Ho Chi Minh City University of Technology
Faculty of Computer Science and Engineering

Data Structures and Algorithms – C++ Implementation

Huỳnh Tấn Đạt

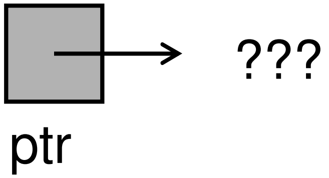
Email: htdat@cse.hcmut.edu.vn

Home Page: http://www.cse.hcmut.edu.vn/~htdat/

Pointer in C++

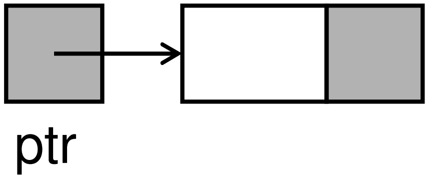
- □ Declaration

  Node *ptr;



- □ Create an object

  ptr = new Node();

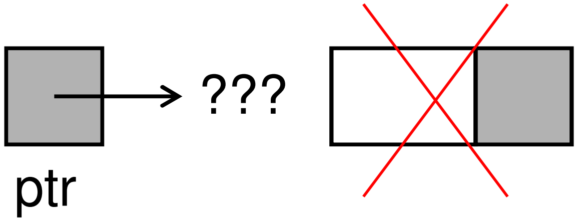


- □ A pointer usage

  printf(“Data in node: %d”, ptr->data);

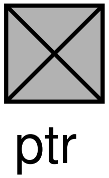
- □ Destroy an object

  delete ptr;



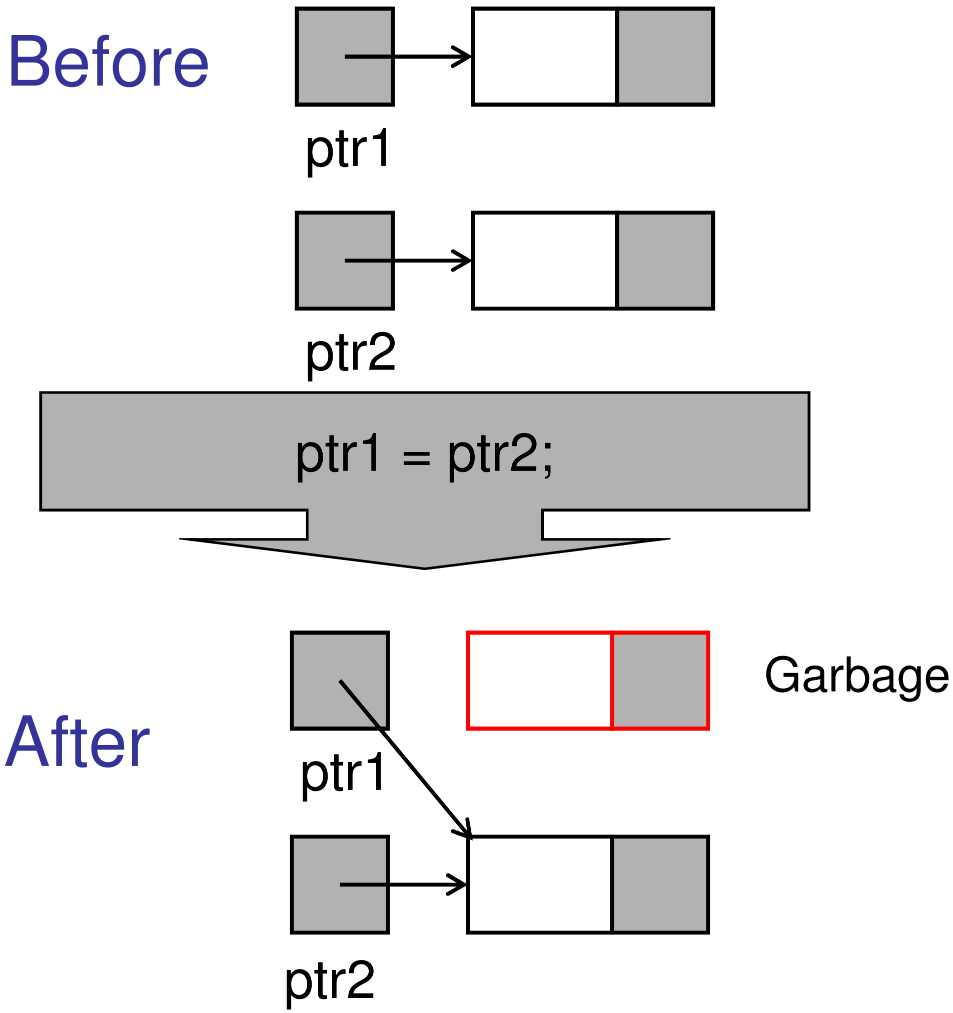
- □ NULL pointer

  ptr = NULL;

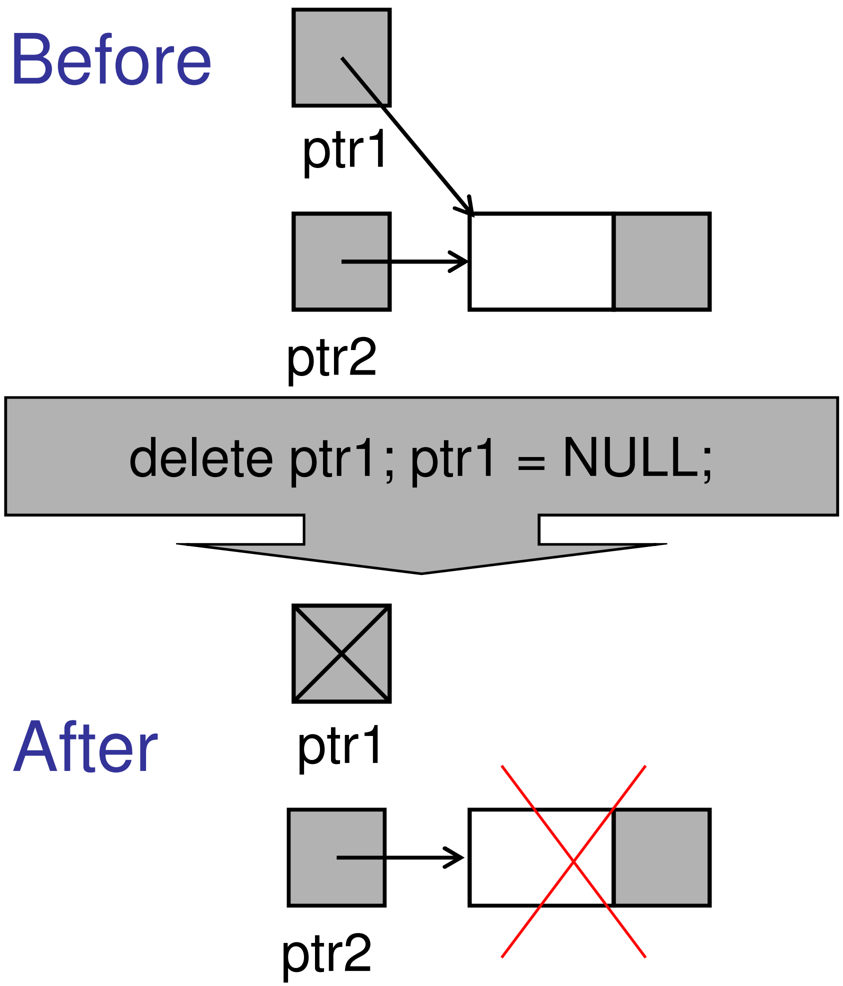


Pointer in C++

- Be careful in these cases:



```
ptr1 = ptr2;
```

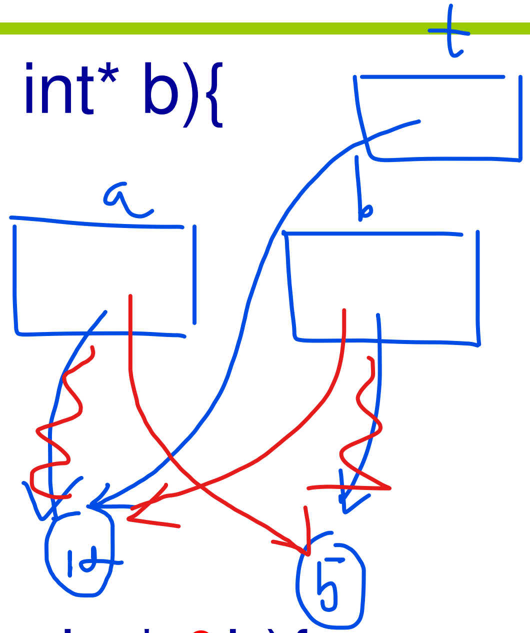


```
delete ptr1; ptr1 = NULL;
```

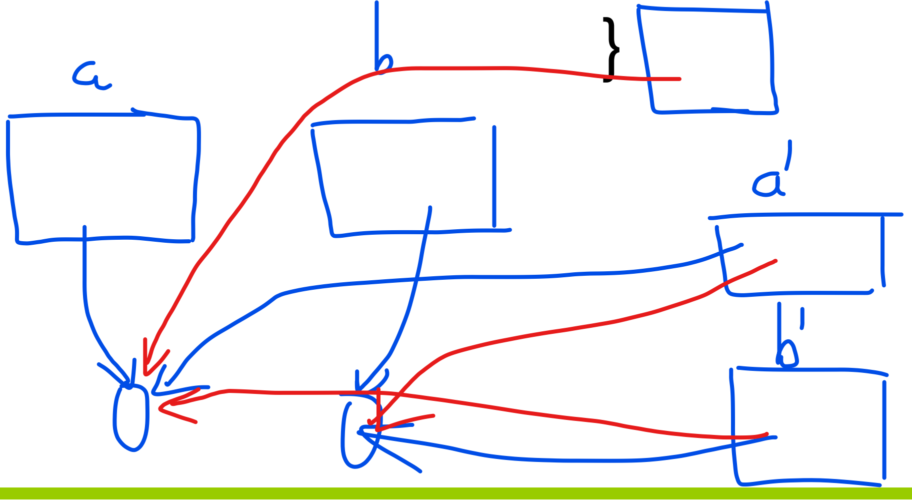
Dangling reference problem

Parameter Passing Techniques

```
void func(int* a, int* b){
    int *t;
    t = a;
    a = b;
    b = t;
}
```



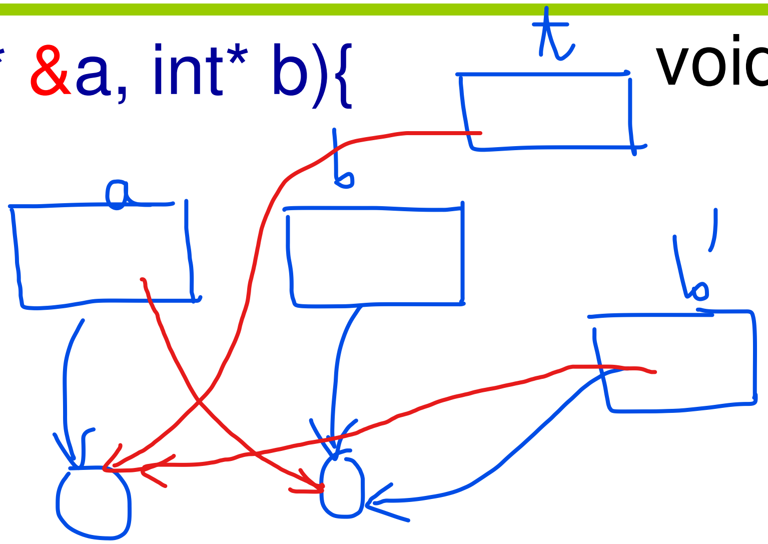
```
void func(int* &a, int* &b){
    int *t;
    t = a;
    a = b;
    b = t;
}
```



```
void main() {
        int *p1 = new int;
        *p1 = 10;
        int *p2 = new int;
        *p2 = 20;
        func(p1, p2);
        printf(“%d”, *p1);
        printf(“%d”, *p2);
}
```

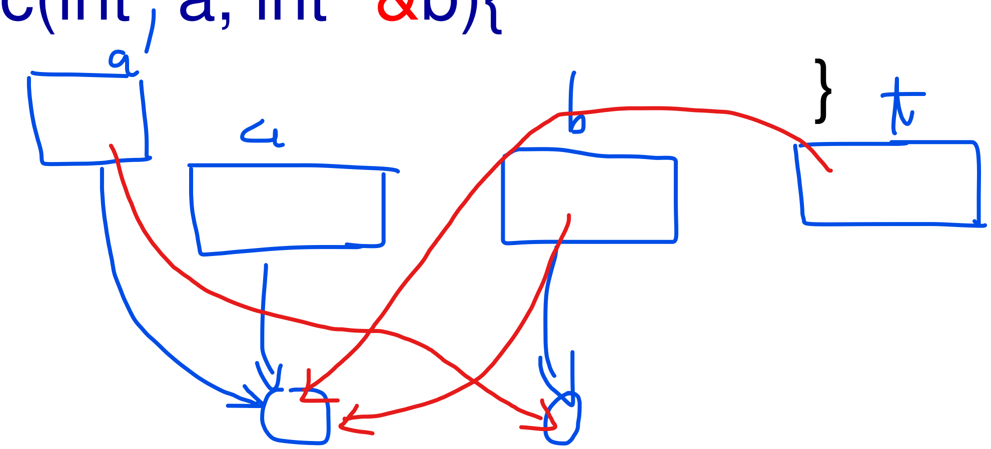
Parameter Passing Techniques

```
void func(int* &a, int* b){
   int *t;
   t = a;
   a = b;
   b = t;
}
```



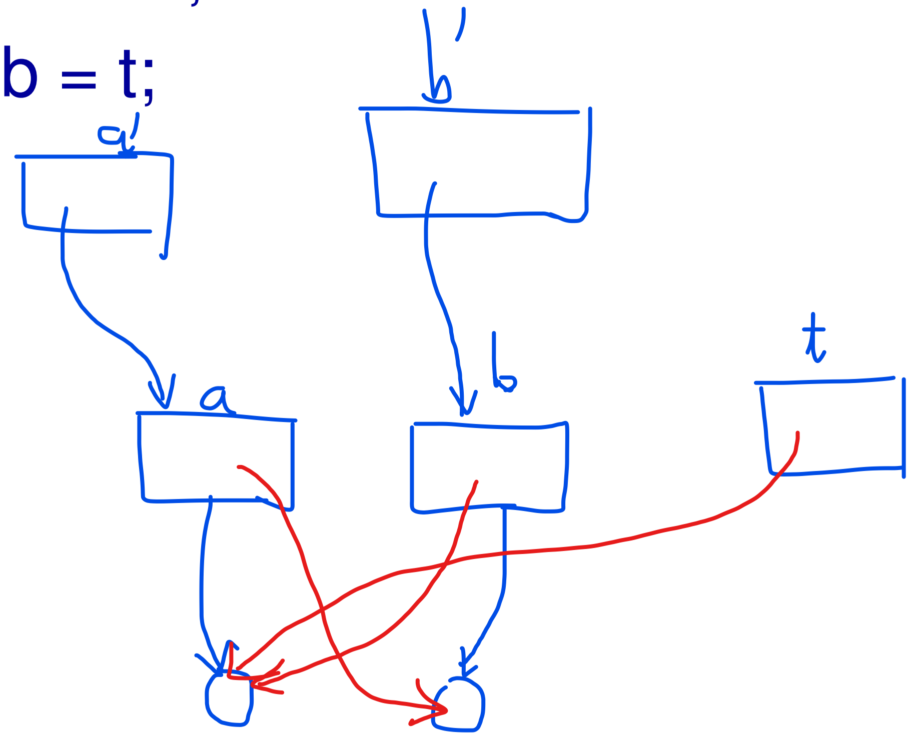
```
void main() {
      int *p1 = new int;
      *p1 = 10;
      int *p2 = new int;
      *p2 = 20;
      func(p1, p2);
      printf(“%d”, *p1);
      printf(“%d”, *p2);
}
```

```
void func(int* a, int* &b){
   int *t;
   t = a;
   a = b;
   b = t;
}
```



Parameter Passing Techniques

```
void func(int **a, int **b){
    int *t;
    t = *a;
    *a = *b;
    *b = t;
}
```

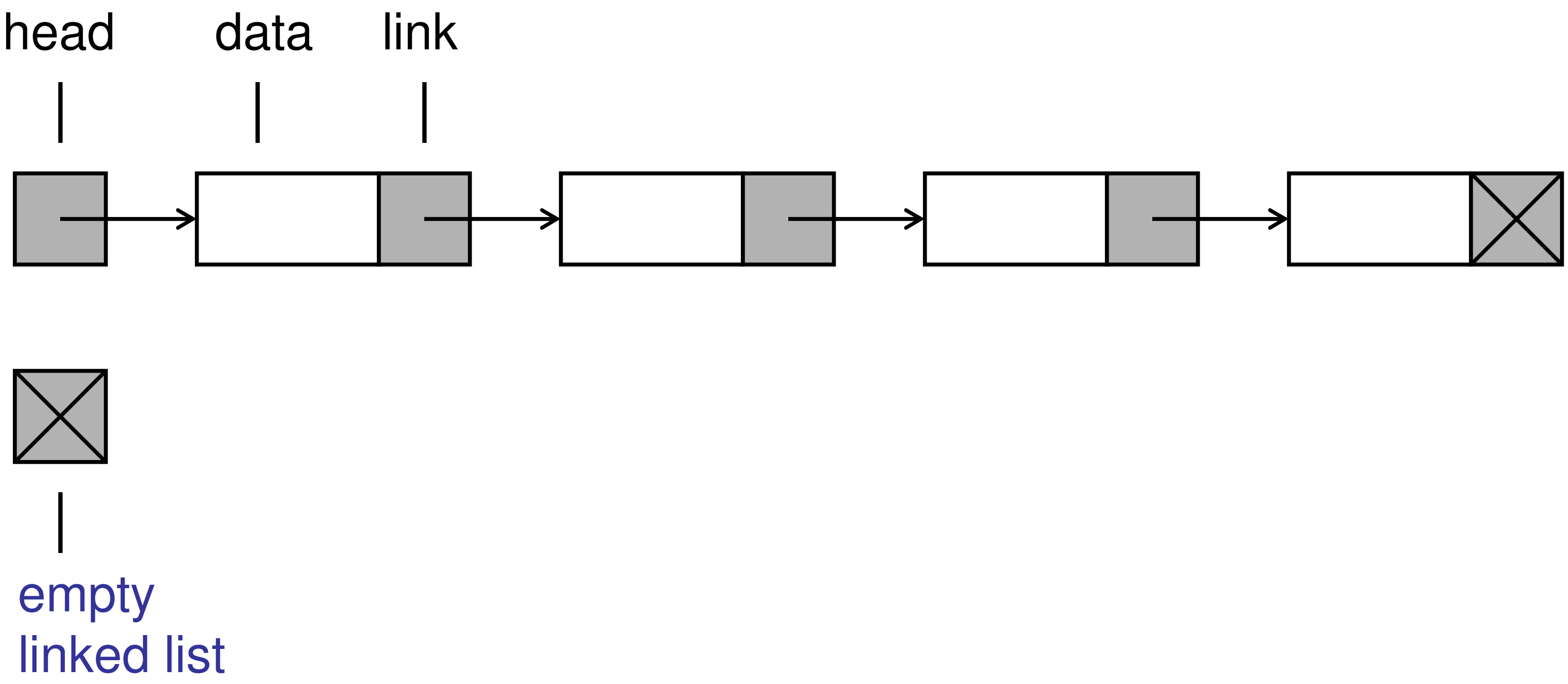


```
void main() {
        int *p1 = new int;
        *p1 = 10;
        int *p2 = new int;
        *p2 = 20;
        func(&p1, &p2);
        printf("%d", *p1);
        printf("%d", *p2);
}
```

Linked Lists

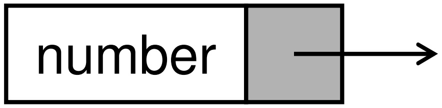
- A linked list is an ordered collection of data in which each element contains the location of the next element

Element = Data + Link



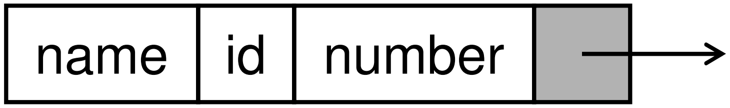
Nodes

A node with
one data field



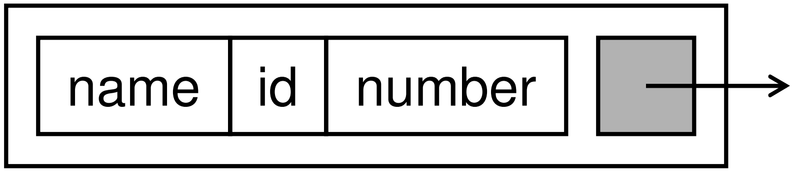
number

A node with
three data fields



name id number

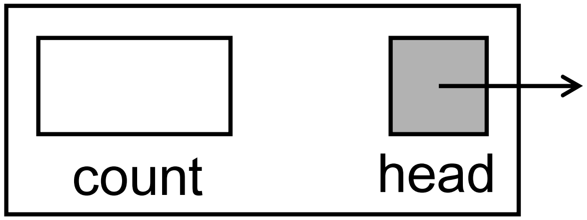
A node with one
structured data field



name id number

Nodes

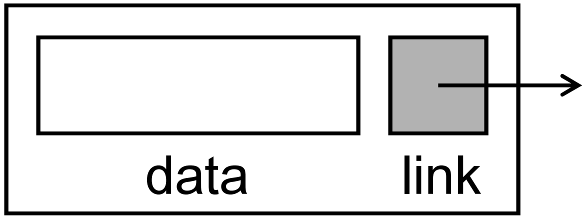
Linked List Structure



count

head

Data node structure



data

link

```
list
    count <integer>
    head <pointer>
end list
```

```
node
    data <dataType>
    link <pointer>
end node
```

```
dataType
    key <keyType>
    field1 <…>
    field2 <…>
    …
    fieldN <…>
end dataType
```

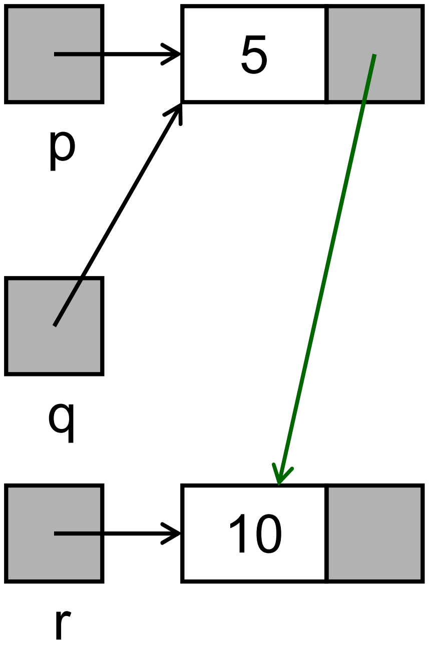
Nodes – Implementation in C++

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

```
node
    data <dataType>
    link <pointer>
end node
```

Nodes – Implementation in C++

```
Node *p = new Node();
p->data = 5;
cout<< p->data;
Node *q = p;
cout<< q->data;
Node *r = new Node();
r->data = 10;
q->next = r;
cout<< p->next->data;
```



Nodes – Implementation in C++

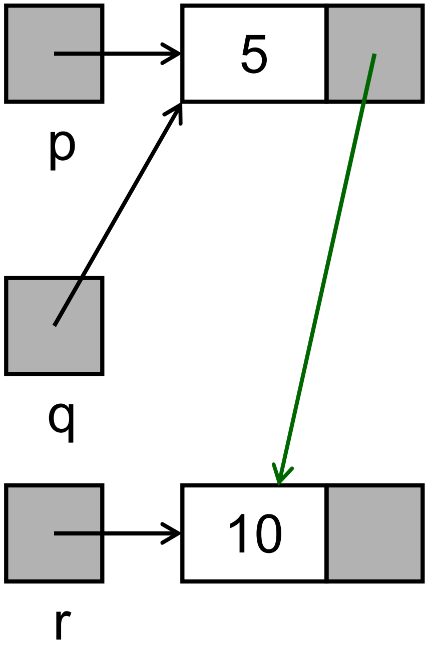
```
struct Node {
        int data;
        Node *next;
};
```

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

```
template <class ItemType>
struct Node {
        ItemType data;
        Node<ItemType> *next;
};
```

Nodes – Implementation in C++

```
Node<int> *p = new Node<int>();
p->data = 5;
cout<< p->data;
Node<int> *q = p;
cout<< q->data;
Node<int> *r = new Node<int>();
r->data = 10;
q->next = r;
cout<< p->next->data;
```



Nodes – Implementation in C++

```
template <class ItemType>
class Node{
public:
  Node(){
    this->next = NULL;
  }
  Node(ItemType data){
    this->data = data;
    this->next = NULL;
  }

  ItemType data;
  Node<ItemType> *next;
};
```

Linked List – Implementation in C++

```cpp
template <class List_ItemType>
class LinkedList{
public:
   LinkedList();
   ~LinkedList();
protected:
   Node<List_ItemType>* head;
   int count;
};
```

```
list
    count <integer>
    head <pointer>
end list
```

Linked List Algorithms

- ❑ Create list
- ❑ Insert node
- ❑ Delete node
- ❑ Traverse
- ❑ Destroy list

Linked List Implementation

```
template <class List_ItemType>
class LinkedList{
public:
  LinkedList();
  ~LinkedList();
protected:
  int InsertNode(Node<List_ItemType>* pPre,
            List_ItemType value);
  List_ItemType DeleteNode(Node<List_ItemType>* pPre,
                           Node<List_ItemType>* pLoc);
  int Search(List_ItemType value, Node<List_ItemType>*
  &pPre, Node<List_ItemType>* &pLoc);
  void Traverse();

  Node<List_ItemType>* head;
  int count;
};
```

Linked List Implementation

```
template <class List_ItemType>
class LinkedList{
public:
   LinkedList();
   ~LinkedList();
   void InsertFirst(List_ItemType value);
   void InsertLast(List_ItemType value);
   int InsertItem(List_ItemType value, int Position);
   List_ItemType DeleteFirst();
   List_ItemType DeleteLast();
   int DeleteItem(int Postion);
   int GetItem(int Position, List_ItemType &dataOut);
   void Print2Console();
   void Clear();
   // Augment your methods for linked list here!!!
   LinkedList<List_ItemType>* Clone();
protected:
// ...
```

Linked List Implementation

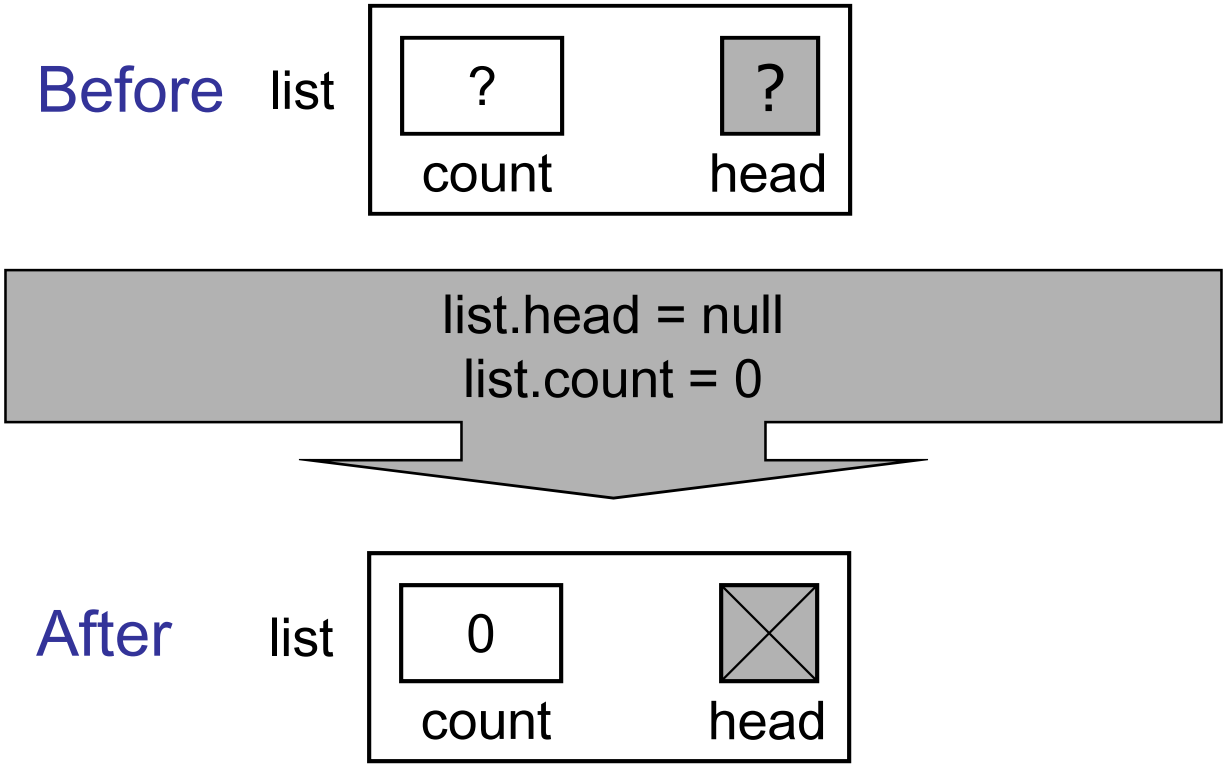
- How to use Linked List data structure?

```
int main(int argc, char* argv[]) {
  LinkedList<int>* myList =
                   new LinkedList<int>();
  myList->InsertFirst(15);
  myList->InsertFirst(10);
  myList->InsertFirst(5);
  myList->InsertItem(18, 3);
  myList->InsertLast(25);
  myList->InsertItem(20, 3);
  myList->DeleteItem(2);
  printf("List 1:\n");
  myList->Print2Console();
```

Linked List Implementation

```
 // ...
 int value;
 LinkedList<int>* myList2 = myList->Clone();
 printf("\nList 2:\n");
 myList2->Print2Console();
 myList2->GetItem(1, value);
 printf(“Value at position 1: %d”, value);

 delete myList;
 delete myList2;
 return 1;
}
```

Create List



Before list

?

count

?

head

list.head = null

list.count = 0

After list

0

count

head

Create List

```
Algorithm createList (ref list <metadata>)
Initializes metadata for a linked list
   Pre     list is a metadata structure passed by reference
   Post    metadata initialized
   list.head = null
   list.count = 0
   return
   End     createList
```

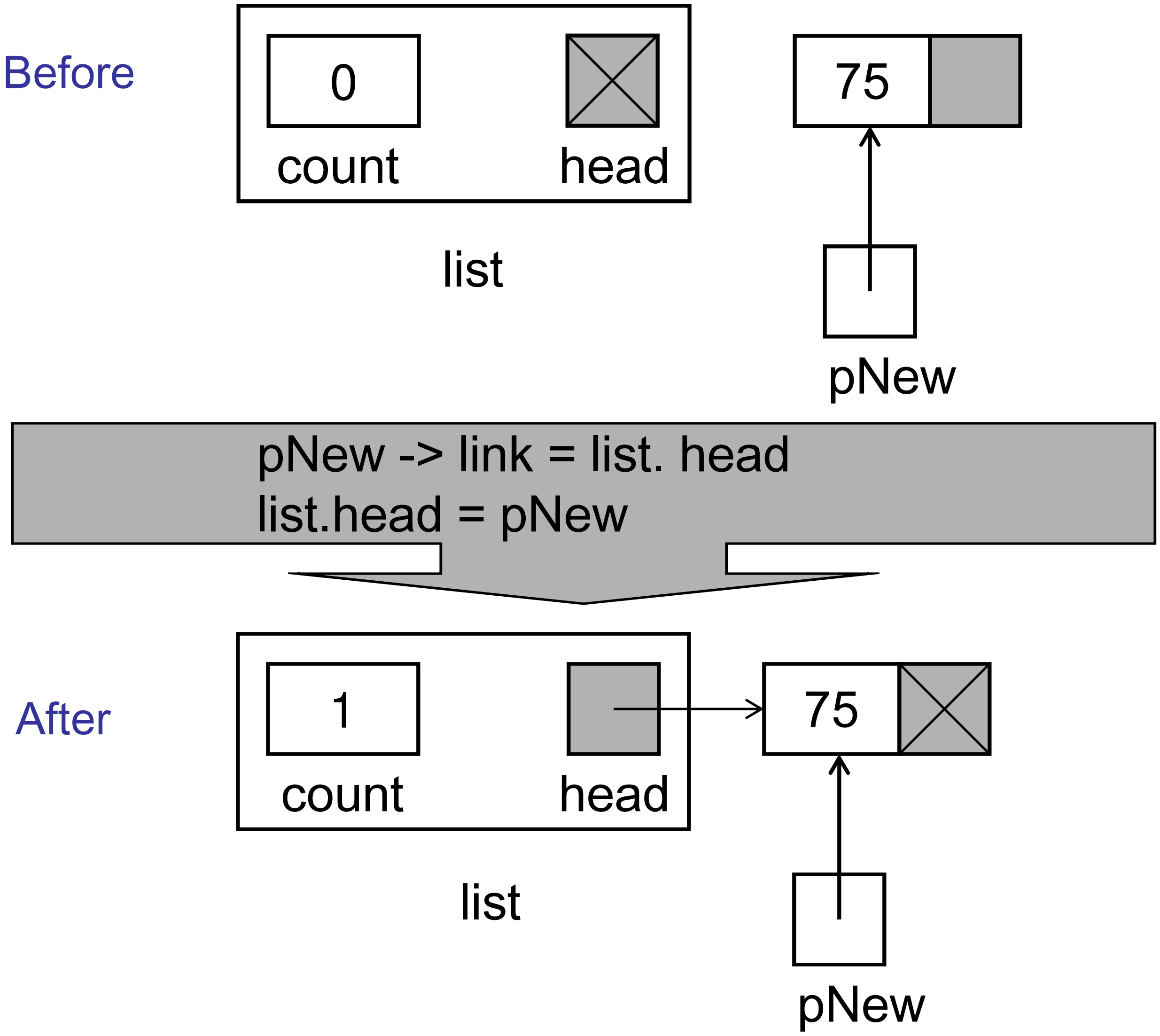
Linked List Implementation

```
template <class List_ItemType>
LinkedList<List_ItemType>::LinkedList(){
  this->head = NULL;
  this->count = 0;
}
```

Insert Node

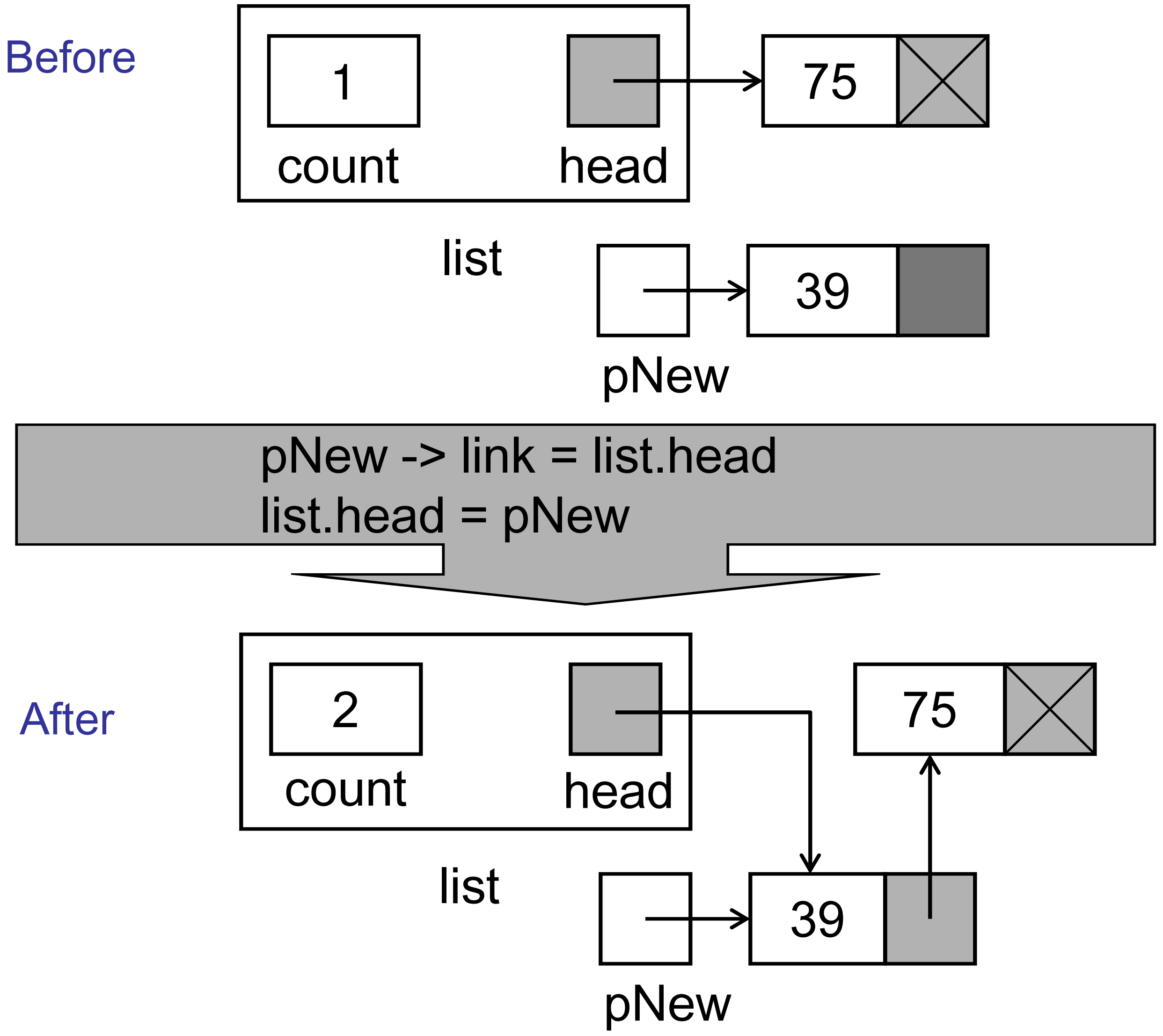
- Allocate memory for the new node and set up data
- Point the new node to its successor
- Point the new node's predecessor to it

Insert into Empty List



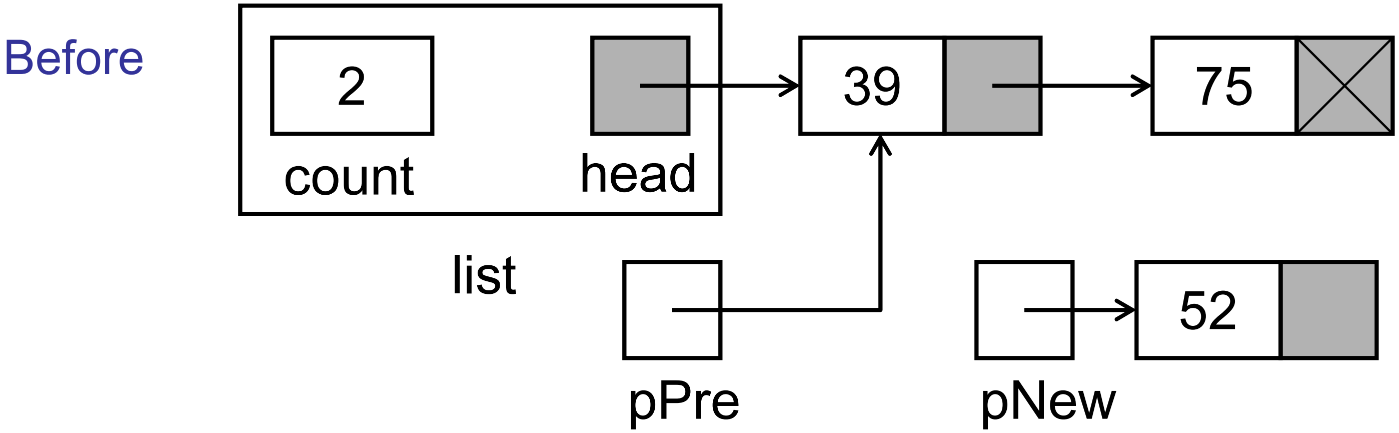
```
pNew -> link = list. head
list.head = pNew
```

Insert at the Beginning

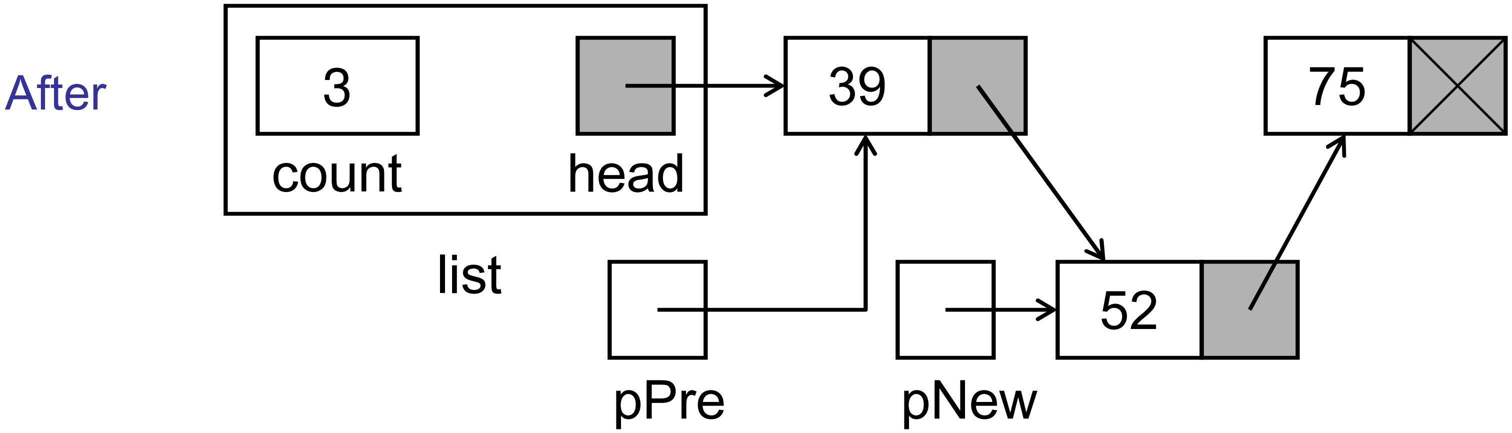


```
pNew -> link = list.head
list.head = pNew
```

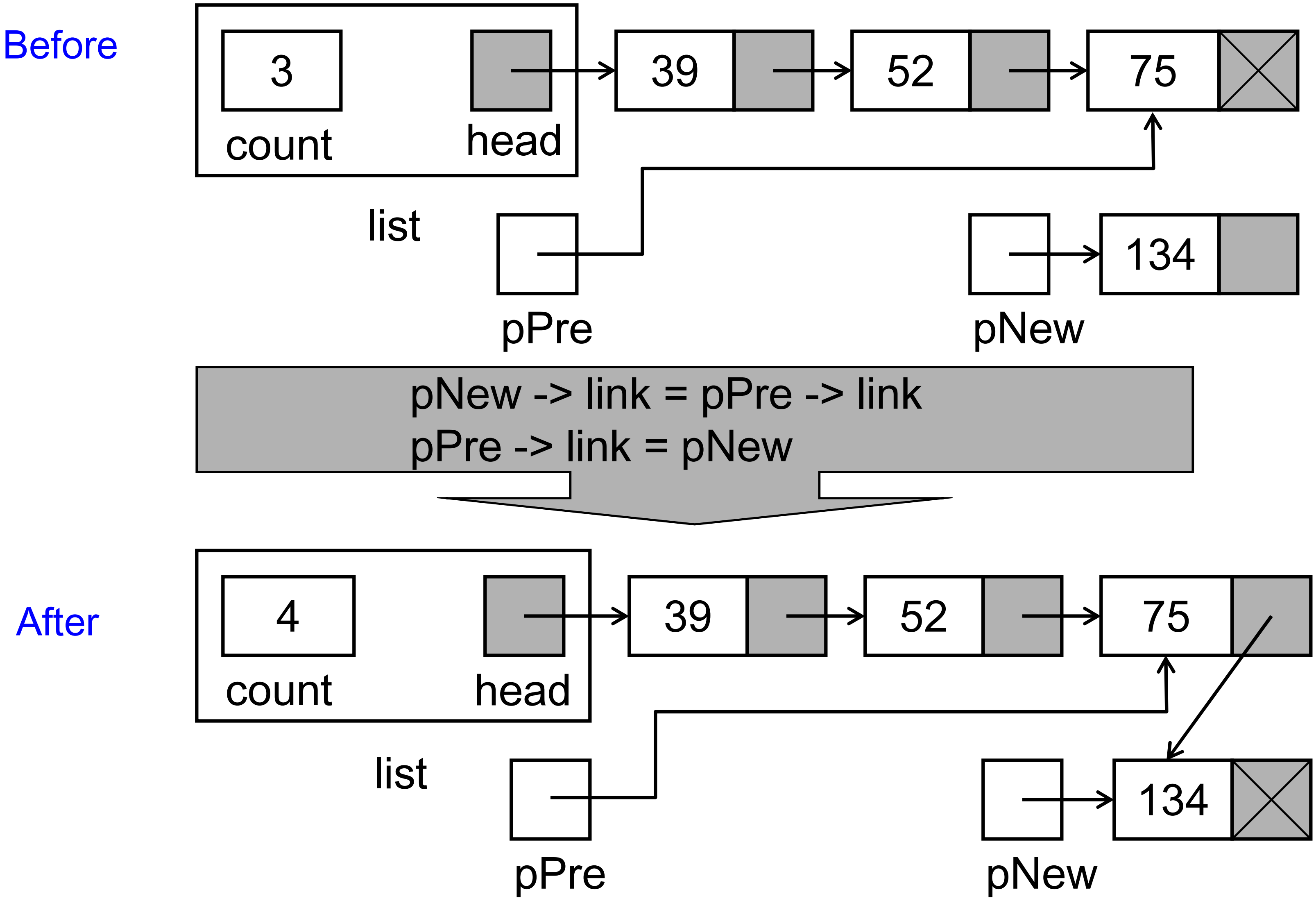
Insert in Middle



```
pNew -> link = pPre -> link
pPre -> link = pNew
```



Insert at End



```
pNew -> link = pPre -> link
pPre -> link = pNew
```

Insert Node Algorithm

```
Algorithm insertNode (ref list <metadata>,
                      val pPre <node pointer>,
                      val dataIn <dataType>)
Inserts data into a new node in the linked list
   Pre     list is metadata structure to a valid list
           pPre is pointer data's logical predecessor
           dataIn contains data to be inserted
   Post    data have been inserted in sequence
   Return true if successful, false if memory overflow
```

Insert Node Algorithm

```
1   allocate(pNew)
2   if (memory overflow)
    1   return false
3   pNew -> data = dataIn
4   if (pPre = null)
    Adding before first node or to empty list
    1   pNew -> link  = list.head
    2   list.head = pNew
5   else
    Adding in middle or at end
    1   pNew -> link  = pPre -> link
    2   pPre -> link = pNew
6   list.count = list.count + 1
7   return   true
End     insertNode
```

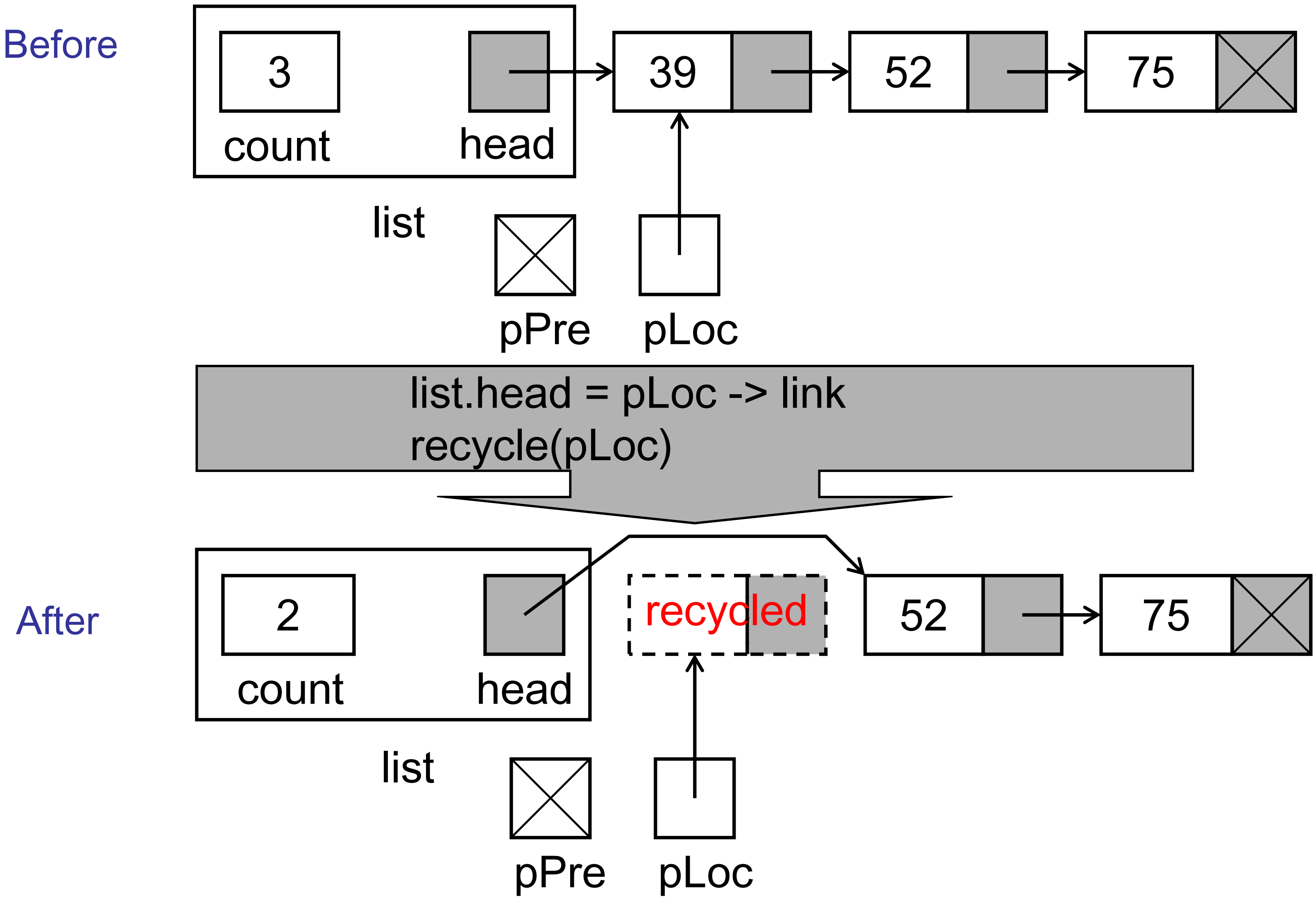
Insert Node

```
template <class List_ItemType>
int LinkedList<List_ItemType>::InsertNode(
               Node<List_ItemType> *pPre, List_ItemType value) {
  Node<List_ItemType> *pNew = new Node<List_ItemType>();
  if (pNew == NULL)
       return 0;
  pNew->data = value;
  if (pPre == NULL){
       pNew->next = this->head;
       this->head = pNew;
  } else {
       pNew->next = pPre->next;
       pPre->next = pNew;
  }
  this->count++;
  return 1;
}
```

Delete Node

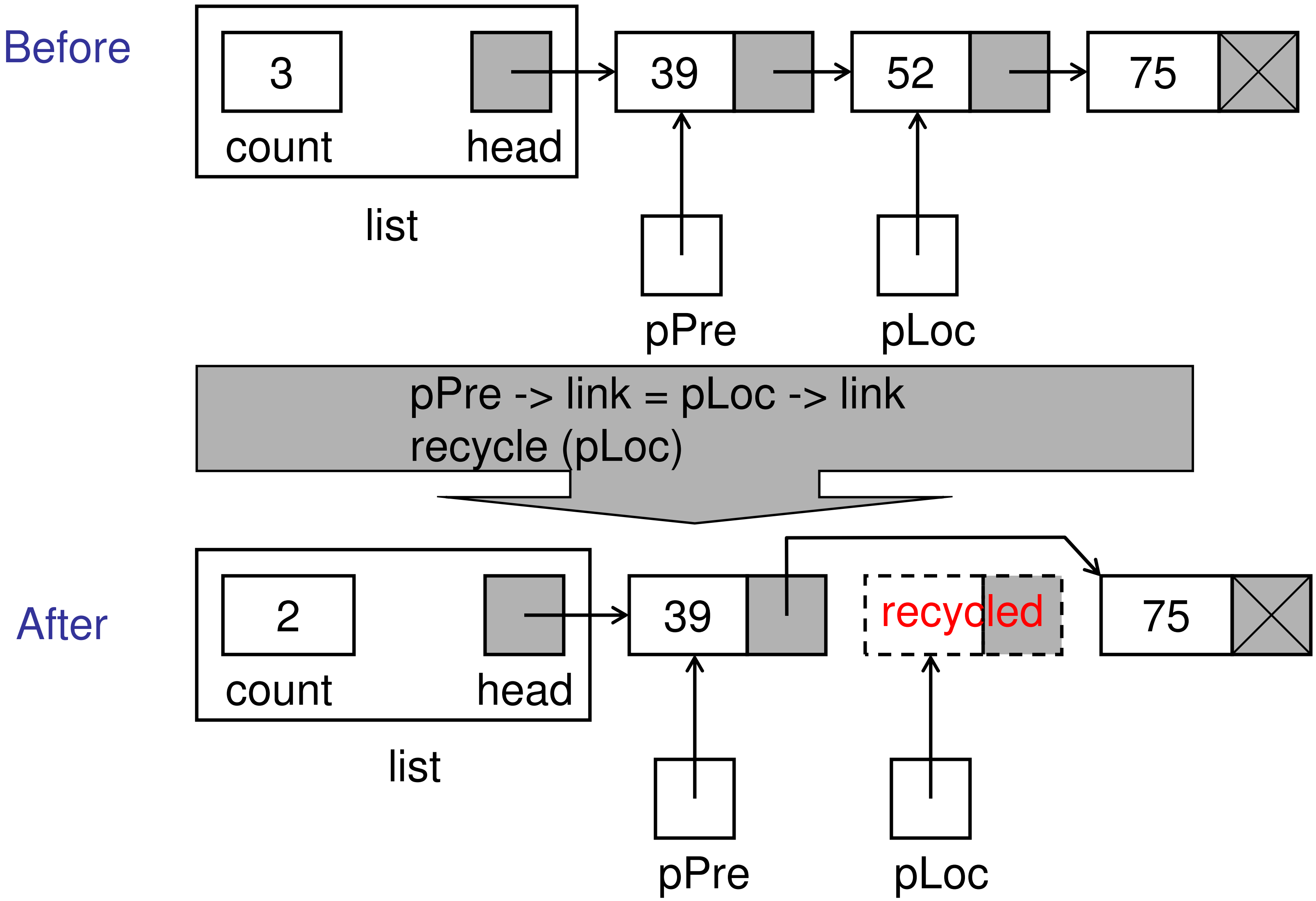
- ❑ Locate the node to be deleted.
- ❑ Point the node predecessor's link to its successor.
- ❑ Release the memory for the deleted node

Delete First Node



```
list.head = pLoc -> link
recycle(pLoc)
```

General Delete Case



```
pPre -> link = pLoc -> link
recycle (pLoc)
```

Delete Node Algorithm

```
Algorithm deleteNode (ref list <metadata>,
                      val pPre <node pointer>,
                      val pLoc <node pointer>
                      ref dataOut <dataType>)
Delete data from a linked list and returns it to calling
   module
   Pre   list is metadata structure to a valid list
         pPre is a pointer to predecessor node
         pLoc is a pointer to node to be deleted
         dataOut is variable to receive deleted data
   Post data have been deleted and returned to caller
```

Delete Node Algorithm

```
1   dataOut = pLoc -> data
2   if (pPre = null)
        Delete first node
    1   list.head  = pLoc -> link
3   else
        Delete other nodes
    1   pPre -> link  = pLoc -> link
4   list.count = list.count - 1
5   recycle (pLoc)
6   return
End    deleteNode
```

Delete Node

```
template <class List_ItemType>
List_ItemType LinkedList<List_ItemType>::DeleteNode(
  Node<List_ItemType> *pPre, Node<List_ItemType> *pLoc){
  List_ItemType result = pLoc->data;
  if (pPre == NULL)
      list->head = pLoc->next;
  else
      pPre->next = pLoc->next;
  this->count--;
  delete pLoc;
  return result;
}
```

Traverse List

- Traverse module controls the loop:
  calling a user-supplied algorithm to process data

```
pWalker = list.head
loop (pWalker not null)
    process (pWalker -> data)
    pWalker = pWalker -> link
```

Traverse List

```
template <class List_ItemType>
void LinkedList<List_ItemType>::Traverse() {
  Node<List_ItemType> *p = head;
  while (p != NULL){
      p->data++; // process data here!!!
      p = p->next;
  }
}

template <class List_ItemType>
void LinkedList<List_ItemType>::Traverse(void
  (*visit)(List_ItemType &)) {
  Node<List_ItemType> *p = head;
  while (p != NULL){
      (*visit)(p->data);
      p = p->next;
  }
}
```

Searching in Linked List

```
template <class List_ItemType>
int LinkedList<List_ItemType>::
  Search(List_ItemType value, Node<List_ItemType>* &pPre,
  Node<List_ItemType>* &pLoc){
  pPre = NULL;
  pLoc = this->head;
  while (pLoc != NULL && pLoc->data != value){
      pPre = pLoc;
      pLoc = pLoc->next;
  }
  return (pLoc != NULL); // found: 1; notfound: 0
}
```

Destroy List Algorithm

```
Algorithm  destroyList (val list <metadata>)
Deletes all data in list.
   Pre     list is metadata structure to a valid list
   Post    all data deleted
   1  loop (list.head not null)
      1  dltPtr = list.head
      2  list.head = this.head -> link
      3  recycle (dltPtr)
      No data left in list. Reset metadata
   2  list.count = 0
   3  return
   End  destroyList
```

Destroy list

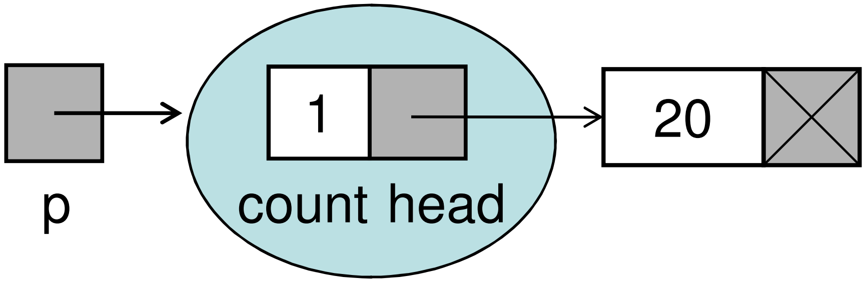
```
template <class List_ItemType>
void LinkedList<List_ItemType>::Clear(){
  Node<List_ItemType> *temp;
  while (this->head != NULL){
      temp = this->head;
      this->head = this->head->next;
      delete temp;
  }
  this->count = 0;
}
template <class List_ItemType>
LinkedList<List_ItemType>::~LinkedList(){
  this->Clear();
}
```

Exercises

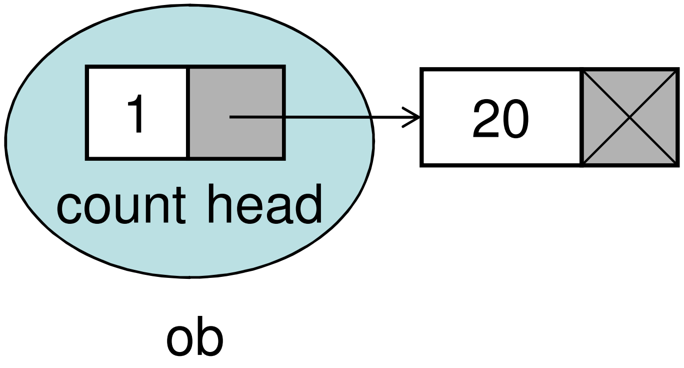
```
template <class List_ItemType>
class LinkedList{
public:
  LinkedList();
  ~LinkedList();

  int InsertFirst(List_ItemType value);
  int InsertLast(List_ItemType value);
  int InsertItem(List_ItemType value, int Position);
  List_ItemType DeleteFirst();
  List_ItemType DeleteLast();
  int DeleteItem(int Postion);
  int GetItem(int Position, List_ItemType &dataOut);
  void Print2Console();
  // Augment more methods for linked list here!!!
  LinkedList<List_ItemType>* Clone();
protected: // as previous slide
```

Pointer vs. Object Variable

```
void main(){
   LinkedList *p = new LinkedList();
   p->InsertLast(20);
   // do sth with p here
   func(p);
   delete p;
}
```

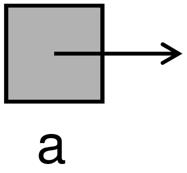


```
void main(){
   LinkedList ob;
   ob.InsertLast(20);
   // do sth with ob here
   func(ob);
}
```

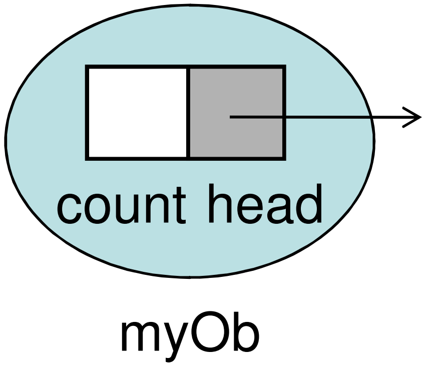


Pointer vs. Object Variable

```
void func(LinkedList *a)
  a->InsertFist(10);
}
```



```
void func(LinkedList myOb)
  myOb.InsertFist(10);
}
```



- ❑ What are the pros and cons?

Sample Solution: Insert

```
template <class List_ItemType>
int LinkedList<List_ItemType>::InsertItem(List_ItemType value,
   int position) {
   if (position < 0 || position > this->count)
       return 0;
   Node<List_ItemType>* newPtr, *pPre;
   newPtr = new Node<List_ItemType>();
   if (newPtr == NULL)
       return 0;
   newPtr->data = value;
   if (head == NULL) {
       head = newPtr;
       newPtr->next = NULL;
   }
   else if (position == 0) {
       newPtr->next = head;
       head = newPtr;
   }
```

Sample Solution: Insert

```
  else {
     // Find the position of pPre
     pPre = this->head;
     for (int i = 0; i < position-1; i++)
          pPre = pPre->next;
     // Insert new node
     newPtr->next = pPre->next;
     pPre->next = newPtr;
  }
  this->count++;
  return 1;
}
```

Sample Solution: Delete

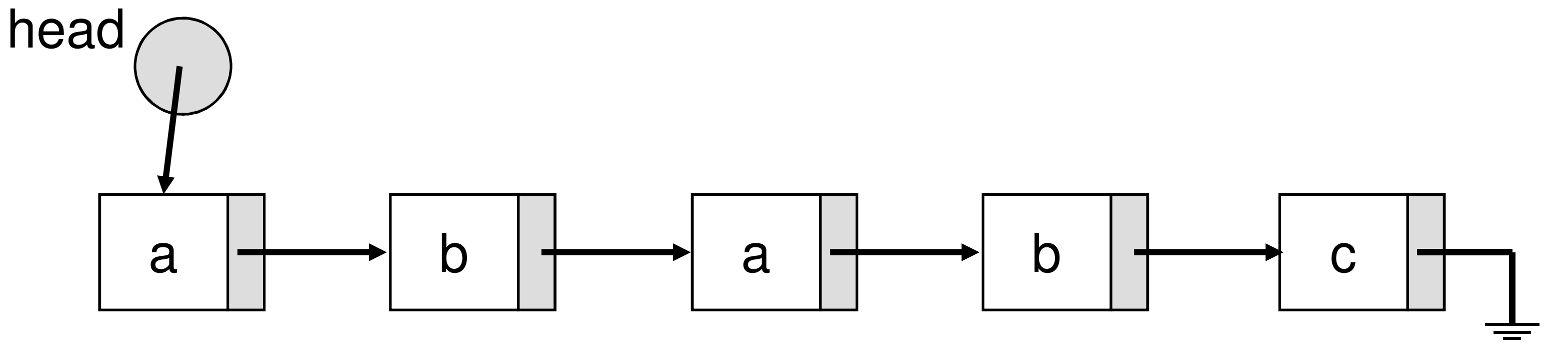
```
template <class List_ItemType>
int LinkedList<List_ItemType>::DeleteItem(int position){
   if (position < 0 || position > this->count)
       return 0;
   Node<List_ItemType> *dltPtr, *pPre;
   if (position == 0) {
       dltPtr = head;
       head = head->next;
   } else {
       pPre = this->head;
       for (int i = 0; i < position-1; i++)
              pPre = pPre->next;
       dltPtr = pPre->next;
       pPre->next = dltPtr->next;
   }
   delete dltPtr;
   this->count--;
   return 1;
}
```

Sample Solution: Clone

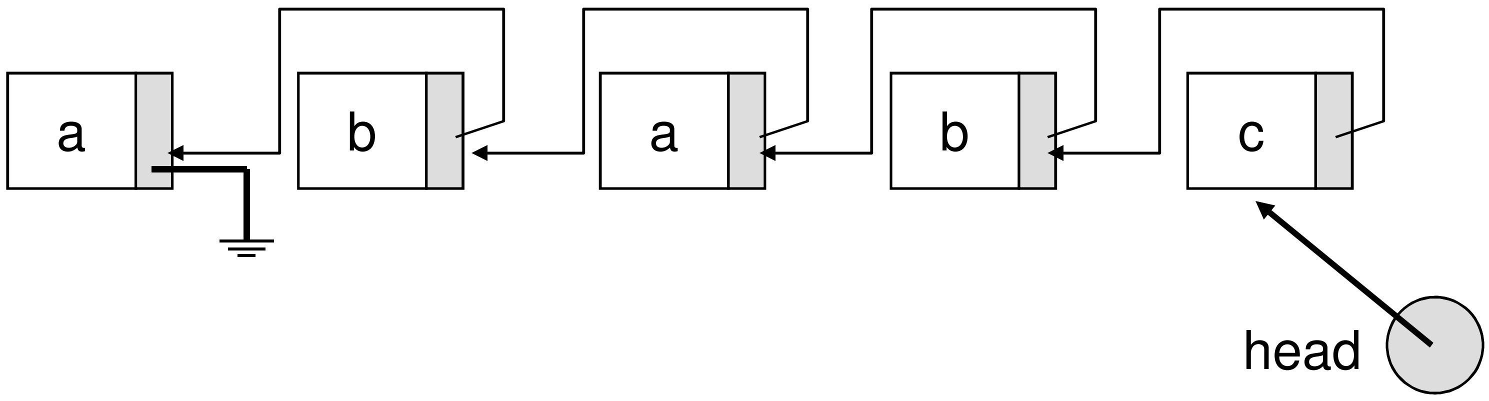
```
template <class List_ItemType>
LinkedList<List_ItemType>*
             LinkedList<List_ItemType>::Clone(){
  LinkedList<List_ItemType>* result =
                New LinkedList<List_ItemType>();
  Node<List_ItemType>* p = this->head;
  while (p != NULL) {
     result->InsertLast(p->data);
     p = p->next;
  }
  result->count = this->count;
  return result;
}
```

Homework

- ❑ Reverse a linked list

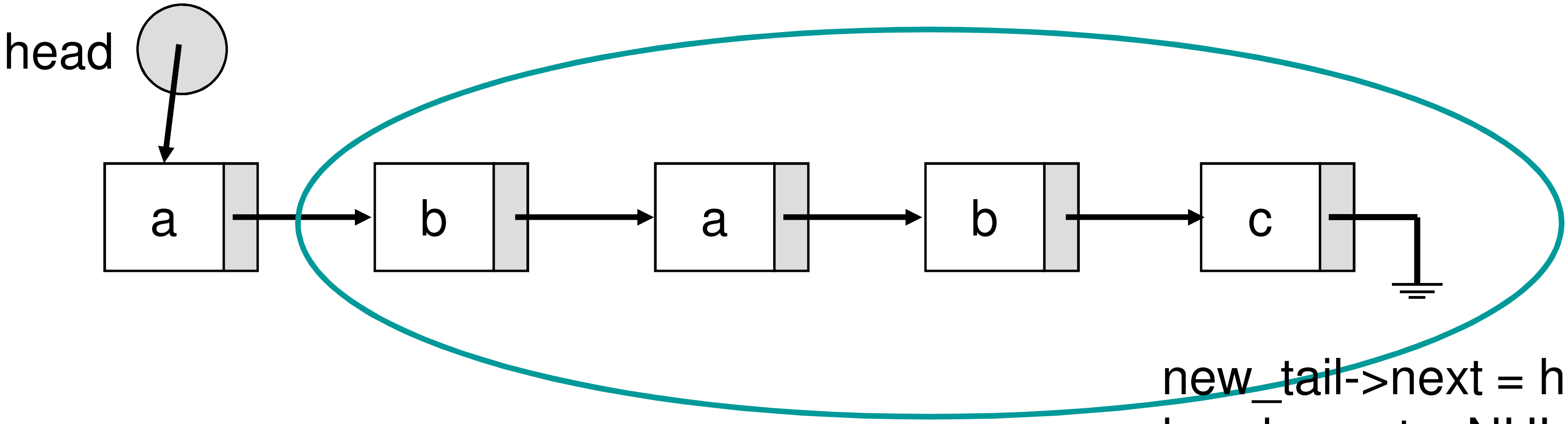


Result:



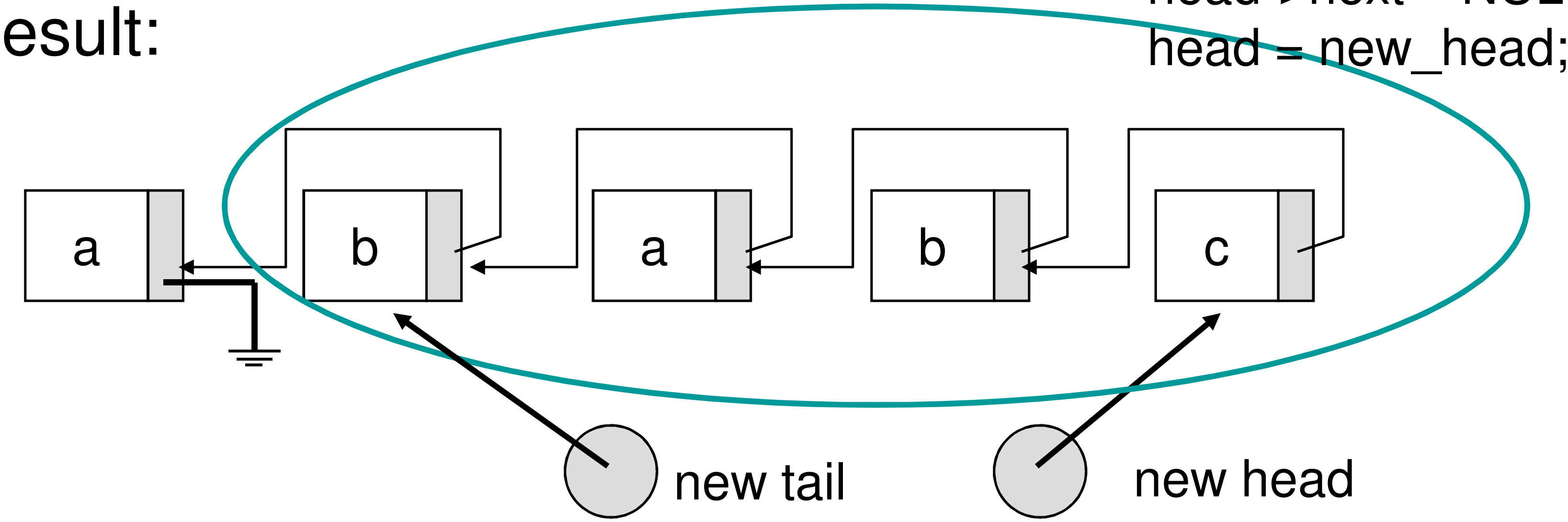
Homework

❑ Hint 1



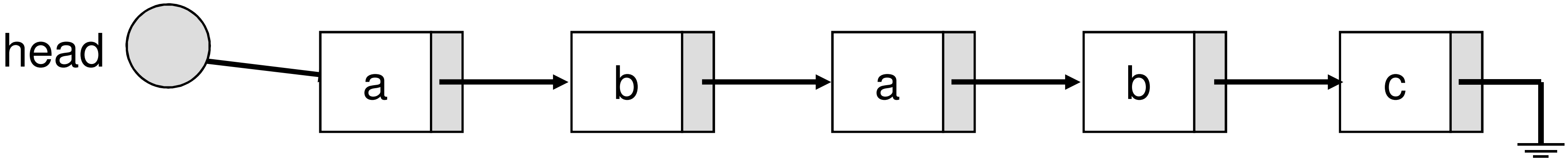
new_tail->next = head;
head->next = NULL;
head = new_head;

Result:



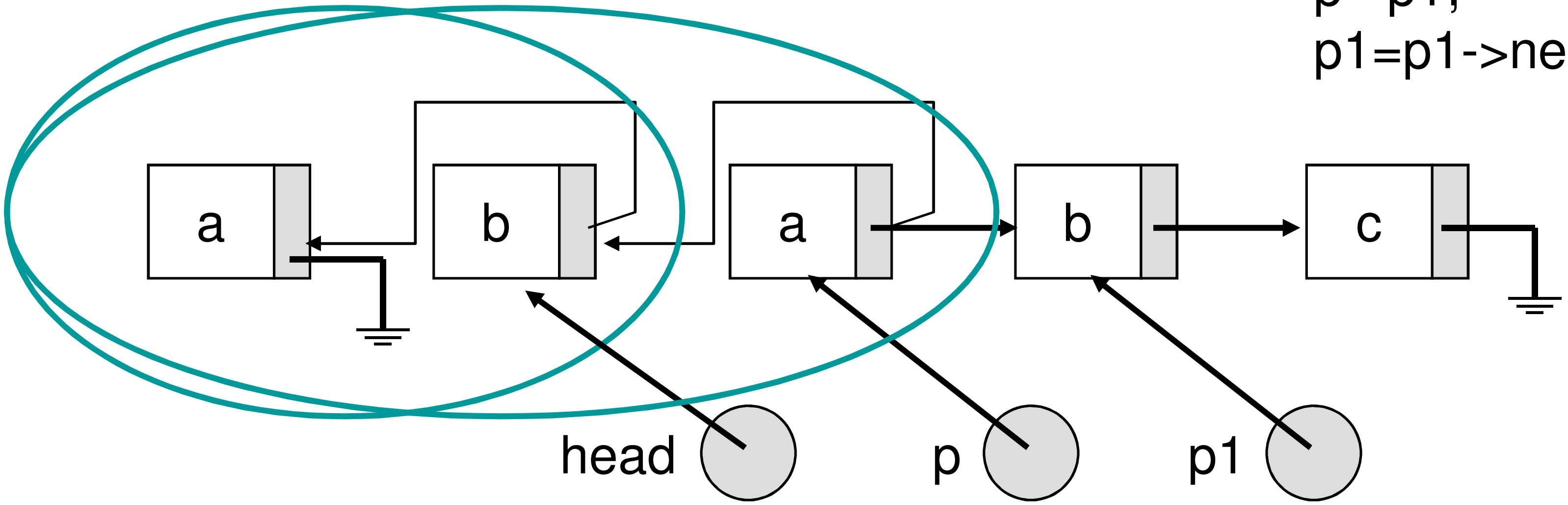
Homework

❑ Hint 2



Result:

```
p->next = head;
head = p;
p= p1;
p1=p1->next
```



Homework

```
template <class List_ItemType>
void LinkedList<List_ItemType>::Reverse(){
   ...
}
```