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!

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:

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

    // Ensure balance of the node
    AVL::_ensureBalance(cur);
};
```

AVL Insertion

```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);
}
```

AVL Removal

```cpp
template <typename K, typename V>
void AVL<K, D>::_ensureBalance(TreeNode *& cur) {
    // Calculate the balance factor:
    int balance = height(cur->right) - height(cur->left);
    // Check if the node is current not in balance:
    if (balance == -2) {
        int l_balance = height(cur->left->right) - height(cur->left->left);
        if (l_balance == -1) {
            // Case 1
        } else if (balance == 2) {
            int r_balance = height(cur->right->right) - height(cur->right->left);
            if (r_balance == 1) {
                // Case 2
            } else {
                // Case 3
            }
        } else if (balance == 1) {
            // Case 4
        } else if (balance == -1) {
            // Case 5
        } else {
            // Case 6
        }
    }
    _updateHeight(cur);
}
```

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