

Trees

why trees?

Tree - collection of tree-nodes

① class Treenode

```

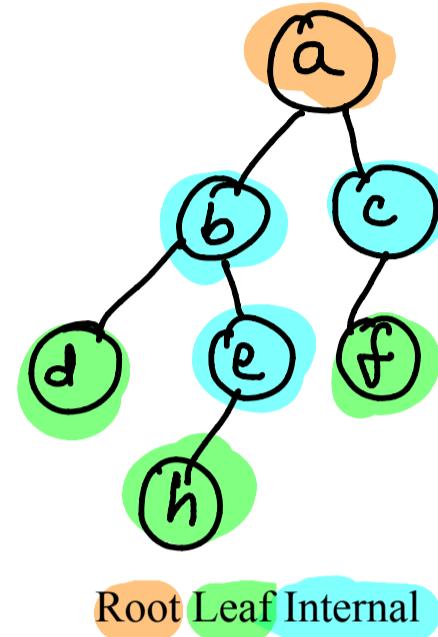
    ↴ data
    ↴ list<Treenode> children
  
```

② Binary Tree → almost 2 children (0,1,2)

```

    ↴ data
    ↴ leftchild
    ↴ rightchild
  
```

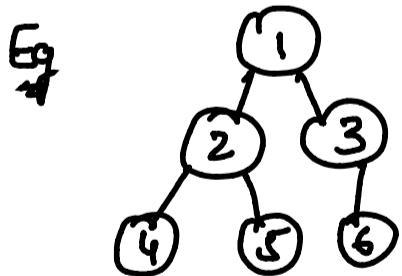
1. Hierarchy
2. Computer system (UNIX)



③ Types →

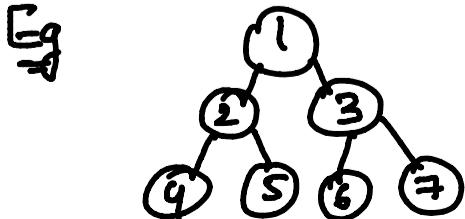
A) Complete Binary Tree

↳ all levels are completely filled except last one



B) Perfect Binary Tree

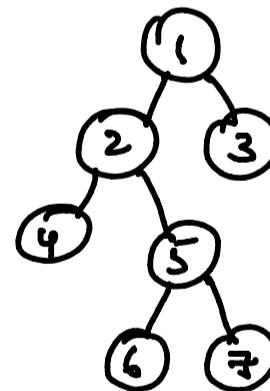
↳ every internal node has exactly 2 children



C) Full Binary tree

↳ if every node has 0 or 2 children

Eg

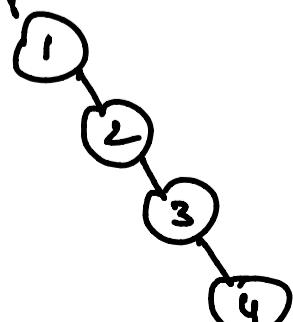


D) Skewed Binary Tree

(* used for finding complexity)

↳ all nodes have either one or no child.

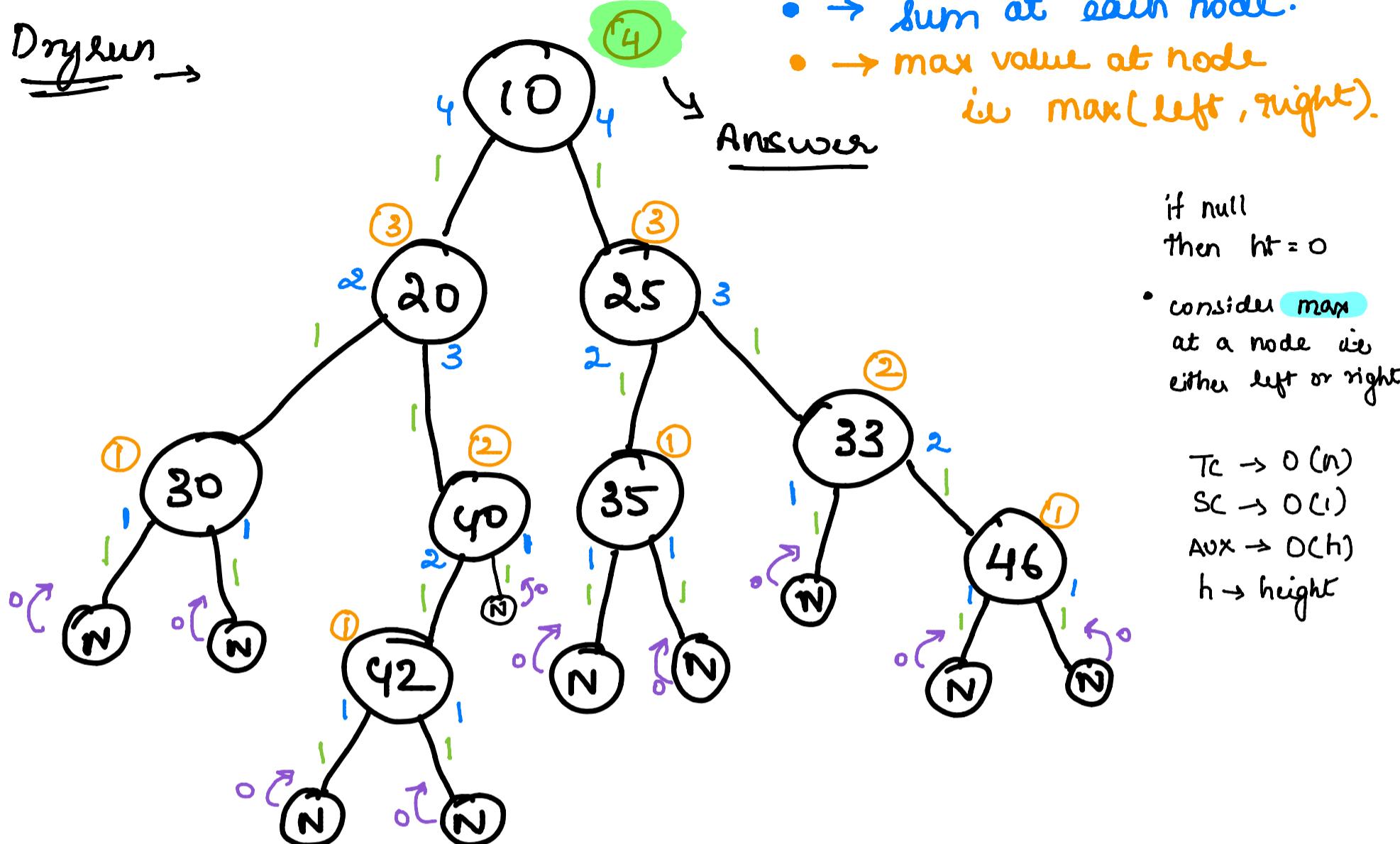
Eg



D1

① Depth of a binary tree (Max depth)

Dry run →



- 1 added while returning.
- sum at each node.
- max value at node is $\max(\text{left}, \text{right})$.

if null
then ht = 0

- consider max
at a node is
either left or right

Tc → O(n)

Sc → O(1)

Aux → O(h)

h → height

Code →

```
C++ v
/*
 * Definition for a binary tree node.
 * struct TreeNode {
 *     int val;
 *     TreeNode *left;
 *     TreeNode *right;
 *     TreeNode() : val(0), left(nullptr), right(nullptr) {}
 *     TreeNode(int x) : val(x), left(nullptr), right(nullptr) {}
 *     TreeNode(int x, TreeNode *left, TreeNode *right) : val(x), left(left), right(right) {}
 * };
 */
class Solution {
public:
    int maxDepth(TreeNode* root) {
        if(root == NULL) return 0;

        int lefth= 1+ maxDepth(root->left);
        int righth = 1+maxDepth(root->right);
        return max(lefth,righth);
    }
};
```

2

Maximum depth of n-ary tree

Idea is same as previous problem, only implementation changes

Code →

```
C++ ▾

/*
// Definition for a Node.
class Node {
public:
    int val;
    vector<Node*> children;

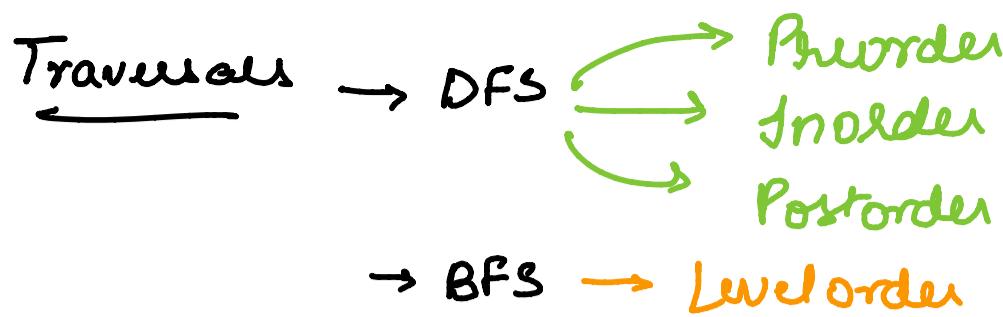
    Node() {}

    Node(int _val) {
        val = _val;
    }

    Node(int _val, vector<Node*> _children) {
        val = _val;
        children = _children;
    }
};

class Solution {
public:
    int maxDepth(Node* root) {
        if(root==NULL) return 0;
        int ans=0;
        for(int i=0;i<root->children.size();i++)
        {
            int tempans = maxDepth(root->children[i]);
            ans = max(ans,tempans);
        }
        return ans+1;
    }
};
```

D2



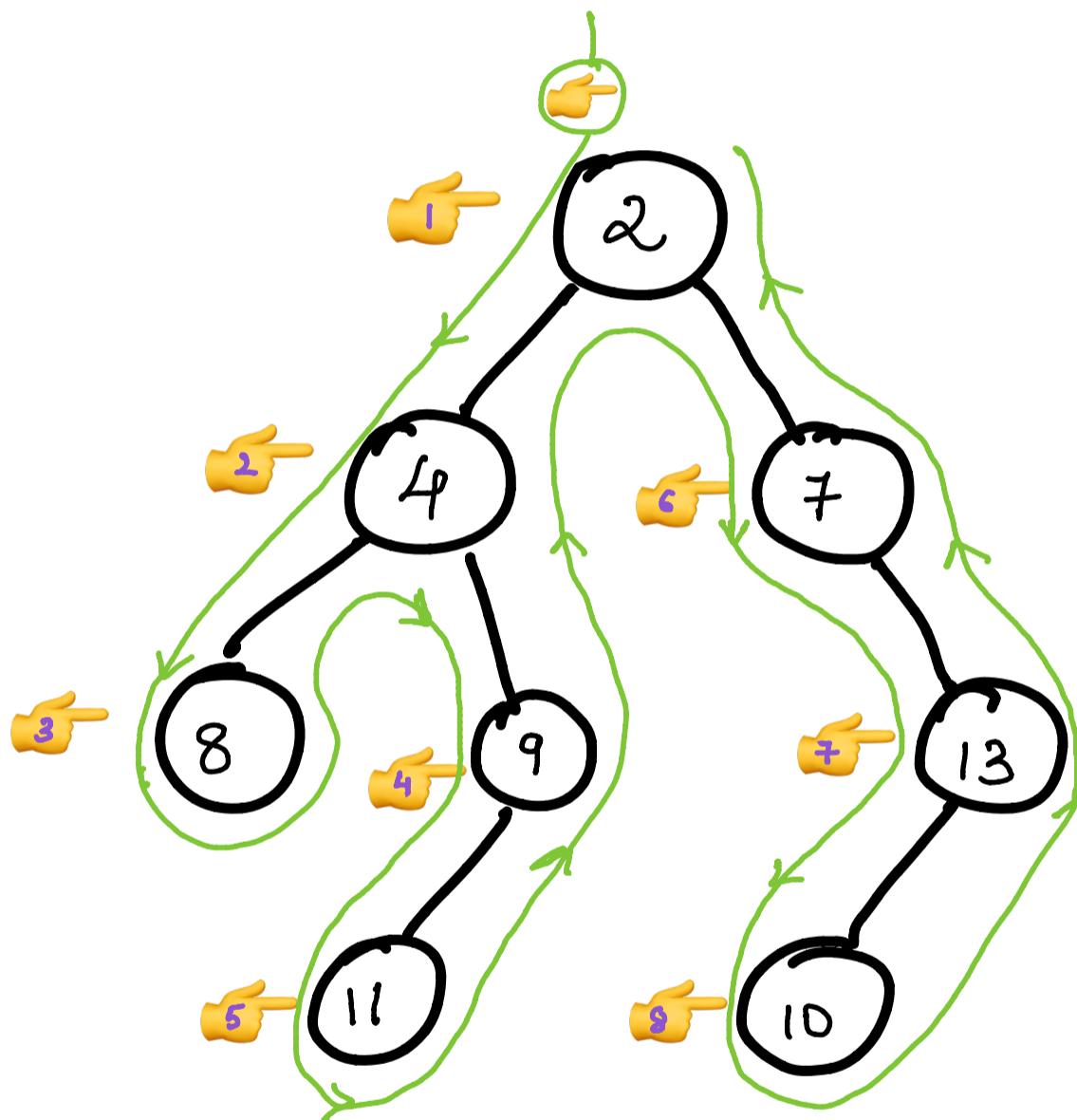
Q4

Preorder →

processing order

node
left child
right child

Eg



* Point fingers as shown
and traverse the
tree starting from Root

* Order of visiting is the
preorder traversal.

Tc → O(n)

Sc → O(n)

~~[2, 4, 8, 9, 11, 6, 13, 10]~~

Recursive Stack space → O(h) h → height.

③ Pre-order traversal of Binary tree

```
class Solution {
public:
    vector<int> preorderTraversal(TreeNode* root) {
        vector<int>ans;
        Preorder(root,ans);
        return ans;
    }
    void Preorder(TreeNode* root,vector<int>&ans)
    {
        if(root == NULL) return;
        ans.push_back(root->val);
        Preorder(root->left,ans);
        Preorder(root->right,ans);
        return;
    }
};
```

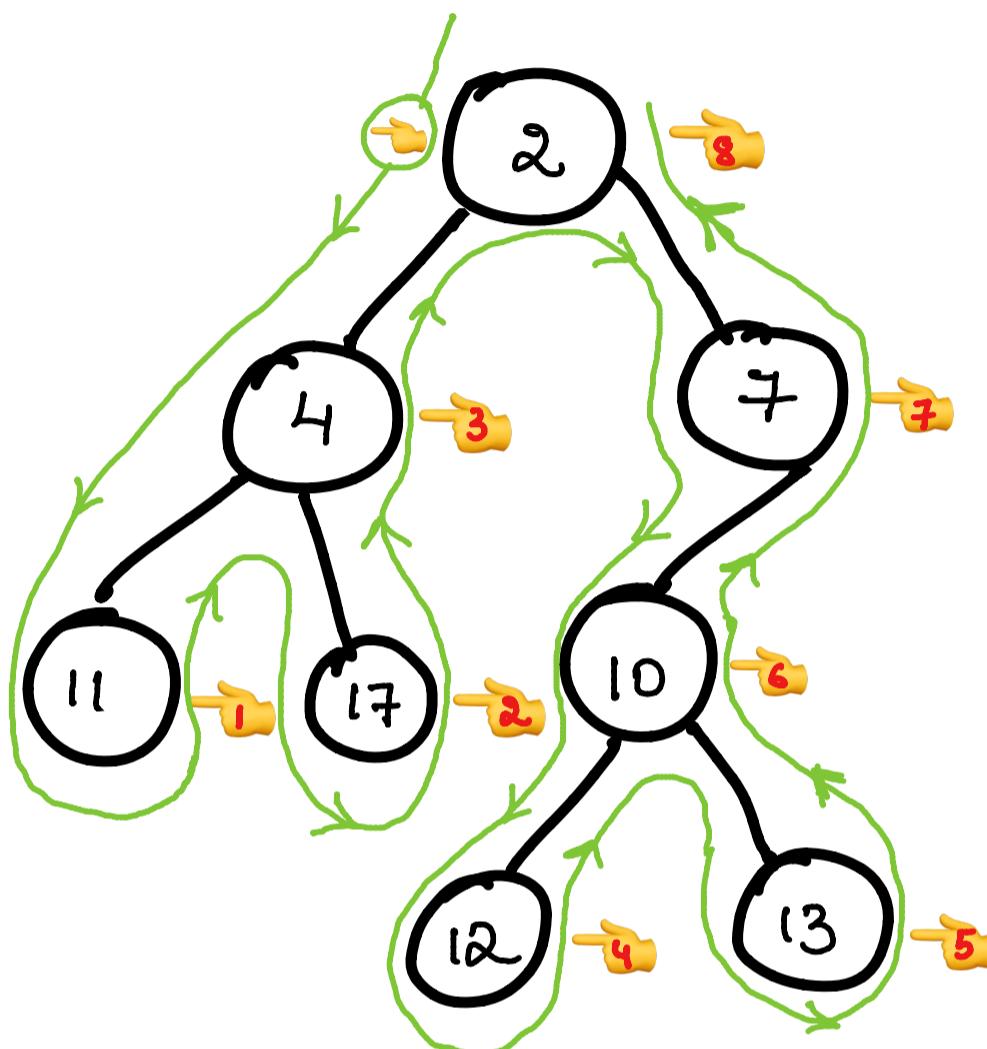
④ Pre-order traversal of n-ary tree

```
class Solution {
public:
    vector<int> preorder(Node* root) {
        vector<int>ans;
        Preorder(root,ans);
        return ans;
    }
    void Preorder(Node* root, vector<int>&ans)
    {
        if(root==NULL) return;
        ans.push_back(root->val);
        for(int i=0;i<root->children.size();i++)
        {
            Preorder(root->children[i],ans);
        }
        return;
    }
};
```

(B) Postorder →
processing order

left child
right child
node

Eg



* Point finger as shown
and traverse the
tree starting from Root

* Order of visiting is the
postorder traversal.

Tc → O(n)

SC → O(n)

~~[11, 17, 4, 12, 13, 10, 7, 2]~~

Recursive Stack space → O(h) h → height .

⑤ Postorder traversal of Binary tree

```
class Solution {
public:
    vector<int> postorderTraversal(TreeNode* root) {
        vector<int>ans;
        Postorder(root,ans);
        return ans;
    }
    void Postorder(TreeNode* root, vector<int>&ans)
    {
        if(root == NULL) return;

        Postorder(root->left,ans);
        Postorder(root->right,ans);
        ans.push_back(root->val);
        return;
    }
};
```

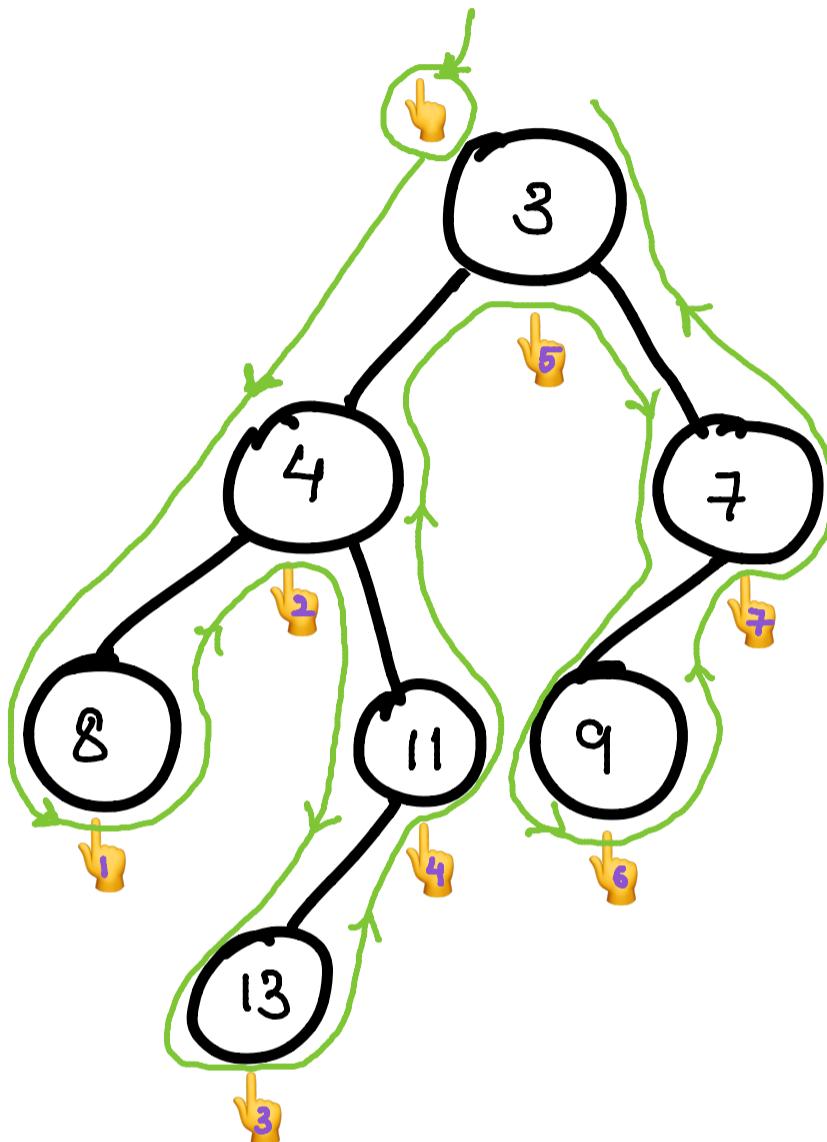
⑥ Postorder traversal of nary tree

```
class Solution {
public:
    vector<int> postorder(Node* root) {
        vector<int>ans;
        Postorder(root,ans);
        return ans;
    }
    void Postorder(Node* root, vector<int>&ans)
    {
        if(root == NULL) return;
        for(int i=0;i<root->children.size();i++)
        {
            Postorder(root->children[i],ans);
        }
        ans.push_back(root->val);
        return;
    }
};
```

(c) Inorder →

processing order →
 left child
 node
 right child

Eg



* Point finger as shown
 and traverse the
 tree starting from Root

* Order of visiting is the
 Inorder traversal.

↙ [8, 4, 13, 11, 3, 9, 7]

Tc → O(n)

Sc → O(n)

Recursive Stack space → O(h) h → height .

7

In-order traversal of Binary tree

```
class Solution {
public:
    vector<int> inorderTraversal(TreeNode* root) {
        vector<int> ans;
        Inorder(root, ans);
        return ans;
    }
    void Inorder(TreeNode* root, vector<int>& ans)
    {
        if (root == NULL) return;
        Inorder(root->left, ans);
        ans.push_back(root->val);
        Inorder(root->right, ans);
        return;
    }
};
```

In-order traversal of n-ary tree

Approach:

The inorder traversal of an N-ary tree is defined as visiting all the children except the last then the root and finally the last child recursively.

- Recursively visit the first child.
- Recursively visit the second child.
-
- Recursively visit the second last child.
- Print the data in the node.
- Recursively visit the last child.
- Repeat the above steps till all the nodes are visited.

```
void inorder(Node *node)
{
    if (node == NULL)
        return;

    // Total children count
    int total = node->length;

    // All the children except the last
    for (int i = 0; i < total - 1; i++)
        inorder(node->children[i]);

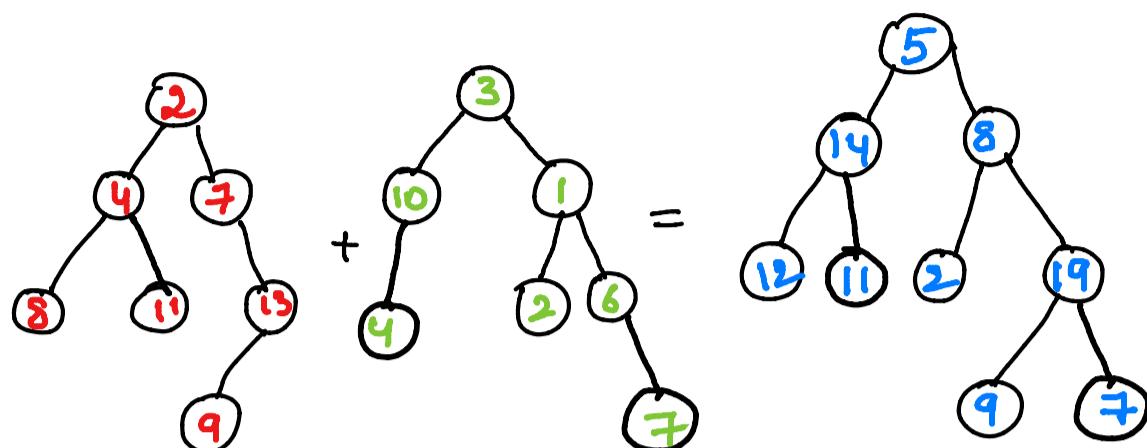
    // Print the current node's data
    cout << node->data << " ";

    // Last child
    inorder(node->children[total - 1]);
}
```

D3 (8) Merge two Binary trees →

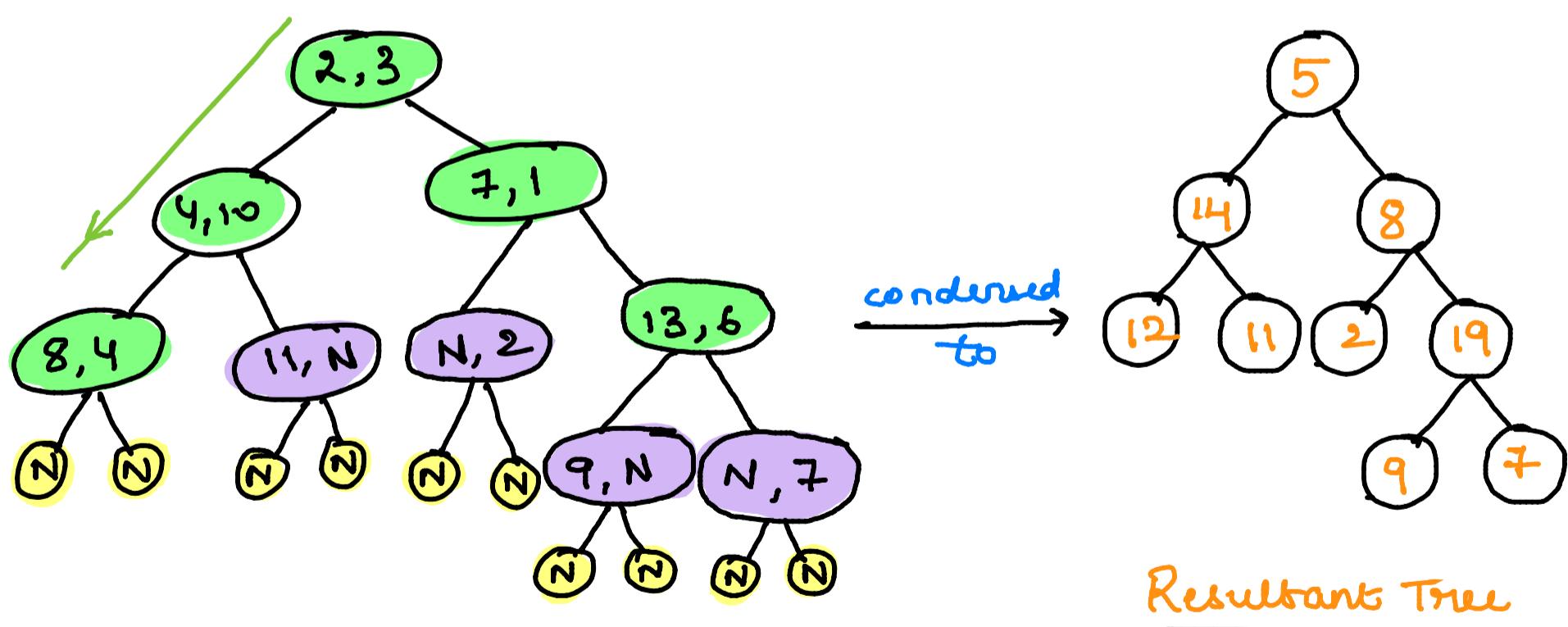
Given root nodes of 2 binary trees, return root of the sum tree

Eg



we will perform preorder traversal on the binary tree because the node/root needs to be processed first.

The recursive tree structure would be like :



- NULL & NULL
- Node & NULL
- Node & Node

TC → O(n+m)

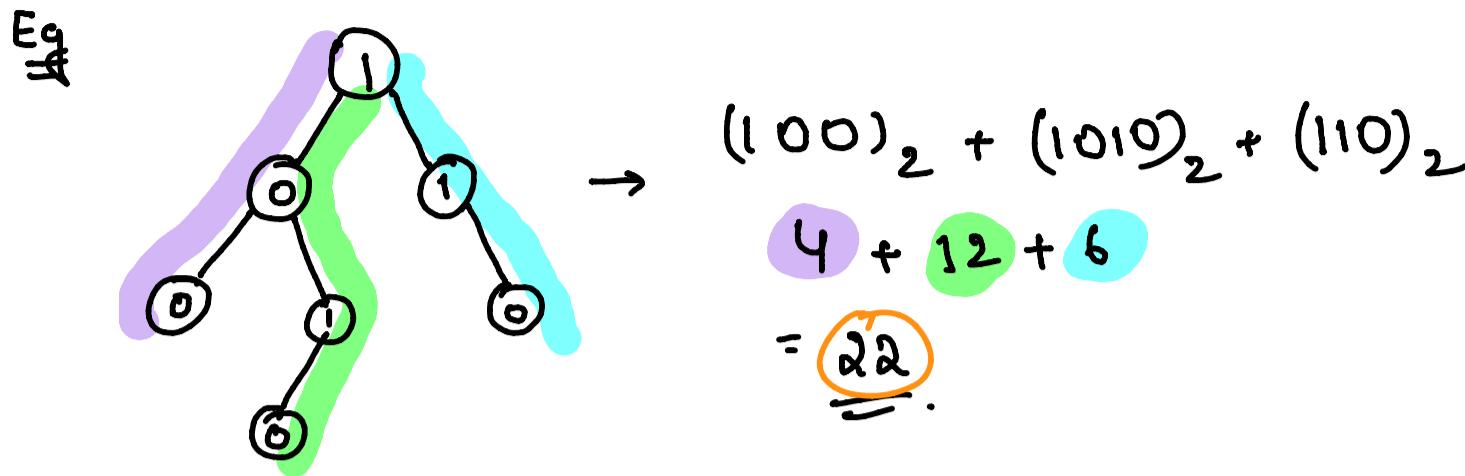
SC → O(max(n,m))

Recursive stack → O(max(h₁, h₂))

Code →

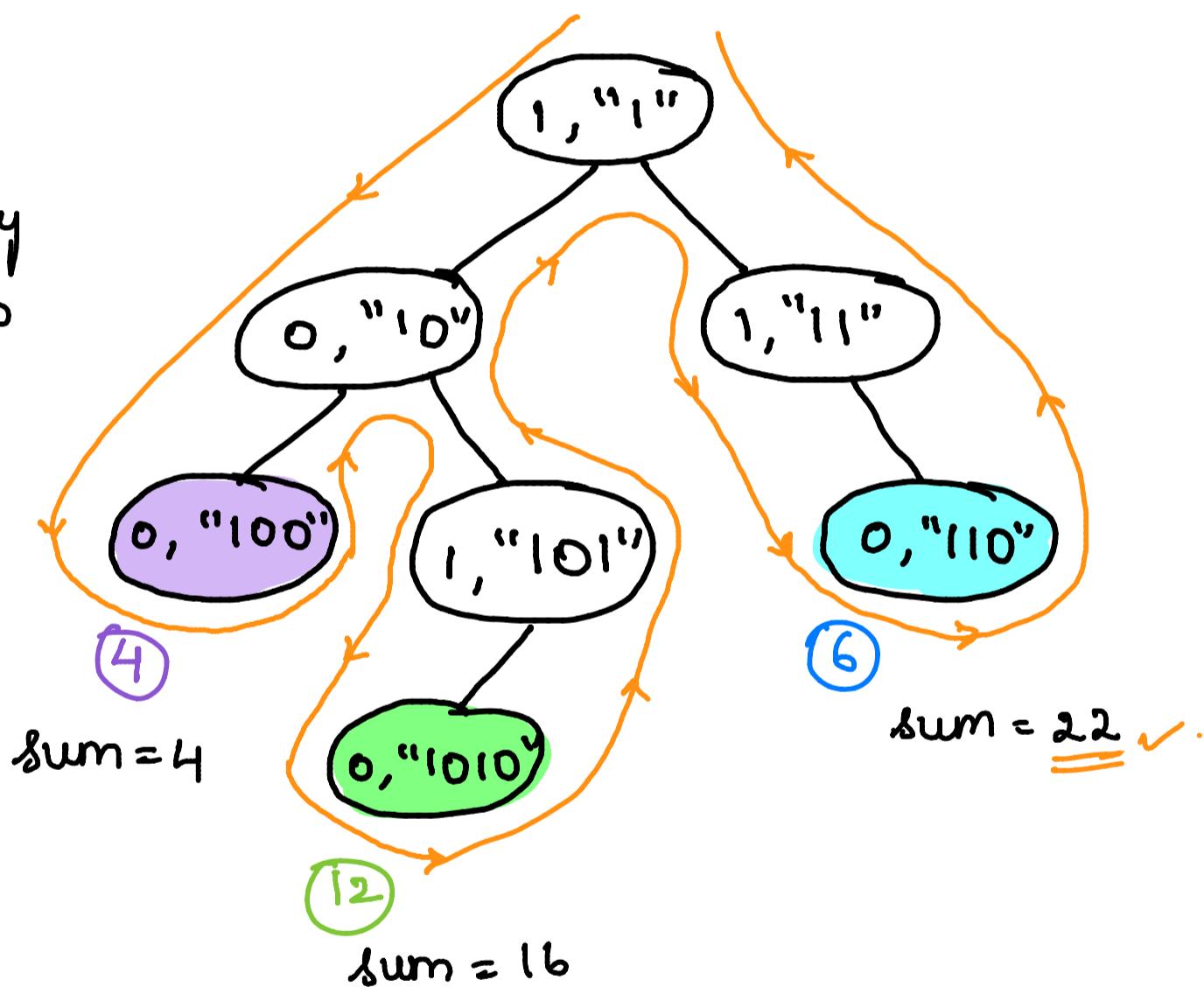
```
class Solution {  
public:  
    TreeNode* merge(TreeNode* root1, TreeNode* root2){  
  
        if(root1==NULL && root2==NULL)  return NULL;  
        if(root1==NULL) return root2;  
        if(root2==NULL) return root1;  
  
        // Create new node to store sum  
        TreeNode *newNode = new TreeNode(root1->val+root2->val);  
  
        // Recursively call the left sub-trees and right sub-trees  
        newNode->left = merge(root1->left, root2->left);  
        newNode->right = merge(root1->right, root2->right);  
  
        // return the new node  
        return newNode;  
    }  
  
    TreeNode* mergeTrees(TreeNode* root1, TreeNode* root2) {  
        return merge(root1, root2);  
    }  
};
```

Q) Sum of root to leaf paths →



=

Initially
 $\text{sum} = 0$



* If root becomes null convert string to integer & add to sum.

Time → $O(n)$

Space → $O(n)$

Recursive stack → $O(h)$

Code

```
class Solution {
public:
    void rootToLeaf(TreeNode* root, string currentString,int* ans)
    {
        if(root->left== NULL && root->right==NULL)
        {
            currentString+=to_string(root->val);
            ans[0]+=stoi(currentString,0,2);
            return;
        }
        string curr=to_string(root->val);
        if(root->left!=NULL)
            rootToLeaf(root->left,currentString+curr,ans);
        if(root->right!=NULL)
            rootToLeaf(root->right,currentString+curr,ans);

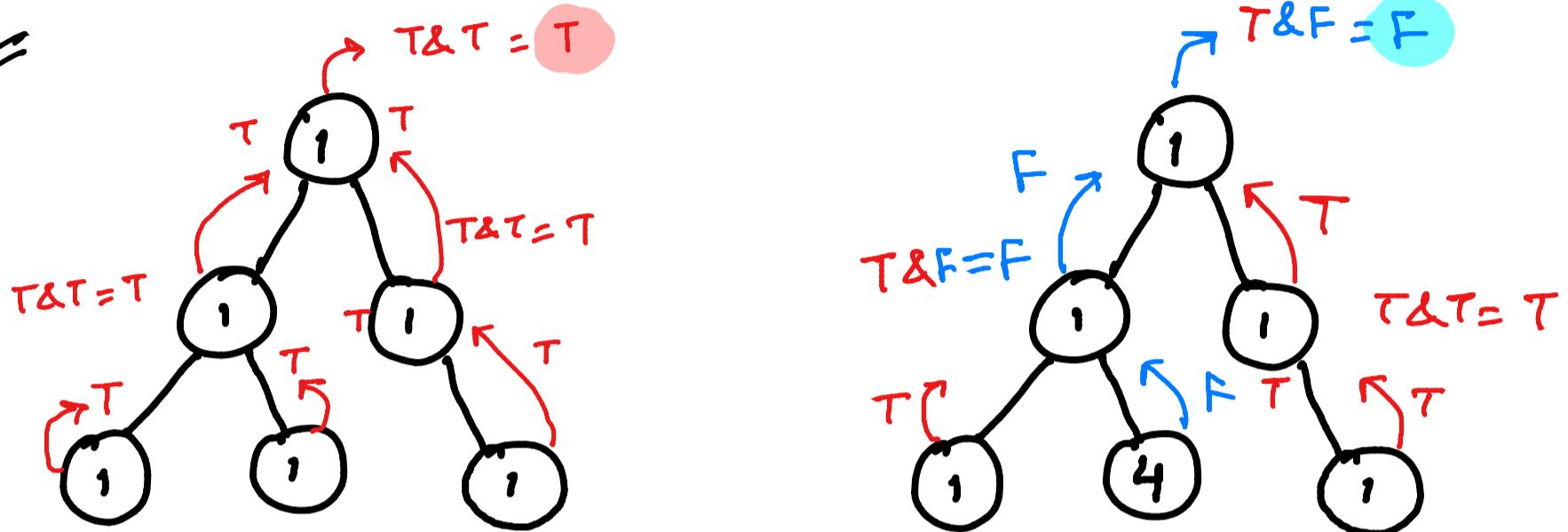
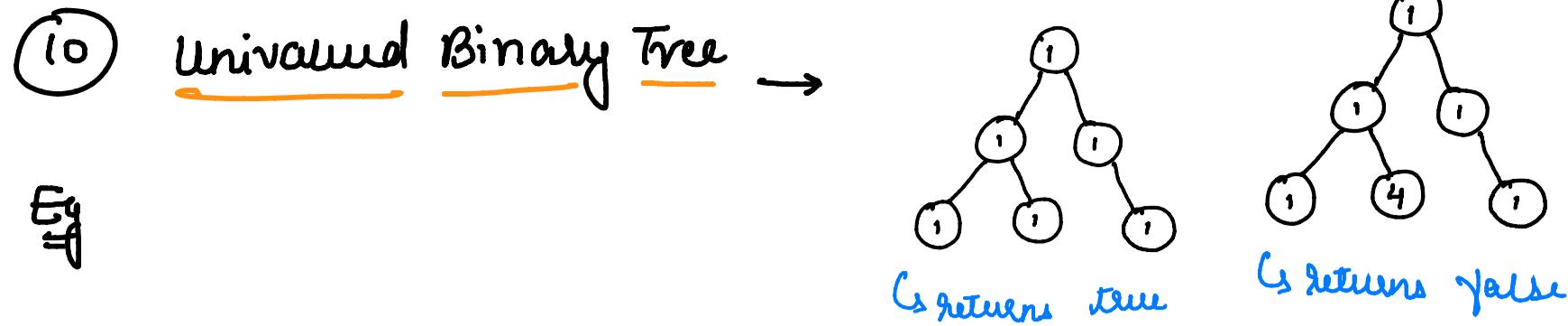
    }
    int sumRootToLeaf(TreeNode* root) {
        int* ans=new int[1];
        ans[0]=0;
        rootToLeaf(root,"",ans);
        return ans[0];
    }
};
```

Note →

stoi() can take upto three parameters, the second parameter is for starting index and third parameter is for base of input number.



[to convert from binary to decimal we give it as 2.]



Code

```
class Solution {
public:
    bool isSame(TreeNode* root, int val){
        if(root==NULL) return true;
        if(root->val!=val) return false;

        bool left = isSame(root->left, val);
        bool right = isSame(root->right, val);

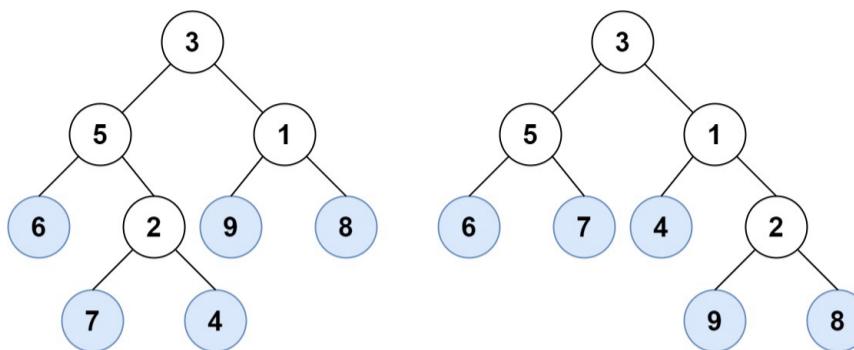
        return left && right;
    }

    bool isUnivalTree(TreeNode* root) {
        return isSame(root, root->val);
    }
};
```

⑪ Leaf Similar trees

→ return true if all leaves are in same order for both trees.

Eg



$$V_1 = 6, 7, 4, 9, 8 \rightarrow V_1 = V_2$$

$$V_2 = 6, 7, 4, 9, 8 \quad \text{↳ returns true else false.}$$

Code →

```
class Solution {
public:
    void traversal(TreeNode* root, vector<int>&v){
        if(root==NULL)
            return;

        if(root->left==NULL && root->right==NULL)
            v.push_back(root->val);

        if(root->left!=NULL)
            traversal(root->left, v);

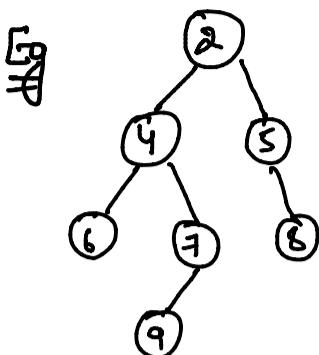
        if(root->right!=NULL)
            traversal(root->right, v);
    }

    bool leafSimilar(TreeNode* root1, TreeNode* root2) {
        vector<int> a;
        vector<int> b;
        traversal(root1,a);
        traversal(root2,b);
        return a==b;
    }
};
```

DS

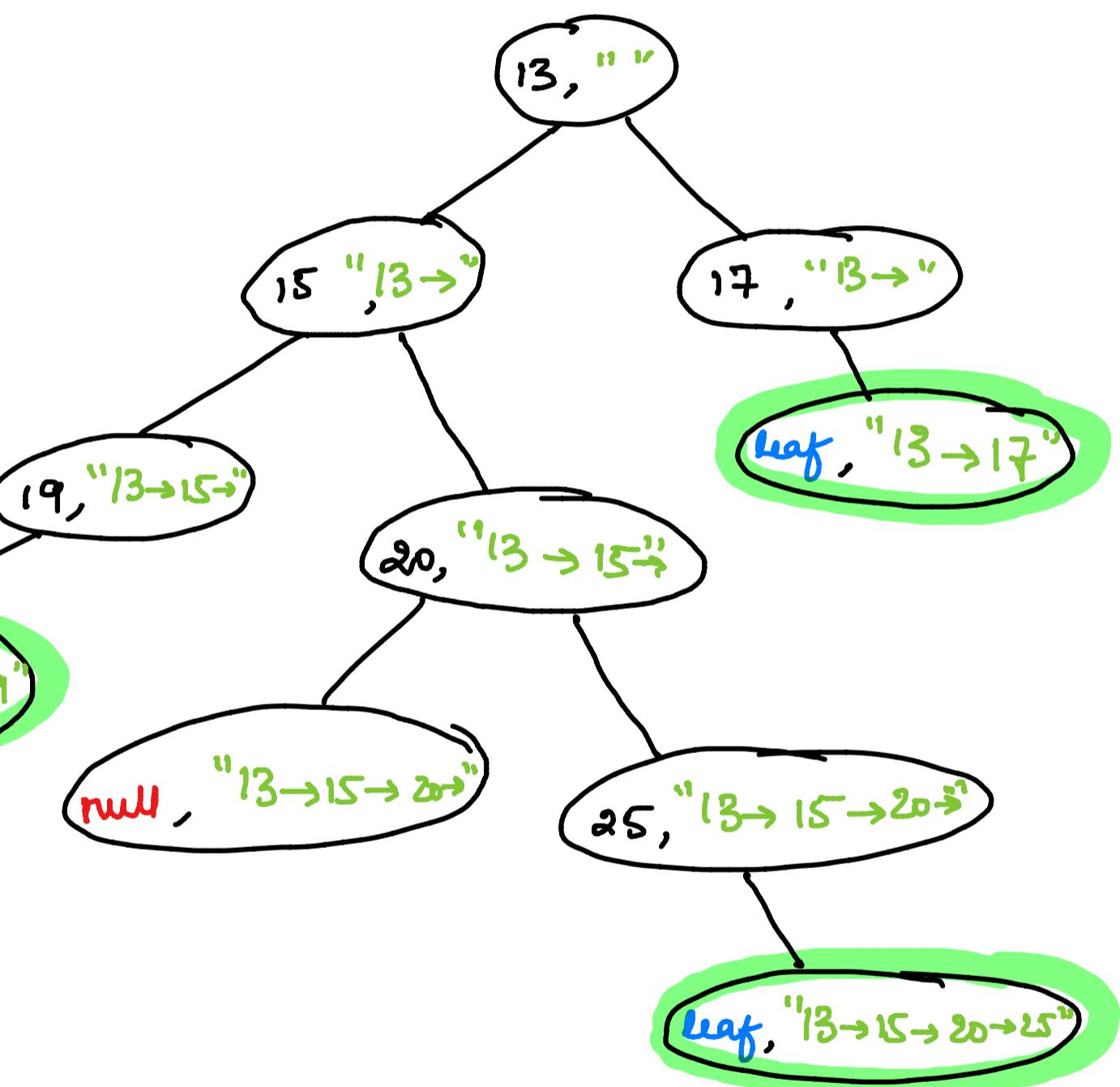
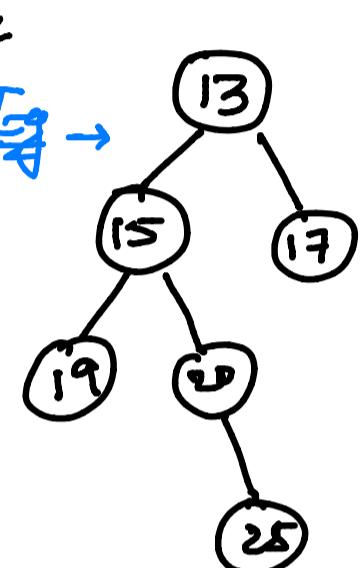
12 Binary tree paths

Given root print all the paths from root to leaf



$\Rightarrow ["2 \rightarrow 4 \rightarrow 6", "2 \rightarrow 4 \rightarrow 7 \rightarrow 9", "2 \rightarrow 5 \rightarrow 8"]$

=



Result =

$["13 \rightarrow 15 \rightarrow 19", "13 \rightarrow 15 \rightarrow 20 \rightarrow 25", "13 \rightarrow 17"]$

Time complexity = $O(n)$

Space complexity = $O(\alpha) + O(h)$ \rightarrow recursive stack.
 \downarrow Answer array

Code →

```
class Solution {
public:
    void pathFinder(TreeNode *root, vector<string> &res, string currPath){

        if(root==NULL)  return;

        // if leaf then add it's value to currentPath
        if(root->left == NULL && root->right==NULL){
            currPath += to_string(root->val);
            res.push_back(currPath);
            return;
        }

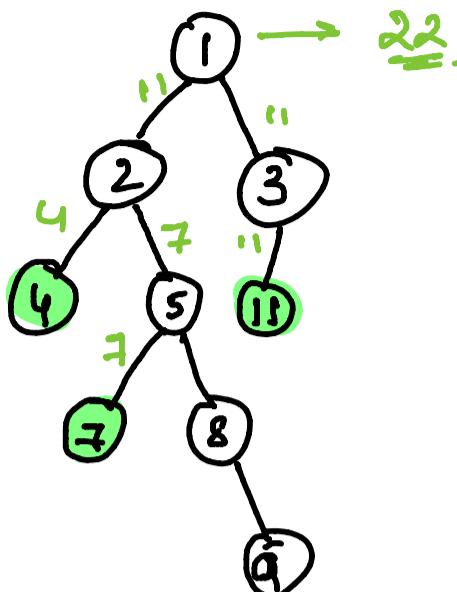
        // else add the node's value to path
        currPath += to_string(root->val)+"->";

        if(root->left)  pathFinder(root->left, res, currPath);
        if(root->right) pathFinder(root->right, res, currPath);
    }

    vector<string> binaryTreePaths(TreeNode* root) {
        vector<string> res;
        pathFinder(root, res, "");
        return res;
    }
};
```

(13) sum of left leaves →

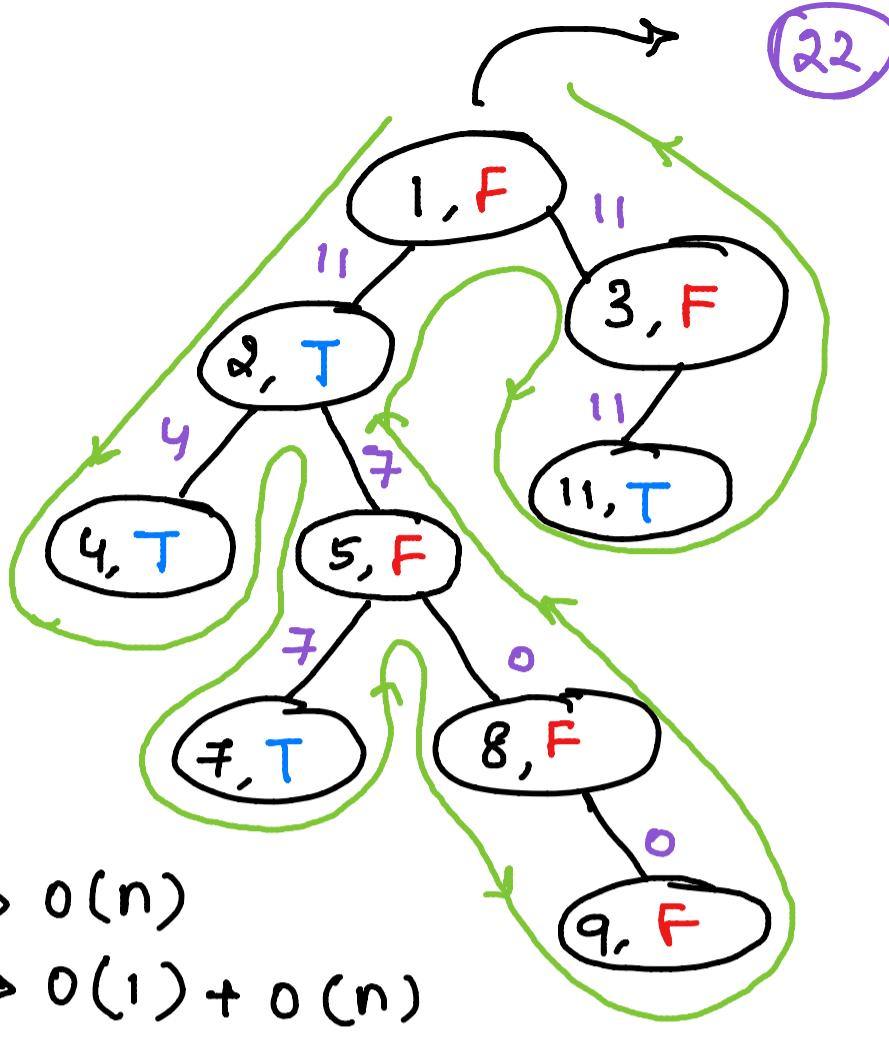
Eg



$$\text{Result} = 4 + 7 + 11 \\ = \underline{\underline{22}}.$$

$$Tc \rightarrow O(n) \\ Sc \rightarrow O(1) + O(n)$$

→ stack

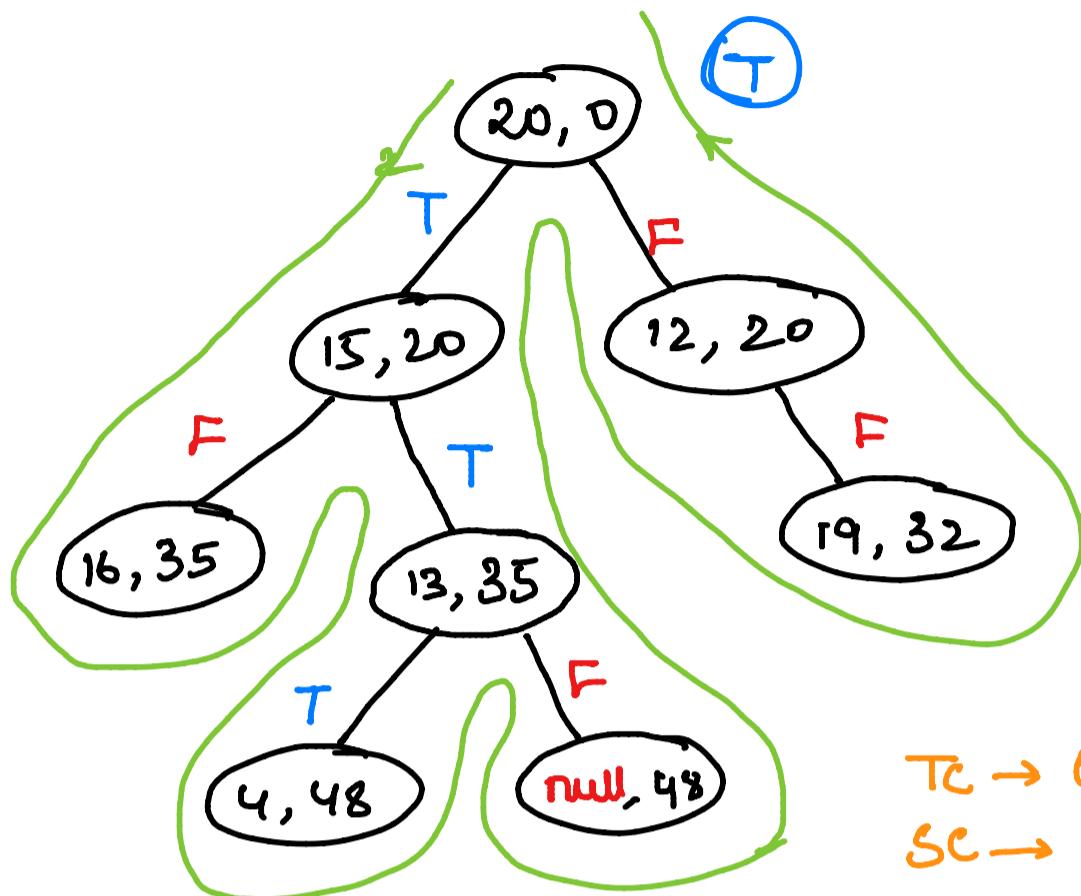
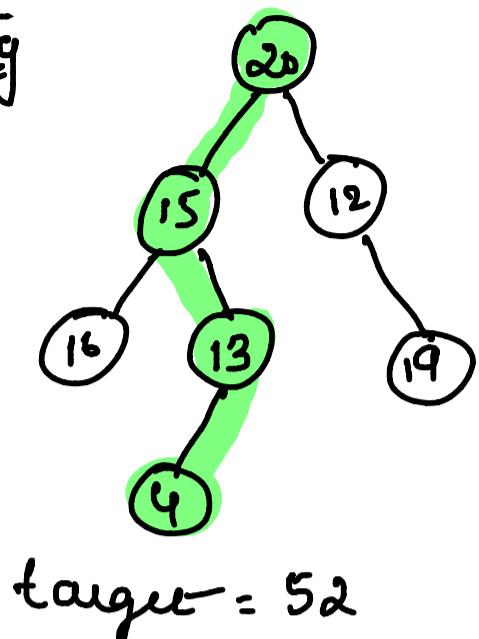


Code →

```
class Solution {  
public:  
    int leftLeafSum(TreeNode *root, bool leaf){  
        if(root==NULL){  
            return 0;  
        }  
        if(root->left==NULL && root->right==NULL && leaf){  
            return root->val;  
        }  
        int ls = leftLeafSum(root->left, true);  
        int rs = leftLeafSum(root->right, false);  
        return ls+rs;  
    }  
  
    int sumOfLeftLeaves(TreeNode* root) {  
        return leftLeafSum(root, false);  
    }  
};
```

14 Path sum → sum of all nodes from root to leaf is equal to target sum → then T else F.

Ex



TC → O(n)

SC → O(1)

Recursive → O(h)
Stack

Code

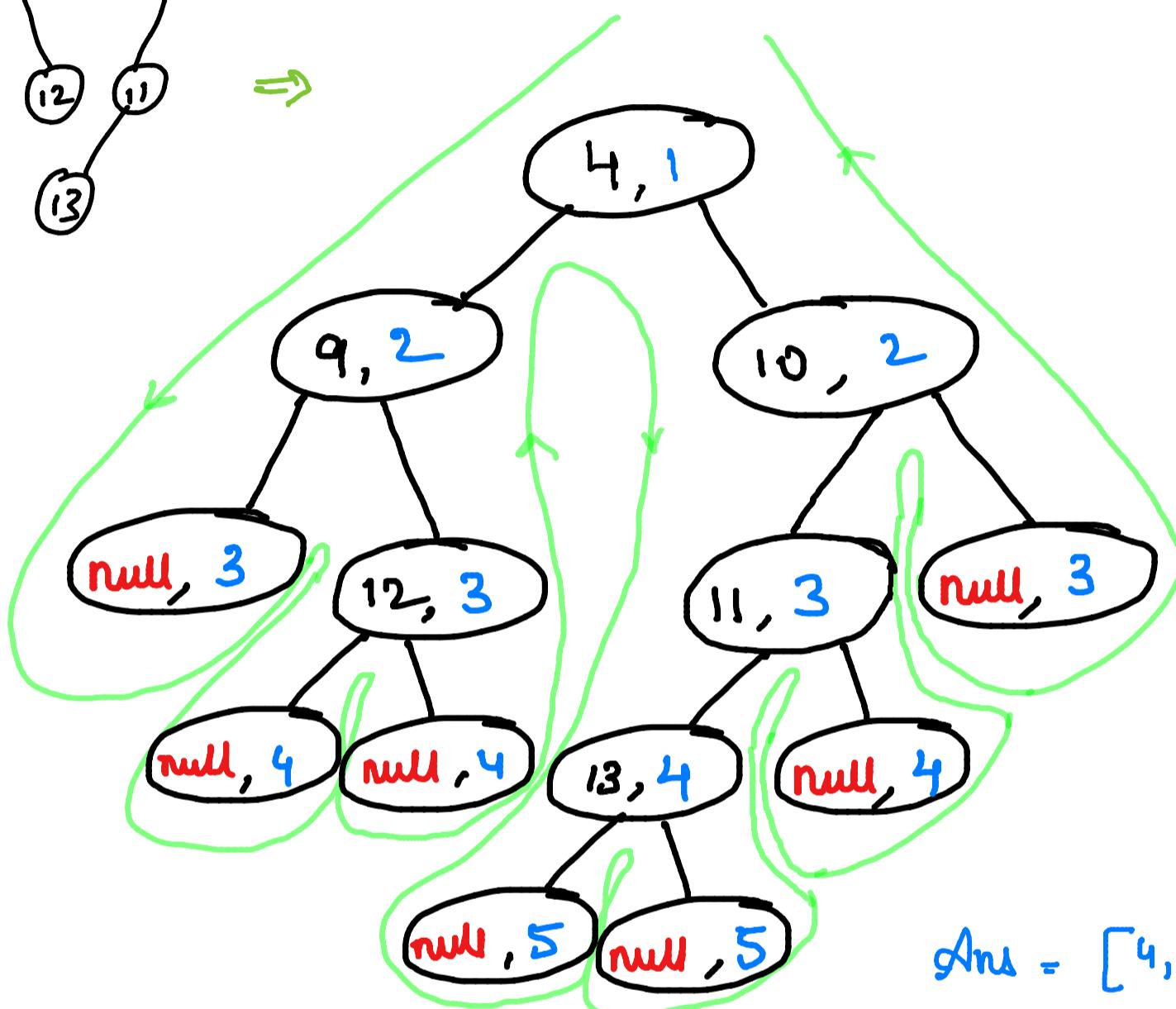
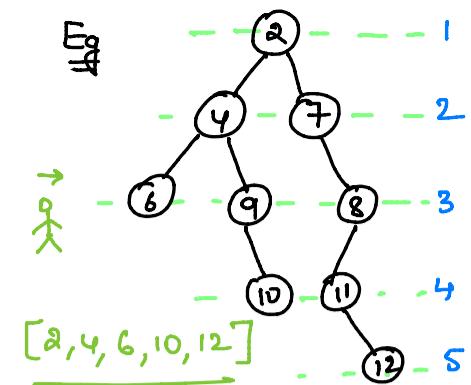
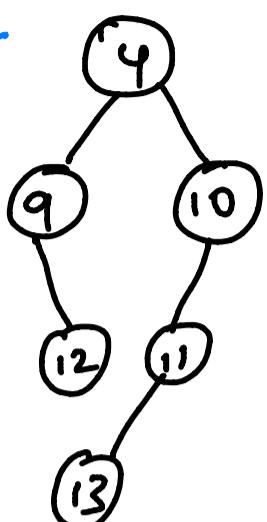
```
class Solution {
public:
    bool pathSumUtil(TreeNode* root, int currSum, int targetSum){
        if(root==NULL)
            return false;

        if(root->left==NULL && root->right==NULL){
            return (currSum+root->val)==targetSum;
        }

        return pathSumUtil(root->left, currSum+root->val, targetSum)
            ||pathSumUtil(root->right, currSum+root->val, targetSum);
    }

    bool hasPathSum(TreeNode* root, int targetSum) {
        return pathSumUtil(root, 0, targetSum);
    }
};
```

DL

(15) Left view of a Binary Tree

→ For every level traversed,
check if it already exist in the set,

if already exist then continue,
else add the root's value
to array q into the set

$T_C \rightarrow O(n)$

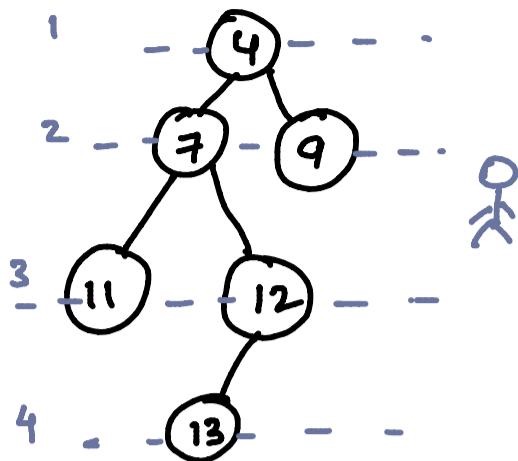
$S_C \rightarrow O(n) + O(n) + O(h)$

↓
result

Code →

```
void viewGenerator(Node *root, vector<int> &res, set<int> &s, int currLevel){  
    if(root==NULL) return;  
    // if level is not reached, then add to result and the set  
    if(s.find(currLevel)==s.end()){  
        s.insert(currLevel);  
        res.push_back(root->data);  
    }  
    // traverse the remaining branches  
    viewGenerator(root->left, res, s, currLevel+1);  
    viewGenerator(root->right, res, s, currLevel+1);  
    return;  
}  
  
vector<int> leftView(Node *root)  
{  
    vector<int> res;  
    set<int> s;  
    viewGenerator(root, res, s, 0);  
    return res;  
}
```

16 Right view of Binary Tree →



Result = [4, 9, 12, 13].

- The entire approach to solve the problem is same as the left view of binary tree. Even the time complexities.
 - Only order of calling the branches change.
- ① right
② left

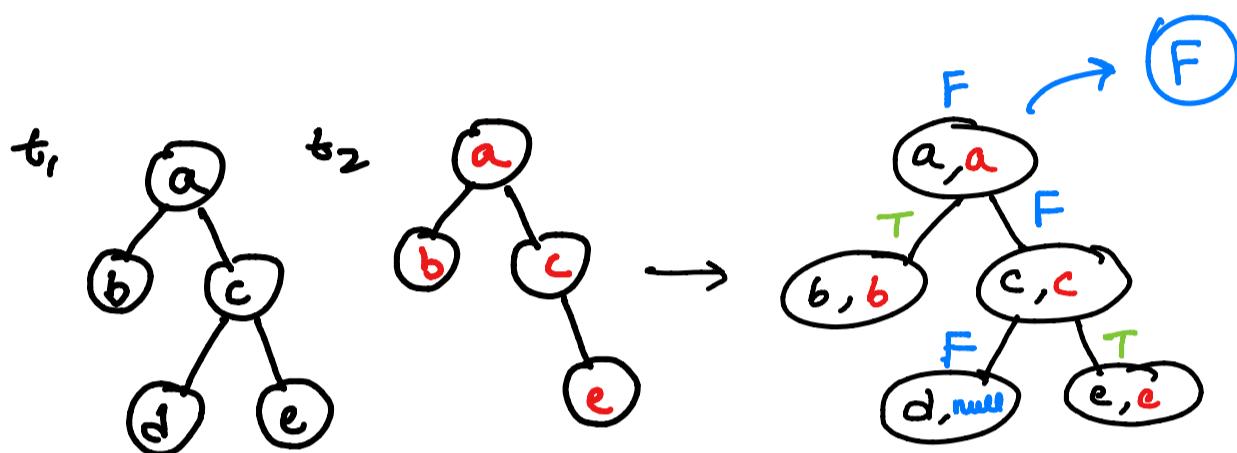
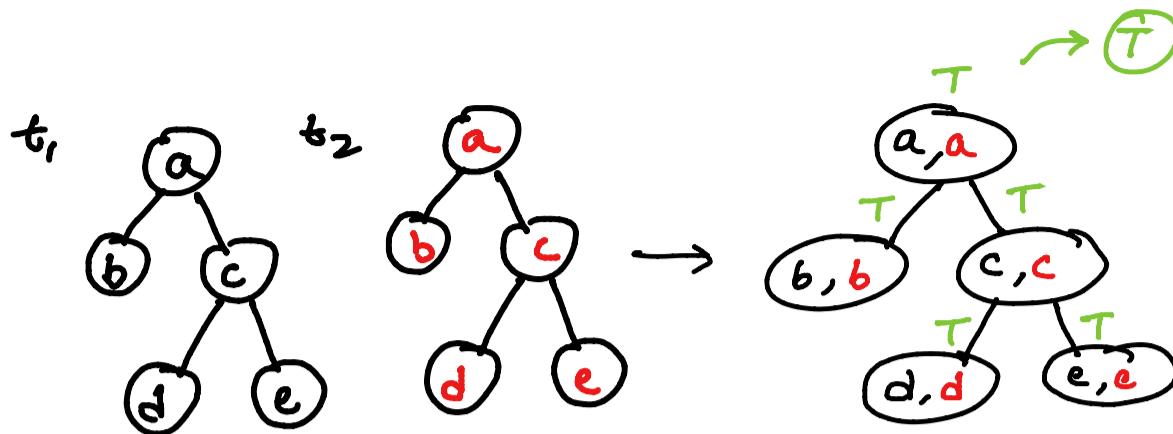
Code

```

class Solution {
public:
    void viewGenerator (TreeNode* root, vector<int> &res, set<int> &s, int currLevel){
        if(root==NULL) return;
        // if level is not reached, then add to result and the set
        if(s.find(currLevel)==s.end()){
            s.insert(currLevel);
            res.push_back(root->val);
        }
        // traverse the remaining branch
        viewGenerator(root->right, res, s, currLevel+1);
        viewGenerator(root->left, res, s, currLevel+1);
        return;
    }
    vector<int> rightSideView(TreeNode* root) {
        vector<int> res;
        set<int> s;
        viewGenerator(root, res, s, 0);
        return res;
    }
};
  
```

$T_C \rightarrow O(n)$
 $S_C \rightarrow O(n) + O(n) + O(h)$
↓
result

17) Same tree → return true if both trees are same
else false



$$TC \rightarrow O(\min(m, n))$$

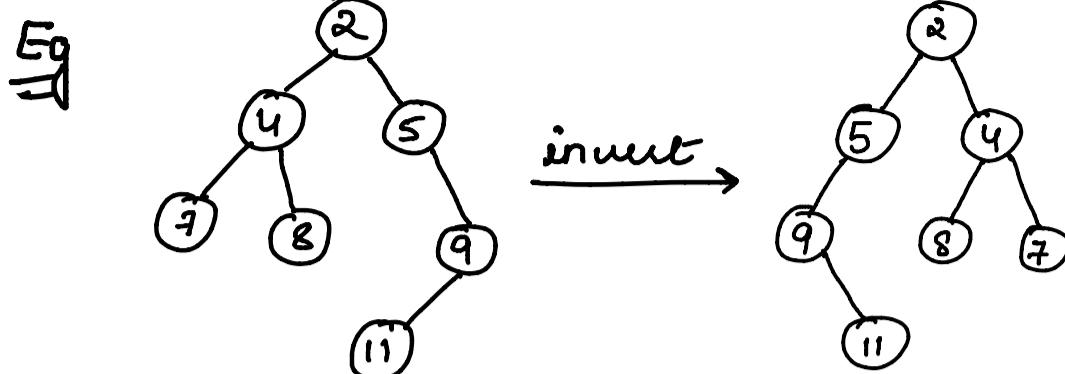
$$SC \rightarrow O(1) + O(\min(h_1, h_2))$$

Code →

```
class Solution {
public:

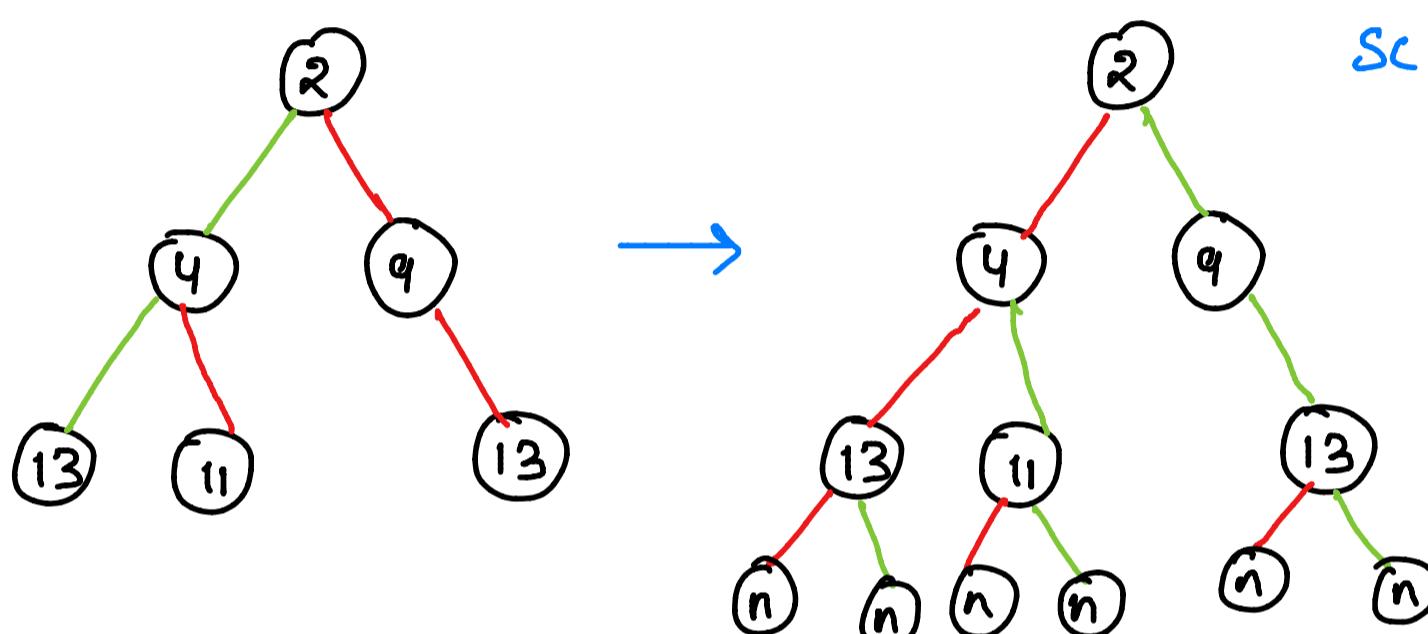
    bool isSameTree(TreeNode* p, TreeNode* q) {
        if(p==NULL && q==NULL) return true;
        if(p==NULL || q==NULL || p->val != q->val) return false;
        return isSameTree(p->left, q->left) && isSameTree(p->right, q->right);
    }
};
```

(18) Invert Binary Tree → given the root of BT, find its mirror img.



TC $\rightarrow O(n)$

SC $\rightarrow O(n) + O(h)$



Code →

```
class Solution {
public:
    TreeNode* invertTree(TreeNode* root) {
        if(root==NULL) return root;

        /* invert the left and right sub-trees and store
           them separately */
        TreeNode *leftSub = invertTree(root->right);
        TreeNode *rightSub = invertTree(root->left);

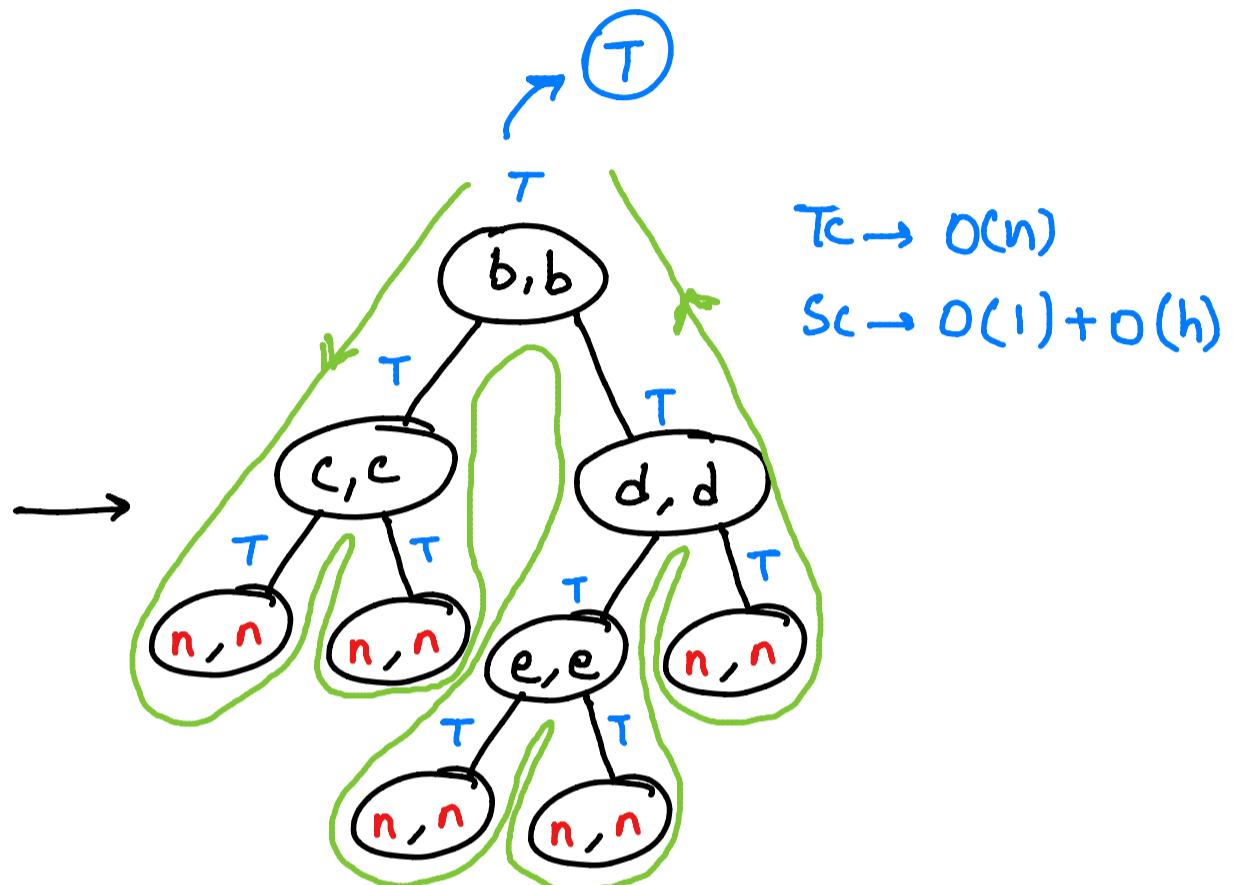
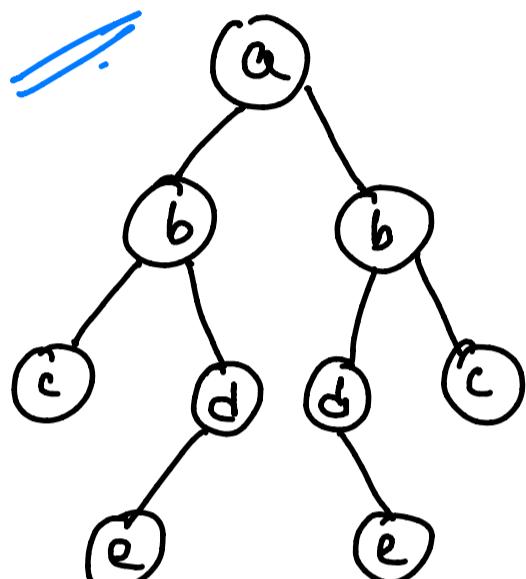
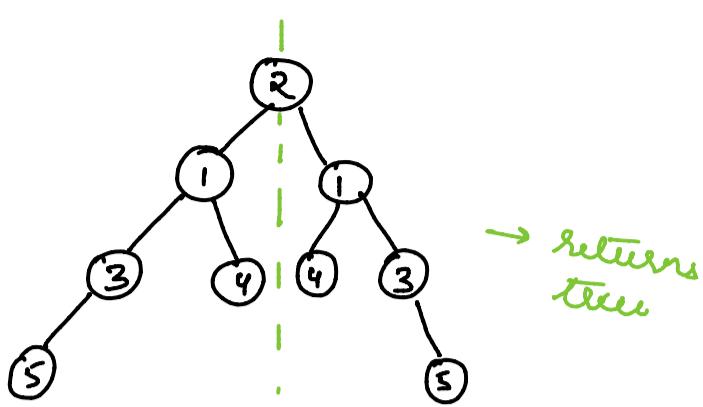
        // attach the branches to root
        root->left = leftSub;
        root->right = rightSub;

        return root;
    }
};
```

D7

19 Symmetric Tree

return true if left subtree
is equal to right subtree,
else return false



Code →

```

class Solution {
public:
    bool isMirror(TreeNode* l, TreeNode* r){

        if(l==NULL && r==NULL)
            return true;
        else if(l==NULL || r==NULL)
            return false;
        else if(l->val != r->val)
            return false;

        return isMirror(l->left,r->right) && isMirror(l->right, r->left);
    }
    bool isSymmetric(TreeNode* root) {
        if(root==NULL) return true;
        return isMirror(root->left, root->right);
    }
};

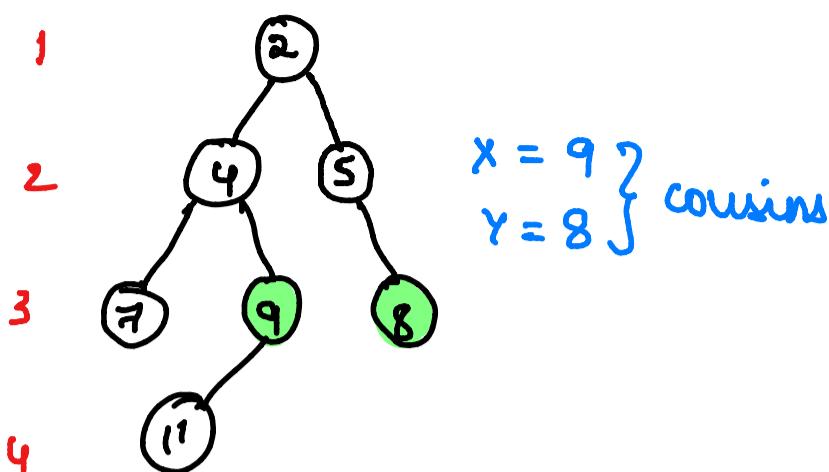
```

20

Cousins of a Binary Tree

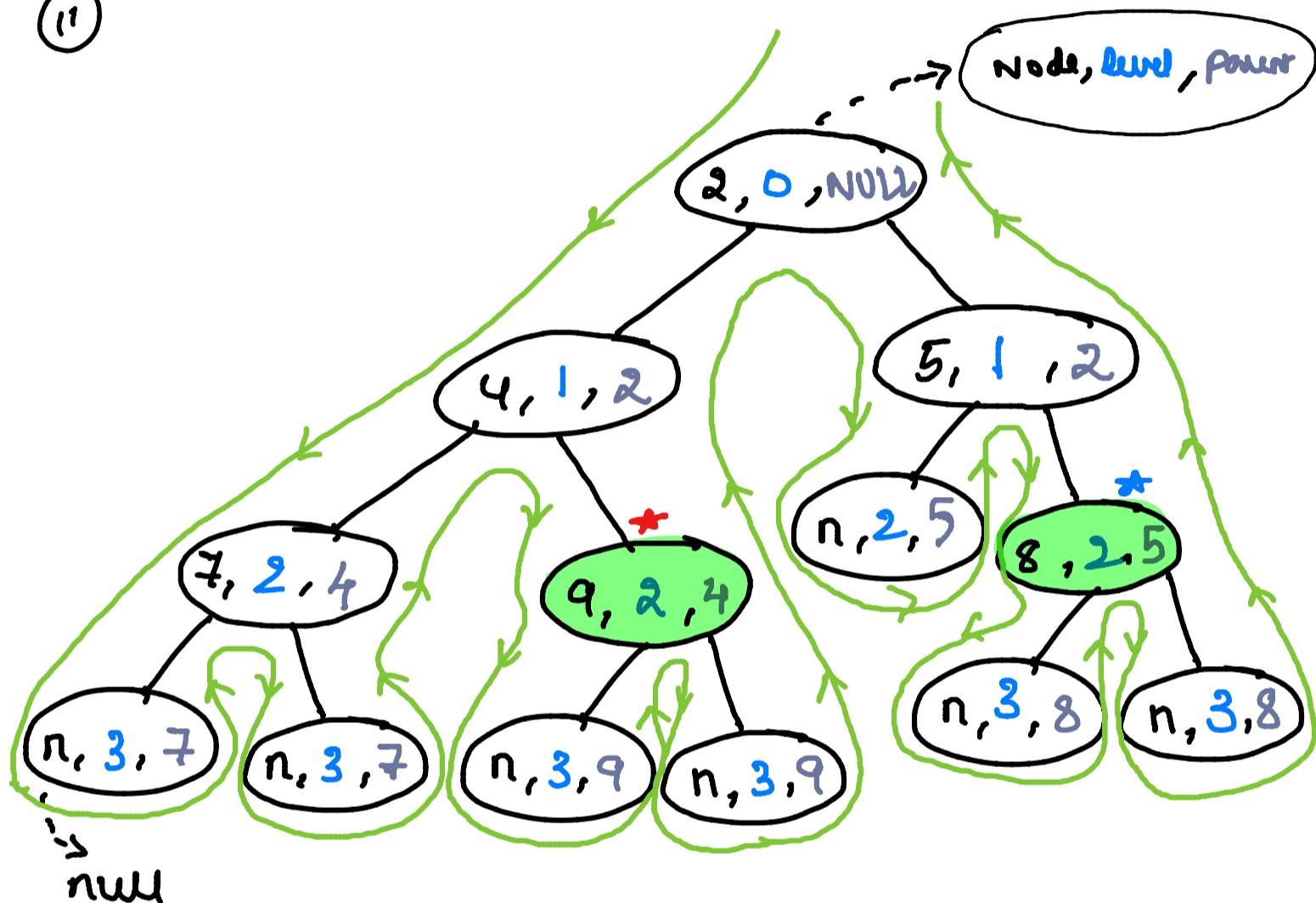
→ given two nodes, find if they are cousins of each other.

Ex:



$$\begin{aligned} x = 9 \\ y = 8 \end{aligned} \} \text{ cousins}$$

same level but diff parents.



- * at this step as value = 9 is x we found store it's parent & level in separate variables
- * later compare its value with other occurrence in Y such that

- 1) x.parent != y.parent
- 2) x.level == y.level.

TC $\rightarrow O(n)$

SC $\rightarrow O(1)$

Recursive stack $\rightarrow O(n)$

Code

```
class Solution {
public:
    void findNodes(TreeNode* root, int x, int y,int level[2],int parents[2],int currlevel,TreeNode* currparent)
    {
        if(root==NULL) return;
        if(root->val == x)
        {
            level[0]=currlevel;
            parents[0]=currparent->val;
        }
        if(root->val == y)
        {
            level[1]=currlevel;
            parents[1]=currparent->val;
        }
        findNodes(root->left, x, y, level, parents, currlevel+1, root);
        findNodes(root->right, x, y, level, parents, currlevel+1, root);
    }
    bool isCousins(TreeNode* root, int x, int y) {
        int level [2] = {-1,-1};
        int parents[2] = {-1,-1};
        findNodes(root, x, y, level, parents, 0, new TreeNode(-1));
        if(level[0]==level[1] && parents[0]!=parents[1])
            return true;
        return false;
    }
};
```