# Trees

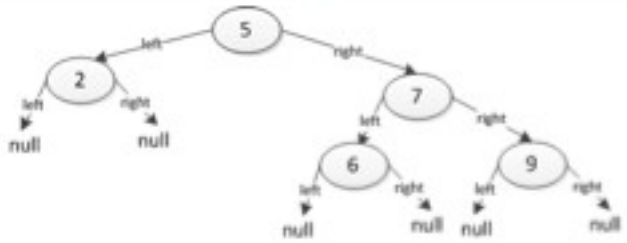
- Snarf the code for today's class
  - and start looking at the code



# Today

- **Definition of a binary tree**
  - **and lingo (e.g. "root", "leaf", "binary search tree")**
- Write recursive code to manipulate binary trees
  - This will be easy and fun!
- By the end of class
  - You will be able to articulate what makes binary search trees so powerfully efficient – including understanding the runtime of the mysterious TreeSet

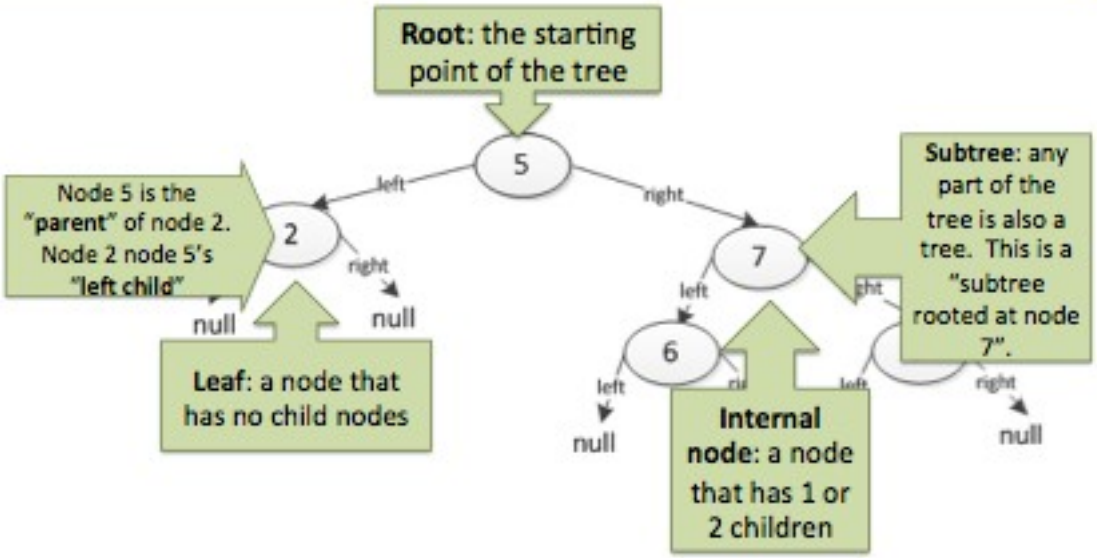
# Binary Tree



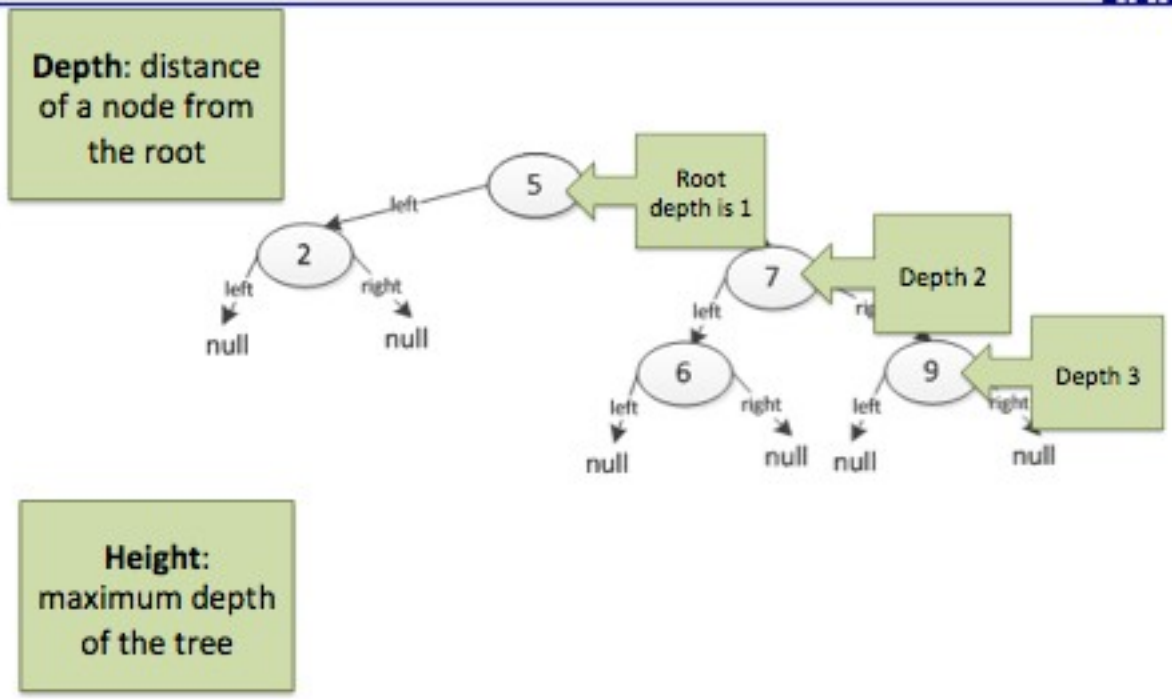

```
IntTreeNode root = null;

    public class IntTreeNode {
        public int value;
        public IntTreeNode left; // holds smaller tree nodes
        public IntTreeNode right; // holds larger tree nodes

        public IntTreeNode(int val) { value = val; }
    }
```



# Binary Tree: Terms



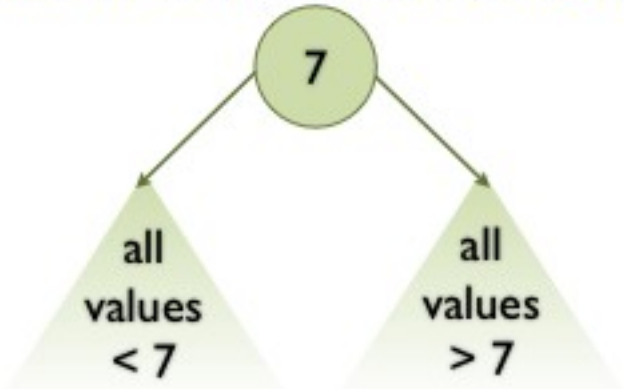
# More terms

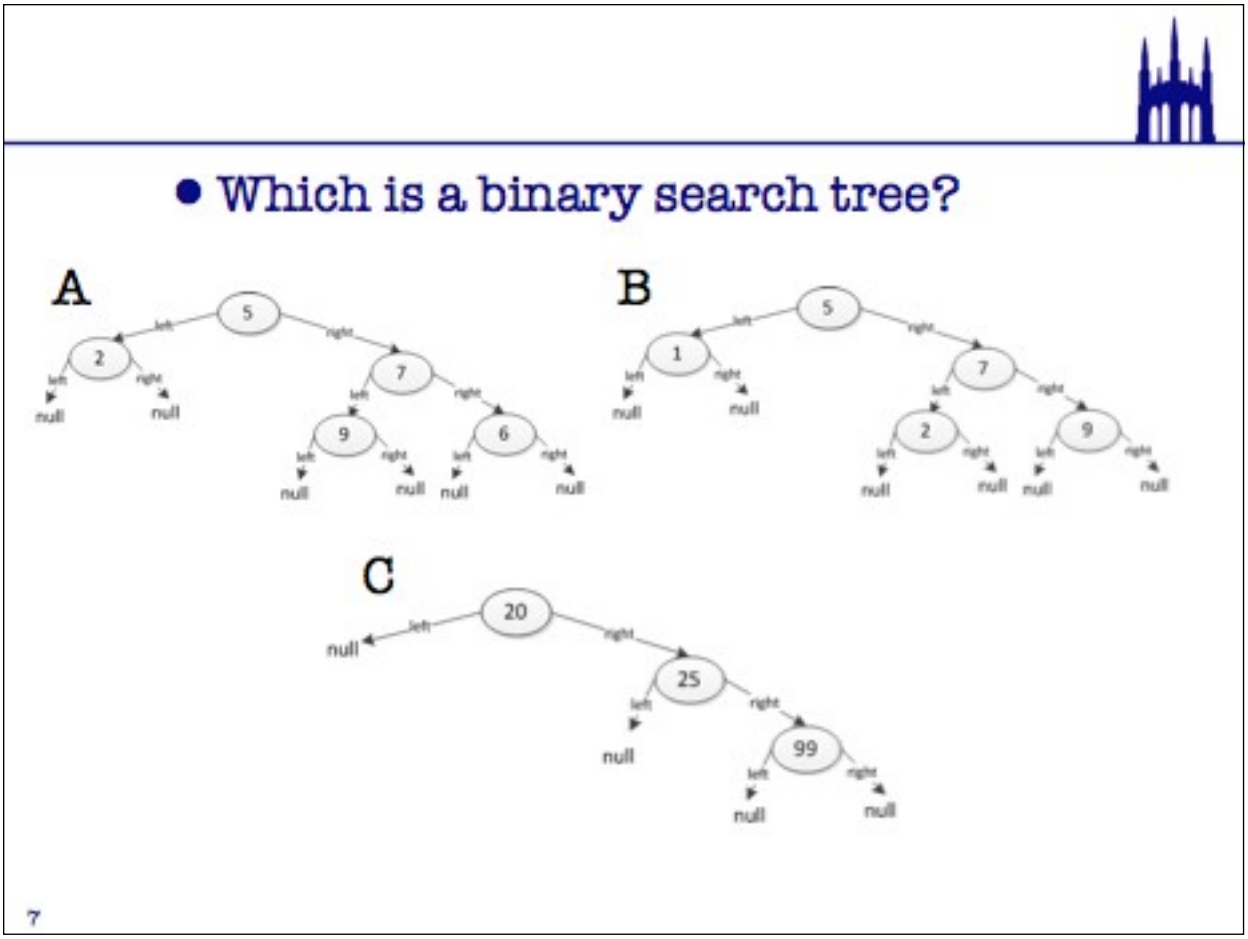





# Binary Search Tree

- Each node has a value
- Nodes with values **less than** their parent are in the **left** subtree
- Nodes with values **greater than** their parent are in the **right** subtree





- Which is a binary search tree?

A



B



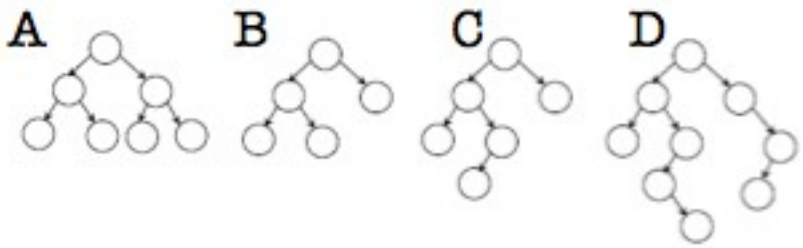
C





# Height Balanced

- A tree is **height-balanced** if
  - left and right subtrees are both height balanced
  - the heights of left and right subtrees do not differ by more than 1
- This matters hugely for efficiency
- Which is NOT height balanced?



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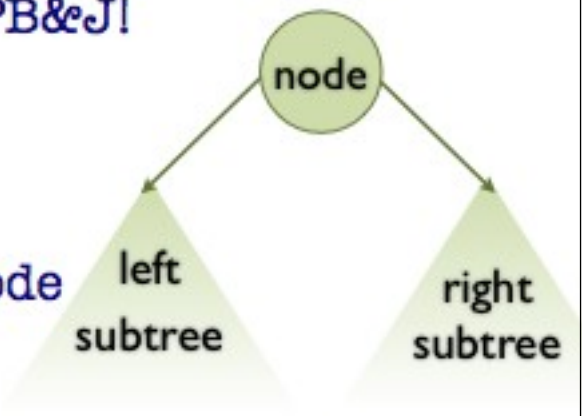
# Recursion and Trees

- They go together like PB&J!




- Pseudocode
  - Check the current node
    - if no
      - check the left subtree
      - check the right subtree

# Your code

- example:

```
public int computeTreeThing(TreeNode current) {
if (we are at the base case) {
  return obviousValue;
} else {
   int lResult = computeTreeThing(current.left);
   int rResult = computeTreeThing(current.right);
   int result = //combine those values;
   return result;
}
```



# Coding exercise

```
public int computeTreeThing(TreeNode current) {
if (we are at the base case) {
  return obviousValue;
} else {
   int lResult = computeTreeThing(current.left);
   int rResult = computeTreeThing(current.right);
   int result = //combine those values;
   return result;
}
```

- Code (as many as you can)countNodes, containsNode, and findMax
- If you get stuck on countNodes raise your hand
- If you finish early, modify your functions to work with a BinaryTree
- Submit your code via ambient

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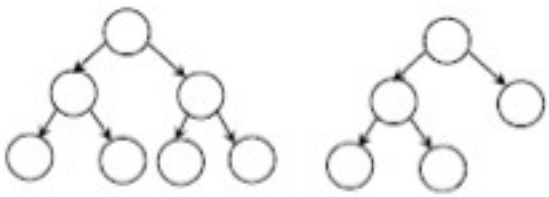
- What is the height of a **height-balanced** tree?



A. O(N)

B. O(Nln(N))

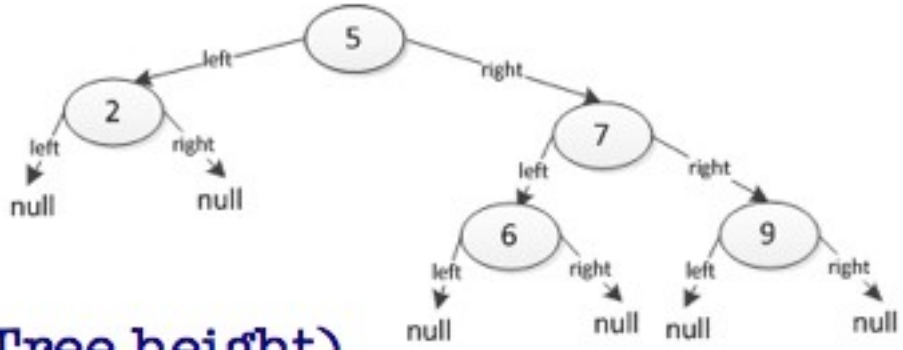
C. O(ln(N))

D. $O(N^2)$

*We can prove this with induction

# In a Binary Search Tree

- What is the maximum time to:
  - insert a node?
  - Find a node?



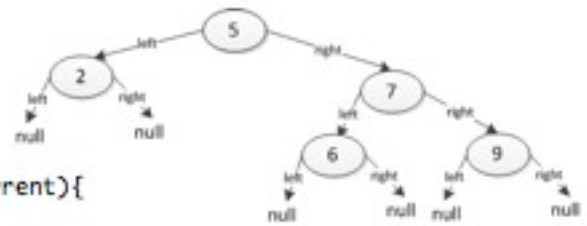

O(Tree height)



# Printing a Tree In Order



- Print **Left** subtree
- Print **Root**
- **Print** Right **subtree**




```
public void printInOrder(IntTreeNode current){
    if(current == null)
      return;
    printInOrder(current.left);
    System.out.print(current.value + " ");
    printInOrder(current.right);
}
```

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- **Complete the worksheet off from the calendar page for today's class!**