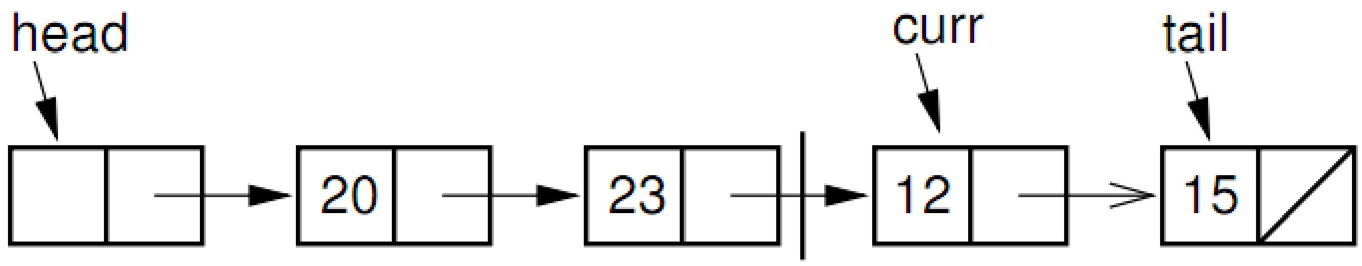
Unit 4 Singly Linked List

College of Computer Science, CQU

Introduction

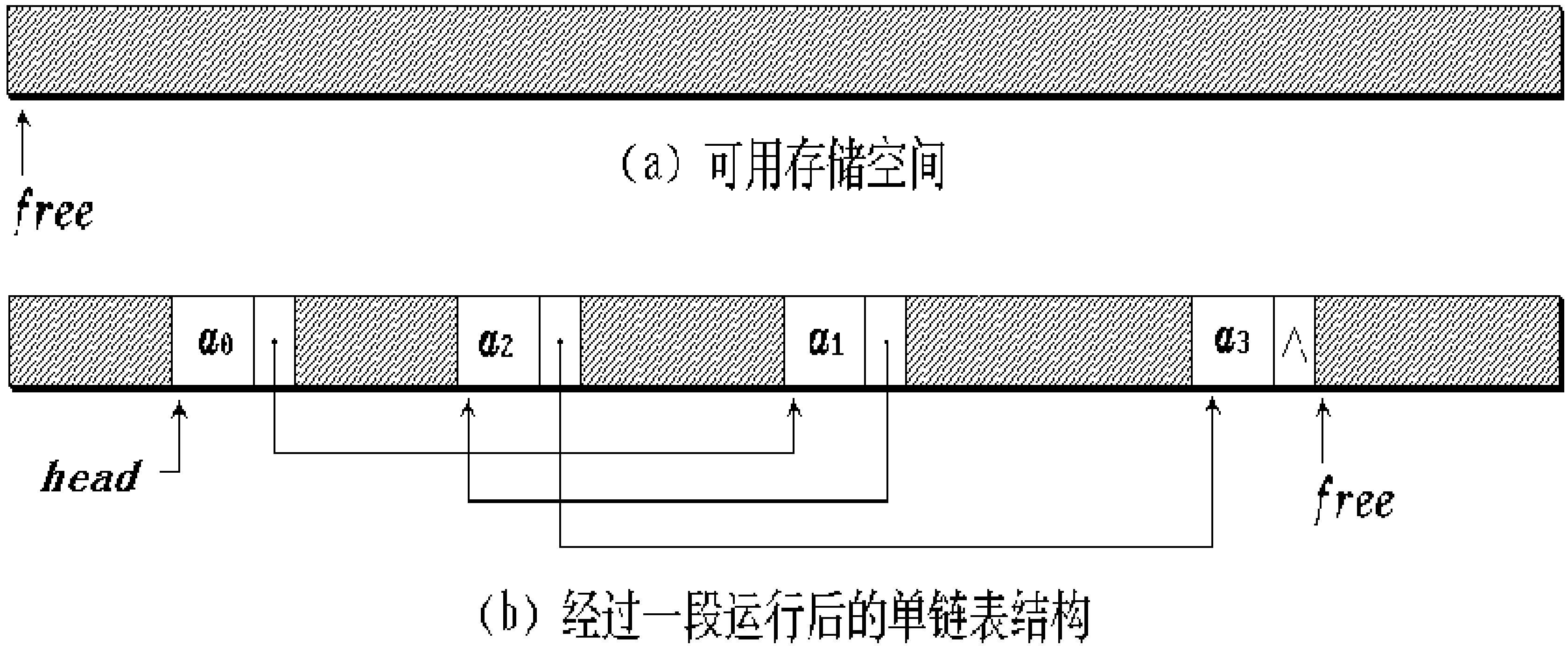
- **Array**
  successive items locate a fixed distance
- **disadvantage**
  - data movements during insertion and deletion
  - waste space in storing n ordered lists of varying size
- **possible solution**
  - linked list



Linked List

- A linked list is made up of a series of objects, called the **nodes** of the list.
- The linked list uses **dynamic memory allocation**

Singly linked list storage mapping



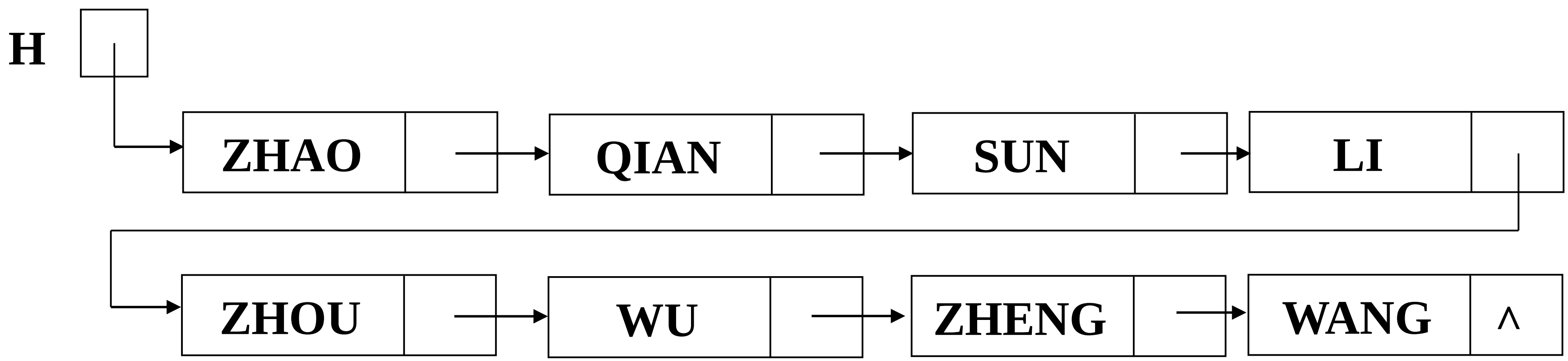
Liear list (ZHAO,QIAN,SUN,LI,ZHOU,WU,ZHENG,WANG)

head

H

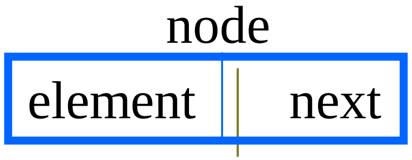
31

adress	data	next
1	LI	43
7	QIAN	13
13	SUN	1
19	WANG	NULL
25	WU	37
31	ZHAO	7
37	ZHENG	19
43	ZHOU	25

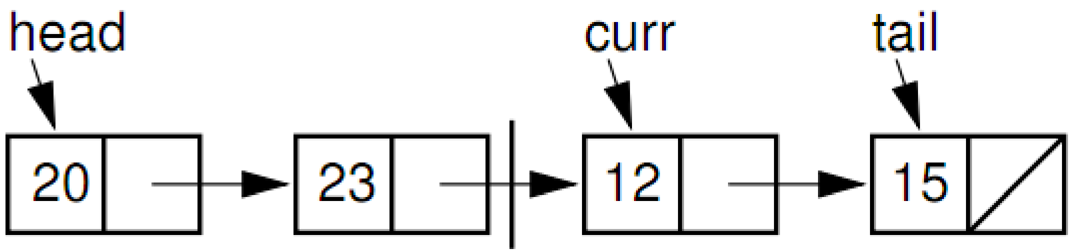


Singly linked Link List(one-way list)

```
// Singly linked list node
template <typename E> class Link {
public:
  E element;      // Value for this node
  Link *next;       // Pointer to next node in list
  // Constructors
  Link(const E& elemval, Link* nextval =NULL)
    { element = elemval;  next = nextval; }
  Link(Link* nextval =NULL) { next = nextval; }
};
```



Singly linked Link List



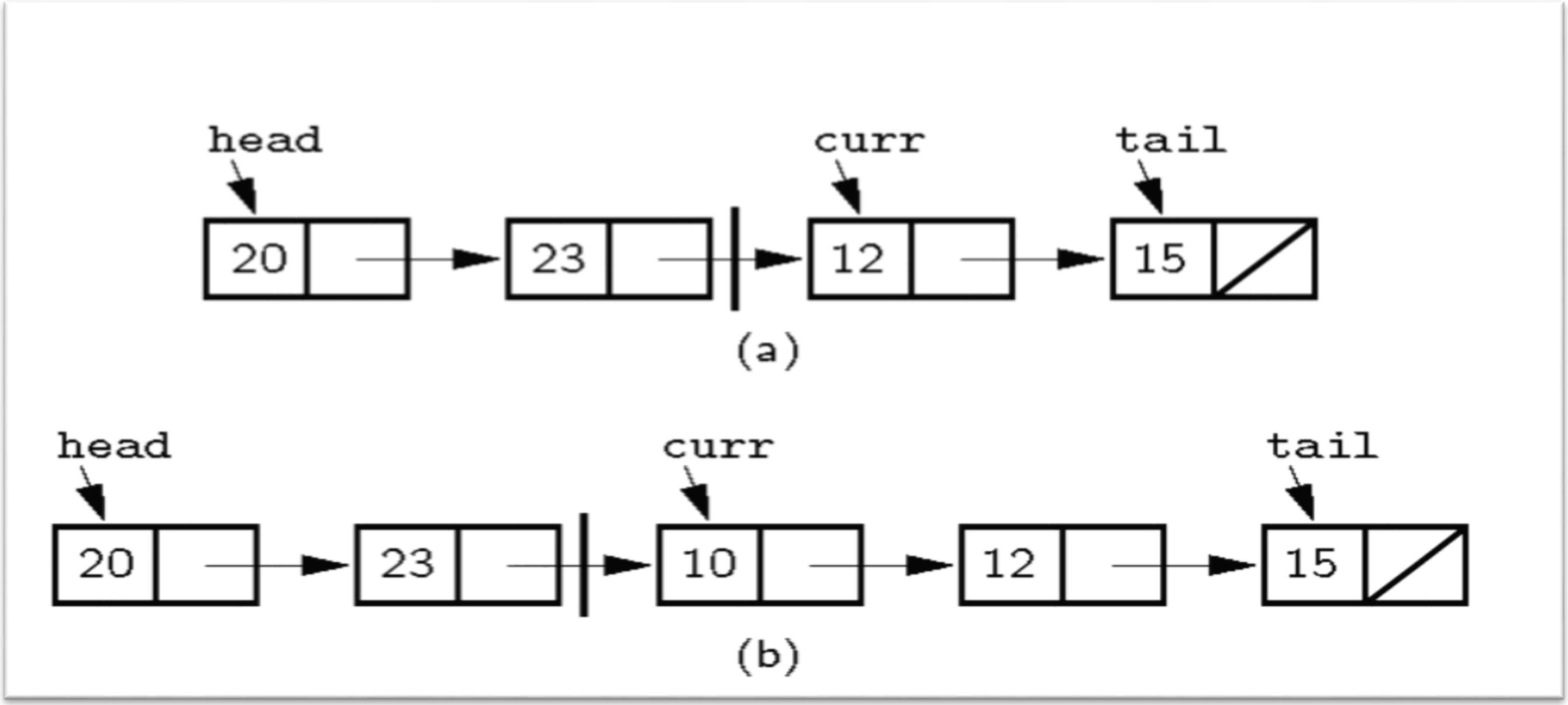
head: a pointer point to the list's first node.

tail: a pointer is kept to the last link of the list.

curr: a pointer indicate the current element.

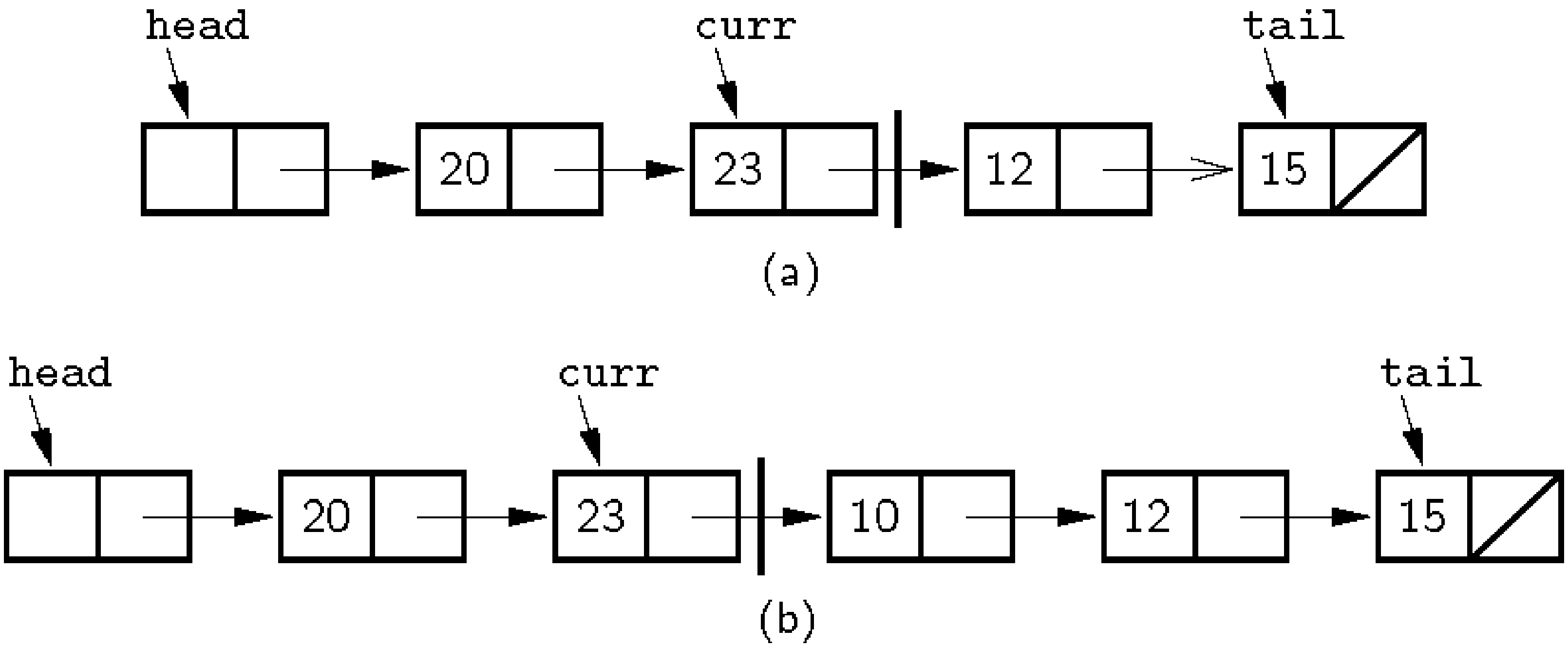
cnt: the length of the list

Singly linked Link List



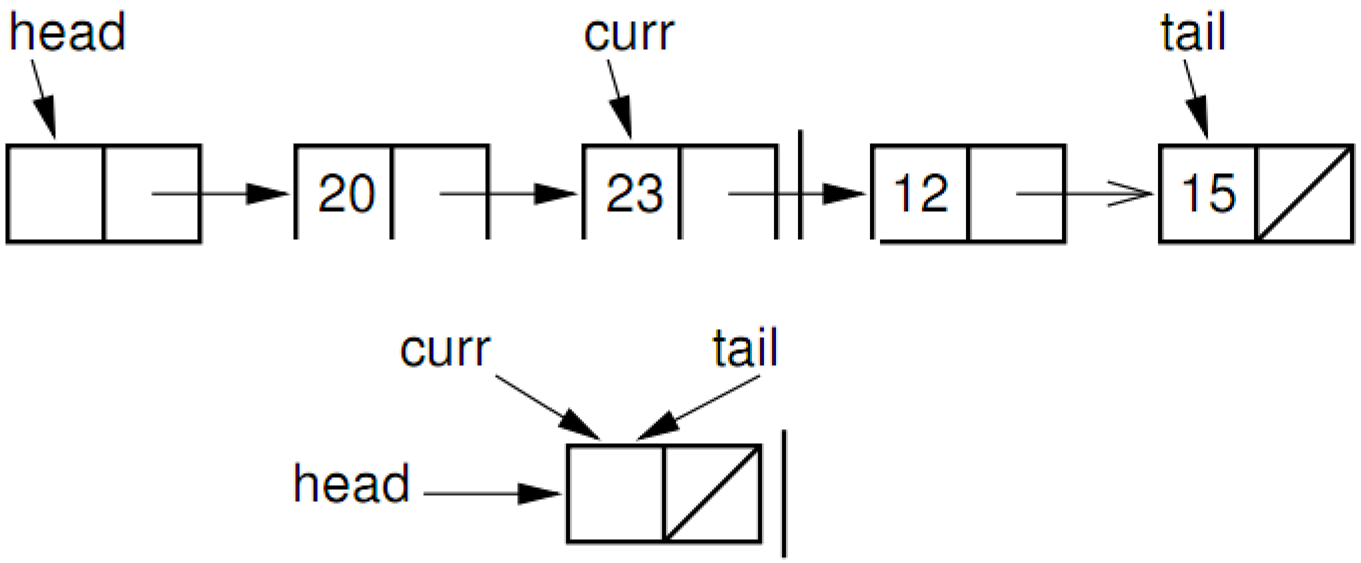
- A faulty linked-list implementation where curr points directly to the current node.

Singly linked Link List



- **Insertion using a header node, with curr pointing one node head of the current element.**

Singly linked List



header node: an additional node before the first element node of the list.

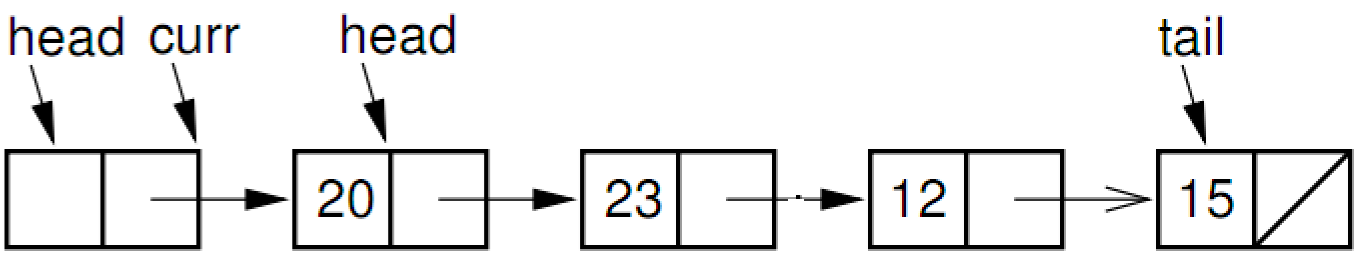
The header node saves coding effort because we no longer need to consider special cases for empty lists or when the current position is at one end of the list.

Linked List Class (1)

```
template <typename E> class LList: public List<E> {
private:
  Link<E>* head;        // Pointer to list header
  Link<E>* tail;        // Pointer to last element
  Link<E>* curr;        // Access to current element
  int cnt;              // Size of list
void init() {         // Initialization helper method
    curr = tail = head = new Link<E>;
    cnt = 0;  }
```

Linked List Class (2)

- void removeall() {   // Return link nodes to free store
- while(head != NULL) {
- curr = head;
- head = head->next;
- delete curr;
- }
- }



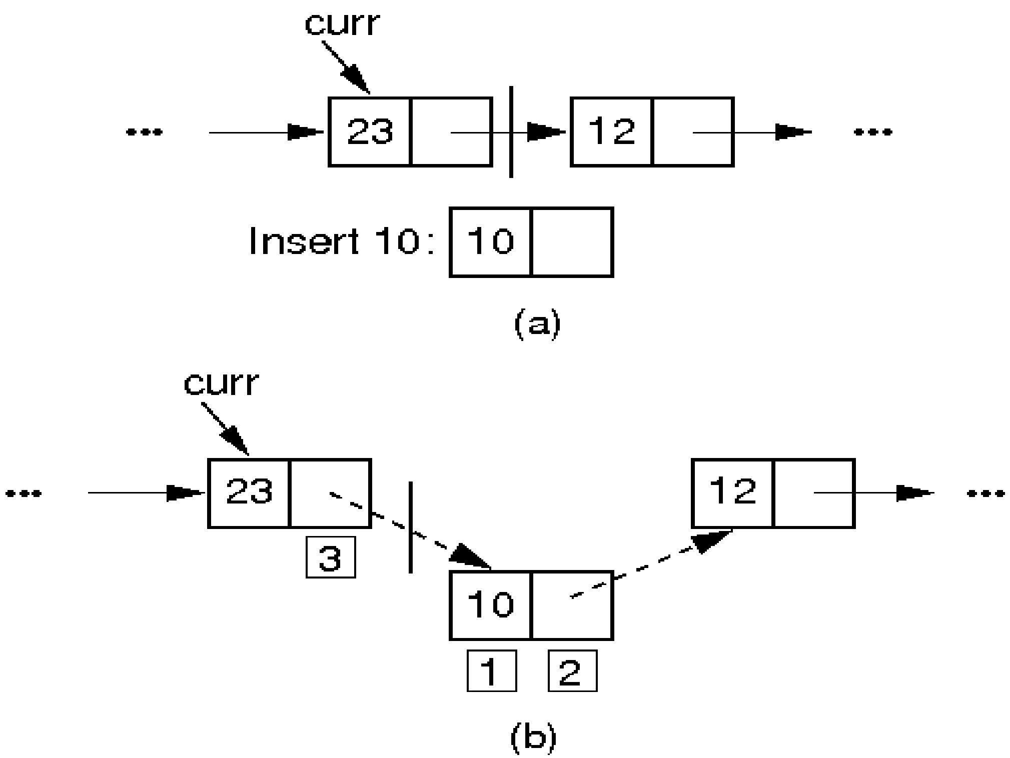
Linked List Class (3)

- public:
- LList(int size=defaultSize) { init(); } // Constructor
- ~LList() { removeall(); } // Destructor
- void print() const; // Print list contents
- void clear() { removeall(); init(); } // Clear list

Insertion

- **Inserting a new element is a three-step process:**
- **First, the new list node is created and the new element is stored into it.**
- **Second, the next field of the new list node is assigned to point to the current node (the one after the node that curr points to).**
- **Third, the next field of node pointed to by curr is assigned to point to the newly inserted node.**

Insertion

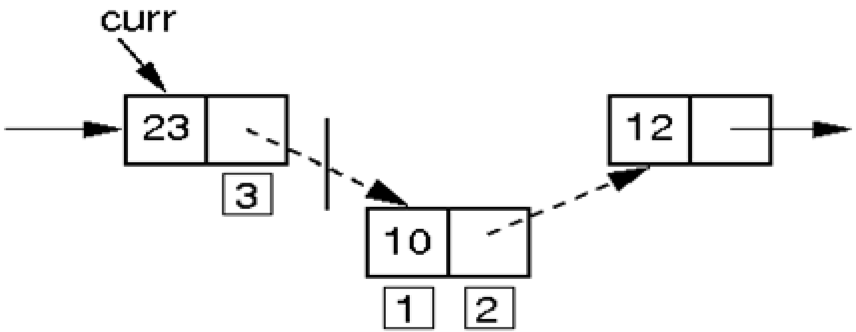


curr->next = new Link<E>(it, curr->next);

- **The linked list insertion process.**

Insertion

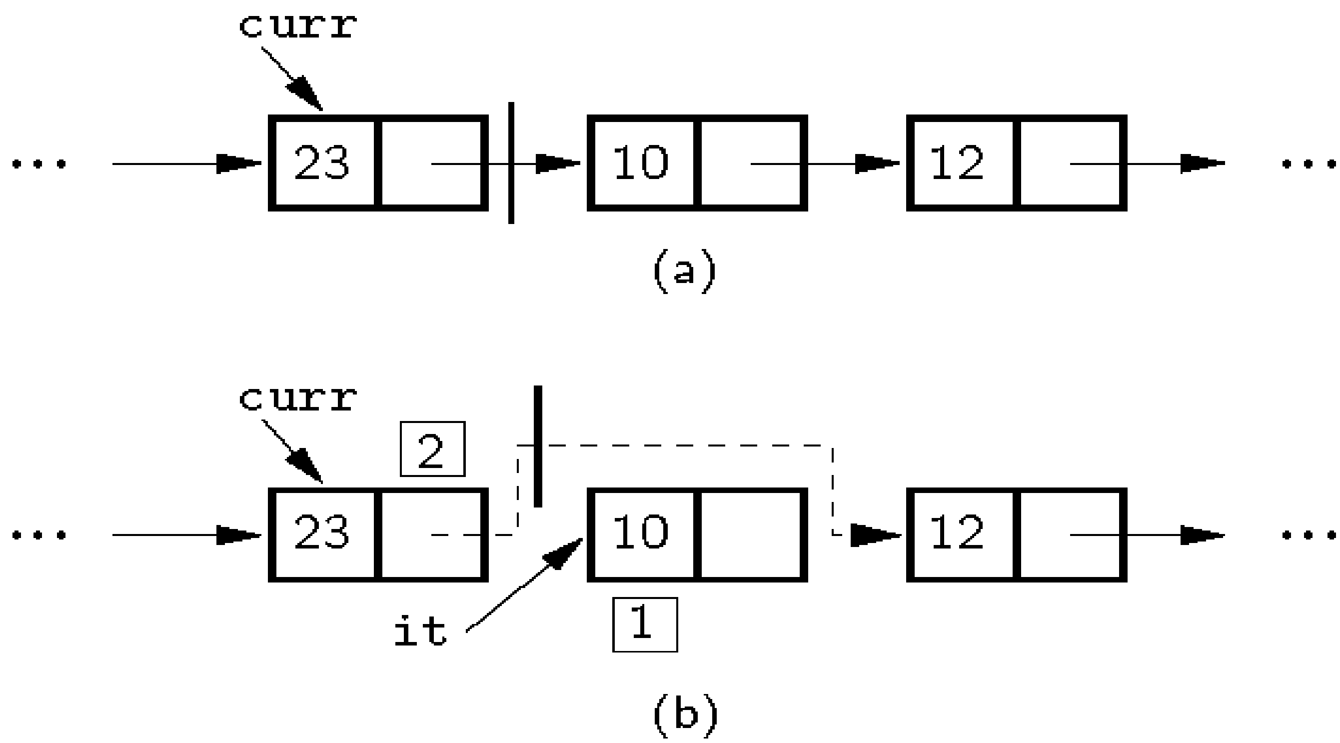
- // Insert "it" at current position
- void insert(const E& it) {
- curr->next = new Link<E>(it, curr->next);
- if (tail == curr) tail = curr->next; // New tail
- cnt++;
- }



Append

```
void append(const E& it) { // Append "it" to list
    tail = tail->next = new Link<E>(it, NULL);
    cnt++;
  }
```

Removal



- **The linked list removal process.**

Remove

```
// Remove and return current element
  E remove() {
    Assert(curr->next != NULL, "No element");
    E it = curr->next->element;       // Remember value
    Link<E>* ltemp = curr->next;      // Remember link node
    if (tail == curr->next) tail = curr; // Reset tail
    curr->next = curr->next->next;   // Remove from list
    delete ltemp;                     // Reclaim space
    cnt--;                            // Decrement the count
    return it;
  }
```

MoveToStart & MoveToEnd

- void moveToStart() // Place curr at list start
- { curr = head; }

- void moveToEnd() // Place curr at list end
- { curr = tail; }

Prev

```
// Move curr one step left; no change if already at front
  void prev() {
    if (curr == head) return;       // No previous element
    Link<E>* temp = head;
    // March down list until we find the previous element
    while (temp->next!=curr) temp=temp->next;
    curr = temp;
  }
```

Next / Length

- // Move curr one step right; no change if already at end
- void next()
- { if (curr != tail) curr = curr->next; }

- int length() const { return cnt; } // Return length

Get/Set Position

```
// Return the position of the current element
 int currPos() const {
   Link<E>* temp = head;
   int i;
   for (i=0; curr != temp; i++)
     temp = temp->next;
   return i;
 }
```

Get/Set Position

```
// Move down list to "pos" position
  void moveToPos(int pos) {
    Assert ((pos>=0)&&(pos<=cnt), "Position out of range");
    curr = head;
    for(int i=0; i<pos; i++) curr = curr->next;
  }
```

GetValue

```
const E& getValue() const { // Return current element
    Assert(curr->next != NULL, "No value");
    return curr->next->element;
}
```

Comparison of Implementations

Array-Based Lists:

- **Insertion and deletion are $\Theta(n)$**
- **Prev and direct access are $\Theta(1)$**
- **Array must be allocated in advance.**
- **No overhead if all array positions are full.**

Linked Lists:

- **Insertion and deletion are $\Theta(1)$**
- **Prev and direct access are $\Theta(n)$**
- **Space grows with number of elements.**
- **Every element requires overhead.**

Space Comparison

"Break-even" point:

$$DE = n(P + E);$$

$$n = \frac{DE}{P + E}$$

E: Space for data value.

P: Space for pointer.

D: Number of elements in array.

Space Example

- **Array-based list: Overhead is one pointer (4 bytes) per position in array – whether used or not.**
- **Linked list: Overhead is two pointers per link node**
  - one to the element, one to the next link
- **Data is the same for both.**
- **When is the space the same?**
  - When the array is half full

Exercise

- **Write a function to merge two sorted linked lists. The input lists have their elements in sorted order, from lowest to highest. The output list should also be sorted from lowest to highest. Your algorithm should run in linear time on the length of the output list.**

Exercise

```
void merge(LList<int> *p1,LList<int> *p2)
{
        p1->moveToStart();
        p2->moveToStart();
        while((p1->currPos()!=p1->length())&&(p2->currPos()!=p2->length()))
        {if(p1->getValue()<p2->getValue())
                p1->next();
         else   p1->insert(p2->remove());
        }
        while(p2->currPos()!=p2->length())  p1->append(p2->remove());
}
```

Freelists

- **The C++ free-store management operators new and delete are relatively expensive to use.** System `new` and garbage collection are slow.
- **Instead of making repeated calls to new and delete, the Link class can handle its own freelist.**
- **A freelist holds those list nodes that are not currently being used.**

Freelists

- **A freelist holds those list nodes that are not currently being used.**
- **When a node is deleted from a linked list, it is placed at the head of the freelist.**
- **When a new element is to be added to a linked list, the freelist is checked to see if a list node is available. If so, the node is taken from the freelist. If the freelist is empty, the standard new operator must then be called.**

Approach to implement freelists

- **One approach would be to create two new operators to use instead of the standard free-store routines new and delete.**
- **This requires that the user's code, such as the linked list class implementation of Figure 4.8, be modified to call these freelist operators.**

Approach to implement freelists

- A second approach is to use C++ operator overloading to replace the meaning of new and delete when operating on Link class objects.
- In this way, programs that use the LList class need not be modified at all to take advantage of a freelist. Whether the Link class is implemented with freelists, or relies on the regular free-store mechanism, is entirely hidden from the list class user.

Link Class Extensions

- // Singly linked list node with freelist support
- template <typename E> class Link {
- private:
-   static Link<E>* freelist; // Reference to freelist head
- public:
-   E element; // Value for this node
-   Link* next; // Point to next node in list

Implementation for the Link class with a freelist

- // Constructors
- Link(const E& elemval, Link* nextval =NULL)
-   { element = elemval; next = nextval; }
- Link(Link* nextval =NULL) { next = nextval; }
-

Implementation for the Link class with a freelist

```
void* operator new(size_t) {  // Overloaded new operator
  if (freelist == NULL) return ::new Link; // Create space
  Link<E>* temp = freelist; // Can take from freelist
  freelist = freelist->next;
  return temp;                    // Return the link
}
```

Implementation for the Link class with a freelist

```
// Overloaded delete operator
void operator delete(void* ptr) {
  ((Link<E>*)ptr)->next = freelist; // Put on freelist
  freelist = (Link<E>*)ptr;
}
};
```

Implementation for the Link class with a freelist

- // The freelist head pointer is actually created here
- template <typename E>
- Link<E>* Link<E>::freelist = NULL;

Reference

- Chapter 4, P103----P112

Preview

- **Chapter 4, pp. 115--P120**

End

Thank you for listening!