Data Structures
Lists and List ADT

CS 225
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UNIVERSITY OF
ILLINOIS
URBANA-CHAMPAIGN
Department of Computer Science

mp_stickers will be releasing next week

Staff Office Hours will begin next week

Add your own music to music-suggestions!

Learning Objectives

Define the functions and operations of the List ADT

Discuss list implementation strategies

Explore how to code and use a linked list

Practice fundamentals of C++ in the context of lists

Last time: Memory management

Local memory on the stack is managed by the computer

Heap memory allocated by **new** and freed by **delete**

Pass by value makes a copy of the object

Pass by pointer can be dereferenced to modify an object

Pass by reference modifies the object directly

Templates

A way to write generic code whose type is determined during completion

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1. Templates are a recipe for code using generic types

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A way to write generic code whose type is determined during completion

1. Templates are a recipe for code using generic types

2. The compiler uses templates to generate C++ code **when needed**

```
T sum(T a, T b){
...
}
```

template1.cpp

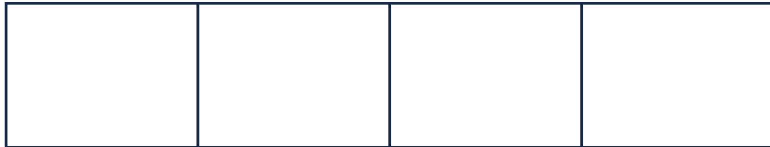
```
1
2
3  T max(T a, T b) {
4    T result;
5    result = (a > b) ? a : b;
6    return result;
7  }
```

Templates are very useful!

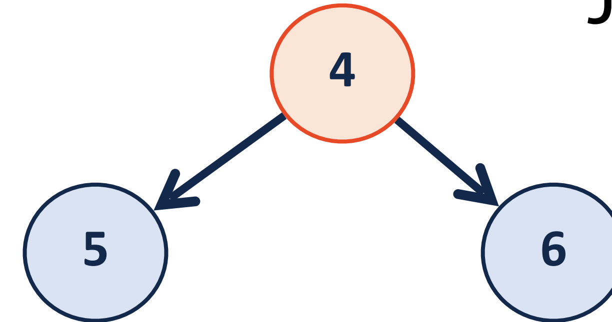
What is your favorite data structure?

Join Code: 225

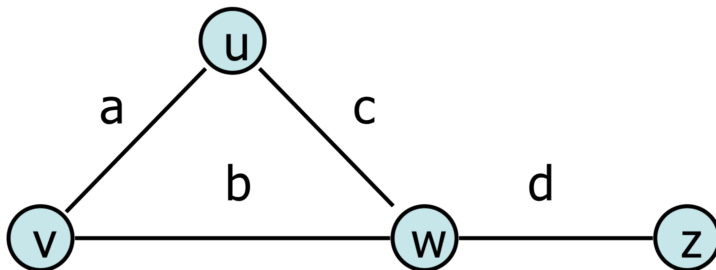
A) Lists



B) Trees



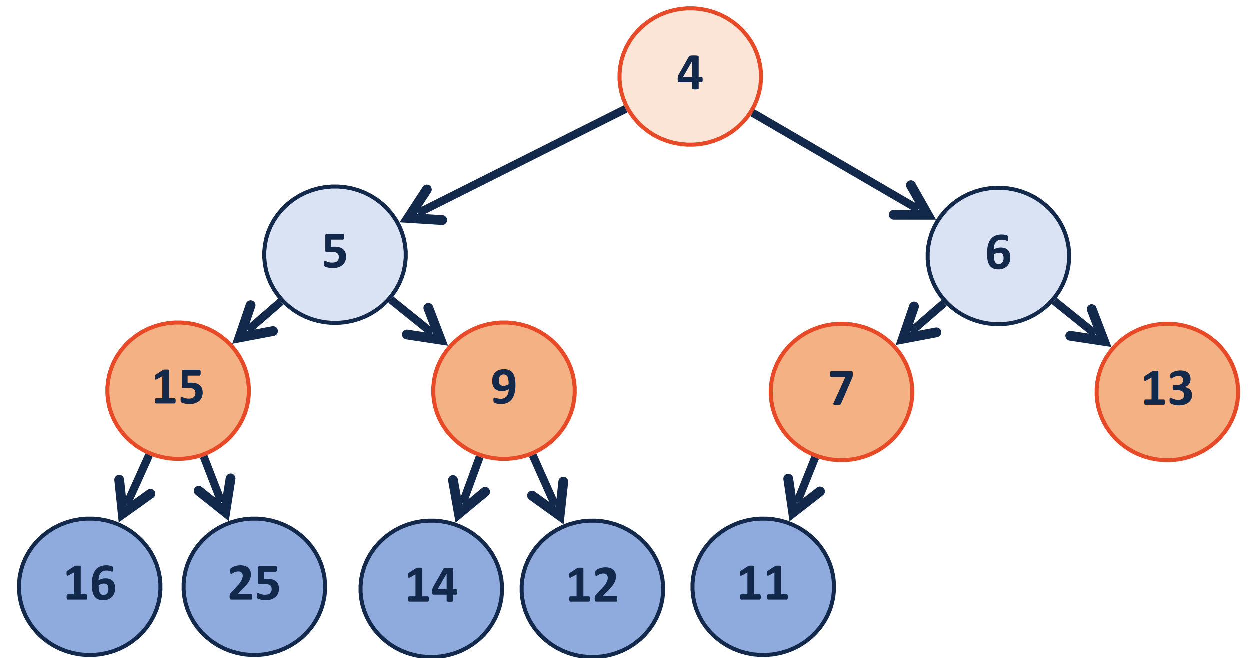
C) Graphs



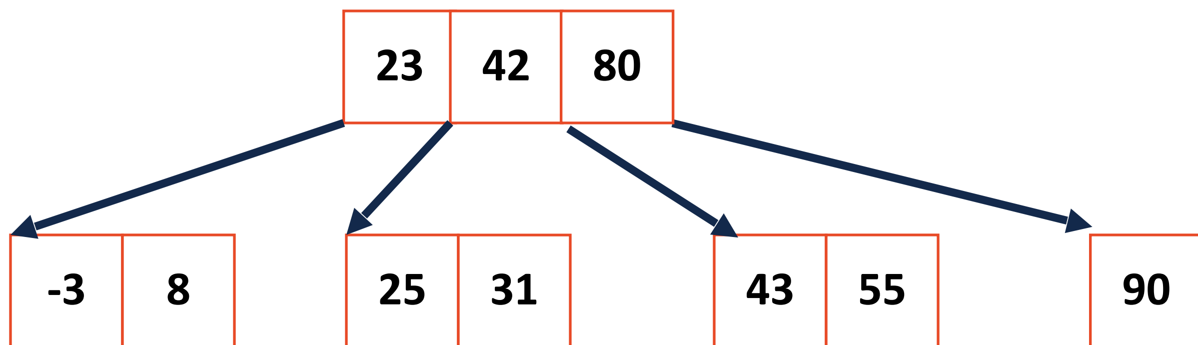
D) Hash Tables

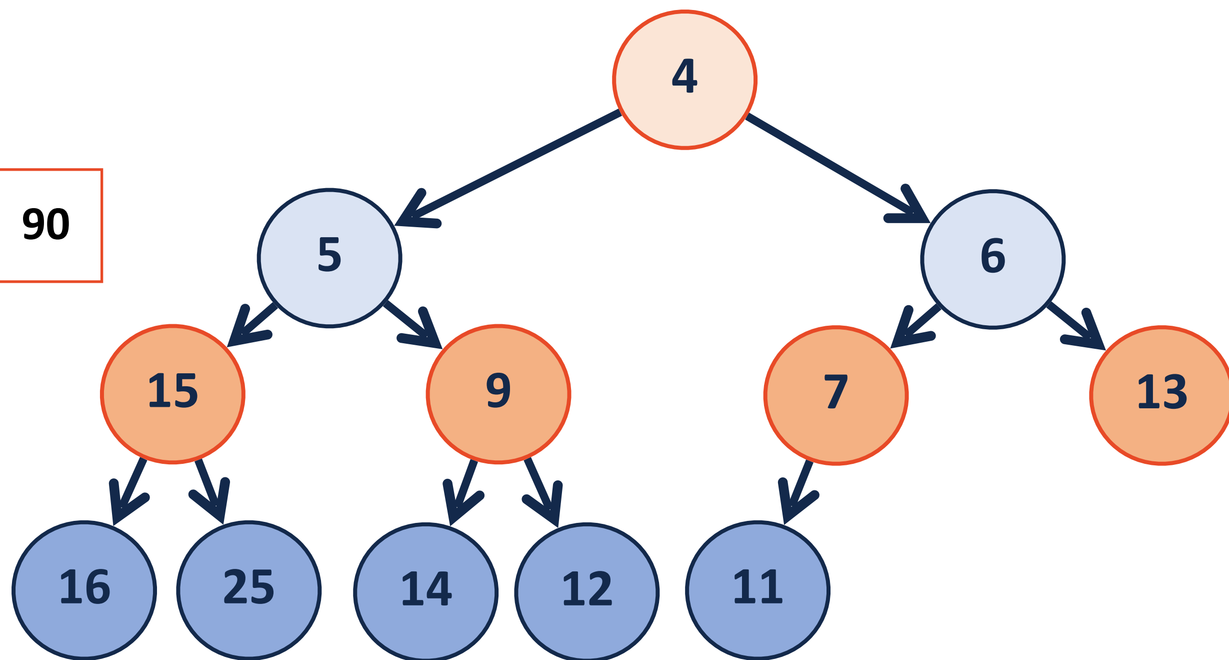
0	Apple
1	∅
2	Pear

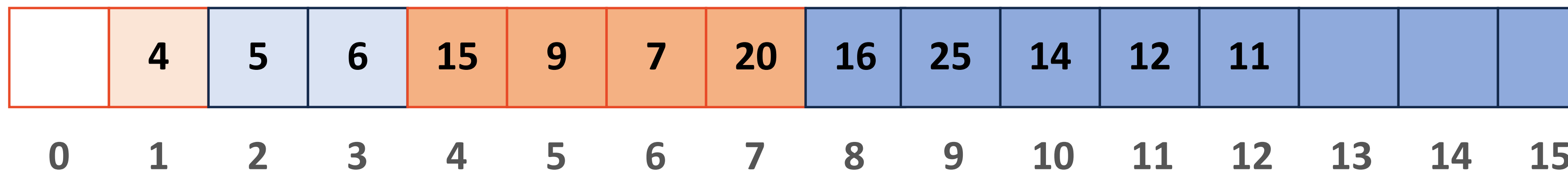
Your favorite data structure: Trees



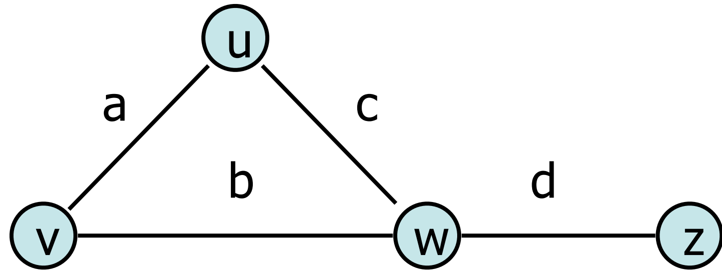
Your favorite data structure: ~~Trees~~ Lists

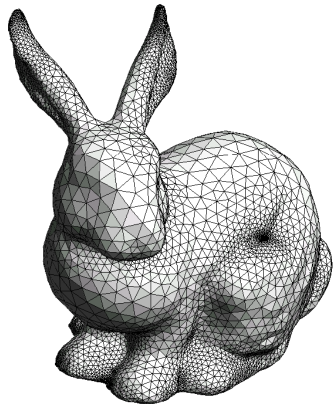


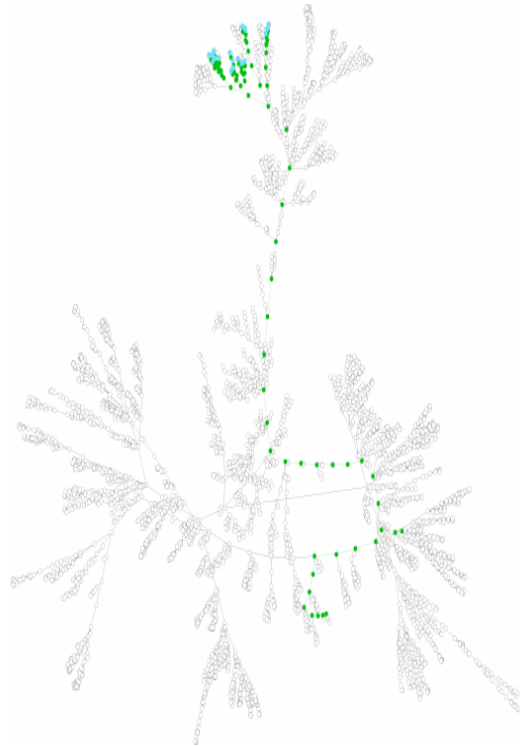




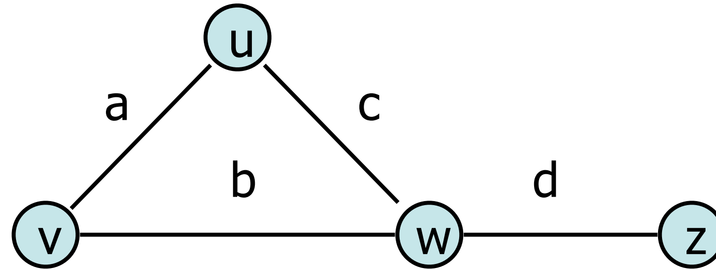
Your favorite data structure: Graphs

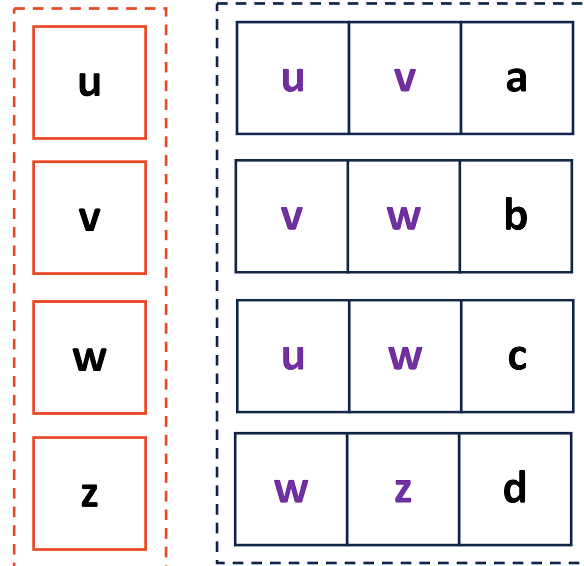




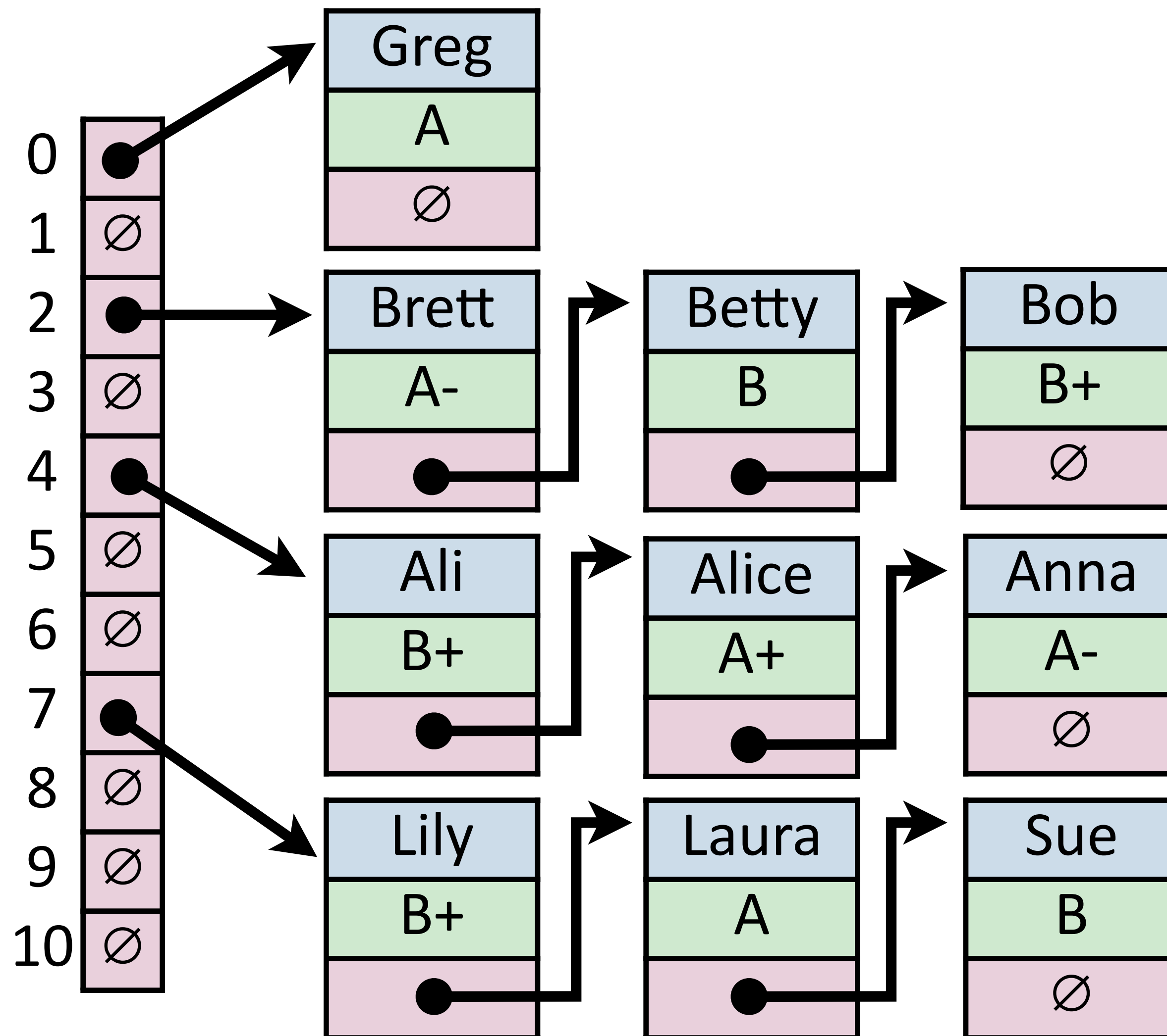


Your favorite data structure: ~~Graphs~~ Lists





Your favorite data structure: Hash Tables

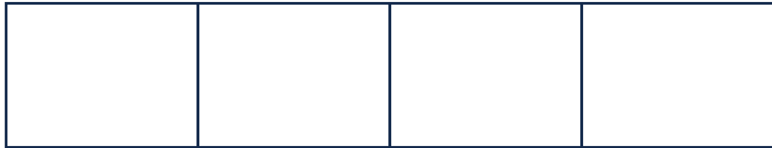


$H = \{h_1, h_2, \ldots, h_k\}$

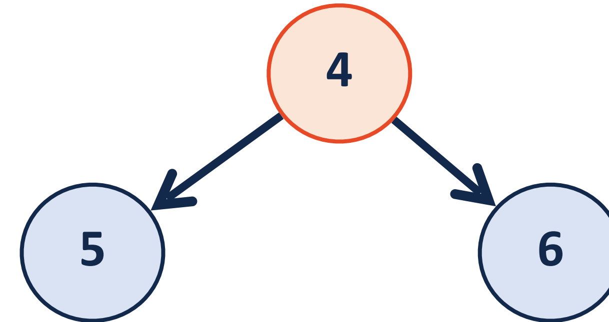
1
0
1
0
1
0
0
1
0
0
0

So 100% of people are excited about lists!

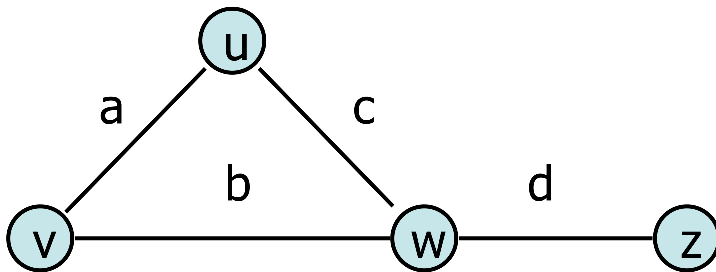
A) Lists



B) Trees



C) Graphs



D) Hash Tables

0	Apple
1	∅
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Note: Not every tree / graph / hash is actually a list :)

Abstract Data Types

A way of describing a data type as a combination of:

- **Data** being stored by the data type
- **Operations** that can be performed on the data type

The actual implementation details of the ADT aren't relevant!

List ADT (What do we want our list to do?)

List ADT

A list is an **ordered** collection of items

Items can be either **heterogeneous** or **homogenous**

The list can be of a **fixed size** or is **resizable**

A minimal set of operations (that can be used to create all others):

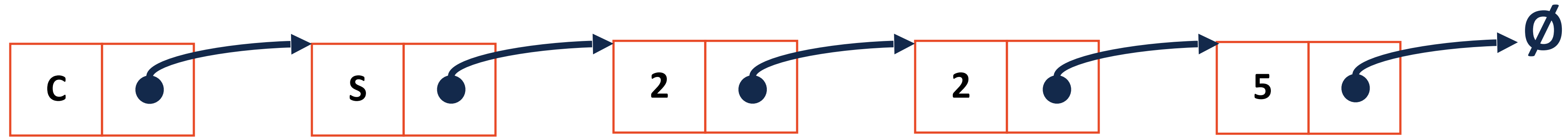
1. Insert
2. Delete
3. isEmpty
4. getData
5. Create an empty list

List Implementations

1.

2.

Linked List



List.h

```
28 class ListNode {
29   T & data;
30   ListNode * next;
31   ListNode(T & data) : data(data), next(NULL) { }
32 };
```

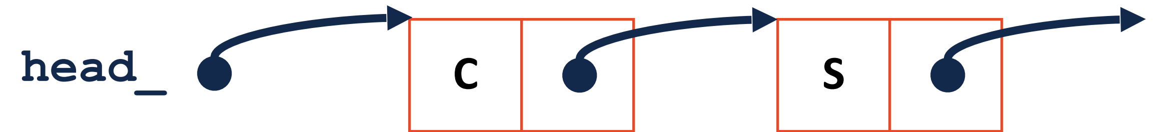
Why is **data** stored as a reference?

Why is **next** a pointer?

List.h

```
1   #pragma once
2
3
4   class List {
5     public:
…       /* ... */
28    void insertAtFront(const T& t);
29
30    private:
31      class ListNode {
32        T & data;
33        ListNode * next;
34        ListNode(T & data) :
35         data(data), next(NULL) { }
36      };
37
38      ListNode *head_;
39
40      /* ... */
…
…   };
…
79
```

How do I access list given head_?



List.h

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…       /* ... */
28    void insertAtFront(const T& t);
29
30    private:
31      class ListNode {
32        T & data;
33        ListNode * next;
34        ListNode(T & data) :
35         data(data), next(NULL) { }
36      };
37
38      ListNode *head_;
39
40      /* ... */
…
…   };
…
79
```

What is missing in this code?

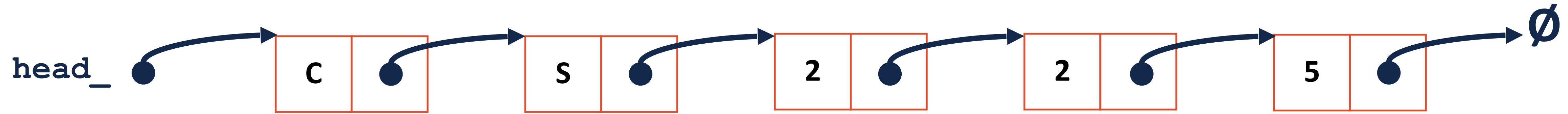
List.h

```
1   #pragma once
2
3   template <typename T>
4   class List {
5     public:
        /* ... */
…
28    void insertAtFront(const T& t);
29
30    private:
31      class ListNode {
32        T & data;
33        ListNode * next;
34        ListNode(T & data) :
35         data(data), next(NULL) { }
36      };
37
38      ListNode *head_;
39
40      /* ... */
…
…   };
…
79  #include "List.hpp"
```

List.hpp

```
1
2
3
4   void List<T>::insertAtFront(const T& t)
5   {
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22  }
```

Linked List: `insertAtFront(data)`



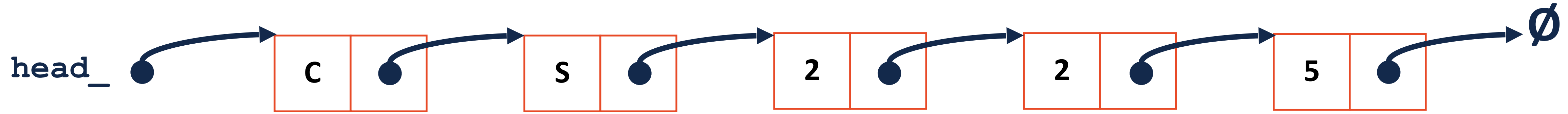
List.h

```
1   #pragma once
2
3   template <typename T>
4   class List {
5     public:
        /* ... */
…
28    private:
29      class ListNode {
30        T & data;
31        ListNode * next;
32        ListNode(T & data) :
           data(data), next(NULL) { }
33      };
34
35      ListNode *head_;
36
37      /* ... */
38
39  };
…
…
79  #include "List.hpp"
```

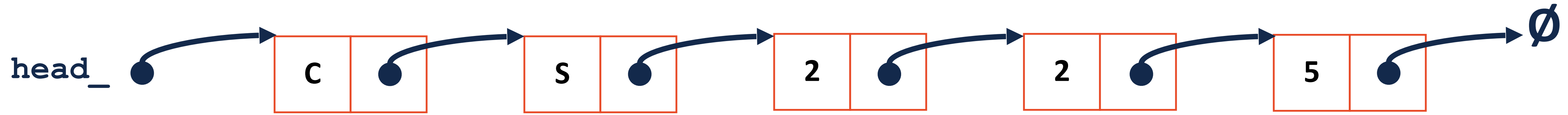
List.hpp

```
1
2
3   template <typename T>
4   void List<T>::insertAtFront(const T& t)
5   {
6
7     ListNode *tmp = new ListNode(data);
8
9
10    tmp->next = head_;
11
12
13    head_ = tmp;
14
15  }
16
17
18
19
20
21
22
```

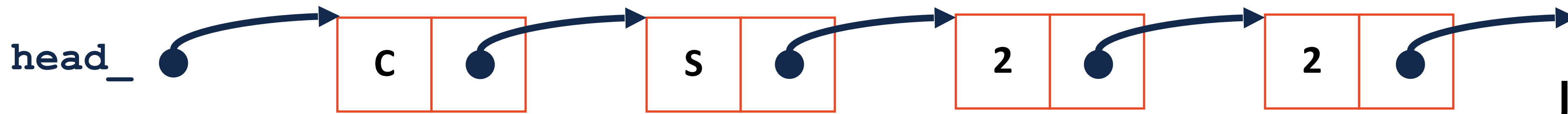
Linked List: `insert(data, index)`



Linked List: `_index(index)`



Linked List: `_index(index)`



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What should the return type of `_index()` be?

`[template <class T>]`

(A) `T &`

(B) `ListNode`

(C) `ListNode *`

(D) `ListNode *&`

List.hpp

```
58 template <typename T>
59 typename List<T>::ListNode *& List<T>::_index(unsigned index){
60       return _index(index, head_)
61 }
```

```
63 template <typename T>
64 typename List<T>::ListNode *& List<T>::_index(unsigned index, ListNode *& root){
65
66
67
68
69
70
71
72
73 }
```

```
58 template <typename T>
59 typename List<T>::ListNode *& List<T>::_index(unsigned index){
60        return _index(index, head_)
61 }
```

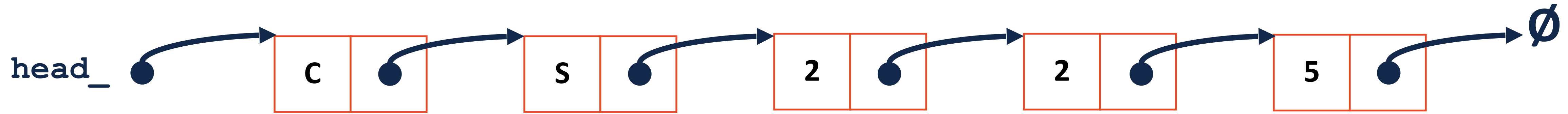
```
63 template <typename T>
64 typename List<T>::ListNode *& List<T>::_index(unsigned index, ListNode *& root){
65
66 if (index == 0 || node == nullptr){
67     return node;
68 }
69
70 return _index(index - 1, root -> next);
71
72
73 }
```

List.hpp

```
1  // Iterative Solution:
2  template <typename T>
3  typename List<T>::ListNode *& List<T>::_index(unsigned index) {
4    if (index == 0) { return head; }
5    else {
6      ListNode *curr = head;
7      for (unsigned i = 0; i < index - 1; i++) {
8          curr = curr->next;
9      }
10     return curr->next;
11   }
12 }
```

Which solution is better (iterative or recursive)?

Linked List: `insert(data, index)`



1) Get reference to previous node's next

```
ListNode *& curr = _index(index);
```

2) Create new ListNode

```
ListNode * tmp = new ListNode(data);
```

3) Update new ListNode's next

```
tmp->next = curr;
```

4) Modify the previous node to point to new ListNode

```
curr = tmp;
```

List.hpp

```
1
2  template <typename T>
3  void List<T>::insertAtFront(const T& t)
4  {
5    ListNode *tmp = new ListNode(t);
6
7    tmp->next = head_;
8
9    head_ = tmp;
10
11 }
12
13
14
15
16
17
18
19
20
21
22
```

```
1
2  template <typename T>
3  void List<T>::insert(const T & data,
4  unsigned index) {
5
6
7
8    ListNode *& curr = _index(index);
9
10
11
12   ListNode * tmp = new ListNode(data);
13
14
15
16   tmp->next = curr;
17
18
19
20   curr = tmp;
21 }
22
```

Next Time: List Random Access [ ]

Given a list L, what operations can we do on L[ ]?

What return type should this function have?