Data Structures

Iterators, Exam 1 Review

CS 225

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Announcements

Reminder: Labs are due on Sunday!

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

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

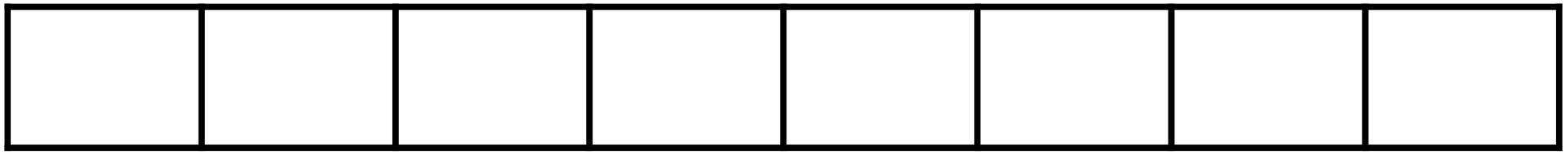
Review content seen on exam 1 (and how to prepare)

Introduce trees and the tree ADT (Time permitting)

Stack and Queue

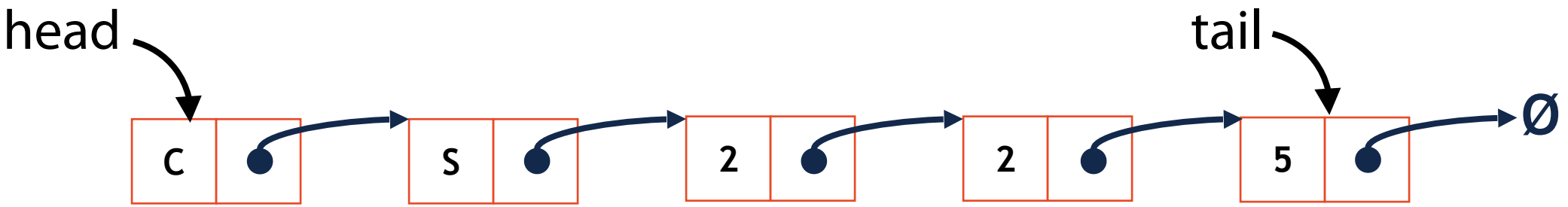
Taking advantage of special cases in lists / arrays

insertBack O(1)



insertFront O(1)

insertBack O(1)



Stack ADT

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

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

Linked List also works using insert / remove Front

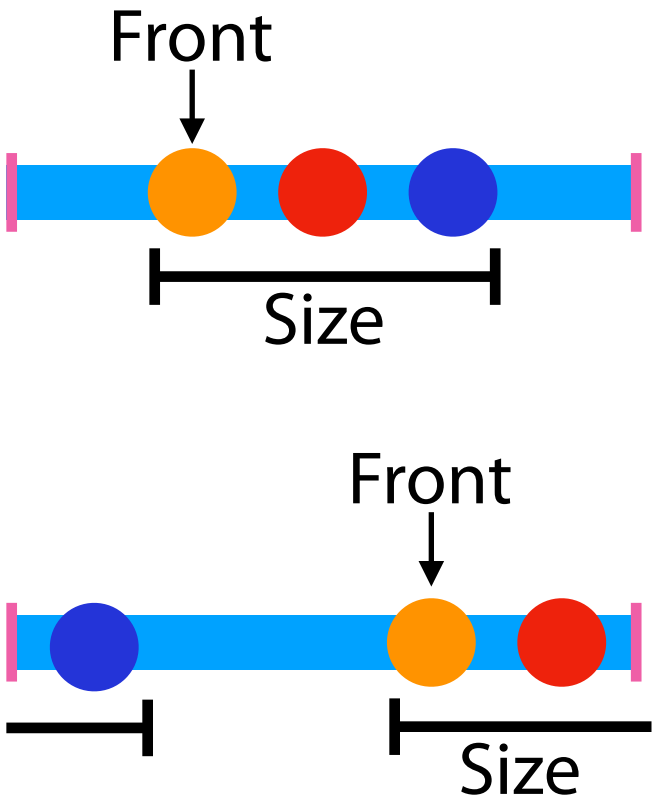
- [Runtime]: O(1) Push, Pop, Top

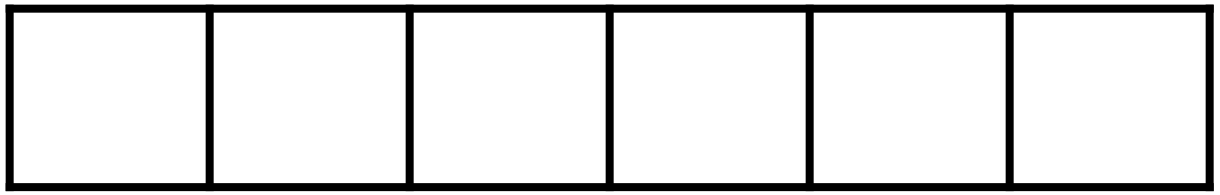
If using array, O(1)* if we need to resize.

(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):

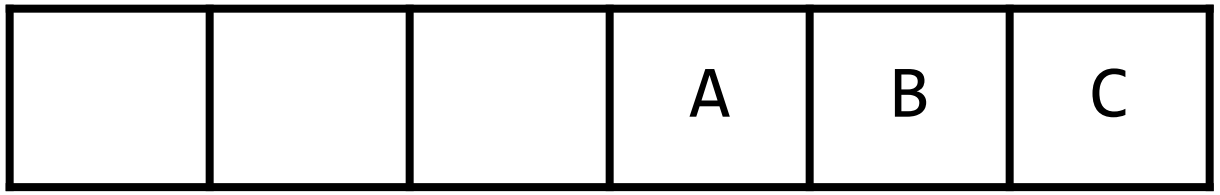
Dequeue():

Size:

Front:

Capacity:

```
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);
```




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

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**

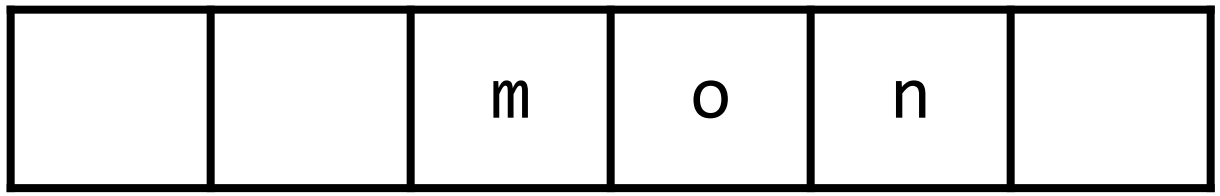
size-- (as long as size != 0)

Size: 3

Front: 3

Capacity: 6

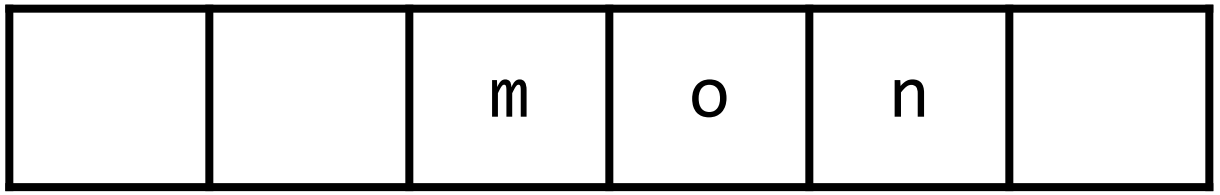
Queue Data Structure: Resizing

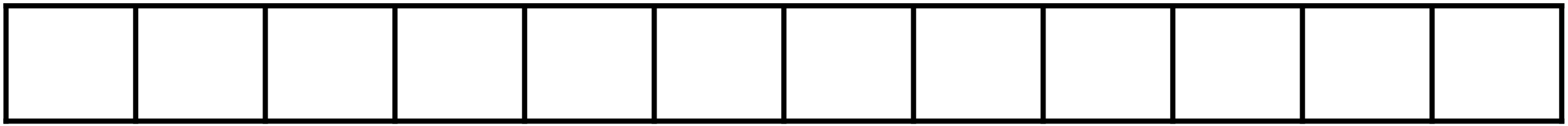



```
Queue<char> q;
…
q.enqueue(d);
q.enqueue(a);
q.enqueue(y);
q.enqueue(i);
q.enqueue(s);
```

Queue Data Structure: Resizing

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



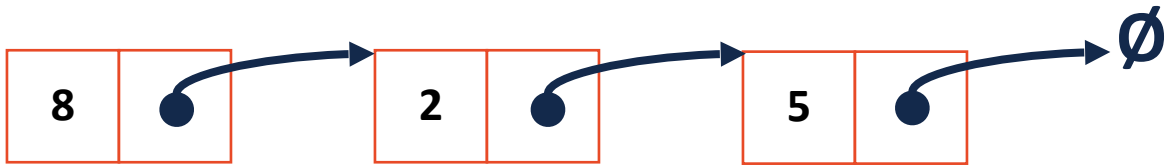


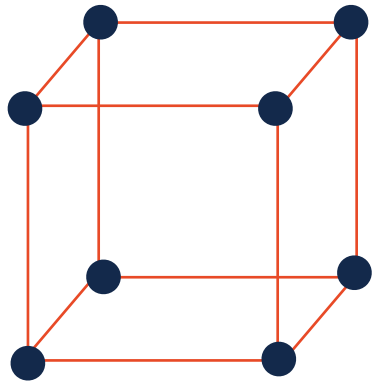
Queue ADT

- [Order]:
- [Implementation]:
- [Runtime]:

Iterators

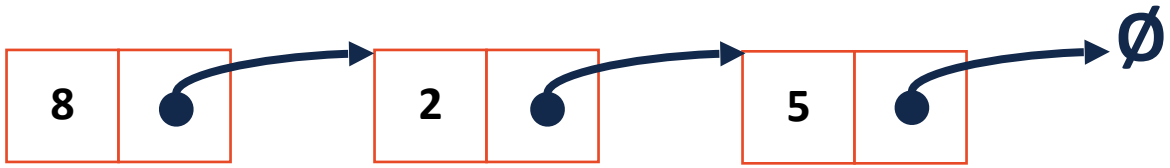
We want to be able to loop through all elements for any underlying implementation in a systematic way

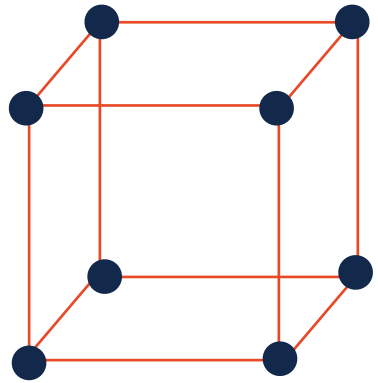




Iterators

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

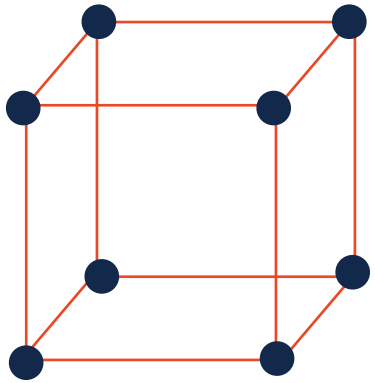




Cur. Location	Cur. Data	Next
`ListNode * curr`		
`unsigned index`		
`Some form of (x, y, z)`		

Iterators

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



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

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 &)
```

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
```

Exam 1 Review

Exam content focuses on fundamentals and lists

To prepare for MCQ:

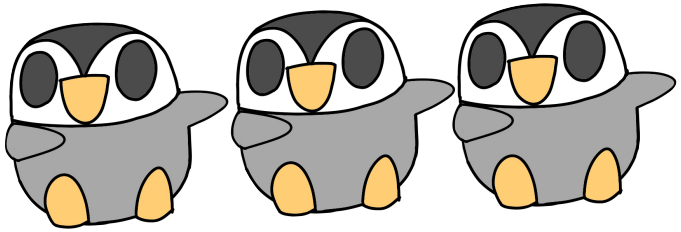
- Have a clear understanding of the list ADT

- 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



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?

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?

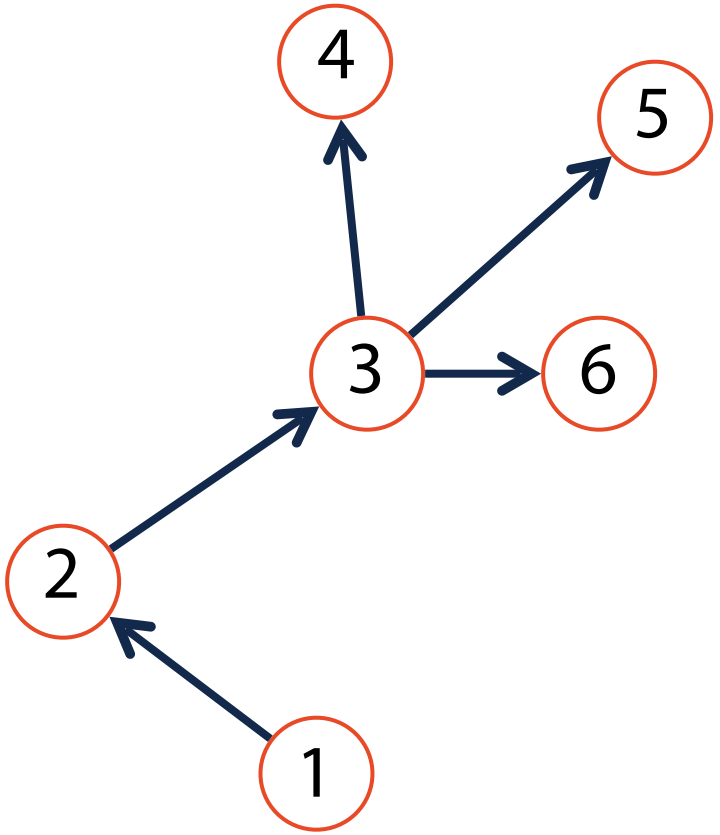
Trees

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

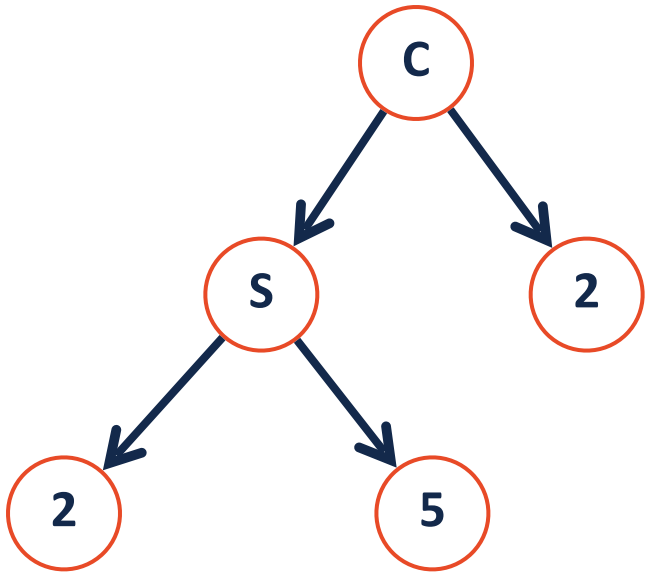


Binary Tree

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

1. $T = \emptyset$

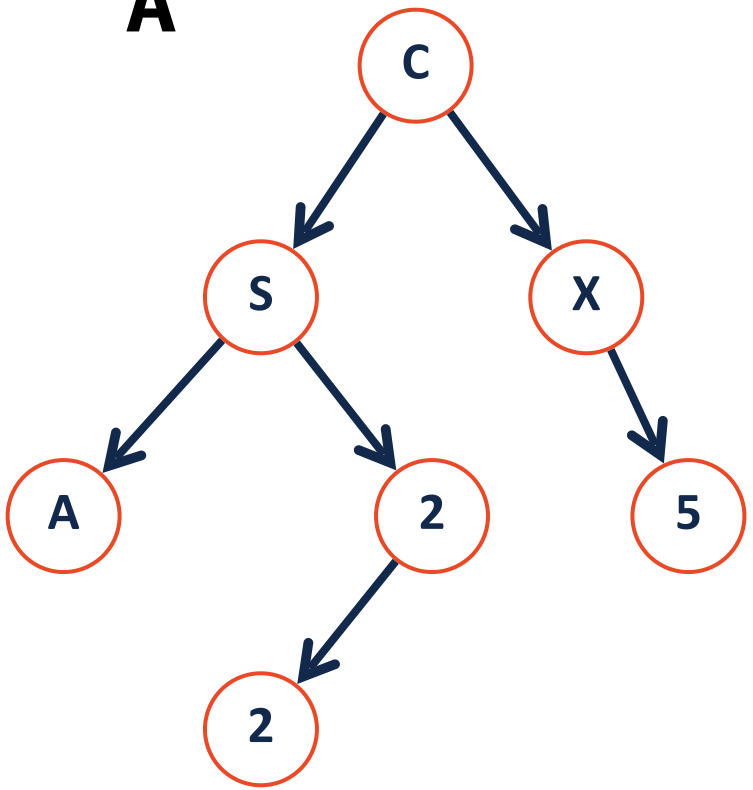
2. $T = (data, T_L, T_R)$



Which of the following are binary trees?

Join Code: 225

A



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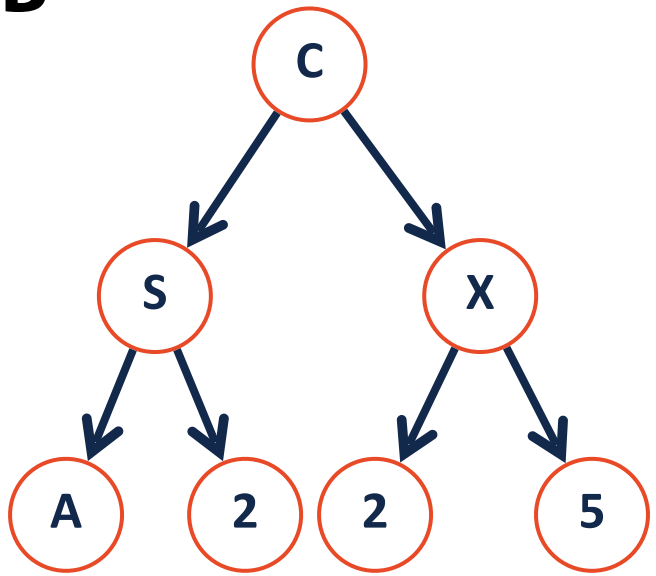
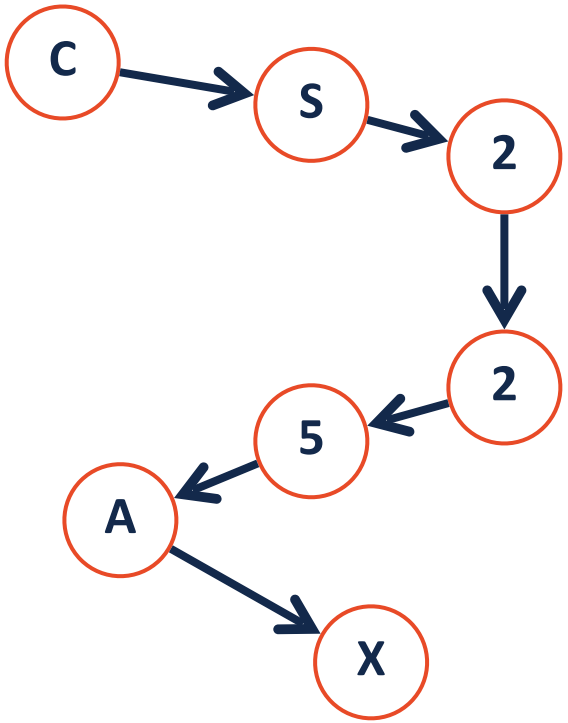


C



Tree ADT