

BINARY SEARCH TREES

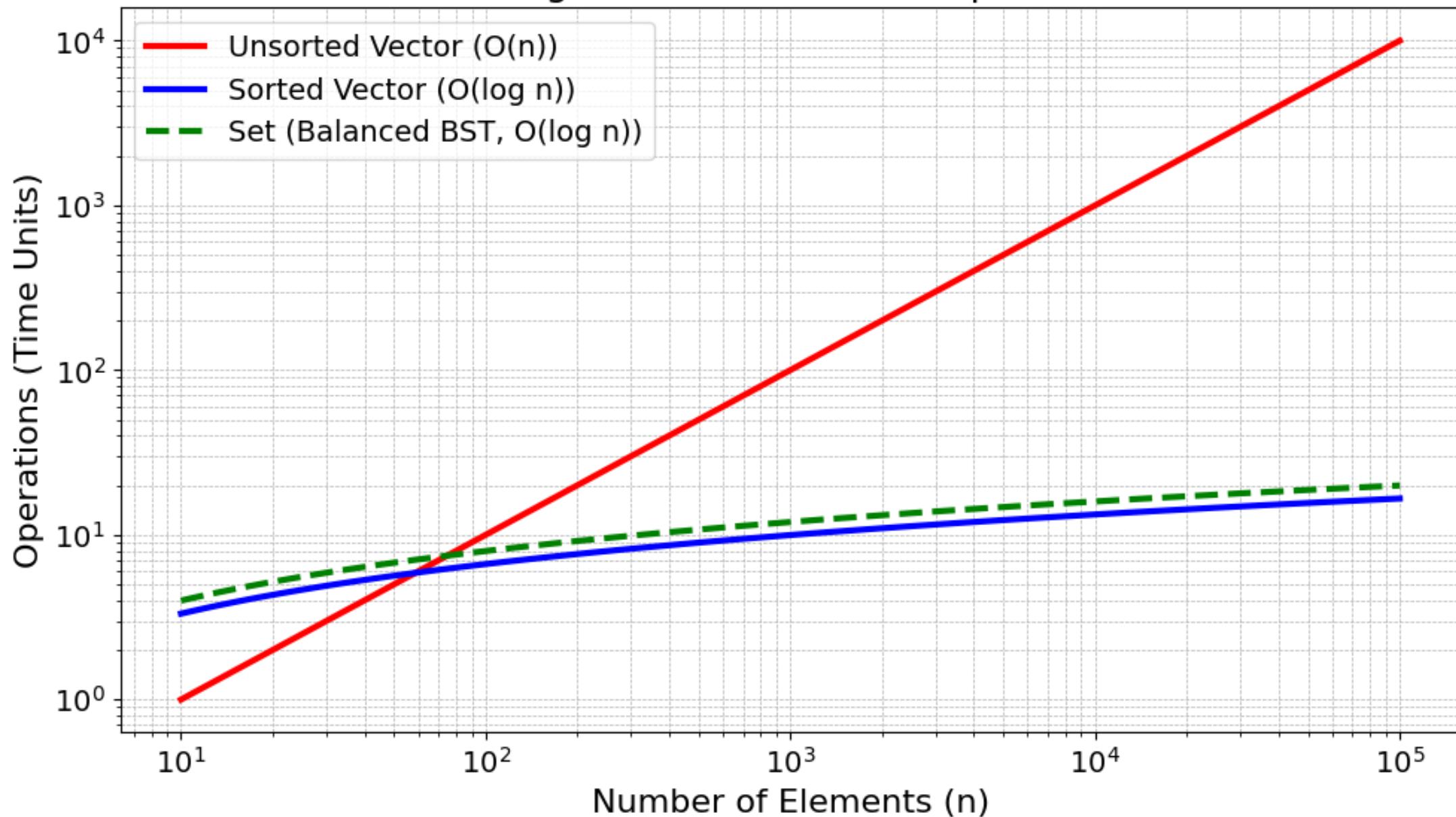
Problem Solving with Computers-II

C++

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

int main(){
    cout<<"Hola Facebook\n";
    return 0;
}
```

Scaling of Worst-Case Find Operations

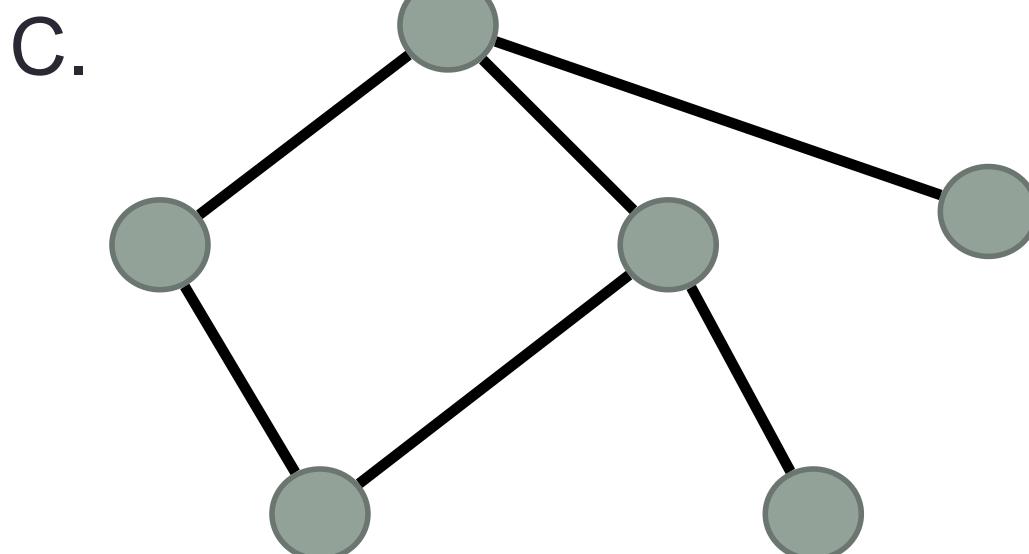
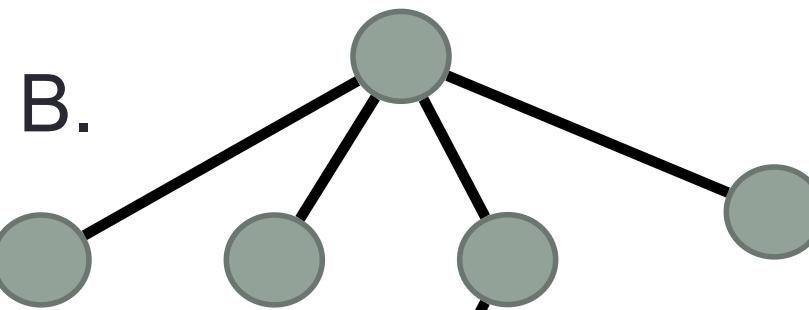


Binary Search Trees (std::set)

- What are the operations supported?
- What are the running times of these operations?
- How do you implement the BST i.e. operations supported by it?

<https://cplusplus.com/reference/set/set/?kw=set>

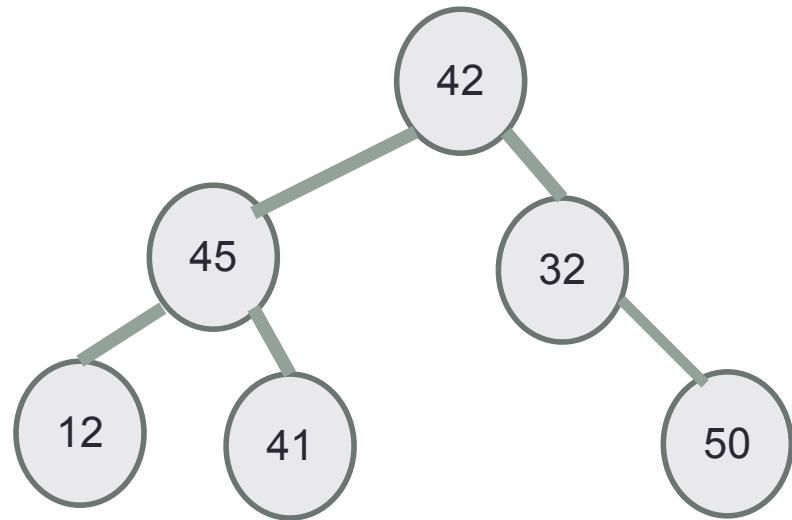
Which of the following is/are a tree?



D. A & B

E. All of A-C

Binary Trees



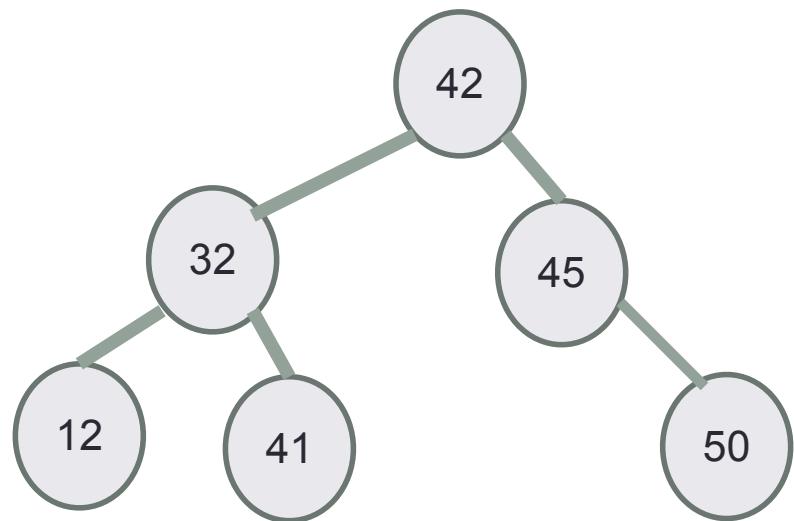
In a tree, nodes are arranged in a hierarchy

- One node is distinguished as the root
- Each node:
 - stores a key
 - has a pointer to child nodes and parent (optional)
- Unique path between any two nodes
- Leaf nodes have no children

In a binary tree, each node has at most _____ children

```
struct TreeNode {  
  
    TreeNode* left;  
    TreeNode* right;  
    TreeNode* parent;  
    int const data;  
  
    TreeNode(int d) : data(d) {  
        left = right = parent = nullptr;  
    }  
};
```

Binary Search Tree – What is it?



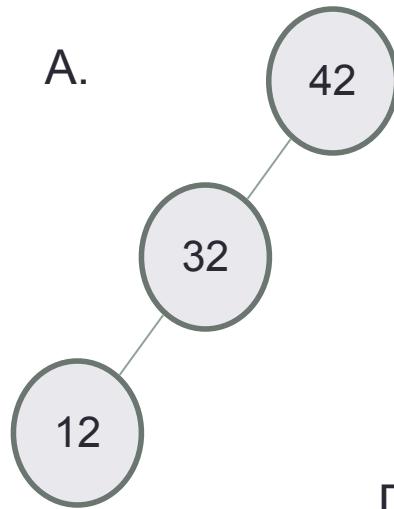
BST is a binary tree where each node satisfies the **Search Tree Property**

For any node,
Keys in node's left subtree < Node's key <
Keys in node's right subtree

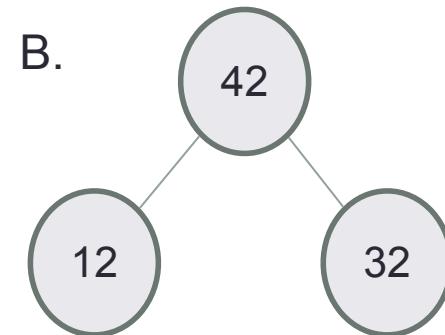
`std::set` does not store duplicate values
Do the keys have to be integers?

Which of the following is/are a binary search tree?

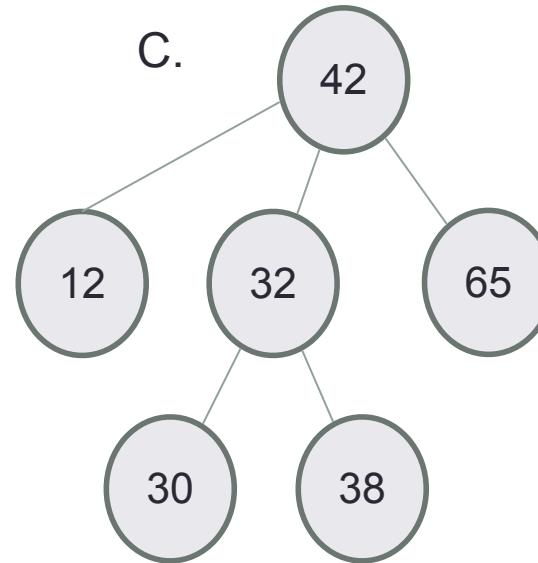
A.



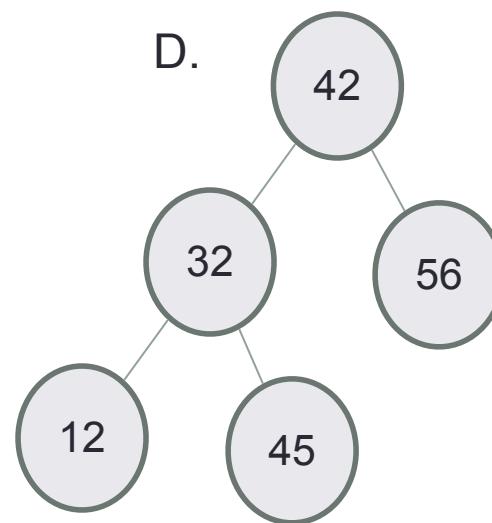
B.



C.



D.



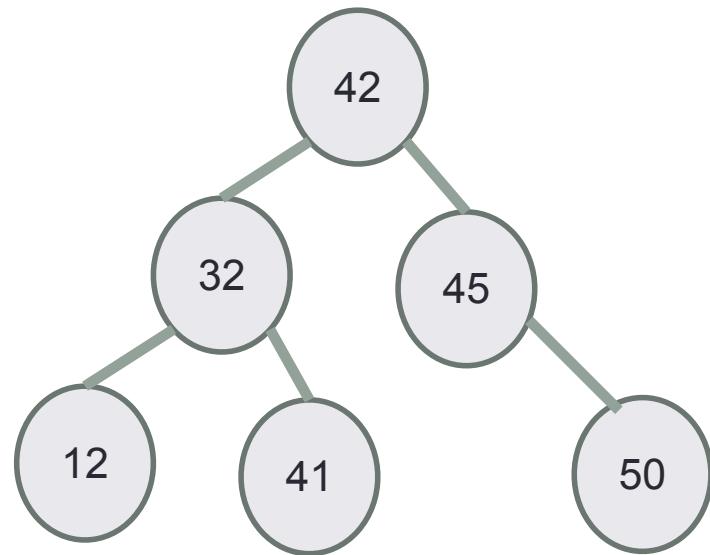
E. More than one of these



- Path – a sequence of (zero or more) connected nodes.
- Length of a path - number of edges traversed on the path
- Height of node – Length of the longest path from the node to a leaf node.
- **Height of the tree** - Length of the longest path from the **root** to a leaf node.

BSTs of different heights are possible with the same set of keys
Examples for keys: 12, 32, 41, 42, 45

search in a BST

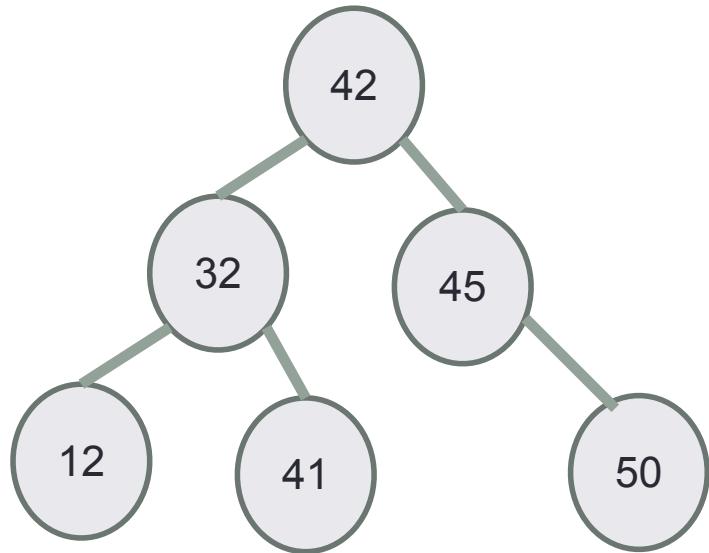


- Start at the root;
- Trace down a path by comparing k with the key of the current node x :
 - If the keys are equal: we have found the key
 - If $k < \text{key}[x]$ search in the left subtree of x
 - If $k > \text{key}[x]$ search in the right subtree of x
- What is the running time of search?



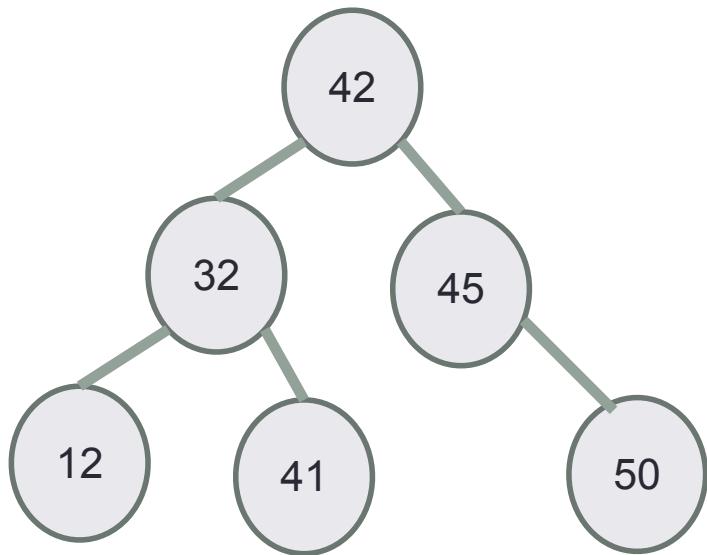
Search for 41, then search for 53

Insert



- Insert 40
- Search for the key
- Insert at the spot you expected to find it
- What is the running time of insert?

Min/Max



Which of the following describes the algorithm to find the maximum value in the BST?

- A. Return the root node's value
- B. Follow **right child** pointers from the root, until a node with no right child is encountered, return that node's key
- C. Follow **left child** pointers from the root, until a node with no left child is encountered, return that node's key

Define the BST ADT

Operations

Search

Insert

Min

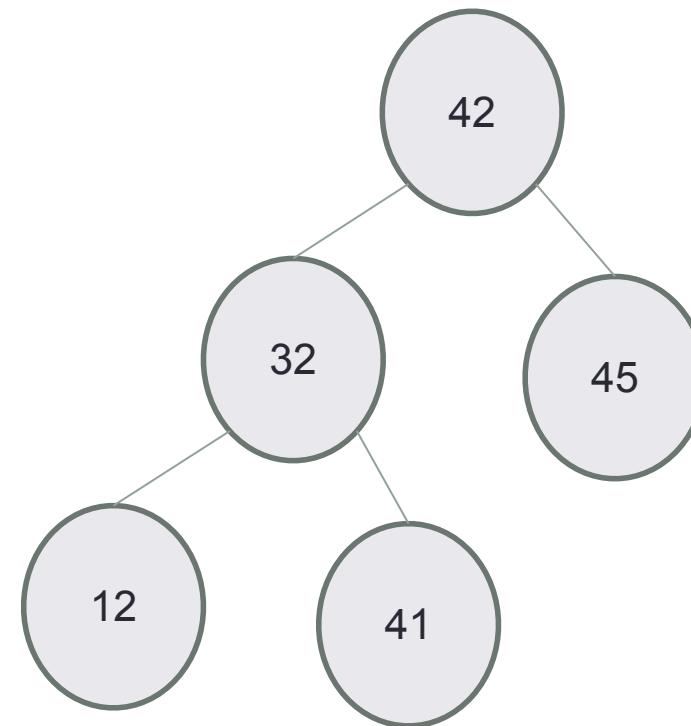
Max

Successor (next largest key)

Predecessor (next smaller key)

Delete

Print elements (3 variations)



Quiz Time!

- This is a closed book, closed notes quiz
- No calculators, phones, or notes are allowed
- Write all answers clearly in pen or dark pencil
- Show your work for partial credit
- Take the rest of class time.
- You can leave when you are done