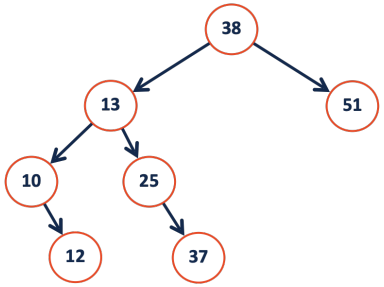
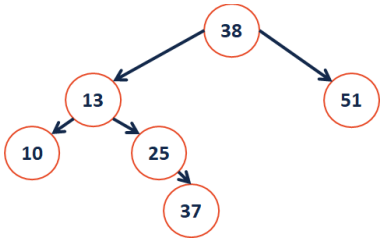
CS 225

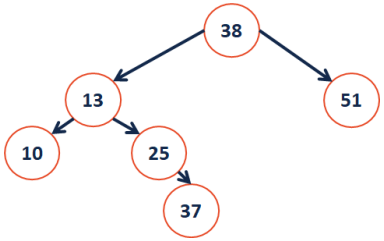
#15: AVL Trees

Example 1: Right Rotation



Example 2: A Complex Rotation

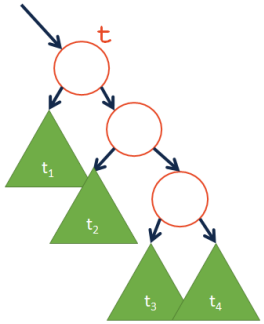




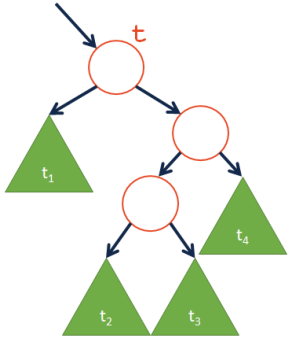
BST Rotation Summary:

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!

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



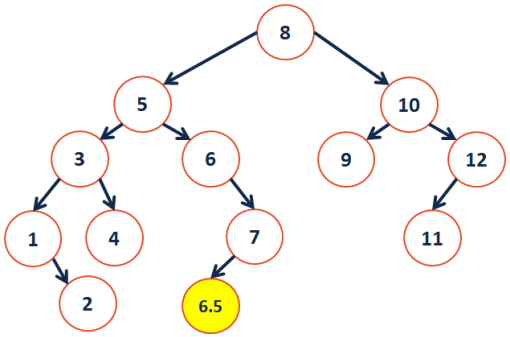
AVL Theorem #2: If an insertion occurred in subtrees $\mathbf{t_2}$ or $\mathbf{t_3}$ and a subtree was detected at **t**, then a _____ rotation about t restores the balance of the tree.



Do you understand the mirrored versions of these theorems?

AVL Insertion

Pseudocode:



AVL.h (snippet)

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

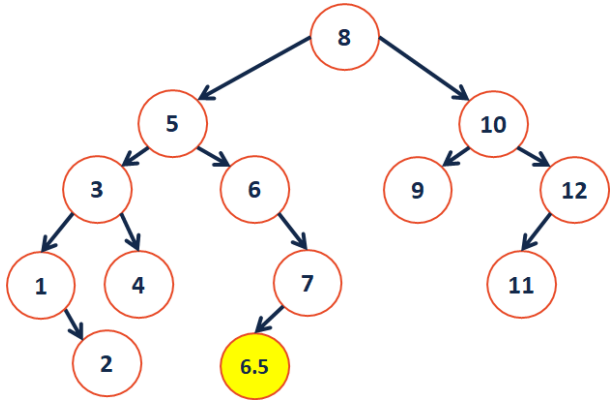
AVL Insertion

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