

# CSCI-1200 Computer Science II — Spring 2006

## Lecture 20 Linked Lists — Part I

### Review from Lecture 19 and Lab

- Building our own version of `vector`, `stack` & `queue`
- Templates
- Classes that allocate dynamic memory really must provide **the BIG 3**:
  - Copy constructor
  - Assignment operator
  - Destructor
- Dynamic resizing

### Today's Class: Linked Lists Part I

- Motivation: implementation of the `std::list` container class.
- Introductory example on linked lists.
- Basic linked list operations:
  - Stepping through a list
  - Push back
  - Insert
  - Remove
- Common mistakes

### 20.1 Motivation

- Thus far our discussion of how `list<T>` is implemented has been only intuitive: it is a “chain” of objects.
- Now we will look at the mechanism — *linked lists*.
- Learning this mechanism is good background for higher-level courses where the design of novel data structures is important.

### 20.2 Objects with Pointers / Linking Objects

- The two fundamental mechanisms of linked lists are:
  - creating objects with pointers as one of the member variables, and
  - making these pointers point to other objects of the same type.
- These mechanisms are illustrated in the following program:

```
#include <iostream>
using namespace std;

template <class T>
class Node {
public:
    T value;
    Node* ptr;
};
```

```

void main() {
    Node<int>* l1;      // l1 is a pointer to a (non-existent) Node
    l1 = new Node<int>; // Create a Node and assign its memory address to l1
    l1->value = 6;     // This is the same as (*l1).value = 6;
    l1->ptr = NULL;    // NULL == 0, which indicates a "null" pointer

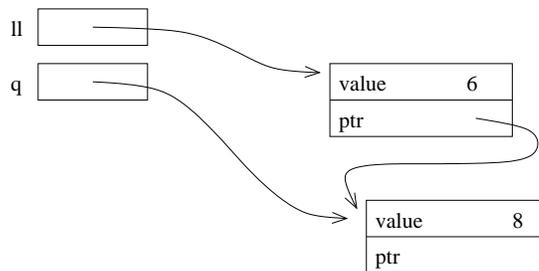
    Node<int>* q = new Node<int>;
    q->value = 8;
    q->ptr = NULL;

    l1->ptr = q;       // l1's ptr member variable now has the same value
                       // as the pointer variable q

    cout << "1st value: " << l1->value << "\n"
         << "2nd value: " << l1->ptr->value << endl;
}

```

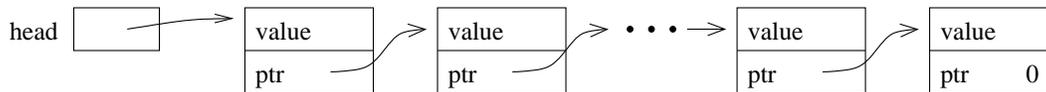
- The following picture illustrates the structure of memory at the end of the program.



### 20.3 Definition: A Linked List

- The definition is recursive: A linked list is either:
  - Empty, or
  - Contains a node storing a value and a pointer to a linked list.
- The first node in the linked list is called the *head* node and the pointer to this node is called the *head* pointer. The pointer's value will be stored in a variable called *head*.

### 20.4 Visualizing Linked Lists



- The *head* pointer variable is drawn with its own box. It is an individual variable.
- The objects (nodes) that have been dynamically allocated and stored in the linked lists are shown as boxes, with arrows drawn to represent pointers.
  - Note that this is a conceptual view only. The memory locations could be anywhere, and the actual values of the memory addresses aren't usually meaningful.
- The last node **MUST** have a 0 (0 == NULL) for its pointer value — you will have all sorts of trouble if you don't ensure this!
- You should make a habit of drawing pictures of linked lists to figure out how to do the operations.

## 20.5 Basic Mechanisms: Stepping Through the List

- We'd like to write a function to determine if a particular value, stored in `x`, is also in the list.
- You can think of this as a precursor to the `find` function. Our function isn't yet returning an iterator, however.
- We can access the entire contents of the list, one step at a time, by starting just from the `head` pointer.
  - We will need a separate, local pointer variable to point to nodes in the list as we access them.
  - We will need a loop to step through the linked list (using the pointer variable) and a check on each value.

## 20.6 Exercise: Write `is_there`

```
template <class T> bool is_there(Node<T>* head, const T& x) {
```

## 20.7 Basic Mechanisms: Pushing on the Back

- Goal: place a new node at the end of the list.
- We must step to the end of the linked list, remembering the pointer to the last node.
  - This is an  $O(n)$  operation and is a major drawback to the ordinary linked-list data structure we are discussing now. We will correct this drawback by creating a slightly more complicated linking structure in our next lecture.
- We must create a new node and attach it to the end.
- We must remember to update the `head` pointer variable's value if the linked list is initially empty.
  - Hence, in writing the function, we must pass the pointer variable **by reference**.

## 20.8 Exercise: Write `push_back`

```
template <class T> void push_back( Node<T>* & head, T const& value ) {
```

## 20.9 Basic Mechanisms: Inserting a Node

- There are two parts to this: finding the location where the insert must take place, and doing the insert operation.
- We will ignore the `find` for now. We will also write only a code segment to understand the mechanism rather than writing a complete function.
- The insert operation itself requires that we have a pointer to the location **before** the insert location.
- If `p` is a pointer to this node, and `x` holds the value to be inserted, then the following code will do the insertion:

```

Node<T> * q = new Node<T>; // create a new node
q -> value = x;           // store x in this node
q -> next = p -> next;    // make its successor be the current successor of p
p -> next = q;           // make p's successor be this new node

```

- Can you draw a picture to illustrate what is happening here?
- This code will not work if you want to insert the value stored in x in a new node at the front of the linked list.

## 20.10 Basic Mechanisms: Removing a Node

- There are two parts to this: finding the node to be removed and doing the remove operation.
- The remove operation itself requires a pointer to the node **before** the node to be removed.
- Removing the first node is an important special case.

## 20.11 Exercise

Suppose p points to node that should be removed from a linked list, q points to the node before p, and head points to the first node in the linked list. Write code to remove p, making sure that if p points to the first node that head points to what was the second node and now is the first after p is removed.

## 20.12 Basic Mechanisms: Common Mistakes

Here is summary of common mistakes. Read these carefully, and read them again when you have problem that you need to solve.

- Allocating a new node to step through the linked list; only a pointer variable is needed.
- Confusing the . and the -> operators.
- Not setting the pointer from the last node to 0 (NULL).
- Not considering special cases of inserting / removing at the beginning or the end of the linked list.
- Applying the delete operator to a node (calling the operator on a pointer to the node) before it is removed. Delete should be done after all pointer manipulations are completed.
- Pointer manipulations that are out of order. These can ruin the structure of the linked list.

## 20.13 Looking Ahead to Lecture 21 — Our Own List Class

- We will alter the structure of our linked list. Nodes will be templated and have two pointers, one going “forward” to the successor in the linked list and one going “backward” to the predecessor in the linked list. We will have a pointer to the beginning *and* the end of the list.

```

template <class T> class Node {
public:
    Node() : next_(0), prev_(0) {}
    Node(const T& v) : value_(v), next_(0), prev_(0) {}
    T value_;
    Node<T>* next_;
    Node<T>* prev_;
};

```

- We’ll reimplement the mechanisms discussed today and we will define list iterators as a class inside a class.