Data Structures

8. Linked Lists

Roadmap

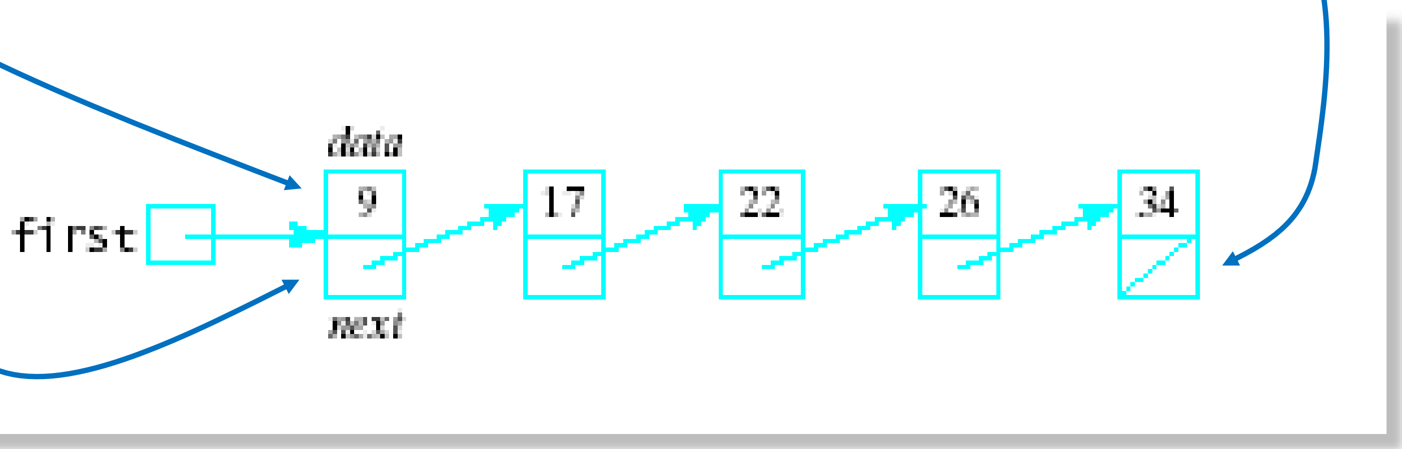
- List as an ADT
- An array-based implementation of lists

- Introduction to linked lists
- A pointer-based implementation in C++
- Variations of linked lists

Linked List Using Pointers-Based Implementation of Lists

Linked List

- Linked list nodes composed of two parts
  - Data part
    - ➢ Stores an element of the list
  - Next part
    - ➢ Stores link/pointer to next element
    - ➢ Stores Null value, when no next element



Simple Linked List Class (1)

- We use two classes: Node and List
- Declare Node class for the nodes
  - `data:` double-type data in this example
  - `next:` a pointer to the next node in the list

```
class Node {
   public:
      double   data;   // data
      Node*    next;   // pointer to next
};
```

Simple Linked List Class (2)

- Declare List, which contains
  - `head:` a pointer to the first node in the list
  - Since the list is empty initially, `head` is set to `NULL`

```
class List {
    public:
        List(void) { head = NULL; } // constructor
        ~List(void);                 // destructor

        bool IsEmpty() { return head == NULL; }
        Node* InsertNode(int index, double x);
        int FindNode(double x);
        int DeleteNode(double x);
        void DisplayList(void);
    private:
        Node* head;
};
```

Simple Linked List Class (3)

Operations of 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

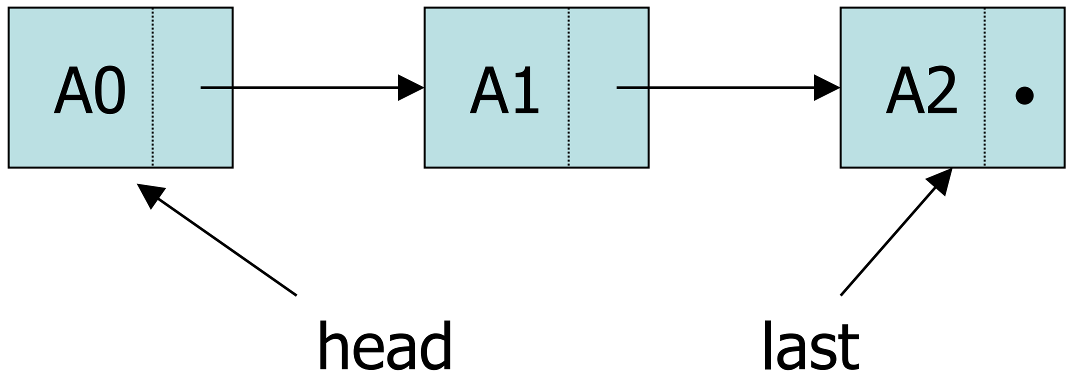
Inserting a New Node

- **`Node* InsertNode(int index, double x)`**
  - Insert a node with data equal to x after the index elements
  - If the insertion is successful
    - Return the inserted node
    - Otherwise, return `NULL`
  - If index is `< 0` or `>` length of the list, the insertion will fail

- Steps
  1. Locate the element at the index position
  2. Allocate memory for the new node, copy data into node
  3. Point the new node to its successor (next node)
  4. Point the new node’s predecessor (preceding node) to the new node

Insertion After The Last Element (1)

- Suppose `last` points to the last element of the list
  - We can add a new last item x by doing this



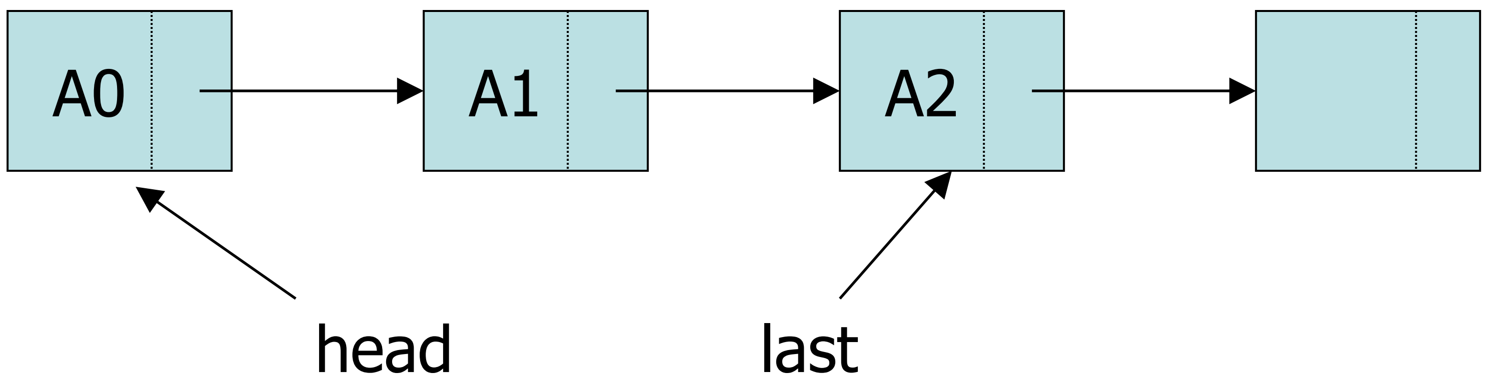

```
last->next = new Node();
last = last->next;
last->data = x;
last->next = null;
```

Steps

- Locate the index element
- Allocate memory for the new node
- Copy data into node
- Point the new node to its successor (next node)
- Point the new node's predecessor (preceding node) to the new node

Insertion After The Last Element (2)

- Suppose `last` points to the last element of the list
  - We can add a new last item x by doing this

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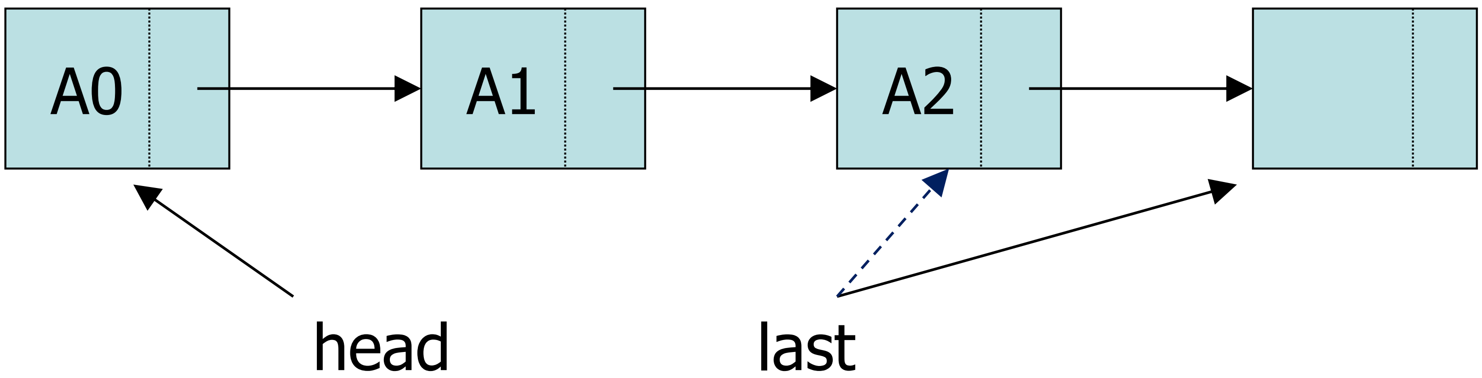


```
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last = last->next;
last->data = x;
last->next = null;
```

Steps

- Locate the index element
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- Copy data into node
- Point the new node to its successor (next node)
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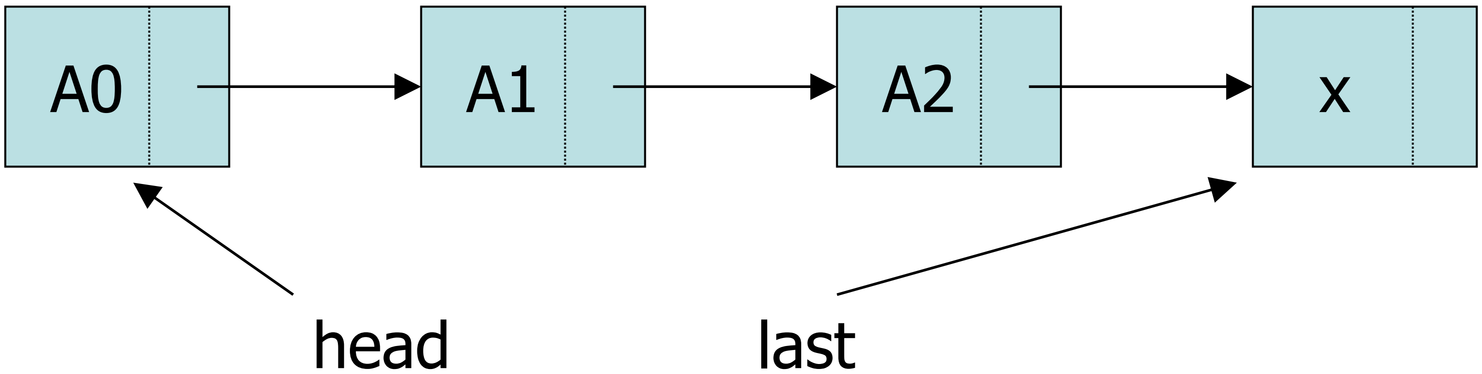
Insertion After The Last Element (4)

- Suppose `last` points to the last element of the list
  - We can add a new last item x by doing this




```
last->next = new Node();
last = last->next;
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last->next = null;
```

Steps

- Locate the index element
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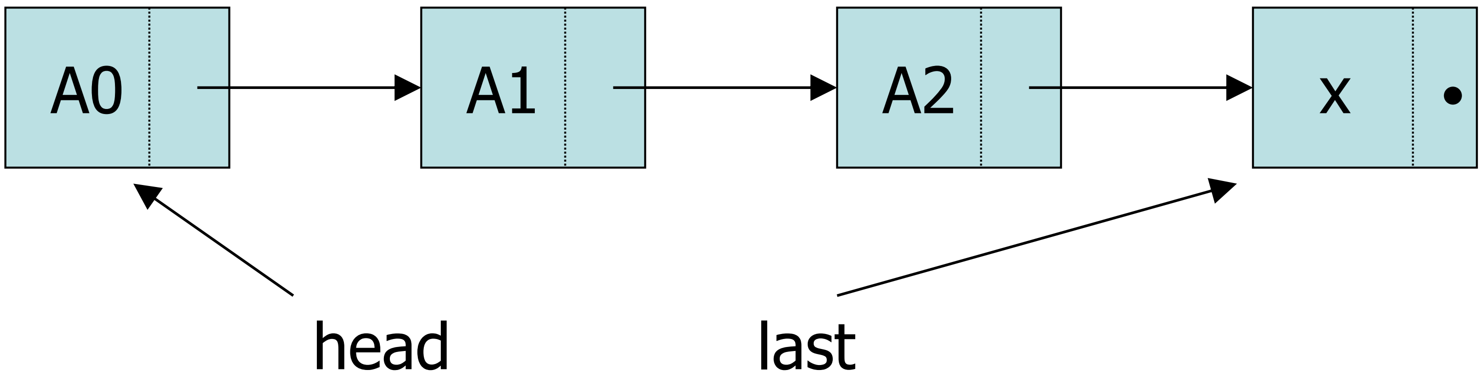


```
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Steps

- Locate the index element
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- Copy data into node
- Point the new node to its successor (next node)
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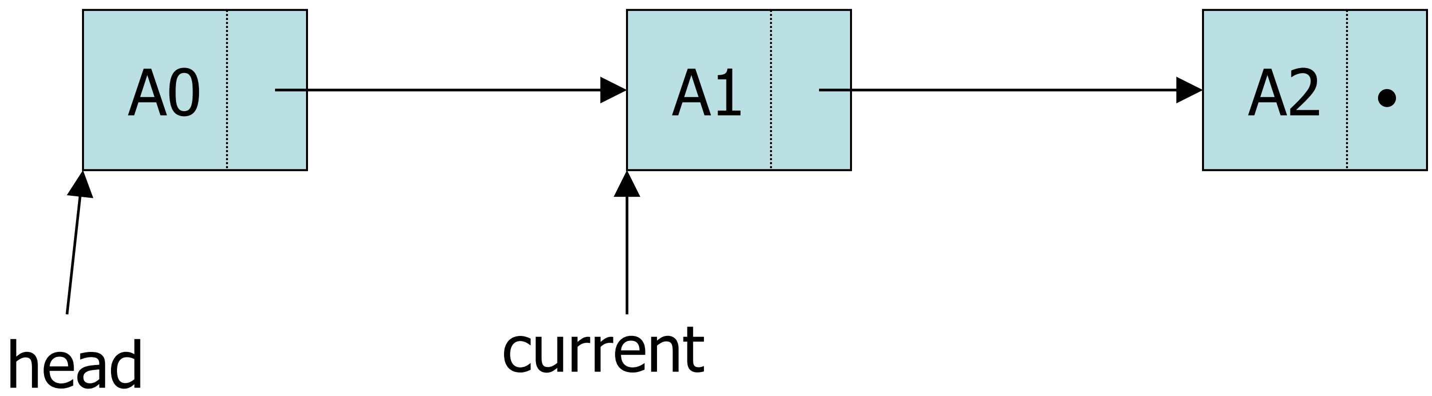
Insertion At The Middle (1)

- Suppose `current` points to the middle element of the list
  - We can add a new last item x by doing this




```
tmp = new Node();
tmp->data= x;
tmp->next = current->next;
current->next = tmp;
```

Insertion At The Middle (1)

- Suppose `current` points to the middle element of the list
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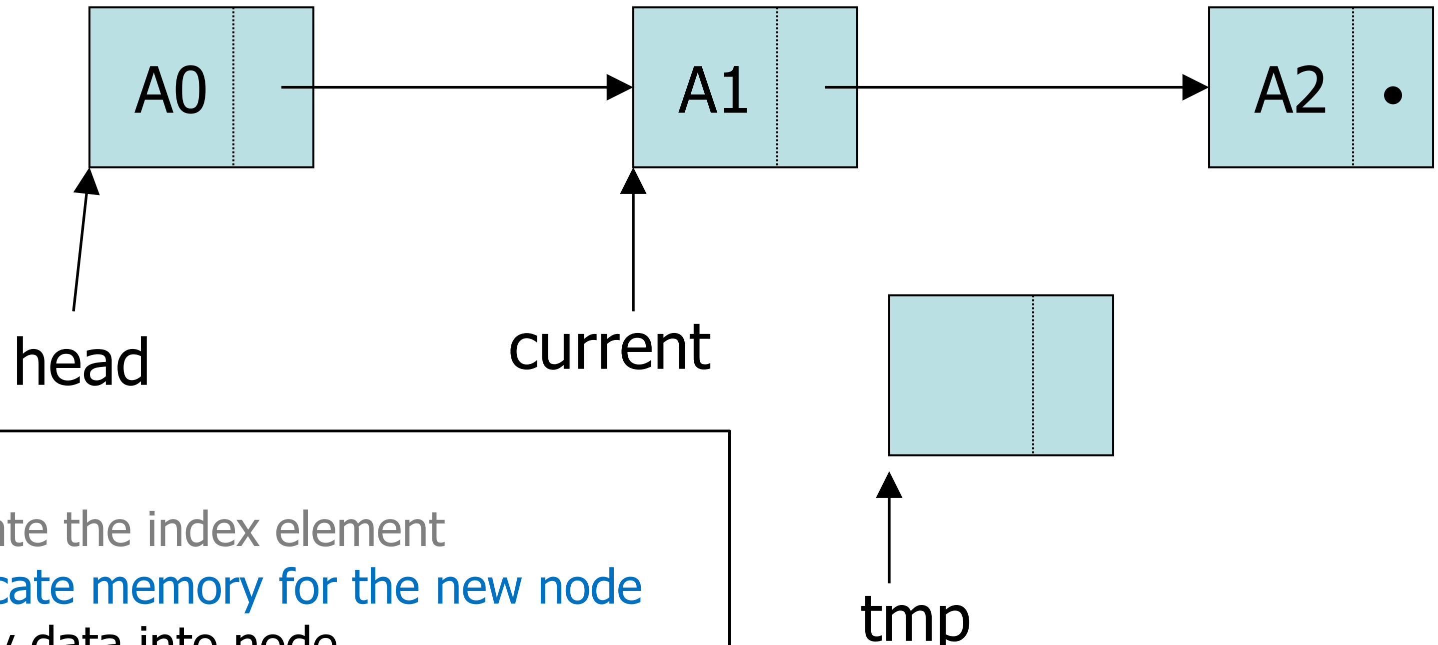

Steps

- Locate the index element
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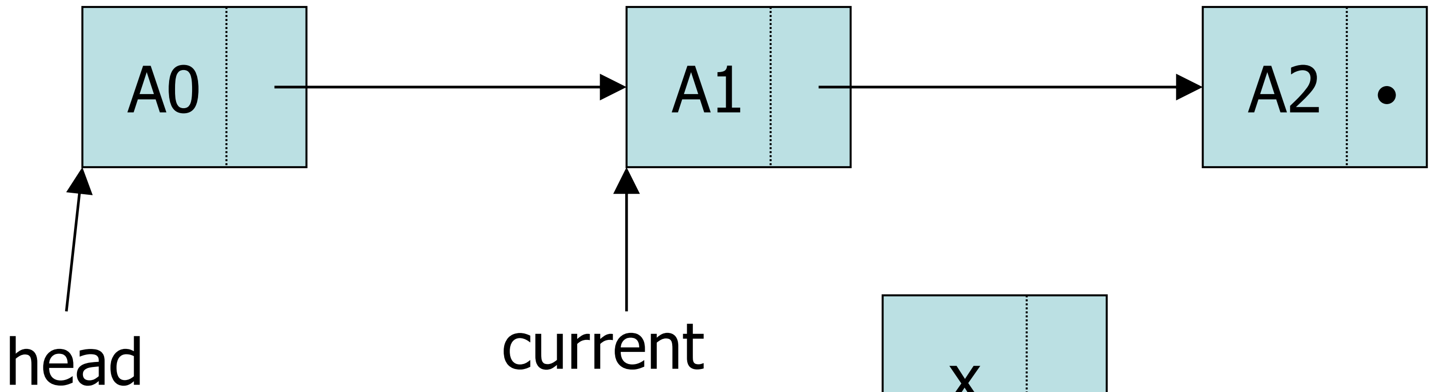

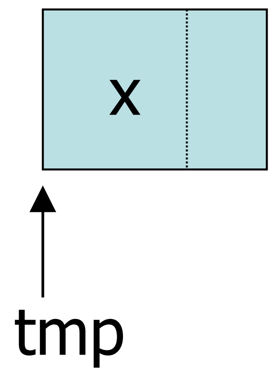

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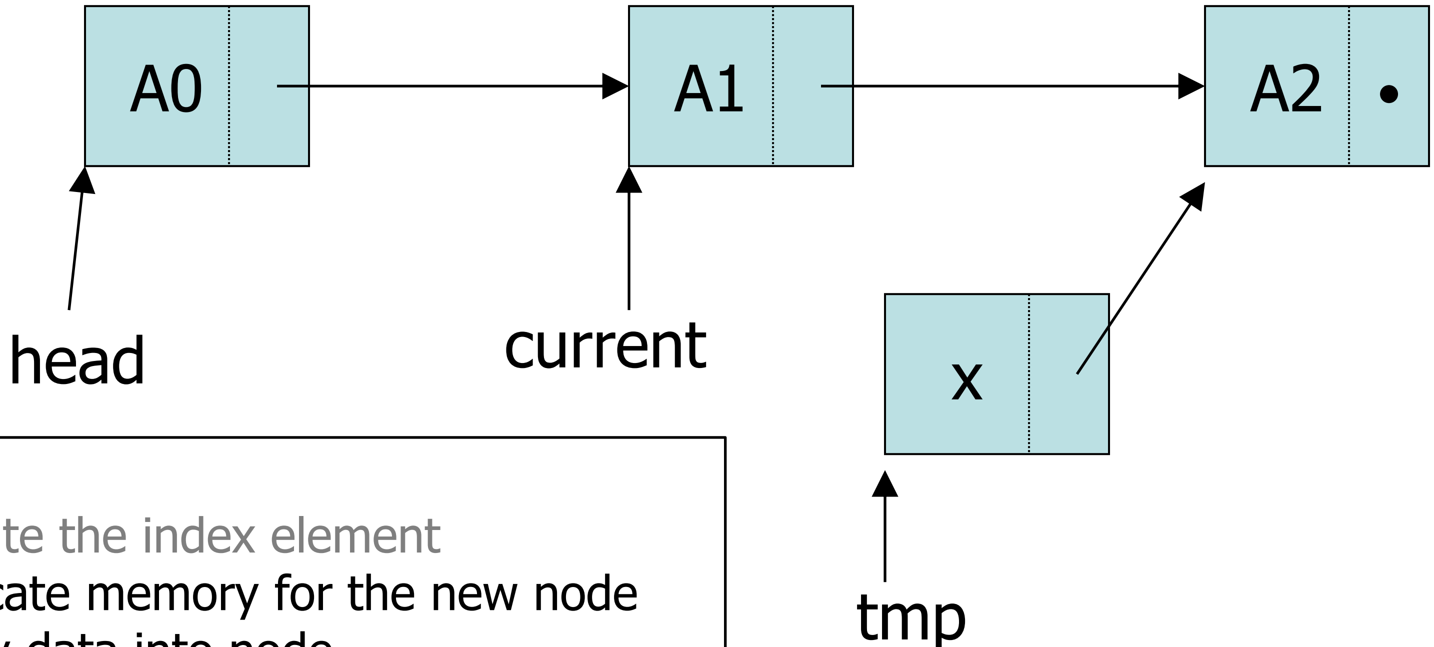

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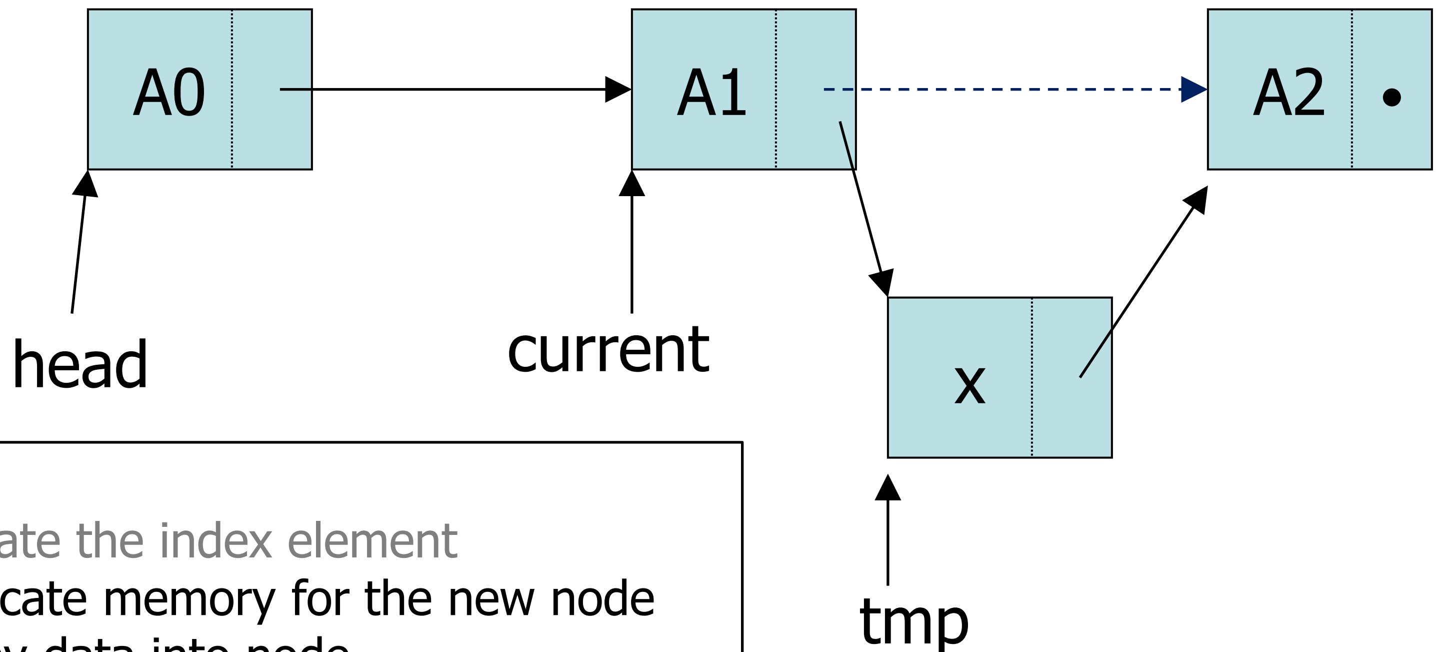

Steps

- Locate the index element
- Allocate memory for the new node
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```
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tmp->data= x;
tmp->next = current->next;
current->next = tmp;
```

Inserting a New Node (2)

- Possible cases of `InsertNode`
  1. Insert into an empty list
  2. Insert in front
  3. Insert at back
  4. Insert in middle

- In fact, only need to handle two cases
  - Insert as the first node (Case 1 and Case 2)
  - Insert in the middle or at the end of the list (Case 3 and Case 4)

Inserting a New Node (3)

```
Node* List::InsertNode(int index, double x) {
        if (index < 0) return NULL;

        int currIndex   =   1;
        Node* currNode  =   head;
        while (currNode && index > currIndex) {
                currNode   = currNode->next;
                currIndex++;
        }
        if (index > 0 && currNode == NULL) return NULL;

        Node* newNode =  new Node;
        newNode->data =  x;
        if (index == 0) {
                newNode->next  =    head;
                head             =   newNode;
        }
        else {
                newNode->next    =   currNode->next;
                currNode->next   =   newNode;
        }
        return newNode;
}
```

Try to locate index'th node. If it doesn't exist, return NULL

Inserting a New Node (3)

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        newNode->data =  x;
        if (index == 0) {
                newNode->next   =    head;
                head              =    newNode;
        }
        else {
                newNode->next    =    currNode->next;
                currNode->next   =    newNode;
        }
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Try to locate index'th node. If it doesn't exist, return NULL

Create a new node

Inserting a New Node (3)

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                currNode  = currNode->next;
                currIndex++;
        }
        if (index > 0 && currNode == NULL) return NULL;

        Node* newNode =  new Node;
        newNode->data =  x;
        if (index == 0) {
                newNode->next   =    head;
                head             =   newNode;
        }
        else {
                newNode->next    =   currNode->next;
                currNode->next   =   newNode;
        }
        return newNode;
}
```
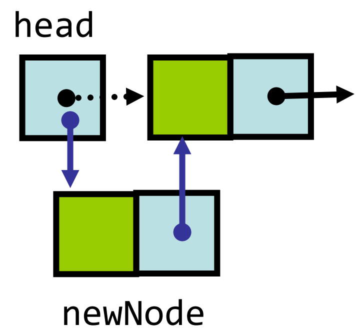

Try to locate index'th node. If it doesn't exist, return NULL

Create a new node

Insert as first element



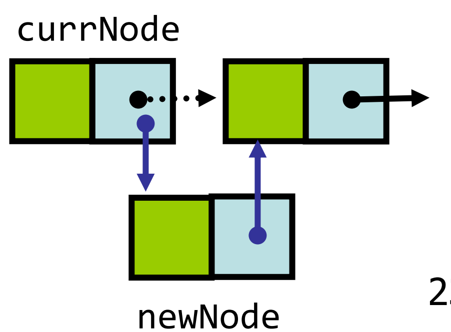
Inserting a New Node (3)

```
Node* List::InsertNode(int index, double x) {
        if (index < 0) return NULL;

        int currIndex   =   1;
        Node* currNode  =   head;
        while (currNode && index > currIndex) {
                currNode   = currNode->next;
                currIndex++;
        }
        if (index > 0 && currNode == NULL) return NULL;

        Node* newNode =  new Node;
        newNode->data =  x;
        if (index == 0) {
                newNode->next   =    head;
                head             =   newNode;
        }
        else {
                newNode->next    =   currNode->next;
                currNode->next   =   newNode;
        }
        return newNode;
}
```

Try to locate index'th node. If it doesn't exist, return NULL

Create a new node

Insert after `currNode`



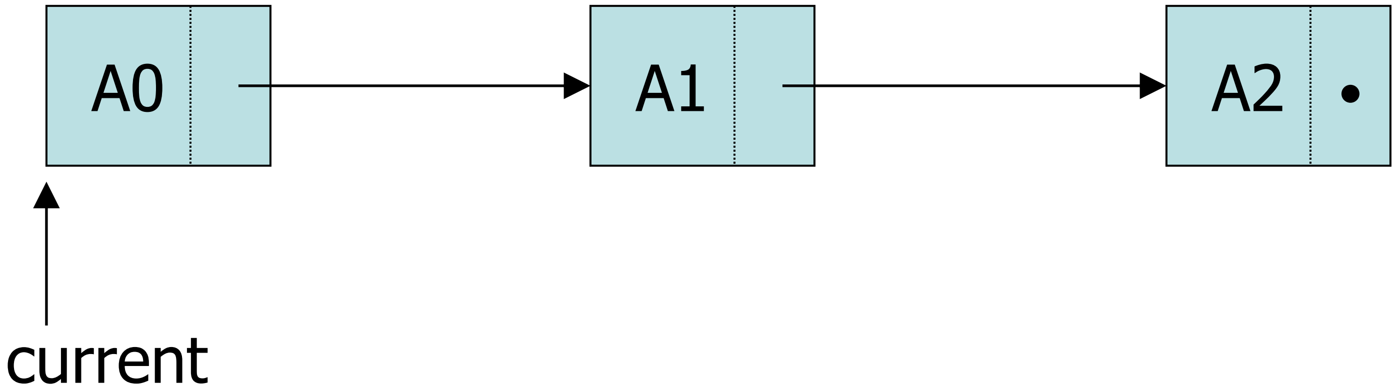
Finding a Node

- **`int FindNode(double x)`**
  - Search for a node with the value equal to x in the list
  - If such a node is found
    - Return its position
    - Otherwise, return 0

```
int List::FindNode(double x) {
        Node* currNode = head;
        int currIndex   = 1;
        while (currNode && currNode->data != x) {
                currNode = currNode->next;
                currIndex++;
        }
        if (currNode) return currIndex;

        return 0;
}
```

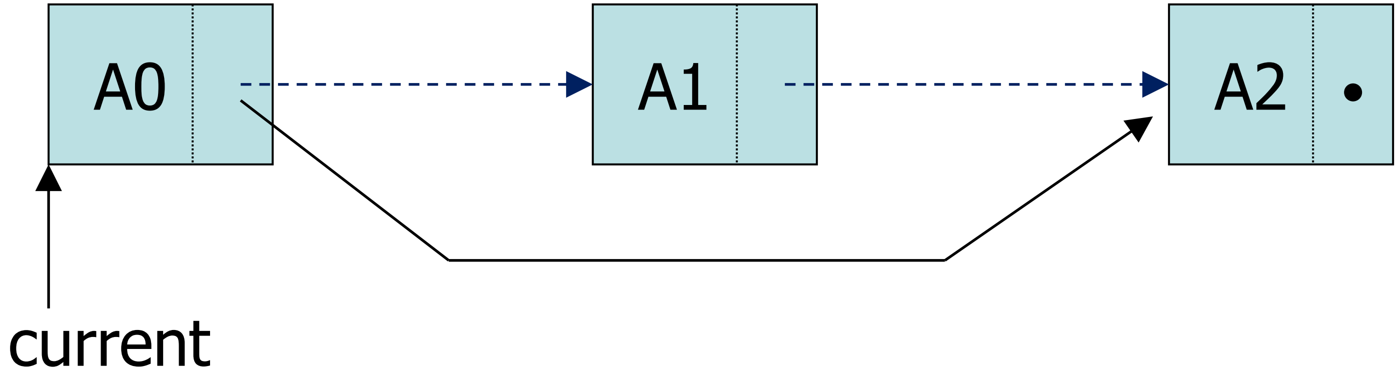
Deleting a Node – Example (1)

- Deleting item A1 from the list



Deleting a Node – Example (2)

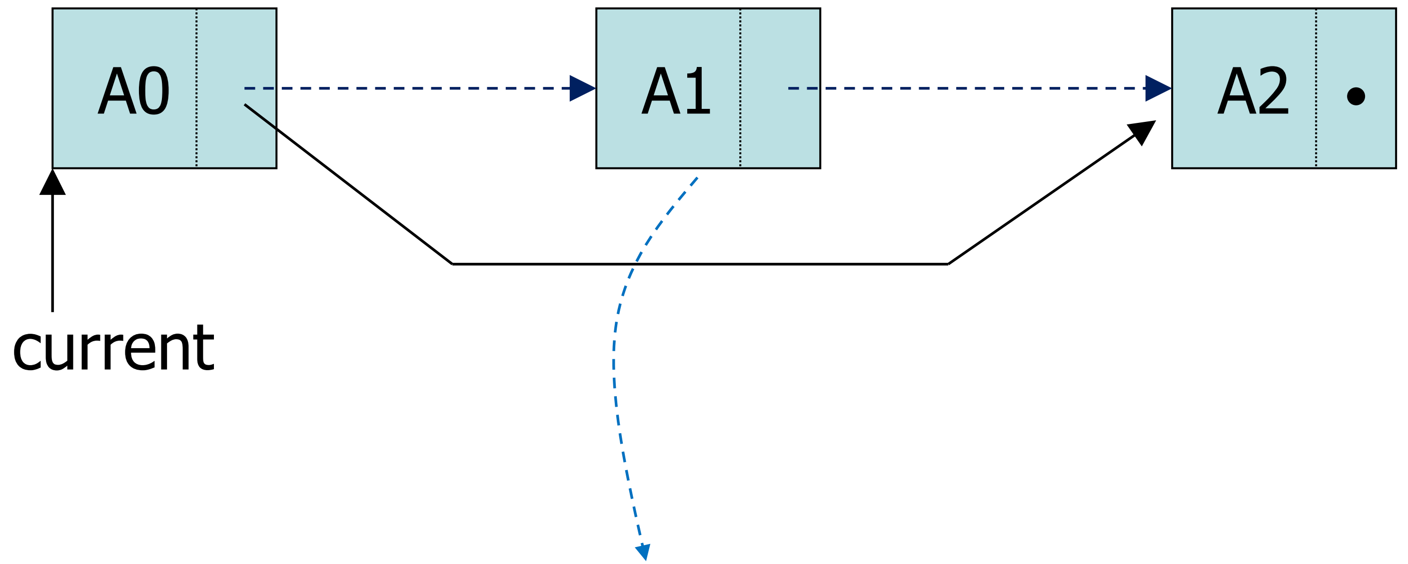
- Deleting item A1 from the list




```
current->next = current->next->next;
```

Deleting a Node – Example (3)

- Deleting item A1 from the list

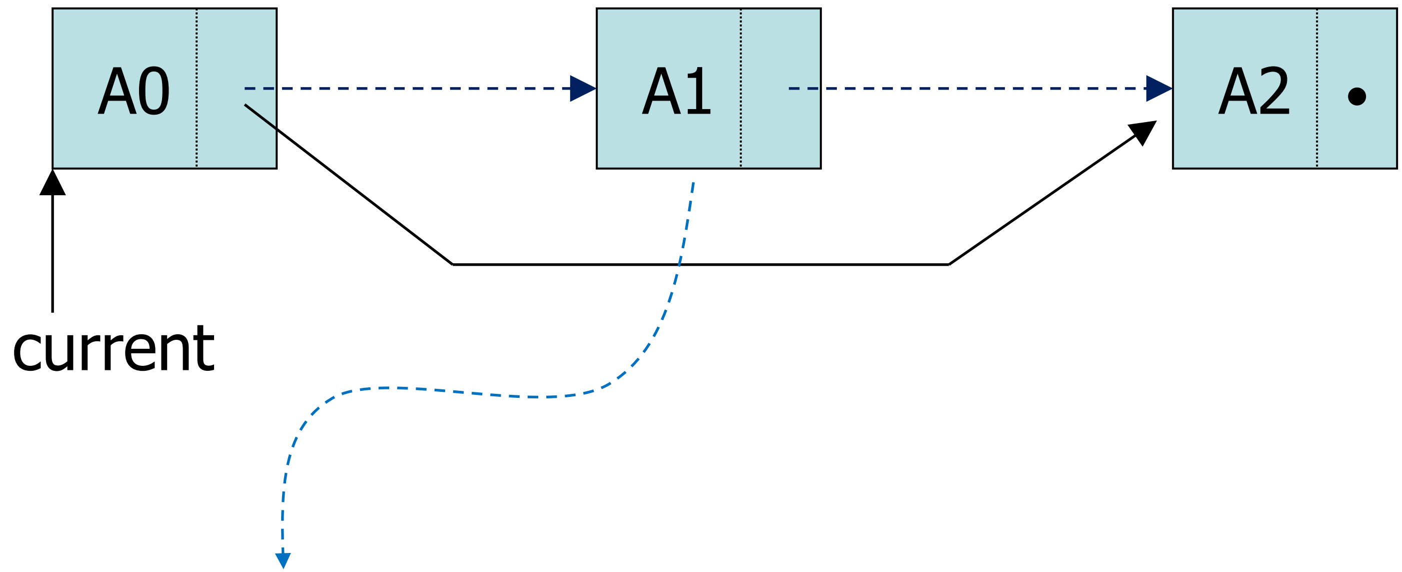



```
current->next = current->next->next;
```

→ Memory Leak

Deleting a Node – Example (4)

- Deleting item A1 from the list




```
Node *deletedNode = current->next;
current->next = current->next->next;
delete deletedNode;
```

Deleting a Node

- **`int DeleteNode(double x)`**
  - Delete a node with the value equal to x from the list
  - If such a node is found return its position
    - Otherwise, return 0
- Steps
  - Find the desirable node (similar to `FindNode`)
  - Release the memory occupied by the found node
  - Set the pointer of the predecessor of the found node to the successor of the found node
- Like `InsertNode`, there are two special cases
  - Delete first node
  - Delete the node in middle or at the end of the list

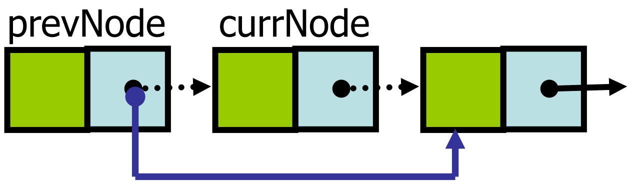
Deleting a Node – Implementation (1)

```
int List::DeleteNode(double x) {
        Node* prevNode      = NULL;
        Node* currNode      = head;
        int currIndex       = 1;
        while (currNode && currNode->data != x) {
                prevNode    = currNode;
                currNode    = currNode->next;
                currIndex++;
        }
        if (currNode) {
                if (prevNode) {
                        prevNode->next     =  currNode->next;
                        delete currNode;
                }
                else {
                        head   =  currNode->next;
                        delete currNode;
                }
                return currIndex;
        }
        return 0;
}
```

Try to find node with its value equal to x.

Deleting a Node – Implementation (2)

```
int List::DeleteNode(double x) {
        Node* prevNode    = NULL;
        Node* currNode    = head;
        int currIndex     = 1;
        while (currNode && currNode->data != x) {
                prevNode   = currNode;
                currNode   = currNode->next;
                currIndex++;
        }
        if (currNode) {
                if (prevNode) {
                        prevNode->next    =  currNode->next;
                        delete currNode;
                }
                else {
                        head  =  currNode->next;
                        delete currNode;
                }
                return currIndex;
        }
        return 0;
}
```



Deleting a Node – Implementation (3)

```
int List::DeleteNode(double x) {
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        Node* currNode     = head;
        int currIndex      = 1;
        while (currNode && currNode->data != x) {
                prevNode    = currNode;
                currNode    = currNode->next;
                currIndex++;
        }
        if (currNode) {
                if (prevNode) {
                        prevNode->next     =  currNode->next;
                        delete currNode;
                }
                else {
                        head   =  currNode->next;
                        delete currNode;
                }
                return currIndex;
        }
        return 0;
}
```

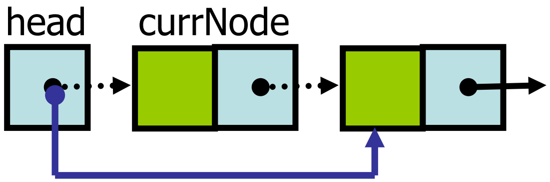

Printing All The Elements

- **`void DisplayList(void)`**
  - Print the data of all the elements
  - Print the number of the nodes in the list

```
void List::DisplayList()
{
   int num     = 0;
   Node* currNode =   head;
   while (currNode != NULL){
      cout << currNode->data << endl;
      currNode = currNode->next;
      num++;
   }
   cout << "Number of nodes in the list: " << num << endl;
}
```

Destroying The List

- **`~List(void)`**
  - Use the destructor to release all the memory used by the list
  - Step through the list and delete each node one by one

```
List::~List(void) {
   Node* currNode = head;
   Node* nextNode = NULL;
   while (currNode != NULL)
   {
      nextNode  =  currNode->next;
      delete currNode; // destroy the current node
      currNode  =  nextNode;
   }
   head = NULL;
}
```

Using List (1)

```
int main(void)
{
   List list;
   list.InsertNode(0, 7.0);      // successful
   list.InsertNode(1, 5.0);      // successful
   list.InsertNode(-1, 5.0);     // unsuccessful
   list.InsertNode(0, 6.0);      // successful
   list.InsertNode(8, 4.0);      // unsuccessful
   // print all the elements
   list.DisplayList();



   return 0;
}
```

Output:
6
7
5
Number of nodes in the list: 3

Using List (2)

```
int main(void)
{
   List list;
   list.InsertNode(0, 7.0);      // successful
   list.InsertNode(1, 5.0);      // successful
   list.InsertNode(-1, 5.0);     // unsuccessful
   list.InsertNode(0, 6.0);      // successful
   list.InsertNode(8, 4.0);      // unsuccessful
   // print all the elements
   list.DisplayList();
   if(list.FindNode(5.0) > 0)    cout << "5.0 found" << endl;
   else                          cout << "5.0 not found" << endl;
   if(list.FindNode(4.5) > 0)    cout << "4.5 found" << endl;
   else                          cout << "4.5 not found" << endl;


   return 0;
}
```

Output:
6
7
5
Number of nodes in the list: 3
5.0 found
4.5 not found

Using List

```
int main(void)
{
   List list;
   list.InsertNode(0, 7.0);     // successful
   list.InsertNode(1, 5.0);     // successful
   list.InsertNode(-1, 5.0);    // unsuccessful
   list.InsertNode(0, 6.0);     // successful
   list.InsertNode(8, 4.0);     // unsuccessful
   // print all the elements
   list.DisplayList();
   if(list.FindNode(5.0) > 0)   cout << "5.0 found" << endl;
   else                         cout << "5.0 not found" << endl;
   if(list.FindNode(4.5) > 0)   cout << "4.5 found" << endl;
   else                         cout << "4.5 not found" << endl;
   list.DeleteNode(7.0);
   list.DisplayList();
   return 0;
}
```

Output:
6
7
5
Number of nodes in the list: 3
5.0 found
4.5 not found
6
5
Number of nodes in the list: 2

Any Question So Far?