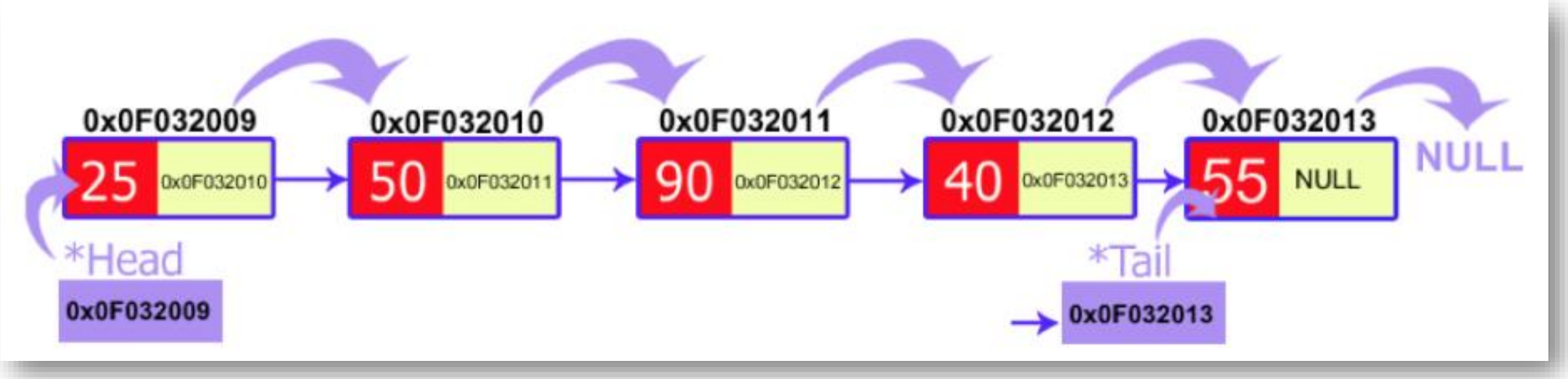
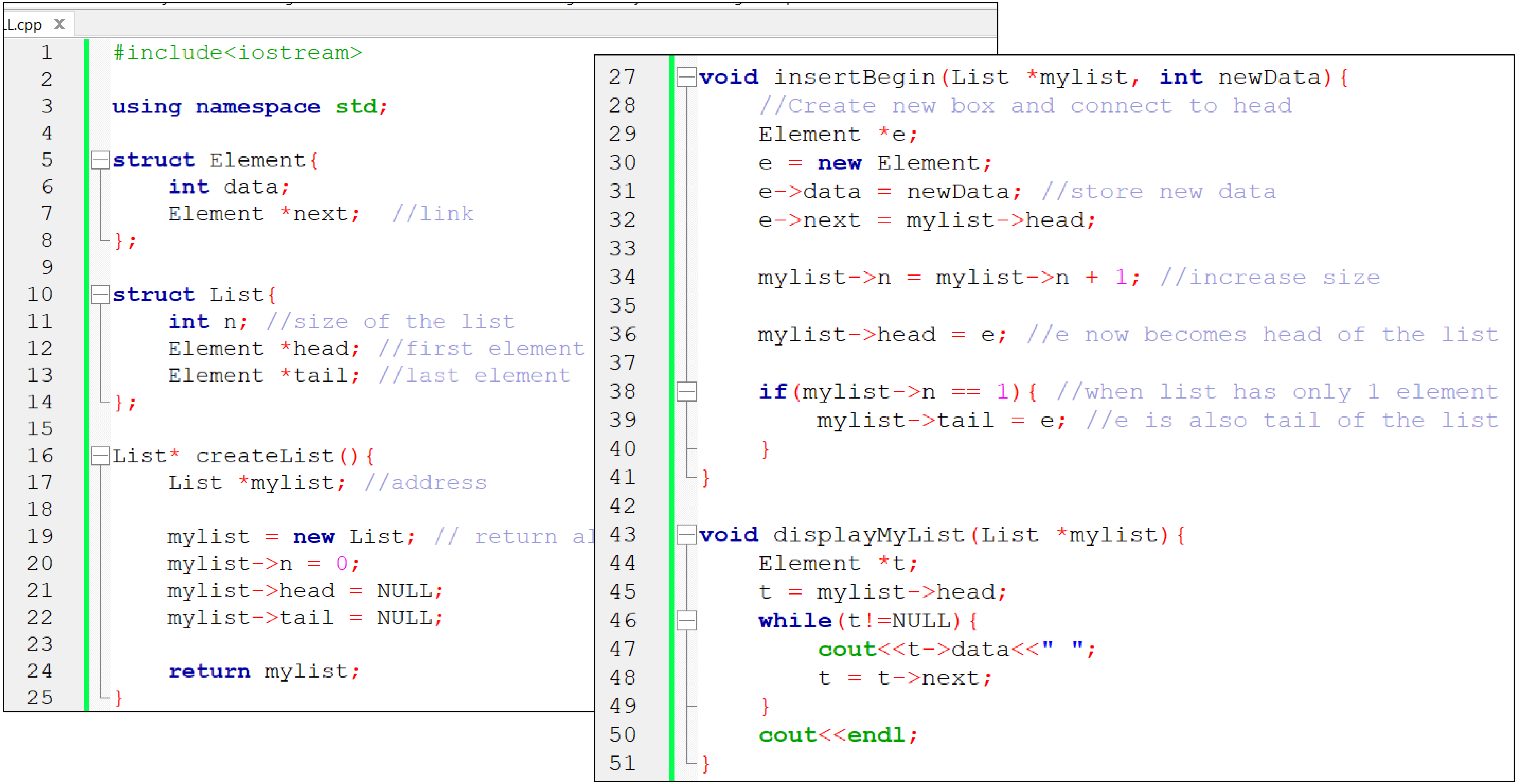
DATA STRUCTURE & PROGRAMMING II

Linked List data structure



A quick review

About the implementation of linked list data structure



```cpp
#include<iostream>

using namespace std;

struct Element{
    int data;
    Element *next;  //link
};

struct List{
    int n; //size of the list
    Element *head; //first element
    Element *tail; //last element
};

List* createList(){
    List *mylist; //address

    mylist = new List; // return al
    mylist->n = 0;
    mylist->head = NULL;
    mylist->tail = NULL;

    return mylist;
}
```

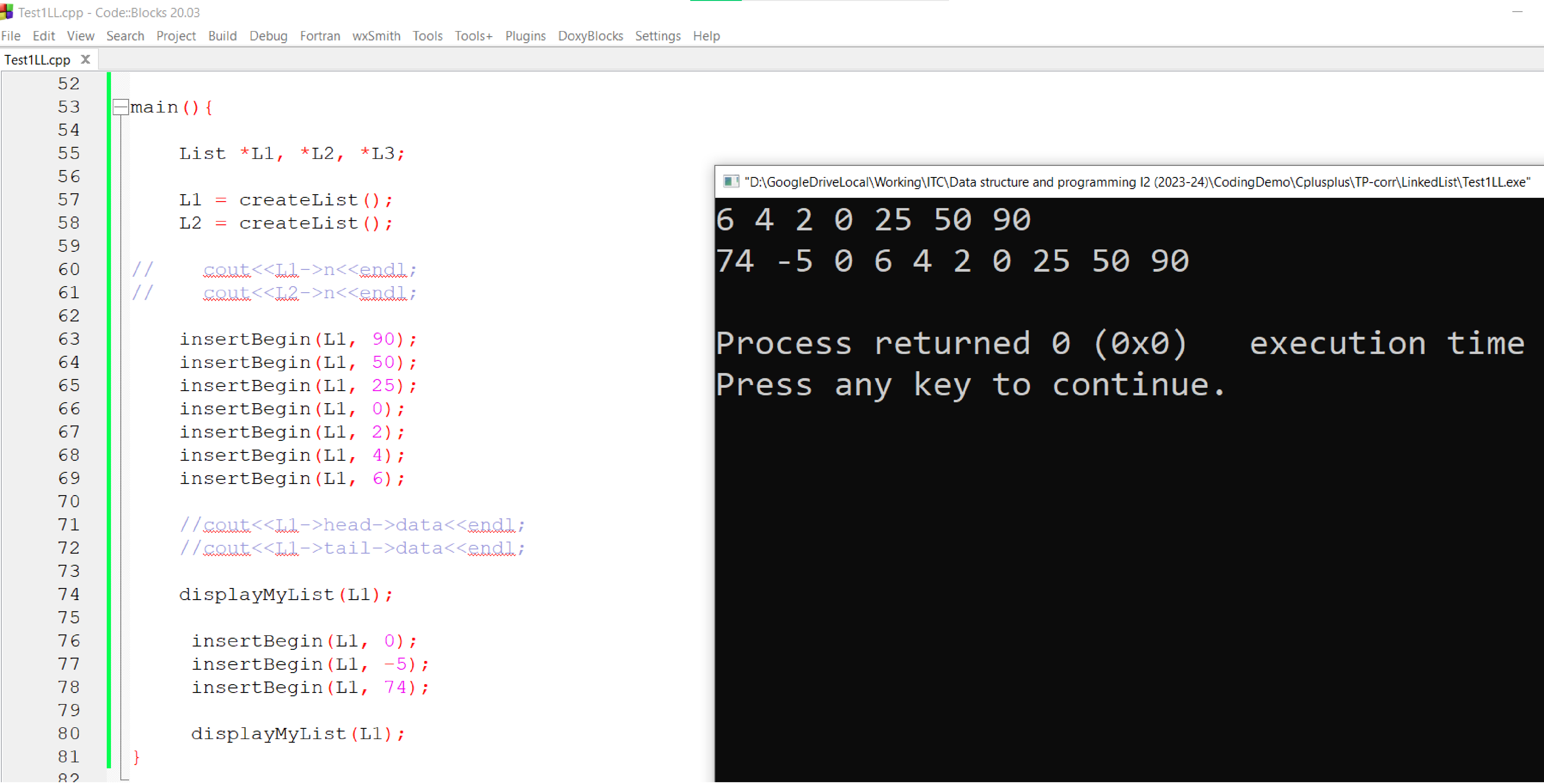
```cpp
void insertBegin(List *mylist, int newData){
    //Create new box and connect to head
    Element *e;
    e = new Element;
    e->data = newData; //store new data
    e->next = mylist->head;

    mylist->n = mylist->n + 1; //increase size

    mylist->head = e; //e now becomes head of the list

    if(mylist->n == 1){ //when list has only 1 element
        mylist->tail = e; //e is also tail of the list
    }
}

void displayMyList(List *mylist){
    Element *t;
    t = mylist->head;
    while(t!=NULL){
        cout<<t->data<<" ";
        t = t->next;
    }
    cout<<endl;
}
```


Test1LL.cpp - Code::Blocks 20.03
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Test1LL.cpp
"D:\GoogleDriveLocal\Working\ITC\Data structure and programming I2 (2023-24)\CodingDemo\Cplusplus\TP-corr\LinkedList\Test1LL.exe"

```cpp

main(){

    List *L1, *L2, *L3;

    L1 = createList();
    L2 = createList();

//    cout<<L1->n<<endl;
//    cout<<L2->n<<endl;

    insertBegin(L1, 90);
    insertBegin(L1, 50);
    insertBegin(L1, 25);
    insertBegin(L1, 0);
    insertBegin(L1, 2);
    insertBegin(L1, 4);
    insertBegin(L1, 6);

    //cout<<L1->head->data<<endl;
    //cout<<L1->tail->data<<endl;

    displayMyList(L1);

     insertBegin(L1, 0);
     insertBegin(L1, -5);
     insertBegin(L1, 74);

     displayMyList(L1);
}
```

```
6 4 2 0 25 50 90
74 -5 0 6 4 2 0 25 50 90

Process returned 0 (0x0)   execution time
Press any key to continue.
```

Lecture overview

❑ Overall lectures

1. Introduction to algorithm
2. Basic data types and statements
3. Control structures and Loop
4. Array
5. Data structure
6. Sub-programs

7. Recursive
8. File IO
9. Pointers
10. *Linked Lists*
11. Stacks and Queues
12. Sorting algorithms
13. Trees

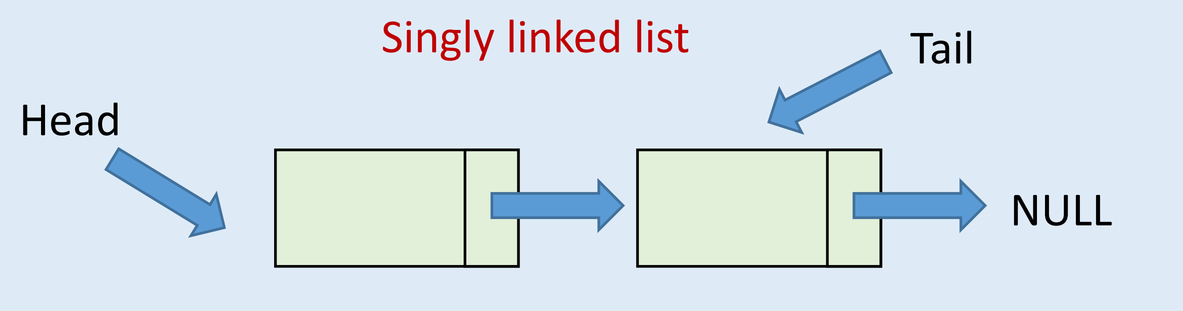
C++

Outline

❑ A Brief of Outline

- What is linked list?
  - Single linked list? Double linked list?
- What are the advantages of using linked list and array?
- Linked list implementation in C++
  - Examples

What is Linked list?



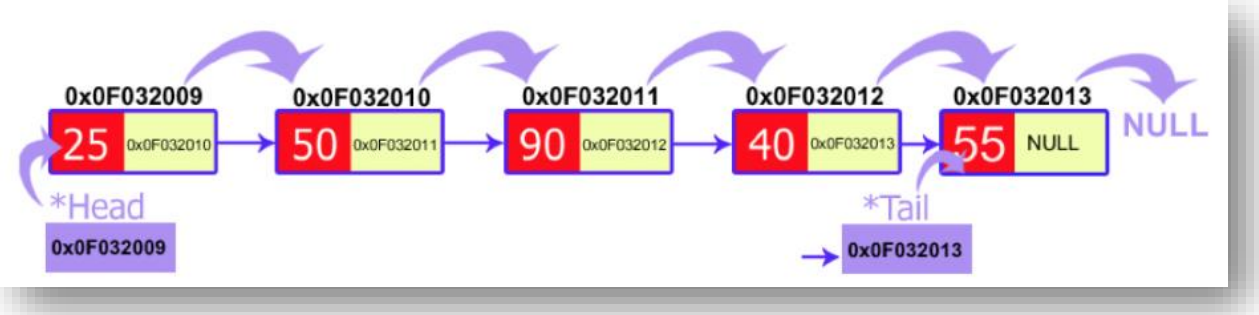
❑ Definition

- **A linked list** is a data structure that can store an indefinite amount of elements (dynamic size)
- In a linked list, each element is linked with each other. Elements in a linked list are accessed sequentially.

```
struct Element
    data: integer
    *next: Element
End struct
```

```
struct List
    n: integer
    *head: Element
    *tail: Element
End struct
```

- Each element contains
  - ✓ **Data**
  - ✓ **A link (pointer)**
    - ✓ to its next element (successor)
    - ✓ and/or to its previous element (predecessor)



- Element = called a ***node***
- In linked list, the first element is ***head*** and the last element is ***tail***

Array Vs. Linked List

❑ Pros and Con

Array

- Fixed size
- Once created, can’t add or reduce number of elements to be stored
- Can random access
- Faster access
  - Elements in contiguous memory locations

Linked List

- Dynamically shrink and grow
- Dynamic memory management
- No random access is allowed
- Slower access
  - Elements not in contiguous memory locations

What is Linked list?

❑ Type of Linked List

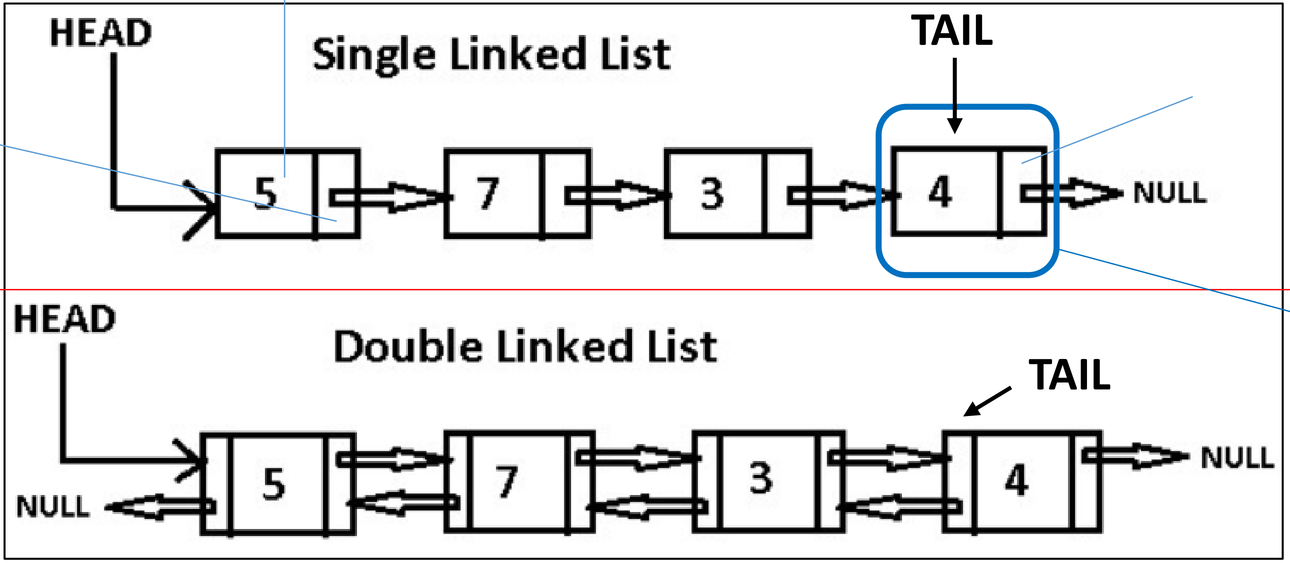
- There are two types of linked lists:
    - A single linked list is a linked list that has **a link to either its successor or predecessor**.
    - A double linked list is a linked list that has **both links** to successor and predecessor.

Data

A pointer points to the next element (successor)

myList1

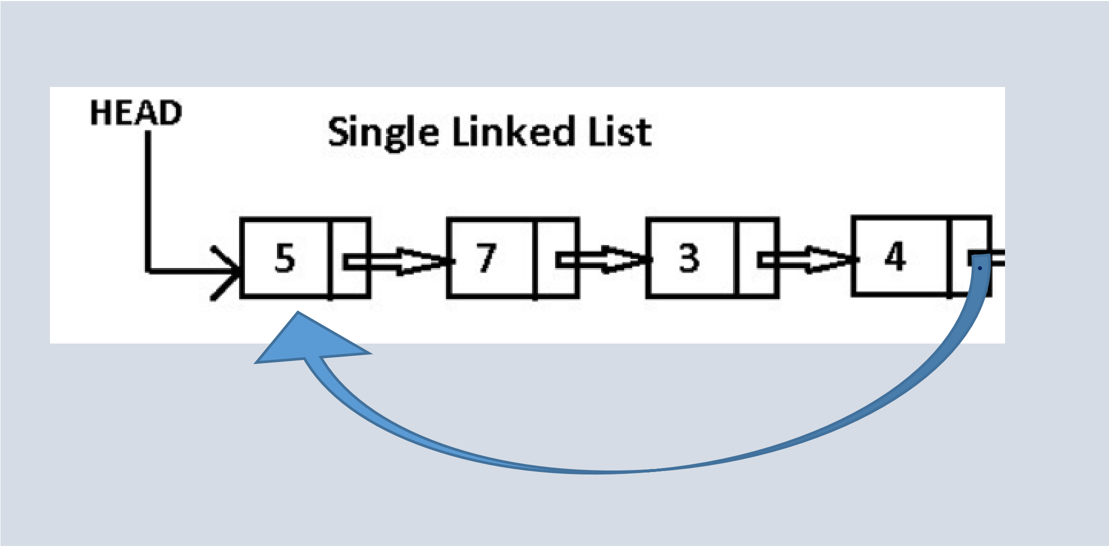
myList2



Last node of the list points to NULL

Remark

- A single or double linked list can be called **a circular linked list** when the last element (tail) points to the first element (head).



Circular linked list

List Operations

❑ Operations with a list

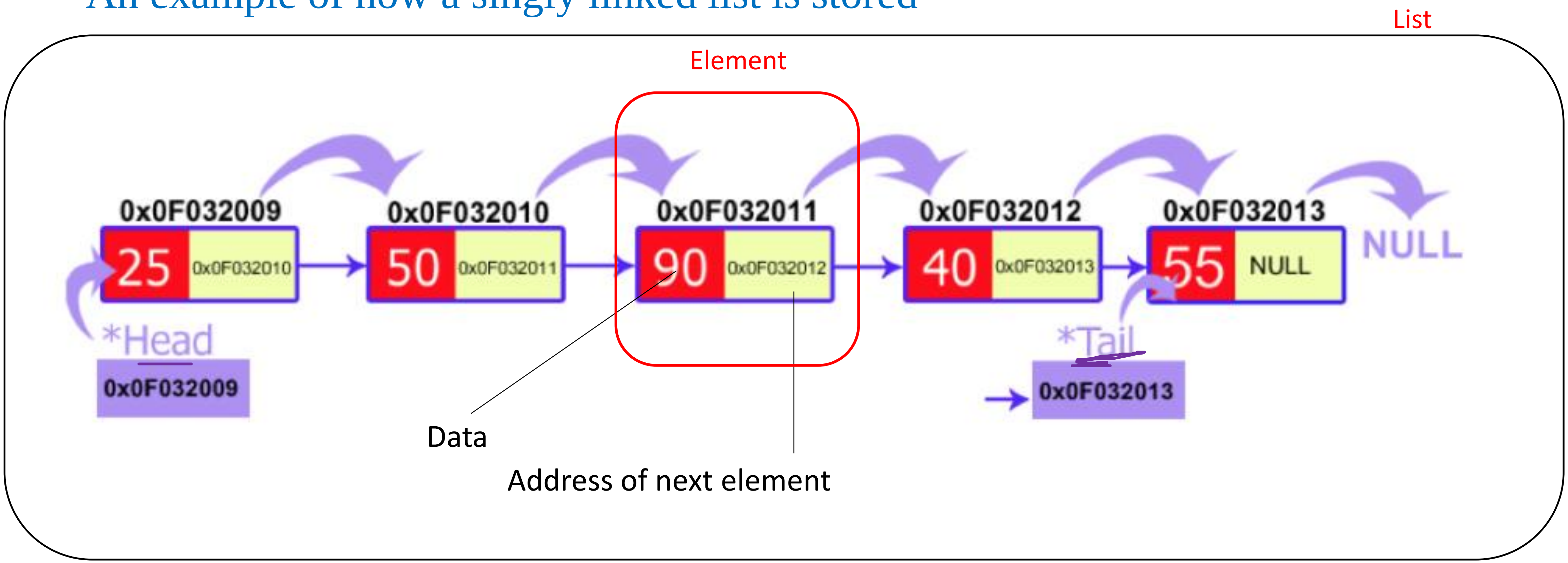
- ✓Creating a list
- ✓Insert a new element to a list
  - ✓ Insert to beginning, end, at a position
- ✓Delete an element from a list
  - ✓ Delete to beginning, end, at a position
- ✓Search an element in a list
- ✓Update an element in a list
- ✓Display data in list
- ✓Reverse a list
- ✓Combine two lists
- ✓… etc.

Singly Linked List (SLL)

Singly linked list

❑ Overview

- An example of how a singly linked list is stored



List operation

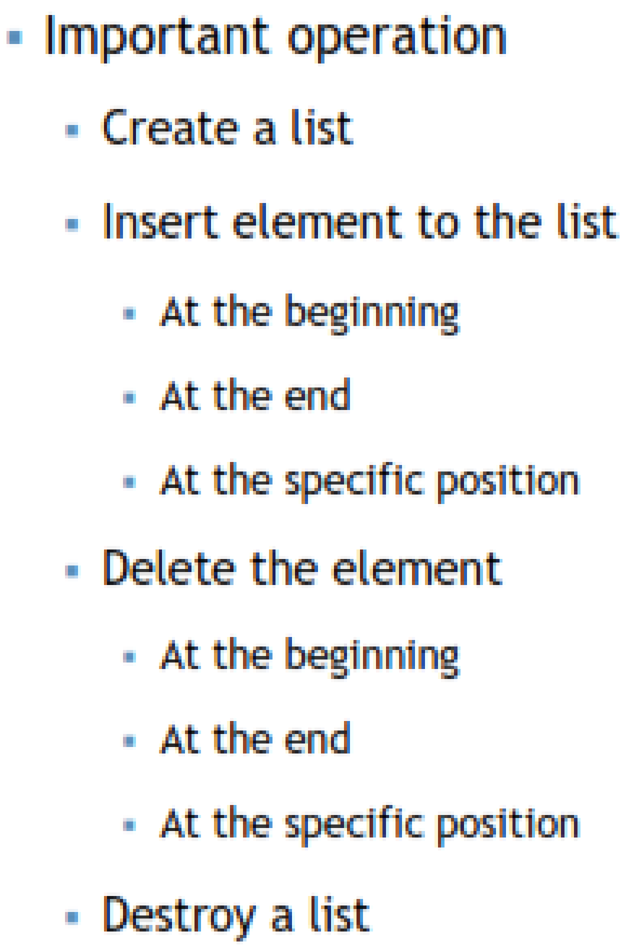
❑ Operation with a list

- All elements of a linked list can be accessed by
  - First setup a pointer pointing to the first element (node) of the list
  - Loop to traverse the list until NULL

- One of the disadvantage of the single linked list is
  - Given a pointer A to a node, we can not reach any of the nodes that precede the node (previous element) to which A is pointing

Operation on linked list

❑ Operations



- Important operation
  - Create a list
  - Insert element to the list
    - At the beginning
    - At the end
    - At the specific position
  - Delete the element
    - At the beginning
    - At the end
    - At the specific position
  - Destroy a list

```
Struct Element
        data: data_type
        *next: Element
End struct
```

```
Struct List
        *head: Element
        *tail: Element
        n: Integer
End struct
```

- **n** store number of elements in list.
- **n** is zero when list is first created. Then n is incremented by 1 when there is an element added to list.

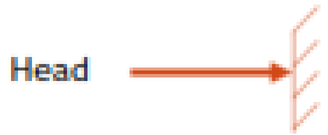
Examples

❑ Create an element

```
Var *head, *tmp : Element
```

- Create an empty list

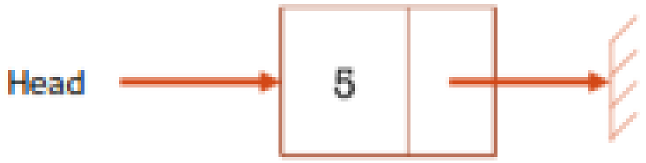
```
head ← null
```



- Add an element of the list with value 5

```
tmp ← new(size(Element))
tmp→ data ← 5
tmp→ next ← null
head ← tmp
```

Reserve/allocate memory for this element

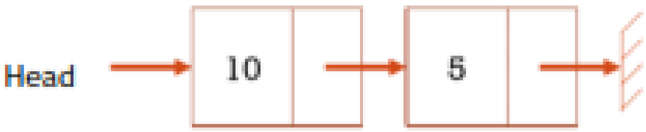


Examples

❑ Add and remove element

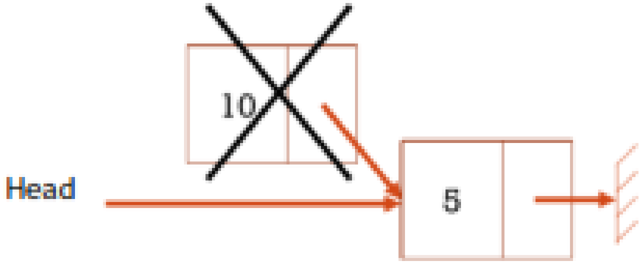
- Add a new element containing value 10 to the beginning of the list

```
tmp ← new(size(Element))
tmp→ data ← 10
tmp→ next ← head
head ← tmp
```



- Delete the first element from the list

```
tmp  ← head
head ← head → next
free(tmp)
```



Create a list

❑ A function to create an empty list

```
Function create_list( ) : Pointer of List
          var  *ls :  List

          ls ← new(size(List))
          ls→n  ←  0
          ls→head ← null
          ls→tail ← null

          return ls

End function
```

Steps to create an empty list:

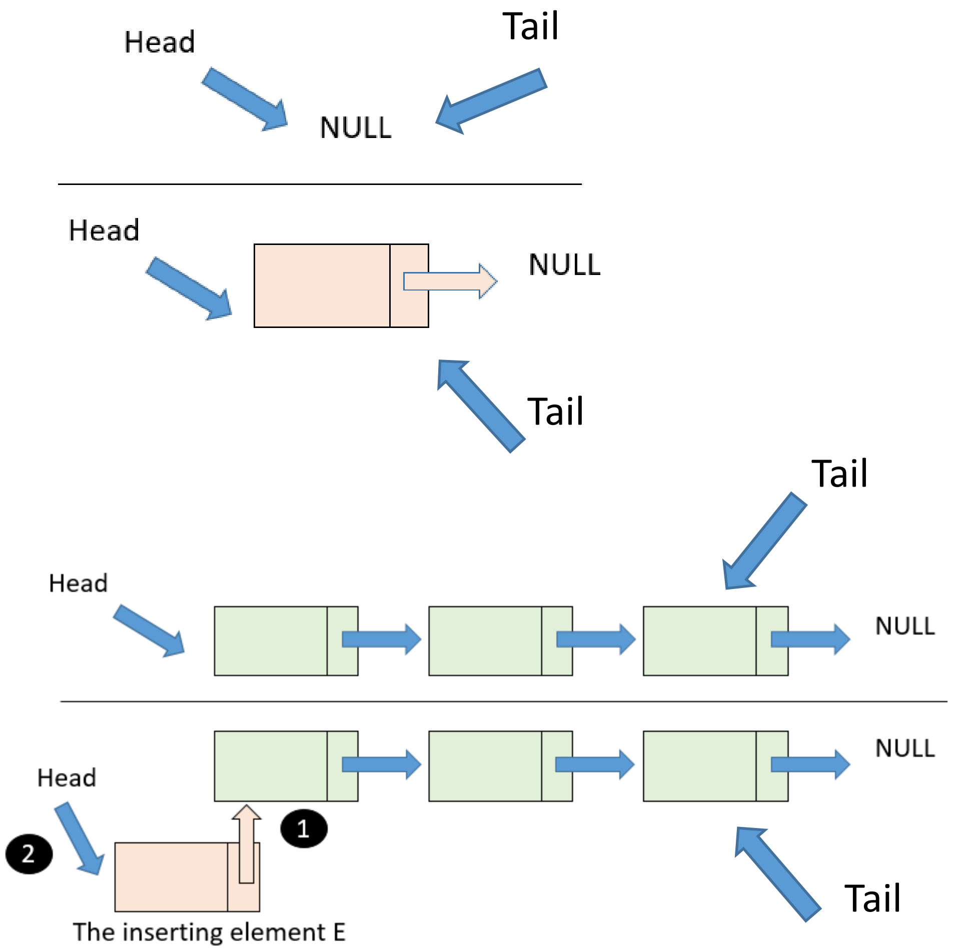
1. Create a list variable
2. Allocate memory
3. Set 0 to n since we are creating an empty list
4. Head points to **null**
5. Tail points to **null**

Insertion

❑ Insert an element to the beginning of the list

```
Procedure insert_be(*ls: List, d: data_type)
          var  *E: Element
    1     E ← new(size(Element))
          E→data ← d

    2     E→next ← ls→head
    3     ls→head ← E
          if(ls→n ==0) then
    4             ls→tail ← E
          end if
    5     ls→n ← ls→n + 1
End procedure
```



Steps to add element to beginning of list

1. Create a new element E
2. Make next pointer of E points to head of list
3. Update E to be head of list
4. Update tail if needed
5. Increase n by 1 (n is number of elements in list)

Display elements in list

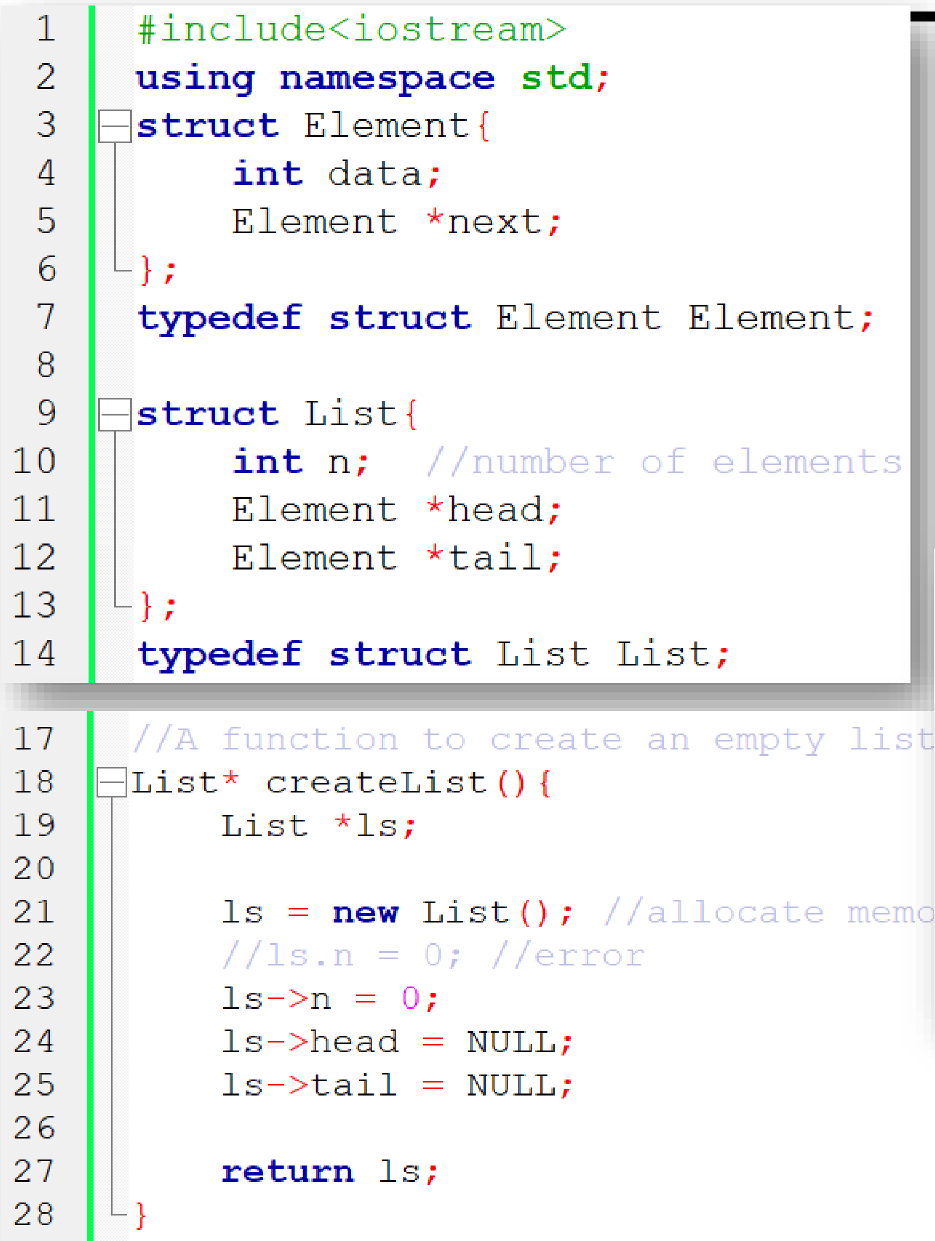
```
Procedure void(*ls: List)
    var *tmp: Element
    tmp ← ls→head

    while(tmp!=NULL) do
        write(tmp→data)
        tmp ← tmp→next
    end while
End procedure
```

Steps to display element in list

1. Start from head
2. Move to each element each time
3. …
4. …

Implementation



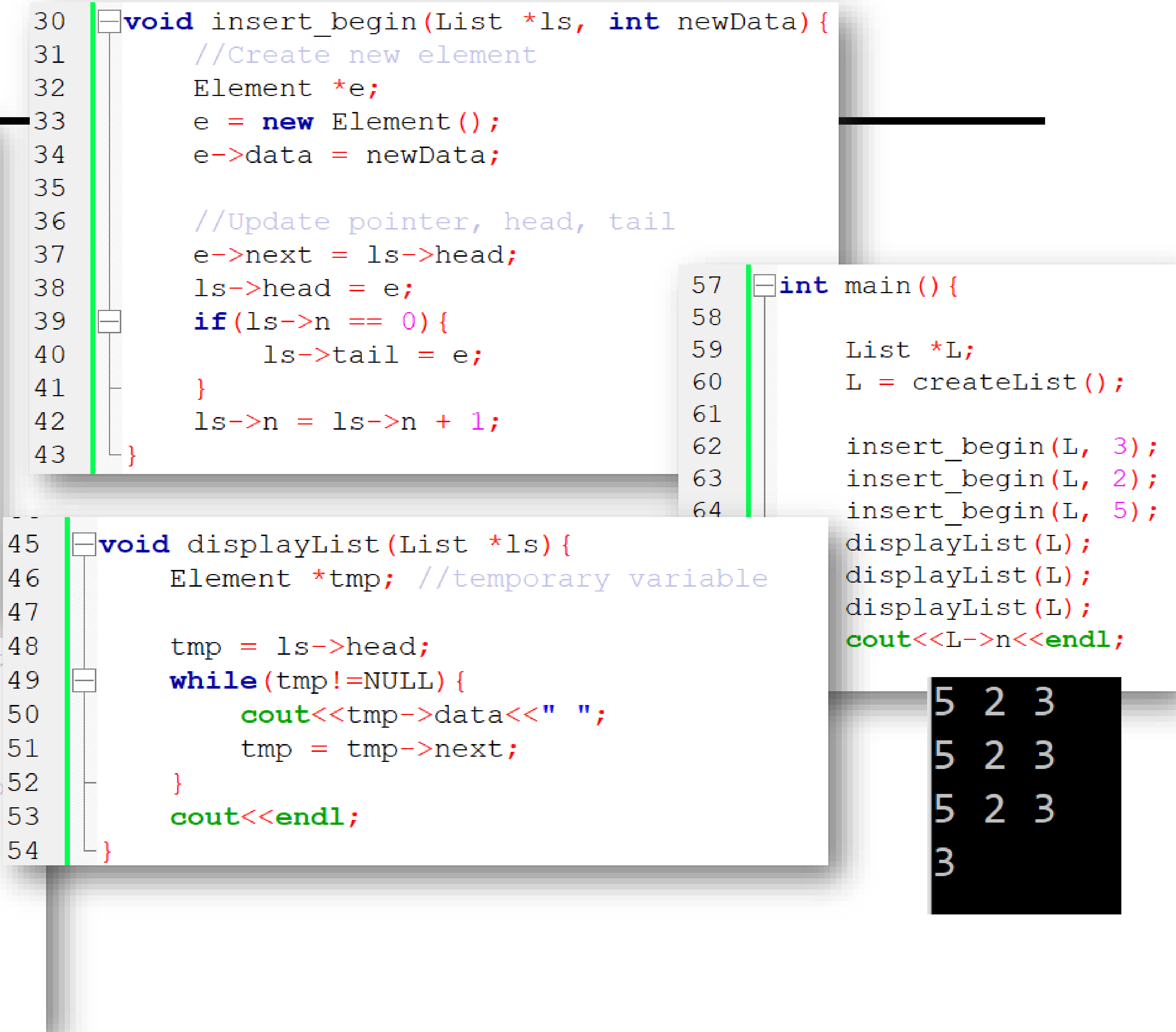
```cpp
#include<iostream>
using namespace std;
struct Element{
    int data;
    Element *next;
};
typedef struct Element Element;

struct List{
    int n;  //number of elements
    Element *head;
    Element *tail;
};
typedef struct List List;
```

```cpp
//A function to create an empty list
List* createList(){
    List *ls;

    ls = new List(); //allocate memo
    //ls.n = 0; //error
    ls->n = 0;
    ls->head = NULL;
    ls->tail = NULL;

    return ls;
}
```



```cpp
void insert_begin(List *ls, int newData){
    //Create new element
    Element *e;
    e = new Element();
    e->data = newData;

    //Update pointer, head, tail
    e->next = ls->head;
    ls->head = e;
    if(ls->n == 0){
        ls->tail = e;
    }
    ls->n = ls->n + 1;
}
```

```cpp
void displayList(List *ls){
    Element *tmp; //temporary variable

    tmp = ls->head;
    while(tmp!=NULL){
        cout<<tmp->data<<" ";
        tmp = tmp->next;
    }
    cout<<endl;
}
```

```cpp
int main(){

    List *L;
    L = createList();

    insert_begin(L, 3);
    insert_begin(L, 2);
    insert_begin(L, 5);
    displayList(L);
    displayList(L);
    displayList(L);
    cout<<L->n<<endl;
```

```
5 2 3
5 2 3
5 2 3
3
```

Q&A

Let’s take a look on another functions

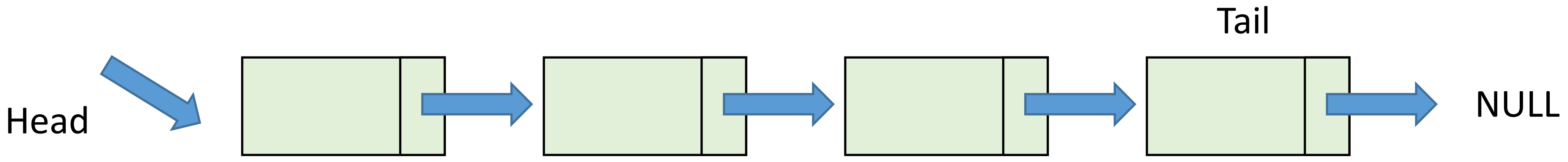
- Add data to end of the list
- Search data in the list
- Delete data from begin of the list

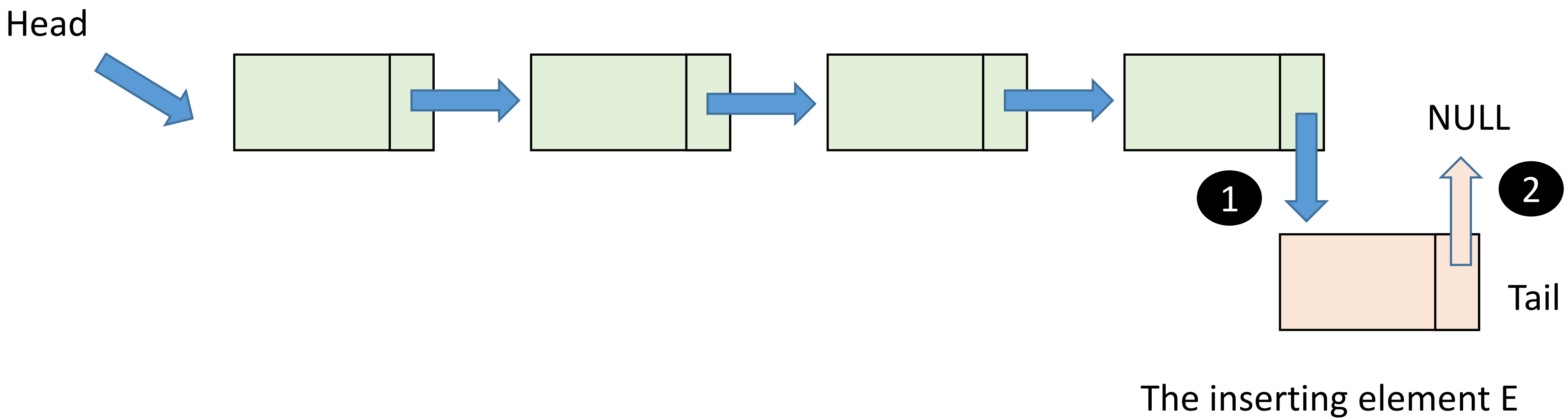
Add data to the end of the linked list

❑ Let’s explore

- Create an element E
- Simply make the last element (tail) points to E.
- Finally, make E becomes tail.

Before





After

Insert an element to the list

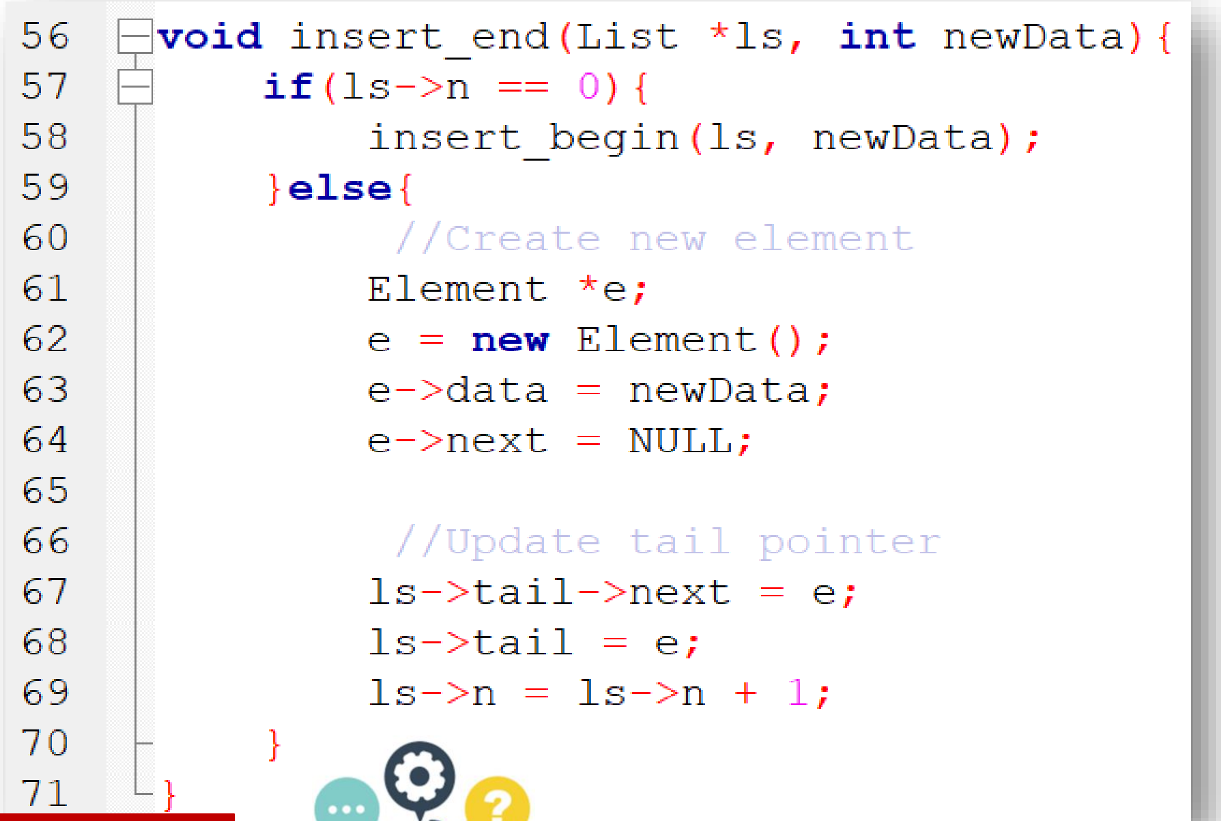
❑ Insert an element to end of the list

Steps to add element to end of list

1. …
2. …
3. …
4. …

```
Procedure insert_end(*ls: List, d: data_type)
        var *E: Element
        if (ls→n == 0) then
                insert_begin(ls, d)
        else
                E ← new(size(Element))
                E→data ← d
                E→next ← null

                ls→tail→next ← E
                ls→tail ← E
                ls→n ← ls→n + 1
        end if
End procedure
```



```
void insert_end(List *ls, int newData){
    if(ls->n == 0){
        insert_begin(ls, newData);
    }else{
         //Create new element
        Element *e;
        e = new Element();
        e->data = newData;
        e->next = NULL;

         //Update tail pointer
        ls->tail->next = e;
        ls->tail = e;
        ls->n = ls->n + 1;
    }
}
```

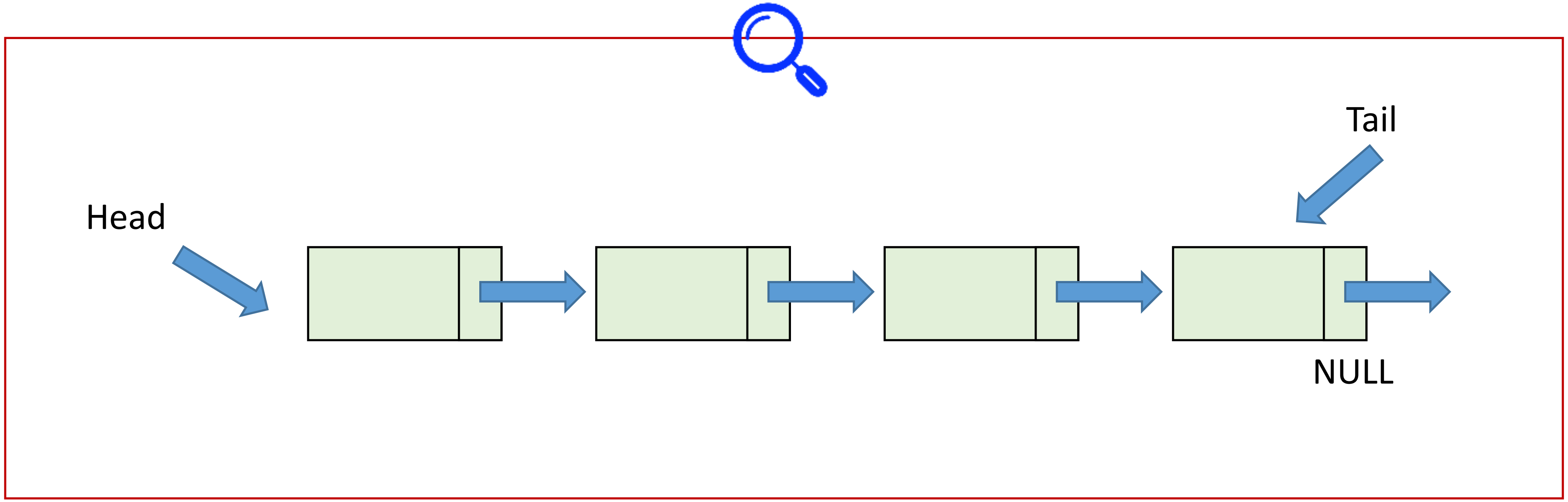
How it works … ?

How to search data in linked list

- Searching for data

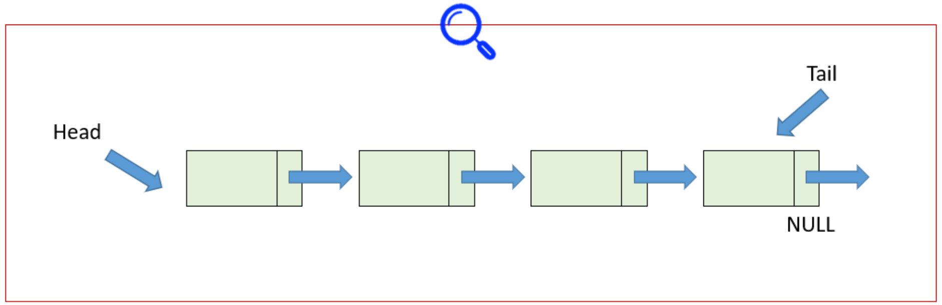
Search

❑ Search for data in list

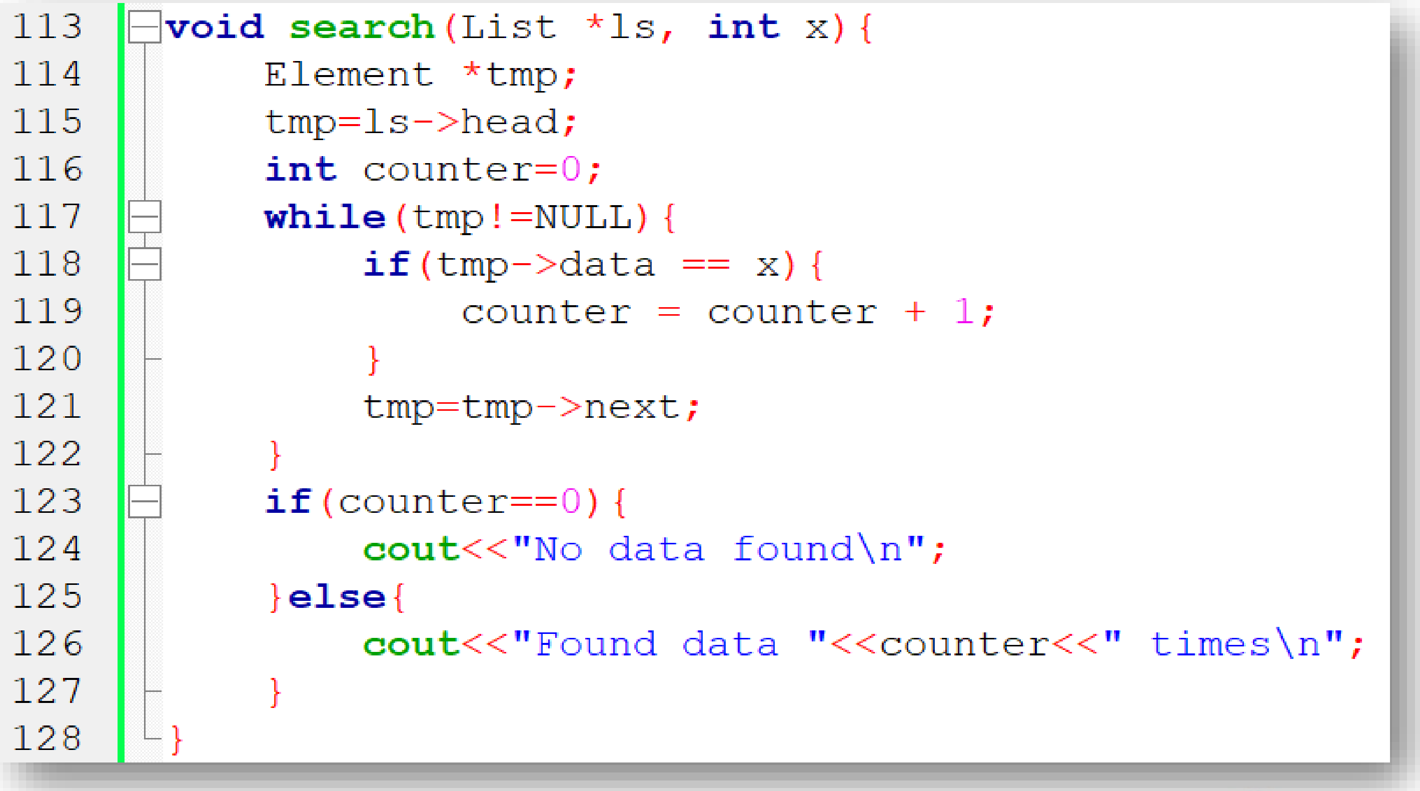


Search

❑ Search for data in list



We need to loop through the list. Test condition for the search.



```
void search(List *ls, int x){
    Element *tmp;
    tmp=ls->head;
    int counter=0;
    while(tmp!=NULL){
        if(tmp->data == x){
            counter = counter + 1;
        }
        tmp=tmp->next;
    }
    if(counter==0){
        cout<<"No data found\n";
    }else{
        cout<<"Found data "<<counter<<" times\n";
    }
}
```

How it works ... ?

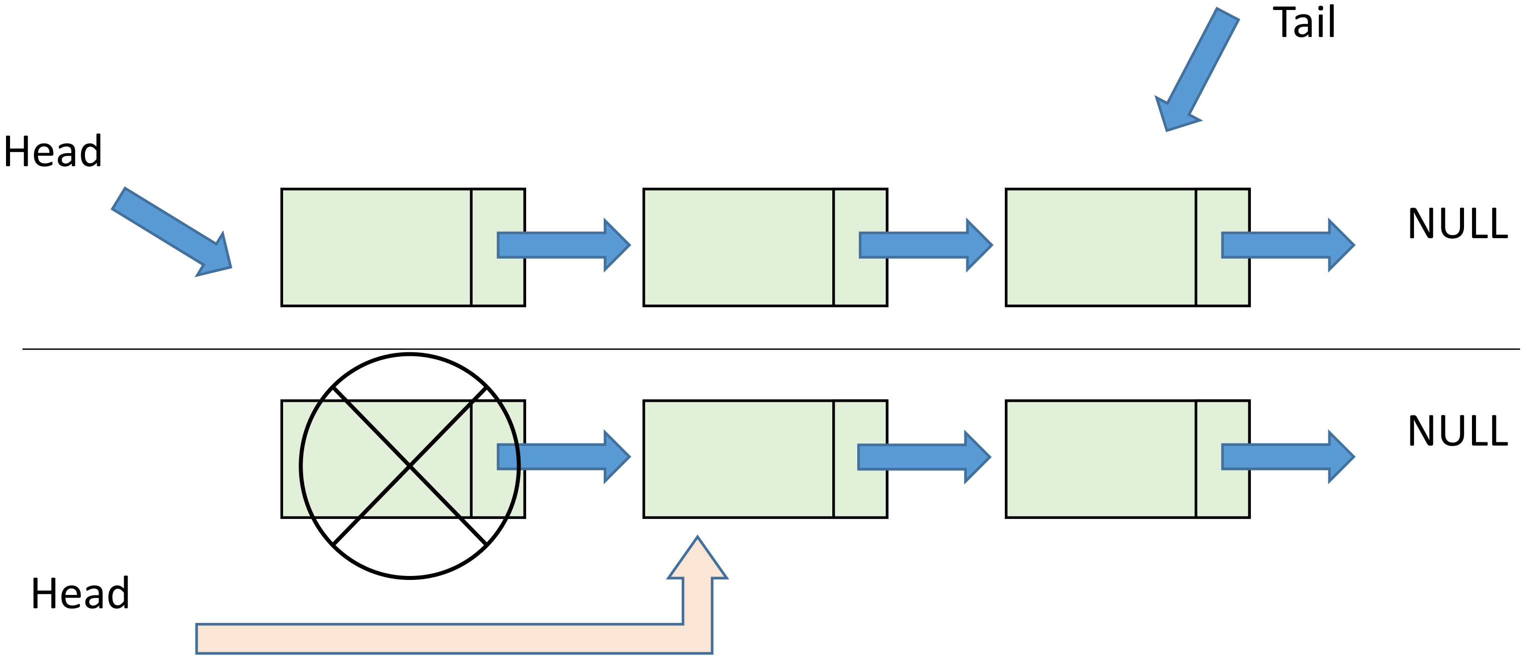
How to delete data from linked list

❖ Delete first element
(delete from beginning)

Deletion

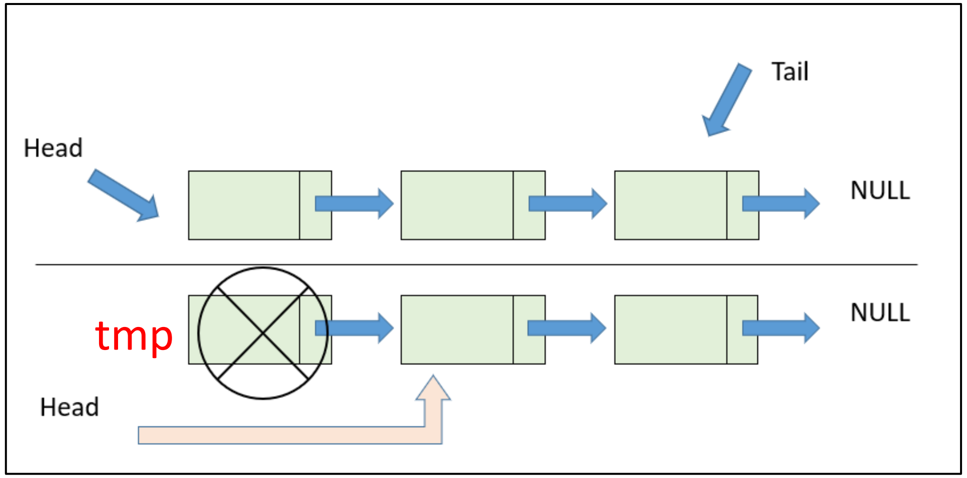
❑ Delete the first element

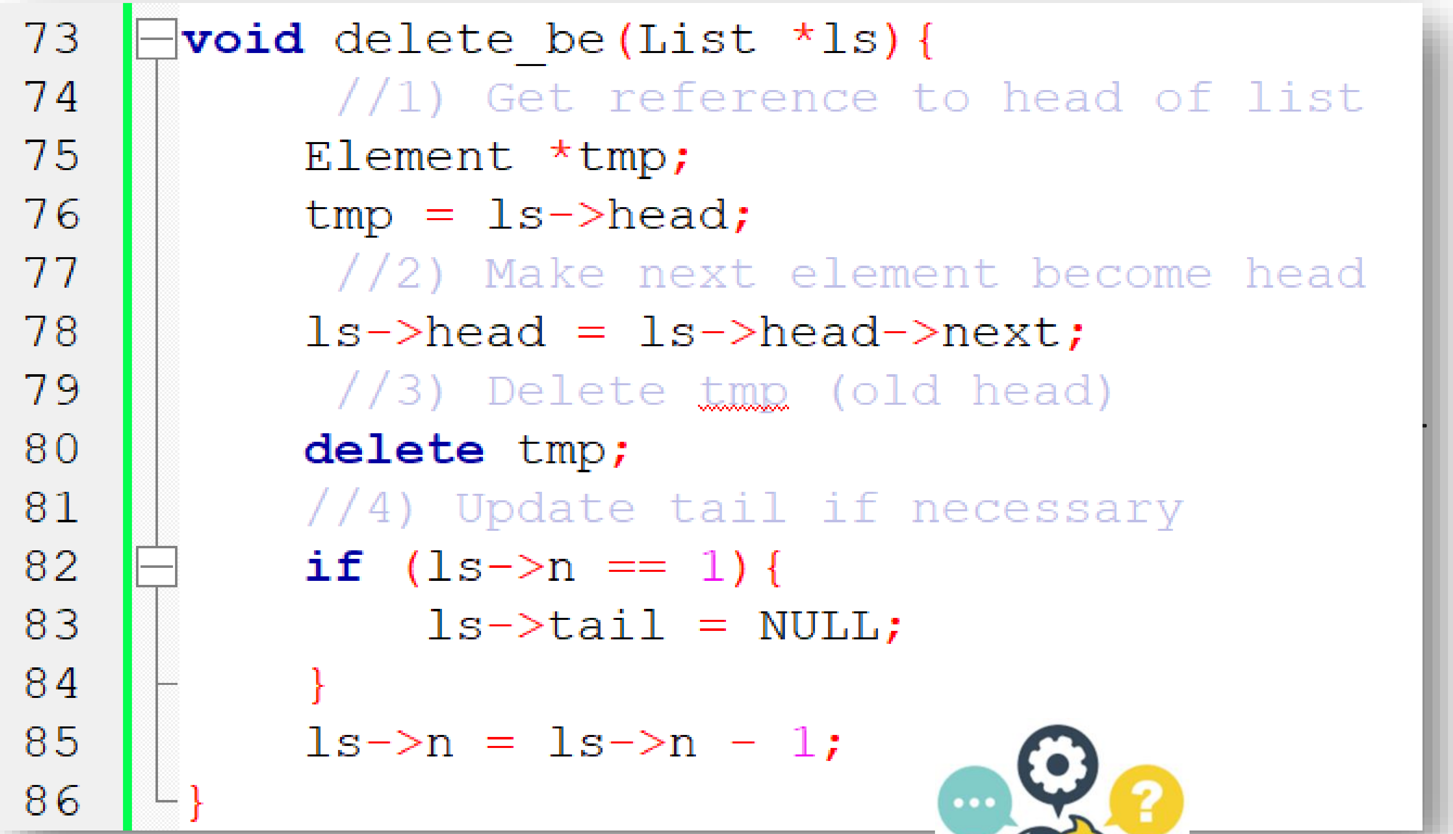
Before



After

Delete the first element (delete beginning)





```
void delete_be(List *ls){
     //1) Get reference to head of list
    Element *tmp;
    tmp = ls->head;
     //2) Make next element become head
    ls->head = ls->head->next;
     //3) Delete tmp (old head)
    delete tmp;
    //4) Update tail if necessary
    if (ls->n == 1){
        ls->tail = NULL;
    }
    ls->n = ls->n - 1;
}
```

How it works ... ?

Q&A

More about delete

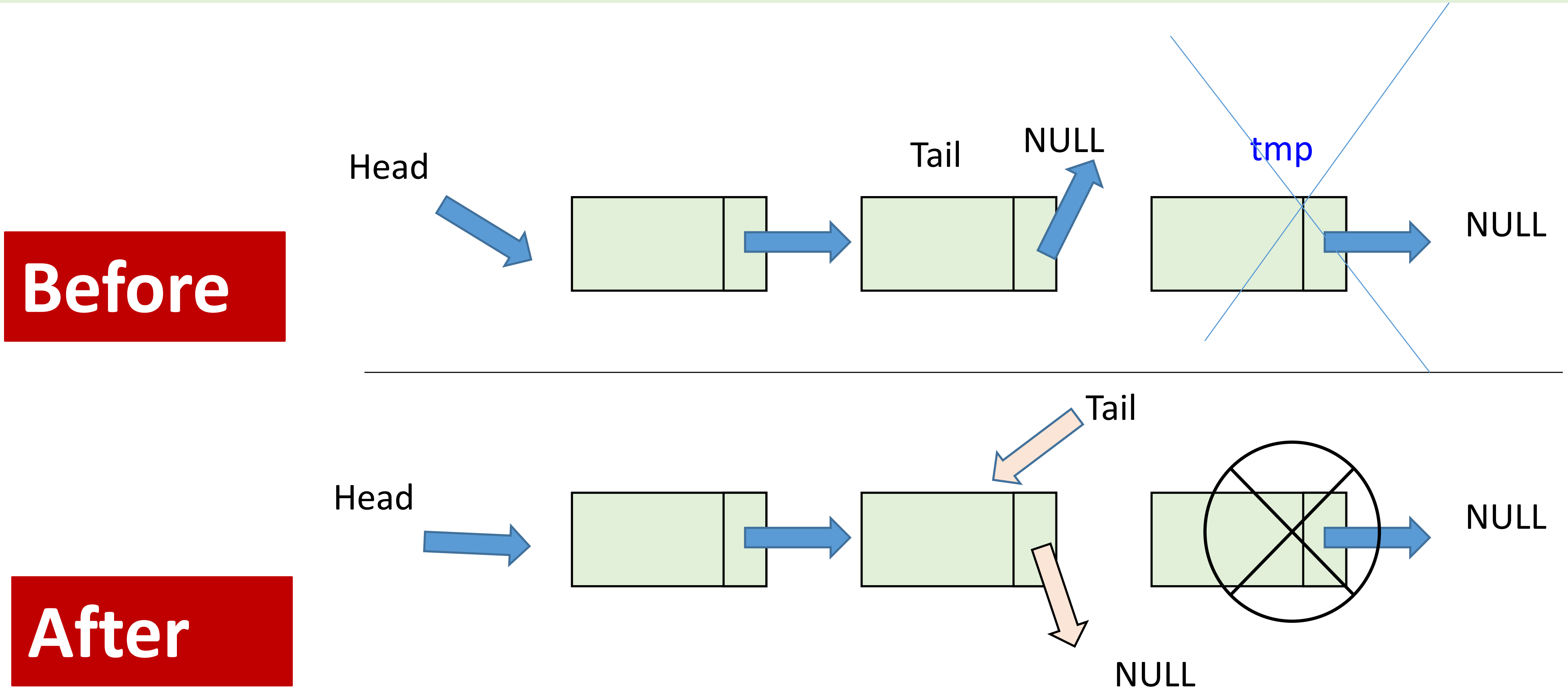
- Delete last element
- Delete all elements in the list

How to delete data from linked list

❖ Delete last element (delete from end)

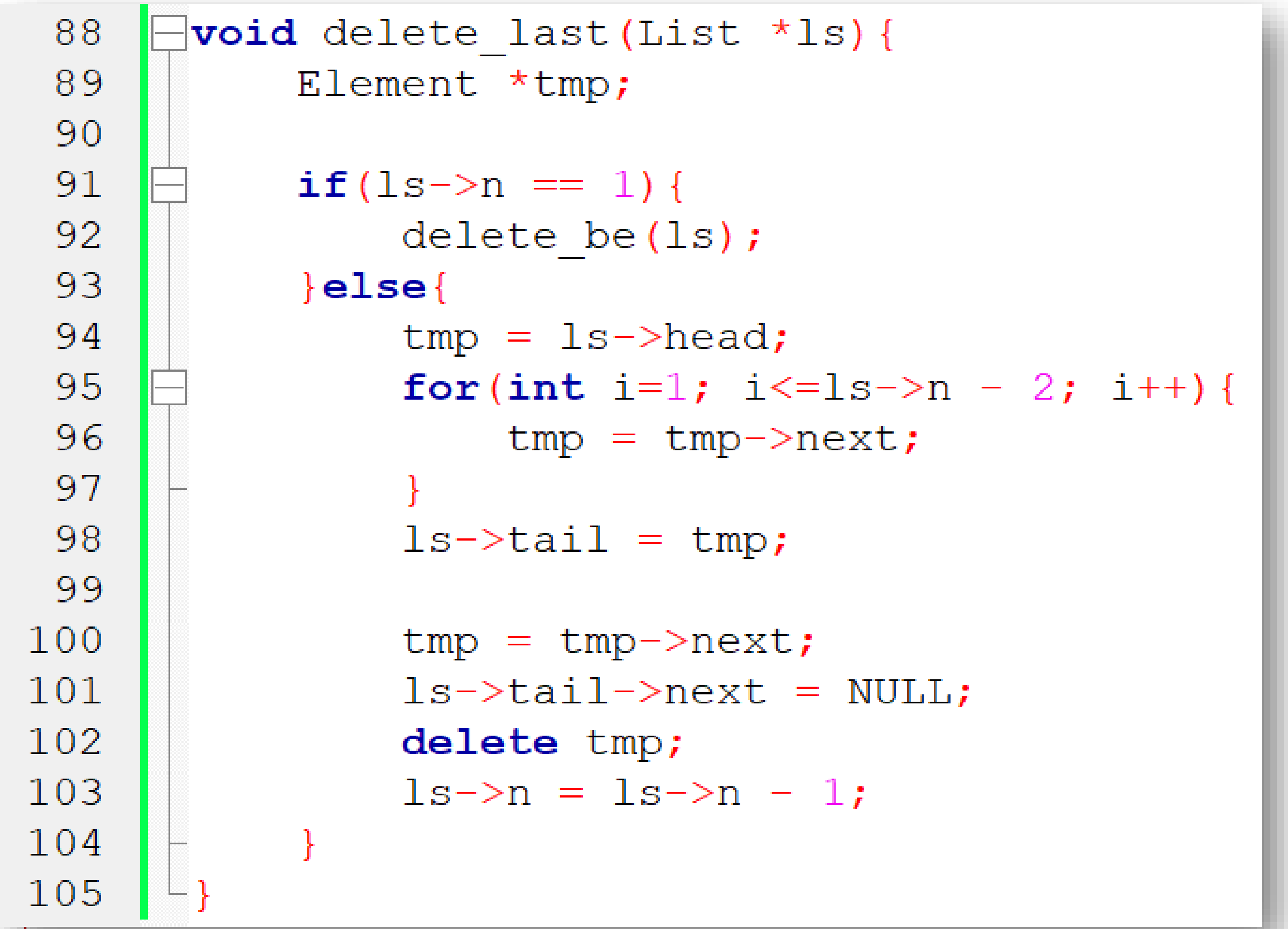
Deletion

❑ Delete the last element from single linked list



Delete the last element

```
Procedure delete_last(*ls: List)
        var *tmp: Element
        var i: integer
        if(ls→n==1) then
                delete_be(li)
        else                                        1
                //Go to the 2nd last element
                tmp ← ls→head
                for(i←1;   <= ls→n  - 2; i++) do
                        tmp ← tmp→next
                end for
        2       //update tail and delete last old element
                ls→tail ← tmp
                tmp ← tmp→next   3
                ls→tail→next ← NULL   4
        5       free(tmp)
                ls→n ← ls→n - 1
        end
End procedures
```



```
void delete_last(List *ls){
    Element *tmp;

    if(ls->n == 1){
        delete_be(ls);
    }else{
        tmp = ls->head;
        for(int i=1; i<=ls->n - 2; i++){
            tmp = tmp->next;
        }
        ls->tail = tmp;

        tmp = tmp->next;
        ls->tail->next = NULL;
        delete tmp;
        ls->n = ls->n - 1;
    }
}
```

Delete first element
(delete beginning)

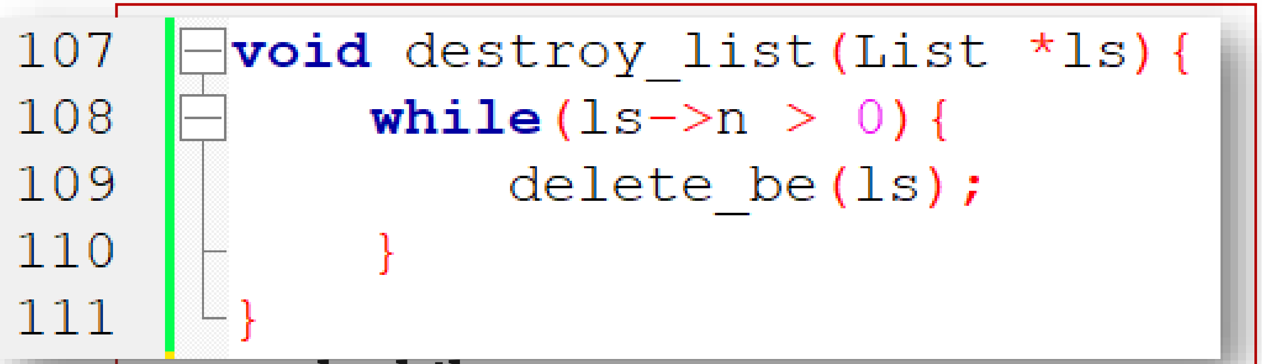
How it works … ?

How to delete data from linked list

- Delete all data (destroy list)

Destroy a list

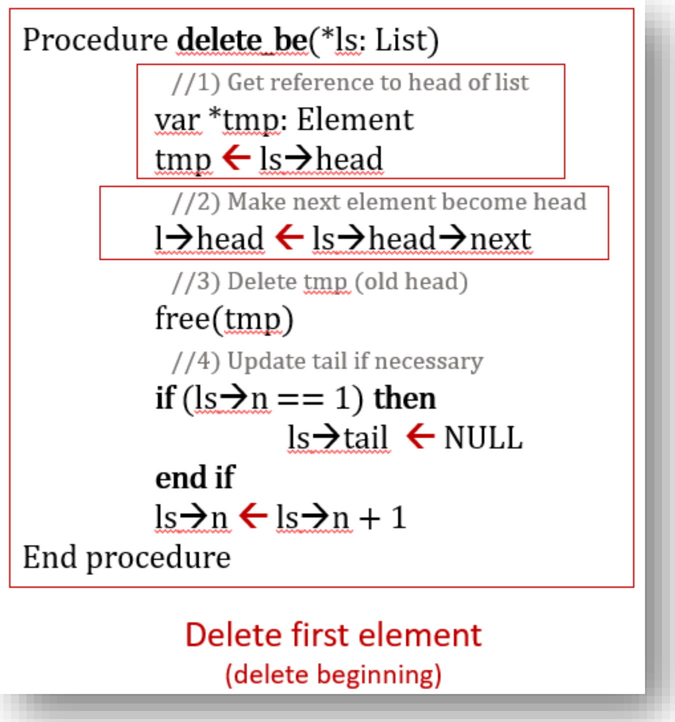
❑ Delete all data in list



```
void destroy_list(List *ls){
    while(ls->n > 0){
        delete_be(ls);
    }
}
```

end while

End procedure



```
Procedure delete_be(*ls: List)
        //1) Get reference to head of list
        var *tmp: Element
        tmp ← ls→head
        //2) Make next element become head
        l→head ← ls→head→next
        //3) Delete tmp (old head)
        free(tmp)
        //4) Update tail if necessary
        if (ls→n == 1) then
                ls→tail ← NULL
        end if
        ls→n ← ls→n + 1
End procedure
```

Delete first element

(delete beginning)

How it works … ?