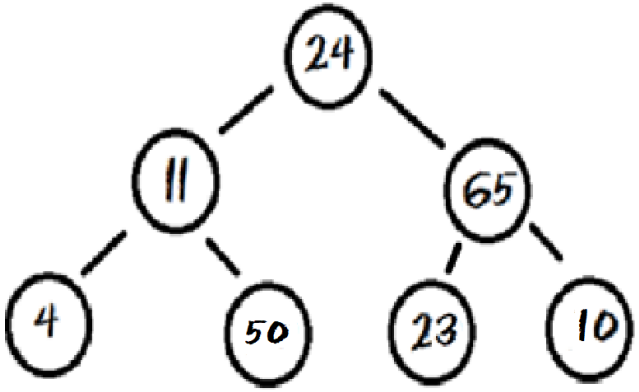
A+ Computer Science

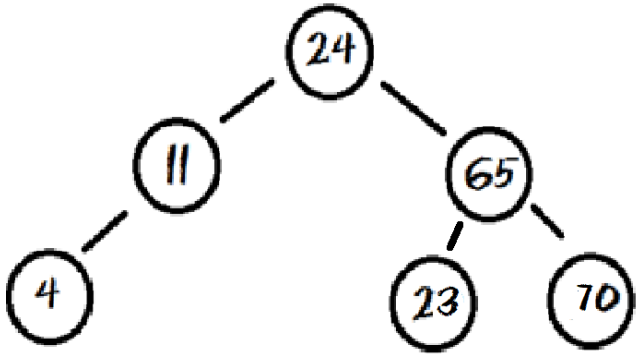
Binary trees

Tree terms

Binary Tree

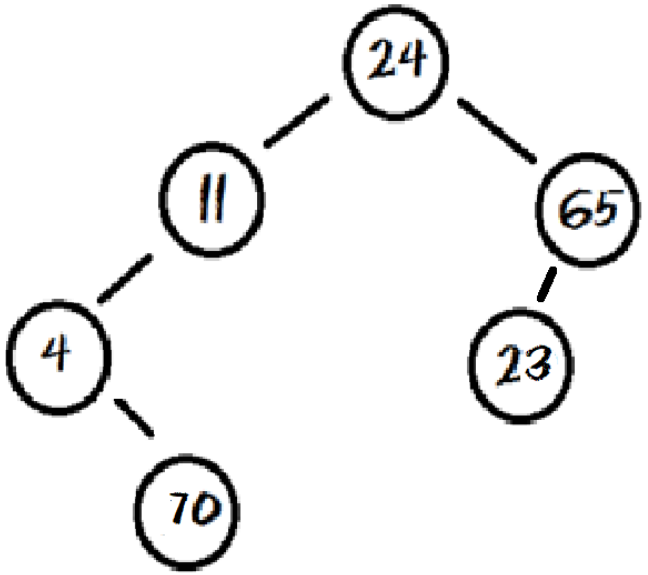
A binary tree is a collection of nodes. Each node has a value and links to other nodes. Each node in a binary tree can have at most 2 links.





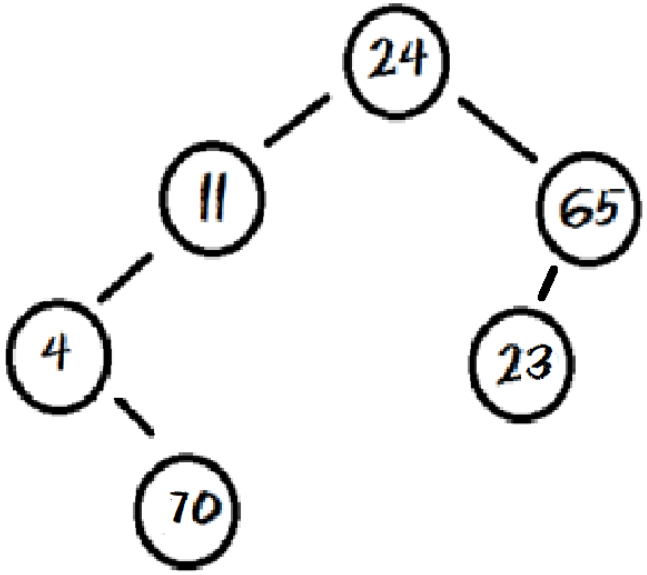
Edges / Links

Nodes have links to other nodes. These links are sometimes called edges. The tree below has 6 nodes and 5 links / edges.



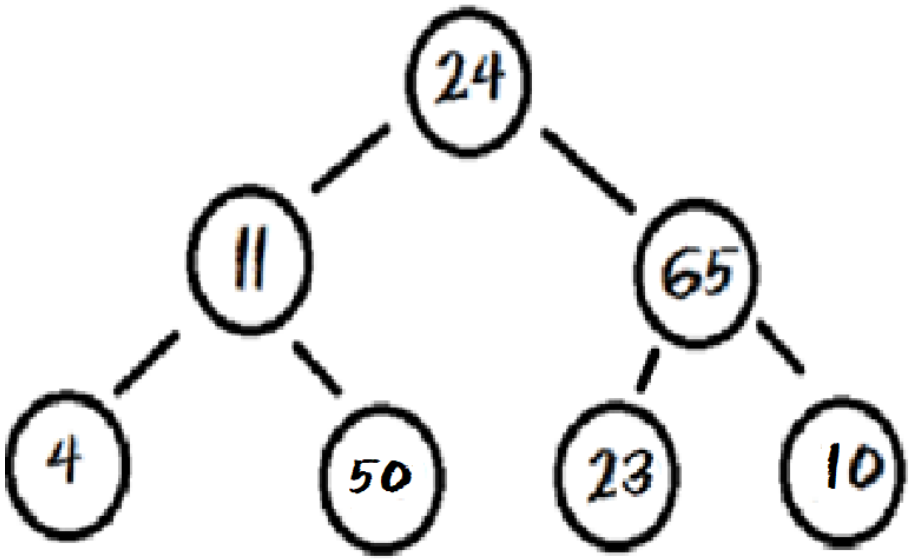
A leaf

A leaf is any node with 0 children.
The following tree has 2 leaves.
The tree contains 6 nodes.



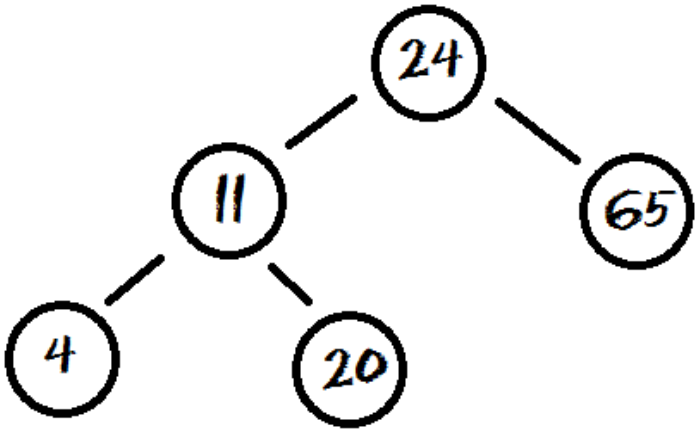
Perfect

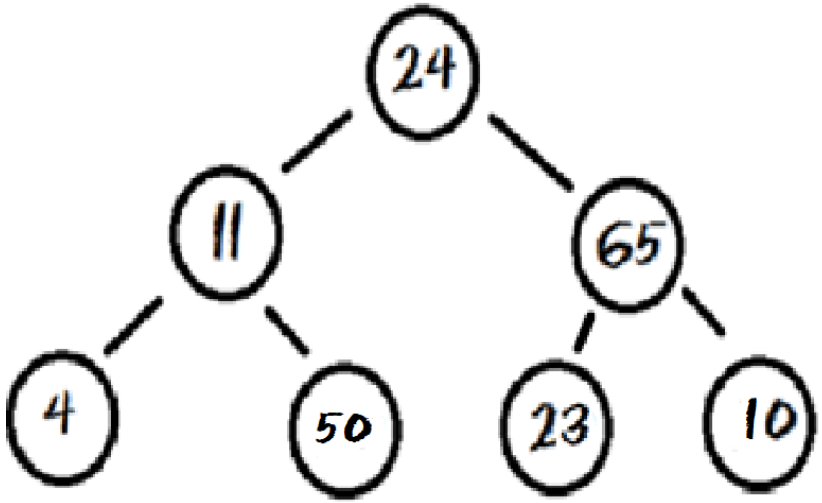
A perfect tree is a tree where the last level is all leaves.



Full

A full tree is a tree where all nodes have either 0 or 2 children.



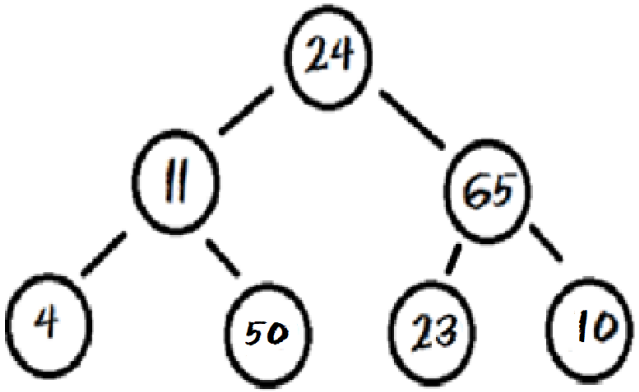


Full

In a full binary tree, every parent has exactly two children or no children at all. The number of nodes in the tree will equal 2 raised to the number of levels -1 if the tree if full.

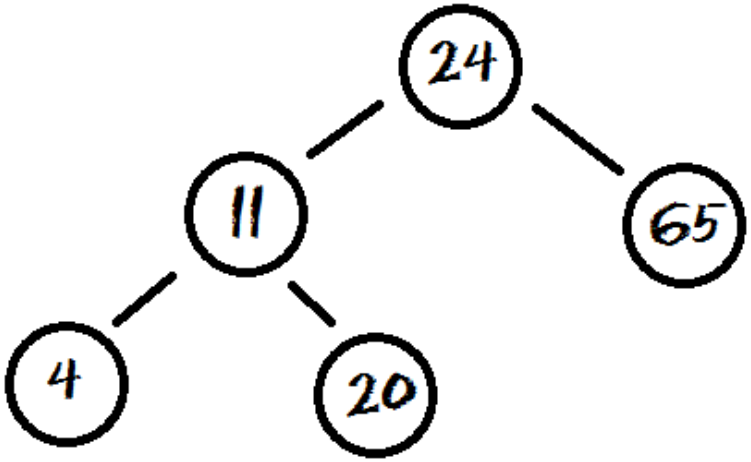
7 is the # of nodes

$2^{3(\text{number of levels})} - 1 = 7$



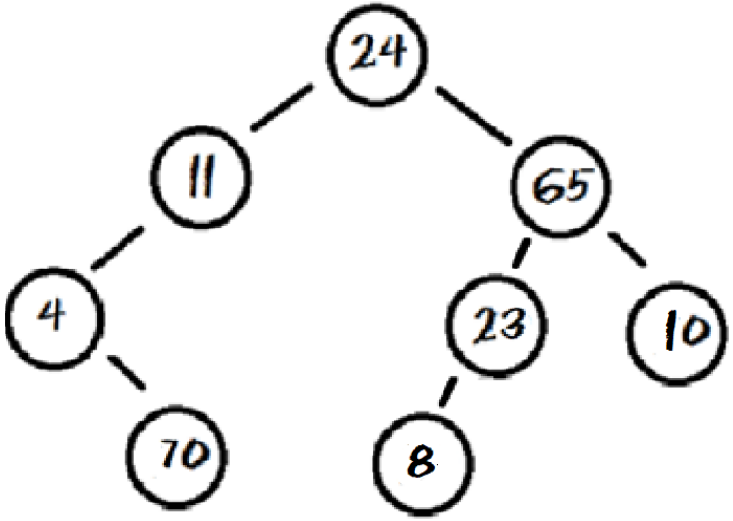
Complete

A complete tree is a tree where all levels are perfect except the very last level. All nodes on the last level are shifted to the left.



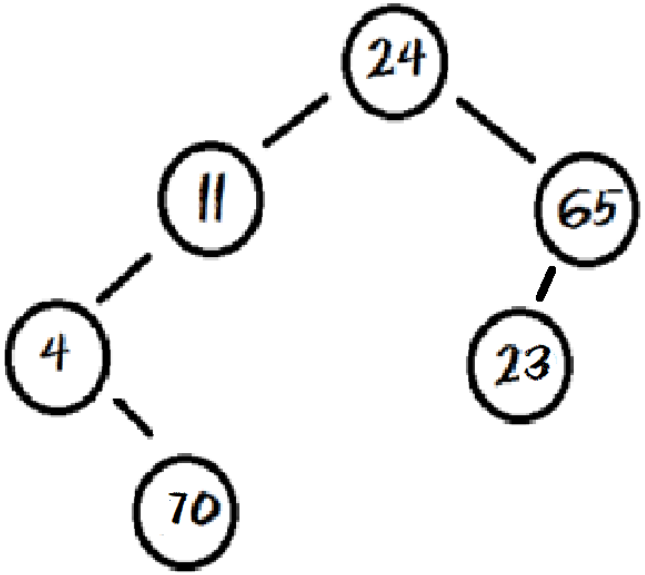
Width

The width of a tree is the level with the most nodes. That level is not always the last level. The tree below has a width of 3.



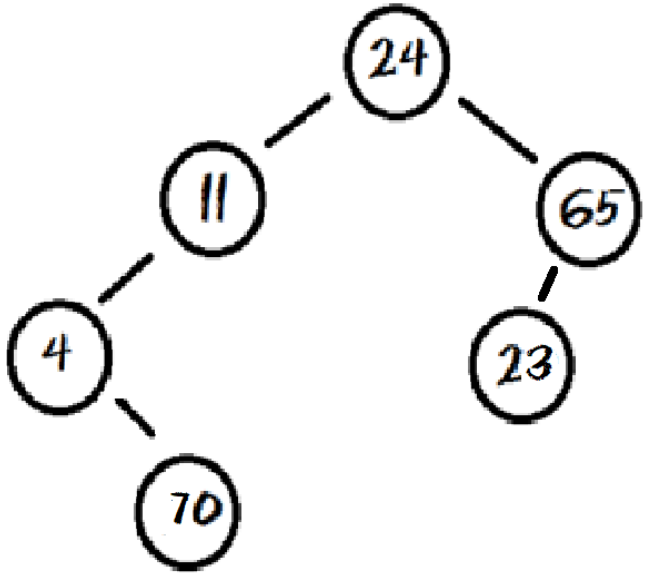
Diameter

A diameter of a tree is the longest path of nodes between any 2 leaves in the tree. The diameter of this tree is 6.



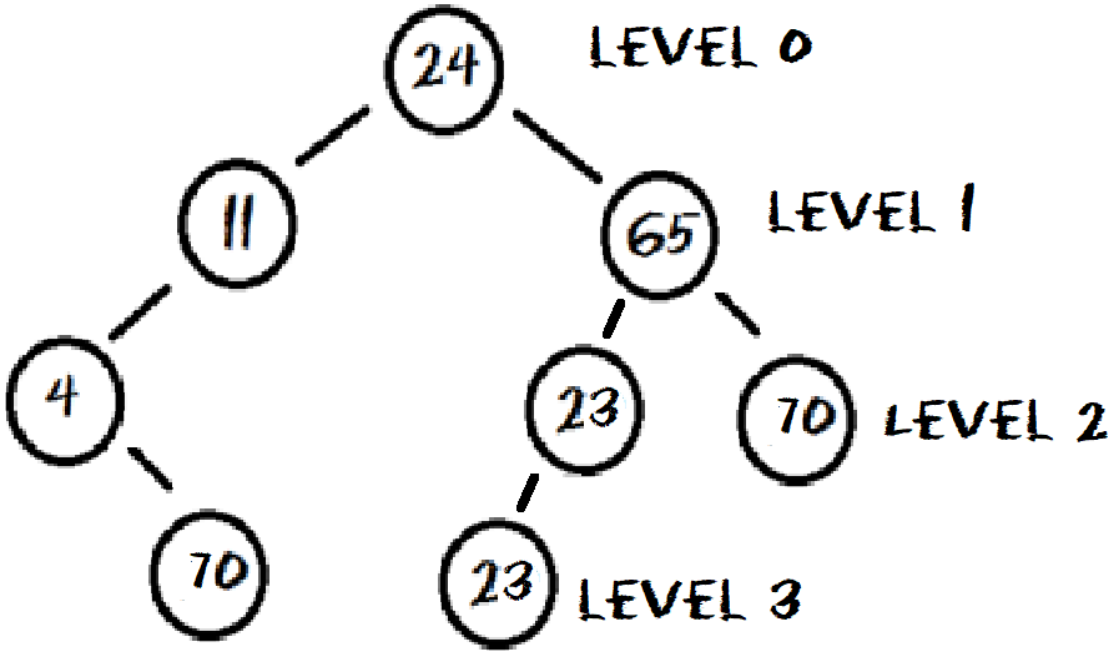
Height

The height of a tree is largest number of links between the root and any leaf.
The height of this tree is 3.



Levels

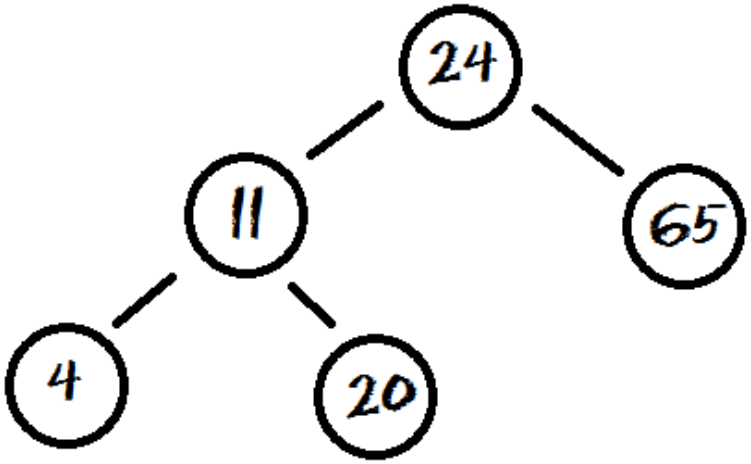
The root is level 0.
Level 1 is the children of the root.

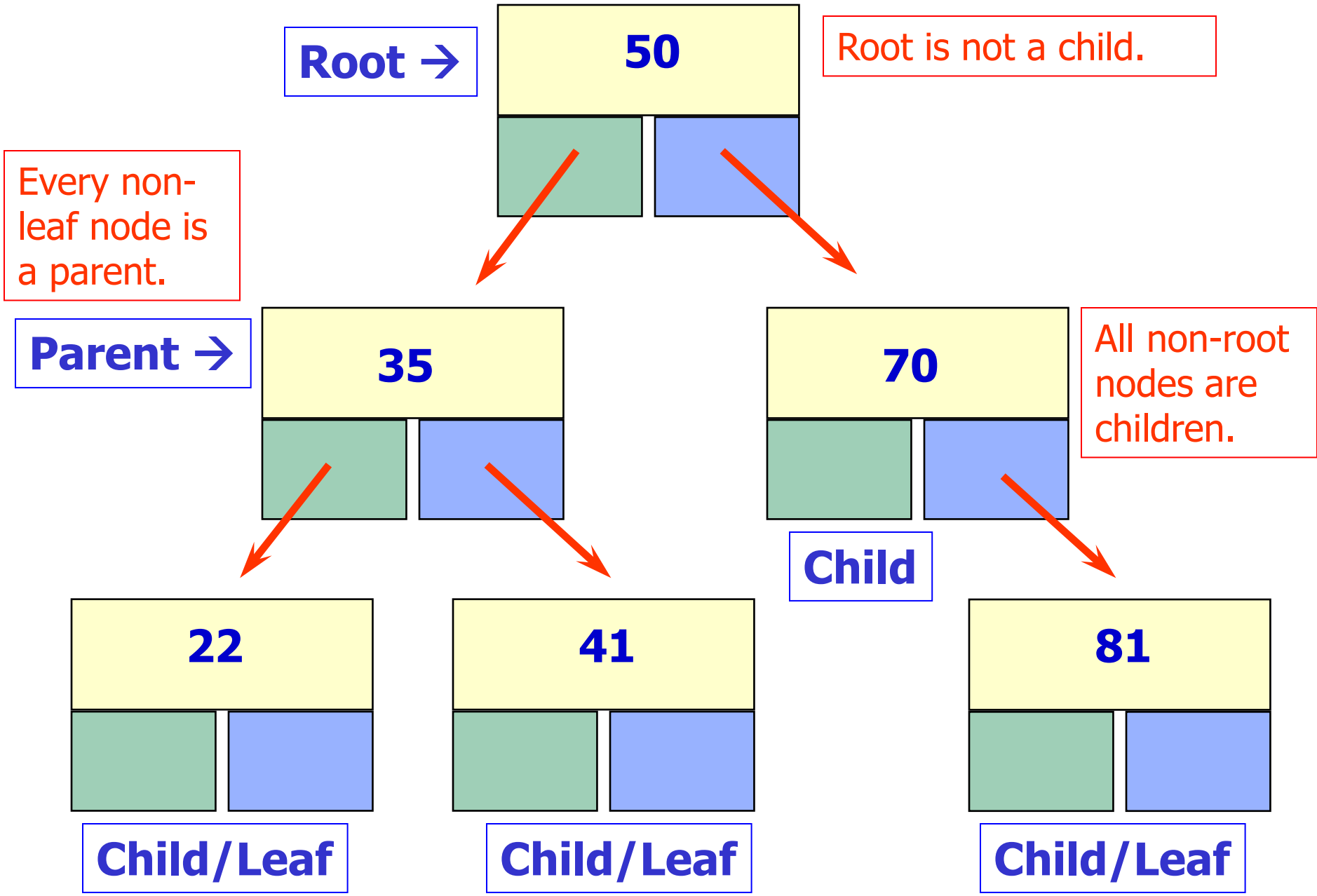


A binary search tree

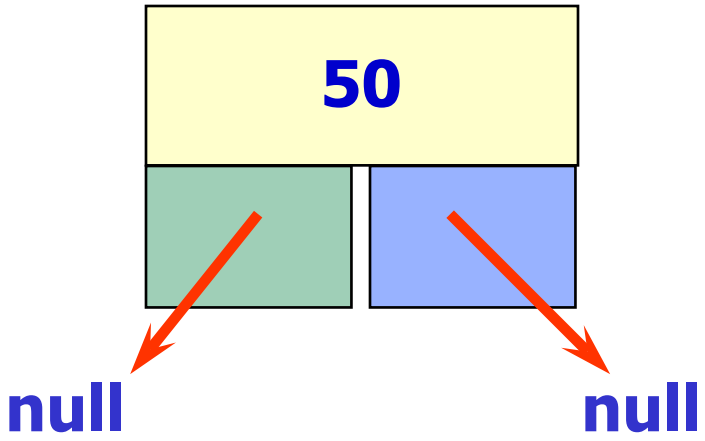
Binary Search Tree

A binary search tree is a binary tree with order. Smaller values are on the left and larger values are on the right.





A Single Node



A tree node typically has a data component and a reference to a left child and a reference to a right child.

Simple Node Class

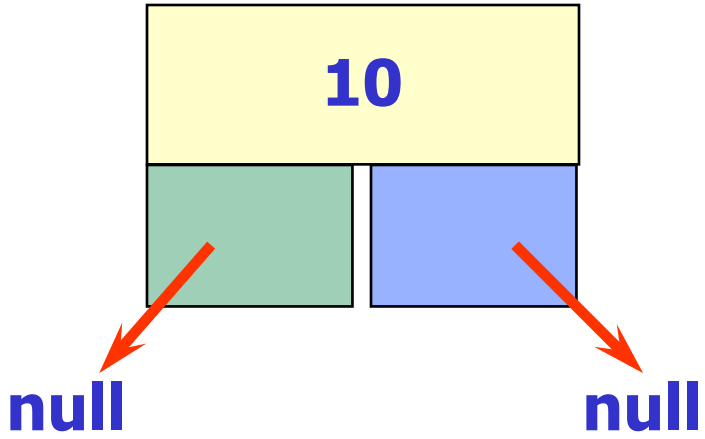
```
public class Node
{
   private Comparable data;
   private Node left;
   private Node right;

   public Node(Comparable dat, Node lft, Node rt)
   {
      data=dat;
      left=lft;
      right=rt;
   }
}
```

Creating a Single TreeNode

```
Tree node = new TreeNode("10", null,null);
out.println(node.getValue());
out.println(node.getLeft());
out.println(node.getRight());
```

OUTPUT

```
10
null
null
```



onetreenode.java

Linking Tree Nodes

Linking Tree Nodes

```
TreeNode node = new TreeNode("10",
                    new TreeNode("5", null,null),
                    new TreeNode("20", null,null));
```

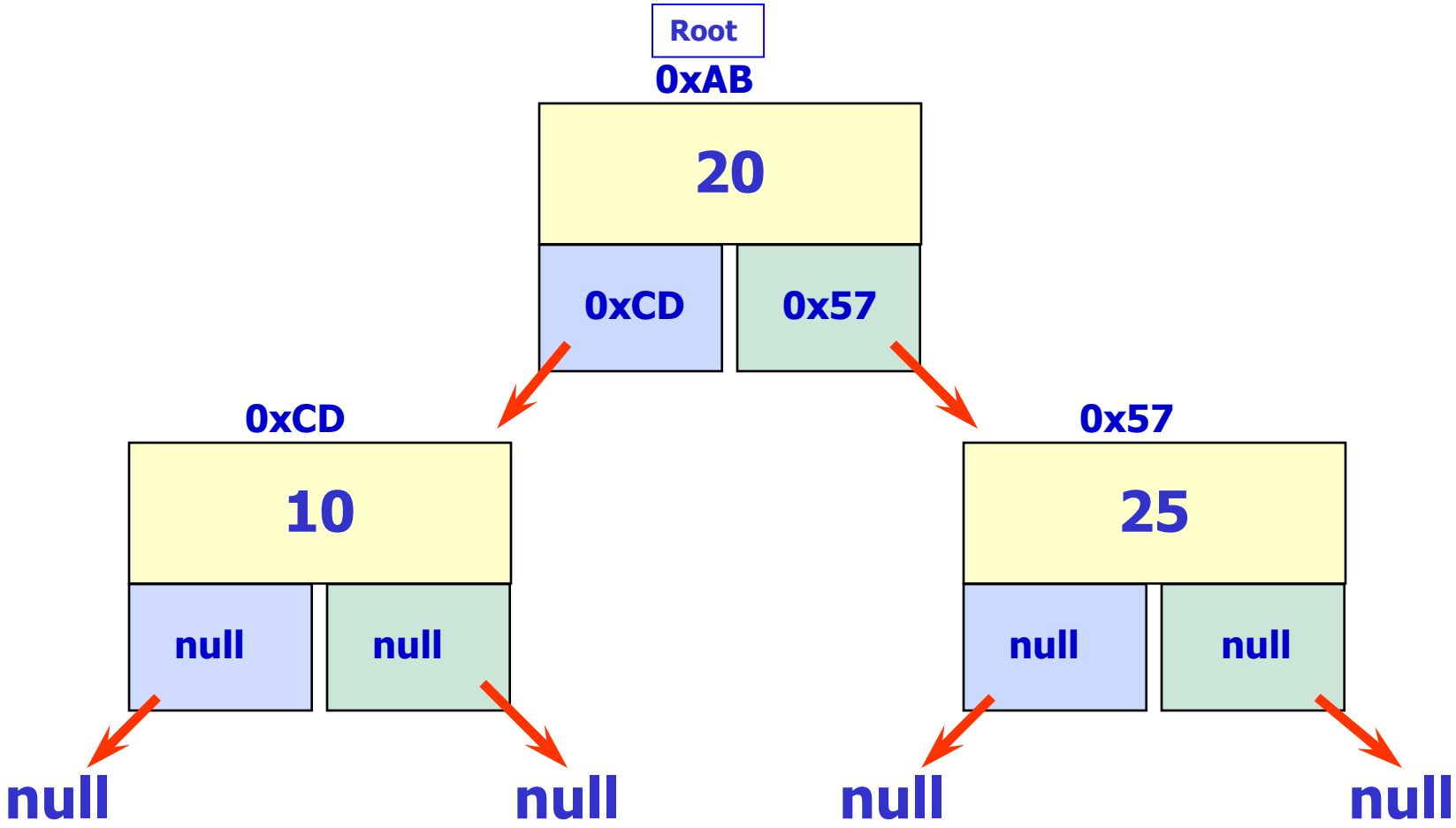
```
out.println(node.getValue());
out.println(node.getLeft().getValue());
out.println(node.getRight().getValue());
```

OUTPUT

```
10
5
20
```

treeone.java

Linking Tree Nodes



Linking Tree Nodes

```
TreeNode x = new TreeNode("10",null,null);
TreeNode y = new TreeNode("25", null,null);
TreeNode z = new TreeNode("20", x, y);
```

```
out.println(z.getValue());
out.println(z.getLeft().getValue());
out.println(z.getRight().getValue());
```

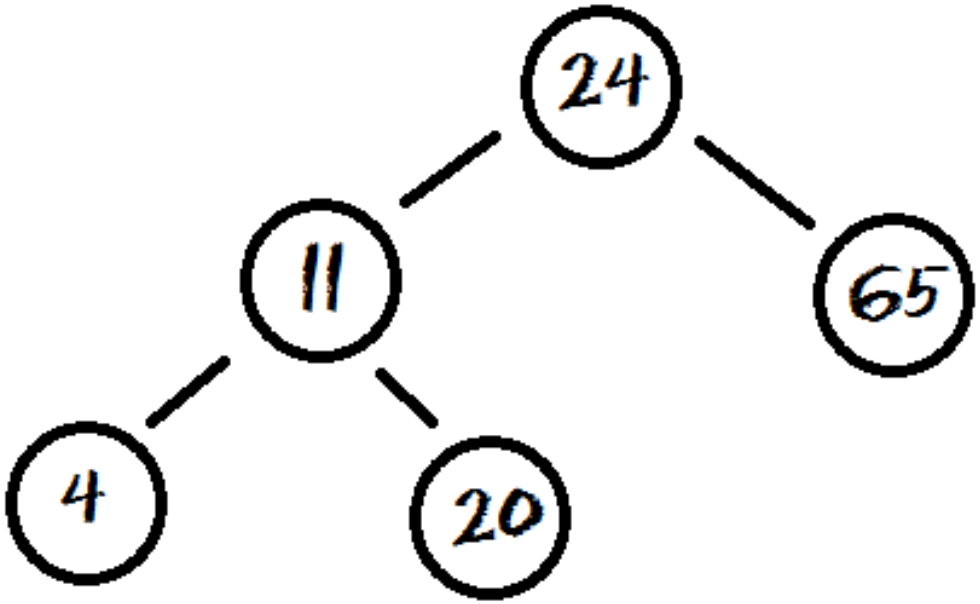
OUTPUT

```
20
10
25
```

treetwo.java

Building a Search Tree

Binary Search Tree



left child is less than the parent and right child is greater

Adding Tree Nodes

Every item that is added to a search tree is first compared to the root. If the item is larger than the root, a recursive call is made on the right sub tree. If the item is smaller than the root, a recursive call is made on the left sub tree. This process continues until a null reference is found.

Adding Tree Nodes

```
private TreeNode add(Comparable val, TreeNode tree)
{
   if (tree == null)
      return new TreeNode(val, null, null);

   int dirTest = val.compareTo(tree.getValue());
   if(dirTest<0)
      tree.setLeft(add(val, tree.getLeft()));
   else if(dirTest>0)
      tree.setRight(add(val, tree.getRight()));
   return tree;
}
```

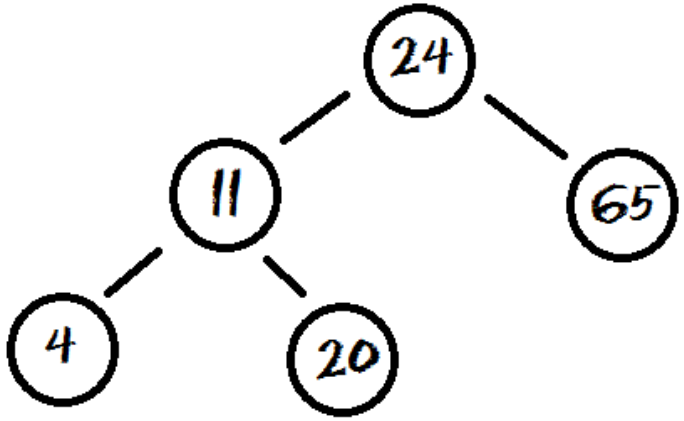
Adding Tree Nodes

```
private TreeNode add(Comparable val, TreeNode tree)
{
  if (tree == null)
    tree = new TreeNode(val, null, null);
  else if (val.compareTo(tree.getValue()) < 0 )
    tree.setLeft(add(val, tree.getLeft()));
  else if (val.compareTo(tree.getValue()) > 0 )
    tree.setRight(add(val, tree.getRight()));
  return tree;
}
```

addprintone.java

Displaying Tree Nodes

Tree Traversals



IN-ORDER = 4 11 20 24 65

PRE-ORDER = 24 11 4 20 65

POST-ORDER = 4 20 11 65 24

REV-ORDER = 65 24 20 11 4

Tree Traversals
In Order

```
private void inOrder(TreeNode tree)
{
   if (tree != null){
         inOrder(tree.getLeft());
         out.print(tree.getValue() + " ");
         inOrder(tree.getRight());
   }
}
```

Tree Traversals
In Order

```
private void inOrder(TreeNode tree)
{
   if (tree == null)
      return;
   inOrder(tree.getLeft());
   out.print(tree.getValue() + " ");
   inOrder(tree.getRight());
}
```

Tree Traversals
In Order

```
private String inOrder(TreeNode tree)
{
   if (tree != null)
      return inOrder(tree.getLeft())
          + tree.getValue() + " " +
          inOrder(tree.getRight());
   return "";
}
```

addprinttwo.java

Searching a Tree

Searching for Values

To search a tree, you will use the same basic logic that you used to add a new node.

First, compare the current node to the search value and see if it is a match. If it is not a match, check to see if you need to search the left sub tree or the right sub tree. Repeat.

Sounds like a binary search.

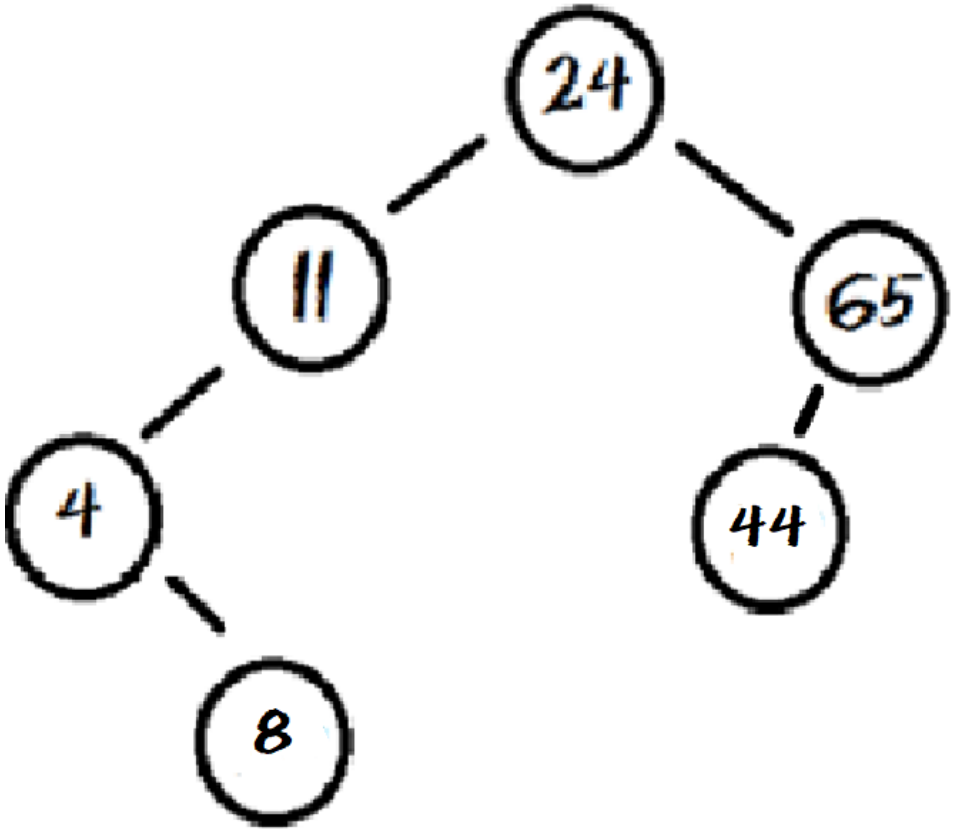
Searching for Values

```
private boolean search(Comparable val, TreeNode tree)
{
   if(tree != null)
   {
      int dirTest = val.compareTo(tree.getValue());
      if(dirTest == 0 )
         return true;
      else if (dirTest < 0)
         return search(val, tree.getLeft());
      else if (dirTest > 0)
         return search(val, tree.getRight());
   }
   return false;
}
```

contains.java

Processing Tree Nodes

Processing Tree Nodes



NUMLEAVES - 2

NUMLEVELS - 4

NUMNODES - 6

Processing Tree Nodes

Diameter - dist between 2 furthest leaves in the tree – does not have to go through the root

Height – longest path from root to a leaf
# of links from root to farthest leaf

Level - a group of equal nodes
the root is level - 0
the children of the root - level - 1

Processing Tree Nodes

```
int  getNumLevels(TreeNode  tree)
{
   if (tree==null)
      return something;
   else
  {
      numLeft = getNumLevels of the left
      numRight = getNumLevels of the right
      if (numLeft > numRight)
          return 1 + numLeft;
      else
          return 1 + numRight;
   }
}
```

Processing Tree Nodes

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

private int getNumLevels(TreeNode tree)
{
  if(tree==null)   return 0;
  else
  {
    int numLeft = getNumLevels(tree.getLeft());
    int numRight = getNumLevels(tree.getRight());
    if(numLeft > numRight)
      return 1 + numLeft;
    return 1 + numRight;
  }
}
```

Processing Tree Nodes

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

private int getNumLevels(TreeNode tree)
{
  if(tree==null)   return 0;
  else
  {
    return
          1 + Math.max(getNumLevels(tree.getLeft() ,
                       getNumLevels(tree.getRight());
  }
}
```

numlevels.java

Work on Programs!

Crank Some Code!

A+ Computer Science

Binary trees