# 19: AVL Trees

March 4, 2020 · G Carl Evans

**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 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.

**AVL Insertion**

Pseudocode:
### AVL Insertion

#### AVL.h (snippet)

```cpp
class TreeNode {
public:
    T key;
    unsigned height;
    TreeNode *left;
    TreeNode *right;
};
```

#### AVL.hpp

```cpp
template <typename K, typename V>
void AVL<K, D>::_insert(const K & key, const V & data, TreeNode *& cur) {
    if (cur == NULL) { cur = new TreeNode(key, data); }
    else if (key < cur->key) { _insert(key, data, cur->left); }
    else if (key > cur->key) { _insert(key, data, cur->right); }
    _ensureBalance(cur);
}
```

```cpp
template <typename K, typename V>
void AVL<K, D>::_ensureBalance(TreeNode *& cur) {
    int balance = height(cur->right) - height(cur->left);
    if (balance == -2) {
        int l_balance = height(cur->left->right) - height(cur->left->left);
        if (l_balance == -1) { ________________; }
        else if (l_balance == 2) {
            int r_balance = height(cur->right->right) - height(cur->right->left);
            if (r_balance == 1) { ________________; }
            else { ________________; }
        }
    } else if (balance == 2) {
        ________________;
    }
    _updateHeight(cur);
}
```

### AVL Insertion Diagram

![AVL Insertion Diagram](image)

### AVL Removal

#### AVL Removal Diagram

![AVL Removal Diagram](image)

### CS 225 – Things To Be Doing:

1. mp_traversal is released! EC deadline (Part 1) is this coming Monday!
2. lab_huffman in labs this week
3. Daily POTDs