

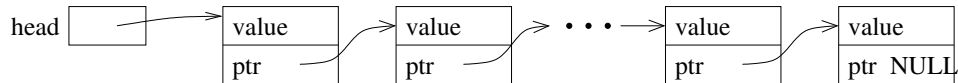
# CSCI-1200 Data Structures — Fall 2015

## Lectures 11 — Doubly Linked Lists

### Review from Lecture 10

- Review of iterators, implementation of iterators in our homemade `Vec` class
- `const` and reference on return values
- Building *our own* basic linked lists: Stepping through a list & push back

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



- Stepping through a list

```
template <class T>
bool is_there(Node<T>* head, const T& x) {
    for (Node<T> *p = head; p != NULL ; p = p->ptr) {
        if (p->value == x) return true;
    }
    return false;
}
```

- Push back

```
template <class T>
void push_back( Node<T>* & head, T const& value ) {
    // test for empty list
    if (head == NULL) {
        Node<T> *q = new Node<T>;
        q->value = value;
        q->ptr = NULL;
        head = q;
    } else {
        Node<T> *p = head;
        for ( ; p->ptr != NULL ; p = p->ptr) {
            // do nothing, just walk to the end of the list
        }
        Node<T> *q = new Node<T>;
        q->value = value;
        q->ptr = NULL;
        p->ptr = q;
    }
}
```

- STL List w/ iterators vs. “homemade” linked list with Node objects & pointers

### Today’s Lecture

- Basic linked list operations, continued: Insert & Remove
- Common mistakes
- Limitations of singly-linked lists
- Doubly-linked lists:
  - Structure
  - Insert
  - Remove

## 11.1 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. Draw a picture to illustrate what is happening.

```
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
```

- Note: This code will not work if you want to insert `x` in a new node at the *front* of the linked list. Why not?

## 11.2 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.

## 11.3 Exercise: Remove a Node

Suppose `p` points to a 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. Draw a picture of each scenario.

## 11.4 Exercise: List Copy

Write a *recursive* function to copy all nodes in a linked list to form a new linked list of nodes with identical structure and values. Here's the function prototype:

```
template <class T> void CopyAll(Node<T>* old_head, Node<T>*& new_head) {
```

## 11.5 Exercise: Remove All

Write a *recursive* function to delete all nodes in a linked list. Here's the function prototype:

```
template <class T> void RemoveAll(Node<T>*& head) {
```

## 11.6 Basic Linked Lists Mechanisms: Common Mistakes

Here is a 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 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 appropriately disconnected from the list. 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.
- Trying to use STL iterators to visit elements of a “home made” linked list chain of nodes. (And the reverse... trying to use `->next` and `->prev` with STL list iterators.)

## 11.7 Limitations of Singly-Linked Lists

- We can only move through it in one direction
- We need a pointer to the node **before** the node that needs to be deleted.
- Appending a value at the end requires that we step through the entire list to reach the end.

## 11.8 Generalizations of Singly-Linked Lists

- Three common generalizations:
  - Doubly-linked: allows forward and backward movement through the nodes
  - Circularly linked: simplifies access to the tail, when doubly-linked
  - Dummy header node: simplifies special-case checks
- Today we will explore and implement a doubly-linked structure.

## 11.9 Transition to a doubly-linked list

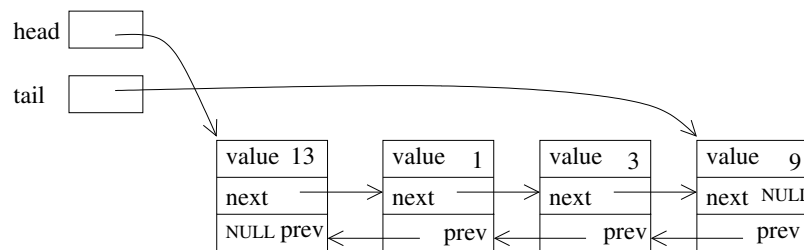
- The revised `Node` class has two pointers, one going “forward” to the successor in the linked list and one going “backward” to the predecessor in the linked list. We will have a `head` pointer to the beginning *and* a `tail` pointer to the end of the list.

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

- First we’ll reimplement some of the basic mechanisms we’ve already worked through for singly-linked lists. In the next lecture we’ll build the full `ds_list` class and will define the list iterators as a class inside a class.

## 11.10 The Structure of Doubly-Linked Lists

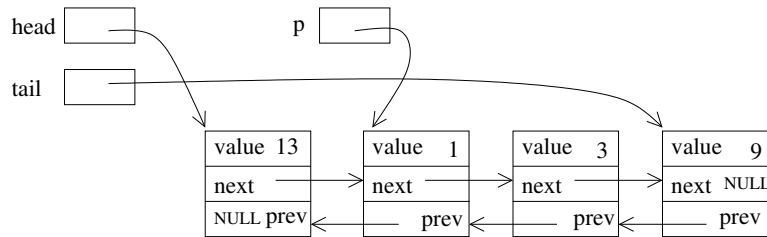
- Here is a picture of a doubly-linked list holding four integer values:



- Note that we now assume that we have both a `head` pointer, as before and a `tail` pointer variable, which stores the address of the last node in the linked list.
- The tail pointer is not strictly necessary, but it allows immediate access to the end of the list for efficient push-back operations.

### 11.11 Inserting in the Middle of a Doubly-Linked List

- Suppose we want to insert a new node containing the value 15 following the node containing the value 1. We have a temporary pointer variable, `p`, that stores the address of the node containing the value 1. Here's a picture of the state of affairs:



- What must happen?
  - The new node must be created, using another temporary pointer variable to hold its address.
  - Its two pointers must be assigned.
  - Two pointers in the current linked list must be adjusted. Which ones?

Assigning the pointers for the new node **MUST** occur before changing the pointers for the current linked list nodes!

- At this point, we are ignoring the possibility that the linked list is empty or that `p` points to the tail node (`p` pointing to the head node doesn't cause any problems).
- **Exercise:** write the code as just described.

### 11.12 Removing from the Middle of a Doubly-Linked List

- Suppose now instead of inserting a value we want to remove the node pointed to by `p` (the node whose address is stored in the pointer variable `p`)
- Two pointers need to change before the node is deleted! All of them can be accessed through the pointer variable `p`.
- **Exercise:** write this code.

### 11.13 Special Cases of Remove

- If `p==head` and `p==tail`, the single node in the list must be removed and both the `head` and `tail` pointer variables must be assigned the value `NULL`.
- If `p==head` or `p==tail`, then the pointer adjustment code we just wrote needs to be specialized to removing the first or last node.
- Next lecture we'll write the `erase` function as part of our implementation mimicing the STL `list` class.