CS202 – Data Structures

LECTURE-10

Balanced Binary Search Trees (AVLs)

Maintaining a balance

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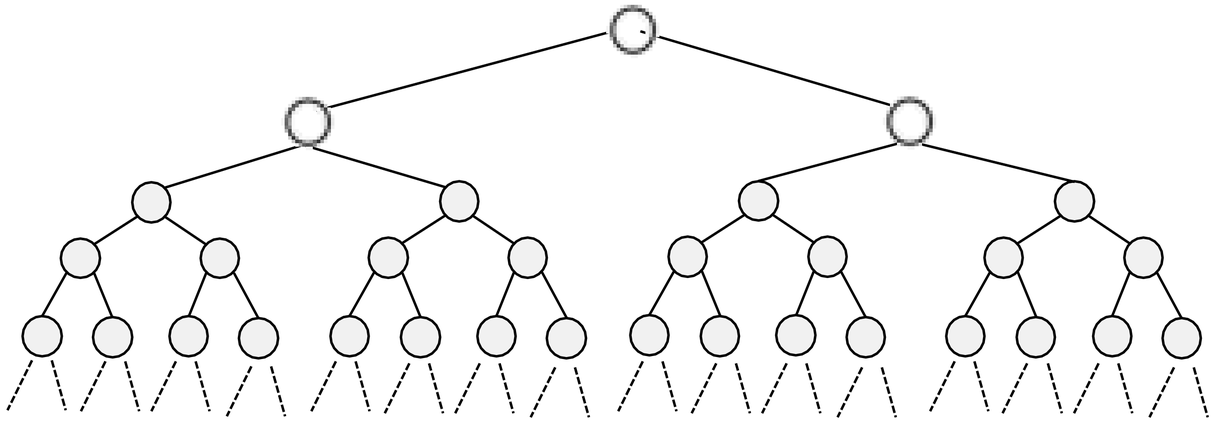
Agenda

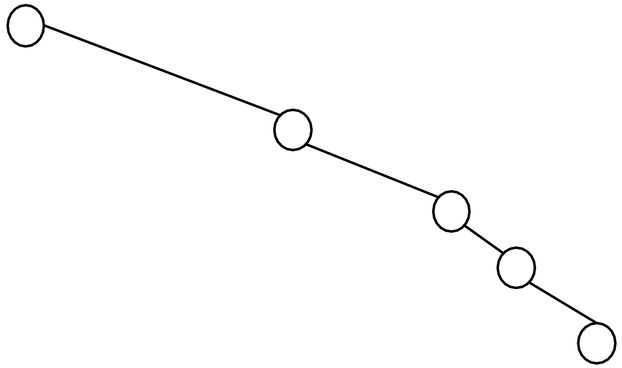
- Why Balance is important?
- Balanced Binary Search Trees

Importance of Balance

- Highly inefficient for unbalanced tree



VS



Perfectly Balanced BST

Unbalanced BST

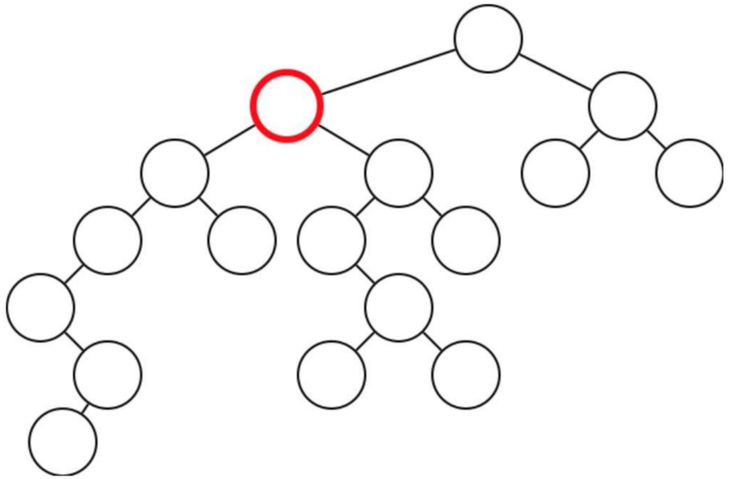
How to Ensure Balance?

Idea: Rearrange tree to maintain balance

Problem: How do we rearrange tree while maintaining the BST property?

How Can We Ensure Balance?

- Rearrange the tree while ensuring BST property
  - Using height of the nodes



- Height

```
If n is a leaf node
   return 0 //n→height = 0
else
   return 1 + max(height(n→right),height(n→left))
```

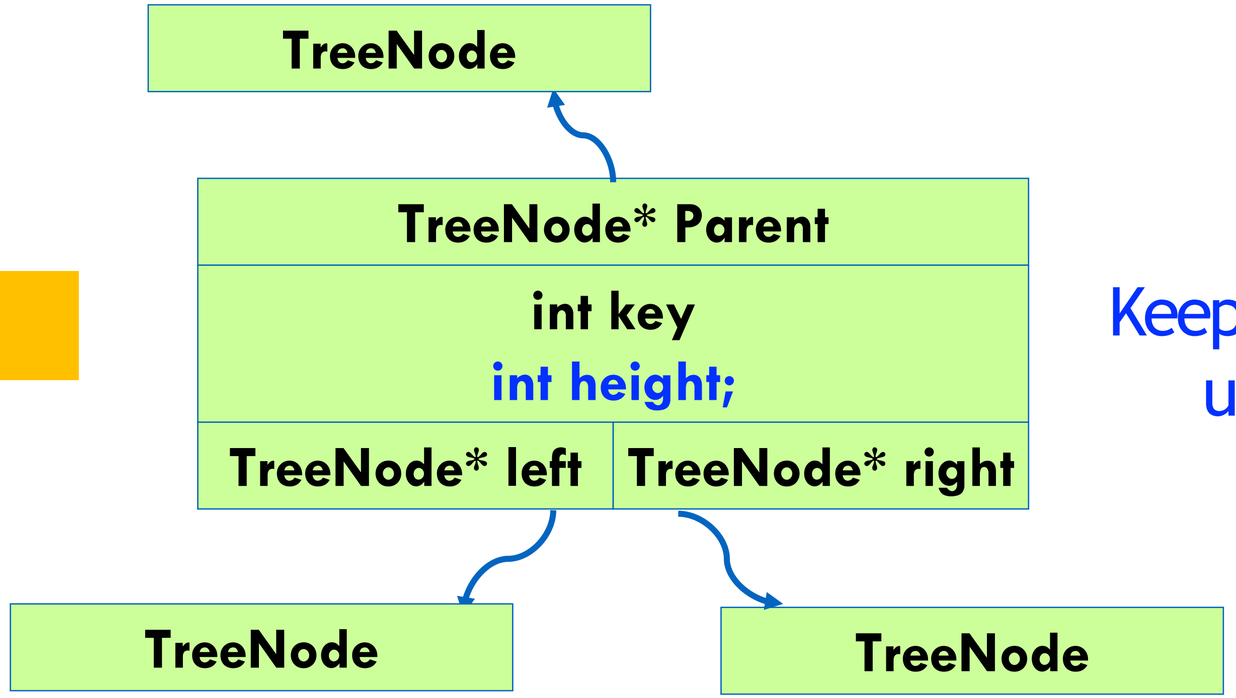
Different Views for Maintaining Balance

- Height-view
  - Balance is maintained if the height is O(log n)

- Size-view
  - Balance can be maintained, if the size of left subtree and right subtree is similar

Modified Binary Tree Structure

Binary Tree Node



Keep the height updated!

AVL Property

- AVLS are
  - BSTs that maintain height-balance property

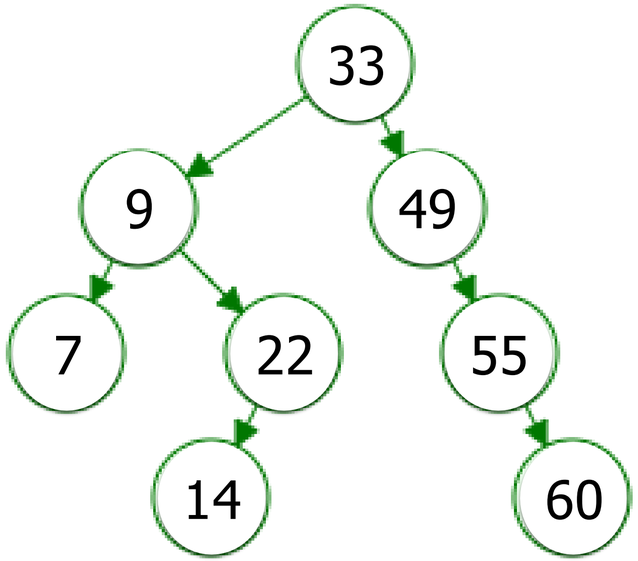
- Height Balance Property
  - For all nodes n,

$$| n\rightarrow left\rightarrow height - n\rightarrow right\rightarrow height | \leq 1$$

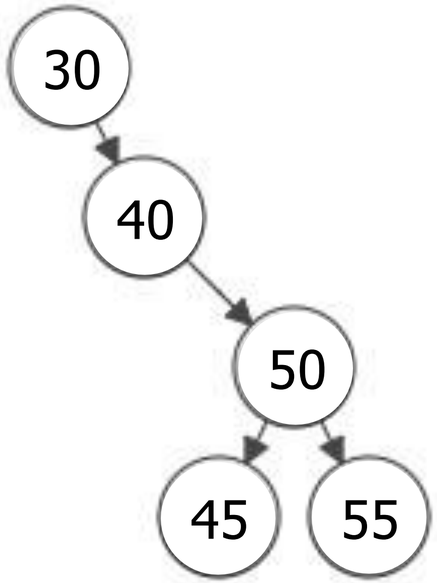
Which of the following are AVLs?

Poll

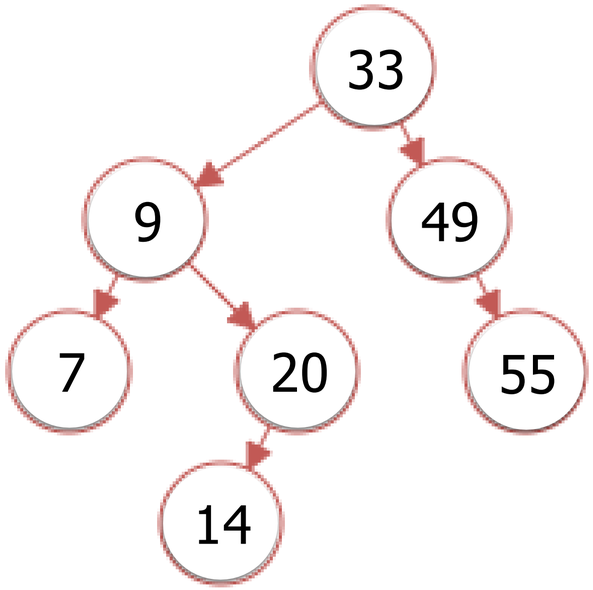
(A)



(B)



(C)



Operations in AVLS

- Search
- Insertion
- Deletion

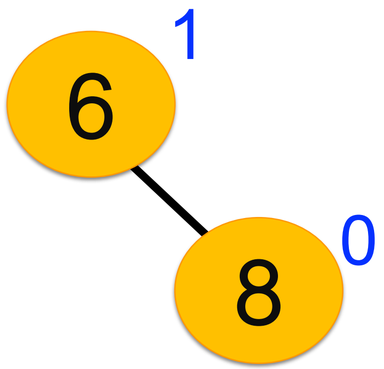
Insertions in AVL

- Insert as in a simple BST
- Work your way up the tree, restoring AVL property
  - Suppose x is the lowest node **violating** the AVL property
    - Ask, "Is x right heavy or left heavy?" then ask, "Is x's child right heavy or left heavy?"

Insertions in Balanced BSTs (AVLs)

Insert 9

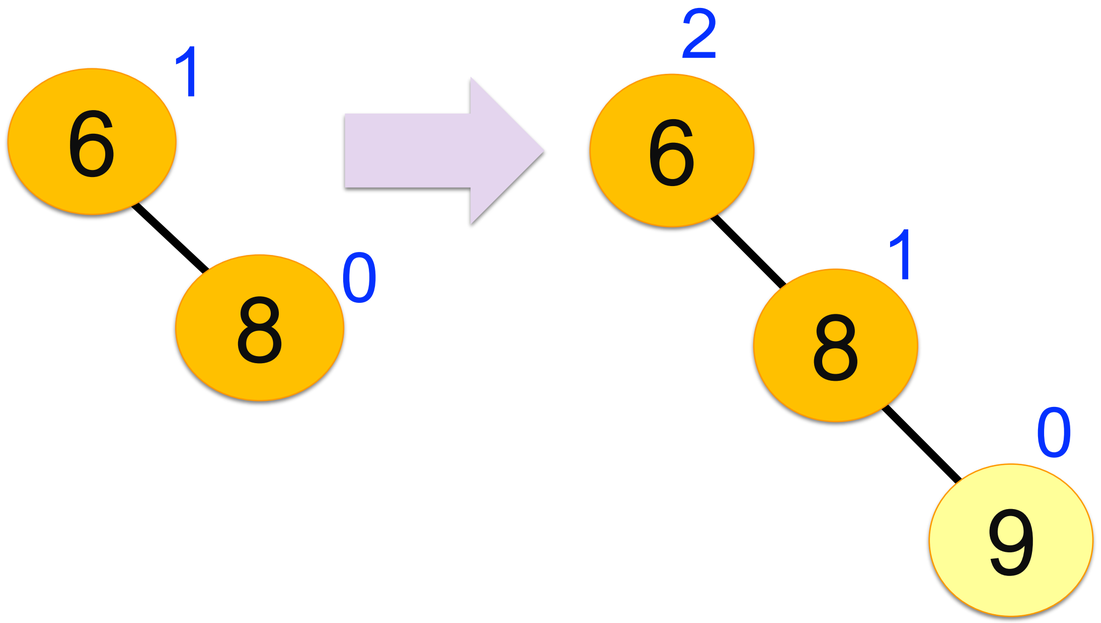
Balance Factor = 1



Insertions in Balanced BSTs (AVLs)

Insert 9

Balance Factor = 2

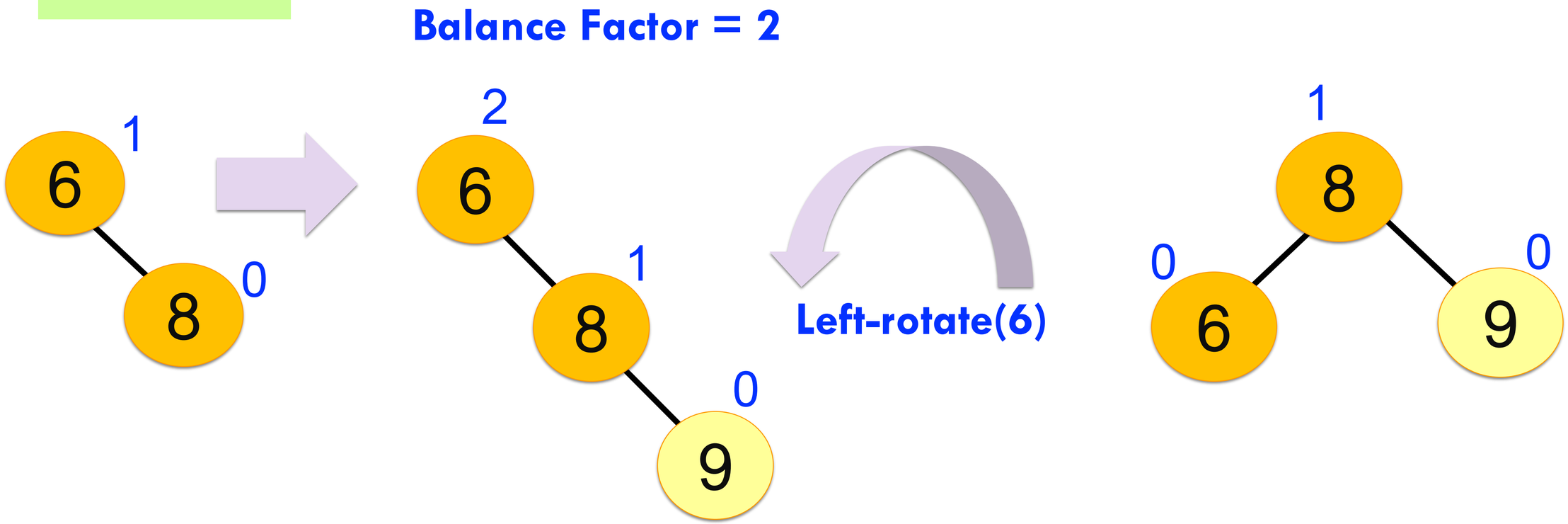


Node **6 violates** the **AVL property.**

What are some possible options for making this tree balanced?

Insertions in Balanced BSTs (AVLs)

Insert 2

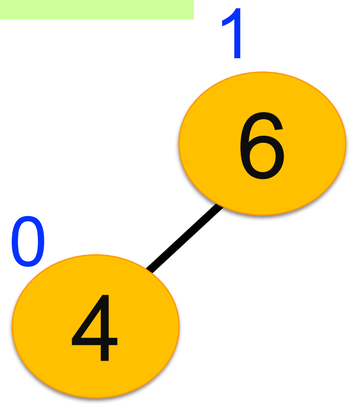


Right- Right Case

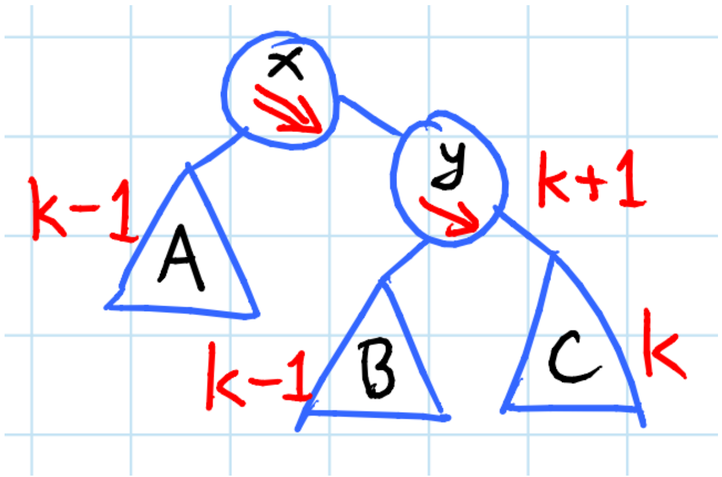
Insertions in Balanced BSTs (AVLs)

Insert 5

Balance Factor = 1



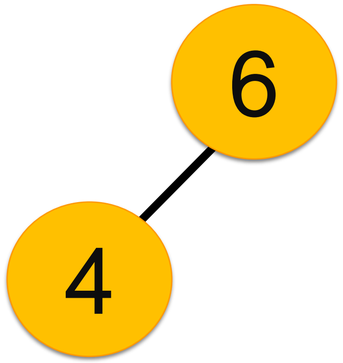
Generalizing



$A < x < B < y < C$

Insertions in Balanced BSTs (AVLs)

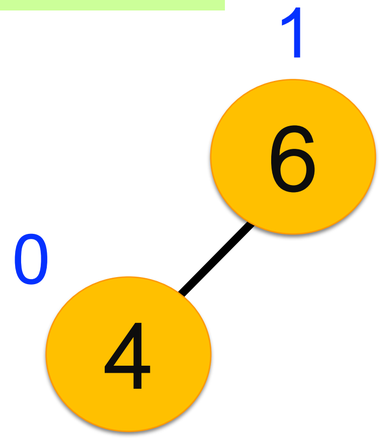
Insert 2



Insertions in Balanced BSTs (AVLs)

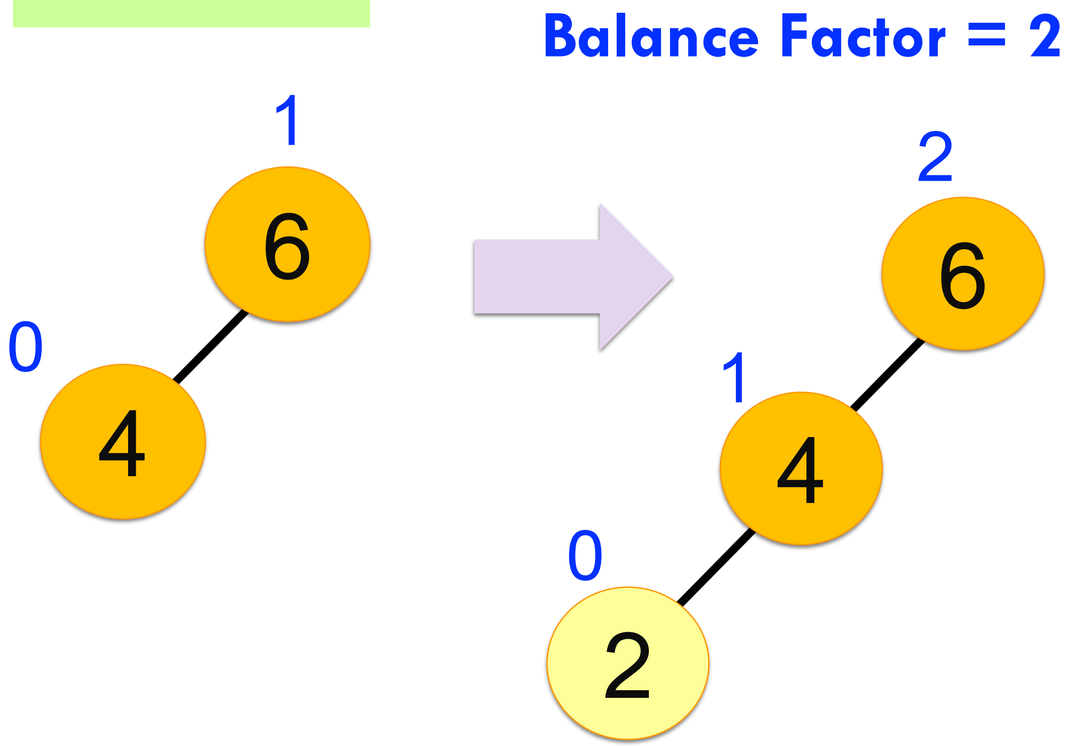
Insert 2

Balance Factor = 1



Insertions in Balanced BSTs (AVLs)

Insert 2



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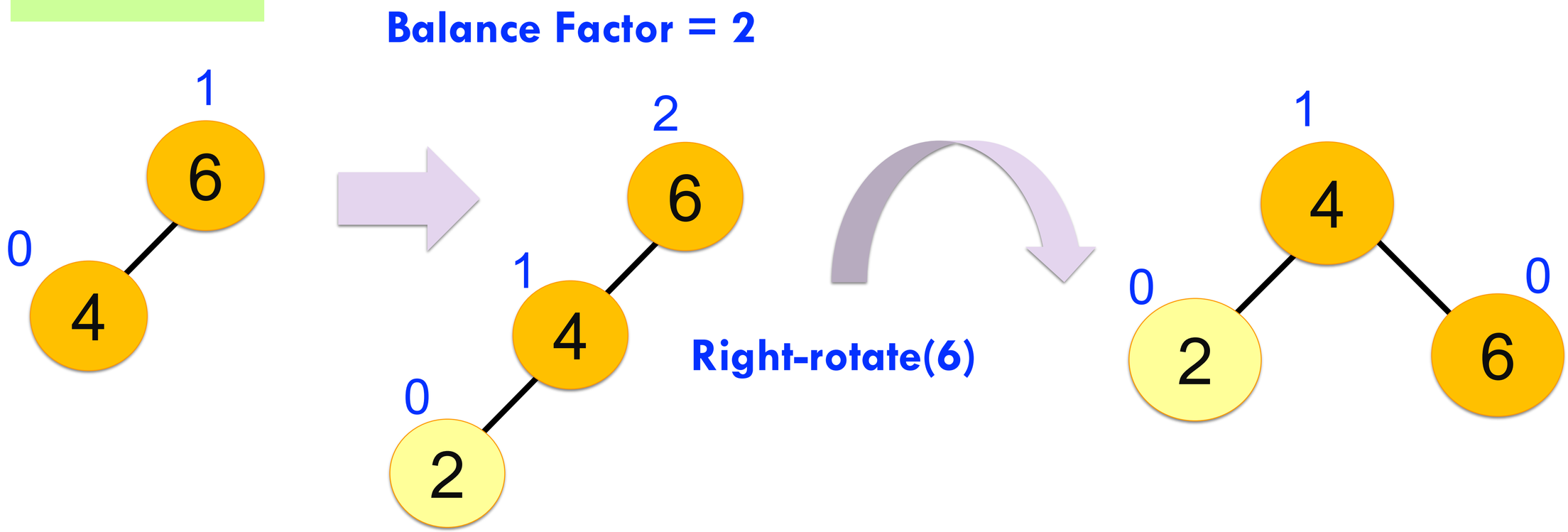
Insertions in Balanced BSTs (AVLs)

Insert 2



Left-Left Case

Questions