4. Trees

4.4 AVL Trees

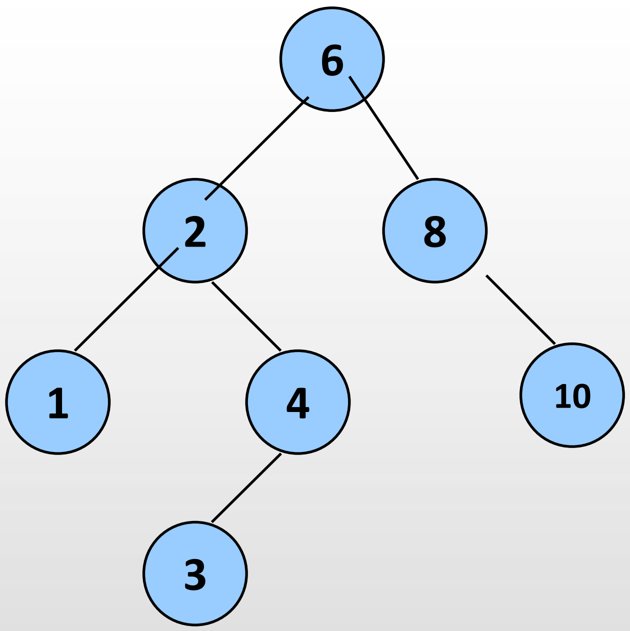
AVL (Adelson-Velskii and Landis) Tree

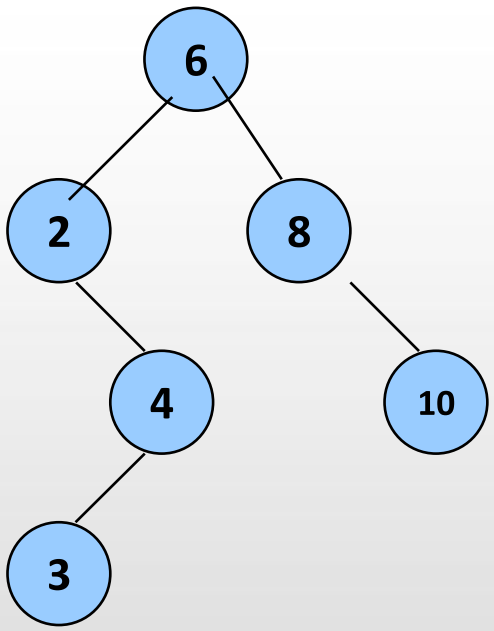
Definition: An AVL tree is a binary search tree wherein the height of the left and right subtrees of every node differs by at most one.

Operations:

- tree operations
- insertion (deletion) uses **rotation**

AVL vs non-AVL



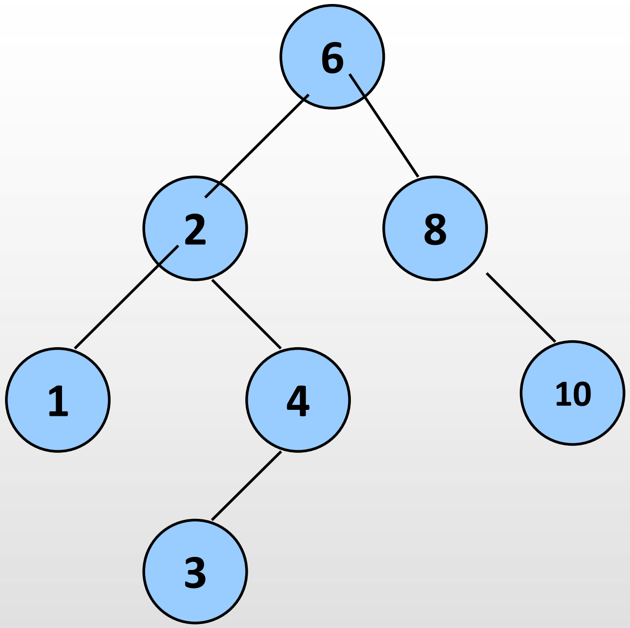


Which is (not) an AVL tree?

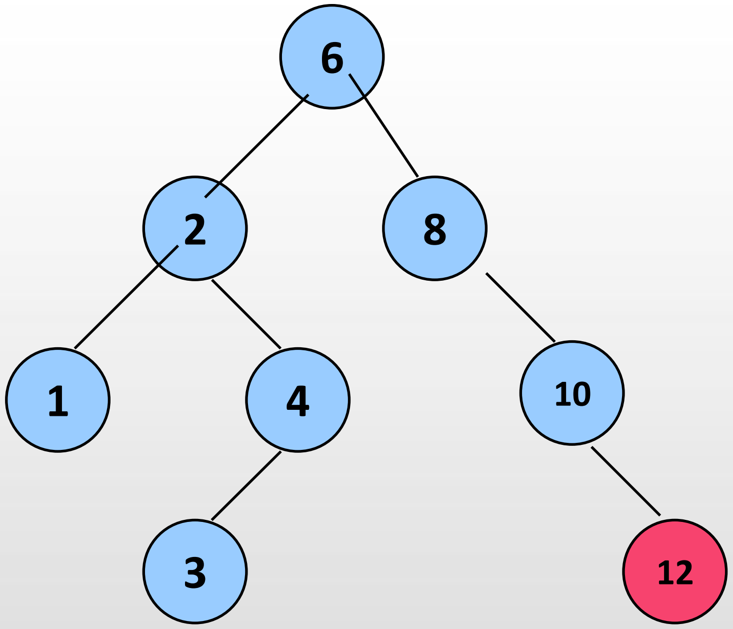
AVL Tree

```
typedef struct node{
  int value;
  int height;
  struct node *left;
  struct node *right;
  struct node *parent;
}AVL;
```

AVL Insertion



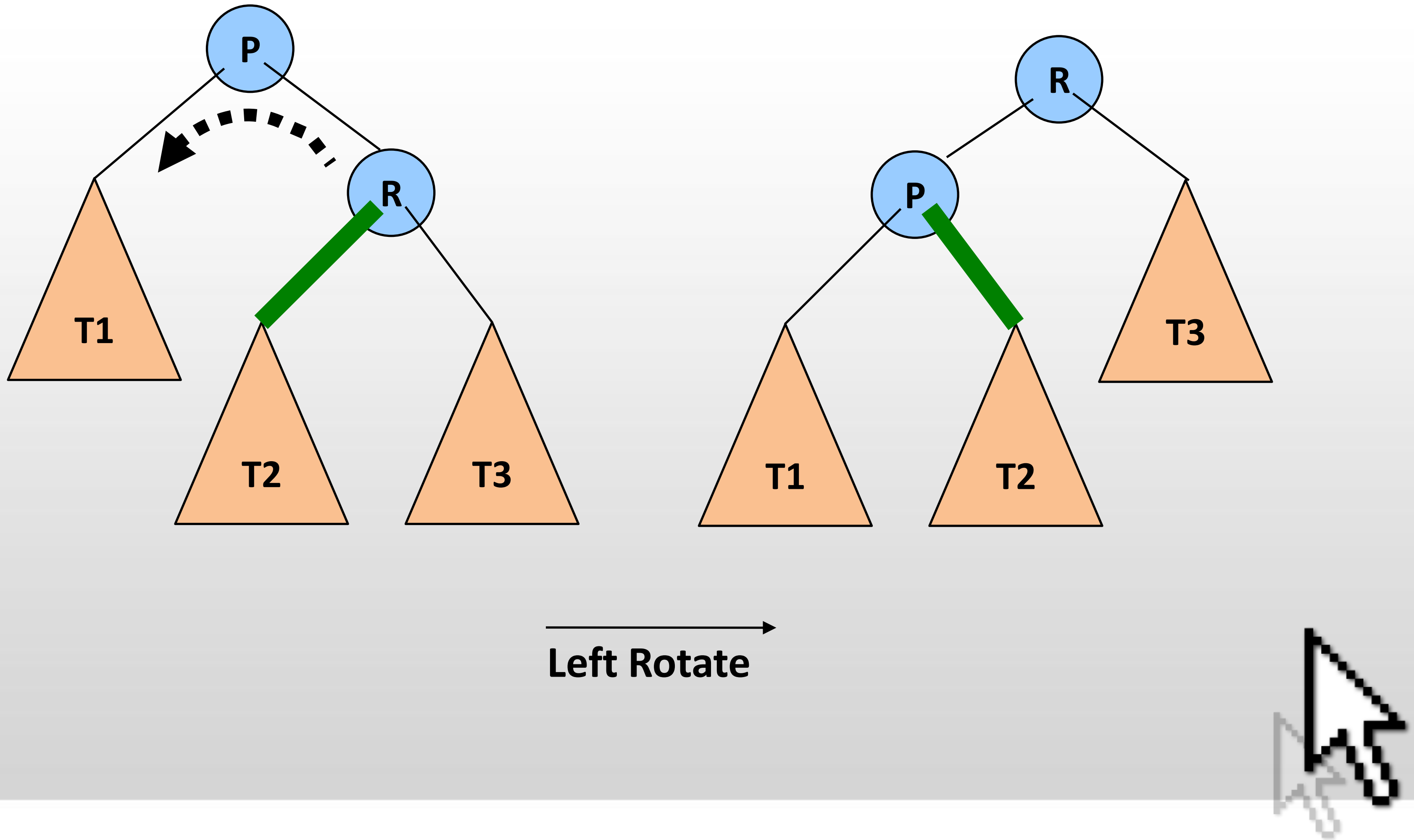
AVL Insertion



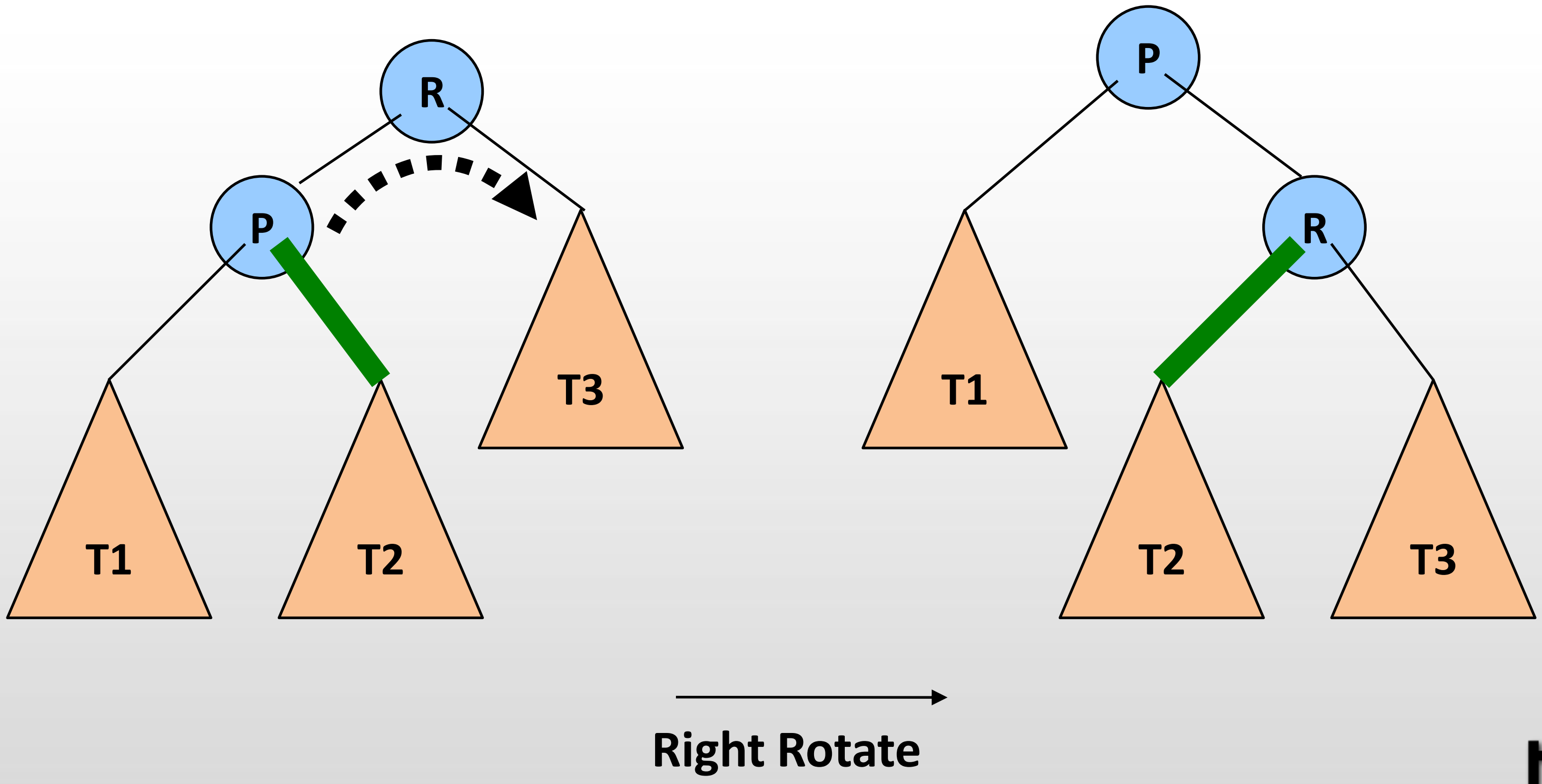
Insert Operation

- Single rotation
  - Left rotate
  - Right rotate
- Double rotation
  - Left-right rotate
  - Right-left rotate

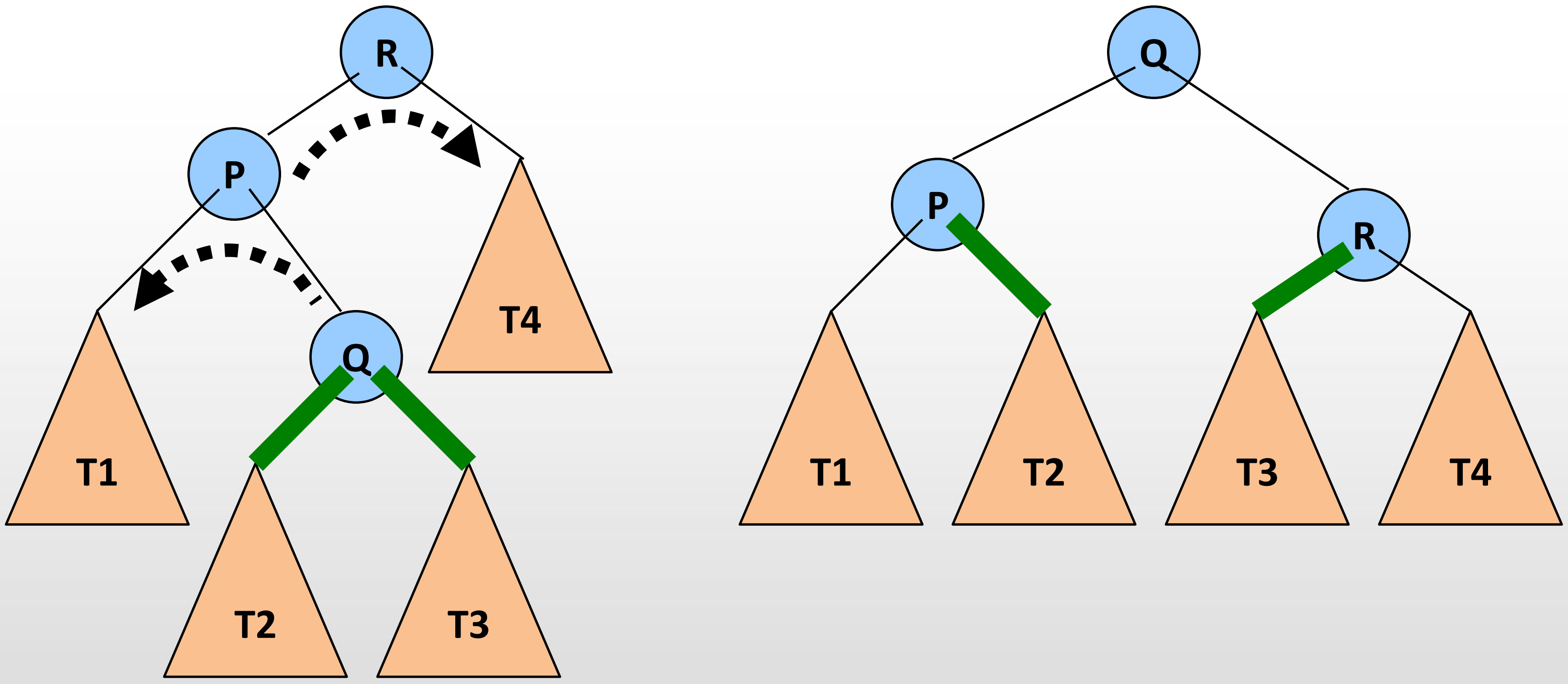
Single Rotation



Single Rotation



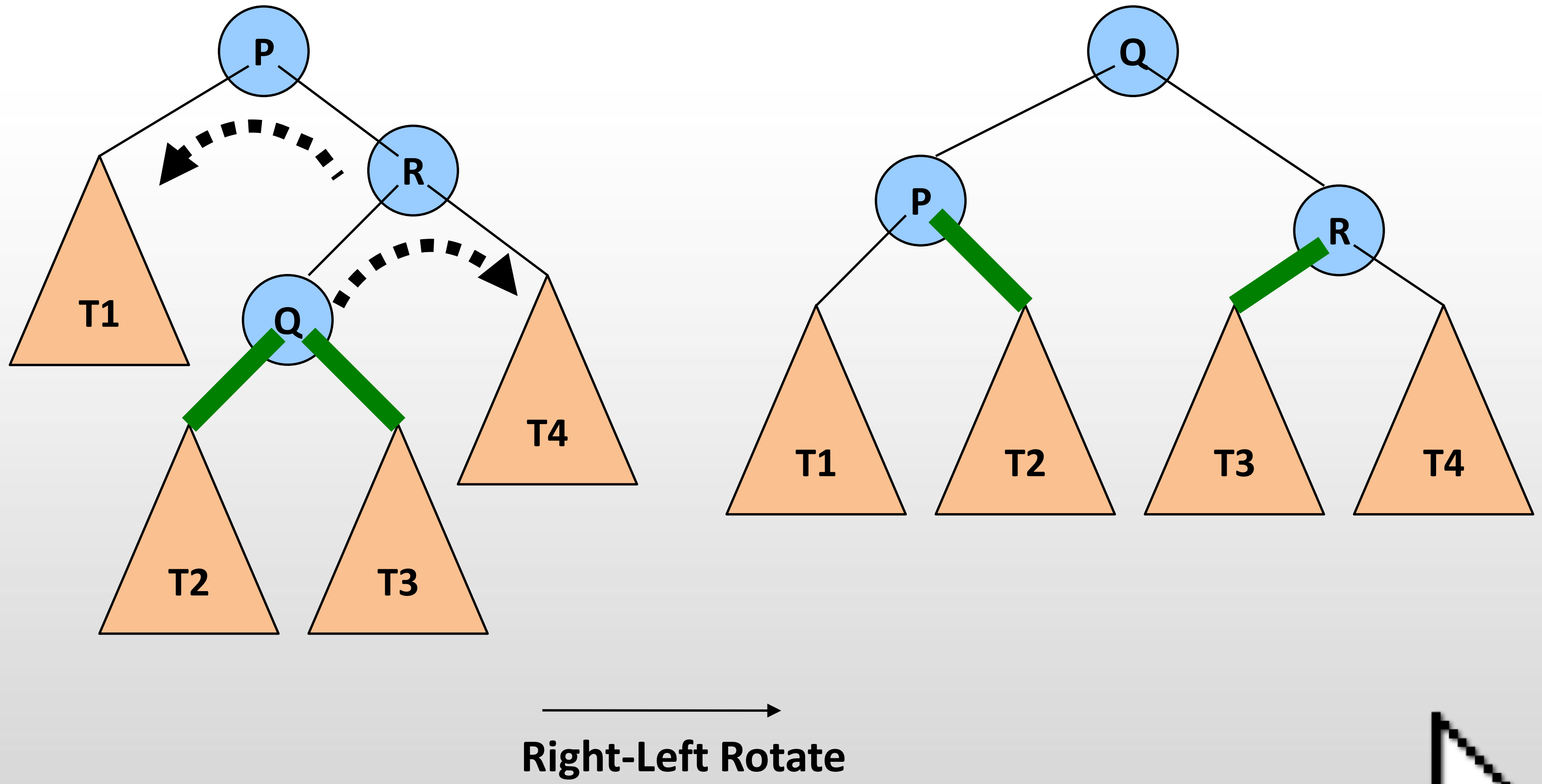
Double Rotation



$\longrightarrow$

Left-Right Rotate

Double Rotation



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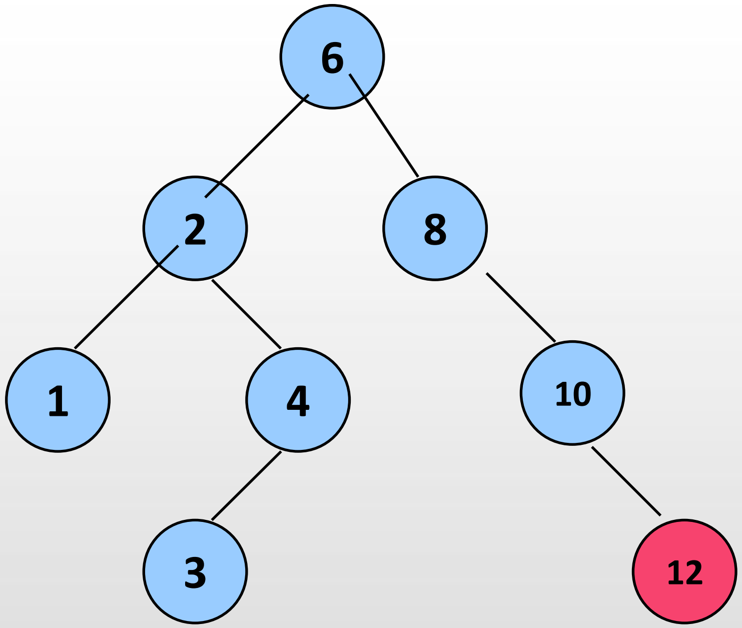

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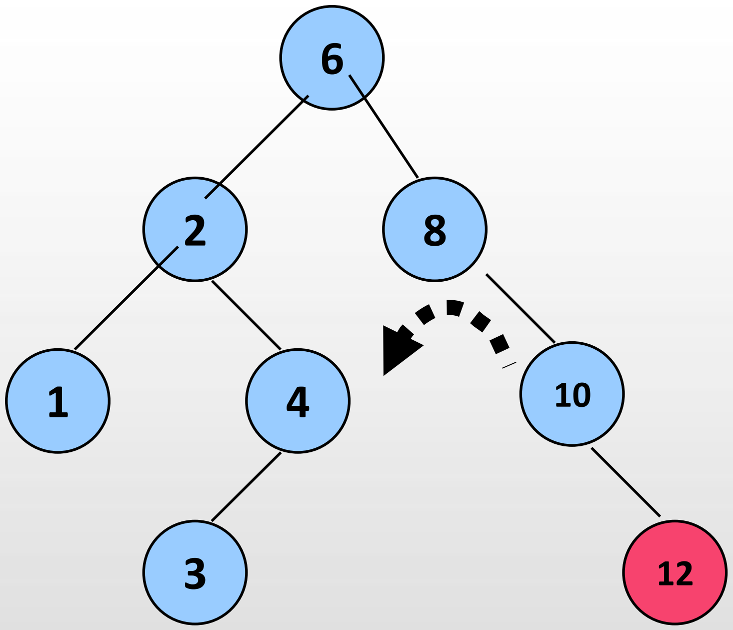

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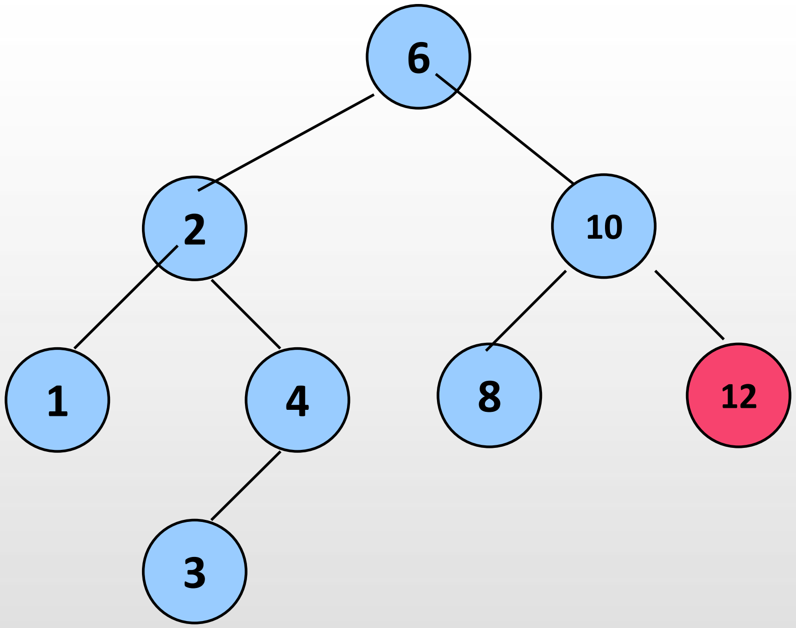
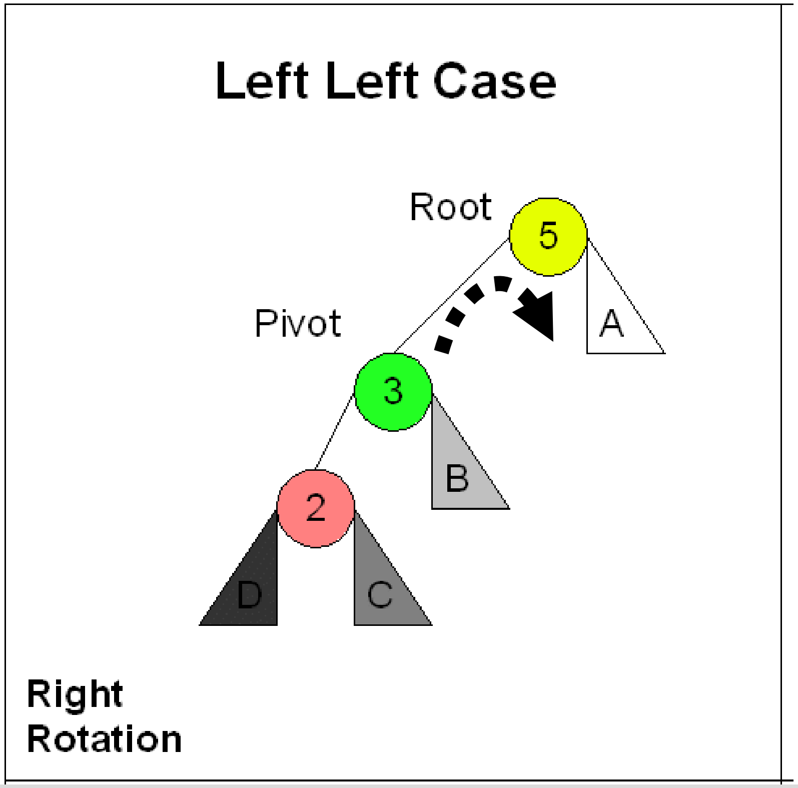
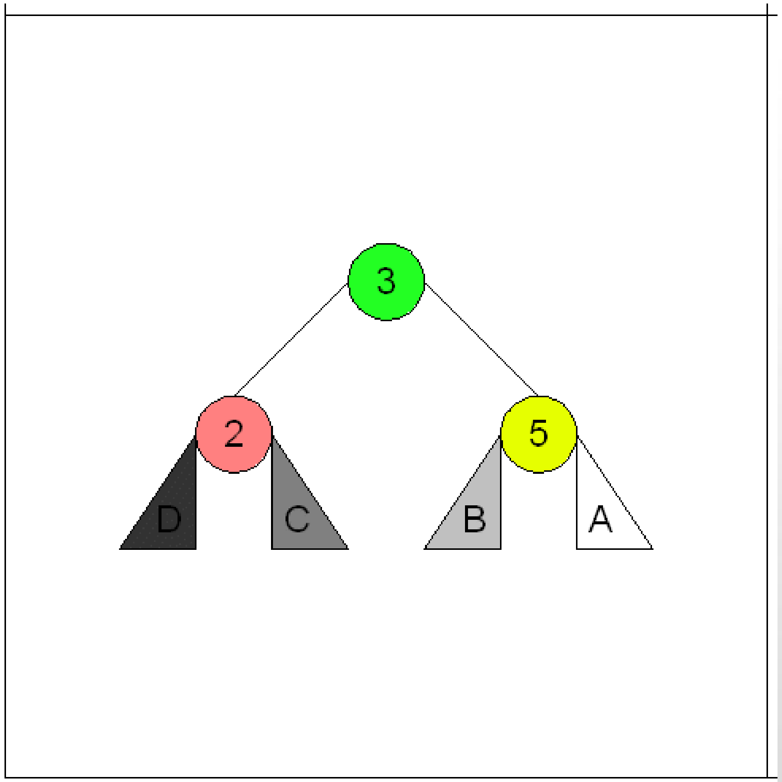


AVL Insertion Guide





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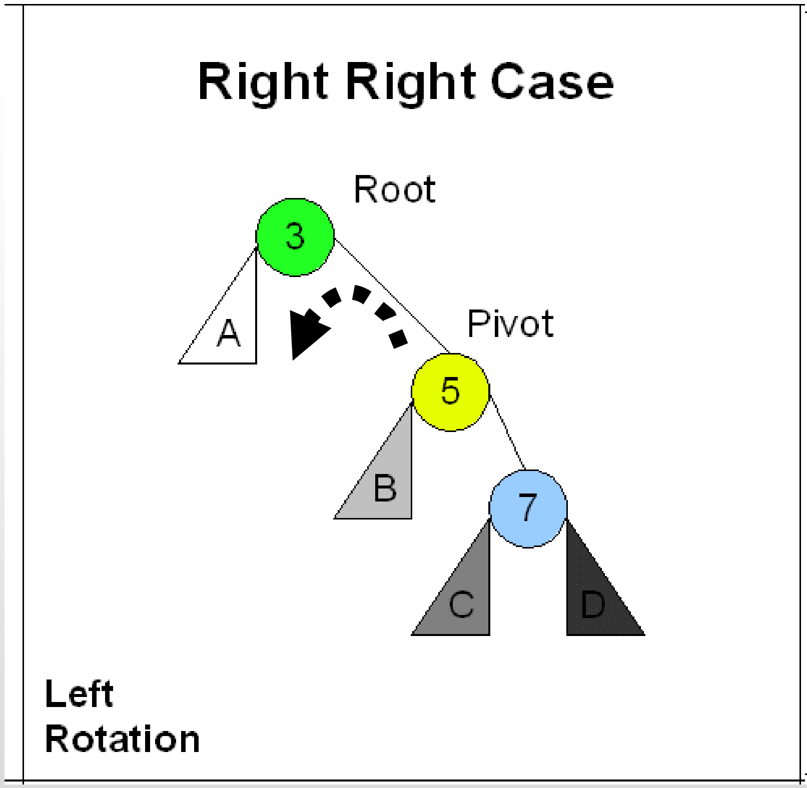

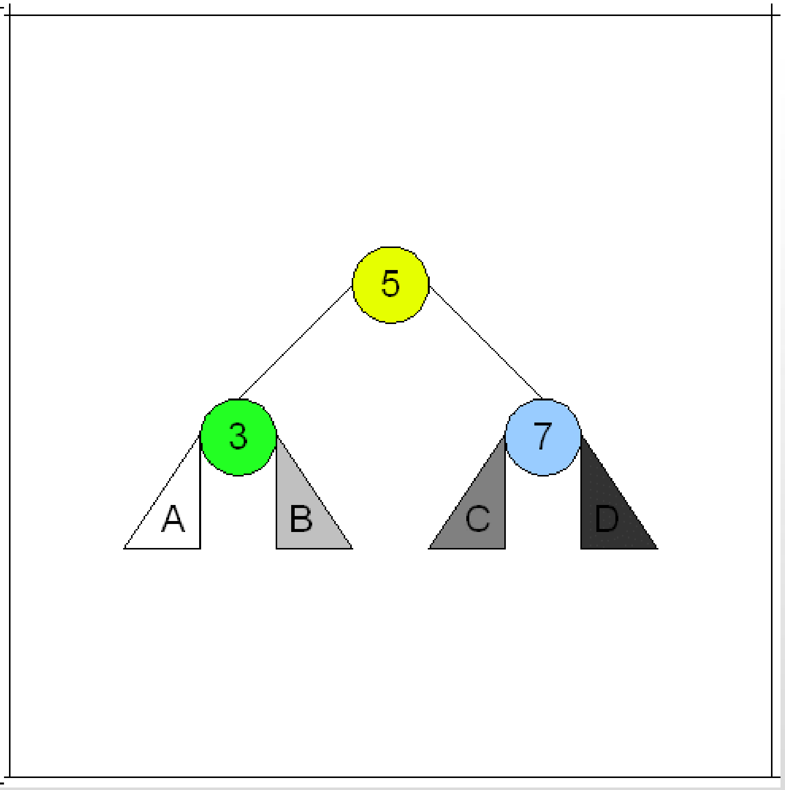

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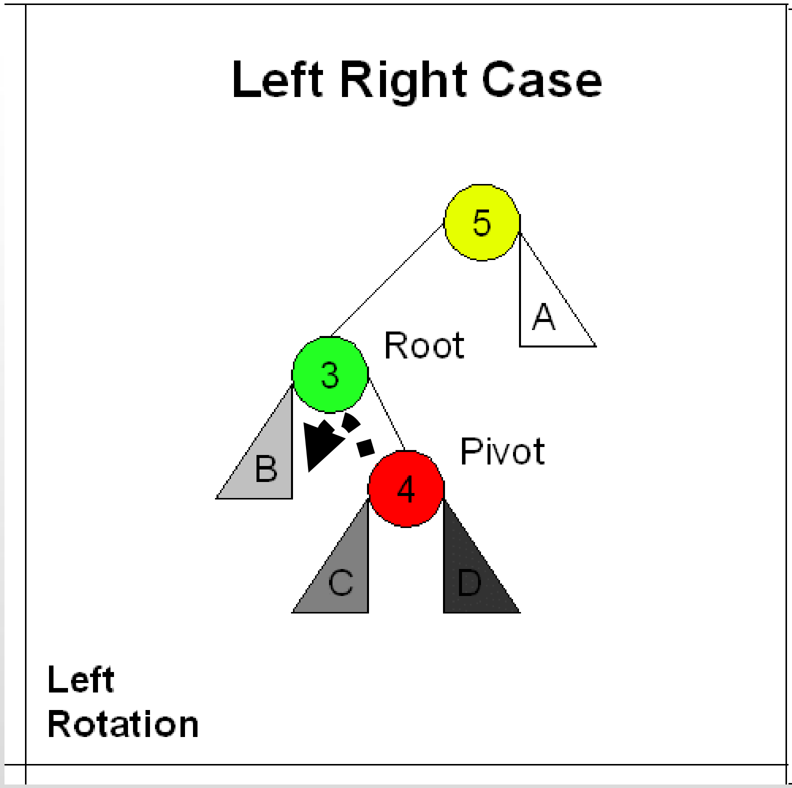

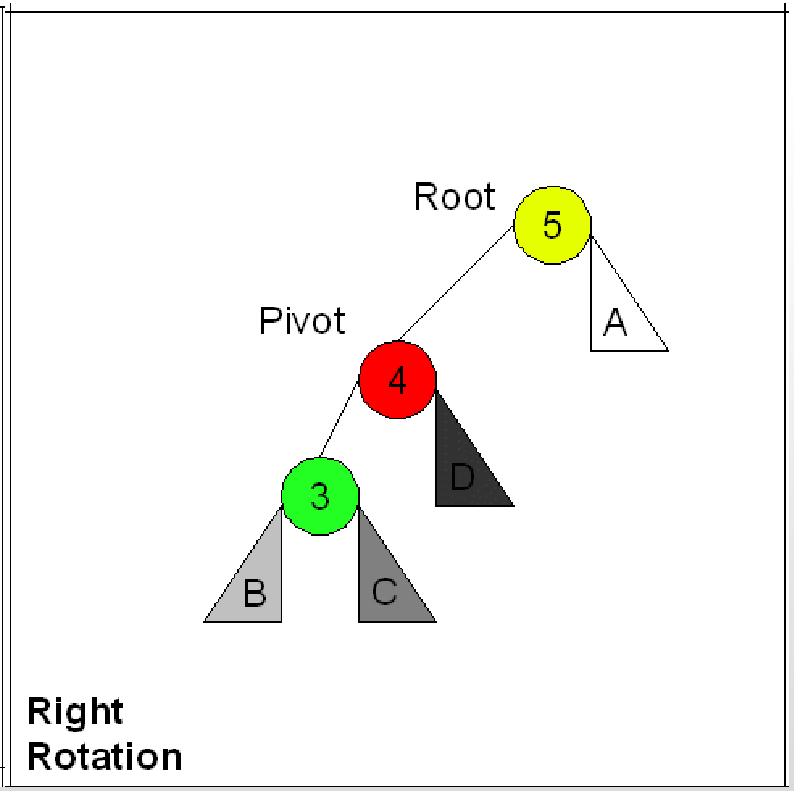

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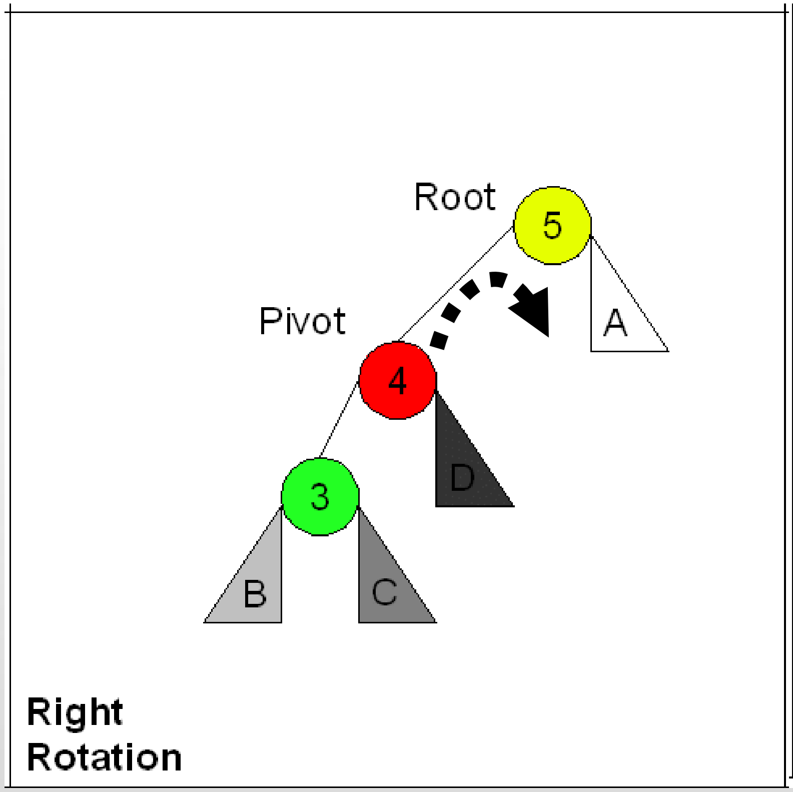
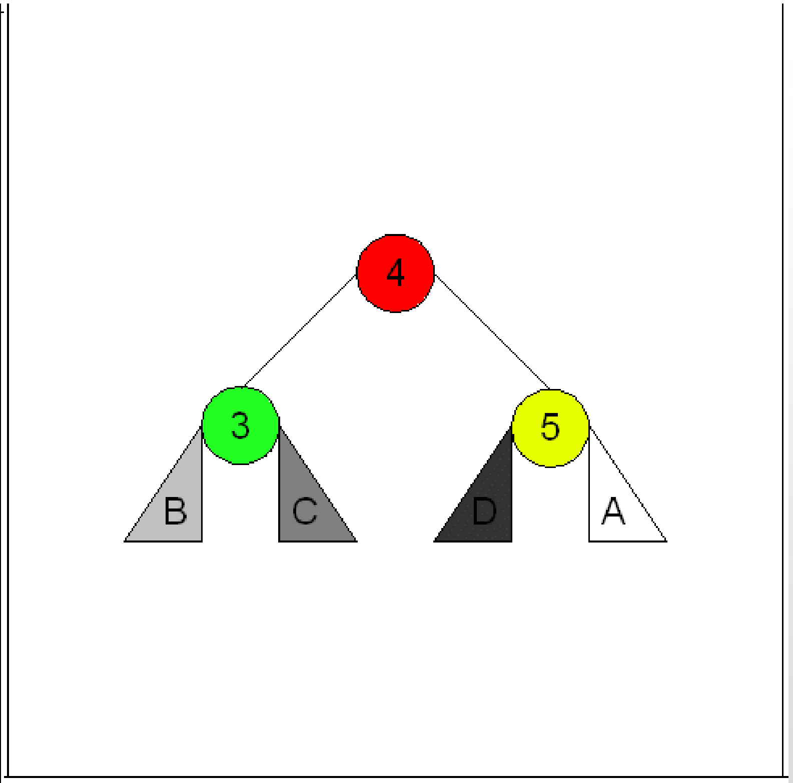


Right Rotation



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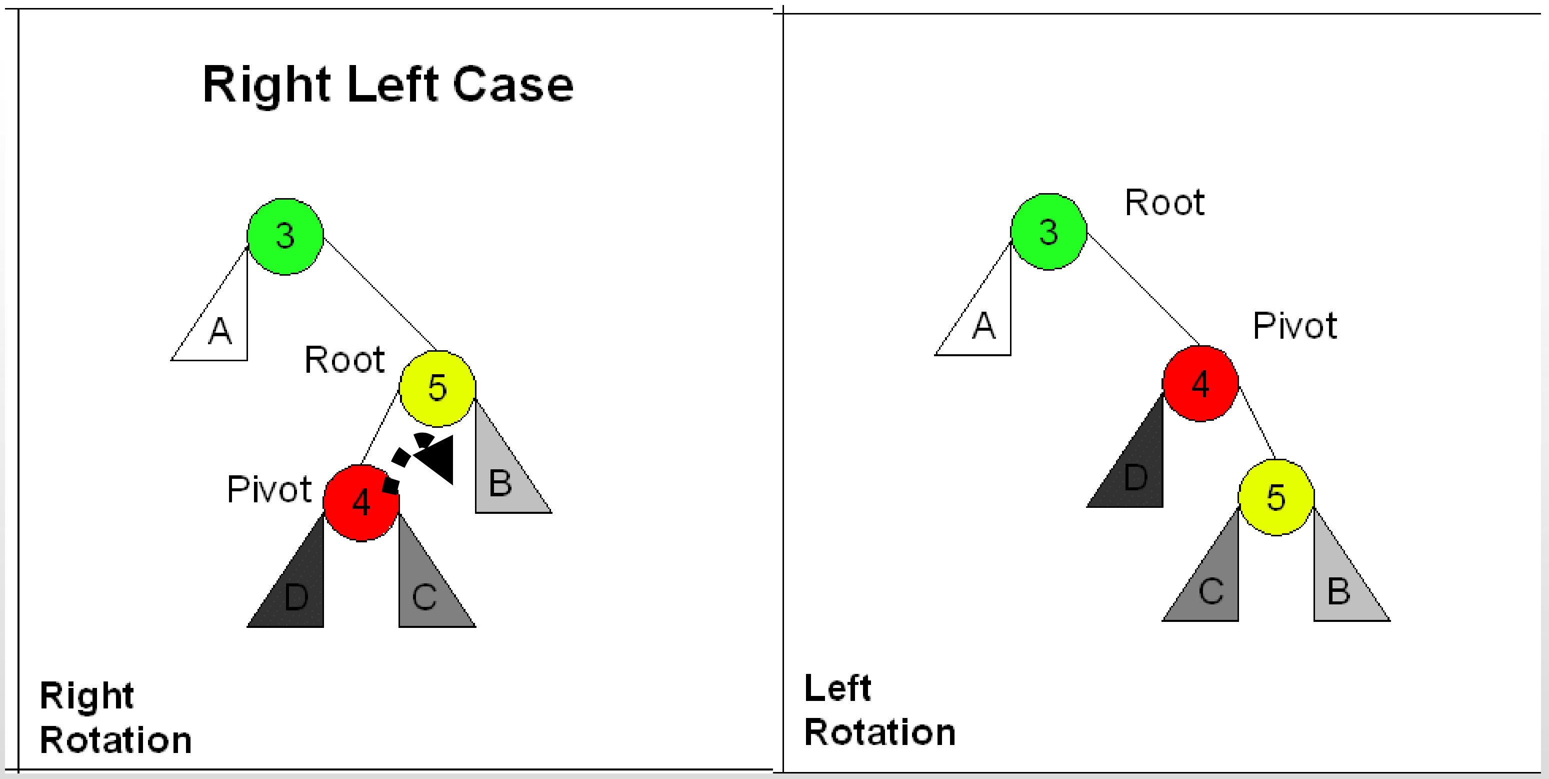

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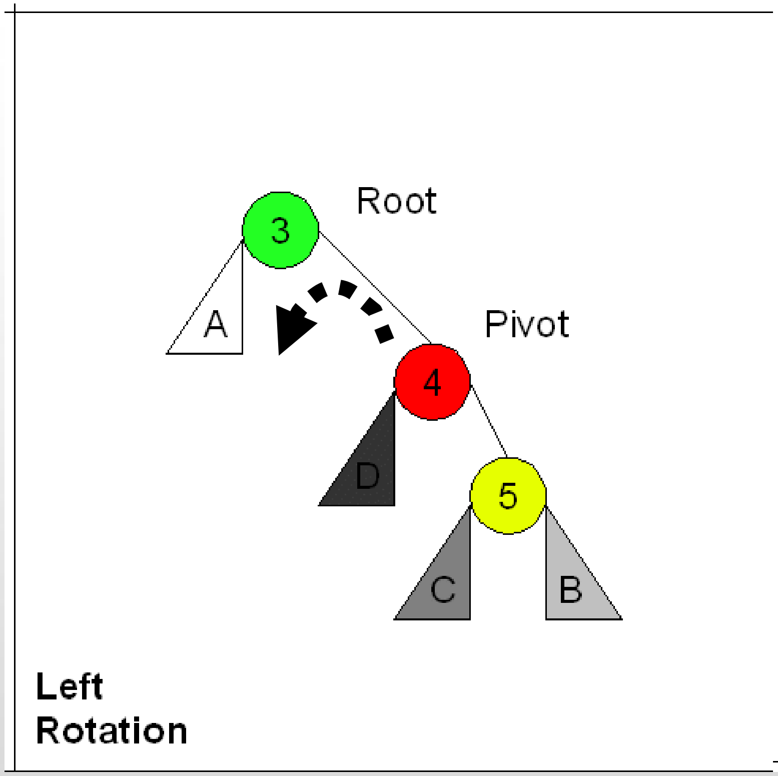

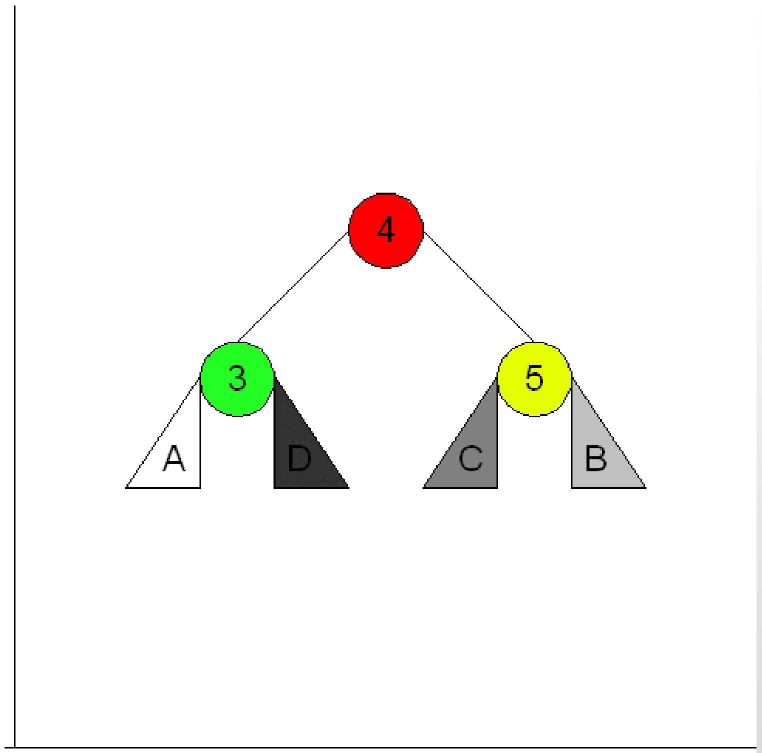

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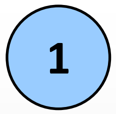

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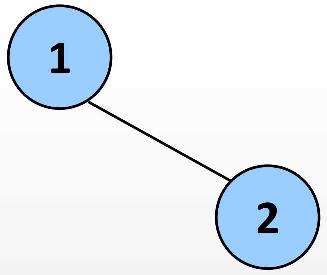

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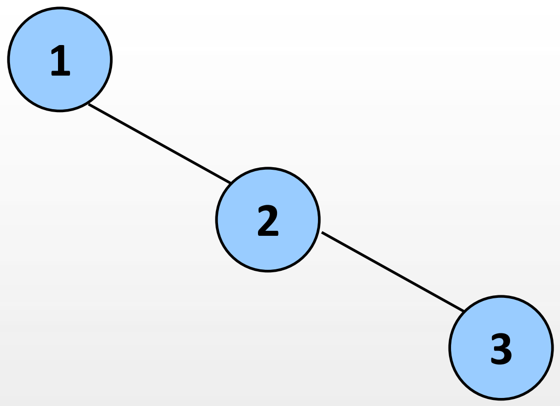

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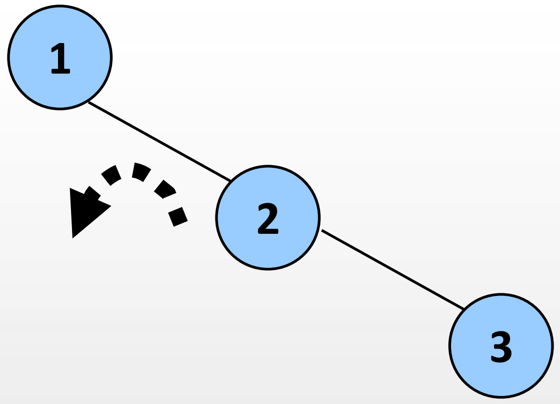

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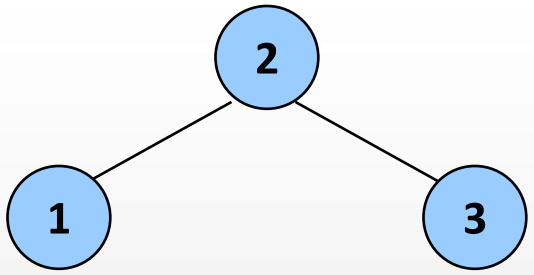

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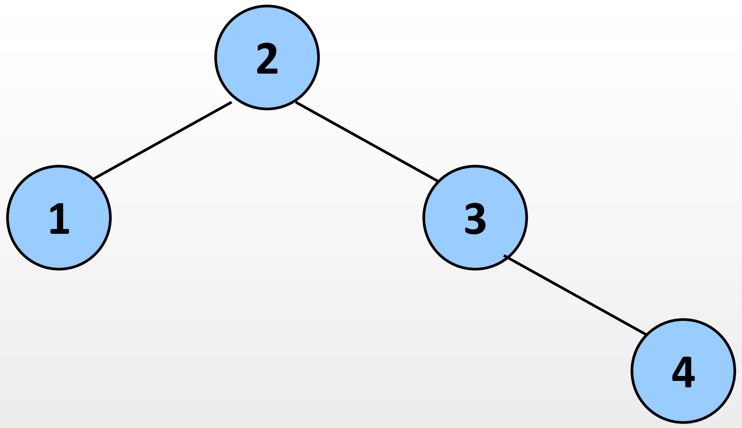

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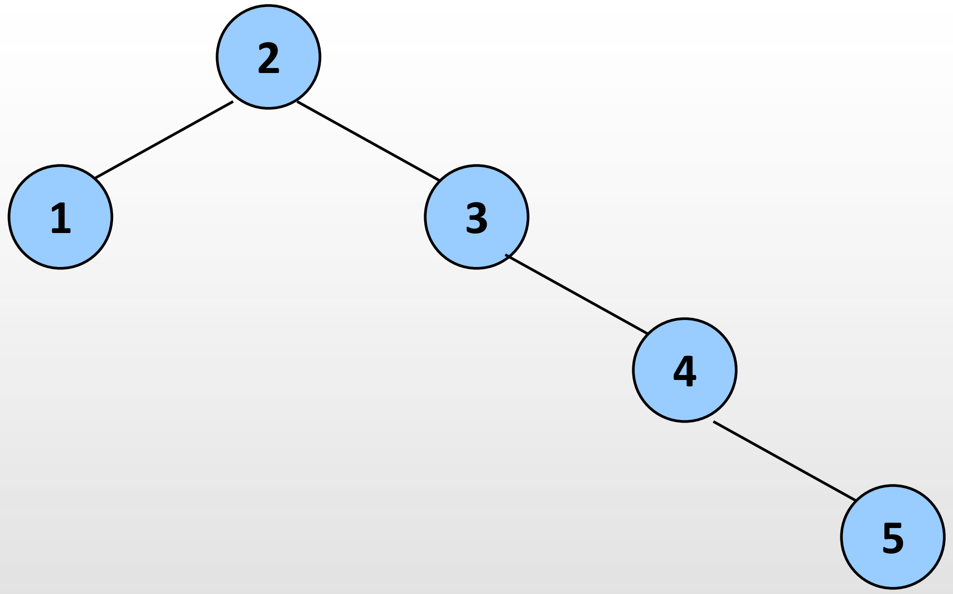

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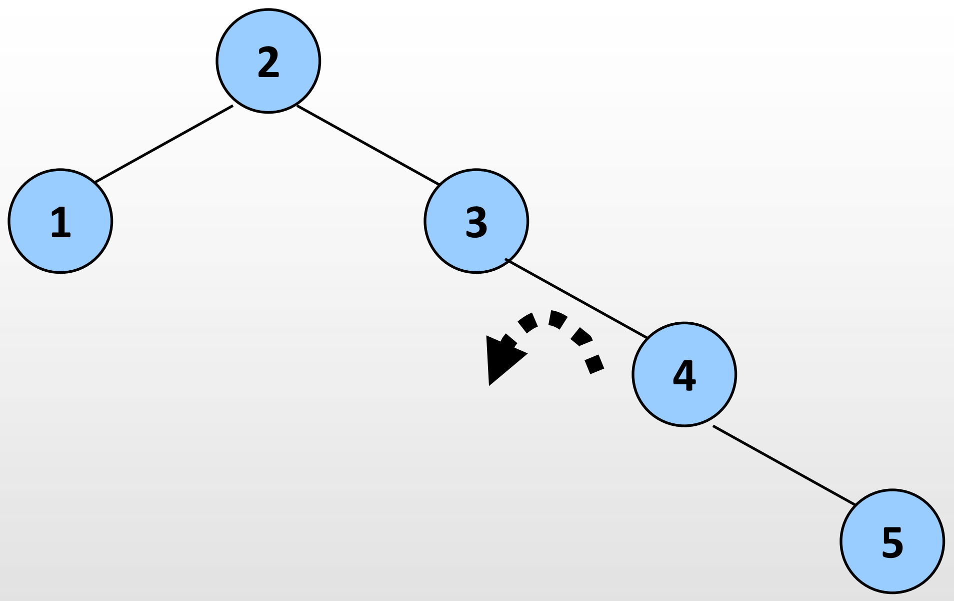

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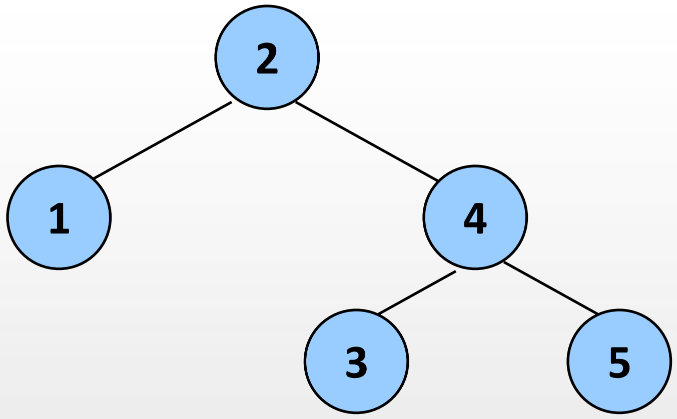

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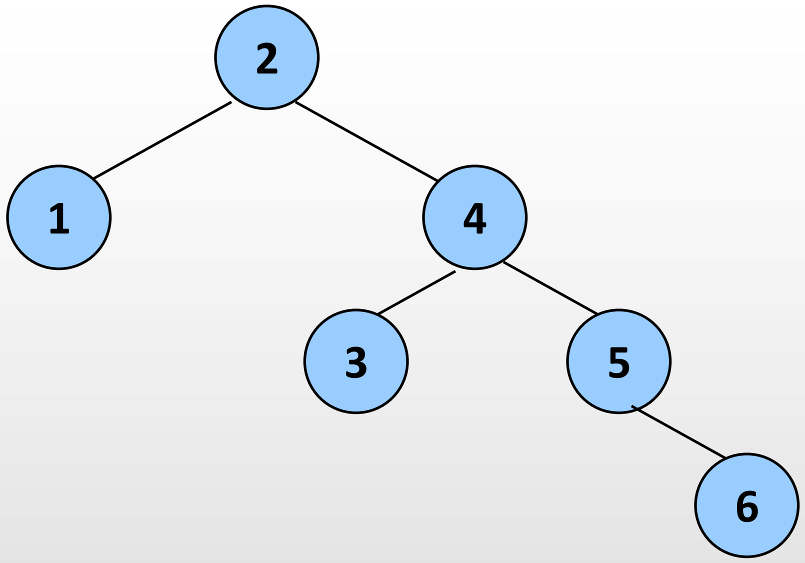

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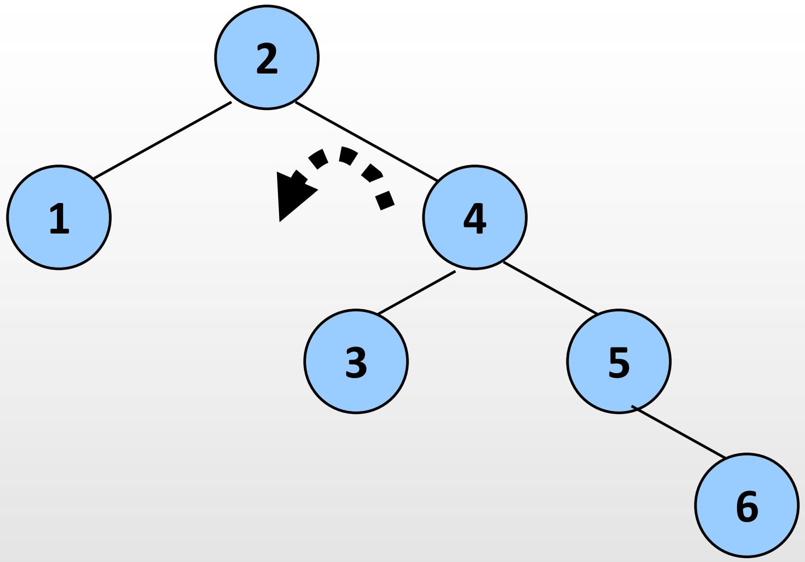

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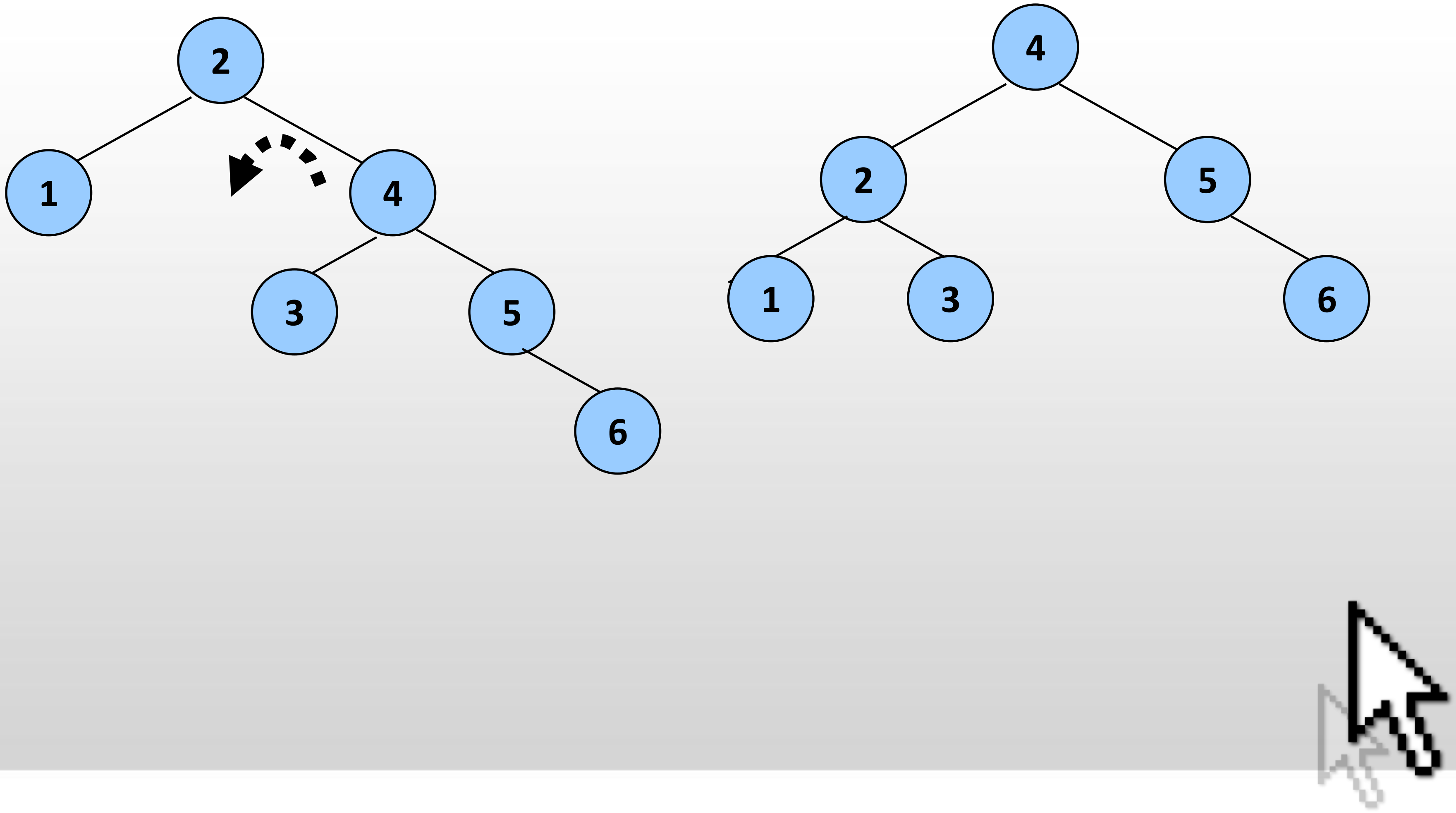

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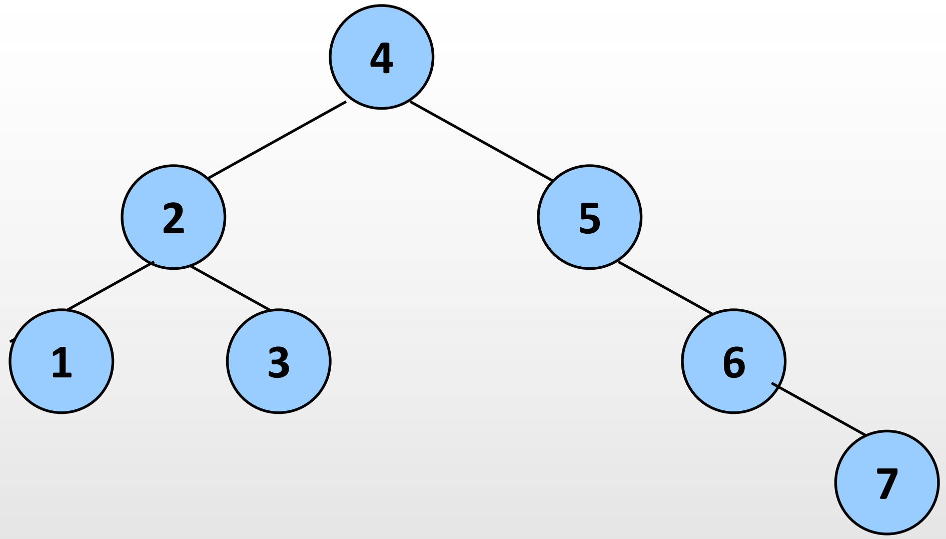

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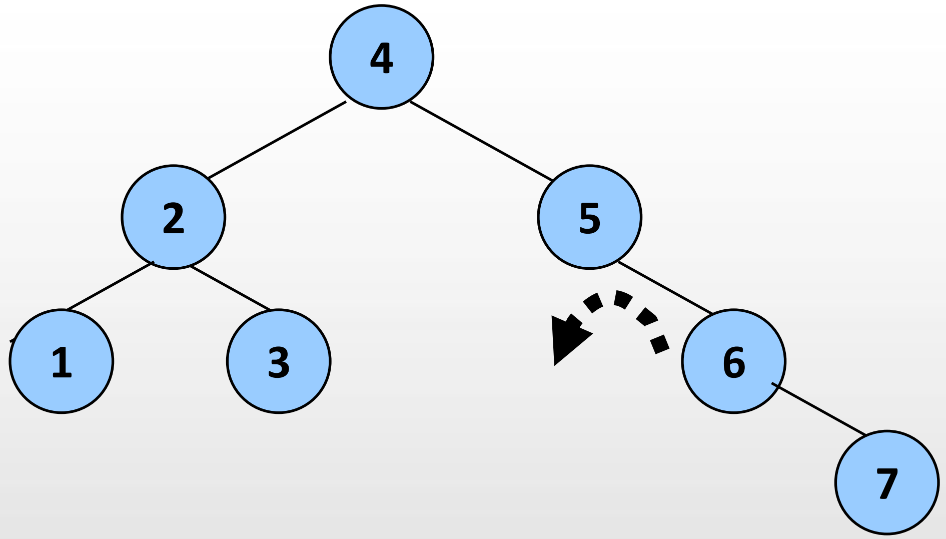

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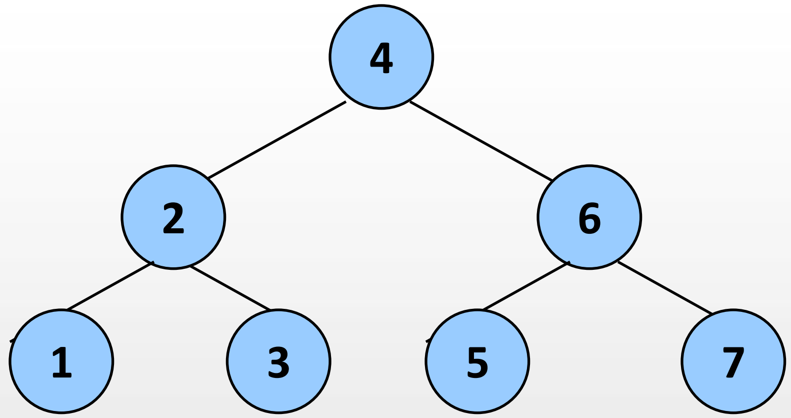

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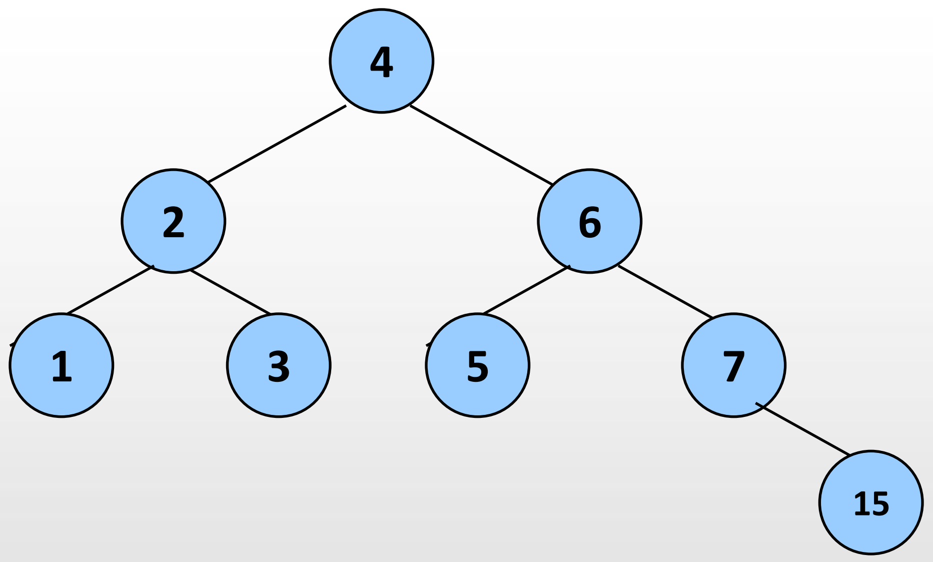

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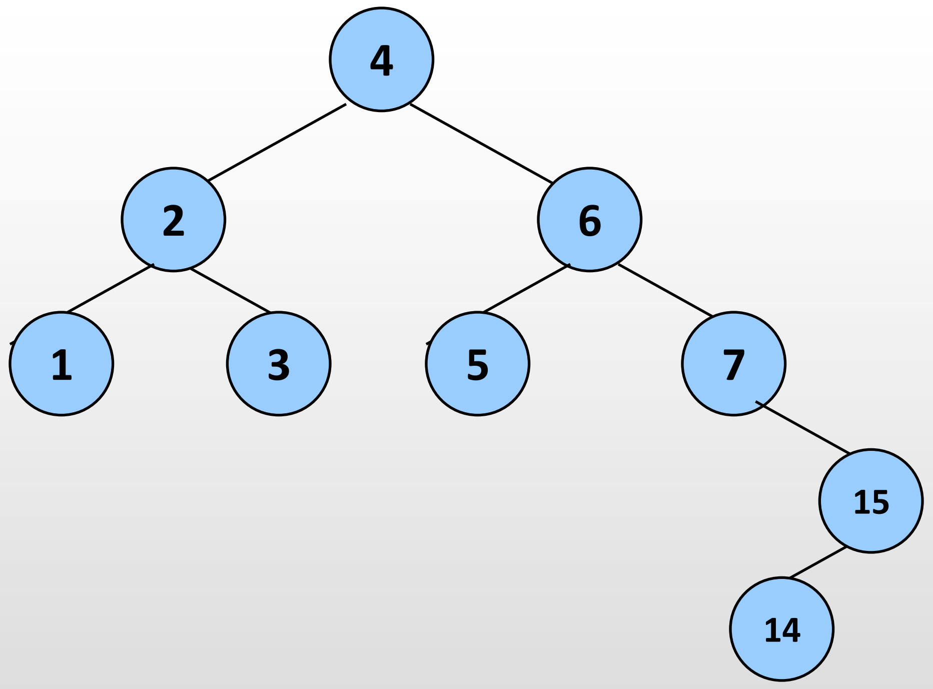

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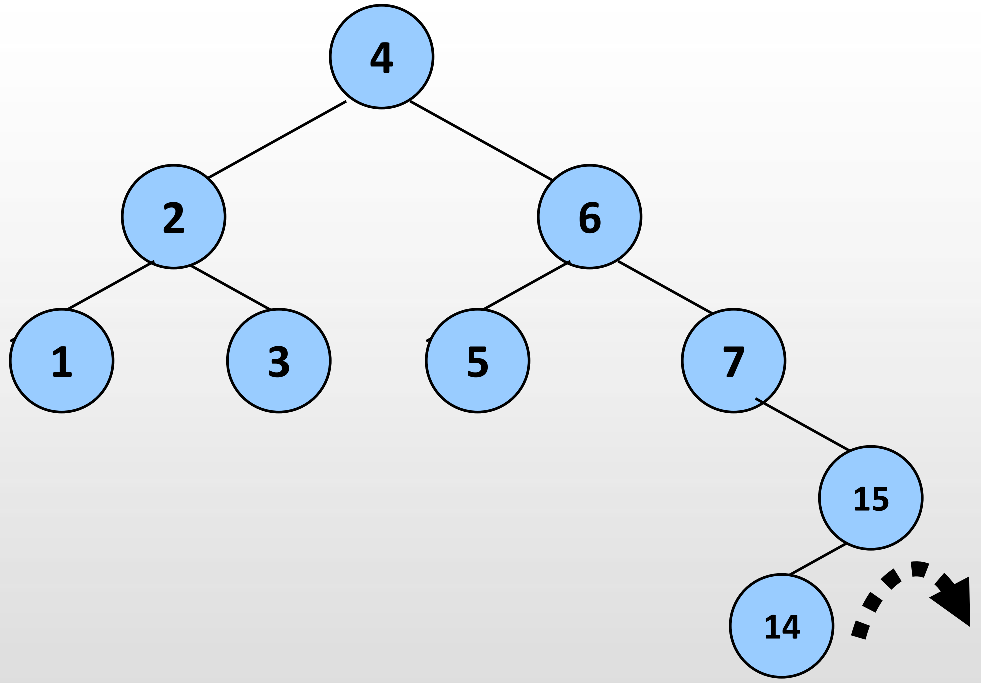

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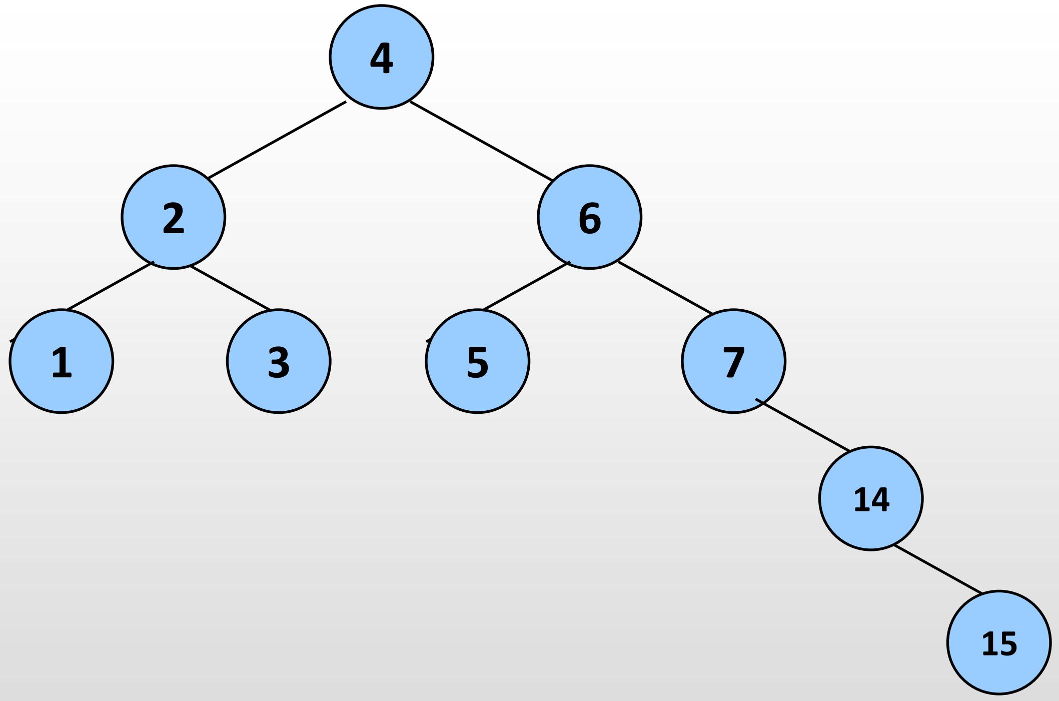

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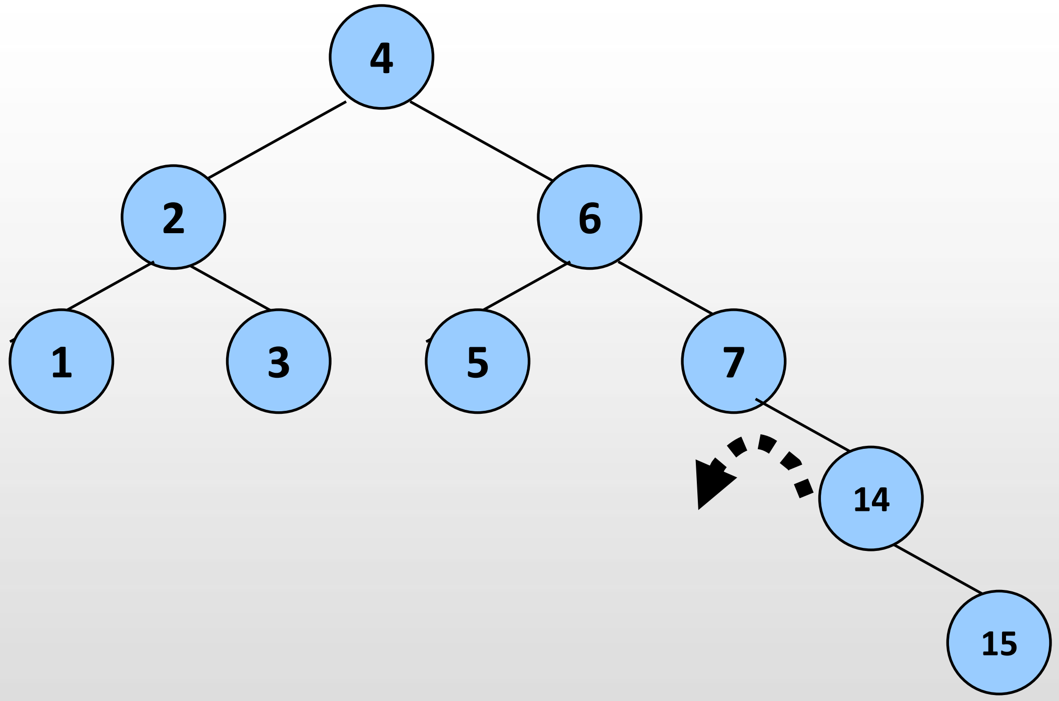

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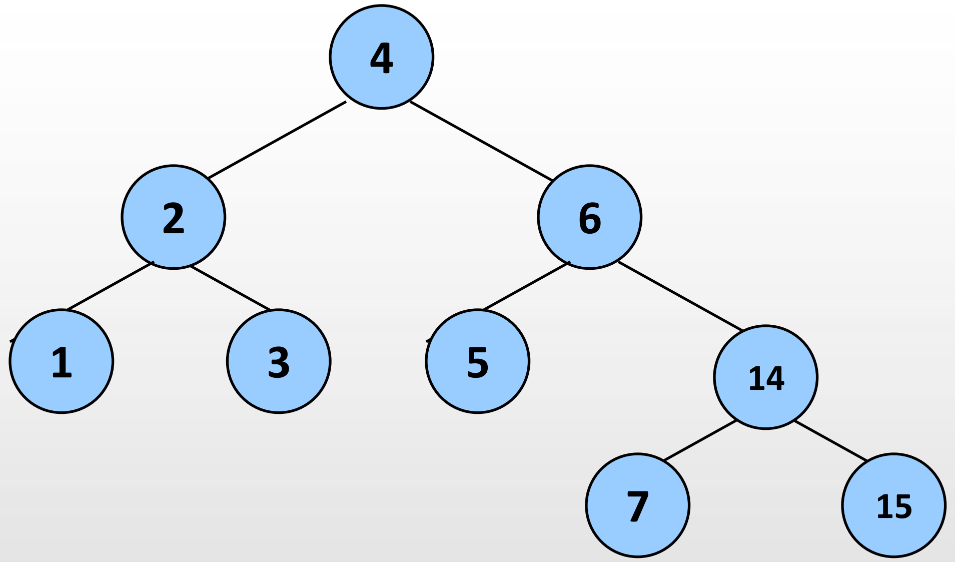

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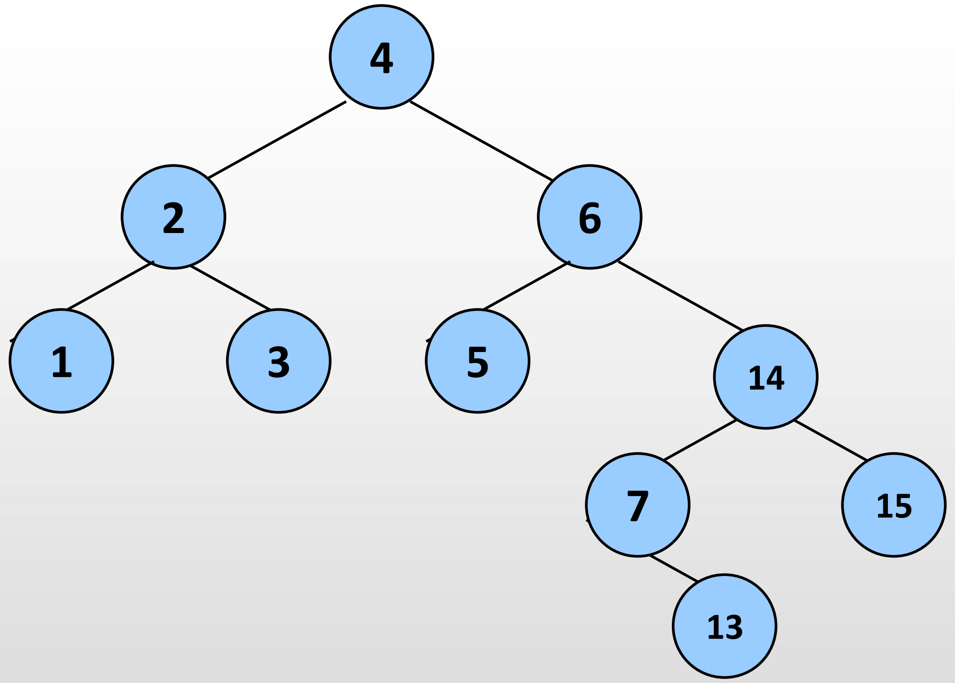

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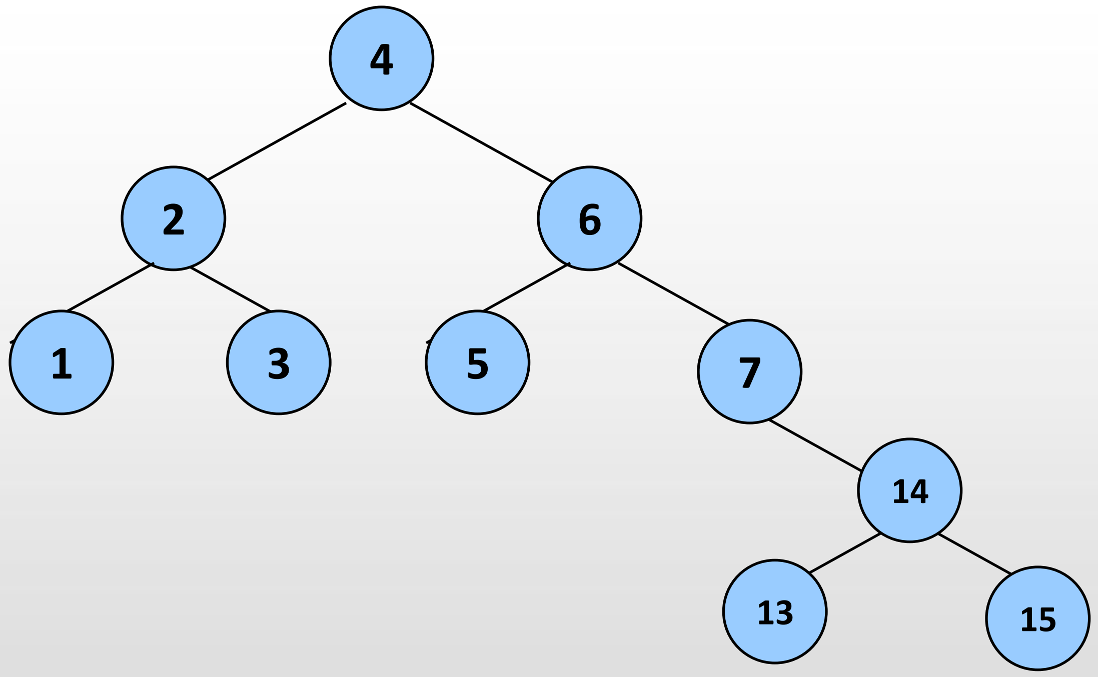

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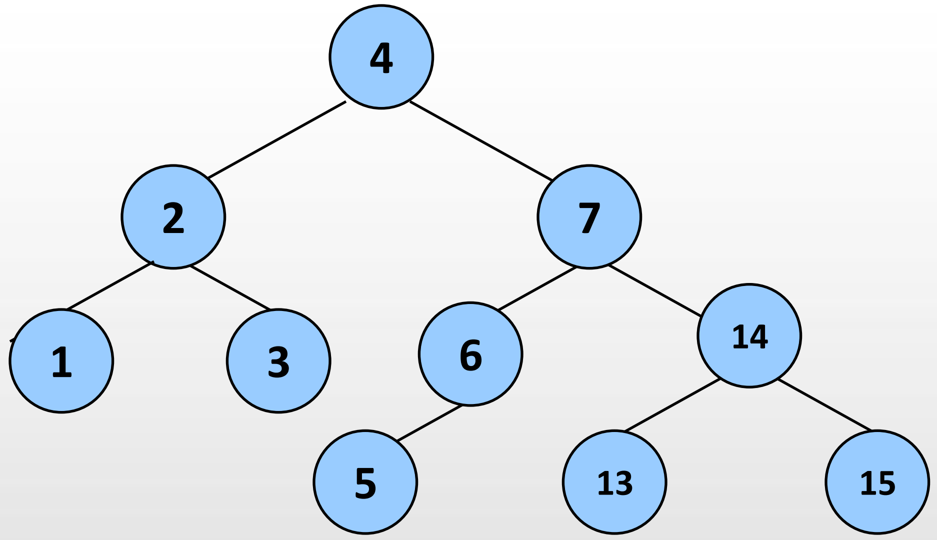

AVL Deletion

- If the node is a leaf, remove it.
- If the node is not a leaf, replace it with either the largest in its left subtree (inorder predecessor) or the smallest in its right subtree (inorder successor), and remove that node.
- The node that was found as replacement has at most one subtree.
- After deletion, retrace the path back up the tree (parent of the replacement) to the root, adjusting the balance factors as needed.