A bit about Queue

Data Structures

Iterators, Exam 1 Review

CS 225

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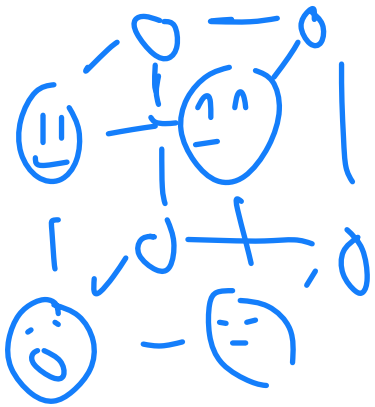
February 6, 2026



Department of Computer Science

Announcements

Reminder: Labs are due on Sunday!

MP is due on Monday (late day Tuesday for 93%)

MP lists out on Monday

Exam 1 (2/09 — 2/11)

Autograded MC and one coding question

Manually graded short answer prompt

Practice exam will be released on PL

Topics covered can be found on website

Register now

https://courses.engr.illinois.edu/cs225/exams/

Learning Objectives

Finish discussing queue implementation details

Discuss the importance of iterators

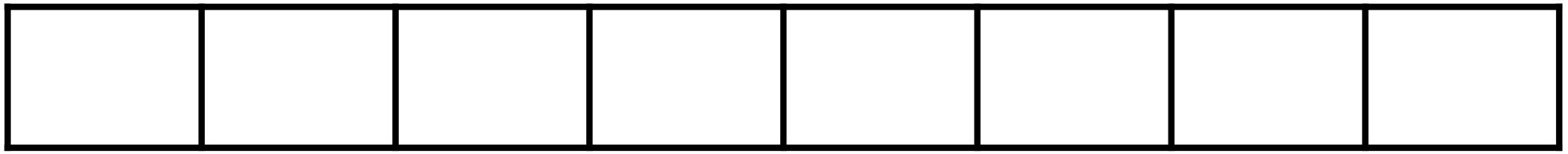
Review content seen on exam 1 (and how to prepare)

Introduce trees and the tree ADT (Time permitting)

Stack and Queue

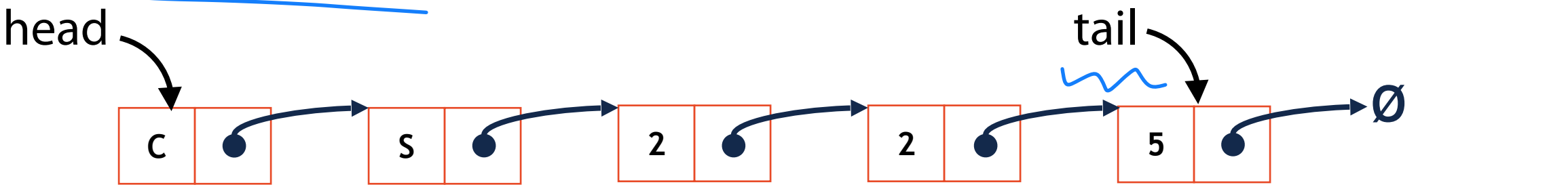
Taking advantage of special cases in lists / arrays

insertBack O(1)



insertFront O(1)

insertBack O(1)



Stack ADT

- [Order]: LIFO (Last in first out)

- [Implementation]: Array (such as std::vector) back as top

Linked List also works using insert / remove Front as top

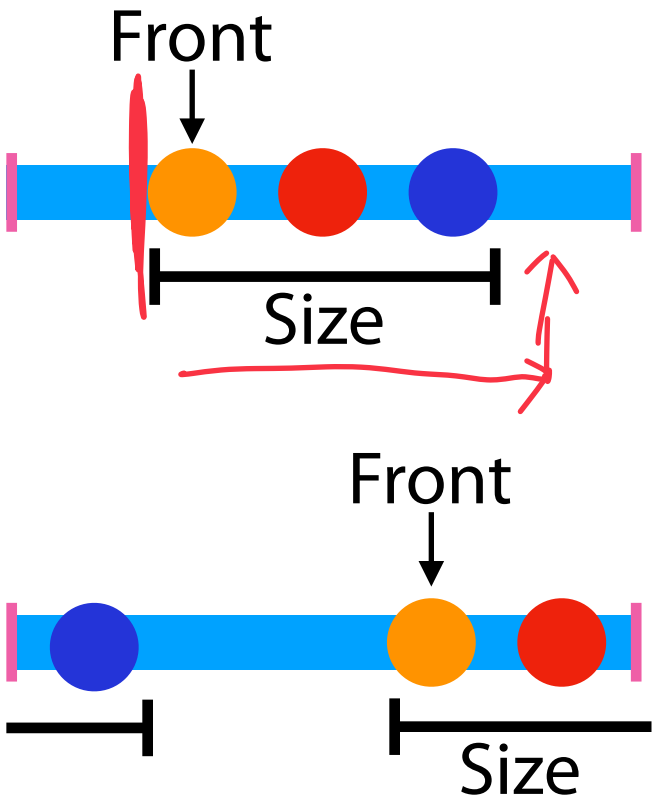
- [Runtime]: O(1) Push, Pop, Top

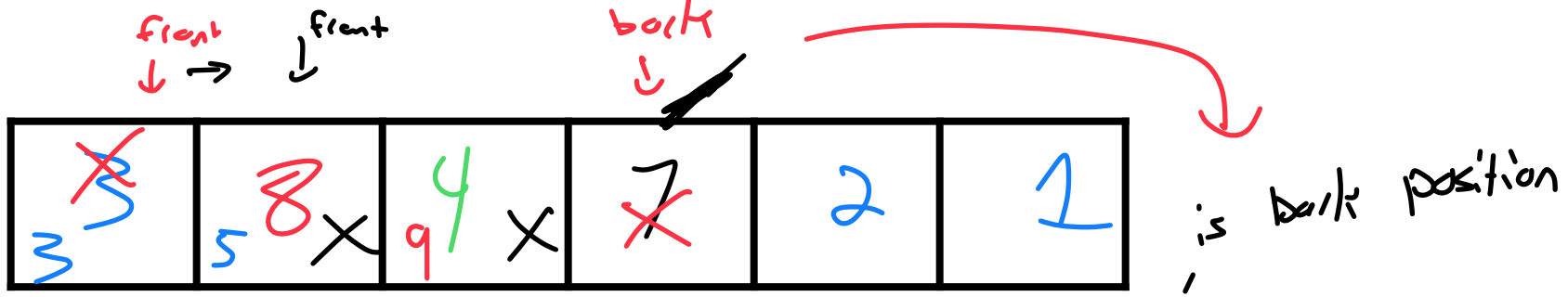
If using array, O(1)* if we need to resize.

(Circular) Queue Data Structure

Queue.h

```
 1  #pragma once
 2
 3  template <typename T>
 4  class Queue {
 5    public:
 6      void enqueue(T e);
 7      T dequeue();
 8      bool isEmpty();
 9
10    private:
11      T *data_;
12      unsigned capacity_;
13      unsigned size_;
14      unsigned front_;
15  };
```





Enqueue(D): Add D to (front + size) % capacity

size++;

Dequeue(): Remove the front item @ index front

front ++;

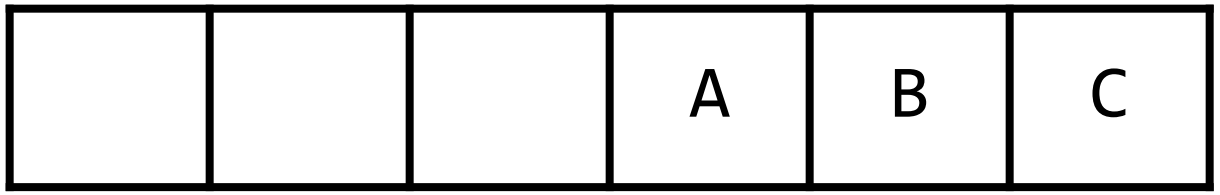
size --;

```
Queue<int> q;
q.enqueue(3);
q.enqueue(8);
q.enqueue(4);
q.dequeue();
q.enqueue(7);
q.dequeue();
q.dequeue();
q.enqueue(2);
q.enqueue(1);
q.enqueue(3);
q.enqueue(5);
q.dequeue();
q.enqueue(9);
```

Size: 0 1 2 3 2 1 0 1 2 3 4 5

Front: 0 1 3 4

Capacity: 6




```
Queue<int> q;
...
q.enqueue(D);
q.dequeue();
q.dequeue();
q.dequeue();
q.dequeue();
q.enqueue(E);
```

Both actions have required checks

Enqueue(D): Add data to ‘back’ of queue

Insert D at index **(size+front) % capacity**

size++ (as long as size != capacity)

Dequeue(): Remove data at index front

front = **(front+1) % capacity**

size-- (as long as size != 0)

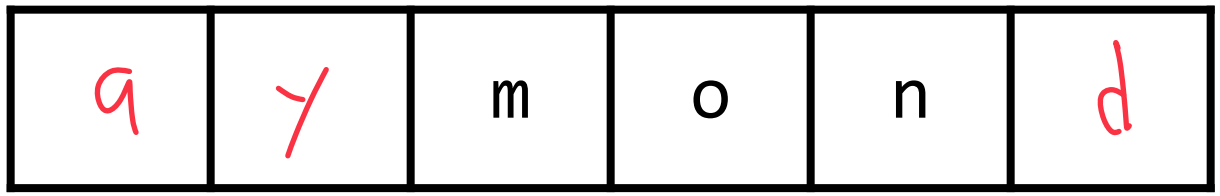
Size: 3

Front: 3

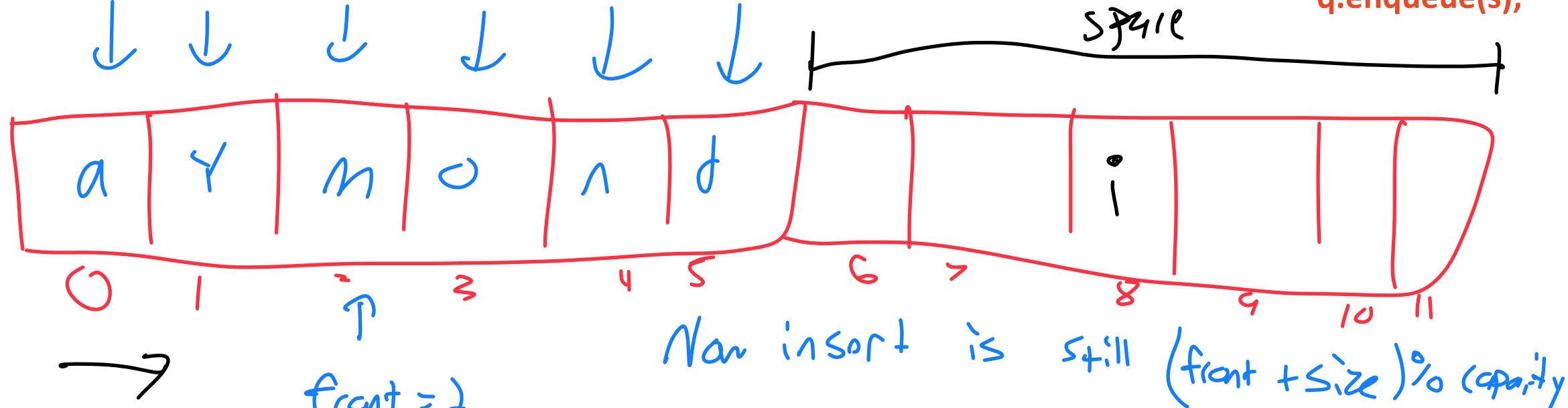
Capacity: 6

Queue Data Structure: Resizing

```
Queue<char> q;
...
q.enqueue(d);
q.enqueue(a);
q.enqueue(y);
q.enqueue(i);
q.enqueue(s);
```



2x allocate



front = 2

size = 6

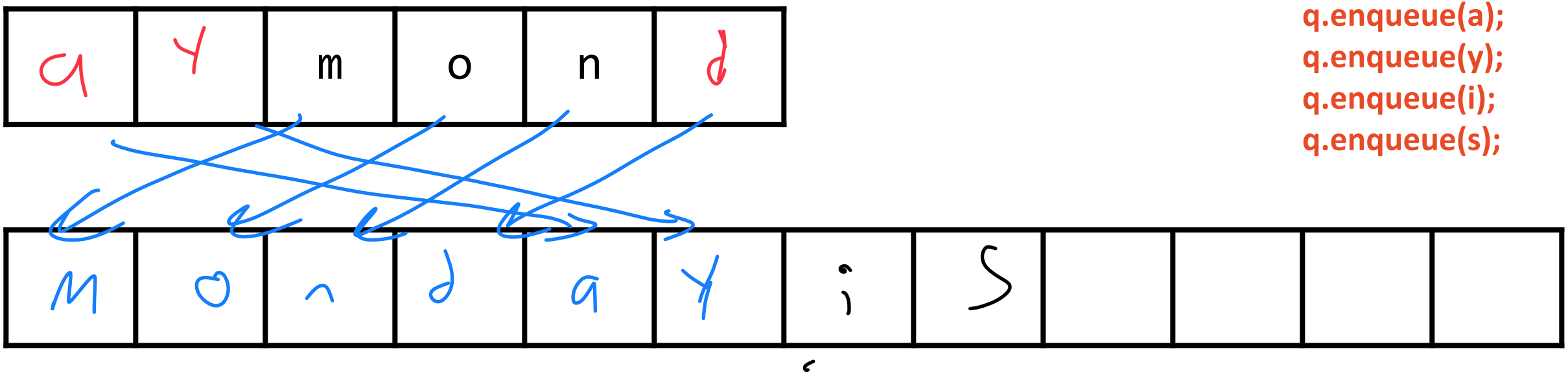
Now insert is still (front + size) % capacity

8

uh oh... this is wrong!

Queue Data Structure: Resizing

```
Queue<char> q;
...
q.enqueue(d);
q.enqueue(a);
q.enqueue(y);
q.enqueue(i);
q.enqueue(s);
```



copy w/ front reset to 0

size is unchanged

O(n) work to resize

↓

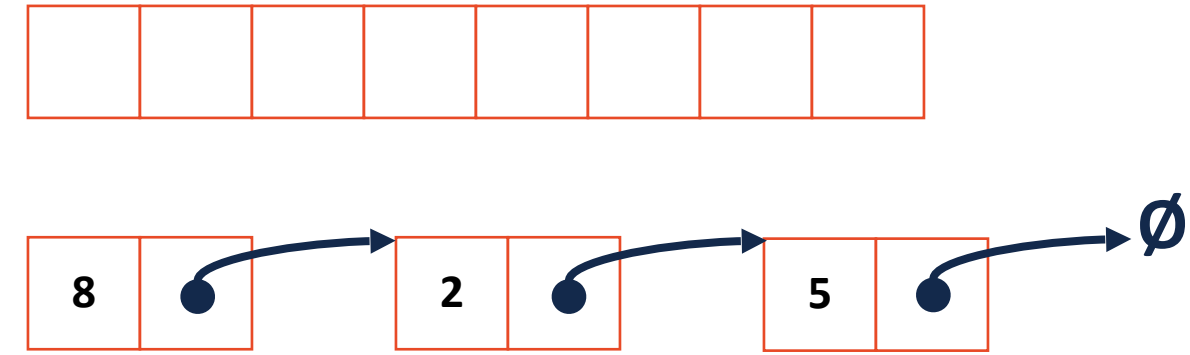
O(1)* amortized

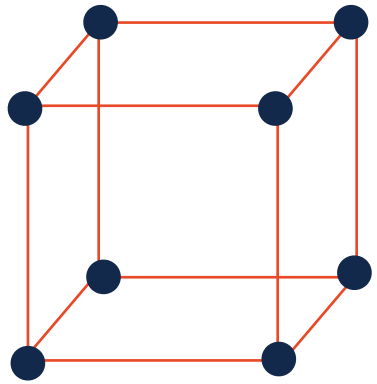
Queue ADT

- [Order]: First in first out (FIFO)
- [Implementation]: Trivial as LL
  - circular array also works
- [Runtime]: O(1)
  - O(1)* w/ resize in array

Iterators

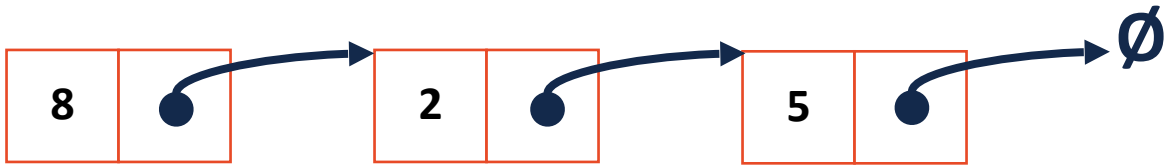
We want to be able to loop through all elements for any underlying implementation in a systematic way

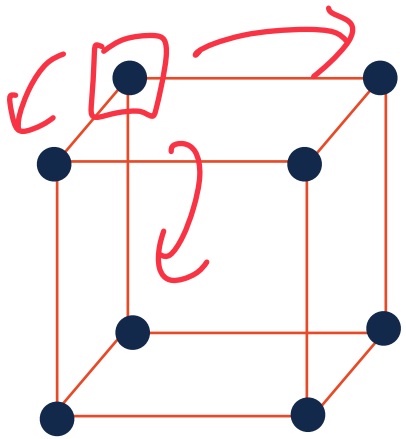




Iterators

We want to be able to loop through all elements for any underlying implementation in a systematic way





Cur. Location	Cur. Data	Next
`ListNode * curr`	curr→data	curr→next
`unsigned index`	A[index]	index++

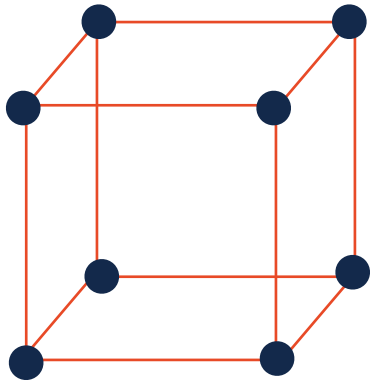
`Some form of`
 	
`(x, y, z)`
	???
	
	get Data(x,y,z)	

Iterators

Cube has an internal Iterator class

Iterators provide a way to access items in a container without exposing the underlying structure of the container

cube has begin()



```
1 Cube::Iterator it = myCube.begin();
2
3 while (it != myCube.end()) {
4     std::cout << *it << " ";
5     it++;
6 }
7
```

Start pos of traversal

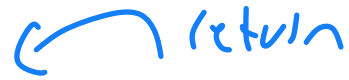
cube has end()
↳ end points one past end of data structure

increment

Can dereference has a pointer to current position

Iterators

For a class to implement an iterator, it needs two functions:




```
Iterator begin()
```

```
Iterator end()
```

Iterators

For a class to implement an iterator, it needs two functions:

`Iterator begin()`

Returns an Iterator object pointing at the ‘first item’

`Iterator end()`

Returns an Iterator object pointing one entry past end of dataset

Iterators

The actual iterator is defined as a class **inside** the outer class:

1. It must be of base class **`std::iterator`**

2. It must implement at least the following operations:

```
Iterator& operator ++()
const T & operator *()
bool operator !=(const Iterator &)
```

– move to next position in a systematic way!

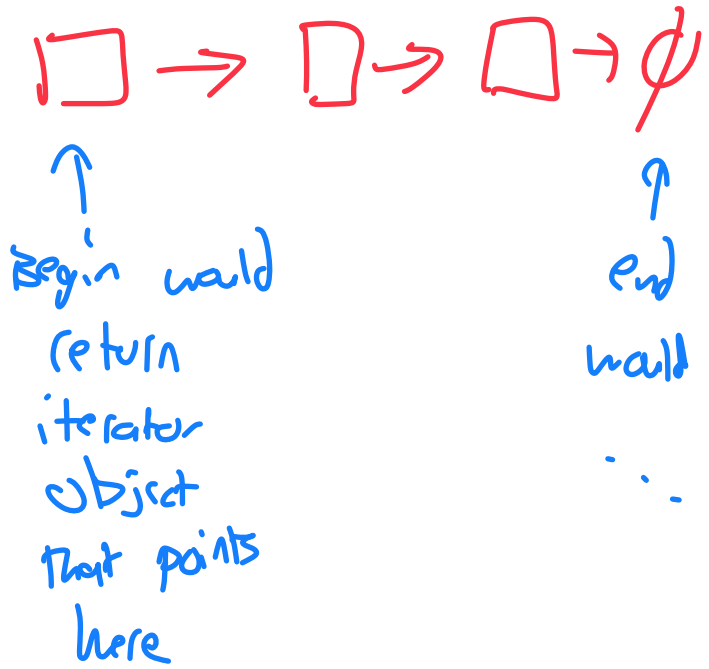
– dereference operator

← compare two iterator objects

Iterators

Here is a (truncated) example of an iterator:

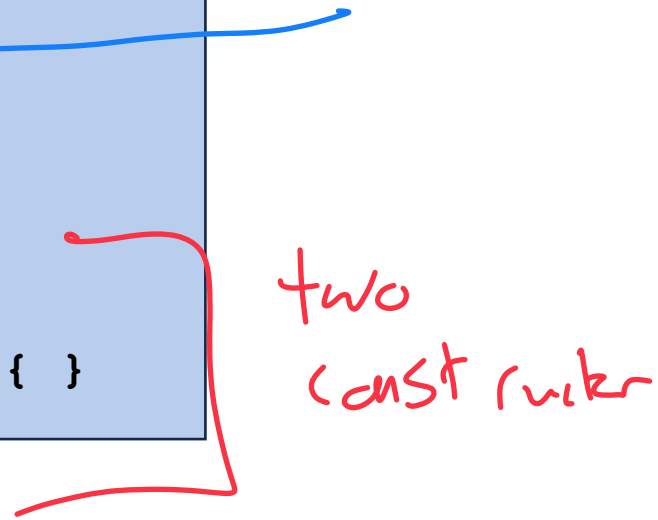
```
 1 template <class T>
 2 class List {
 3
 4     class ListIterator : public
   std::iterator<std::bidirectional_iterator_tag, T> {
 5       public:
 6
 7         ListIterator& operator++();
 8
 9         ListIterator& operator--()
10
11         bool operator!=(const ListIterator& rhs);
12
13         const T& operator*();
14     };
15
16     ListIterator begin() const;
17
18     ListIterator end() const;
19 };
```



MP_List Iterator

```
1  class ListIterator {
2    private:
3      // @TODO: graded in mp_lists part 1
4      ListNode* position_;

5    public:
6      …
7
8      ListIterator() : position_(NULL) { }
9      ListIterator(ListNode* x) : position_(x) { }
```



stlList.cpp

```
1  #include <list>
2  #include <string>
3  #include <iostream>
4
5  struct Animal {
6    std::string name, food;
7    bool big;
8    Animal(std::string name = "blob", std::string food = "you", bool big = true) :
9      name(name), food(food), big(big) { /* nothing */ }
10 };
11
12 int main() {
13   Animal g("giraffe", "leaves", true), p("penguin", "fish", false), b("bear");
14   std::vector<Animal> zoo;
15
16   zoo.push_back(g);
17   zoo.push_back(p);   // std::vector's insertAtEnd
18   zoo.push_back(b);
19
20   for (std::vector<Animal>::iterator it = zoo.begin(); it != zoo.end(); ++it ) {
21     std::cout << (*it).name << " " << (*it).food << std::endl;
22   }
23
24   return 0;
25 }
```

```
1
2  std::vector<Animal> zoo;
3
4
5  /* Full text snippet */
6
7    for ( std::vector<Animal>::iterator it = zoo.begin(); it != zoo.end(); ++it ) {
8      std::cout << (*it).name << " " << (*it).food << std::endl;
9    }
10
11
12 /* Auto Snippet */
13
14   for ( auto it = zoo.begin(); it != zoo.end; ++it ) {
15     std::cout << (*it).name << " " << (*it).food << std::endl;
16   }
17
18 /* For Each Snippet */
19
20   for ( const Animal & animal : zoo ) {
21     std::cout << animal.name << " " << animal.food << std::endl;
22   }
23
24
25
```

auto

it → food

for each animal in zoo

Exam 1 Review

Exam content focuses on fundamentals and lists

To prepare for MCQ:

- Have a clear understanding of the list ADT

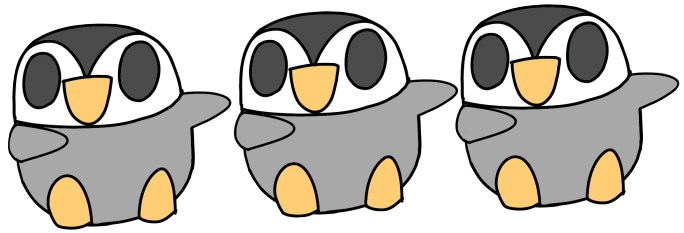
- Understand the Big O details behind linked list and array list

- Be able to apply this knowledge in new contexts

e.g. 'What if I had a linked list and made this modification…'

Lists

Level 1: Know this table
2: Why are the items here these values



The not-so-secret underlying implementation for many things

	Singly Linked List	Array
Look up **arbitrary** location	O(n)	O(1)
Insert after **given** element	O(1)	O(n)
Remove after **given** element	O(1)	O(n)
Insert at **arbitrary** location	O(n)	O(n)
Remove at **arbitrary** location	O(n)	O(n)
Search for an input **value**	O(n)	O(n)

Special Cases: insertFront insertBack (not full)

Exam 1 Review

To prepare for the free response question:

- Have a clear understanding of the list ADT

- Understand the Big O details behind linked list and array list

- Be able to apply this knowledge in new contexts

Brainstorm: What are some variations on linked lists / arrays?

singly linked vs doubly linked

addition of tail (middle) → any specific pointer (min max)

Exam 1 Review

Preparing for the coding question:

- Make sure you understand the fundamentals of debugging

- Review your coding assignments so far (debug / stickers)

- The coding question will be similar to that of practice exam

Brainstorm: What are some ways we could test your knowledge of PNGs / HSLAPixels in the context of arrays?

Questions?

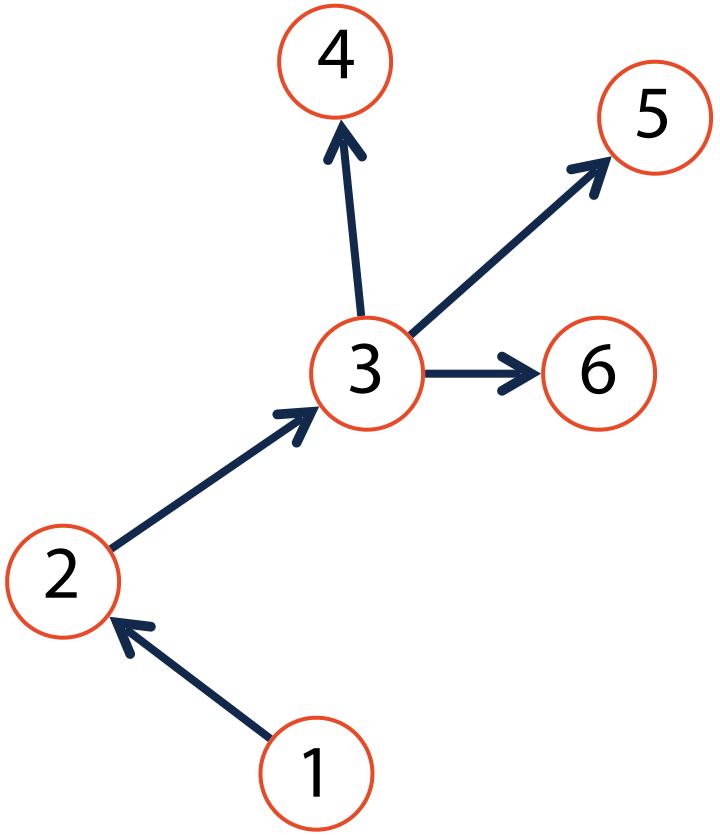
Trees

A non-linear data structure defined recursively as a collection of nodes where each node contains a value and zero or more connected nodes.

[In CS 225] a tree is also:

1) Acyclic — No path from node to itself

2) Rooted — A specific node is labeled root

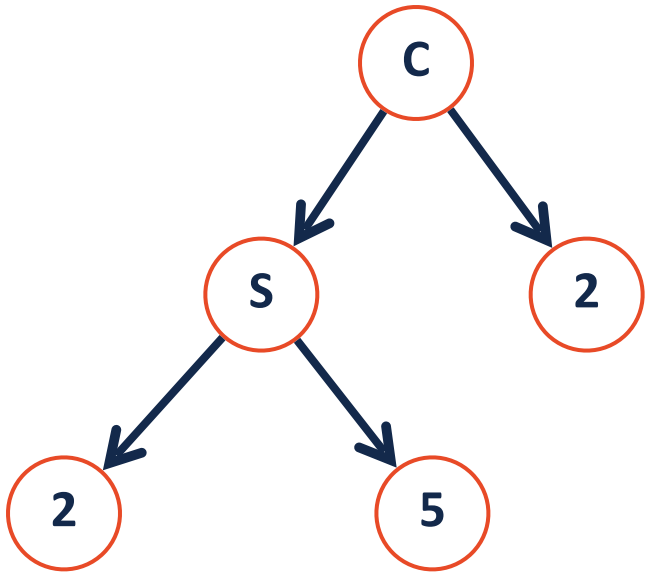


Binary Tree

A **binary tree** is a tree T such that:

1. $T = \emptyset$

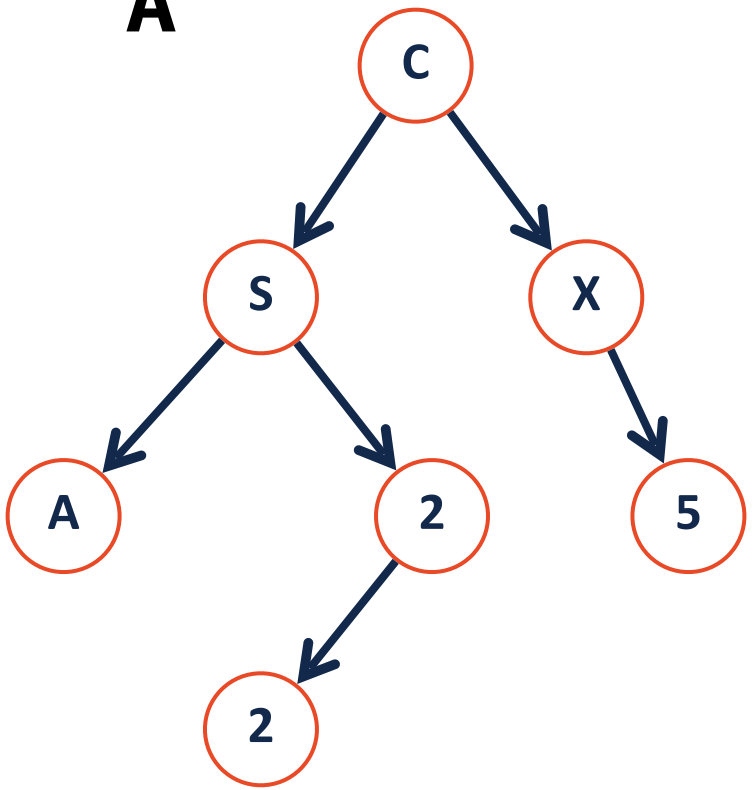
2. $T = (data, T_L, T_R)$



Which of the following are binary trees?

Join Code: 225

A



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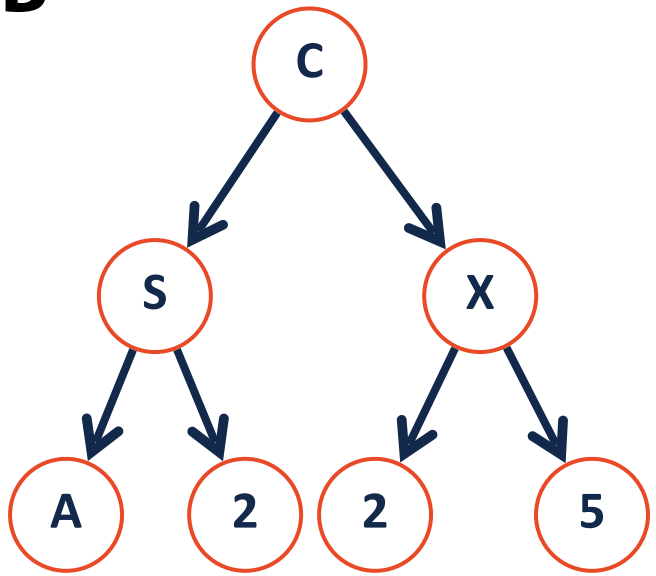

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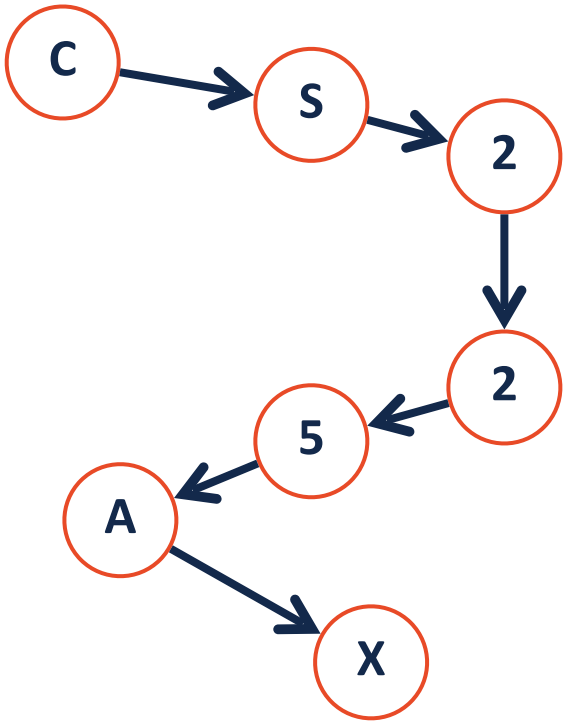

Tree ADT