next;



Finishing the deletion

Step 2: Remove the pointer from the deleted link.

delNode - > next = NULL;

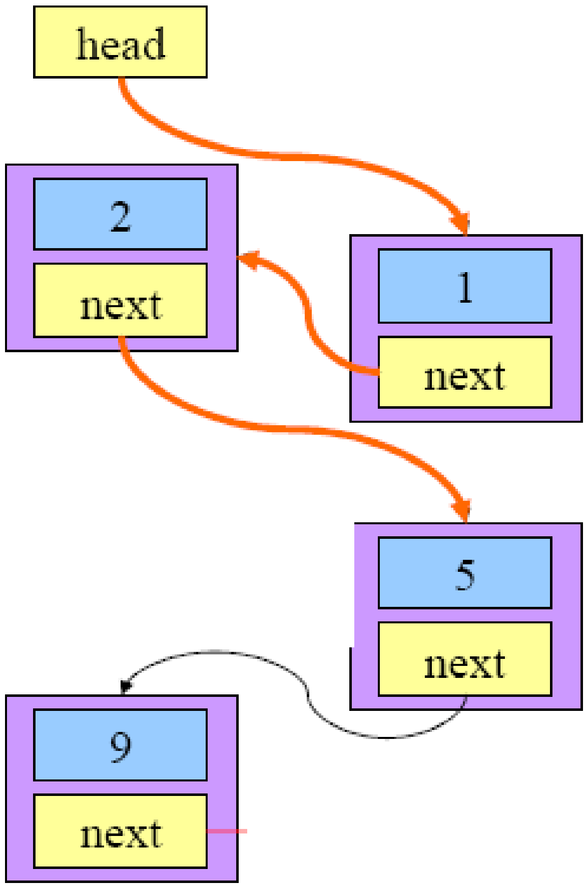


Step 3: Free up the memory used for the deleted node:

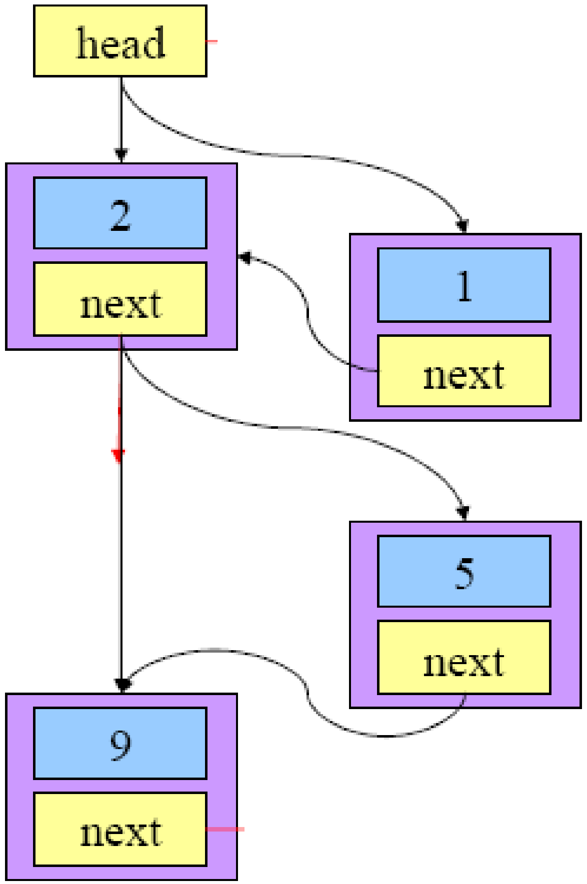
delete delNode;

List Operations - Summarized

Traversing a Linked List



Insertion in a Linked List



Deletion from a Linked List