C++ Object-Oriented Prog.
Unit 4: Objects and Lists

CHAPTER 16: LINKED STRUCTURES

DR. ERIC CHOU

IEEE SENIOR MEMBER

LECTURE 1

Overview

Chapter 16 Topics

- Meaning of a Linked List
- Meaning of a Dynamic Linked List
- Traversal, Insertion and Deletion of Elements in a Dynamic Linked List
- Specification of a Dynamic Linked Sorted List
- Insertion and Deletion of Elements in a Dynamic Linked Sorted List

What is a List?

- A list is a varying-length, linear collection of homogeneous elements
- Linear means that each list element (except the first) has a unique predecessor and each element (except the last) has a unique successor

To implement the List ADT

The programmer must

1) choose a concrete data representation for the list, and
2) implement the list operations

Recall:
4 Basic Kinds of ADT Operations

Constructors -- create a new instance (object) of an ADT
Transformers -- change the state of one or more of the data values **of an instance**

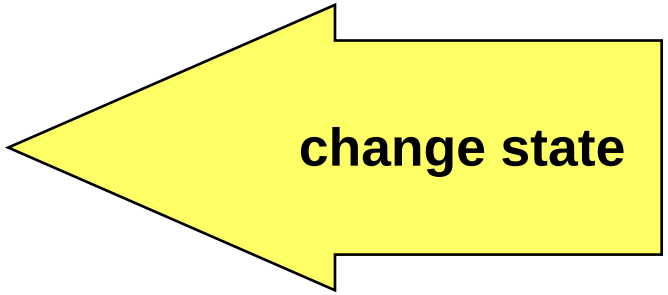
Observers -- allow client to observe the state of one or more of the data values of an instance without changing them

Iterators -- allow client to access the data values in sequence

List Operations

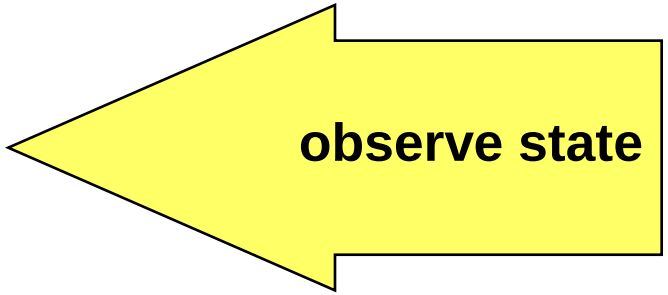
Transformers

- Insert
- Delete
- Sort



Observers

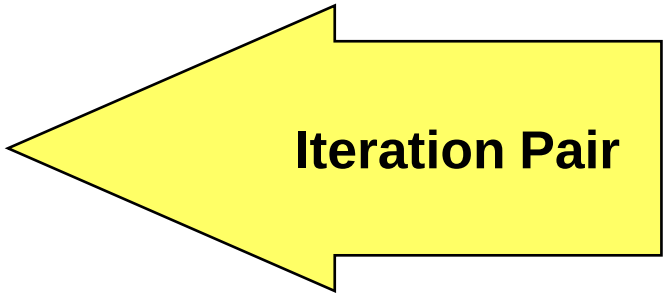
- IsEmpty
- IsFull
- Length
- IsPresent



ADT List Operations

Iterator

- Reset
- GetNextItem

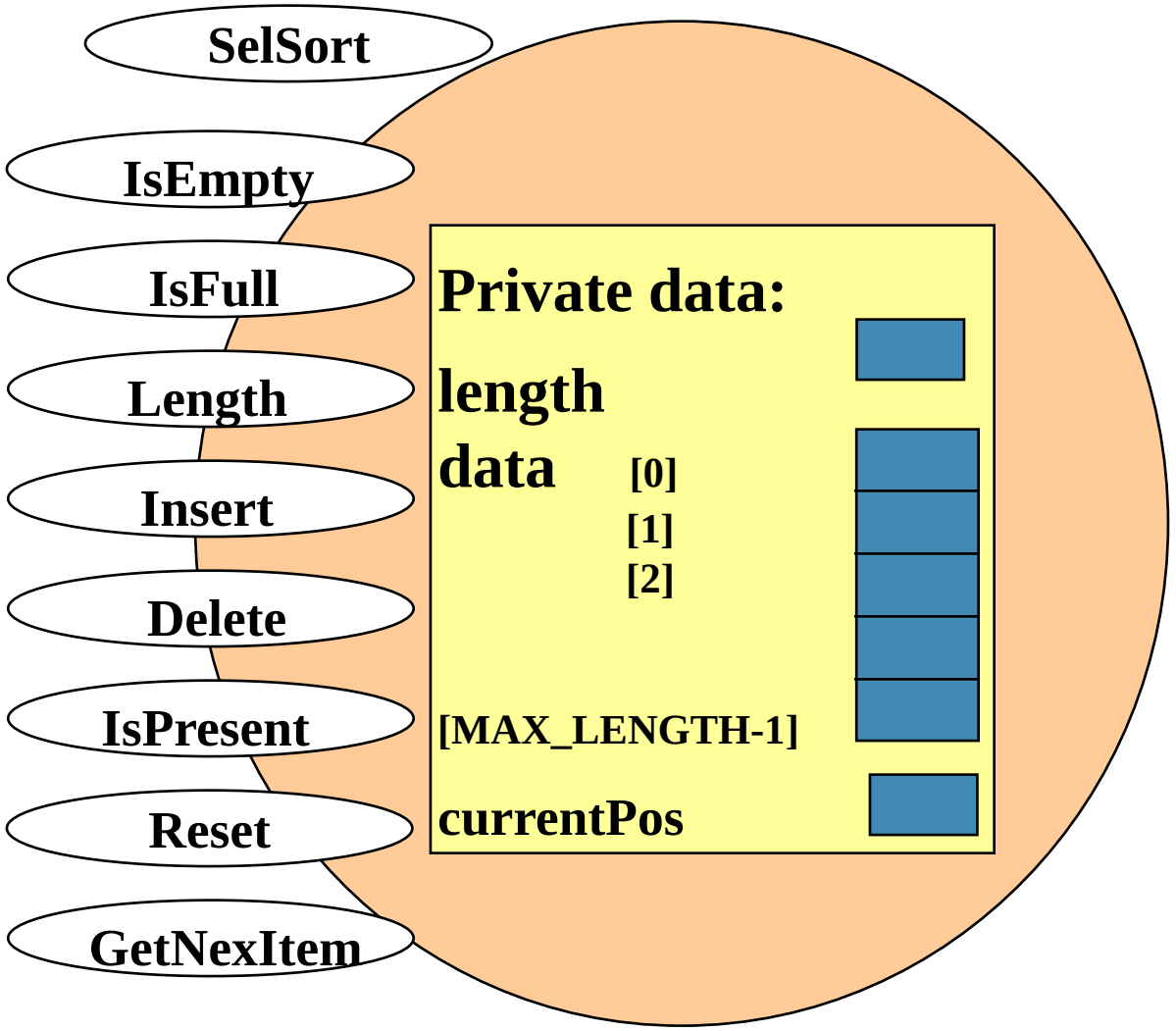


Reset prepares for the iteration

GetNextItem returns the next item in sequence

No transformer can be called between calls to GetNextItem *(Why?)*

Array-based `class List`



```
// Specification file array-based list ("list.h")
const  int  MAX_LENGTH  =  50;
typedef int   ItemType;

class  List              // Declares a class data type
{
public:                  // Public member functions
    List();             // constructor
    bool IsEmpty () const;
    bool IsFull ()  const;
    int  Length ()  const; // Returns length of list
    void Insert (ItemType  item);
    void Delete (ItemType  item);
    bool IsPresent(ItemType  item)  const;
    void SelSort ();
    void Reset ();
    ItemType GetNextItem ();

private:               // Private data members
 int length;   // Number of values currently stored
 ItemType data[MAX_LENGTH];
     int  CurrentPos;  // Used in iteration
};
```

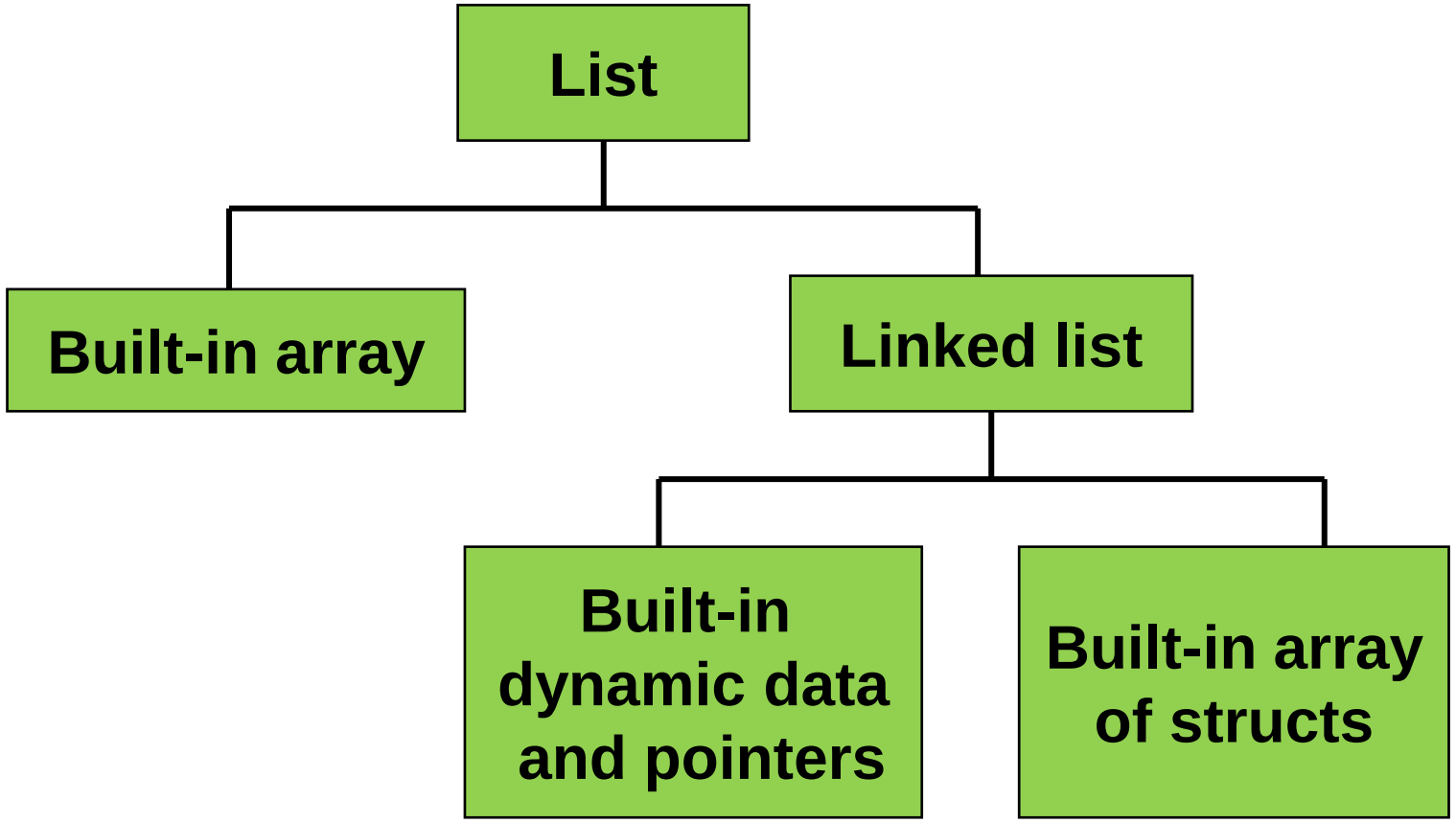
LECTURE 2

Implementations of List

Implementation Structures

- Use a built-in array stored in contiguous memory locations, implementing operations Insert and Delete by moving list items around in the array, as needed
- Use a linked list in which items are not necessarily stored in contiguous memory locations
- A linked list avoids excessive data movement from insertions and deletions

Implementation Possibilities for a List ADT



LECTURE 3

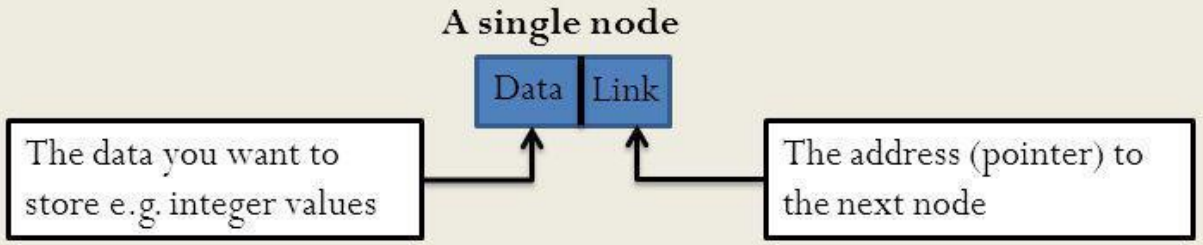
Nodes

Node Types

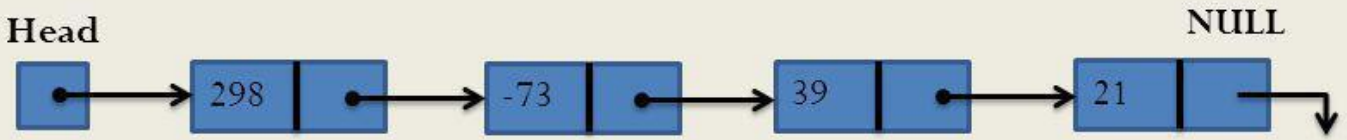
- Link Node (Next Node)
- Double Link Node (Next-Prev Node)
- Tree Node (Left-Right Node)
- Matrix Node (Quadruple Node – up/down, left/right node)
- Link Node to Linked List (Adjacent List or Hash Table Entry)

(List Node the List can be one of the four node types above)

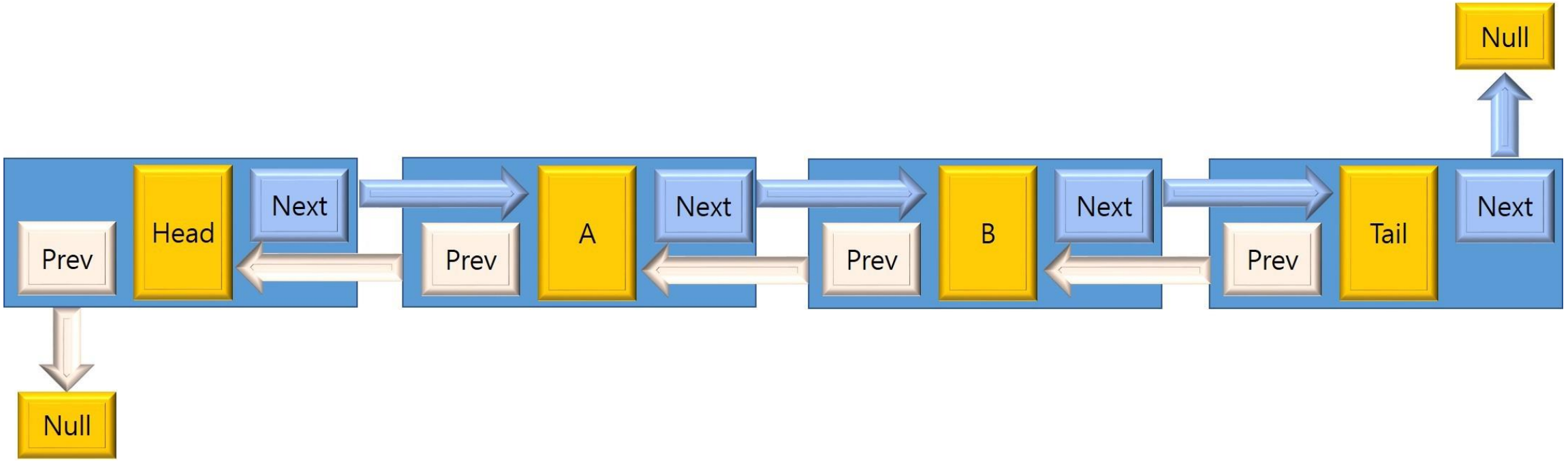
Linked List in Pictures

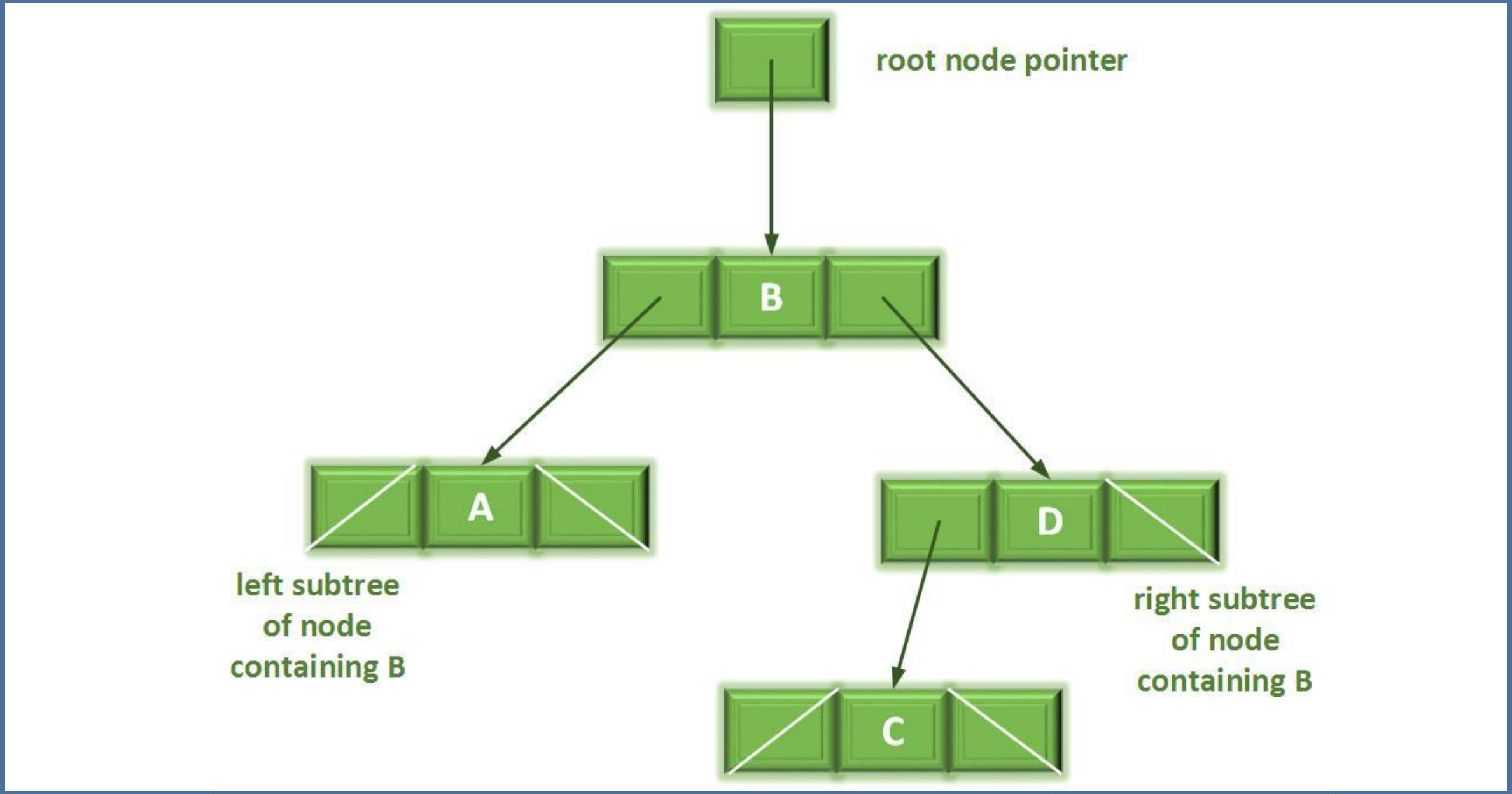


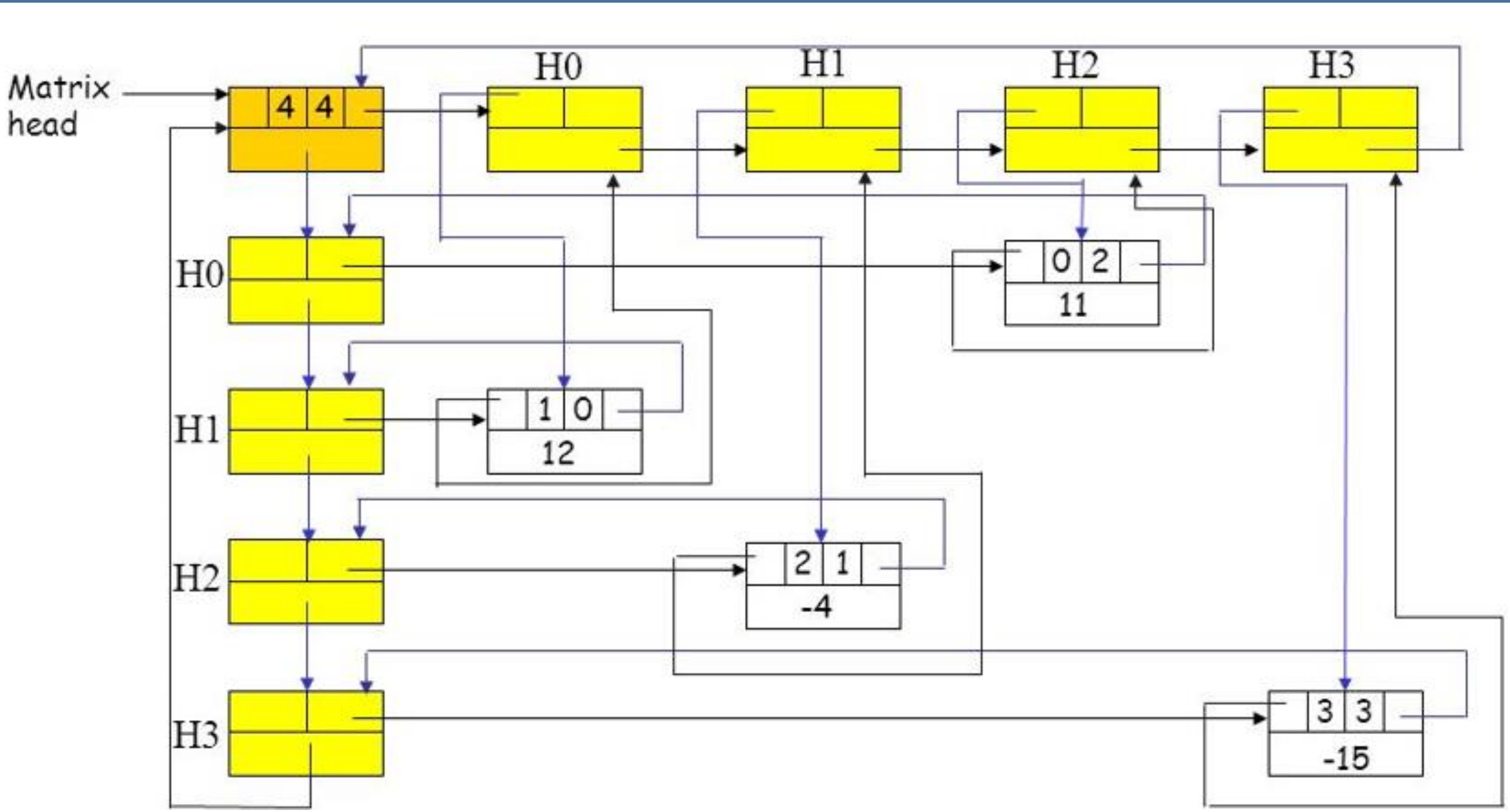
Example

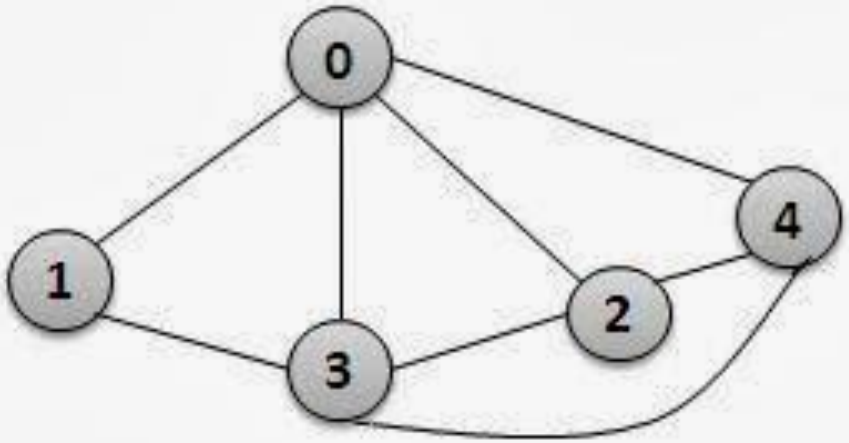


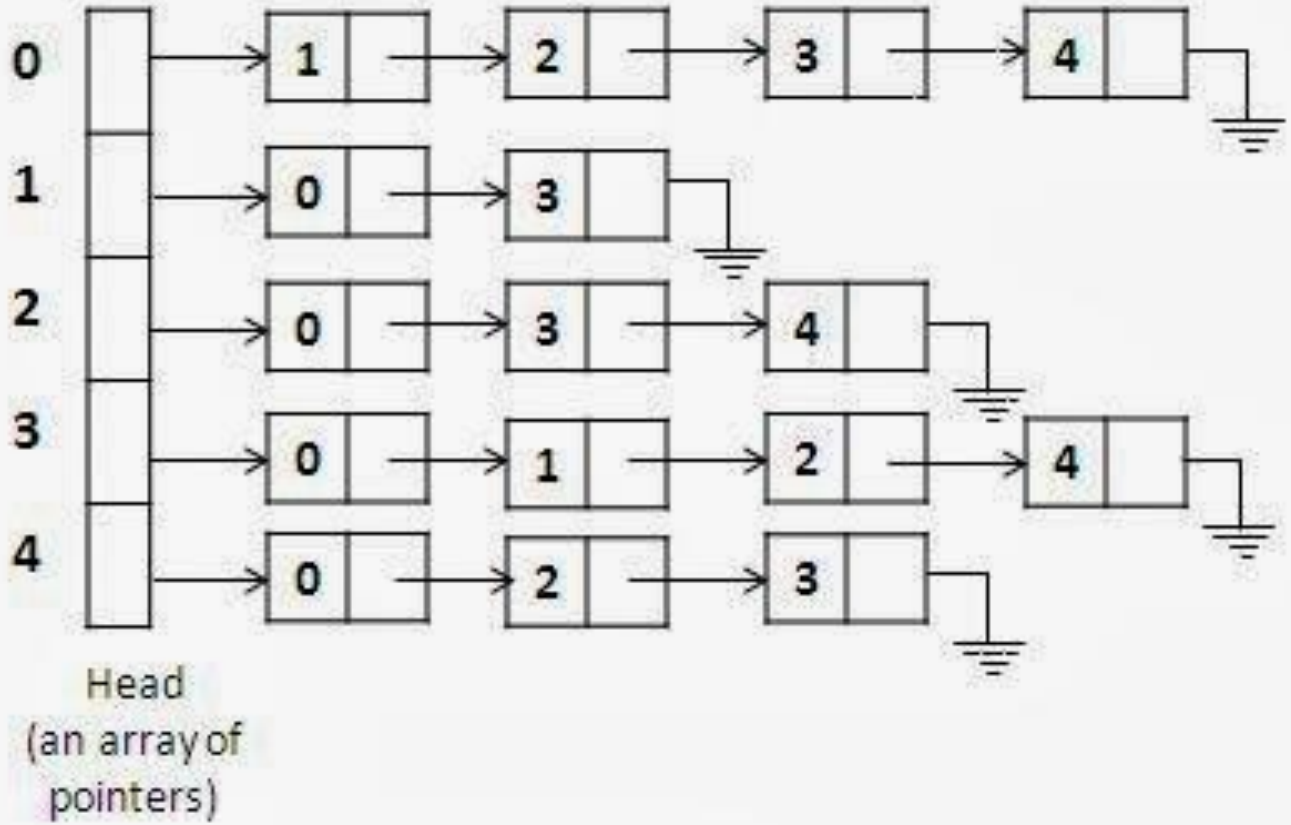
Linked List: A list of items, called nodes, in which the order of the nodes is determined by the address, called the link, stored in each node.


Null
Prev
Head
Next
Prev
A
Next
Prev
B
Next
Prev
Tail
Next
Null

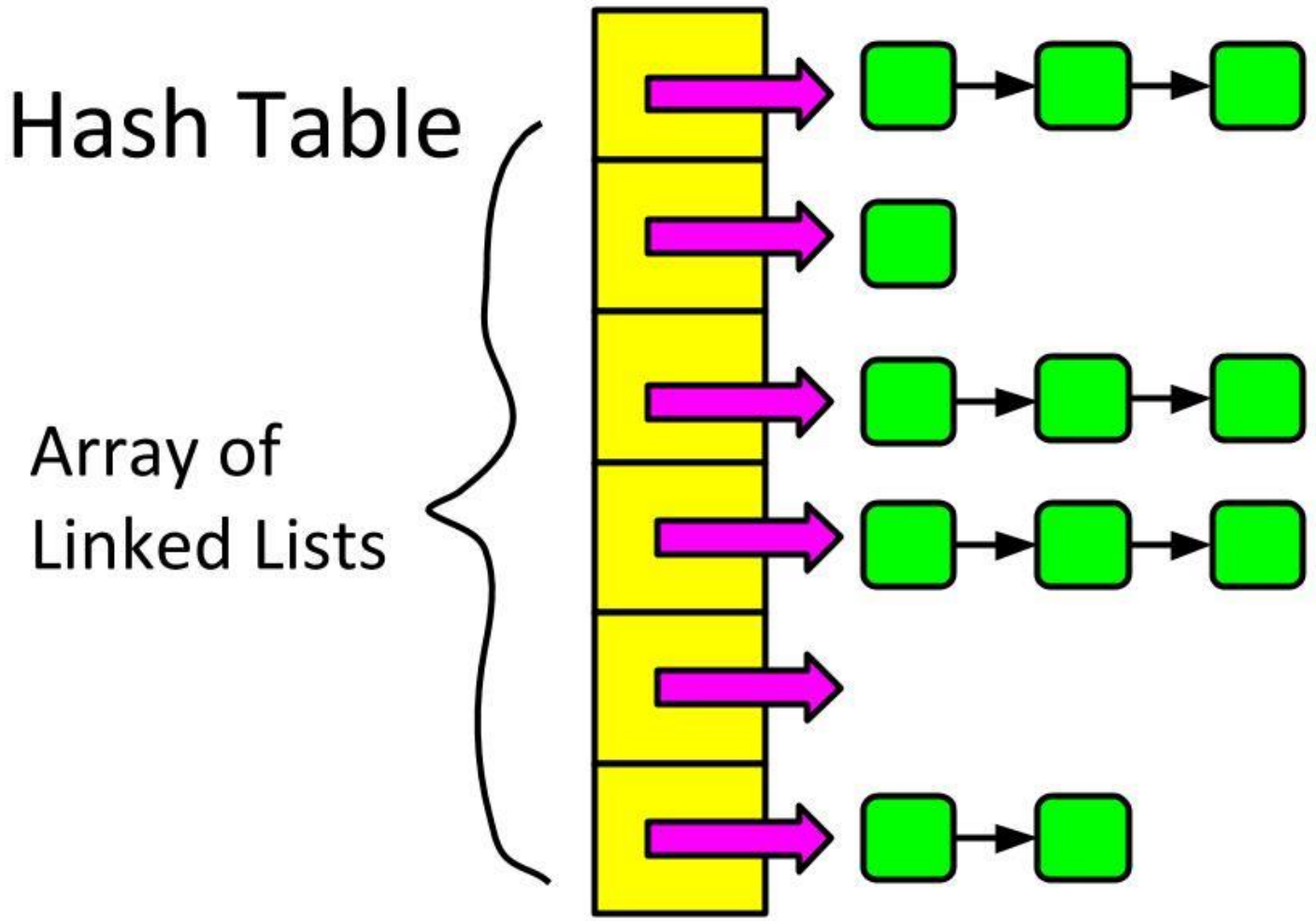

root node pointer
B
A
D
C
left subtree
of node
containing B
right subtree
of node
containing B

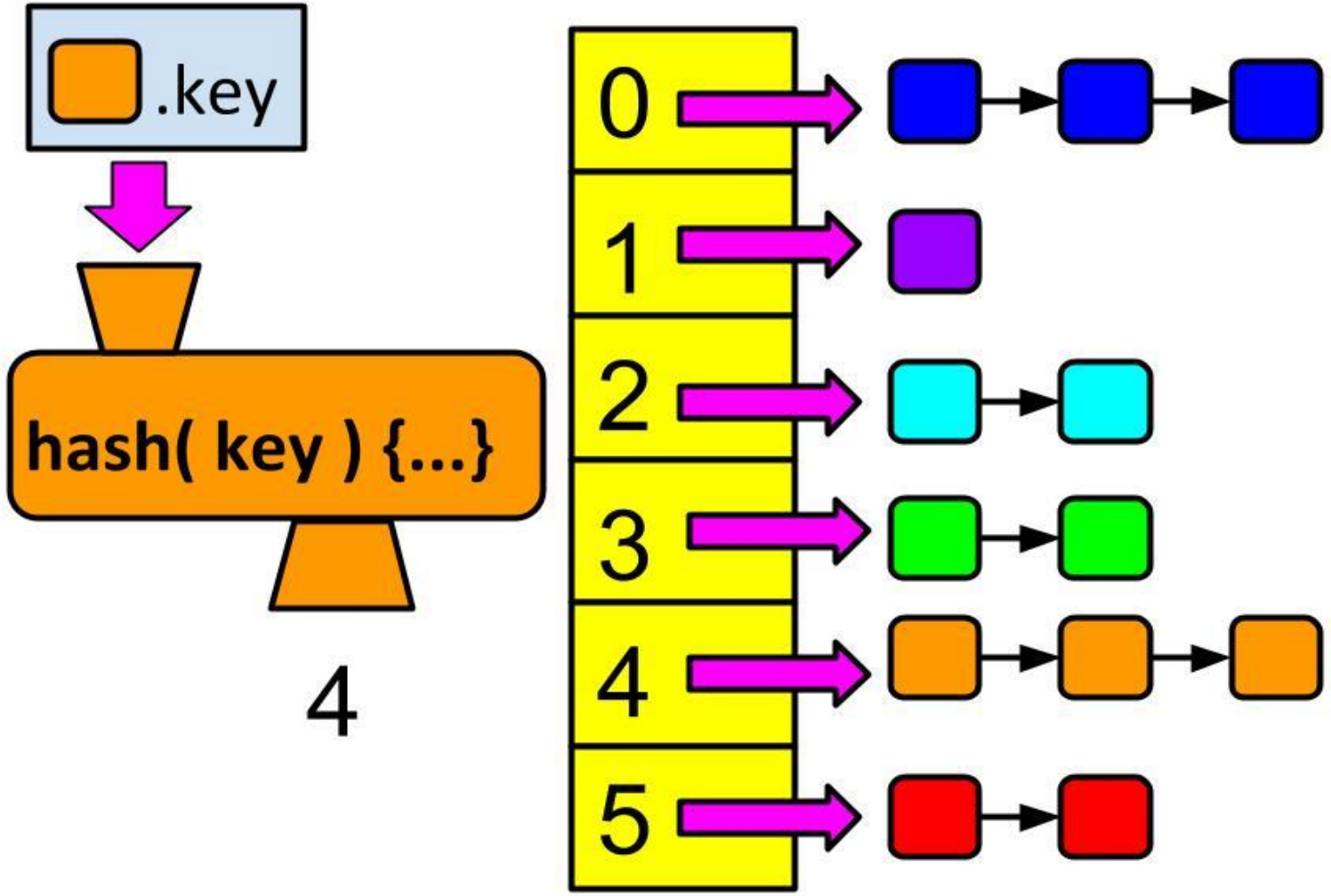

Matrix
head
4 4
H0
H1
H2
H3
H0
0 2
11
H1
1 0
12
H2
2 1
-4
H3
3 3
-15





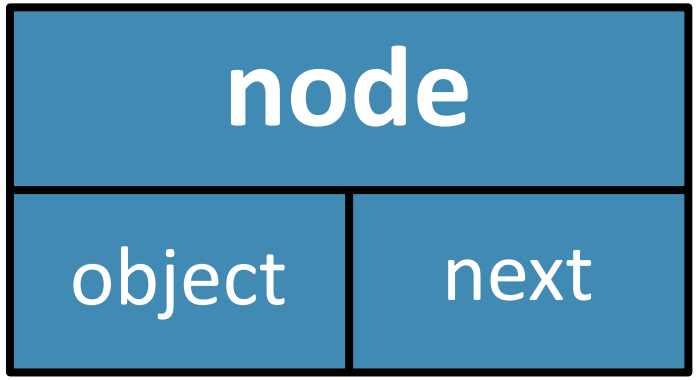
Adjacency List Representation of Graph


Hash Table
Array of
Linked Lists


.key
hash(key) {...}
4
0
1
2
3
4
5

LECTURE 2

Single Linked Node



public data:

```
node<T>*  next;
```

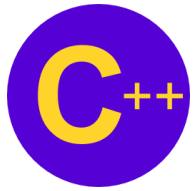
private data:

```
T         object;
```

public method:

```
          node();
          node(T t);
T         get();
void      setNext(node<T> *n);
node<T>*  getNext();
bool      hasNext();
string    to_string();
```

```
#define MAIN
#ifndef NODE_H
#define NODE_H
#include "to_string.h"
using namespace std;
template <typename T>
class node{
   public:
      node<T> *next;
      node(): object(NULL), next(NULL){}
      node(T t){ next = NULL;  object = t; }
      void setNext(node<T> *n){ next = n; }
      node<T> *getNext(){ return next; }
      bool hasNext(){
         if (getNext()!= NULL) return true;
         else return false;
      }
      string to_string(){ return st::to_string(object); }
      T get(){ return object; }
   private:
      T object;
};
#endif
```

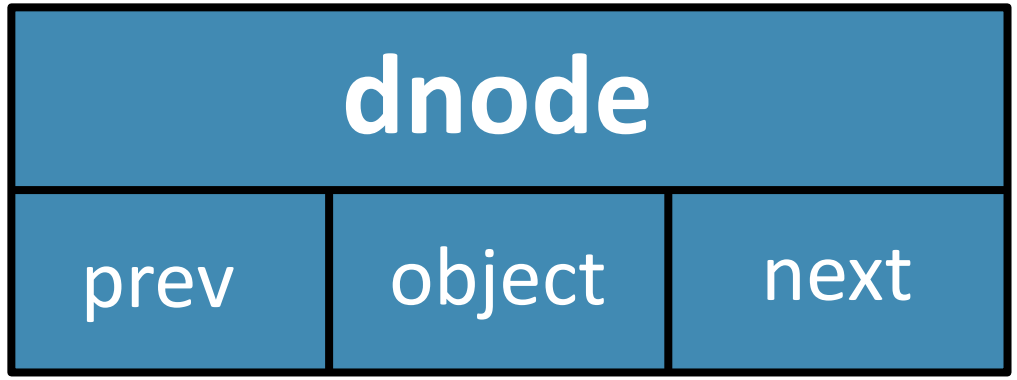


Demo Program: node.cpp

Go Notepad++!!!

LECTURE 2

Double Linked Node



public data:

```
node<T>*    next;
node<T>*    prev;
```

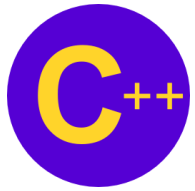
private data:

```
T           object;
```

public method:

```
            node();
            node(T t);
T           get();
void        setNext(node<T> *n);
node<T>*    getNext();
bool        hasNext();
void        setPrev(node<T> *n);
node<T>*    getPrev();
bool        hasPrev();
string      to_string();
```

```
#define MAIN
#ifndef DNODE_H
#define DNODE_H
#include "to_string.h"
using namespace std;
template <typename T>
class dnode{
   public:
      dnode<T> *next;
      dnode<T> *prev;
      dnode(): next(NULL), prev(NULL) {}
      dnode(T t){ next=NULL; prev=NULL; object = t; }
      void setNext(dnode<T> *n){ next = n; }
      void setPrev(dnode<T> *p){ prev = p; }
      dnode<T> *getNext(){ return next; }
      dnode<T> *getPrev(){ return prev; }
      bool hasNext(){
         if (getNext()!= NULL) return true;
         else return false;
      }
      bool hasPrev(){
         if (getPrev()!=NULL) return true;
         else return false;
      }
      string to_string(){ return st::to_string(object); }
      T get(){ return object; }
   private:
      T object;
};
#endif
```

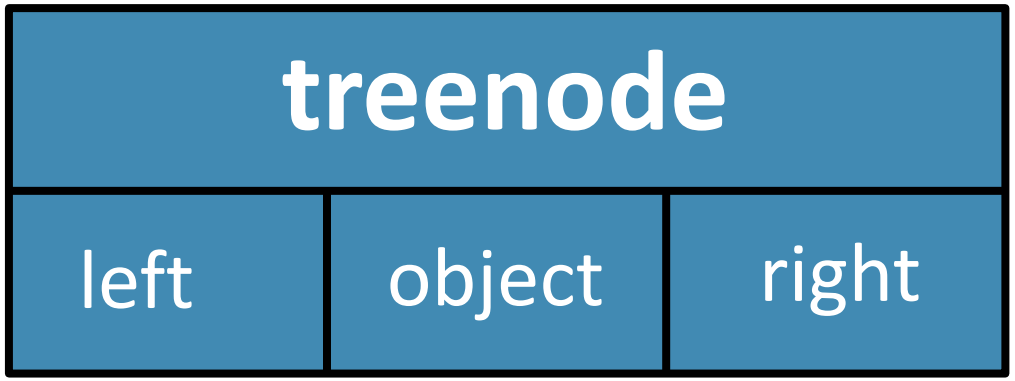


Demo Program: dnode.cpp

Go Notepad++!!!

LECTURE 2

Tree Node



public data:

node<T>*	left;
node<T>*	right;

private data:

T	object;

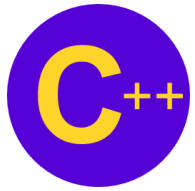
public method:

	node();
	node(T t);
T	get();
void	setLeft(node<T> *n);
node<T>*	getLeft();
bool	hasLeft();
void	setRight(node<T> *n);
node<T>*	getRight();
bool	hasRight();
string	to_string();

```
string preorder(treenode<T> *top) ;
string inorder(treenode<T> *top);
string postorder(treenode<T> *top);
```

Note:
If not the tree traversal methods,
dnode is the same as treenode.

```
#define MAIN
#ifndef TREENODE_H
#define TREENODE_H
#include "to_string.h"
using namespace std;
template <typename T>
class treenode{
  public:
    treenode<T> *left;
    treenode<T> *right;
    treenode(): left(NULL), right(NULL) {}
    treenode(T t){ left=NULL; right=NULL; object = t; }
    void setLeft(treenode<T> *le){ left = le; }
    void setRight(treenode<T> *r){ right = r; }
    treenode<T> *getLeft(){ return left; }
    treenode<T> *getRight(){ return right; }
    bool hasLeft(){
      if (getLeft()!= NULL) return true;
      else return false;
    }
    bool hasRight(){
      if (getRight()!=NULL) return true;
      else return false;
    }
    string preorder(treenode<T> *top){
      string rtn = "";
      if (top != NULL ) {
        rtn = rtn + top->to_string() + " ";
        rtn = rtn + top->preorder( top->left );
        rtn = rtn + top->preorder( top->right );
       }
      return rtn;
    }
    string inorder(treenode<T> *top){
      string rtn = "";
      if (top != NULL ) {
        rtn = rtn + top->inorder( top->left );
        rtn = rtn + top->to_string() + " ";
        rtn = rtn + top->inorder( top->right );
       }
      return rtn;
    }
    string postorder(treenode<T> *top){
      string rtn = "";
      if (top != NULL ) {
        rtn = rtn + top->postorder( top->left );
        rtn = rtn + top->postorder( top->right );
        rtn = rtn + top->to_string() + " ";
       }
      return rtn;
    }
    string to_string(){ return st::to_string(object); }
    T get(){ return object; }
  private:
    T object;
};
#endif
```



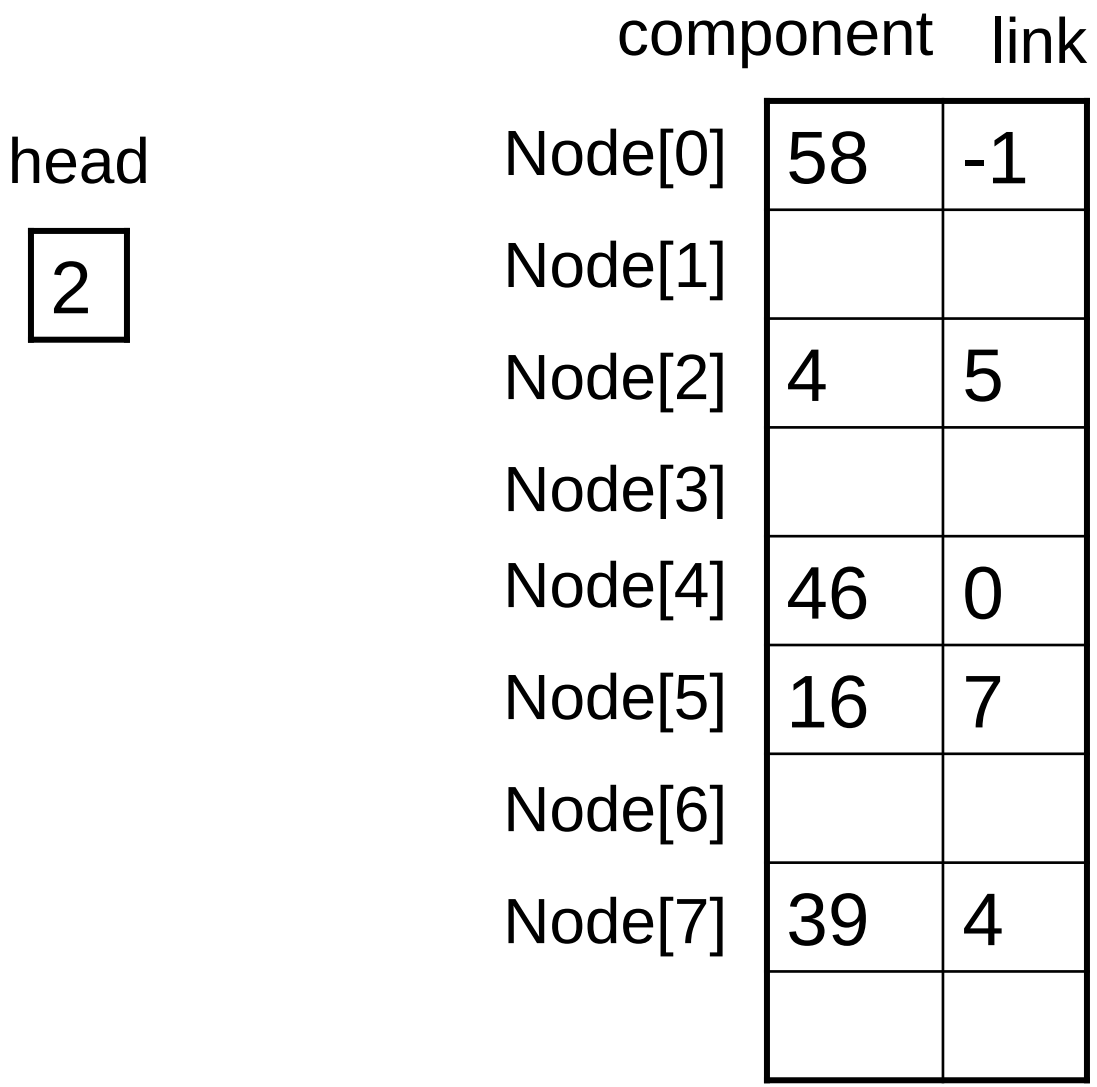
Demo Program: treenode.cpp

Go Notepad++!!!

LECTURE 3

Linked List

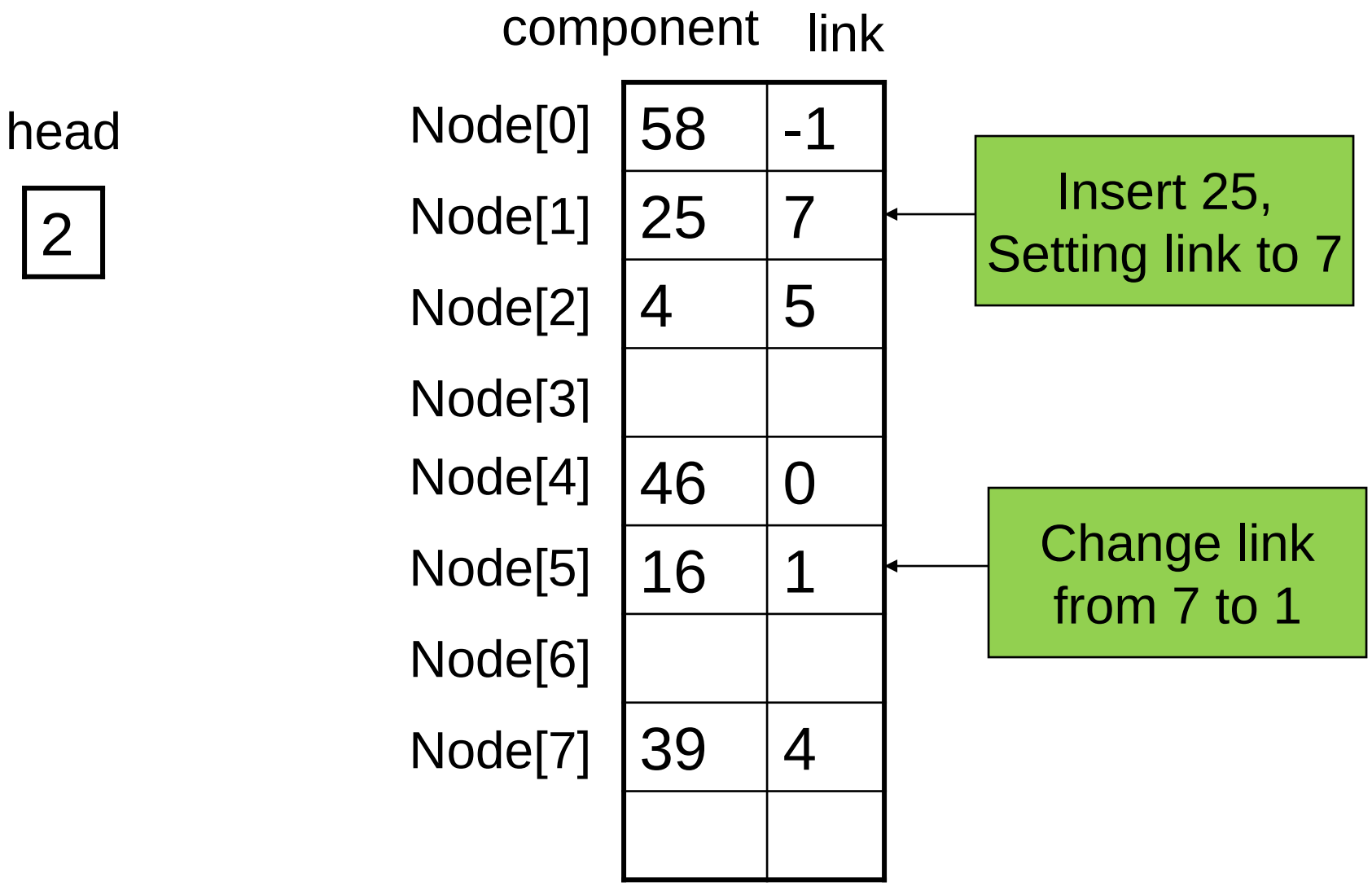
Array Representation of a Linked List



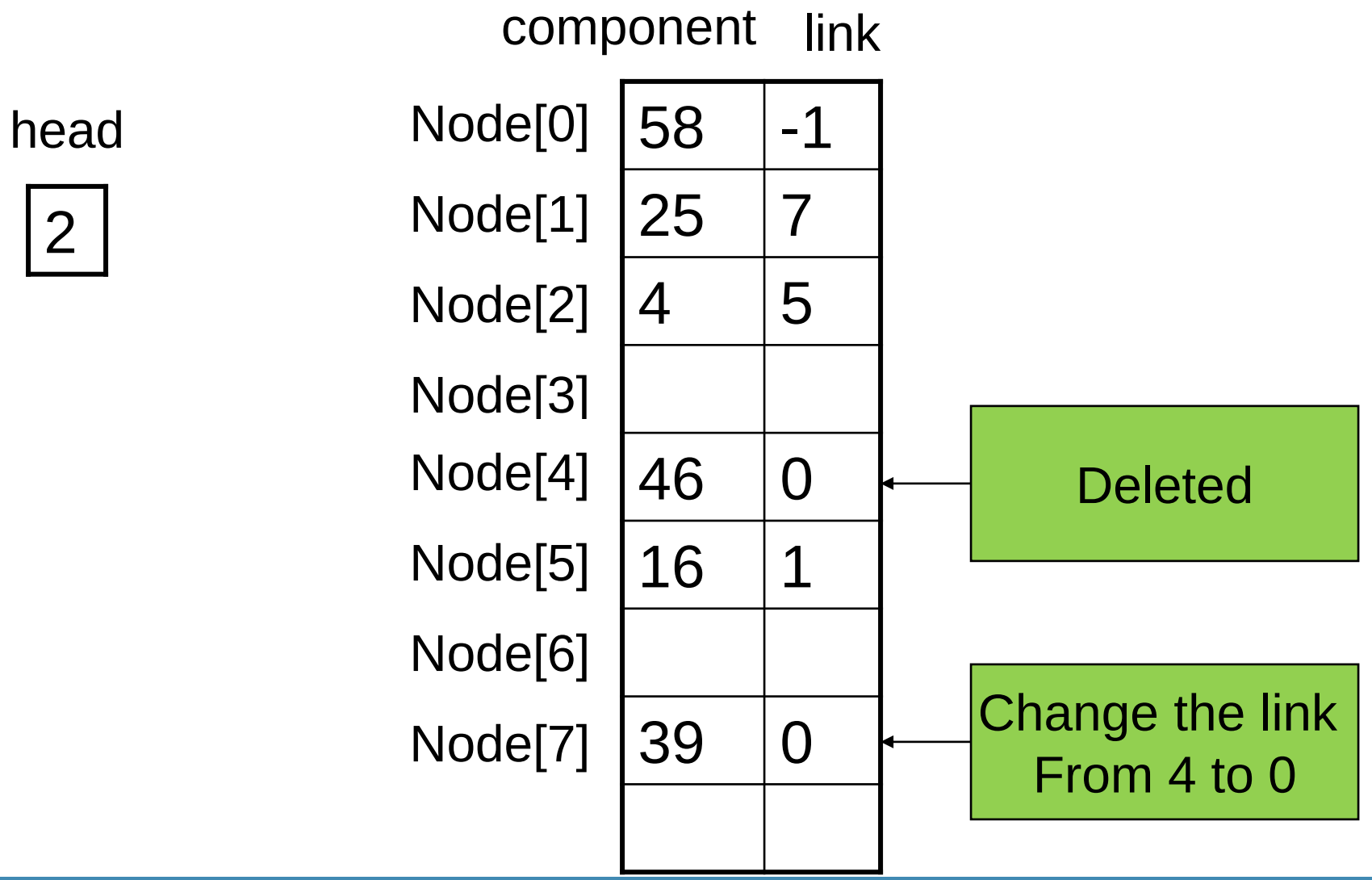
Data Structure of Array Based Linked List

```
struct NodeType
{
  int component;
  int link;
};

NodeType node[1000];          // Max. 1000 nodes
int head;
```

Insert a New Node into a Linked List

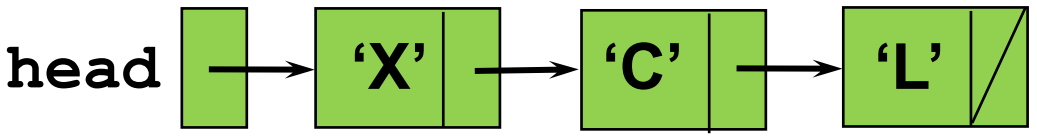


Delete a Node from a Linked List



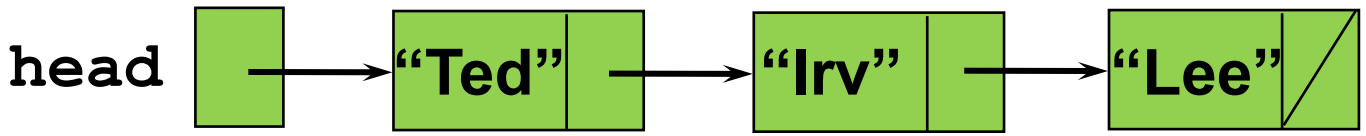
A Linked List

- A linked list is a list in which the order of the components is determined by an explicit link member in each node
- Each node is a `struct` containing a data member and a link member that gives the location of the next node in the list



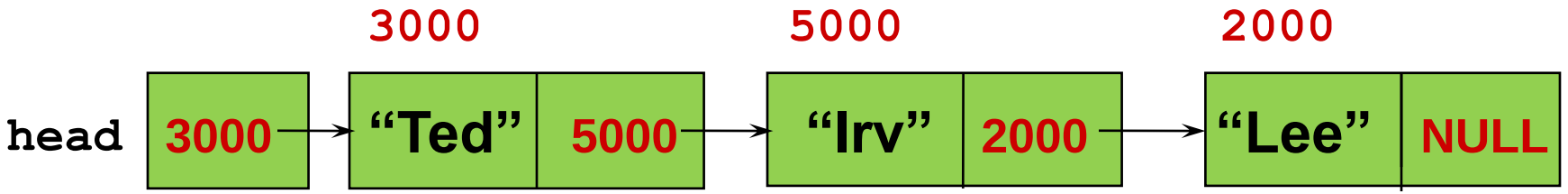
Dynamic Linked List

- A dynamic linked list is one in which the nodes are linked together by pointers and an external pointer (or head pointer) points to the first node in the list



Nodes can be located anywhere in memory

- The link member holds the memory address of the next node in the list



```
#define MAIN
#ifndef LINKEDLIST_H
#define LINKEDLIST_H
#include "node.h"
#include "to_string.h"
using namespace std;
template <typename T>
class linkedlist{
 public:
    // data
    int length;
    node<T> *head, *tail;

    // constructor
    linkedlist(){ head=NULL; tail=NULL; length=0; }

    // methods
    int size();
    bool isempty();
    int indexOf(T obj);
    T get(int idx);
    string to_string();
    void set(int idx, T v);
    void add(T v);
    void add_front(T v);
    void insert(int idx, T v);
    node<T> *remove();
    node<T> *remove_front();
    void append(linkedlist<T> *alist);
};
#endif
```

LECTURE 4

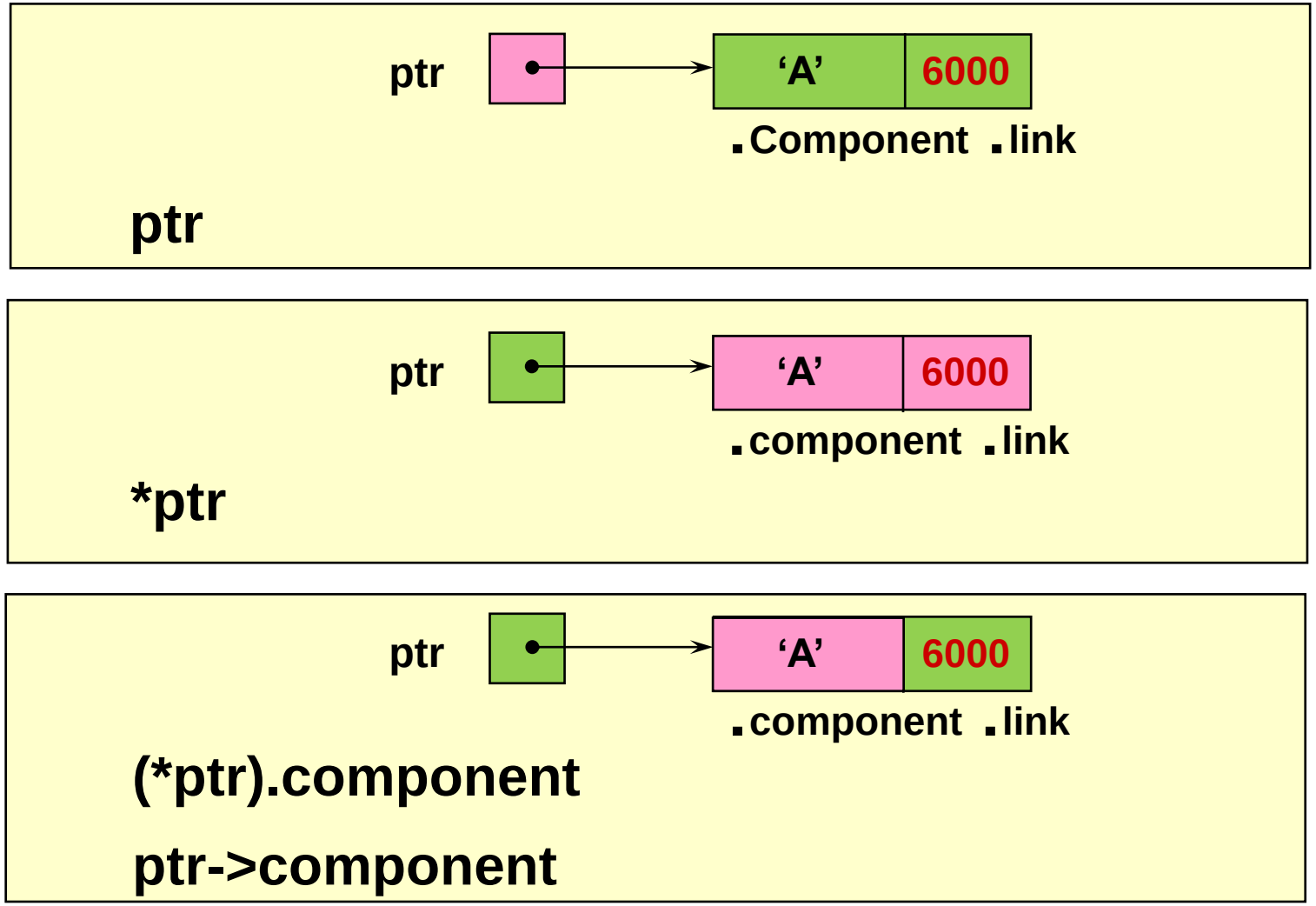
Dynamic Linked List

Declarations for a Dynamic Linked List

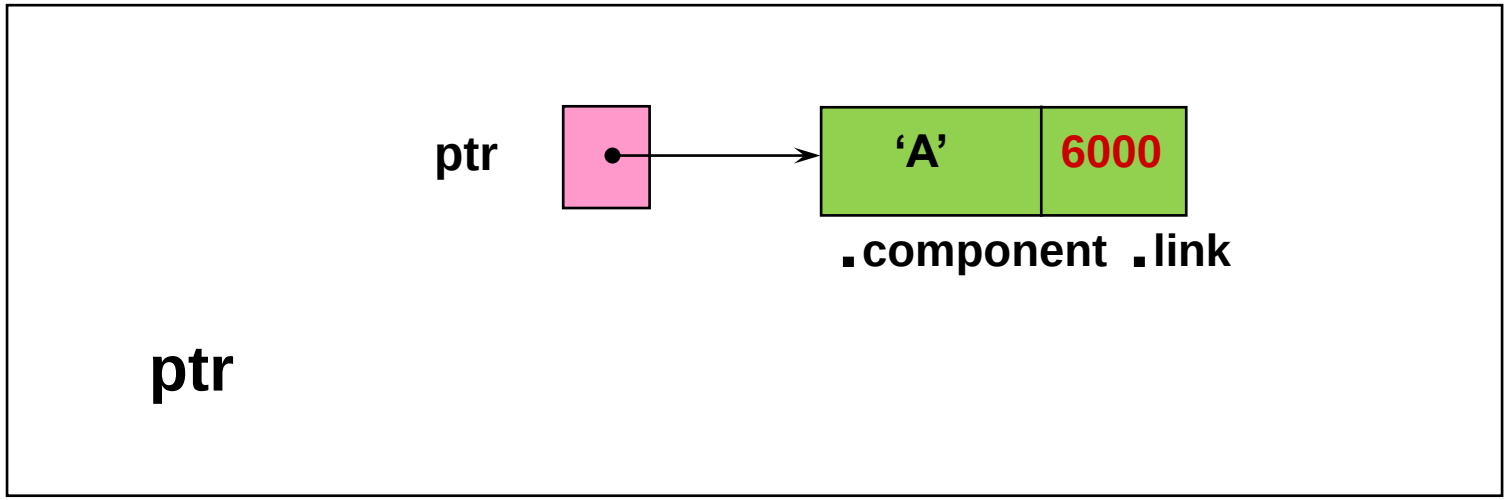
```
// Type declarations
struct NodeType  {
    char component;
    NodeType* link;
}
typedef  NodeType*  NodePtr;
// Variable DECLARATIONS
NodePtr  head;
NodePtr  ptr;
```

.component .link

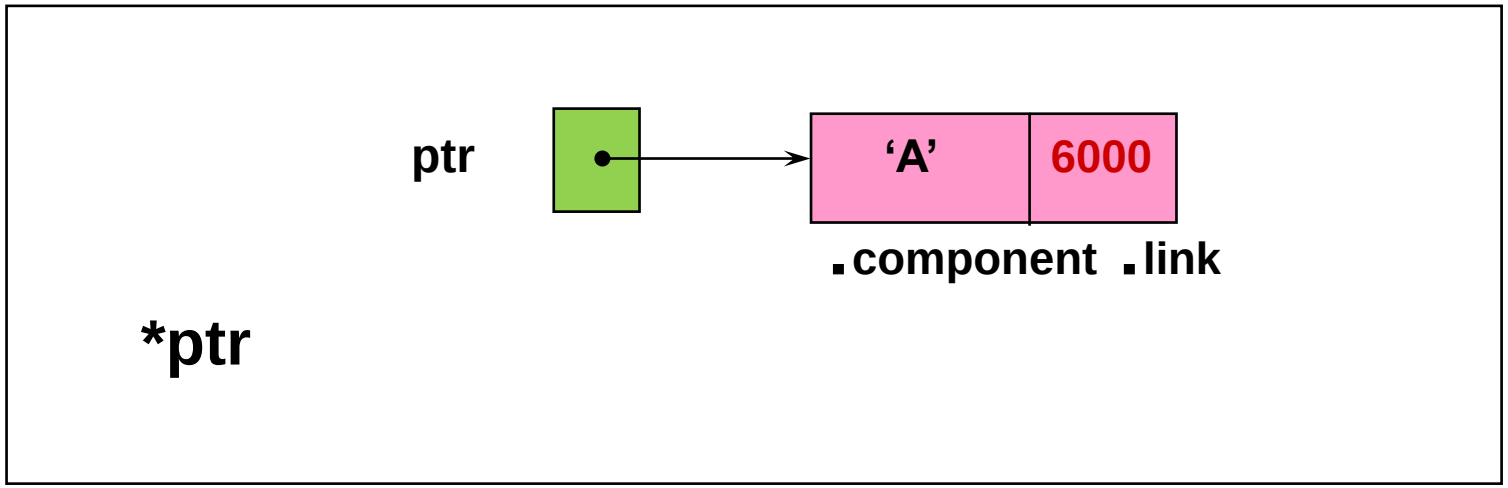
Pointer Dereferencing and Member Selection



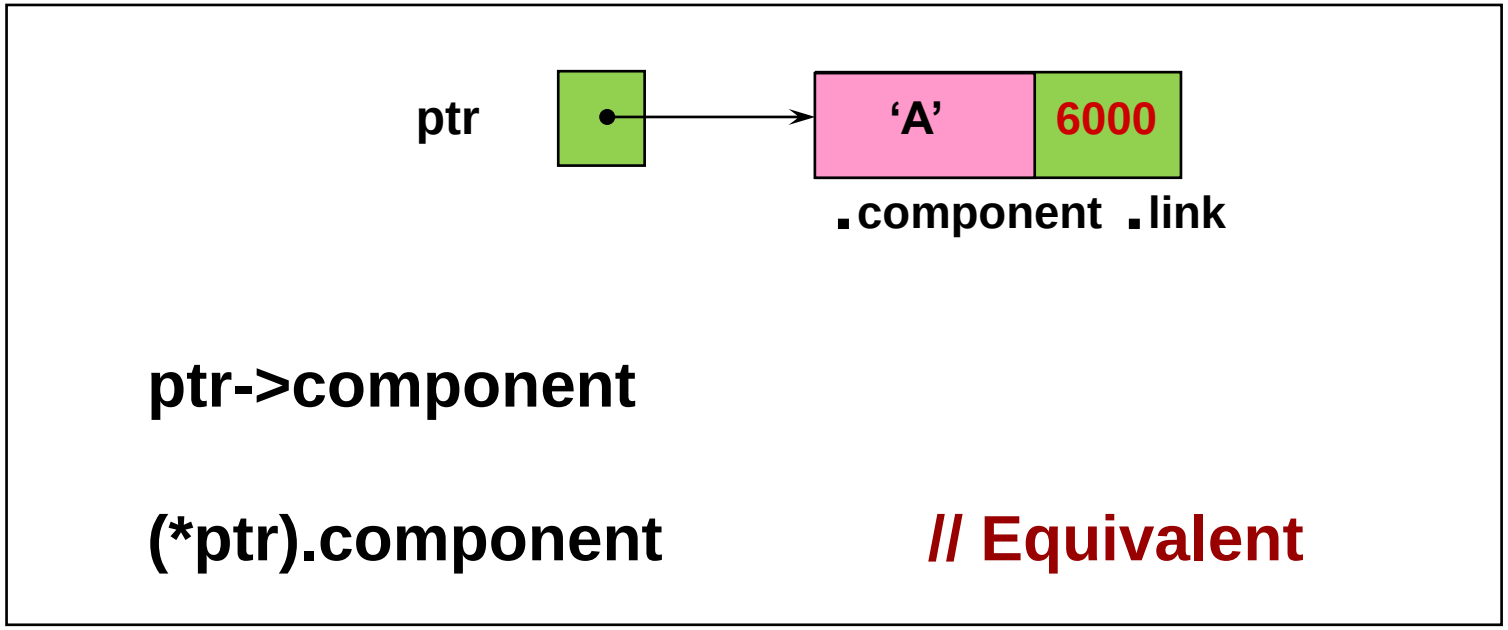
`ptr` is a pointer to a node



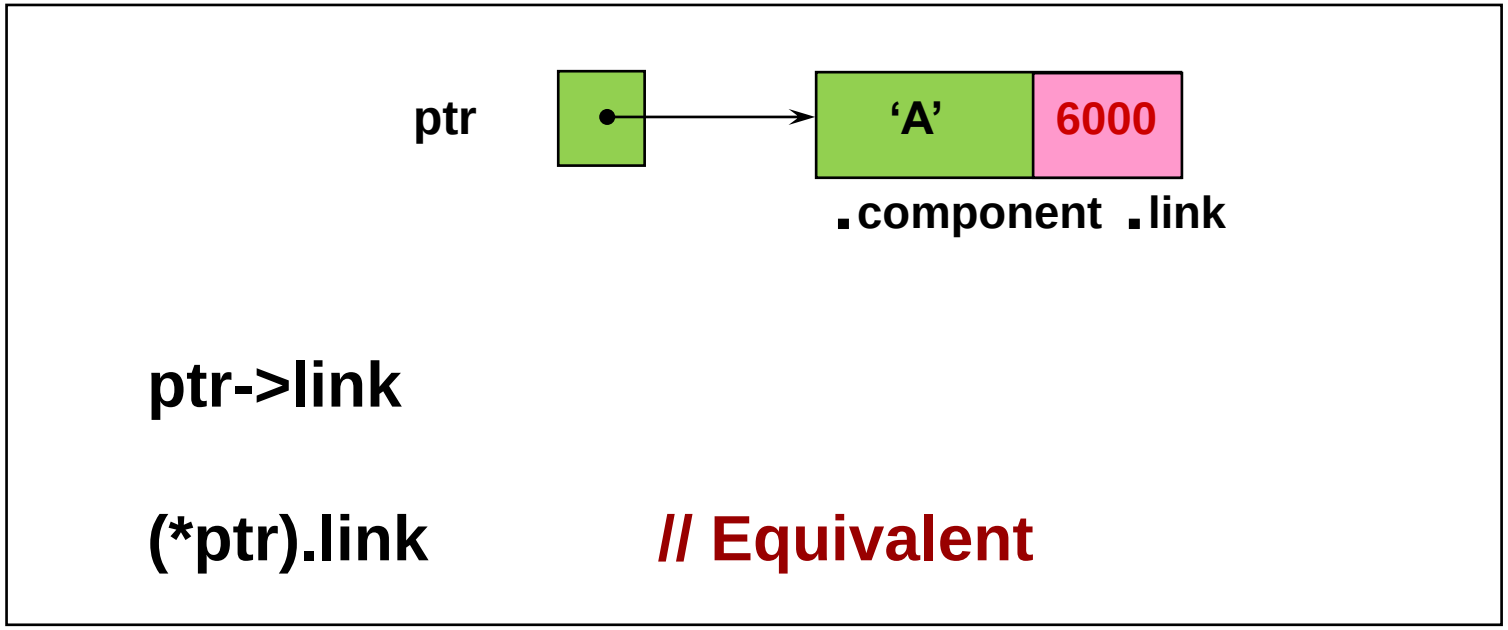
*ptr is the entire node pointed to by ptr



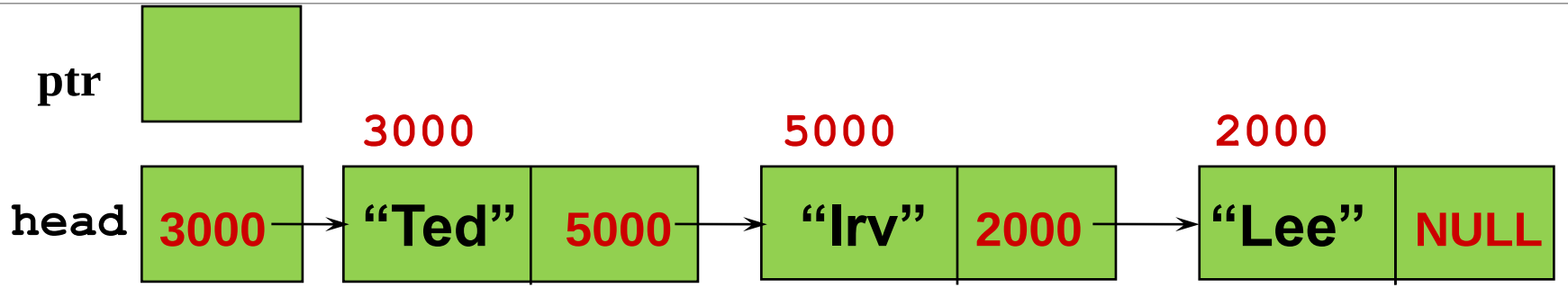
`ptr->component` is a node member



`ptr->link` is a node member

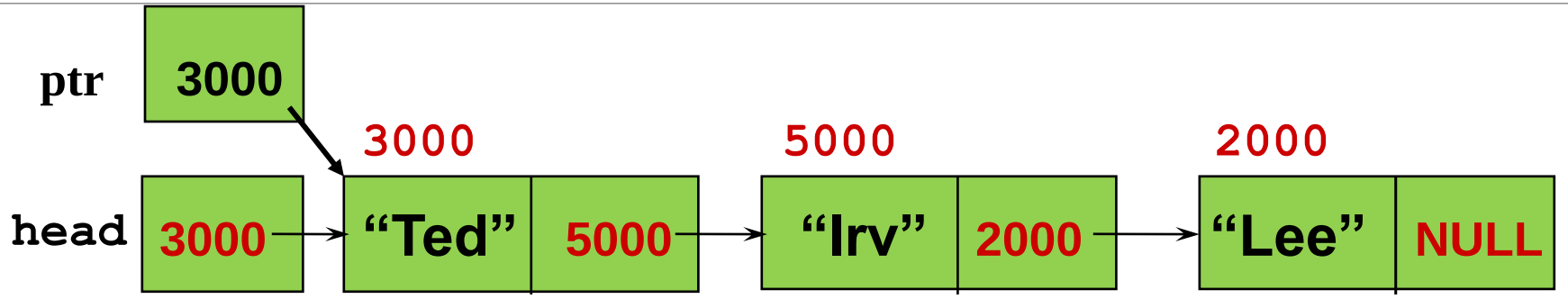


Traversing a Dynamic Linked List



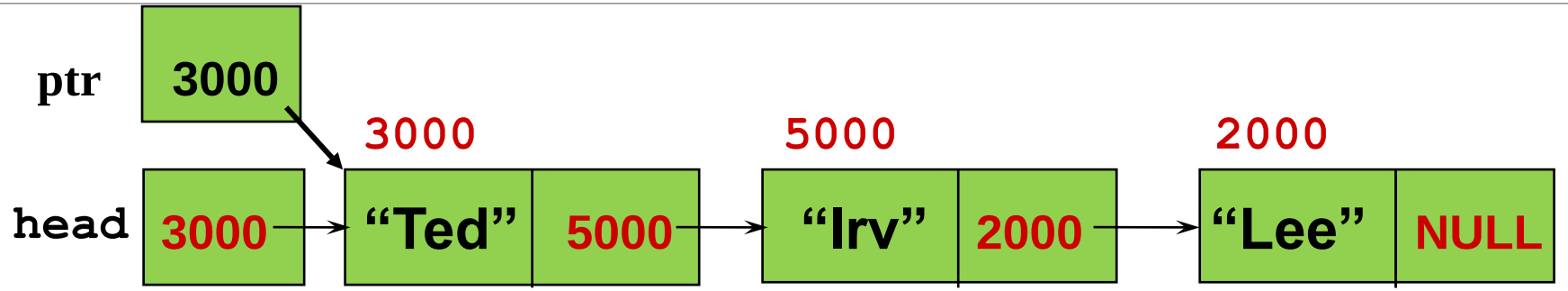

```
// Pre:  head points to a dynamic linked list
ptr   =  head;
while (ptr != NULL)
{
     cout  <<  ptr->component
    // Or, do something else with node *ptr
     ptr   =  ptr->link;
}
```

Traversing a Dynamic Linked List



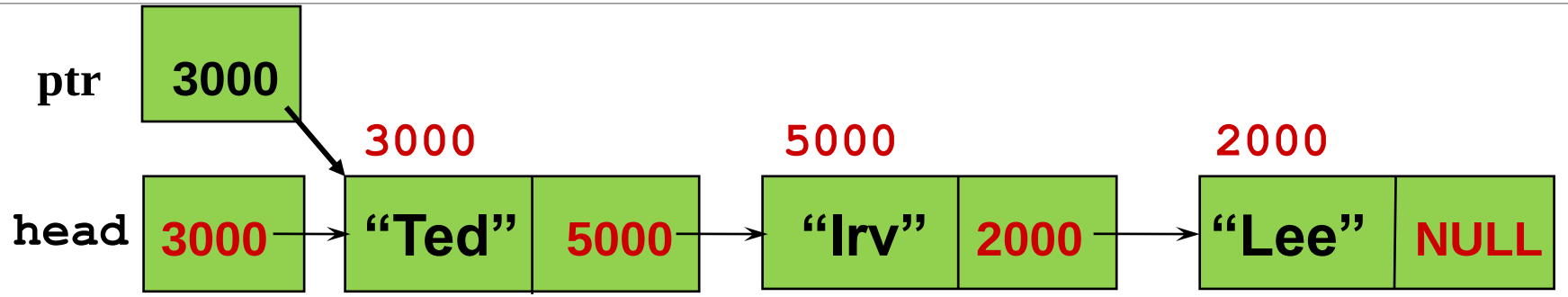

```
// Pre:  head points to a dynamic linked list
ptr  =  head;
while (ptr != NULL)
{
     cout  <<  ptr->component;
    // Or, do something else with node *ptr
    ptr  =  ptr->link;
}
```

Traversing a Dynamic Linked List



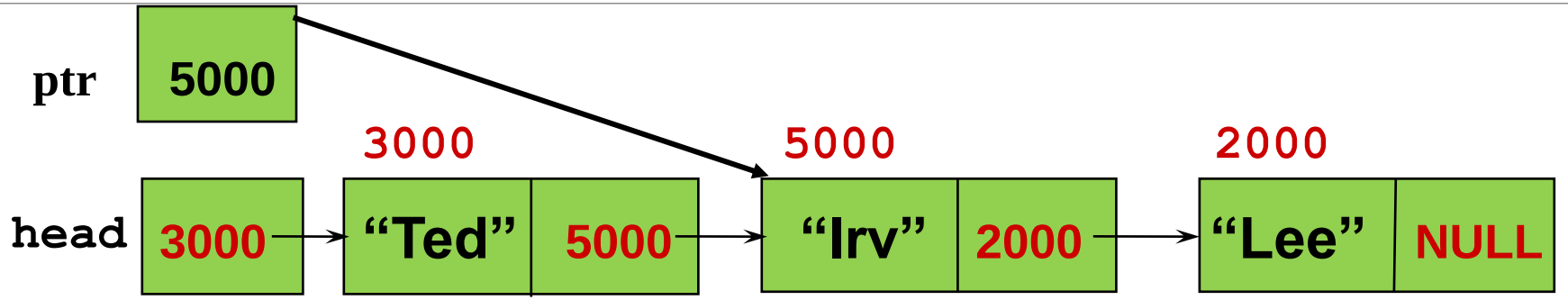

```
// Pre:  head points to a dynamic linked list
ptr   =   head;
while (ptr != NULL)
{
     cout   <<   ptr->component;
    // Or, do something else with node *ptr
    ptr   =   ptr->link;
}
```

Traversing a Dynamic Linked List



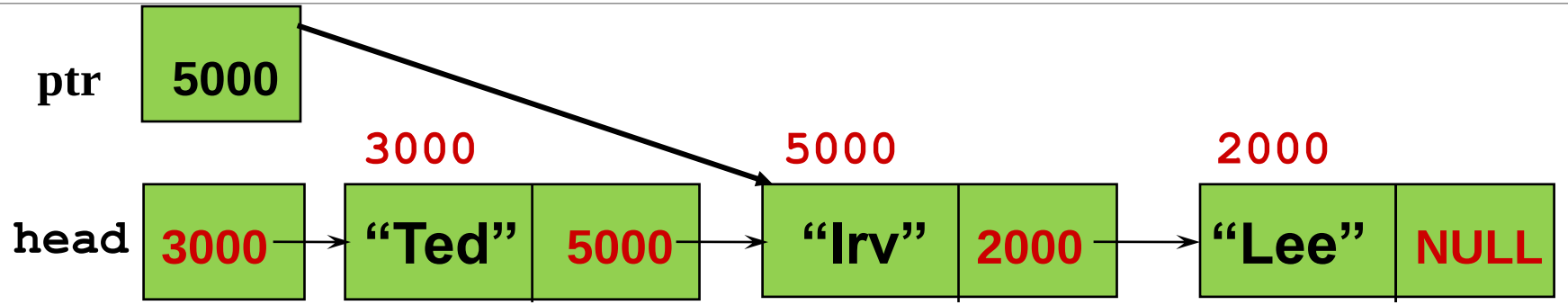

```
// Pre:  head points to a dynamic linked list
ptr   =   head;
while (ptr != NULL)
{
     cout  <<  ptr->component;
     // Or, do something else with node *ptr
     ptr   =   ptr->link;
}
```

Traversing a Dynamic Linked List



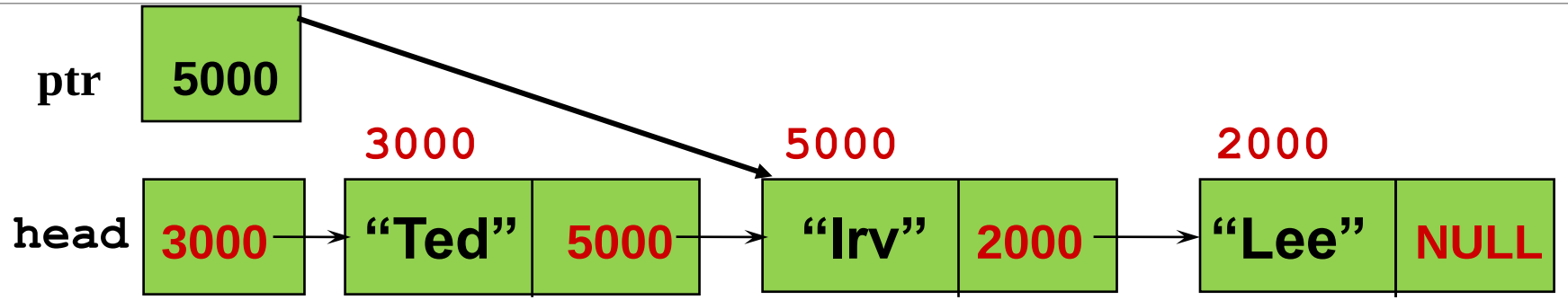

```
// Pre:  head points to a dynamic linked list
ptr  =  head;
while (ptr != NULL)
{
     cout  <<  ptr->component;
     // Or, do something else with node *ptr
     ptr  =  ptr->link;
}
```

Traversing a Dynamic Linked List



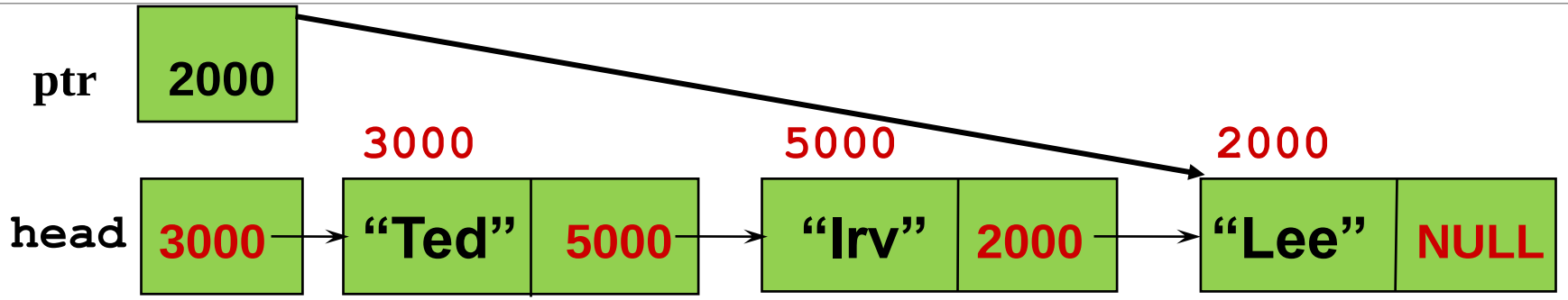

```
// Pre:  head points to a dynamic linked list
ptr  =  head;
while (ptr != NULL)
{
     cout  <<  ptr->component;
    // Or, do something else with node *ptr
    ptr  =  ptr->link;
}
```

Traversing a Dynamic Linked List



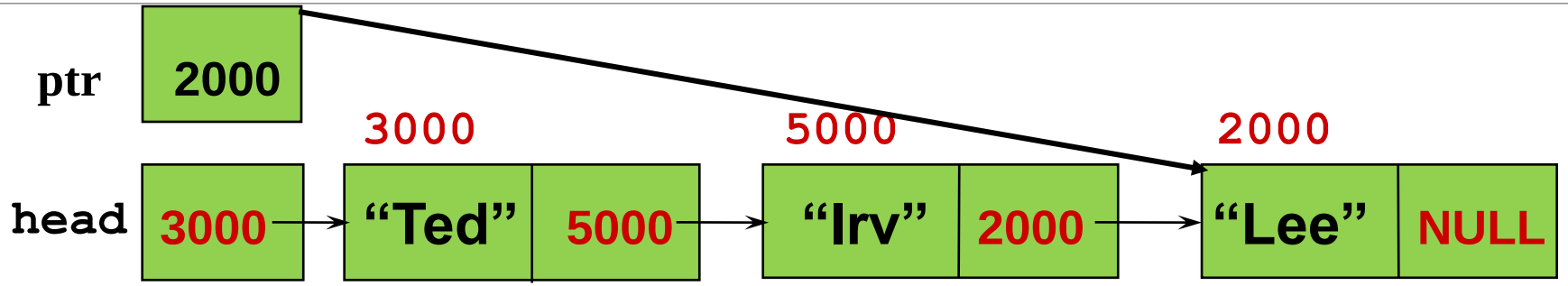

```
// Pre:  head points to a dynamic linked list
ptr   =   head;
while (ptr != NULL)
{
     cout   <<   ptr->component;
     // Or, do something else with node *ptr
     ptr   =   ptr->link;
}
```

Traversing a Dynamic Linked List



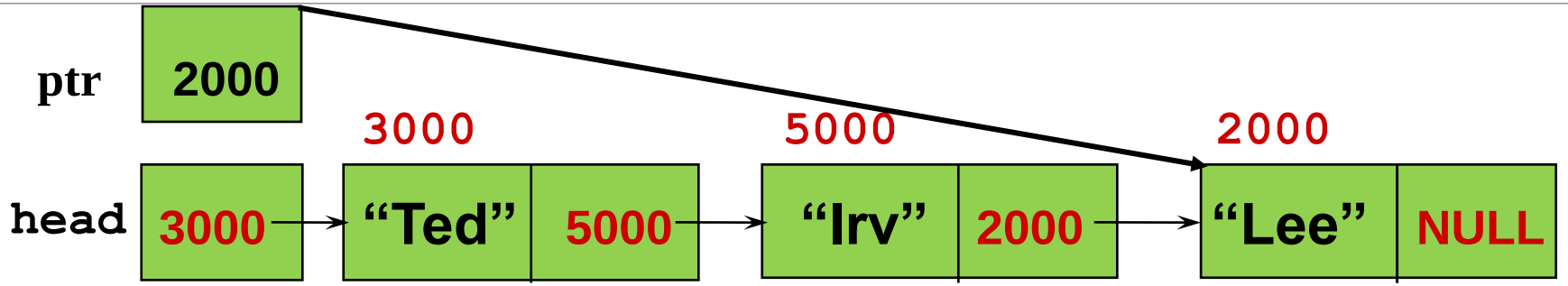

```
// Pre:  head points to a dynamic linked list
ptr  =  head;
while (ptr != NULL)
{
     cout  <<  ptr->component;
     // Or, do something else with node *ptr
     ptr  =  ptr->link;
}
```

Traversing a Dynamic Linked List



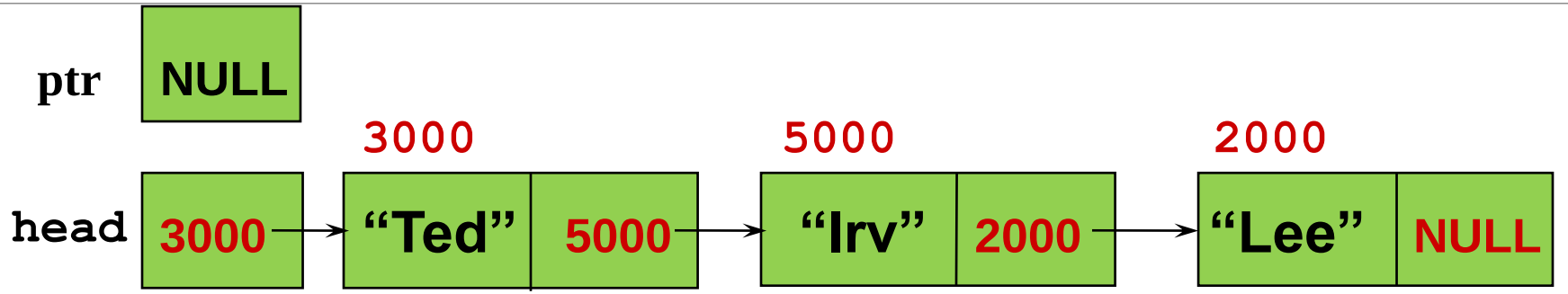

```
// Pre:  head points to a dynamic linked list
ptr   =   head;
while (ptr != NULL)
{
     cout  <<  ptr->component;
    // Or, do something else with node *ptr
    ptr   =   ptr->link;
}
```

Traversing a Dynamic Linked List



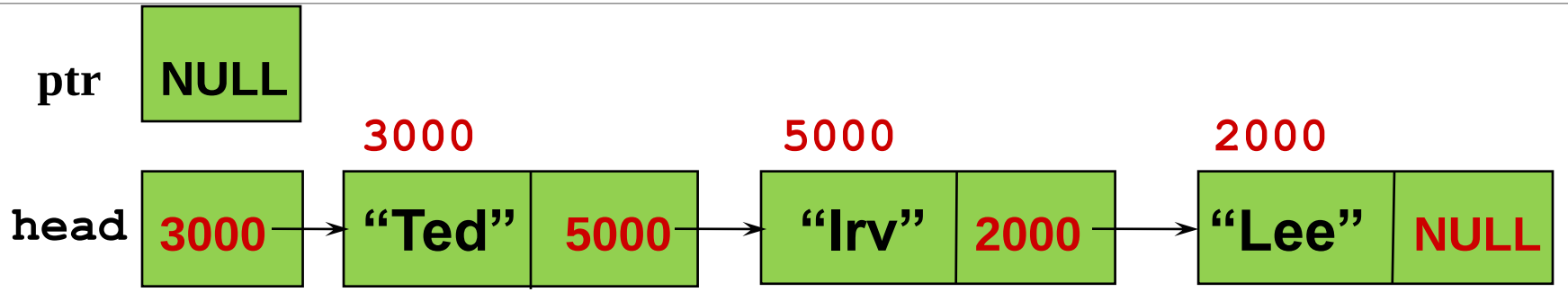

```
// Pre:  head points to a dynamic linked list
ptr  =  head;
while (ptr != NULL)
{
     cout  <<  ptr->component;
     // Or, do something else with node *ptr
     ptr  =  ptr->link;
}
```

Traversing a Dynamic Linked List




```
// Pre:  head points to a dynamic linked list
ptr  =  head;
while (ptr != NULL)
{
     cout  <<  ptr->component;
     // Or, do something else with node *ptr
     ptr  =  ptr->link;
}
```

Traversing a Dynamic Linked List




```
// Pre:  head points to a dynamic linked list
ptr  =  head;
while (ptr != NULL)
{
     cout  <<  ptr->component;
    // Or, do something else with node *ptr
    ptr  =  ptr->link;
}
```

```
template <typename T>
string linkedlist<T>::to_string(){
   string str("");
   node<T> *p = head;
    str += "[";
    int count = 0;
    while (p!= NULL){
        if (count ==0) str += st::to_string(head->get());
        else str += ", "+ st::to_string(p->get());
        count++;
        p=p->next;
    }
    str += "]";
    return str;
}
```

LECTURE 4

new Operator for Dynamic Linked List

Using Operator **`new`**

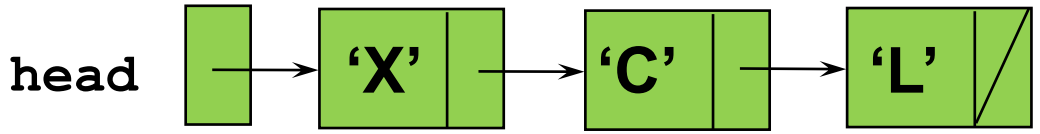
Recall

- If memory is available in the free store (or heap), operator new allocates the requested object and returns a pointer to the memory allocated
- The dynamically allocated object exists until the delete operator destroys it

Inserting a Node at the Front of a List

item ‘B’

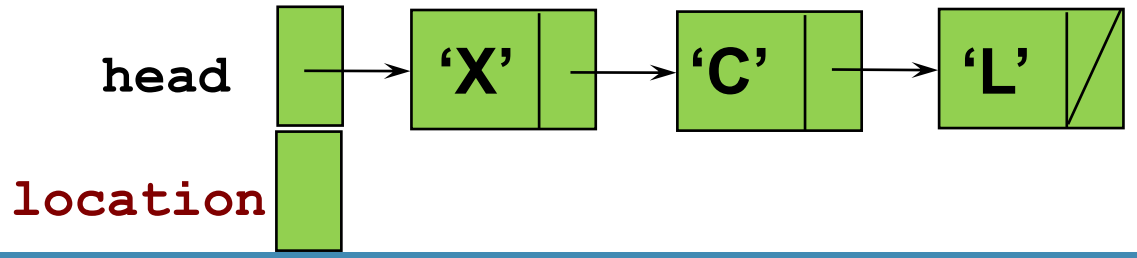
```
char     item = 'B';
NodePtr  location;
location = new  NodeType;
location->component = item;
location->link = head;
head = location;
```



Inserting a Node at the Front of a List

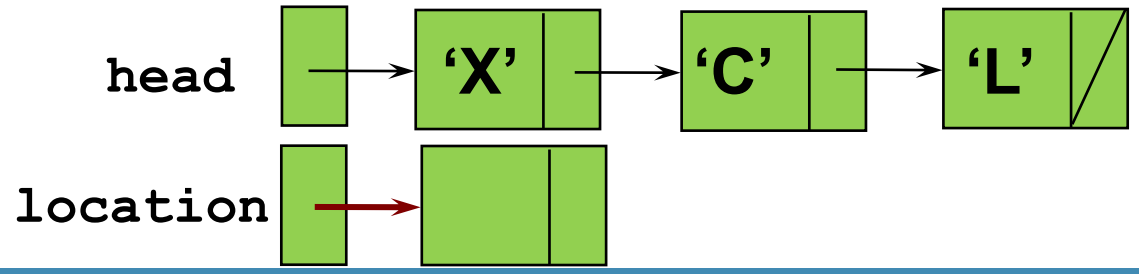
item ‘B’

```
char     item = 'B';
NodePtr  location;
location = new  NodeType;
location -> component  = item;
location -> link = head;
head = location;
```



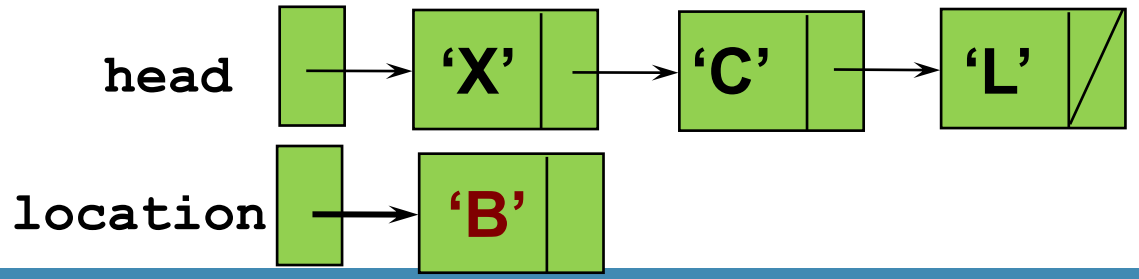
Inserting a Node at the Front of a List


```
char      item = 'B';
NodePtr   location;
location = new  NodeType;
location -> component = item;
location -> link = head;
head = location;
```



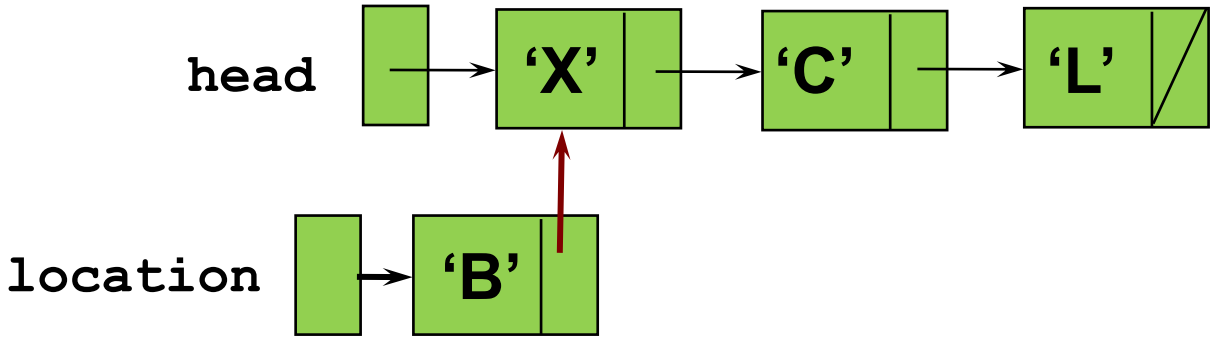
Inserting a Node at the Front of a List


```
char      item = 'B';
NodePtr   location;
location = new  NodeType;
location -> component = item;
location -> link = head;
head = location;
```



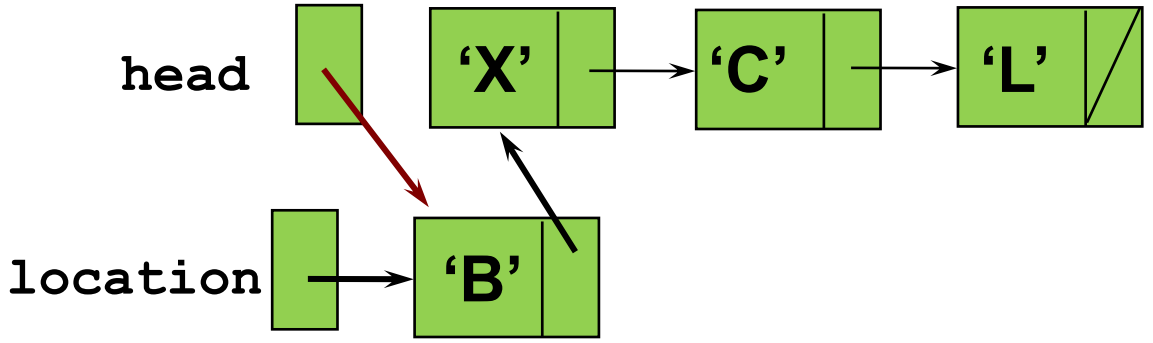
Inserting a Node at the Front of a List


```
char      item = 'B';
NodePtr   location;
location = new  NodeType;
location -> component = item;
location -> link = head;
head = location;
```



Inserting a Node at the Front of a List


```
char     item = 'B';
NodePtr  location;
location = new  NodeType;
location -> component = item;
location -> link = head;
head = location;
```



```
template <typename T>
void linkedlist<T>::add(T v){
    length++;
    node<T> *n = new node<T>(v);
    if (head == NULL){
        head = n;
        head->next = NULL;
        tail = n;
        return;
    }

    node<T> *p = (node<T> *) head;
    node<T> *q = NULL;
        while (p!= NULL){
        q = p;
        p=p->next;
    }
    tail = n;
    q->next = n;
    n->next = NULL;
}
```

```
template <typename T>
void linkedlist<T>::add_front(T v){
    length++;
    node<T> *n = new node<T>(v);
    if (head == NULL){
        head = n;
        head->next = NULL;
        tail = n;
        return;
    }

    node<T> *p = (node<T> *) head;
    head = n;
    n->next = p;
}
```

LECTURE 4

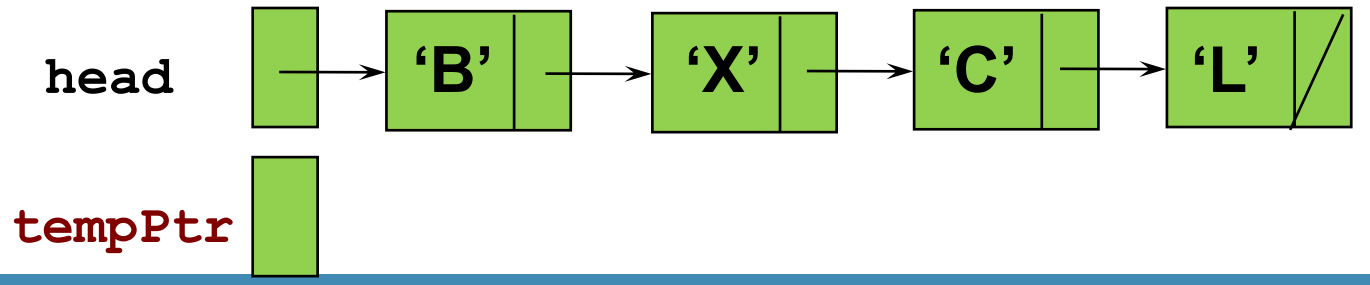
delete Operator for Dynamic Linked List

Using Operator `delete`

- When you use the operator `delete`
- The object currently pointed to by the pointer is deallocated and the pointer is considered undefined
- The object's memory is returned to the free store

Deleting the First Node from the List

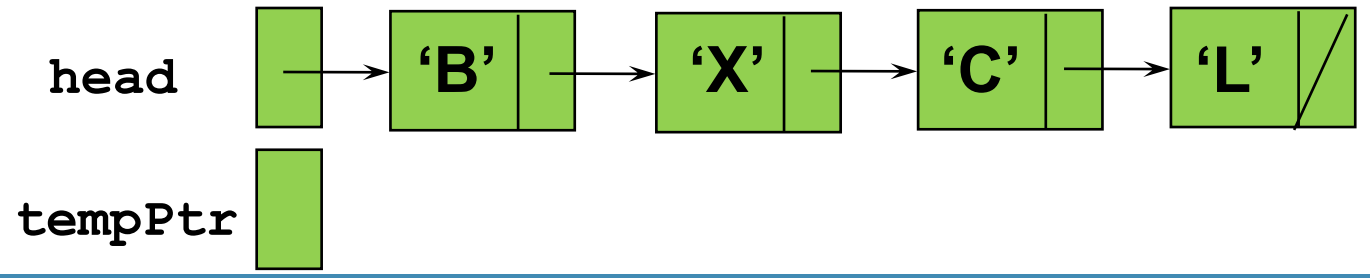

```
NodePtr   tempPtr;

item = head->component;
tempPtr = head;
head = head->link;
delete  tempPtr;
```



Deleting the First Node from the List

item ‘B’

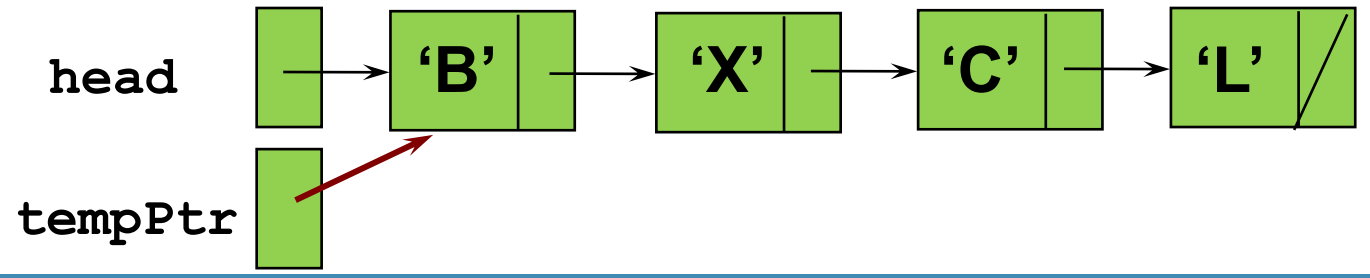
```
NodeType *   tempPtr;
item = head->component;
tempPtr = head;
head = head->link;
delete   tempPtr;
```



Deleting the First Node from the List

item ‘B’

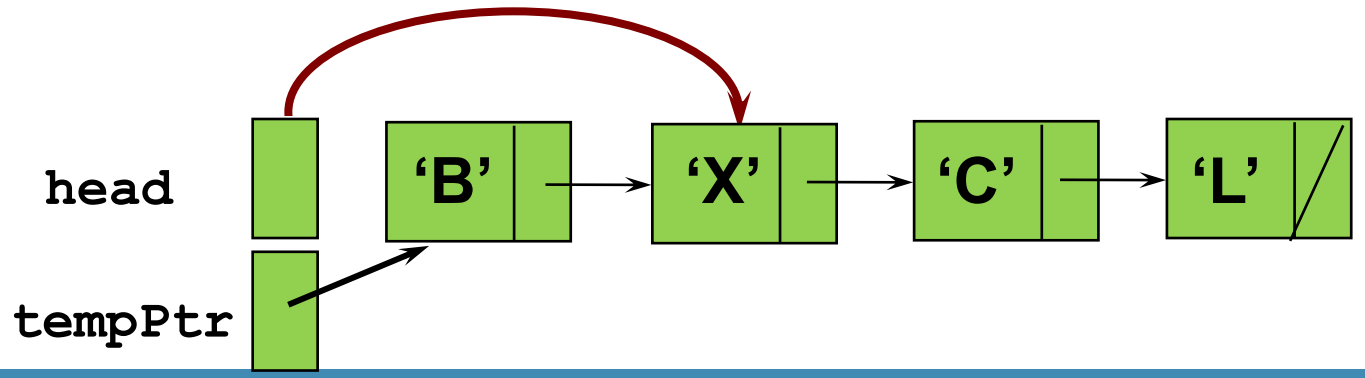
```
NodeType *   tempPtr;
item = head->component;
tempPtr = head;
head = head->link;
delete  tempPtr;
```



Deleting the First Node from the List

item ‘B’

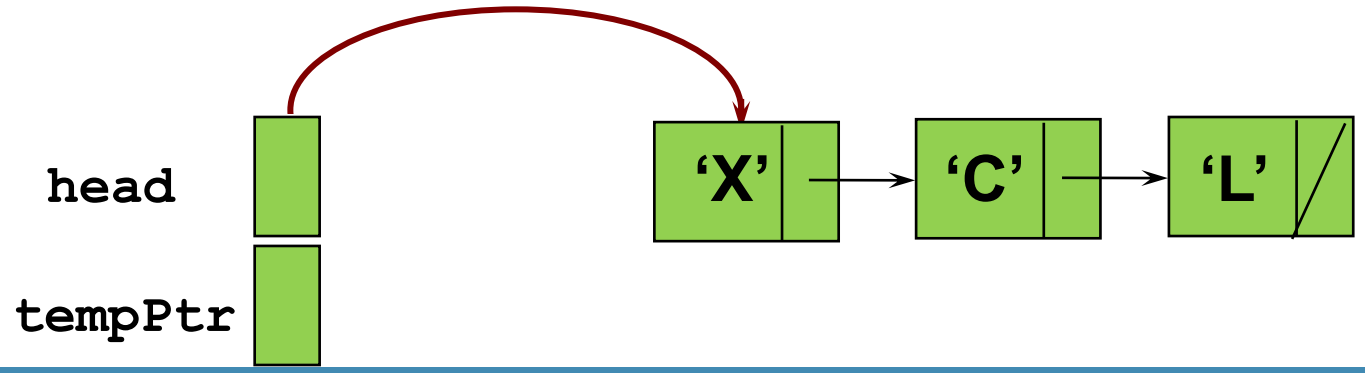
```
NodeType *   tempPtr;
item = head->component;
tempPtr = head;
head = head->link;
delete   tempPtr;
```



Deleting the First Node from the List

item ‘B’

```
NodeType *  tempPtr;
item = head->component;
tempPtr = head;
head = head->link;
delete  tempPtr;
```



```
template <typename T>
node<T>* linkedlist<T>::remove(){
  if (head == NULL){ // zero element
    return NULL;
  }

  length--;
  node<T> *p = (node<T> *) head;
  node<T> *q = NULL;
  node<T> *r = NULL;
    while (p!= NULL){
    r = q;
     q = p;
     p=p->next;
  }

  if (r==NULL){ // only one element
    head = NULL;
    tail = NULL;
    return q;
  }

  r->next = NULL;
  tail = r;
  return q;
}
```

```
template <typename T>
node<T>* linkedlist<T>::remove_front(){
  if (head == NULL){ // zero element
    return NULL;
  }

  length--;
  if (head->next == NULL){
    node<T>* q = head;
    head = NULL;
    tail = NULL;
    return q;
  }

  node<T>* q = head;
  head = head->next;
  return q;
}
```

LECTURE 4

Sorted List

What is a Sorted List?

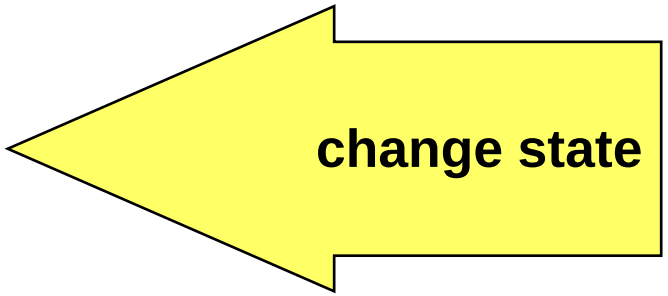
- A sorted list is a variable-length, linear collection of homogeneous elements, ordered according to the value of one or more data members
- The transformer operations must maintain the ordering
- In addition to Insert and Delete, let's add two new operations to our list

InsertAsFirst* and *RemoveFirst

ADT HybridList Operations

Transformers

- InsertAsFirst
- Insert
- RemoveFirst
- Delete



Same observers and iterators as ADT List

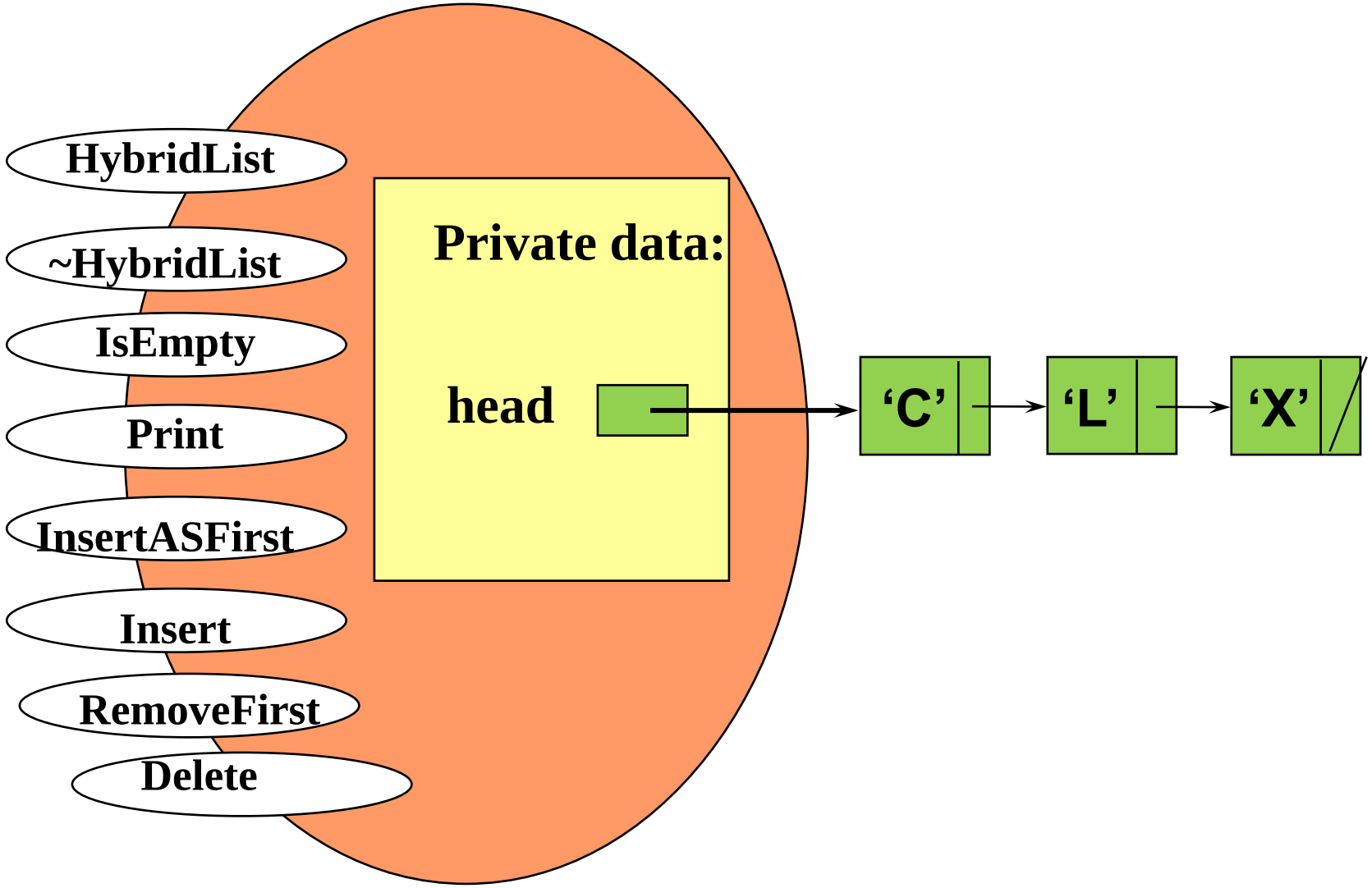
Since we have two insertion and two deletion operations, let's call this a Hybrid List

struct NodeType

```
// Specification file sorted list ("slist2.h")

typedef int ItemType;   // Type of each component is
                        // a simple type or a string
struct  NodeType
{
    ItemType component;      // Pointer to person's name
    NodeType* link;     // Link to next node in list
};

typedef  NodeType*  NodePtr;
```

```
// Specification file  hybrid sorted list("slist2.h")
class  HybridList
{
public:

    bool IsEmpty () const;

    void InsertAsFirst (/* in */  ItemType  item);

    void Insert (/* in */  ItemType  item);

    void RemoveFirst(/* out */  ItemType&  item);

    void Delete (/* in */  ItemType  item);
    void Print () const;
    HybridList ();   // Constructor
    ~HybridList ();  // Destructor
    HybridList (const HybridList&  otherList);
                     // Copy-constructor

private:

    NodeType*  head;
};
```

class HybridList



```
// IMPLEMENTATION DYNAMIC-LINKED SORTED LIST (slist2.cpp)


HybridList :: HybridList ( )        // Constructor
// Post:      head == NULL
{
  head = NULL ;
}



HybridList :: ~ HybridList (  )     // Destructor
// Post:  All linked nodes deallocated
{
  ItemType  temp ;
                                          // keep deleting top node
  while  ( !IsEmpty () )
              RemoveFirst ( temp );
}
```

```
void HybridList::InsertAsFirst(/* in */  ItemType  item)
// Pre: item is assigned &&  components in ascending order
// Post: New node containing item is the first item in the list
//                      && components in ascending order
{
    NodePtr newNodePtr = new NodeType;

    newNodePtr -> component = item;
    newNodePtr -> link = head;
    head = newNodePtr;
}
Void HybridList::Print() const
// Post: All values within nodes have been printed
{
    NodePtr currPtr = head;  // Loop control pointer
    while (currPtr != NULL)
    {
        cout << currPtr->component << endl;
        currPtr = currPtr->link;
    }
}
```

```
void HybridList::RemoveFirst (
      /* out */  ItemType&  item)
// Pre: list is not empty && components in ascending order
// Post: item == element of first list node @ entry
//   &&  node containing item is no longer in list
//   &&  list components in ascending order
{
    NodePtr  tempPtr = head;
    // Obtain item and advance head
    item = head->component;
    head = head->link;
    delete  tempPtr;
}
```

LECTURE 4

Insertion Algorithm for Sorted List

Insert Algorithm

- What will be the algorithm to Insert an item into its proper place in a sorted linked list?
- That is, for a linked list whose elements are maintained in ascending order?

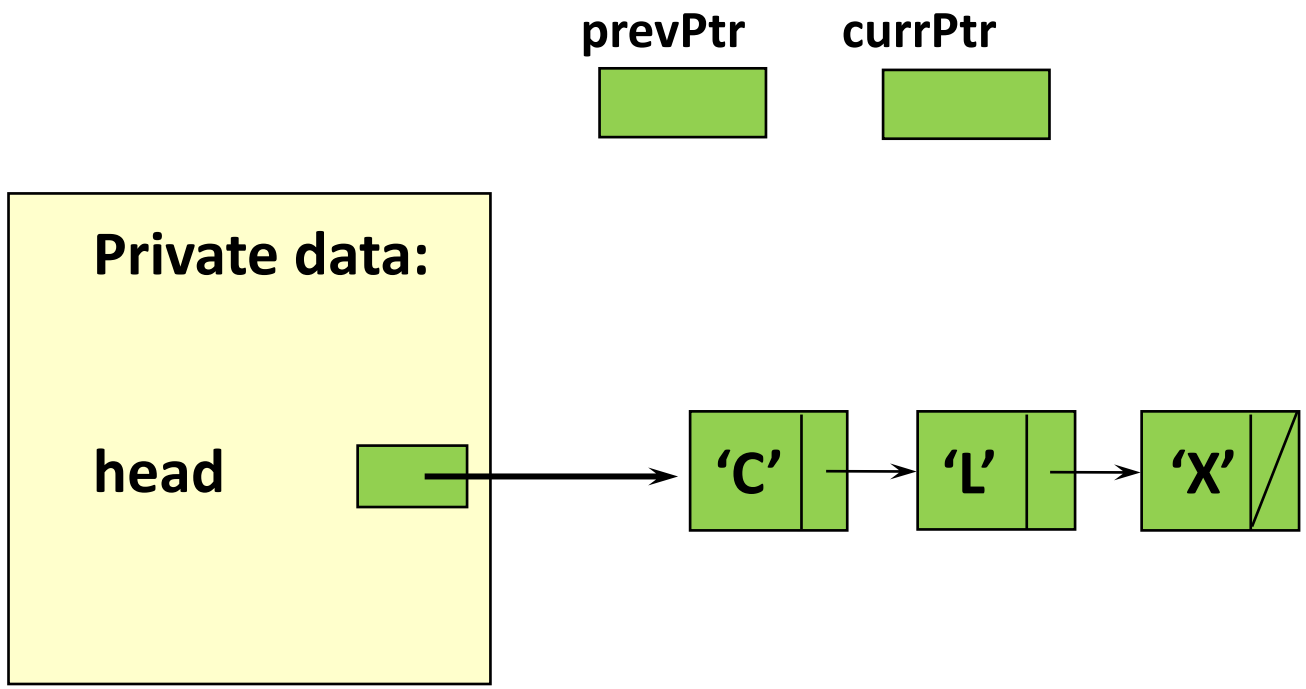
Insert algorithm for `HybridList`

- Find proper position for the new element in the sorted list using two pointers prevPtr and currPtr, where prevPtr trails behind currPtr
- Obtain a new node and place item in it
- Insert the new node by adjusting pointers

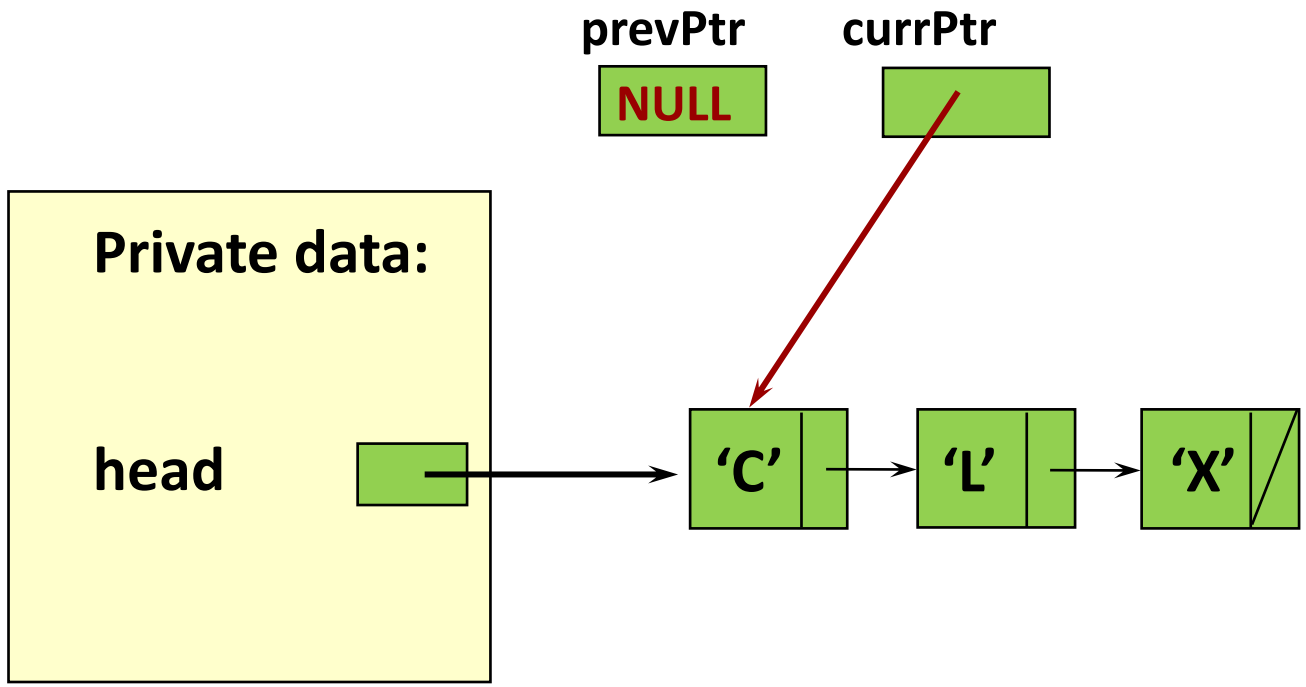
Implementing `HybridList` Member Function **Insert**

```
// Dynamic linked list implementation ("slist2.cpp")

void  HybridList::Insert (/* in */  ItemType  item)
// PRE:
//    item is assigned && components in ascending order
// POST:
//    item is in List && components in ascending order
{
      .
      .
      .

}
```

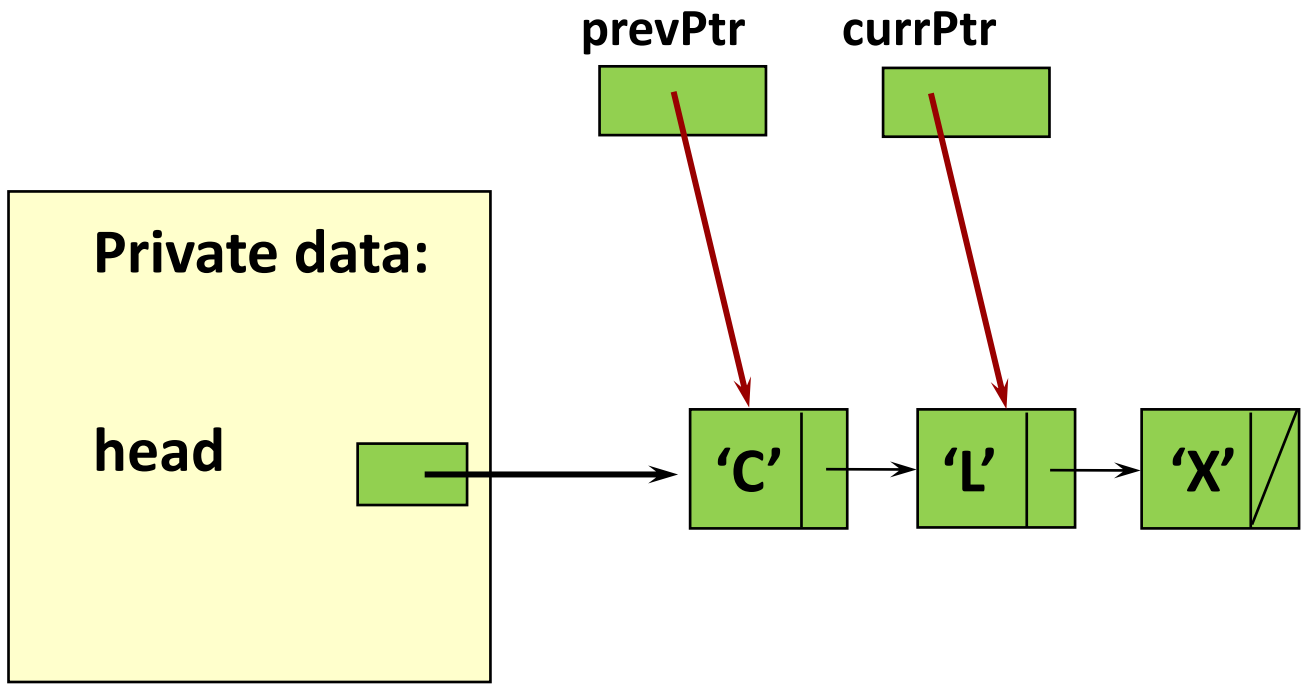
Inserting ‘S’ into a List



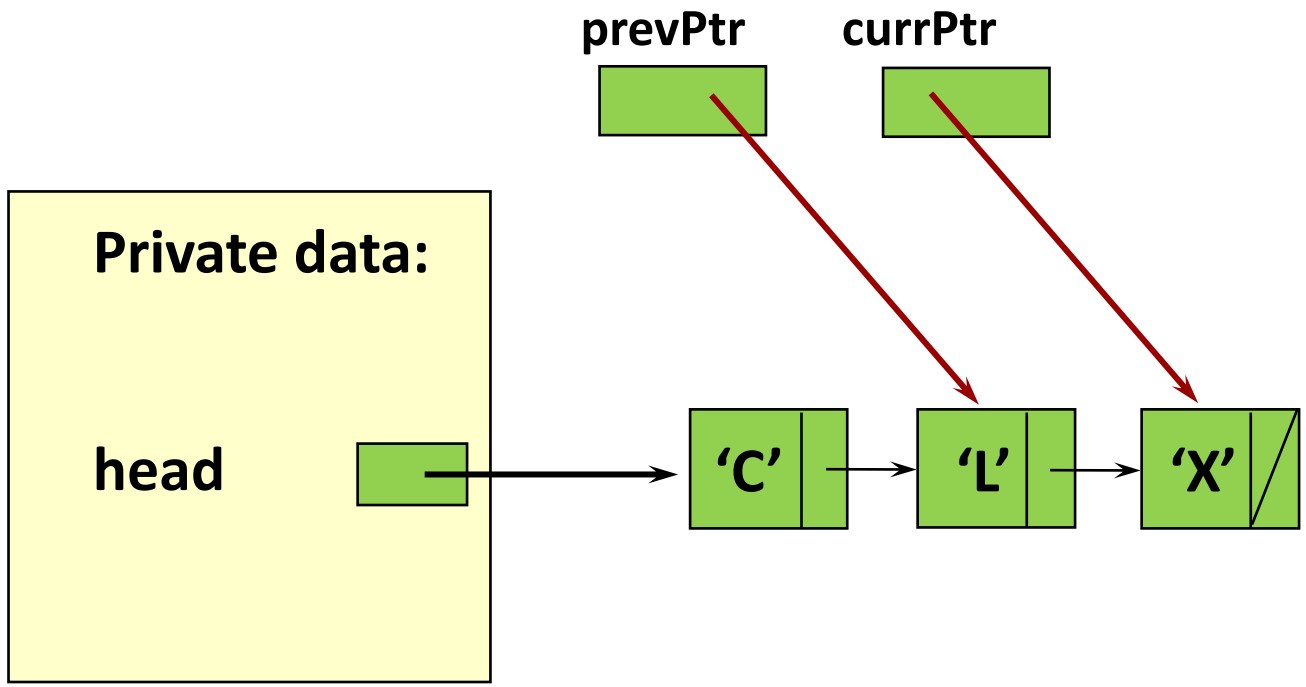
Finding Proper Position for ‘S’



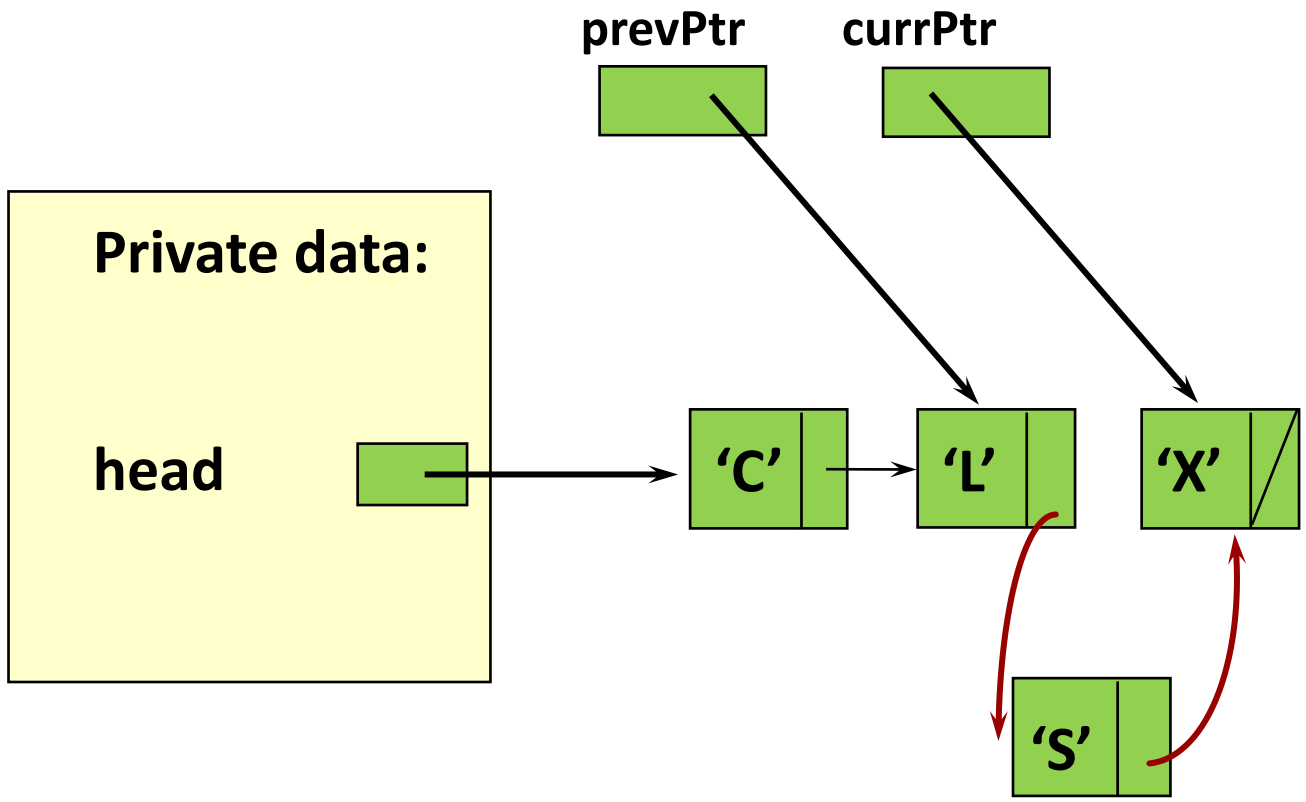
Finding Proper Position for ‘S’



Finding Proper Position for ‘S’



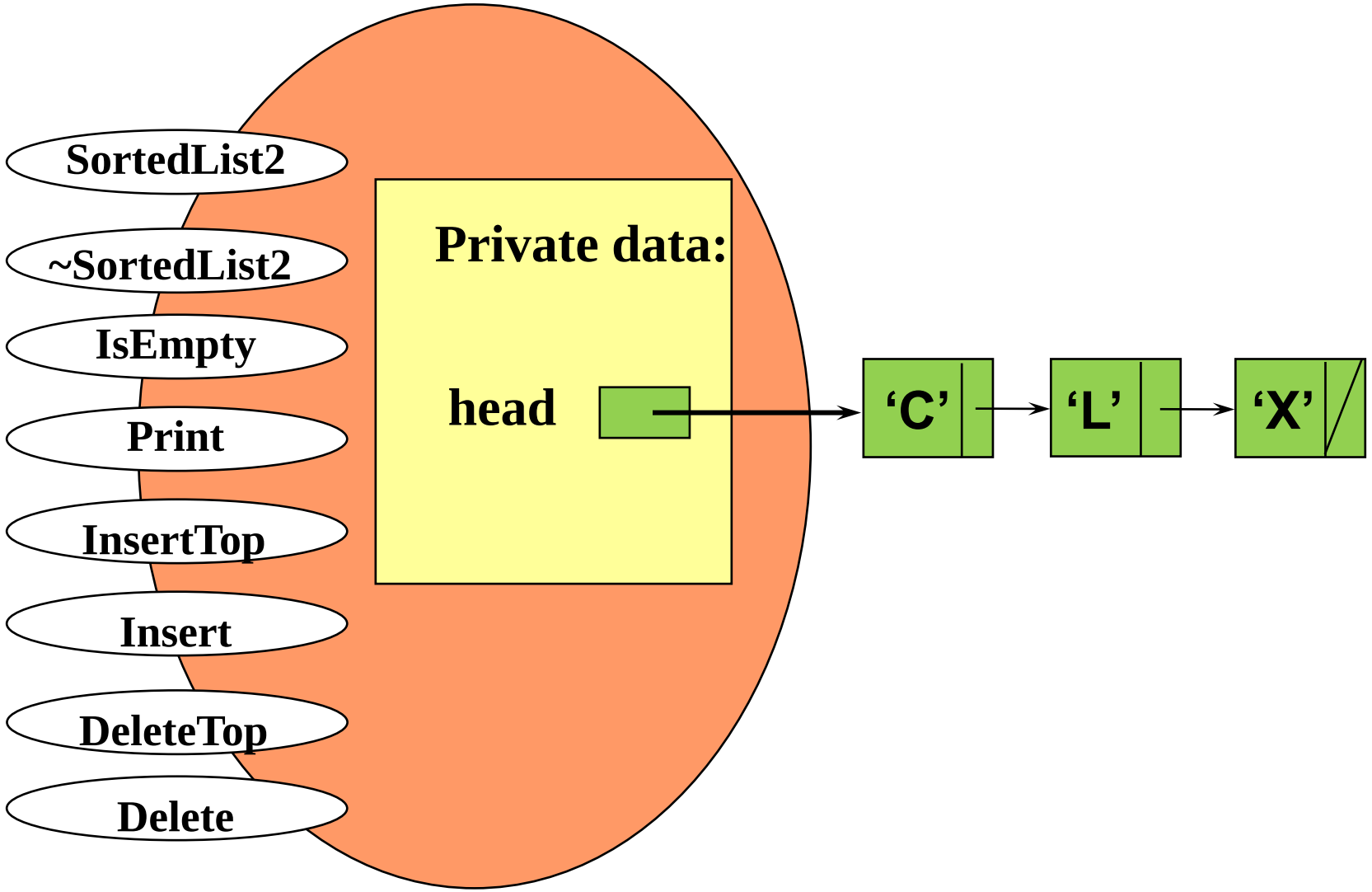
Inserting ‘S’ into Proper Position



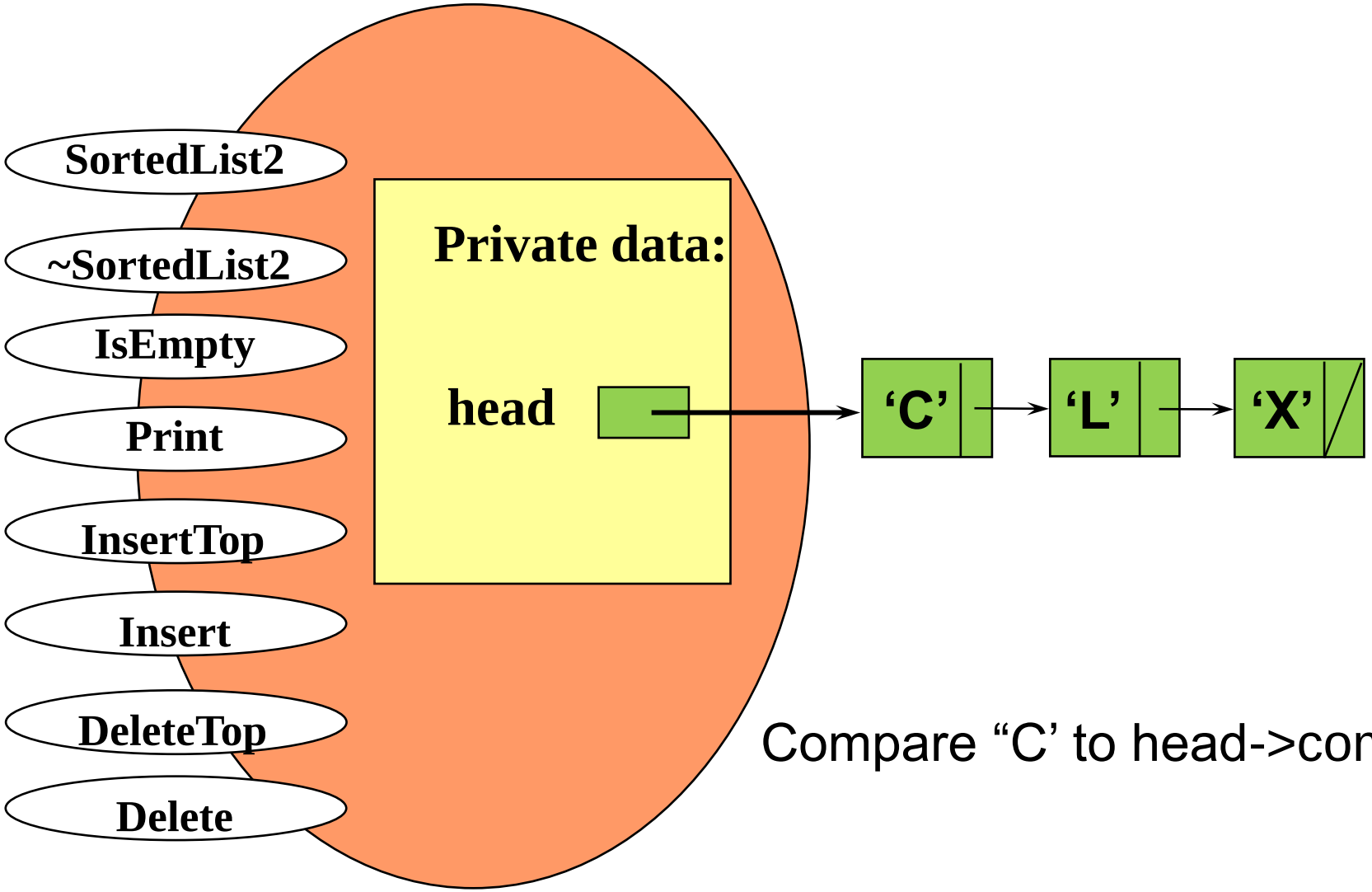
```
void  HybridList::Insert(/* in */  ItemType  item)
// Pre: item is assigned &&  components in ascending order
// Post: new node containing item is in its proper place
//            && components in ascending order
{
    NodePtr currPtr;
    NodePtr prevPtr;
    NodePtr location;
     location = new  NodeType;
    location ->component = item;
    prevPtr = NULL;
     currPtr = head;
    while (currPtr != NULL  &&  item > currPtr->component)
 {
          prevPtr = currPtr;          // Advance both pointers
          currPtr = currPtr->link;
 }
 location->link = currPtr;// Insert new node here
 if  (prevPtr == NULL)
           head = location;
  else
      prevPtr->link = location;
}
```

```cpp
template <typename T>
void linkedlist<T>::insert(int idx, T v){
   //cout << idx << "-"<< v << endl;
   if (head == NULL){
      length++;
      add(v);
      return;
   }
   if (idx<0 || idx>length){
      throw "index out of bound";
   }

   if (idx==0)      { add_front(v); return; }
   if (idx==length) { add(v);      return; }

   length++;
   node<T>*p = head;
   node<T>*q = NULL;
   for (int i=0; i<=idx; i++){
      if (i==idx) {
         //cout << i << " " << q->get() << " " << p->get() << endl;
         node<T> *n = new node<T>(v);
         q->next =n;
         n->next =p;
      }
      q = p;
      p = p->next;
   }
}
```

class SortedList2

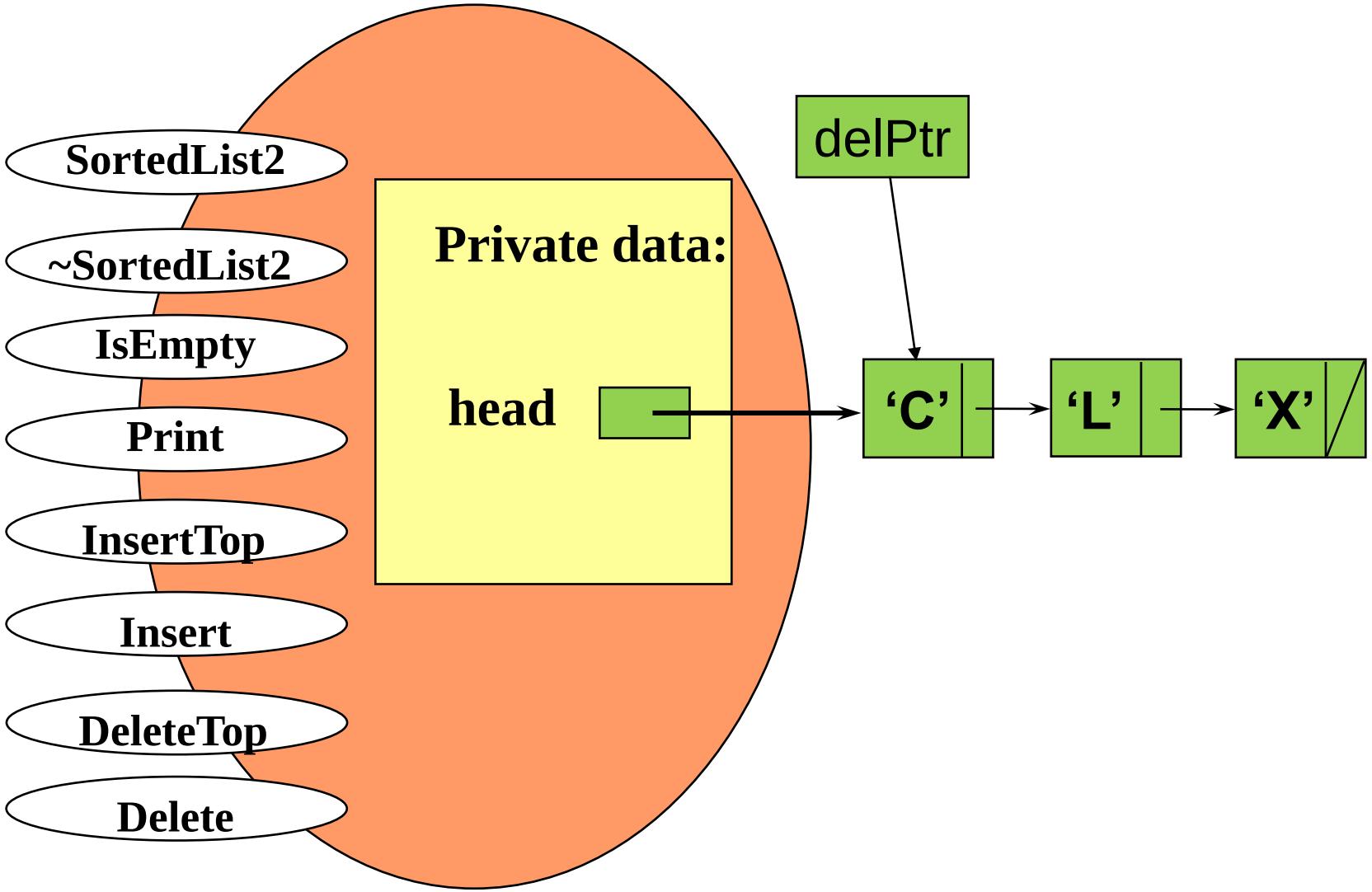


Deleting 'C' from the List

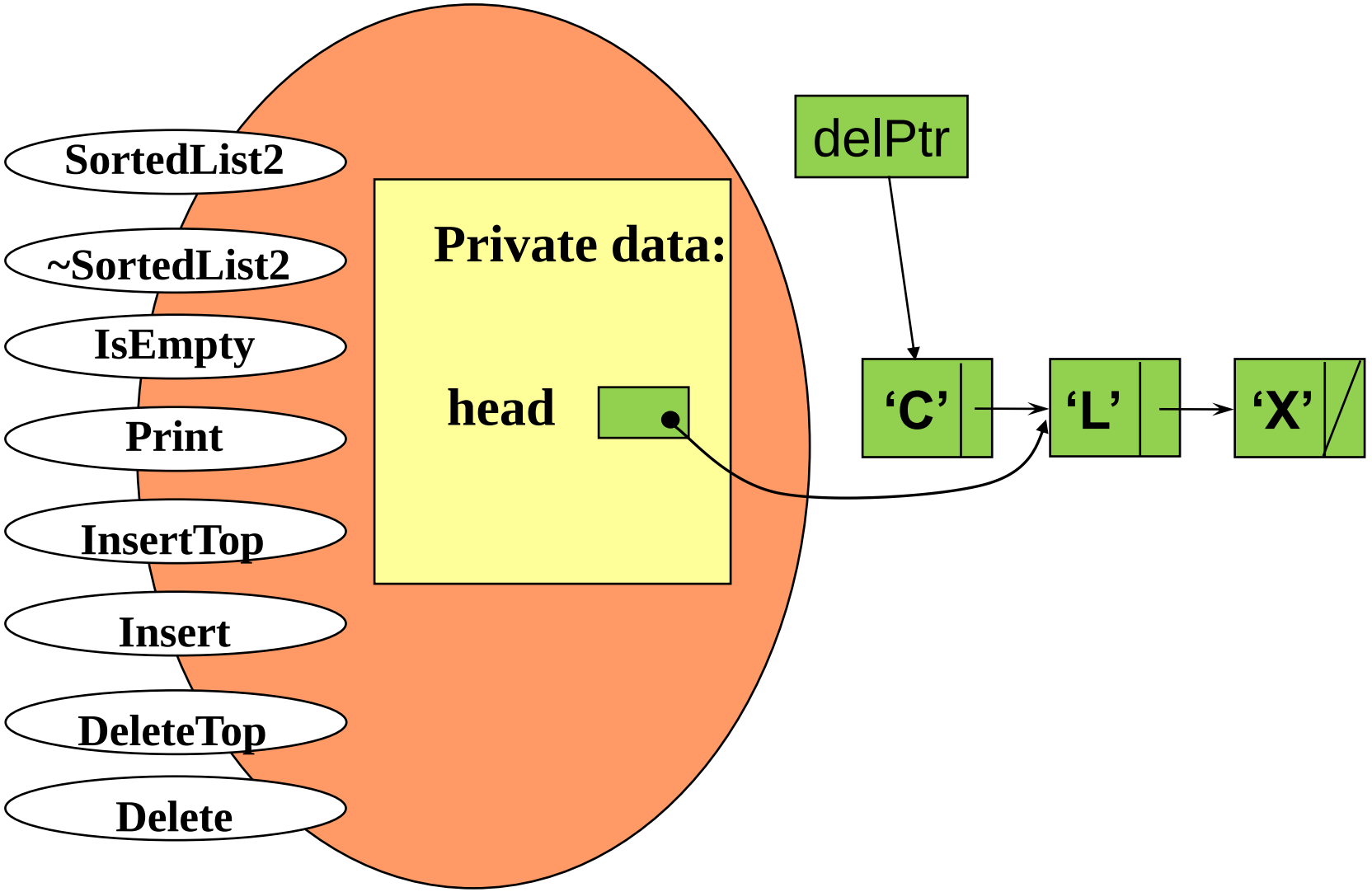


Compare "C' to head->component

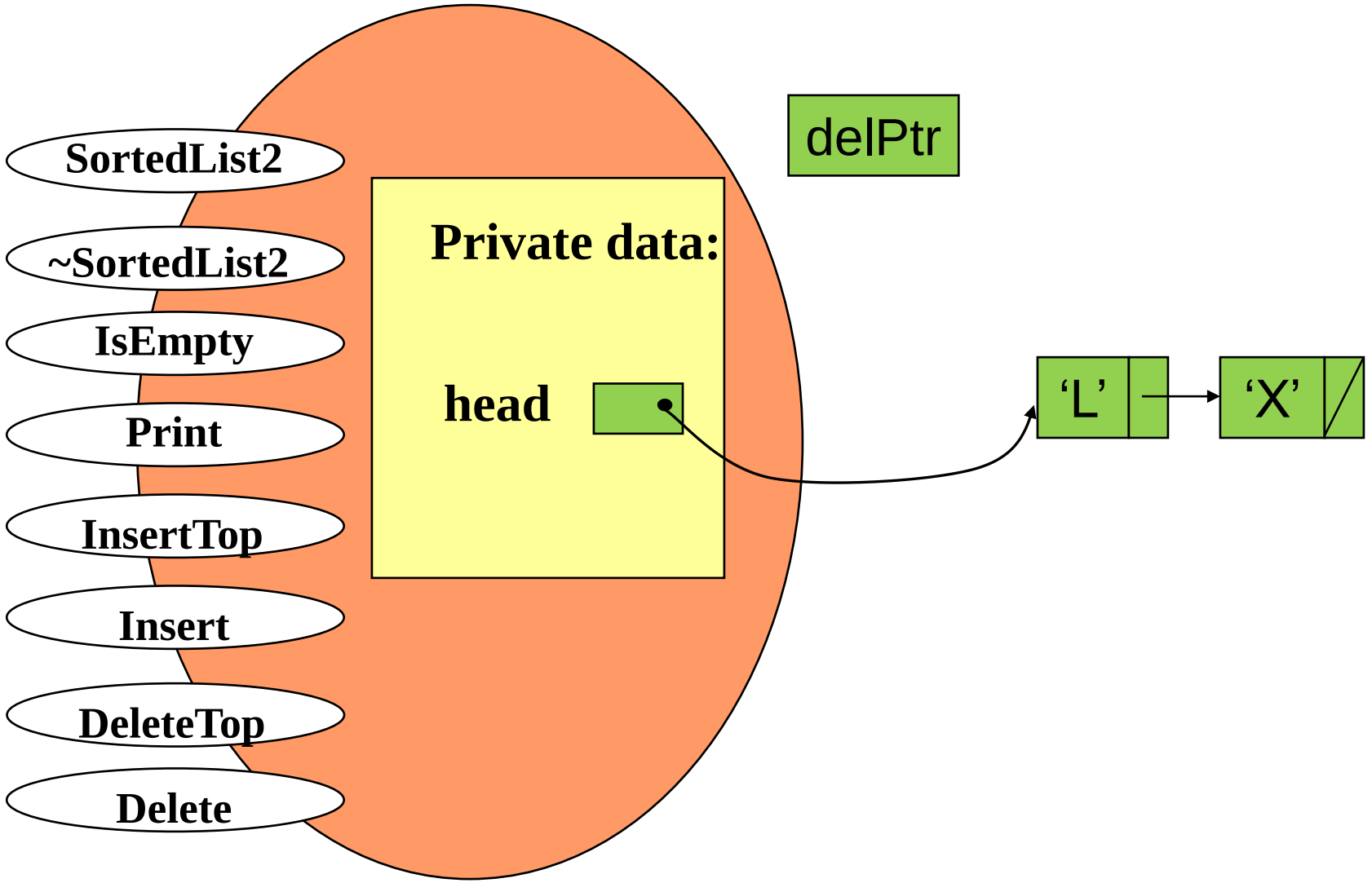
Deleting 'C' from the List



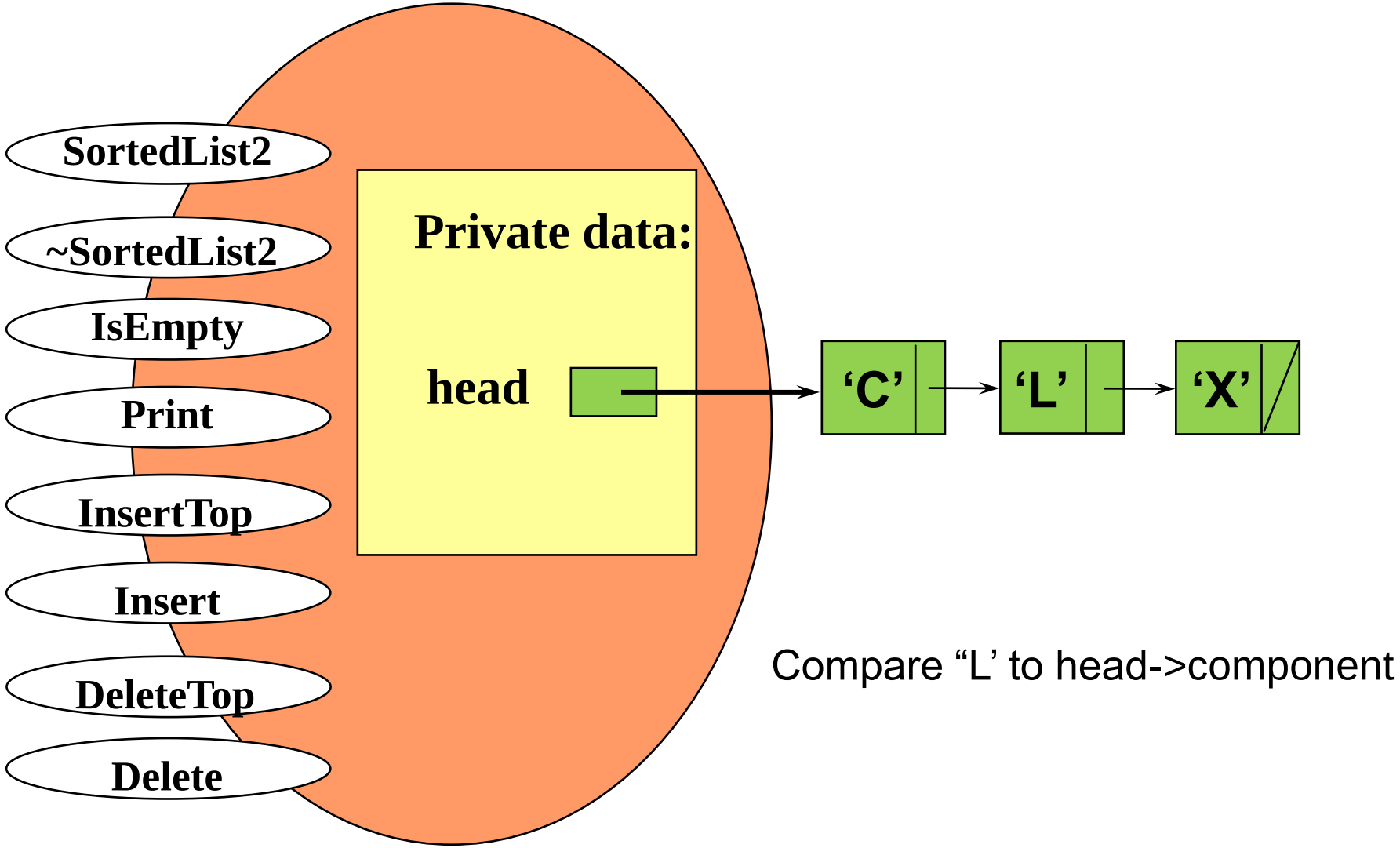
Deleting 'C' from the List



Deleting 'C' from the List

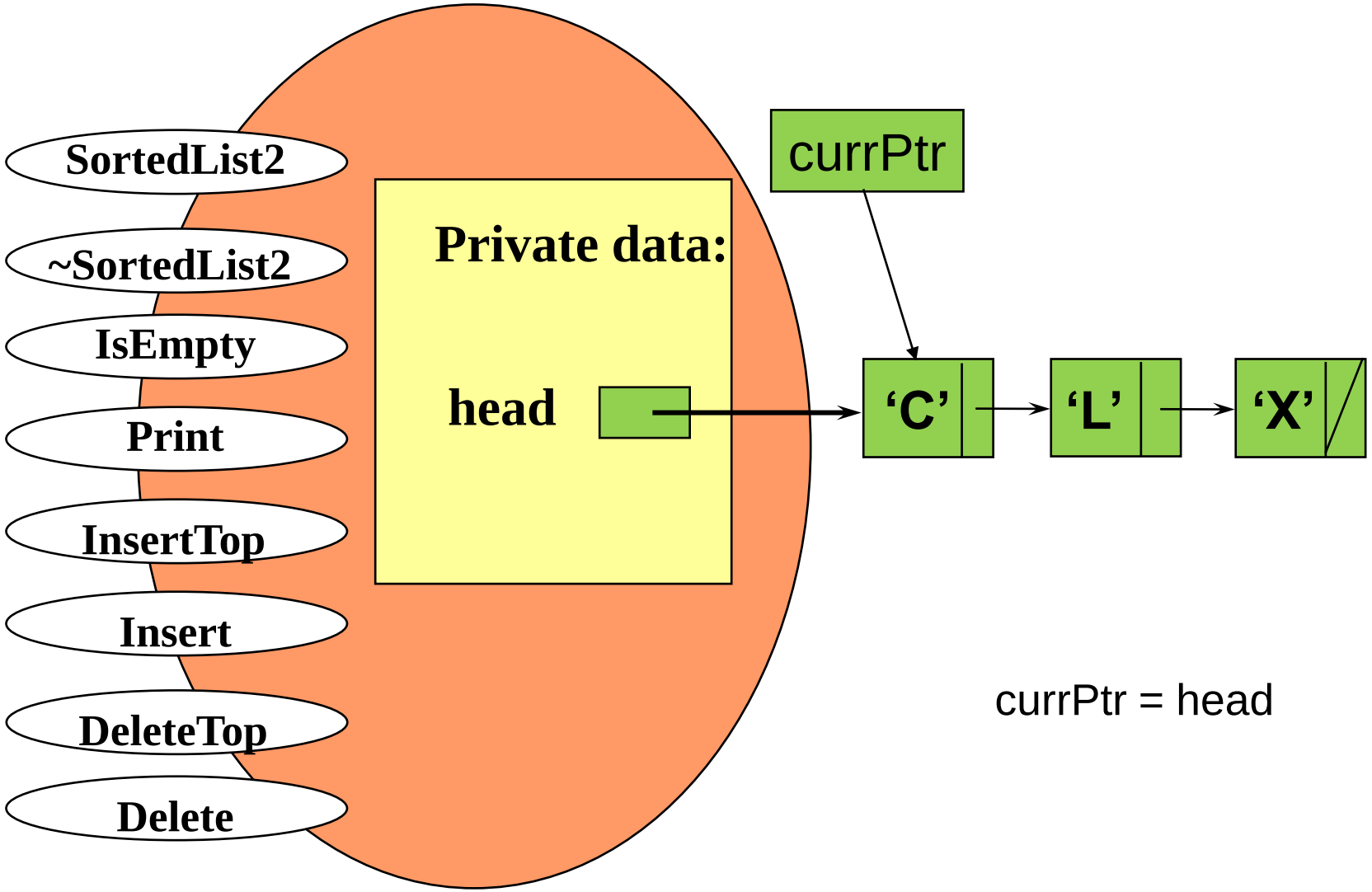


Deleting 'L' from the List

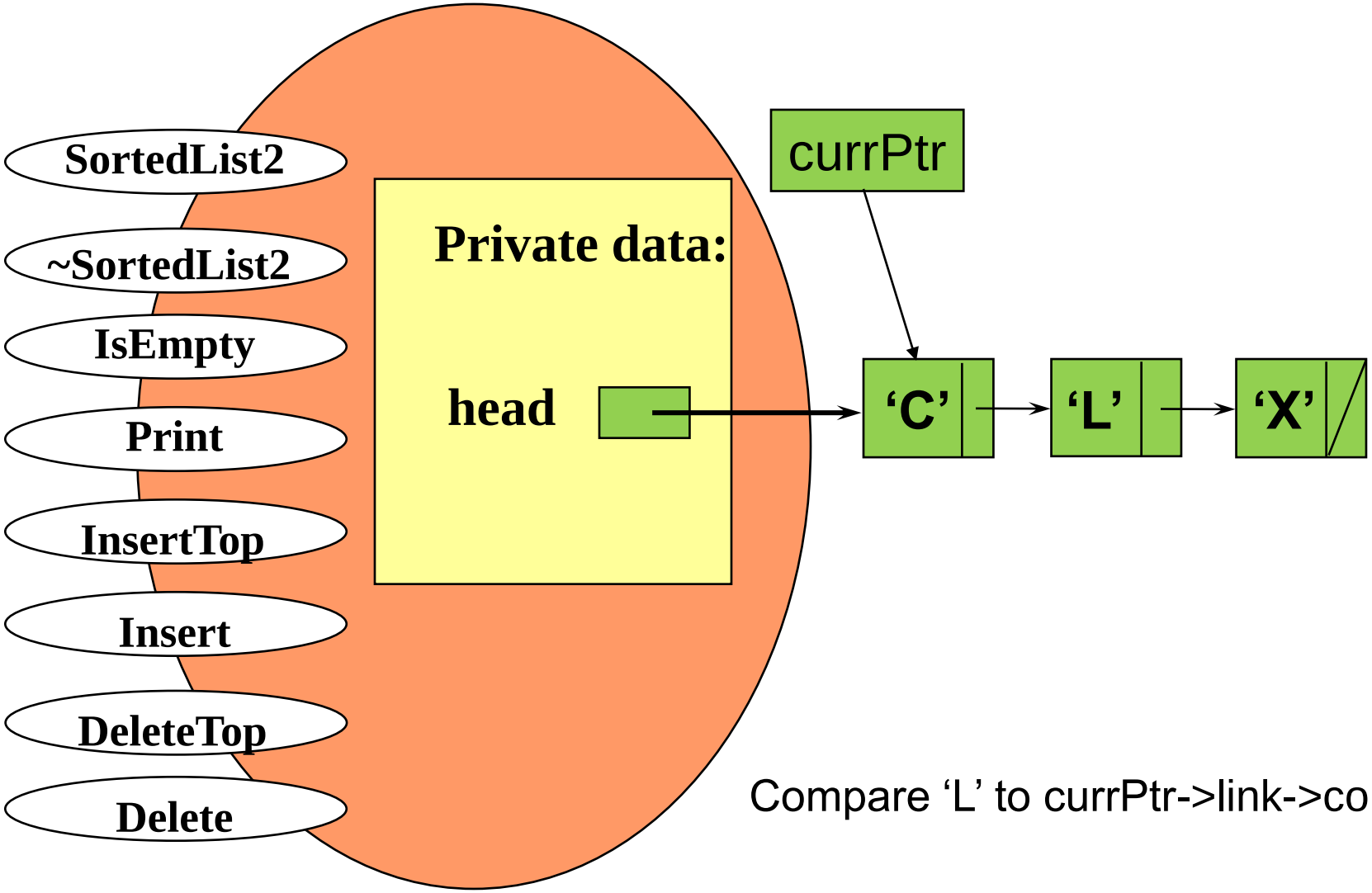


Compare "L' to head->component

Deleting 'L' from the List

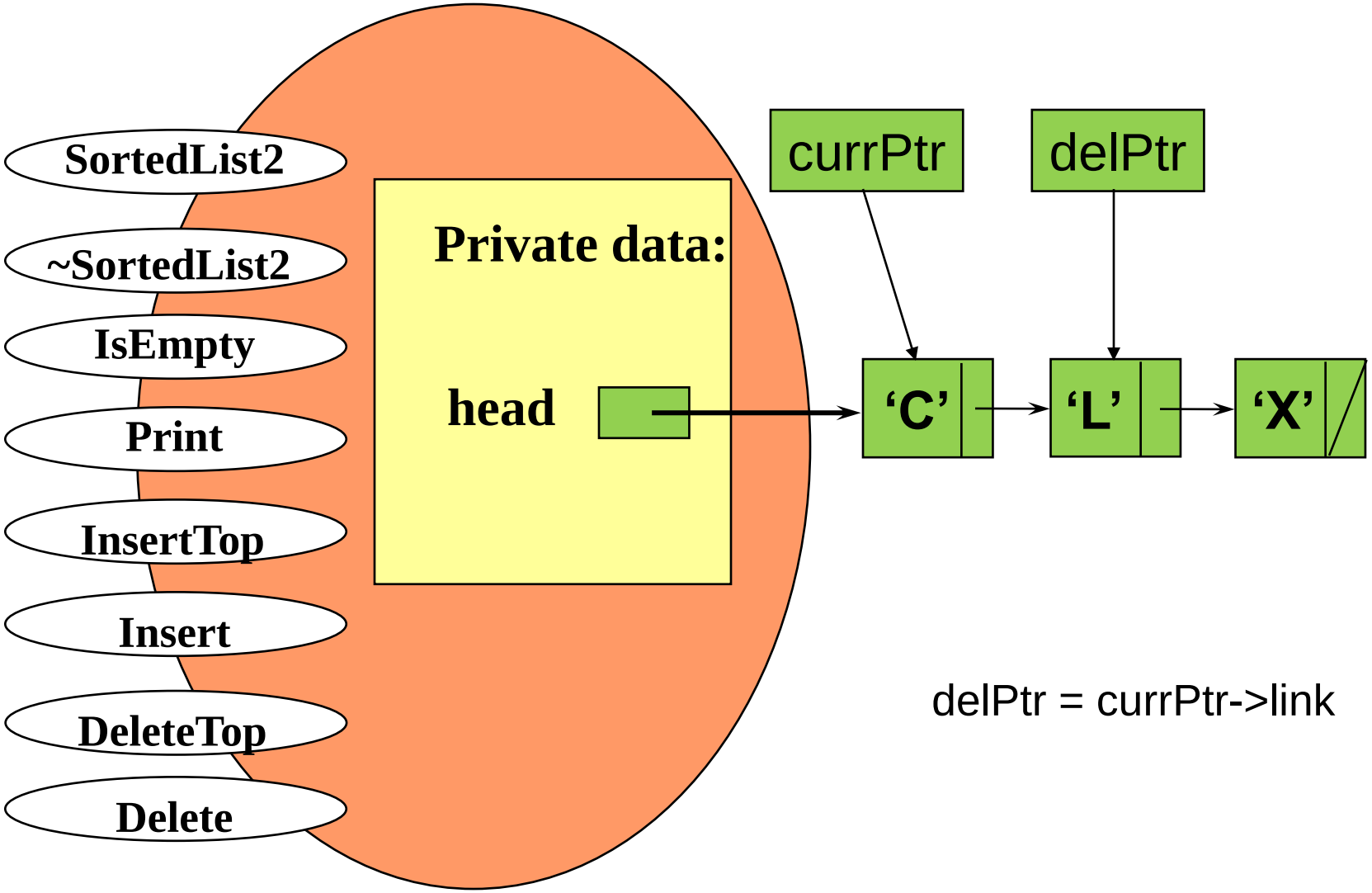


Deleting 'L' from the List

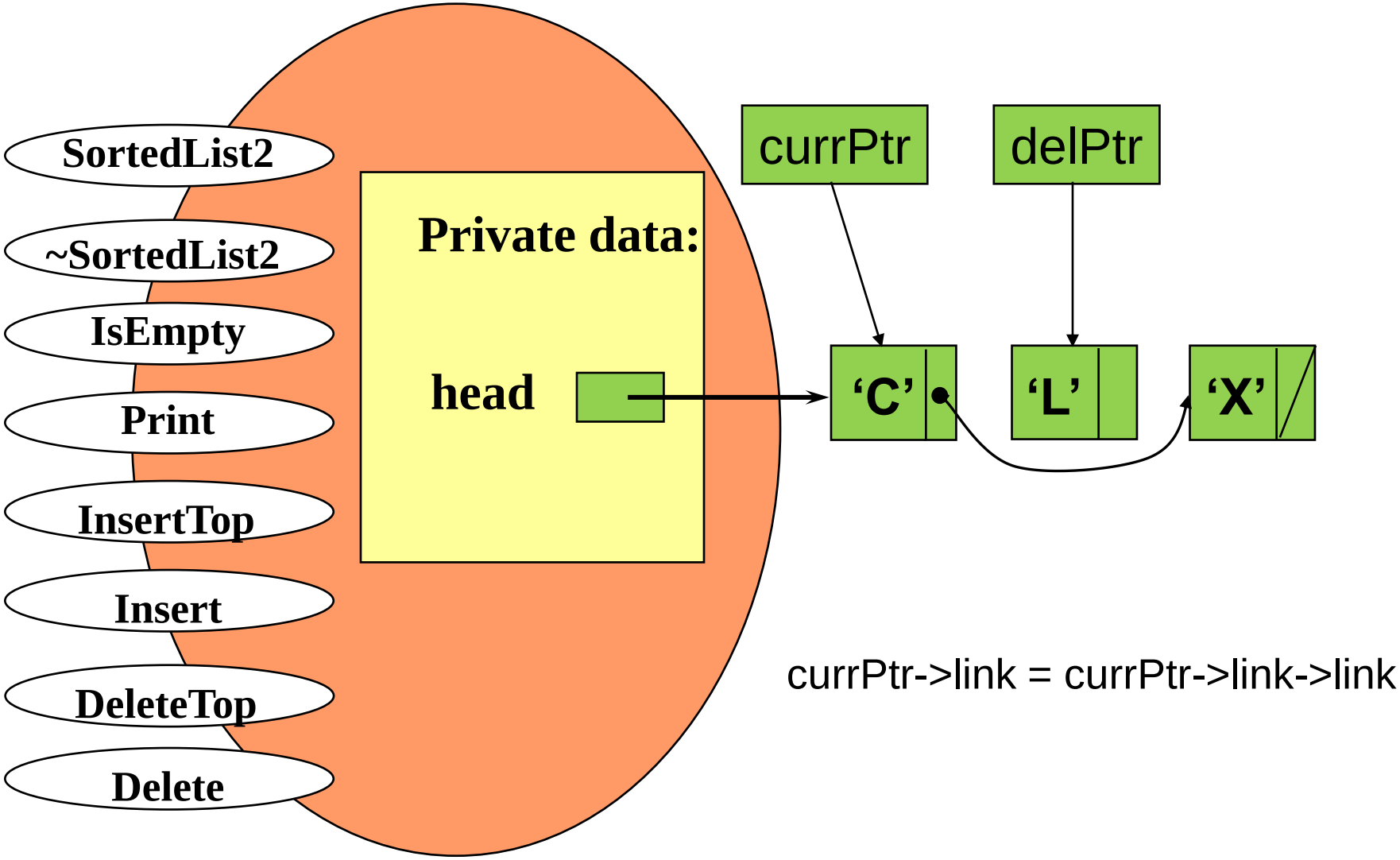


Compare 'L' to currPtr->link->component

Deleting 'L' from the List

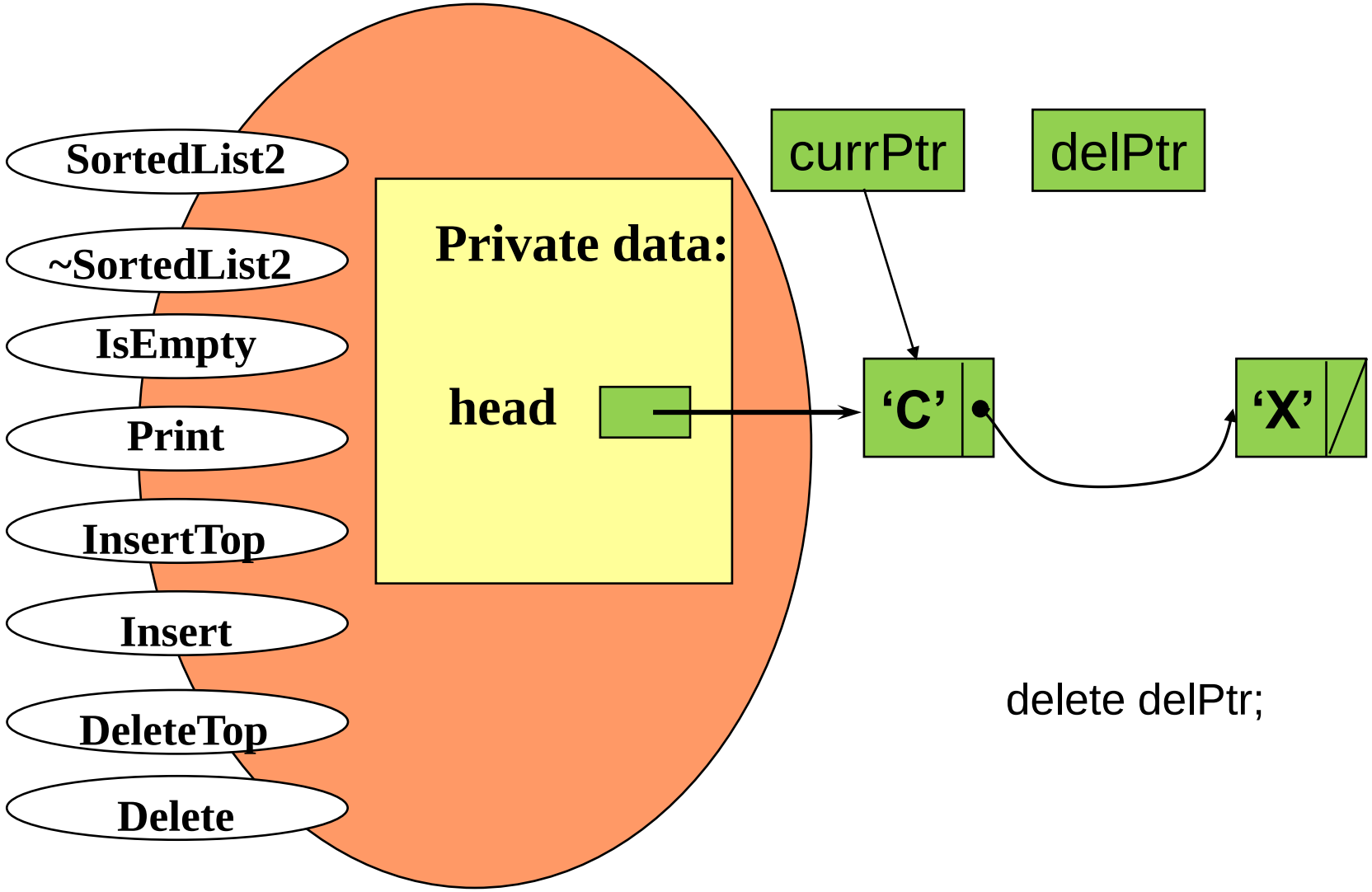


Deleting 'L' from the List



currPtr->link = currPtr->link->link

Deleting 'L' from the List



```
void  HybridList::Delete (/* in */  ItemType  item)
//  Pre: list is not empty && components in ascending order
//            &&  item == component member of some list node
// Post: item == element of first list node @ entry
//       &&  node containing first occurrence of item no longer
//       in list   &&  components in ascending order
{
    NodePtr   delPtr;
    NodePtr   currPtr; // Is item in first node?
    if (item == head->component)
    {   // If so, delete first node
        delPtr = head;
        head = head->link;
    }
    else {// Search for item in rest of list
    {
        currPtr = head;
        while (currPtr->link->component !=  item)
            currPtr = currPtr->link;
        delPtr = currPtr->link;
        currPtr->link = currPtr->link->link;
   }
    delete  delPtr;
}
```

LECTURE 4

Copy Constructor for Hybrid List

Copy Constructor

- Most difficult algorithm so far
  - If the original is empty, the copy is empty
  - Otherwise, make a copy of the head with pointer to it
  - Loop through original, copying each node and adding it to the copy until you reach the end

```
// IMPLEMENTATION DYNAMIC-LINKED SORTED LIST (slist2.cpp)
HybridList :: HybridList ( const HybridList &  otherList ) ;
// Copy Constructor
// Pre: otherList is assigned
// Post:        create a deep copy of the otherList
{
  if (otherList.head == NULL)
                head = NULL ;
  else
  {
                NodePtr otherPtr = otherList.head, thisPtr;
                head = new NodeType;
                head -> component = otherPtr -> component;
                thisPtr = head;
                otherPtr = otherPtr -> link;
                while (otherPtr != NULL)
                {
                                NodePtr tempPtr = new NodeType;
                                tempPtr -> component = otherPtr -> component;
                                thisPtr -> link = tempPtr;
                                thisPtr = tempPtr;
                                otherPtr = otherPtr -> link;
                }
                thisPtr -> link = NULL;
}
```

```
template <typename T>
void linkedlist<T>::append(linkedlist<T> *alist){
    if (head == NULL) {
        head = alist->head;
        tail    = alist->tail;
        return;
    }

    tail->next = alist->head;
    tail = alist->tail;
}
```

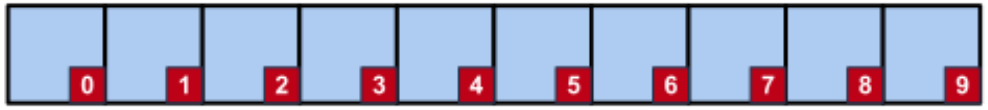
LECTURE 4

Linked Structure for Data Structure

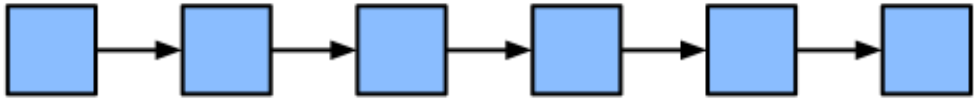
Linked-List, Array and Heap-Tree

Array & Linked List

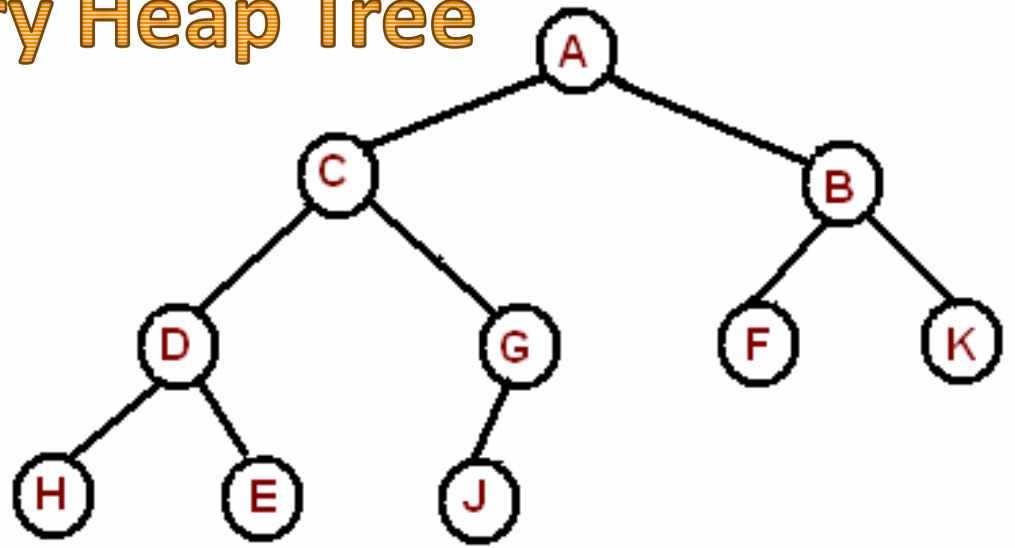
Access A[k] in O(1) time!



Access L[k] in O(n) time!



Binary Heap Tree



0	1	2	3	4	5	6	7	8	9	10
	A	C	B	D	G	F	K	H	E	J

Note: Array, Linked List and Binary Heap Tree are used to build all data collections

Data Structures

Basic Abstract Data Type:

- Array
- Linked List
- Binary Tree (Iterable Heap Tree)

Note: In this course, we covered these topics.

Advanced Abstract Data Type:

- Hashing
- Graph
- Matrix
- Misc
- Advanced Data Structure

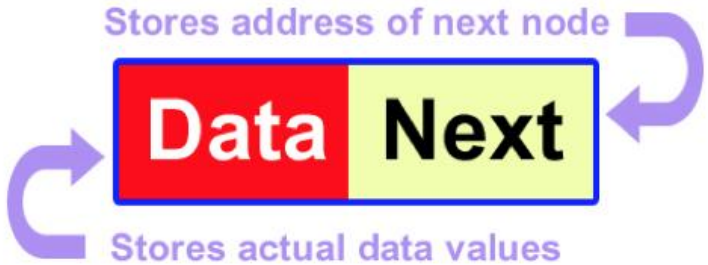
Abstract Data Type (Data Collections):

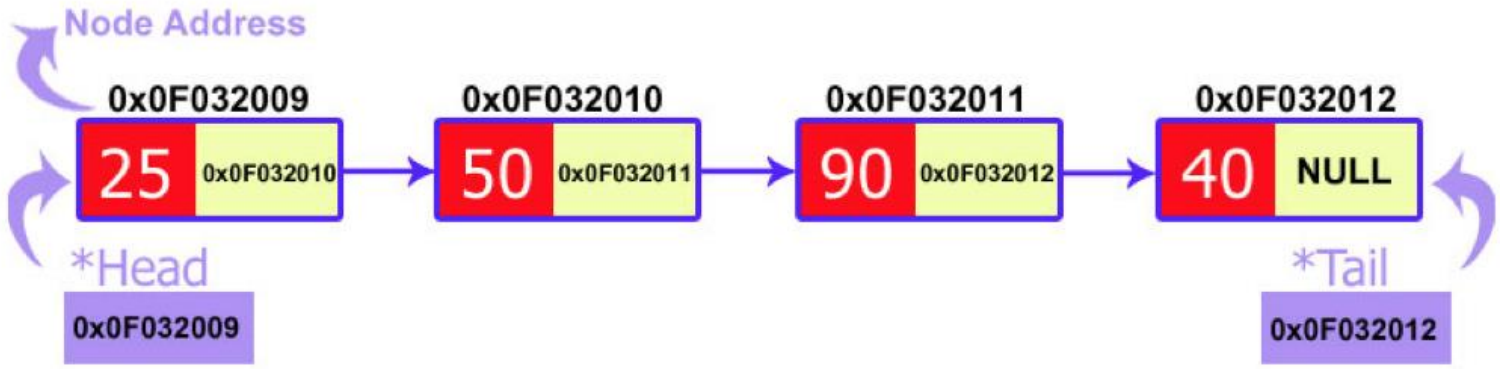
- Stack
- Queue
- Priority Queue
- Binary Tree
- Binary Search Tree
- Heap
- Set
- Map

linkedlist<T>

+length: int;
+head: node<T>
+tail: node<T> *

+size(void): int
+isempty(): bool
+indexOf(T obj): int
+get(int idx): T
+to_string():string
+set(int idx, T v): void
+add(T v):void
+add_front(T v): void
+insert(int idx, T v): void
+remove(): node<T> *
+remove_front(): node<T>*
+append(linkedlist<T> *alist): void





```
template<typename T>
int linkedlist<T>::size(){  // list.length
   return length;
}

template<typename T>
bool linkedlist<T>::isempty(){
   return (length==0);
}

template <typename T>
int linkedlist<T>::indexOf(T obj){
   node<T> *p = head;

   int i = 0;
   int idx = -1;
   bool found = false;

   while (p != NULL && !found){
      if (p->get() == obj){
         idx = i;
      }
      i++;
      p = p->next;
   }
   return idx;
}
```

```
T linkedlist<T>::get(int idx){
   T rtn;
   node<T>*p = head;
   if (head == NULL){
      throw "empty list";
   }
   if (idx<0 || idx>=length){
      throw "index out of bound";
   }
   for (int i=0; i<=idx; i++){
      if (i==idx) rtn = p->get();
      p = p->next;
   }
   return rtn;
}

template <typename T>
void linkedlist<T>::set(int idx, T v){
   node<T>*p = head;
   if (head == NULL){
      throw "empty list";
   }
   if (idx<0 || idx>=length){
      throw "index out of bound";
   }
   for (int i=0; i<=idx; i++){
      if (i==idx) p->set(v);
      p = p->next;
   }
}
```

```
template <typename T>
void linkedlist<T>::add(T v){
   length++;
   node<T> *n = new node<T>(v);
   if (head == NULL){
      head = n;
      head->next = NULL;
      tail = n;
      return;
   }

   node<T> *p = (node<T> *) head;
   node<T> *q = NULL;
      while (p!= NULL){
      q = p;
      p=p->next;
   }
   tail = n;
   q->next = n;
   n->next = NULL;
}
```

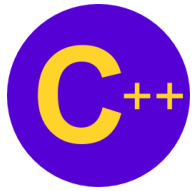
```
template <typename T>
void linkedlist<T>::add_front(T v){
   length++;
   node<T> *n = new node<T>(v);
   if (head == NULL){
      head = n;
      head->next = NULL;
      tail = n;
      return;
   }

   node<T> *p = (node<T> *) head;
   head = n;
   n->next = p;
}
```

```
template <typename T>
void linkedlist<T>::insert(int idx, T v){
   //cout << idx << "-"<< v << endl;
   if (head == NULL){
      length++;
      add(v);
      return;
   }
   if (idx<0 || idx>length){
      throw "index out of bound";
   }

   if (idx==0)      { add_front(v); return; }
   if (idx==length) { add(v);       return; }

   length++;
   node<T>*p = head;
   node<T>*q = NULL;
   for (int i=0; i<=idx; i++){
      if (i==idx) {
         //cout << i << " " << q->get() << " " << p->get() << endl;
         node<T> *n = new node<T>(v);
         q->next =n;
         n->next =p;
      }
      q = p;
      p = p->next;
   }
}
```

```
template <typename T>
node<T>* linkedlist<T>::remove(){
  if (head == NULL){ // zero element
    return NULL;
  }

  length--;
  node<T> *p = (node<T> *) head;
  node<T> *q = NULL;
  node<T> *r = NULL;
    while (p!= NULL){
    r = q;
     q = p;
     p=p->next;
  }

  if (r==NULL){ // only one element
    head = NULL;
    tail = NULL;
    return q;
  }

  r->next = NULL;
  tail = r;
  return q;
}
```

```
template <typename T>
node<T>* linkedlist<T>::remove_front(){
  if (head == NULL){ // zero element
    return NULL;
  }

  length--;
  if (head->next == NULL){
    node<T>* q = head;
    head = NULL;
    tail = NULL;
    return q;
  }

  node<T>* q = head;
  head = head->next;
  return q;
}
```

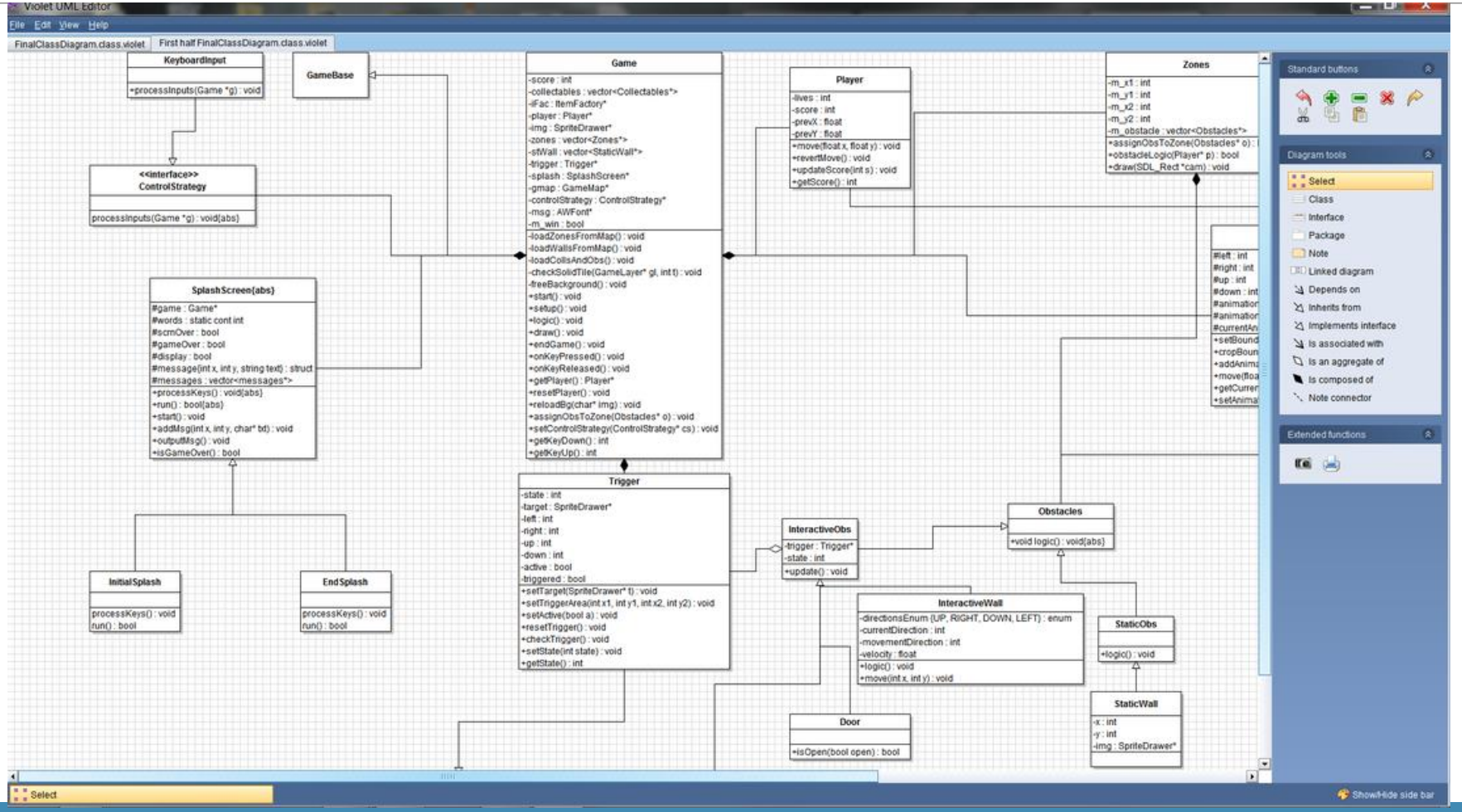
```
template <typename T>
string linkedlist<T>::to_string(){
  string str("");
  node<T> *p = head;
   str += "[";
   int count = 0;
   while (p!= NULL){
     if (count ==0) str += st::to_string(head->get());
     else str += ", "+ st::to_string(p->get());
     count++;
     p=p->next;
   }
   str += "]";
   return str;
}

template <typename T>
void linkedlist<T>::append(linkedlist<T> *alist){
   if (head == NULL) {
     head = alist->head;
     tail   = alist->tail;
     return;
   }

   tail->next = alist->head;
   tail = alist->tail;
}
```



Demo Program: linkedlist.cpp

Go Notepad++!!!

Demo Program: linkedlist.class.violet.html



Violet UML Editor

Get ready for Violet 2.0.0!

home demo

- Home
- What is UML?
- Quick tour
- Features
- Wish List
- Demo
- Download
- Documentation
  - Installation
  - User guide
  - Developer guide
  - Books
- Authors
- Contact us

Violet is a UML editor with these benefits:
Very easy to learn and use. Draws nice-looking diagrams. Completely free.
Cross-platform. Violet is intended for developers, students, teachers, and authors who need to produce simple UML diagrams quickly

Download now

Run it now!

LECTURE 5

Binary Tree Implementation

tnode class

Data Field:

- val (data), left/right pointers

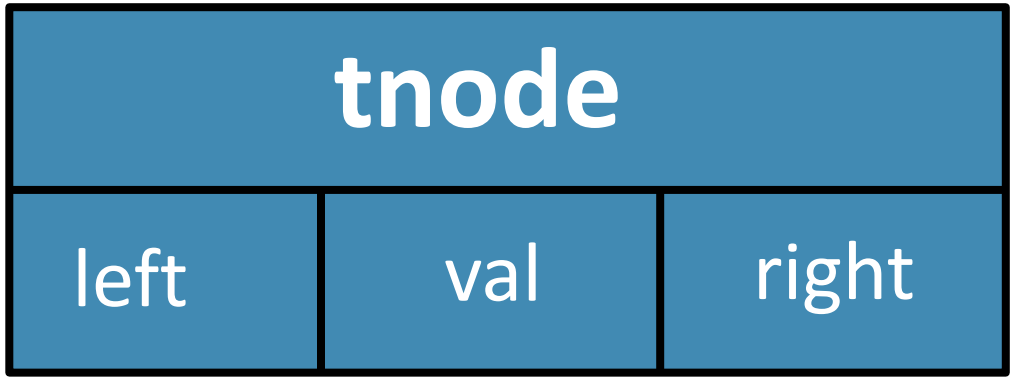
Methods:

- get(), set(v), getLeft(), hasLeft(), setLeft(), getRight(), hasRight(), setRight()
- Constructors: tnode(), tnode(v), tnode(v, lp, rp)
- tostring()

Friend Functions:

- tostring(tnode<T> *p), >>, <<

tnode



tnode.h

```
template<typename T>
class tnode{
      T val;
      tnode<T> *left;
      tnode<T> *right;
      char buf[256];
    public:
      tnode(): val(0), left(nullptr), right(nullptr){}
      tnode(int v): val(v), left(nullptr), right(nullptr){}
      tnode(int v, tnode<T> *lp, tnode<T> *rp): val(v), left(lp), right(rp){}
      tnode(tnode<T> &p): val(p.val), left(p.left), right(p.right){}
      void operator=(tnode<T> &p){ val = p.val; left = p.left; right=p.right;}

      T get(){ return val; }
      void set(int v){ val = v; }
      tnode<T> *getLeft(){ return left; }
      void setLeft(tnode<T> *ll){ left=ll; }
      bool hasLeft(){ return left != nullptr; }
      tnode<T> *getRight(){ return right; }
      void setRight(tnode<T> *rr){ right=rr; }
      bool hasRight(){ return right != nullptr; }

      string tostring(){ return to_string(val); }
      friend string to_string(tnode<T> &p){ return p.tostring(); }
```

tnode.h

```
  void print(ostream& out){
    out << tostring().c_str();
  }

  void read(istream& in){
    in >> buf;
    val = atoi(buf); // ASCII to integer in cstring
  }

  friend ostream& operator<<(ostream& out, tnode<T>& n){
       n.print(out);
       return out;
}

  friend istream& operator>>(istream& in, tnode<T>& n){
      n.read(in);
      return in;
}
```

tnode.h

```
friend void inorder(tnode<T> *top){
    if (top==nullptr) return;
    cout << "[" ;
    inorder(top->getLeft());
    if (top->getLeft()) cout << ", " ;
    cout << top->val;
    if (top->getRight()) cout << ", " ;
    inorder(top->getRight());
    cout << "]";
}

friend void preorder(tnode<T> *top){
    if (top==nullptr) return;
    cout << "{" ;
    cout << top->val;
    if (top->getLeft()) cout << "->";
    preorder(top->getLeft());
    if (top->getRight()) cout << "->" ;
    preorder(top->getRight());
    cout << "}";
}
```

```
friend void postorder(tnode<T> *top){
    if (top==nullptr) return;
    cout << "(" ;
    postorder(top->getLeft());
    if (top->getLeft()) cout << "->" ;
    postorder(top->getRight());
    if (top->getRight()) cout << "->";
    cout << top->val;
    cout << ")";
}
};
```

Demo Program: testtnode.cpp

```
#include <iostream>
#include "tnode.h"
using namespace std;
int main(){
    tnode<int> *t1 = new tnode<int>(3);
    tnode<int> *t2 = new tnode<int>(2);
    tnode<int> *t3 = new tnode<int>(4);

    t1->setLeft(t2);
    t1->setRight(t3);
    inorder(t1);
    cout << endl;
    preorder(t1);
    cout << endl;
    postorder(t1);
    delete t1, t2, t3;
    return 0;
}
```

```
[[2], 3, [4]]
{3->{2}->{4}}
((2)->(4)->3)
```

tree class

Data Field:

- tnode<T> root;

Method:

- add(int v);
- print();

tree.h

```
template <typename T>
class tree{
      tnode<T> *root;
    public:
      tree(): root(nullptr){}

      void add(int v){
          if (!root){
              tnode<T> *n = new tnode<T>(v);
              root = n;
              return;
          }
          addx(root, v);
      }
      void print(){
         inorder(root);
      }
```

```
      void addx(tnode<T> *top, int v){
         if (v < top->get()){
             if (top->hasLeft()){
                addx(top->getLeft(), v);
             }
             else {
                tnode<T> *n = new tnode<T>(v);
                top->setLeft(n);
                return;
             }
         }
         if (v > top->get()){
             if (top->hasRight()){
                addx(top->getRight(), v);
             }
             else {
                tnode<T> *n = new tnode<T>(v);
                top->setRight(n);
                return;
             }
         }
      }
};
```

Demo Program: testtree.cpp

```
#include <iostream>
#include "tree.h"
#include "tnode.h"
using namespace std;
int main(void){
    tree<int> t;
    t.add(10);
    t.add(12);
    t.add(3);
    t.add(4);
    t.add(1);
    t.add(13);
    t.add(6);
    t.add(9);
    t.add(15);
    t.add(14);
    t.add(19);
    t.print();
    return 0;
}
```

[[[1], 3, [4, [6, [9]]]], 10, [12, [13, [[14], 15, [19]]]]]