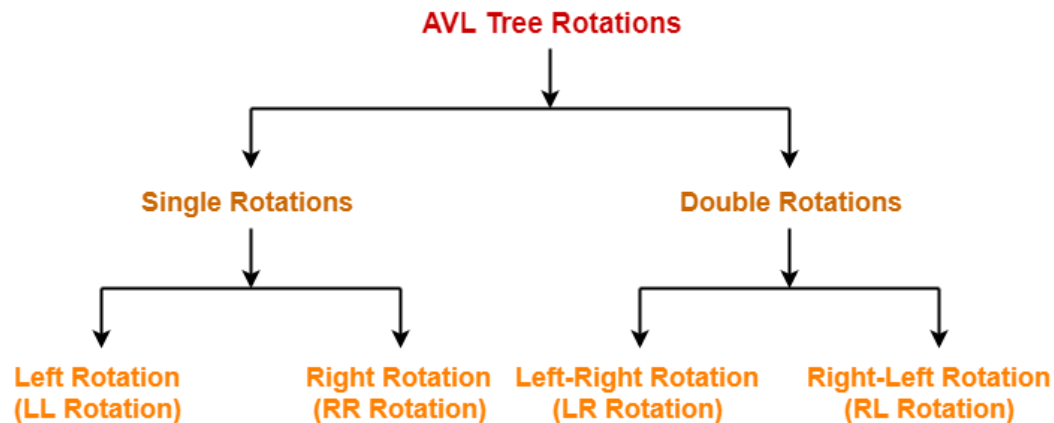**AVL Tree Balancing**

Important Concepts:

Height: Number of edges to deepest leaf
Balance Factor: $balanceFactor = height(leftSubTree) - height(rightSubTree)$
Tolerance: {-1, 0, 1}
Leaf Nodes: Balance factor of 0

AVL Tree Rotations

Single Rotations

Double Rotations

Left Rotation (LL Rotation)

Right Rotation (RR Rotation)

Left-Right Rotation (LR Rotation)

Right-Left Rotation (RL Rotation)
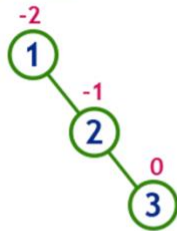
AVL Insertion Process
You will do an insertion similar to a normal Binary Search Tree insertion. After inserting, you fix the AVL property using left or right rotations.

- If there is an imbalance in left child of right subtree, then you perform a left-right rotation.
- If there is an imbalance in left child of left subtree, then you perform a right rotation.
- If there is an imbalance in right child of right subtree, then you perform a left rotation.
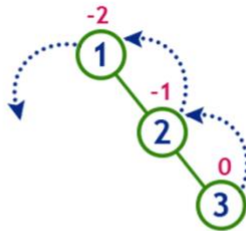- If there is an imbalance in right child of left subtree, then you perform a right-left rotation.

Single Tree Rotation:

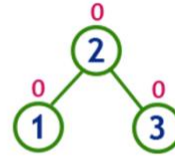- **Left Rotation:** "right heavy tree" will have a balance factor < -1

insert 1, 2 and 3

Tree is imbalanced

To make balanced we use
LL Rotation which moves
nodes one position to left

After LL Rotation
Tree is Balanced

- o 2 Becomes **new root**
  - 2->parent = 1->parent (update parent left or right child -> 2)
- o 1 Becomes **new root's** left child
  - 1->parent = 2
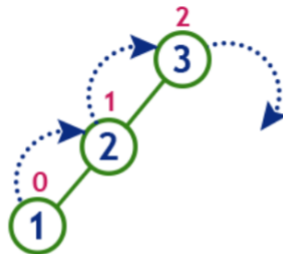- o Left Child of 2 (if present) becomes right child of 1

- **Right Rotation:** "left heavy tree" will have a balance factor > 1
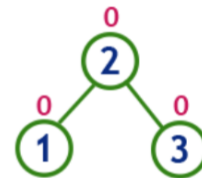
insert 3, 2 and 1

Tree is imbalanced
because node 3 has balance factor 2

To make balanced we use
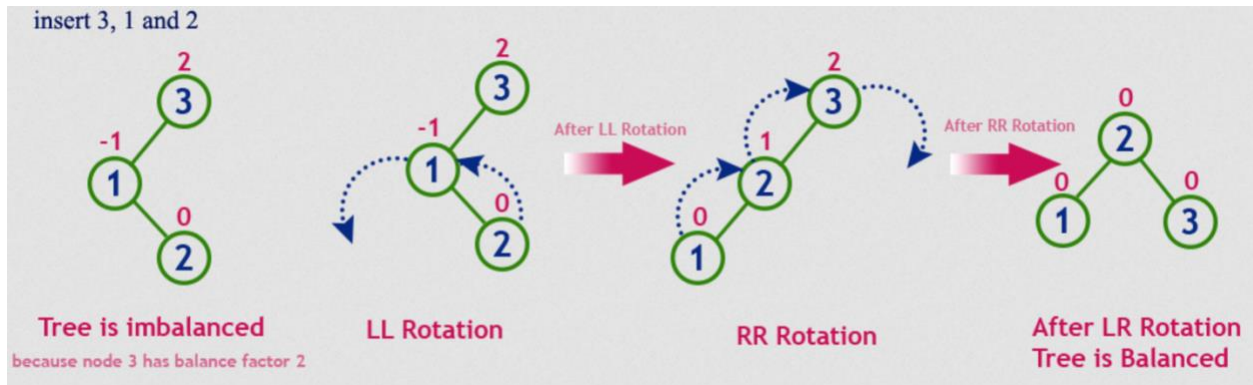RR Rotation which moves
nodes one position to right

After RR Rotation
Tree is Balanced

Double Tree Rotation:
- Left Heavy Tree has right subtree
- Right Heavy Tree has left subtree

Left Right Rotation (LR Rotation): The LR Rotation is a sequence of single left rotation followed by a single right rotation. In LR Rotation, at first, every node moves one position to the left and one position to right from the current position.

Right Left Rotation (RL Rotation): The RL Rotation is sequence of single right rotation followed by single left rotation. In RL Rotation, at first every node moves one position to right and one position to left from the current position.