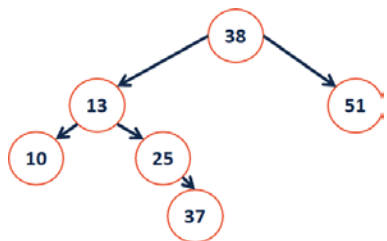
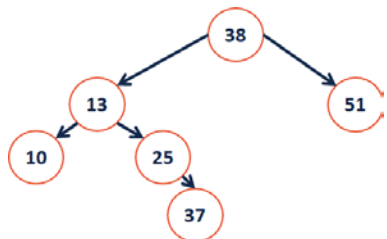
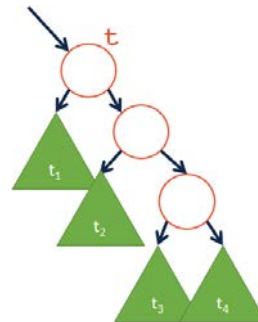


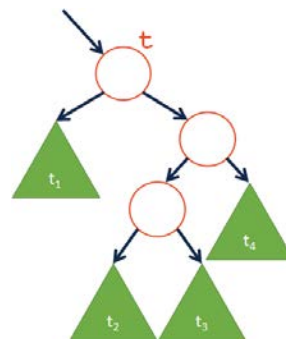
**Example 2: A Complex Rotation**



**AVL Theorem #1:** If an insertion occurred in subtrees  $t_3$  or  $t_4$  and a subtree was detected at  $t$ , then a \_\_\_\_\_ rotation about  $t$  restores the balance of the tree.



**AVL Theorem #2:** If an insertion occurred in subtrees  $t_2$  or  $t_3$  and a subtree was detected at  $t$ , then a \_\_\_\_\_ rotation about  $t$  restores the balance of the tree.

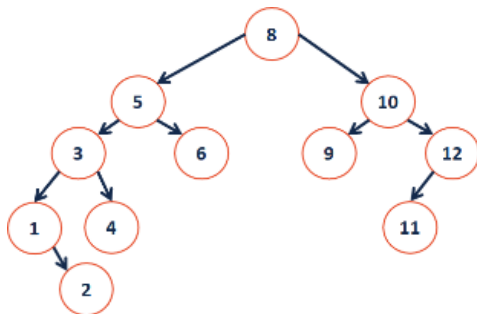


**BST Rotation Summary:**

1. Four kinds of rotations (L, R, LR, and RL)
2. All rotations are local
3. All rotations run in constant time,  $O(1)$
4. BST property is maintained!

**Overall Goal:**

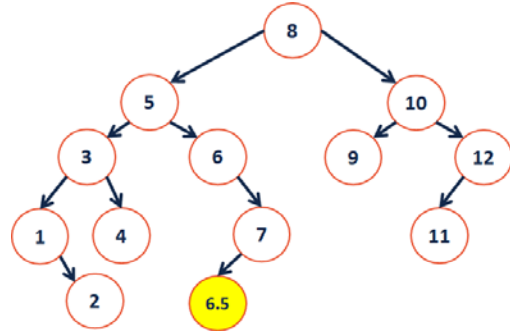
...and we call these trees:



...additional property:

## AVL Insertion

Pseudocode:



```

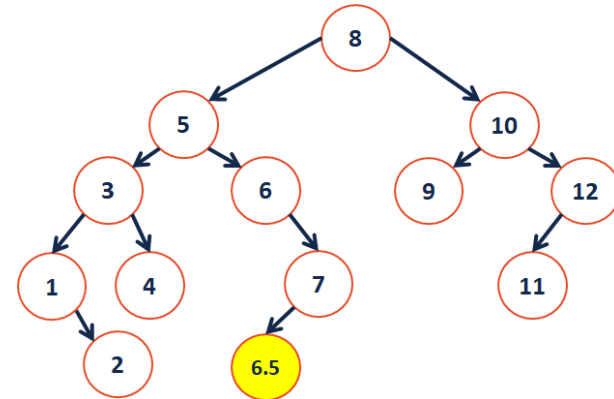
AVL.h (snippet)
23 class TreeNode {
24     public:
25         T key;
26         unsigned height;
27         TreeNode *left;
28         TreeNode *right;
...
    
```

## AVL Insertion

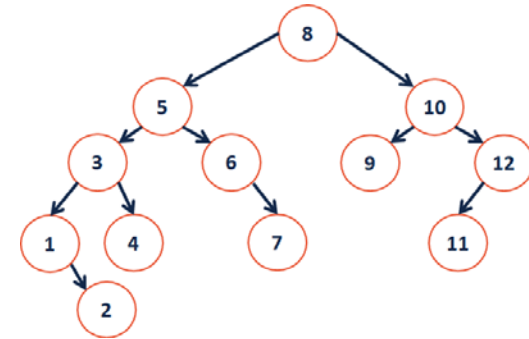
```

AVL.hpp
151 template <typename K, typename V>
152 void AVL<K, D>::_insert(const K & key, const V & data, TreeNode
*& cur) {
153     if (cur == NULL) { cur = new TreeNode(key, data); }
157     else if (key < cur->key) { _insert( key, data, cur->left ); }
160     else if (key > cur->key) { _insert( key, data, cur->right ); }
166     _ensureBalance(cur);
167 }
---
119 template <typename K, typename V>
120 void AVL<K, D>::_ensureBalance(TreeNode *& cur) {
121     // Calculate the balance factor:
122     int balance = height(cur->right) - height(cur->left);
123
124     // Check if the node is current not in balance:
125     if ( balance == -2 ) {
126         int l_balance =
            height(cur->left->right) - height(cur->left->left);
127         if ( l_balance == -1 ) { _____; }
128         else { _____; }
129     } else if ( balance == 2 ) {
130         int r_balance =
            height(cur->right->right) - height(cur->right->left);
131         if( r_balance == 1 ) { _____; }
132         else { _____; }
133     }
134
135     _updateHeight(cur);
136 };
    
```

## AVL Insertion



## AVL Removal



- | CS 225 – Things To Be Doing:                                    |
|-----------------------------------------------------------------|
| 1. Theory Exam 2 starts tomorrow!                               |
| 2. MP4 is released! EC deadline (Part 1) is this coming Monday! |
| 3. lab_huffman in labs this week                                |
| 4. Daily POTDs                                                  |