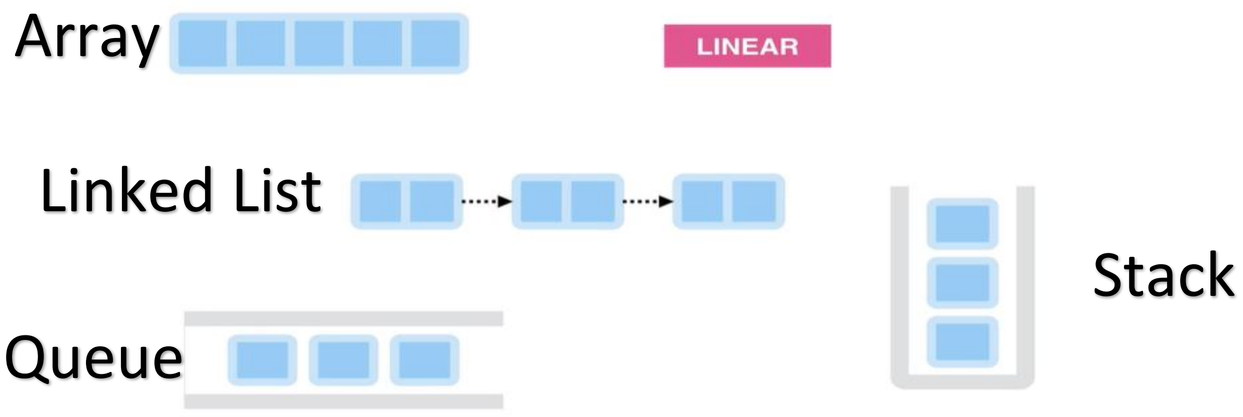
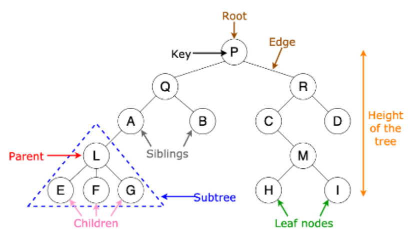
Tree

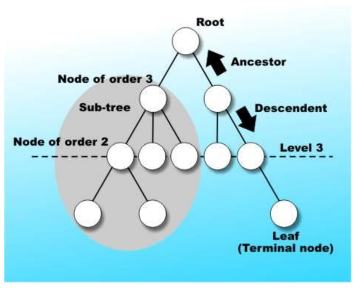
V-1-Introduction:-

So far we learned linear data structure.



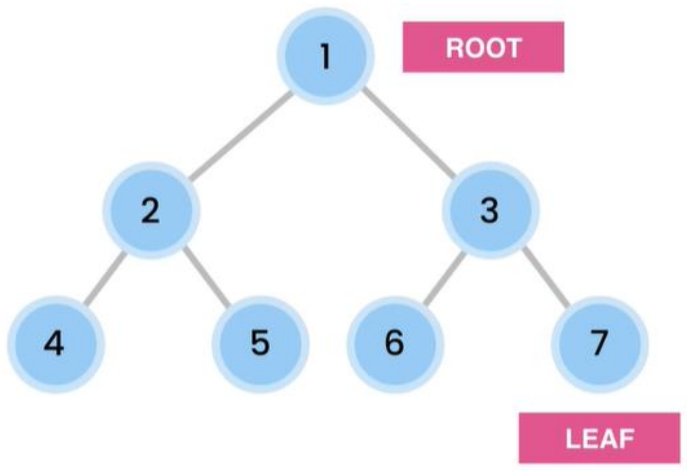
Tree is one of the Non-Linear Data Structure.





V-2-What are Trees:-

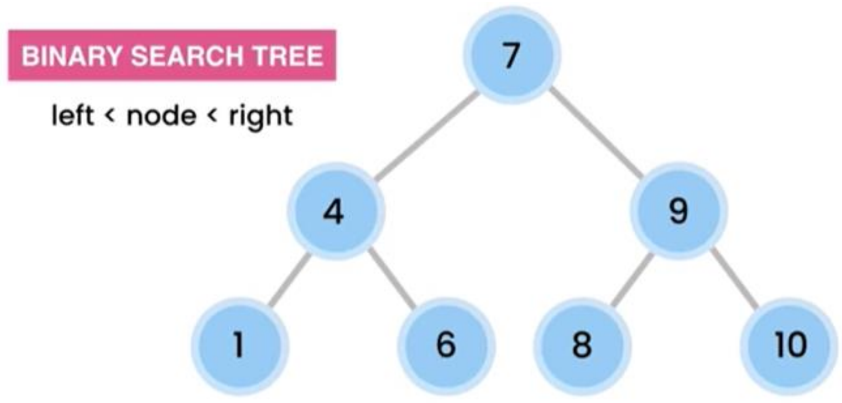
Tree is a Data Structure where we store values in a Hierarchy. The picture below is a binary tree. Cause each parent has at most two children.



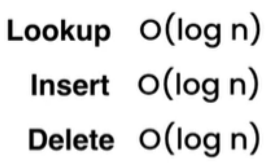
TREES

- Represent hierarchical data
- Databases
- Autocompletion In chrome it store pass in tree Structure
- Compilers
- Compression (JPEG, MP3)

Now BST(Binary Search Tree):-



Any Node is greater than left subtree and Less than then the Right subtree.[4<7<9]
7 is greater than 1,4,6
7 is less than 8,9,10



Lookup	O(log n)
Insert	O(log n)
Delete	O(log n)

Tree structure operation always make It half to work any operation. That's Why it is faster than array,LinkedList.

V_3_E_1)

Binary Search Trees

Add the following numbers to a binary search tree. Remember, in a binary search tree:

left < parent

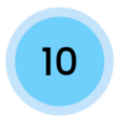
right > parent

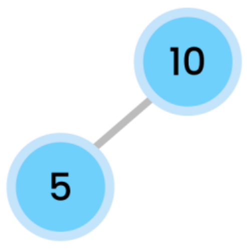
[10, 5, 15, 6, 1, 8, 12, 18, 17]

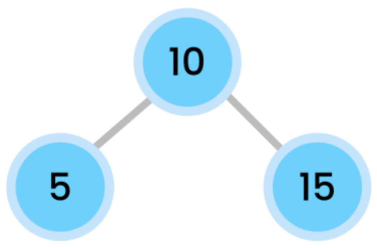
Solution:

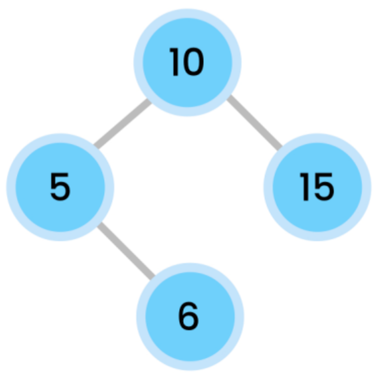
You can also use the following tool to see how a binary search tree evolves as you add new items:

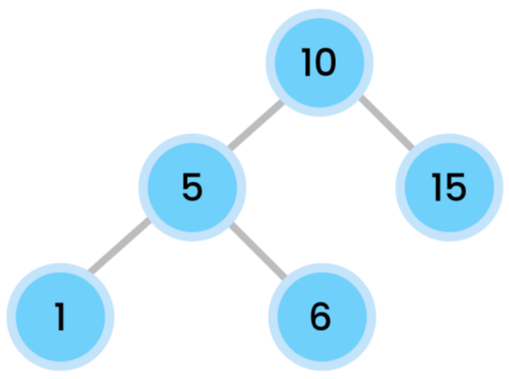
https://visualgo.net/en/bst

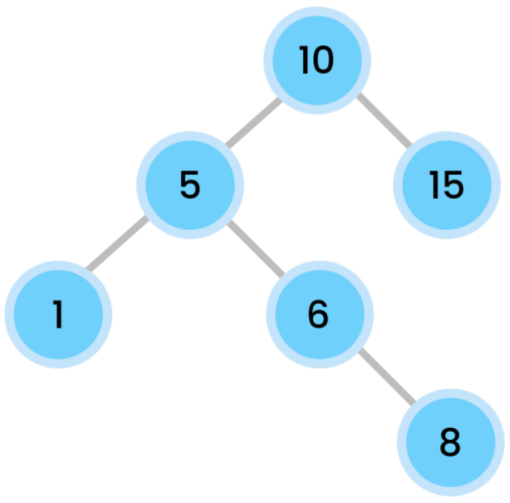

10

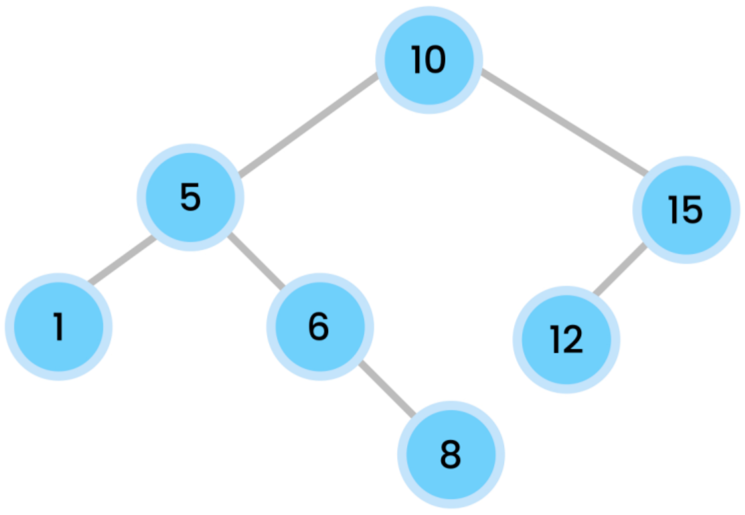

10
5

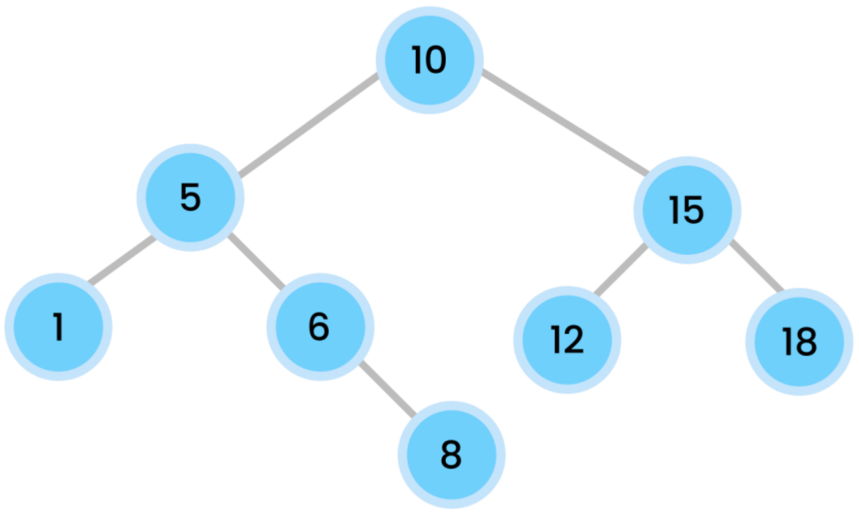

10
5
15

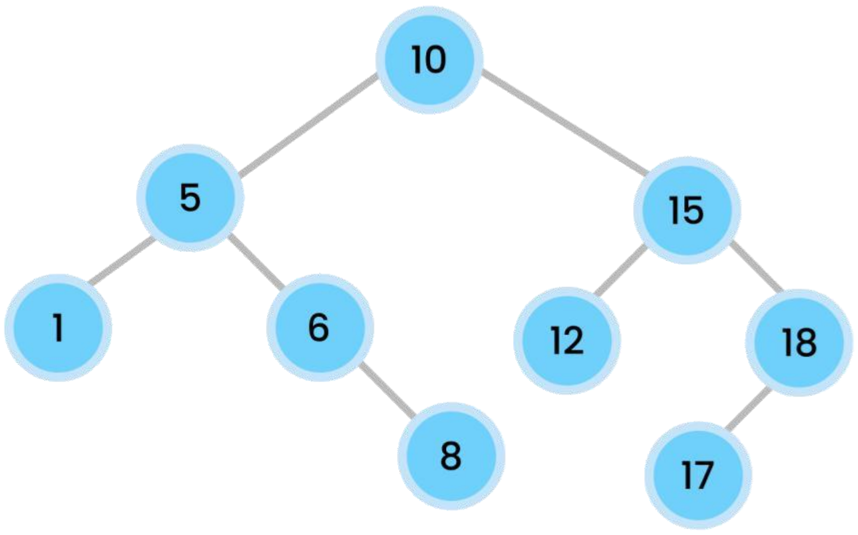

10
5
15
6


10
5
15
1
6

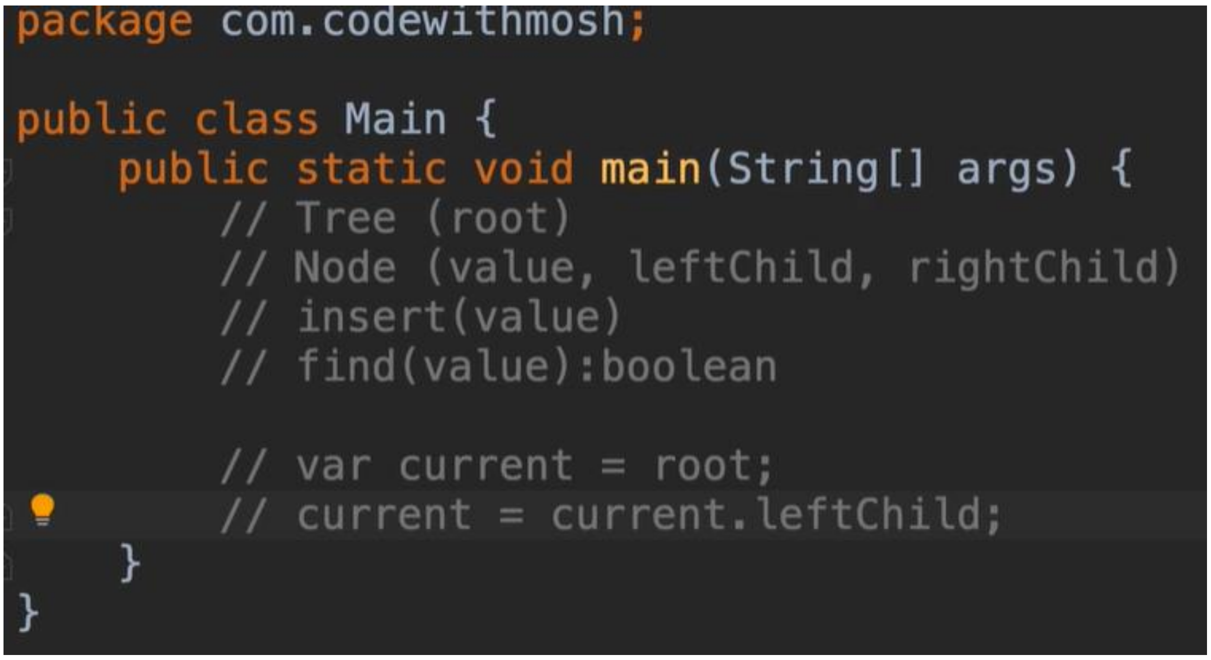

10
5
15
1
6
8


10
5
15
1
6
12
8


10
5
15
1
6
12
18
8

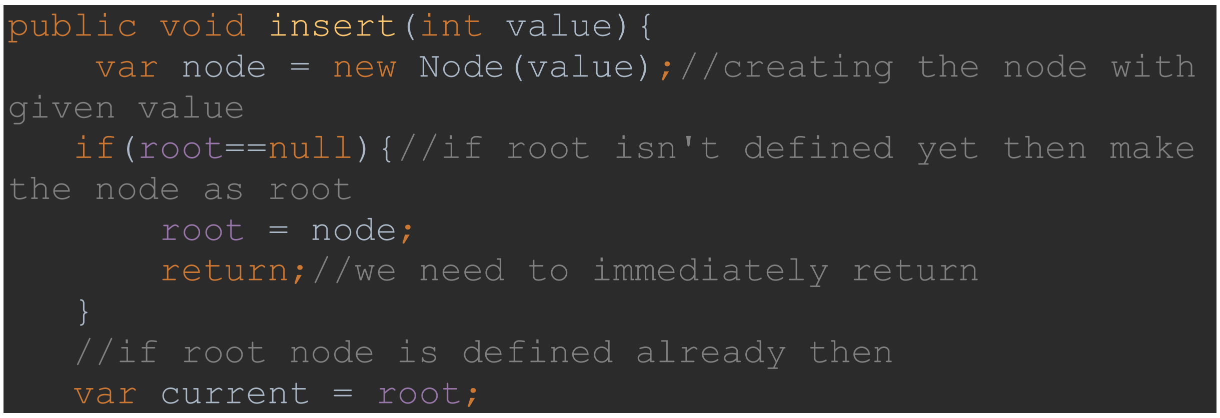


V-4-Build A TREE:-



```
package com.codewithmosh;

public class Main {
    public static void main(String[] args) {
        // Tree (root)
        // Node (value, leftChild, rightChild)
        // insert(value)
        // find(value):boolean

        // var current = root;
        // current = current.leftChild;
    }
}
```

V-5-Insert item in a tree:-



```
public void insert(int value){
     var node = new Node(value);//creating the node with
given value
    if(root==null){//if root isn't defined yet then make
the node as root
        root = node;
        return;//we need to immediately return
    }
    //if root node is defined already then
    var current = root;
```

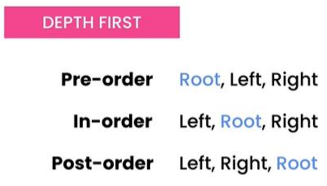
```
   while(true){//insert nodes by left<root<right (by
comparing values)
   if(value< current.value){
       if(current.leftchild==null){//if leftchild is
null then insert(set) leftchild here(current is the
parent of the leftchild)
           current.leftchild=node;
           break;
       }
       current = current.leftchild;
   }
   else{
       if(current.rightchild==null){//same logic as
rightchild
           current.rightchild=node;
           break;
       }
       current = current.rightchild;
   }
   }

}
```

V-6-Find item in a tree:-

```
public boolean find(int value){
    var current = root;
    while(current!=null){
        if(value<current.value)
            current=current.leftchild;
        else if (value> current.value)
            current=current.rightchild;
        else
            return true;
    }
    return false;
}
```

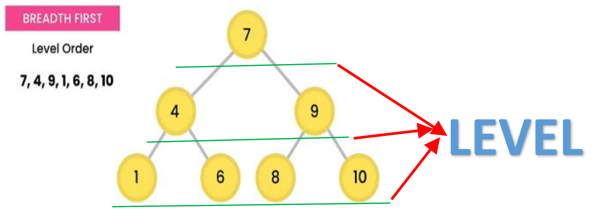
V-8-Traversing Trees:-

We can traverse a tree in two ways. 1. BFS(Level Order Traversal) 2. DFS

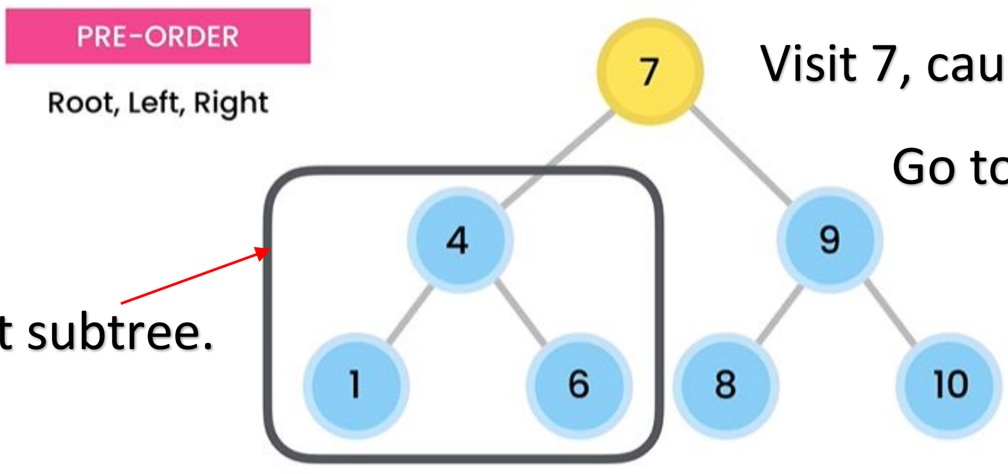


DEPTH FIRST

Pre-order	Root, Left, Right
In-order	Left, Root, Right
Post-order	Left, Right, Root



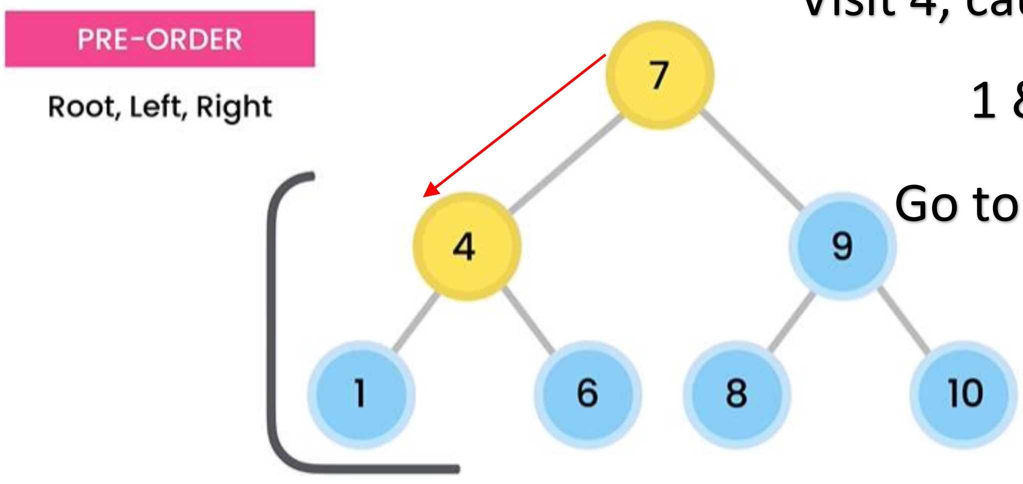
Pre-Order-Traversl: (Step by Step)



Visit 7, cause this is root, then

Go to left subtree.

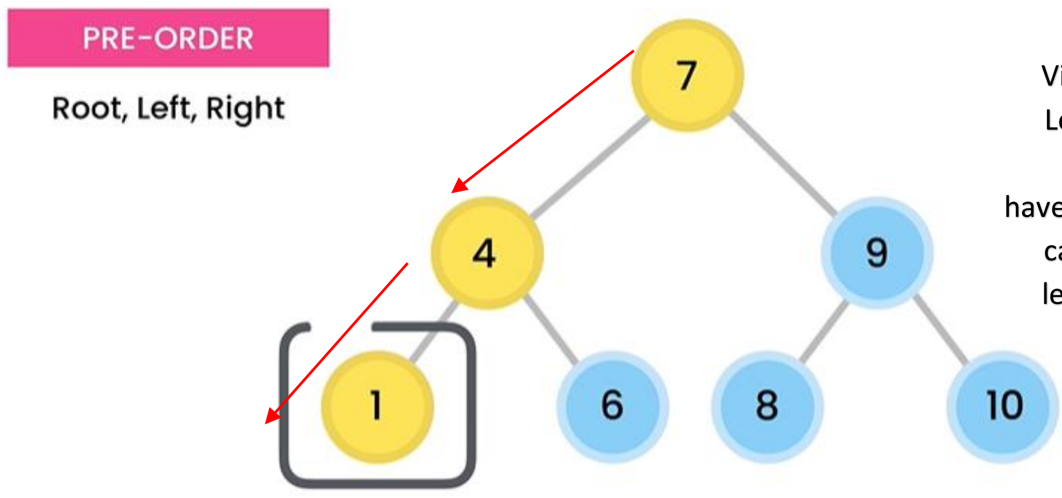
left subtree.



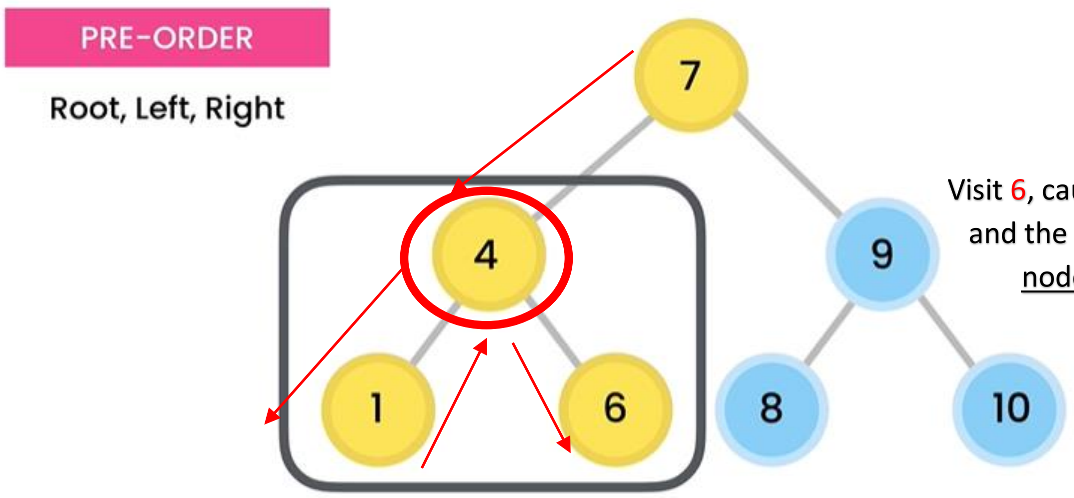
Visit 4, cause this is root of

1 & 6 , then

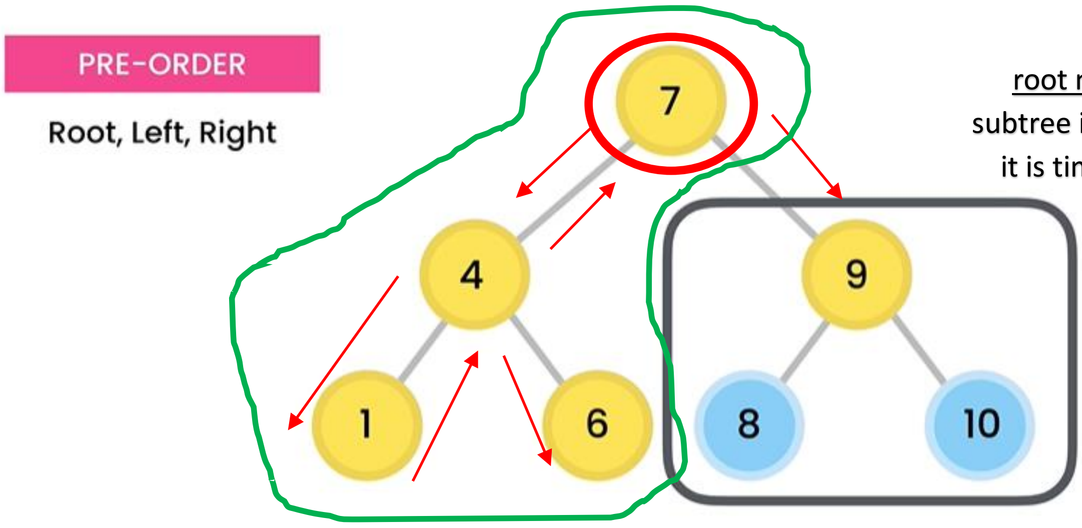
Go to left subtree.



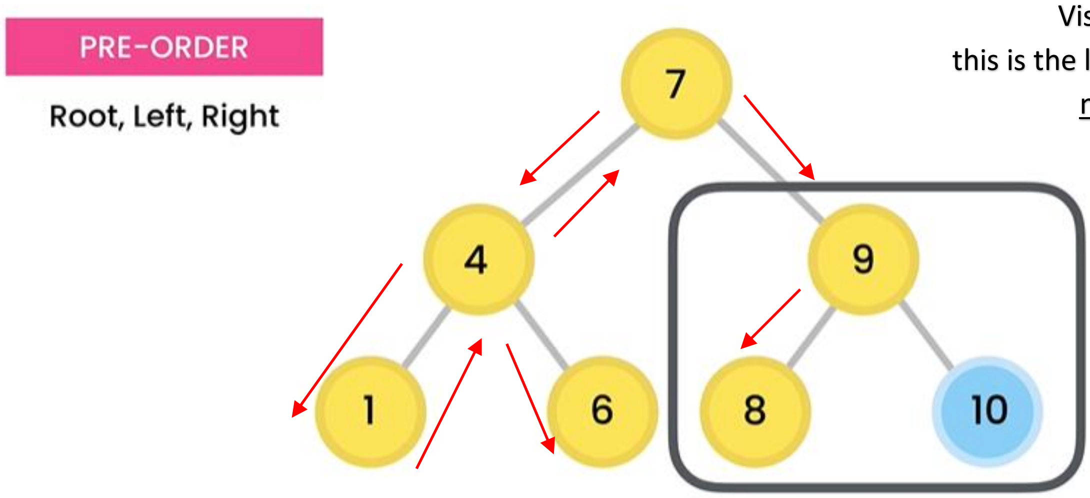
Visit 1, cause this is the
Left subtree of node 4.
but after that we
have to come back to node 4
cause there is no more
left subtree for node 1.



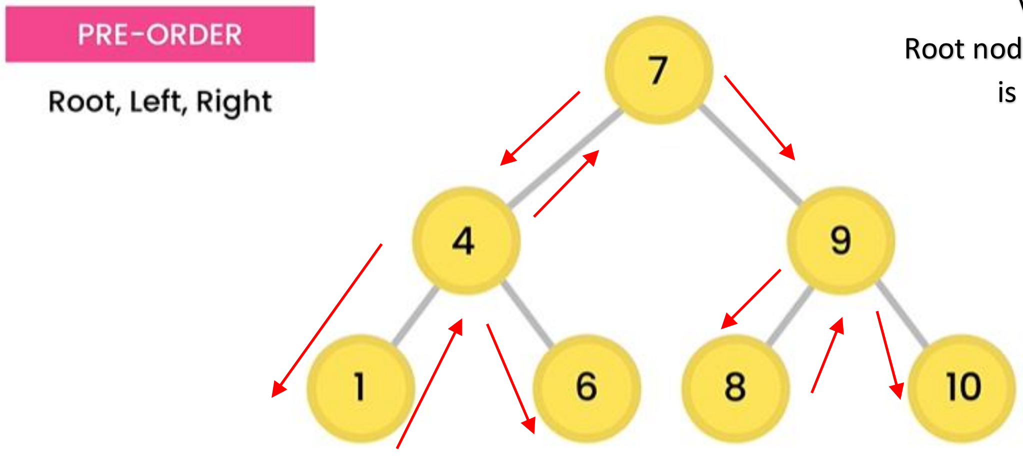
Visit 6, cause *root(4)* of node 6 and the left subtree of root node(4) is visited already.



Visit 9, cause root node (7) and its left subtree is already visited. Now it is time for right subtree.



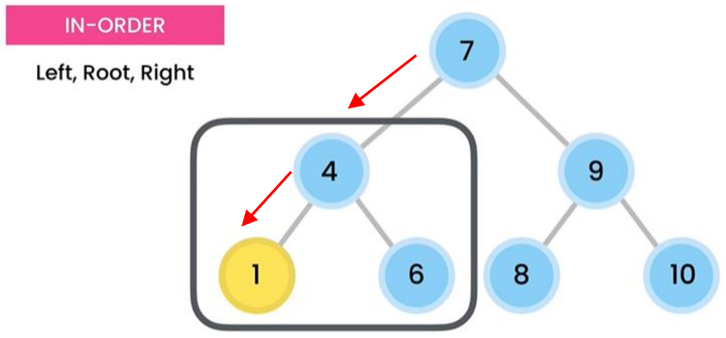
Visit 8, cause this is the left subtree of root node (9) .



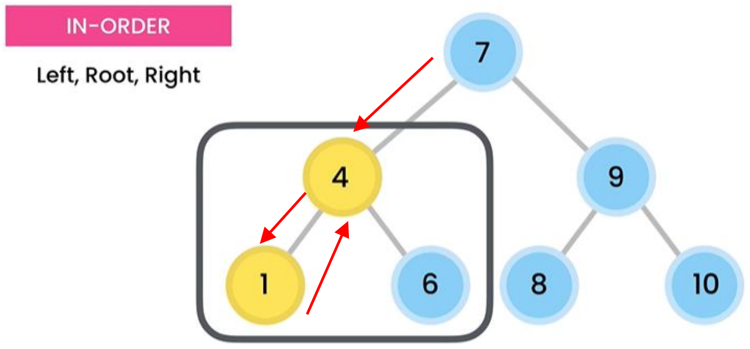
Visit 10, cause
Root node 9 and its left subtree
is already visited.

We are done for pre-order traversal . The order for pre order traversal is **7 -> 4 -> 1 -> 6 -> 9 -> 8 -> 10.**

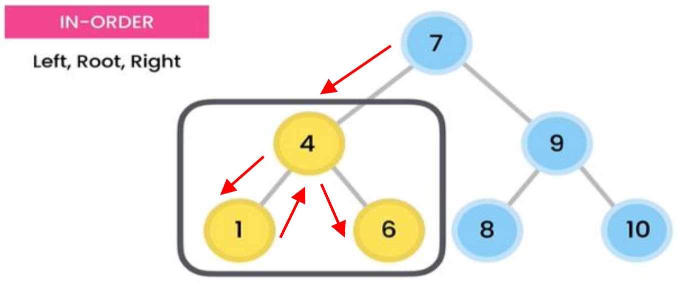
In-Order-Traversal:- (Step By Step)



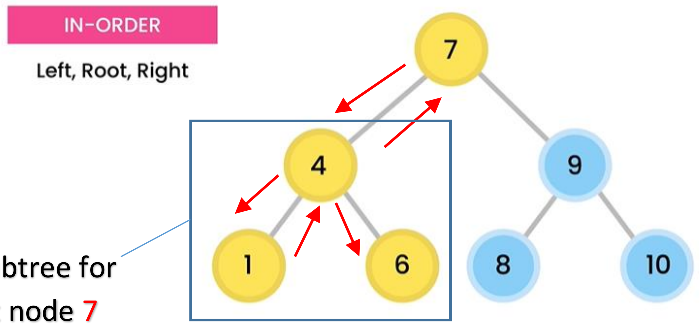
Visit 1, cause
this is the leftmost node possible
for the whole tree.



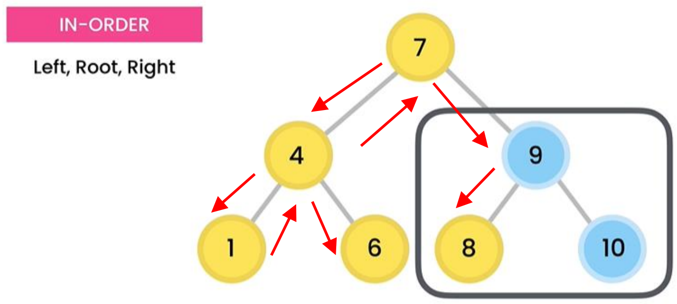
Visit 4, cause
this is the root
of the leftmost node 1.



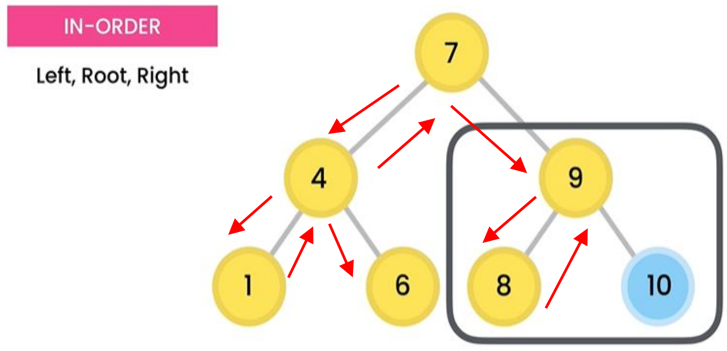
Visit 6, cause
left node 1 and root node 4 is
visited already.



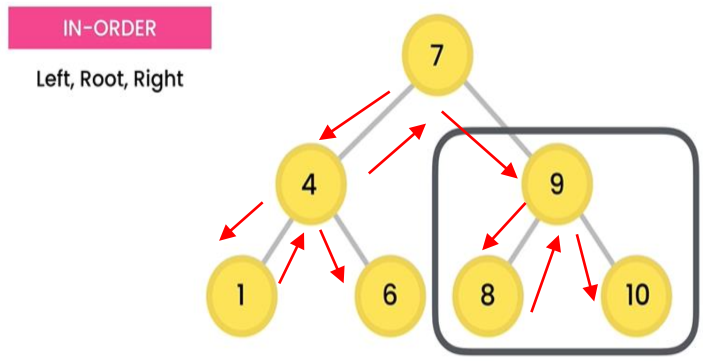
Visit 7, cause
left subtree for root node 7
is already visited.



Visit 8, cause
Right subtree of root node 7
has another root 9 , where
8 is at the leftchild of root node 9.



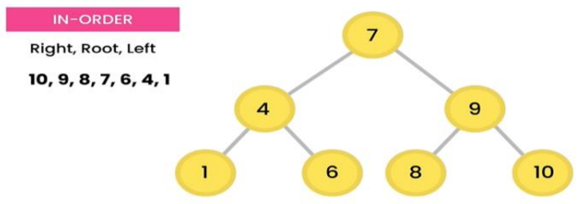
Visit 9, cause
Left node of root node 9 is
Visited already.



Visit 10, cause
Left node and root node 9 is
Visited already.

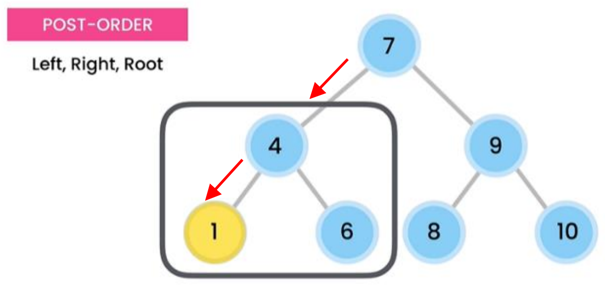
We are done for in-order traversal . The order for in order traversal is 1 -> 4 -> 6 -> 7 -> 8 -> 9 -> 10.

Magic – sorting - (We always get the numbers in ascending order for in-order traversal)

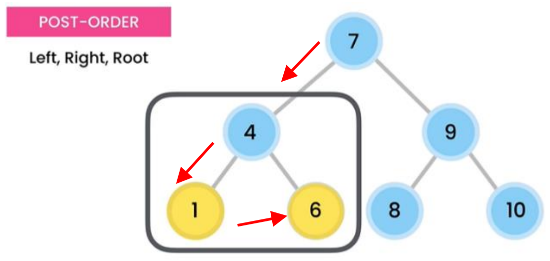


If we swap the order of visit to
Right>Root>Left
Then we got the nodes
In descending order (Sorted)

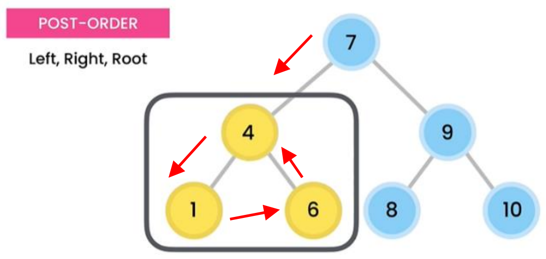
Post-Order-Traversal:- (Step By Step)



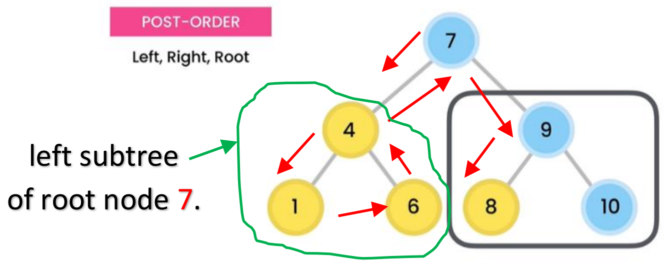
visit 1, cause it is the leftmost node.



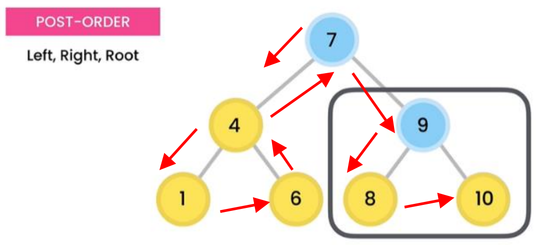
visit 6, cause we visited the left node of root node 4.



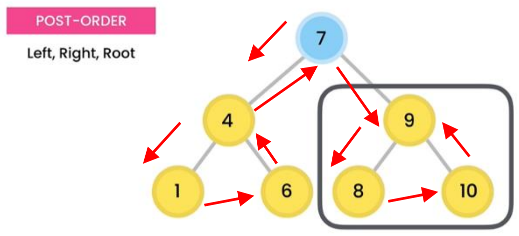
visit 4, cause we visited the left node & right node of root node 4.



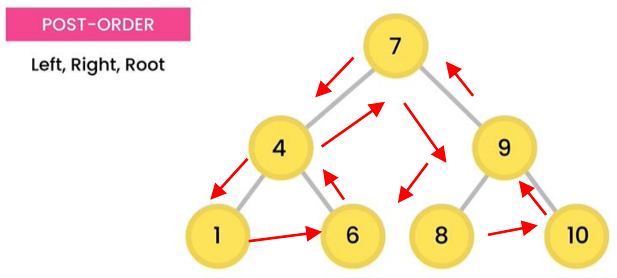
visit 8, cause we visited the left subtree of root node 7.



visit 10, cause we visited the left node of root node 9.



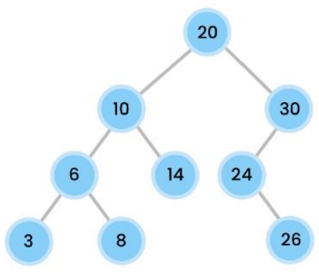
visit 9, cause we visited the left node & right node of root node 9.



visit 7, cause we visited the both
the left & right subtree of root node 7.

We are done for post-order traversal. The order for in order traversal is **1 -> 6 -> 4 -> 8 -> 10 -> 9 -> 7.**

Exercise(BFS & DFS):



- **Breadth First (Level Order)**: 20, 10, 30, 6, 14, 24, 3, 8, 26
- **Depth First**
  - **Pre-order:** 20, 10, 6, 3, 8, 14, 30, 24, 26
  - **In-order:** 3, 6, 8, 10, 14, 20, 24, 26, 30
  - **Post-order:** 3, 8, 6, 14, 10, 26, 24, 30, 20

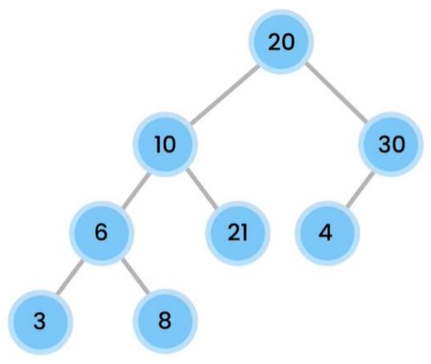
V-9-Recursion:-

```
public static int factorial(int n){
    // 4! = 4 x 3 2 x 1
    // 3! = 3 x 2 x 1
    var factorial = 1;
    for (int i=n ; i>1 ;i--)//using traditional for
loop
        factorial*=i;
    return factorial;
}
public static int factorialUsingRecursion(int n){
    // 4! = 4 x 3!
    // 3! = 3 x 2 x 1
    // 2! = 2 x 1
    // n! = n x (n-1)!
    // 0! = 1 [this will be the case where recursion
for factorial should be stopped
    if(n==0) return 1;//base case to stop recursion
otherwise it will give stack overflow
    return n*factorialUsingRecursion(n-1);
}
```

V-10-DFS-(Pre,In,Post):-

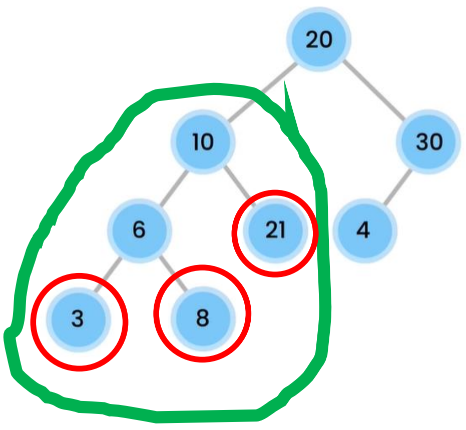
```
public void traversPreOrder(){
    traversPreOrder(root);
}
private void traversPreOrder(Node root){
    if(root==null)
        return;
    System.out.println(root.value);
   traversPreOrder(root.leftchild);
   traversPreOrder(root.rightchild);
}
public void traversInOrder(){
    traversInOrder(root);
}
private void traversInOrder(Node root){
    if(root==null)
        return;
    traversInOrder(root.leftchild);
    System.out.println(root.value);
    traversInOrder(root.rightchild);
}
public void traversPostOrder(){
    traversPostOrder(root);
}
private void traversPostOrder(Node root){
    if(root==null)
        return;
    traversPostOrder(root.leftchild);
    traversPostOrder(root.rightchild);
    System.out.println(root.value);
}
```

V-11-Depth & Height of Trees:-



Finding Depth of any nodes in a tree:- (2 Ways):-

1. Count nodes (from root to that node-1). Ex-
Depth(3) = (20->10->6->3)-1= 4-1 = 3.
2. Count the edges from root to that node. Ex-
Depth(3) = (20->10->6->3) = 3. [edges (20->10,10->6,6->3).



Finding Height of any nodes in a tree:-

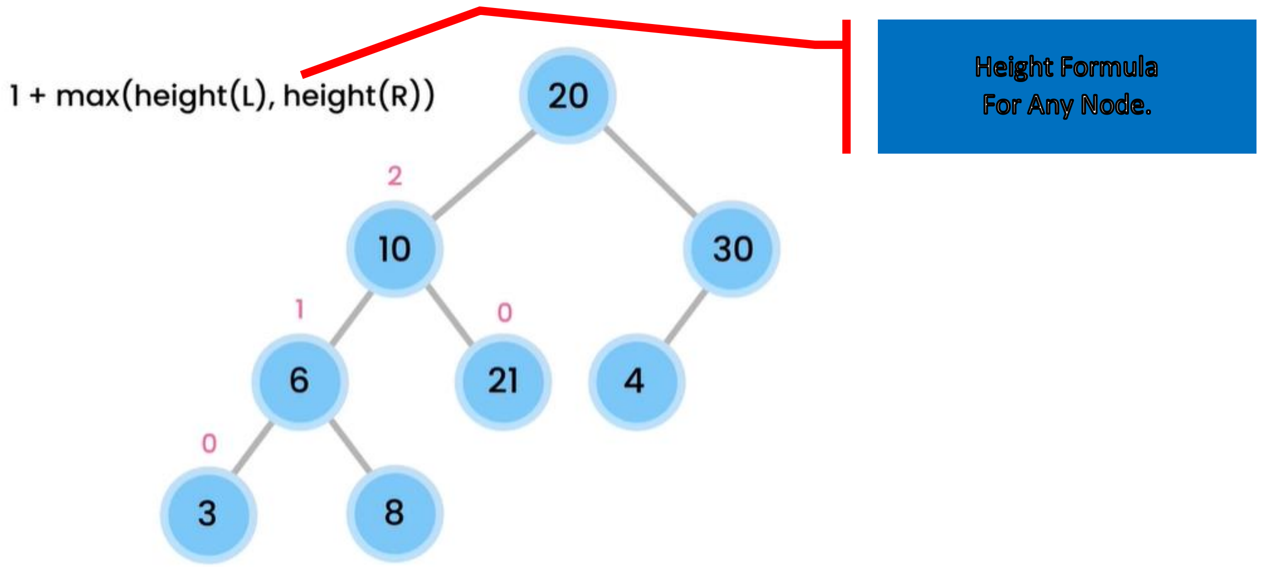
Height of the root node is also called the height of the tree

The picture(Tree) beside has a height of 3.As, Height(root) = 3.

1. Count edges from leaf node to that particular node but Strictly followed by the longest path. Ex-

Height(3) = Height(8)= Height(21) = Height(4) = 0 , cause they are leaf nodes.

Height(10) = 2. Because in that particular subtree [marked as green circle] has 3 leaf nodes for node 10 we can choose. They are 3,8,21[marked as red circle.] But we have count the edges from any of these leaf nodes[3,8,21] so that the path can be maximum. This is like post-order traversal. As we count the root node last.



```java
public int height(){
   return height(root);
}
private int height(Node root){
    if(root==null) return -1;
    if(isLeaf(root))
        return 0;
return 1+Math.max(height(root.leftchild),height(root.rightchild));
}
```

V-12-Minimum Value in a Binary Tree(also maximum by me):-

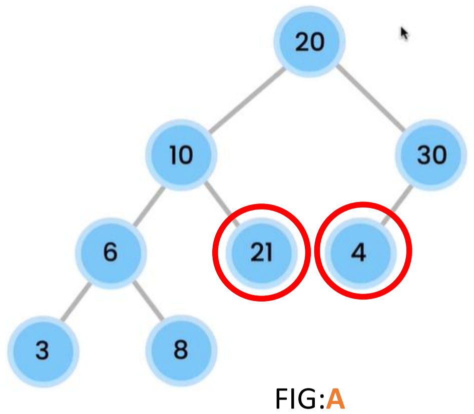


FIG:A

Binary Tree but not BST(Binary Search Tree)

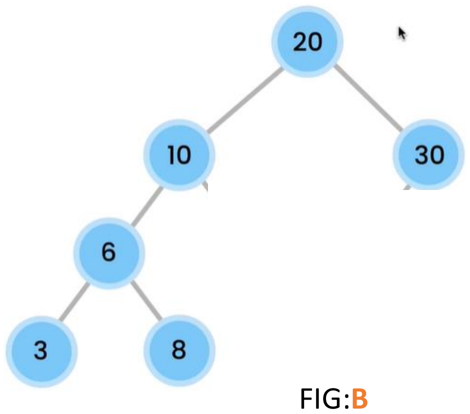


FIG:B

BST(Binary Search Tree) + Binary Tree.

Fig A is not BST cause in BST (left Subtree<root<right Subtree) we have 21 in left subtree which is greater than the root(20) & also we have 4 in right subtree which is less than the root(20). But if we see Fig B it followed BST rule left Subtree<root<right Subtree.

```
private boolean isLeaf(Node node){
    return node.leftchild == null && node.rightchild==null;
}
public int min2(){
    //O(log n) cause it will works with half of the elements
    //if the tree is BST , then only we can apply this method to find
minimum
    //cause in leftmost node carry the minimum value in a BST
    root_null_throw_exception();
    var current = root;
    var last=current;
    while(current!=null){
        last = current;
        current = current.leftchild;
    }
    return last.value;
}
public int max2(){
    //O(log n) cause it will works with half of the elements
    //if the tree is BST , then only we can apply this method to find
maximum
    //cause in rightmost node carry the maximum value in a BST
    root_null_throw_exception();
    var current = root;
    var last=current;
    while(current!=null){
        last = current;
        current = current.rightchild;
    }
    return last.value;
}
public int min(){
    root_null_throw_exception();
    return min(root);
}
```

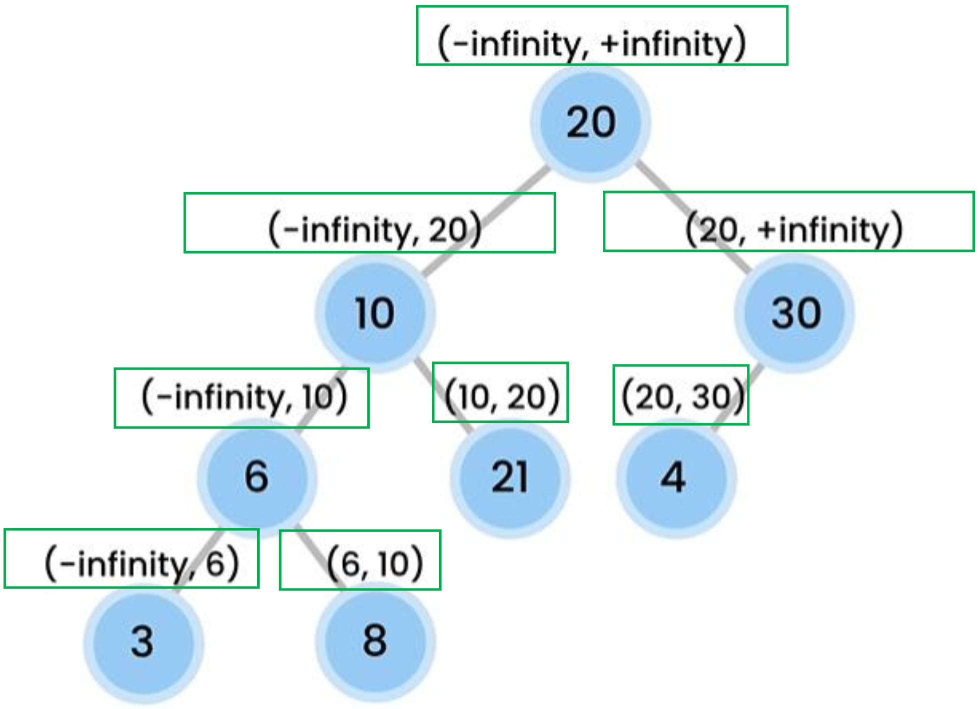
```
private int min(Node root){ // O(n) cause it is like post-order
traversal, we have to iterate through every nodes
    //this works for Binary Tree+ BST(Binary Search Tree)
    if(isLeaf(root)) return root.value;
  var left = min(root.leftchild);
  var right = min(root.rightchild);
  return Math.min(Math.min(left,right), root.value);
}
public int max(){
    root_null_throw_exception();
    return max(root);
}
private int max(Node root){//this works for Binary Tree+ BST(Binary
Search Tree)
    if(isLeaf(root)) return root.value;
    var left = max(root.leftchild);
    var right = max(root.rightchild);
    return Math.max(Math.max(left,right), root.value);
}
private void root_null_throw_exception(){
    if(root==null)
        throw new IllegalStateException();
}
```

V-(13+14)-Equality Checking:-

```
private void root_null_throw_exception(){
    if(root==null)
        throw new IllegalStateException();
}
public boolean equals(Tree other){
    if(other == null) return false;
return equals(root,other.root);
}
private boolean equals(Node first,Node second){
    //1st case, if both trees are null then they are equal
if(first== null && second==null) return true;
//2nd case, if both nodes are not null , then check root and left+right
subtrees
if(first!=null && second!=null)
    return first.value == second.value &&
            equals(first.leftchild,second.leftchild) &&
            equals(first.rightchild, second.rightchild);
return false;
//if one of the tree root is null but other is not(3rd case)
}
```

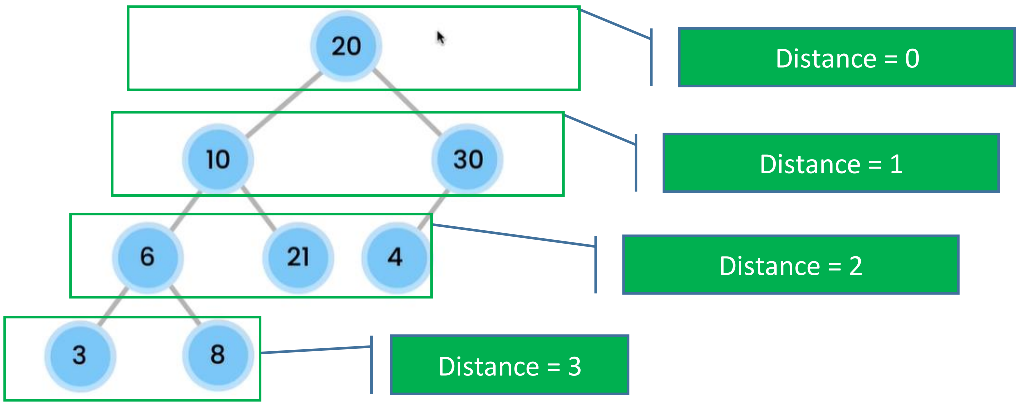
V-(15+16)-Validity Checking of BST-(Pre-Order Traversal Exercise):-

The exercise is pre-order traversal. Because we have to define root first, then its left child, after that it's right child. The green marked below is the valid range for every node value in BST.



```
public boolean istreeBST(){
    return istreeBST(root,Integer.MIN_VALUE,Integer.MAX_VALUE);
}
private boolean istreeBST(Node root,int min,int max){
    //if tree has nothing then nothing to check
    if(root==null)
        return true;
    //We know in BST left(min) <root< right(max) , if break this then false
    if(root.value>max || root.value<min)
        return false;
    //if above two of the cases aren't then we have to check for every node and
left and right child value
    //if we have a root of 10 , then its left child  must be in range of -
infinity to 9(root-1)
    // & right child must be in range of root+1 to infinity, that mean for root
10
    // right child must be at least 11.
    return istreeBST(root.leftchild,min, root.value-1)
            && istreeBST(root.rightchild, root.value+1,max);
}
```

V-(17+18)-Nodes at K distance from a root:-



The Green Marked labeling is the distances calculated from root node. If distance = 0 , then print only the root node & that is 20. If distance = 1, then print 10,3. If distance = 2, then print 6,21,4. If distance is 3 , then print 3,8.

```
public ArrayList<Integer> getNodesAtDistance(int distance){
    var list = new ArrayList<Integer>();
    getNodesAtDistance(root,distance,list);
    return list;
}
private void getNodesAtDistance(Node root,int
distance,ArrayList<Integer> list){
if(root==null) return;
if(distance==0){
    list.add(root.value);
    return;
}
getNodesAtDistance(root.leftchild,distance-1,list);
getNodesAtDistance(root.rightchild,distance-1,list);
}
```

V-(19)-Nodes at K distance from a root:-

```
public void traverseLevelOrder(){
    for (int i=0;i<=height();i++){
        for(var item :getNodesAtDistance(i))
            System.out.println(item);
    }
}
```

EXERCISE:-

1- Implement a method to calculate the size of a binary tree.

ANS:-

```
public int size() {
    return size(root);
}
private int size(Node root) {
    if (root == null)
        return 0;

    if (isLeaf(root))
        return 1;

    return 1 + size(root.leftchild) + size(root.rightchild);
}
```

2- Implement a method to count the number of leaves in a binary tree.

Ans:-

```
public int countLeaves() {
    return countLeaves(root);
}

private int countLeaves(Node root) {
    if (root == null)
        return 0;

    if (isLeaf(root))
        return 1;

    return countLeaves(root.leftchild) + countLeaves(root.rightchild);
}
```

3- Implement a method to return the maximum value in a binary search tree using recursion.

Ans:-

```
public int max3() {
    if (root == null)
        throw new IllegalStateException();
    return max_3(root);
}
private int max_3(Node root) {
    if (root.rightchild == null)
        return root.value;
    return max(root.rightchild);
}
```

4- Implement a method to check for the existence of a value in a binarytree using recursion. Compare this method with the find() method. The
find() method does the same job using iteration.

Ans:-

```
public boolean contains(int value) {
    return contains(root, value);
}
private boolean contains(Node root, int value) {
    if (root == null)
        return false;

    if (root.value == value)
        return true;

    return contains(root.leftchild, value) || contains(root.rightchild, value);
}
```

5- Implement a method to check to see if two values are siblings in a binary tree.

Ans:-

```
public boolean areSibling(int first, int second) {
    return areSibling(root, first, second);
}
private boolean areSibling(Node root, int first, int second) {
    if (root == null)
        return false;

    var areSibling = false;
    if (root.leftchild != null && root.rightchild != null) {
        areSibling = (root.leftchild.value == first &&
root.rightchild.value == second) ||
                (root.rightchild.value == first &&
root.leftchild.value == second);
    }

    return areSibling ||
            areSibling(root.leftchild, first, second) ||
            areSibling(root.rightchild, first, second);
}
```

6- Implement a method to return the ancestors of a value in a List<Integer>.

[Helping to get Idea-{ https://youtu.be/qjD-CmuCoMQ }]

Ans:-

```
public List<Integer> getAncestors(int value) {
    var list = new ArrayList<Integer>();
    getAncestors(root, value, list);
    return list;
}
private boolean getAncestors(Node root, int value, List<Integer>
list) {
    // We should traverse the tree until we find the target
value. If
    // find the target value, we return true without adding the
current node
    // to the list; otherwise, if we ask for ancestors of 5, 5
will be also
    // added to the list.
    if (root == null)
        return false;

    if (root.value == value)
        return true;

    // If we find the target value in the left or right sub-
trees, that means
    // the current node (root) is one of the ancestors. So we add
it to the list.
    if (getAncestors(root.leftchild, value, list) ||
            getAncestors(root.rightchild, value, list)) {
        list.add(root.value);
        return true;
    }

    return false;
}
```

Ex-7 . Is the tree balance or not?

Ans:-

```
public boolean isBalanced() {
    return isBalanced(root);
}

private boolean isBalanced(Node root) {
    if (root == null)
        return true;

    var balanceFactor = height(root.leftchild) -
height(root.rightchild);

    return Math.abs(balanceFactor) <= 1 &&
            isBalanced(root.leftchild) &&
            isBalanced(root.rightchild);
}
```

Ex-8 . Is the tree perfect or not?

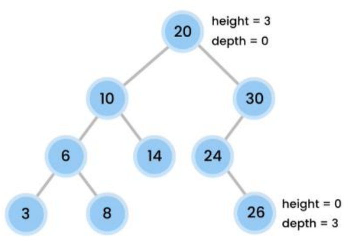
[hint :- If all parents had exactly two child in a tree then we called it a pefect binary Tree]

[Resource(for more):- https://www.programiz.com/dsa/perfect-binary-tree]

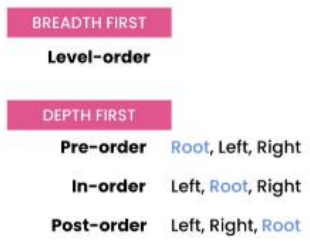
Ans:-

```
public boolean isPerfect() {
    return size() == (Math.pow(2, height() + 1) - 1);
}
```

Summary:-



1. A tree can have at most two children.
2. A node without any children is called a leaf node.
3. The height of a leaf node is 0. As we go up in the tree from leaf node the height increases.[The height of a tree is the height of a root node.]
4. The depth of the root node is 0. As we go down from root node, the depth of nodes will be increased.[More accurately the edges from root node to that node]
5. In BST [left Subtree<root<Right Subtree]



BREADTH FIRST

Level-order

DEPTH FIRST

Pre-order	Root, Left, Right
In-order	Left, Root, Right
Post-order	Left, Right, Root