

*<https://www.cpp.edu/~ftang/courses/CS241/.../trees/AVL%20tree%20animation.ppt>*

Note: This ppt contains only definitions, examples and homework questions.

Insertion and deletion was explained on the board.

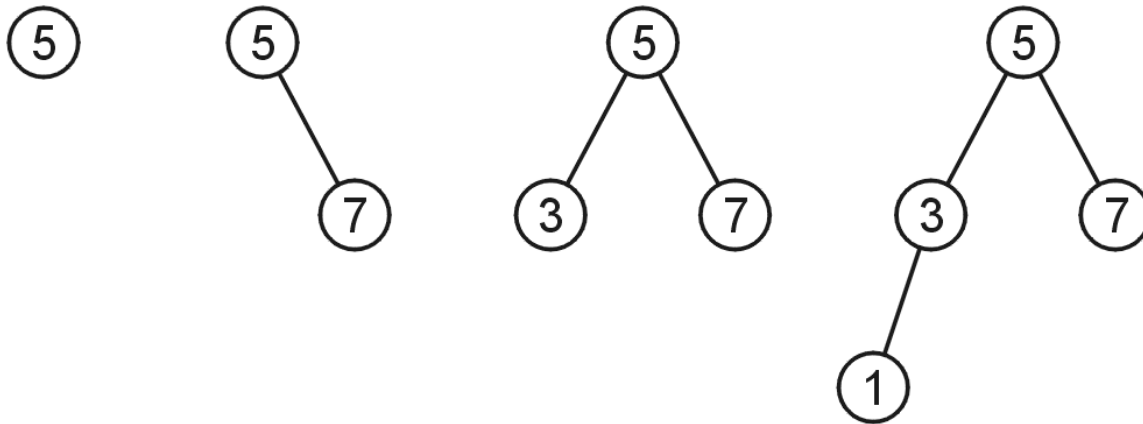
# AVL Trees

A binary search tree is said to be AVL balanced if:

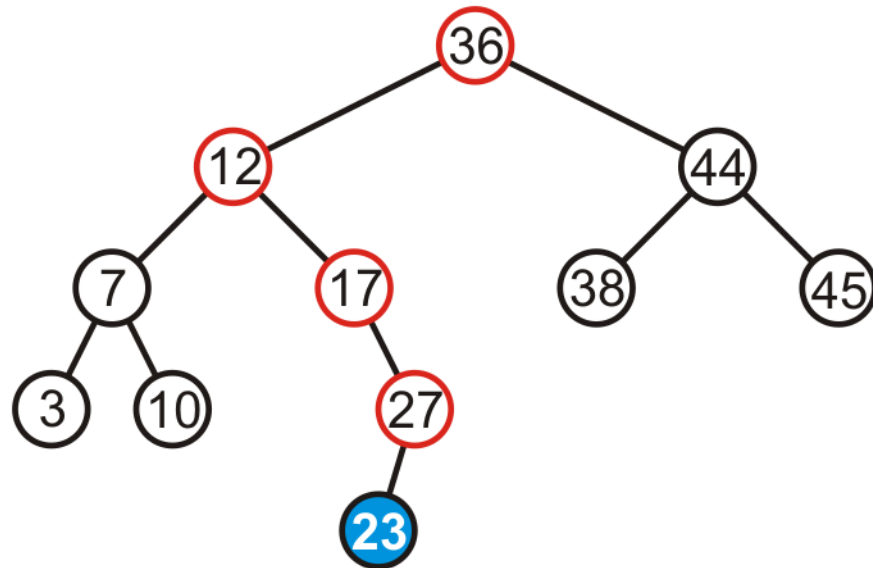
- The difference in the heights between the left and right sub-trees is at most 1, and
- Both sub-trees are themselves AVL trees

# AVL Trees

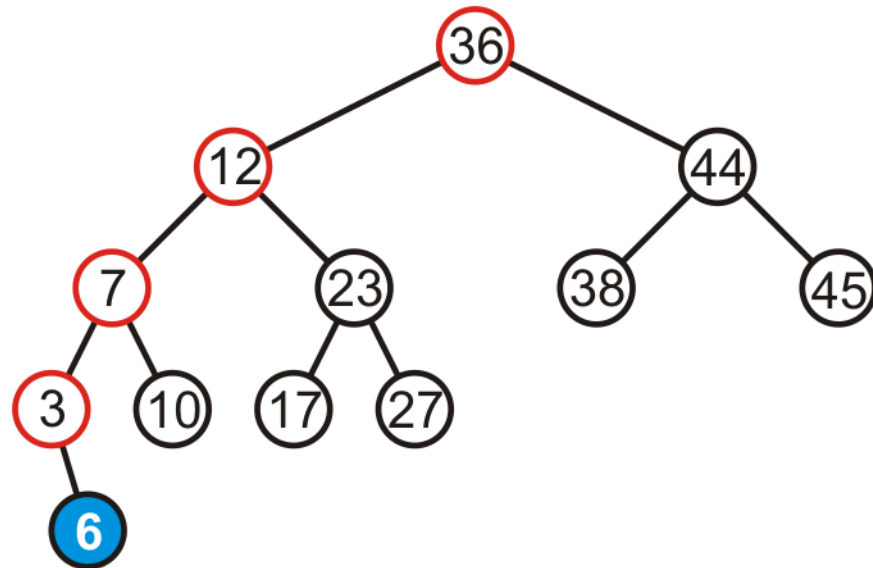
AVL trees with 1, 2, 3, and 4 nodes:



# AVL tree?



# AVL tree?



Height of an AVL tree ? Proved  $2\log(N) > h$  where  $N$  is the number of nodes in the AVL Tree

Height of an AVL tree ? HW:

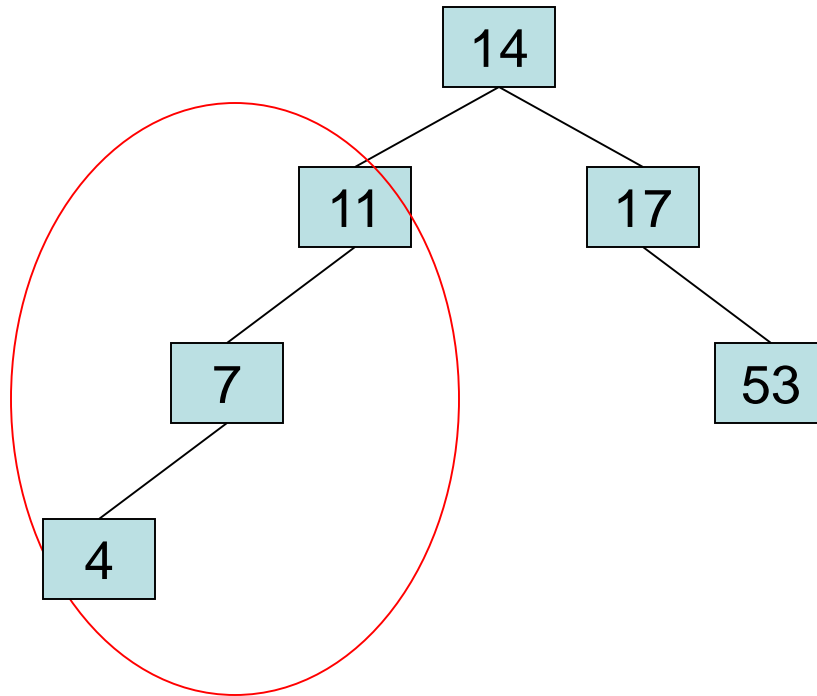
Maximum number of nodes in an AVL tree of height  $h$ ?

HW:

Minimum number of nodes in an AVL tree of height  $h$  ?

## AVL Tree Example:

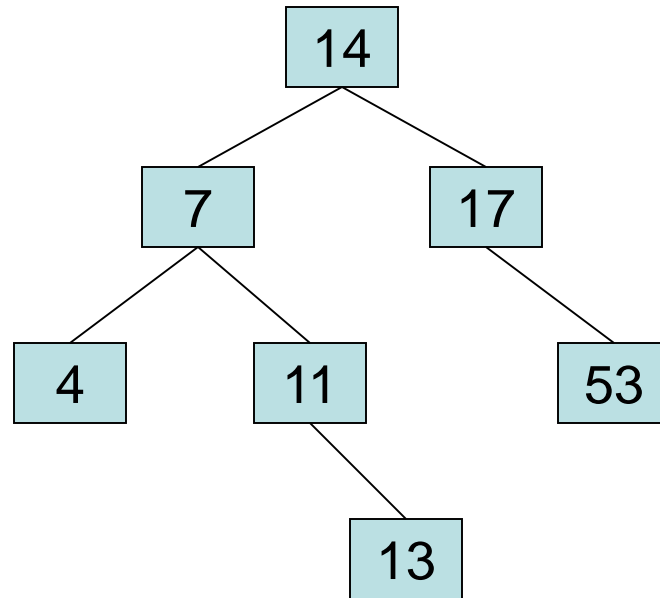
- Insert 14, 17, 11, 7, 53, 4, 13 into an empty AVL tree





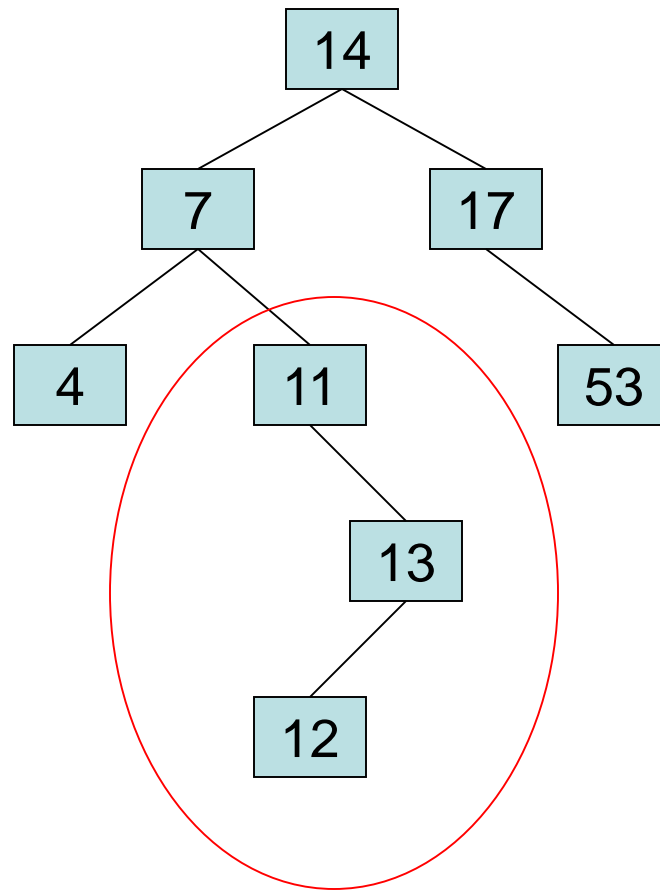
## AVL Tree Example:

- Insert 14, 17, 11, 7, 53, 4, 13 into an empty AVL tree



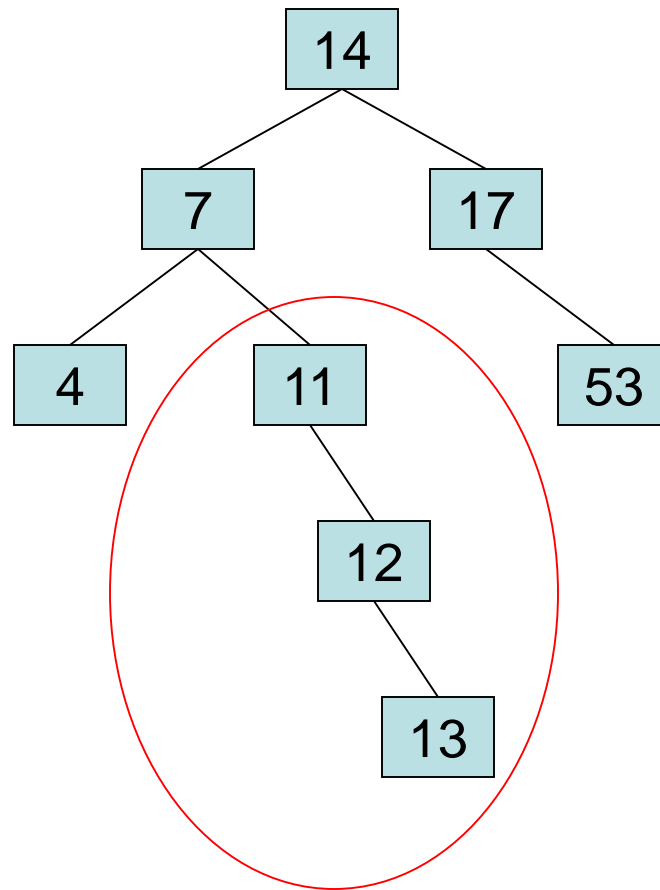
## AVL Tree Example:

- Now insert 12



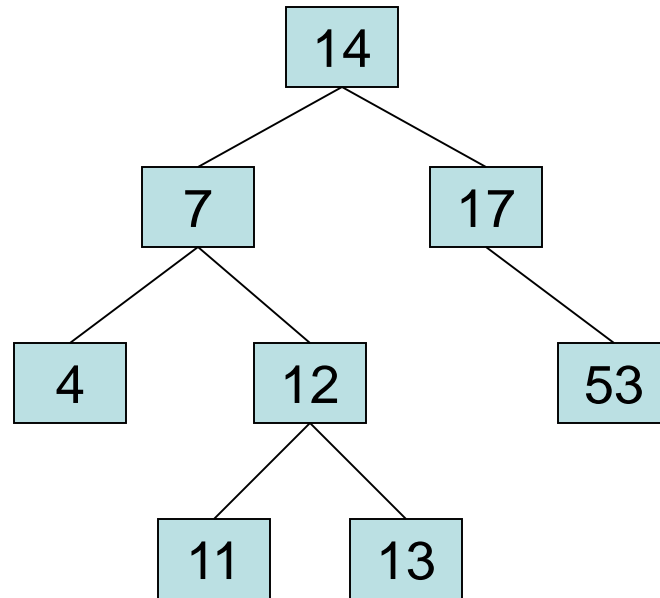
## AVL Tree Example:

- Now insert 12



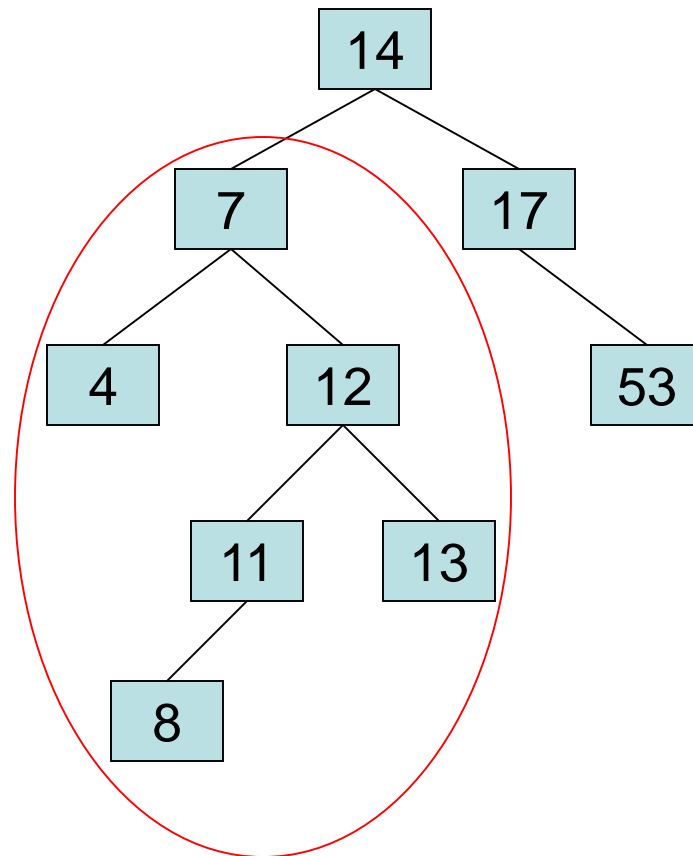
## AVL Tree Example:

- Now the AVL tree is balanced.



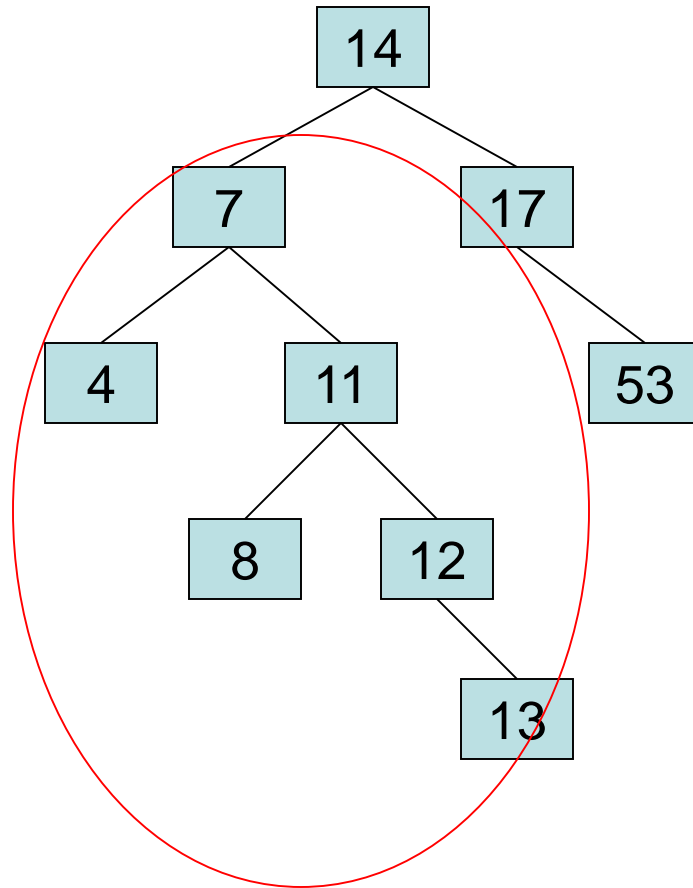
## AVL Tree Example:

- Now insert 8



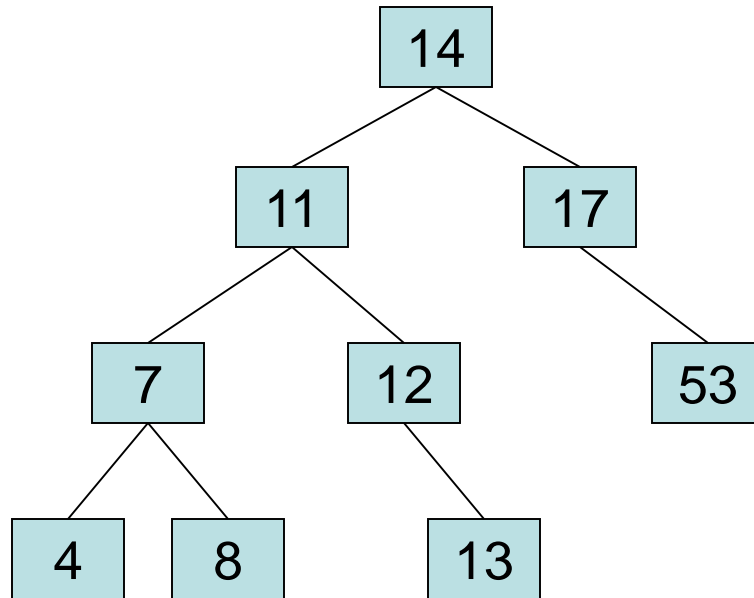
## AVL Tree Example:

- Now insert 8



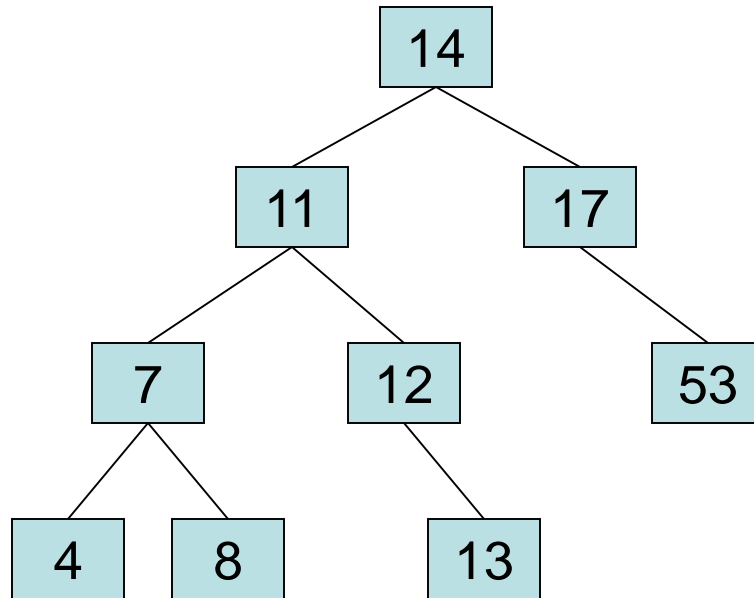
## AVL Tree Example:

- Now the AVL tree is balanced.



## AVL Tree Example:

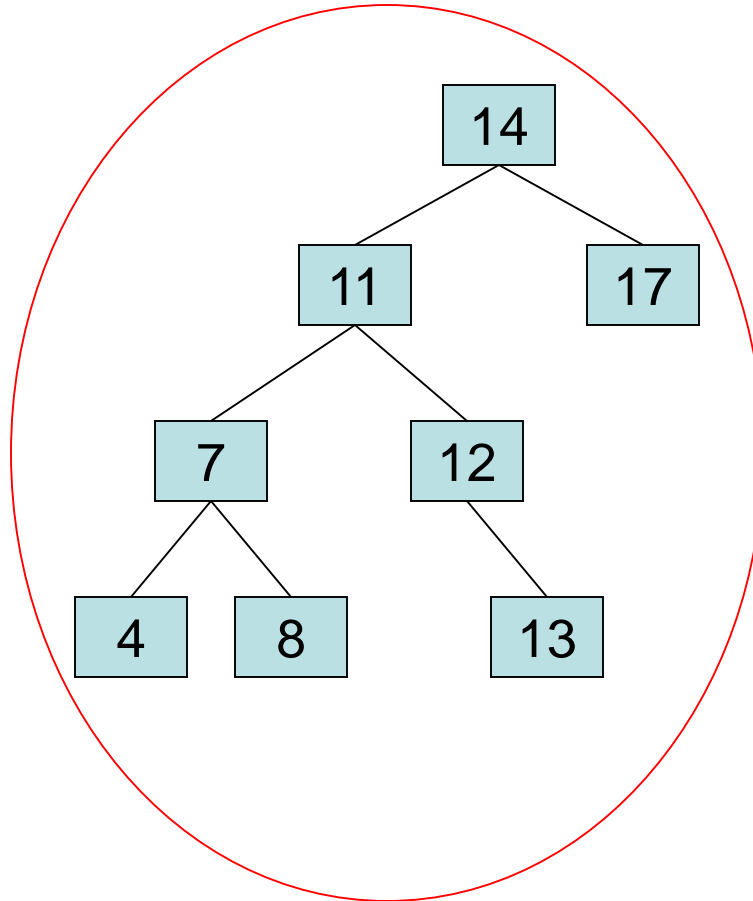
- Now remove 53





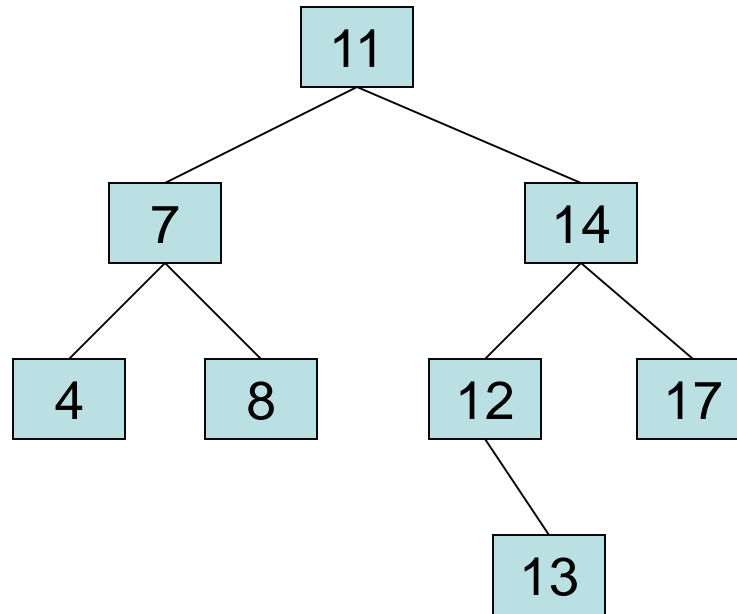
## AVL Tree Example:

- Now remove 53, unbalanced



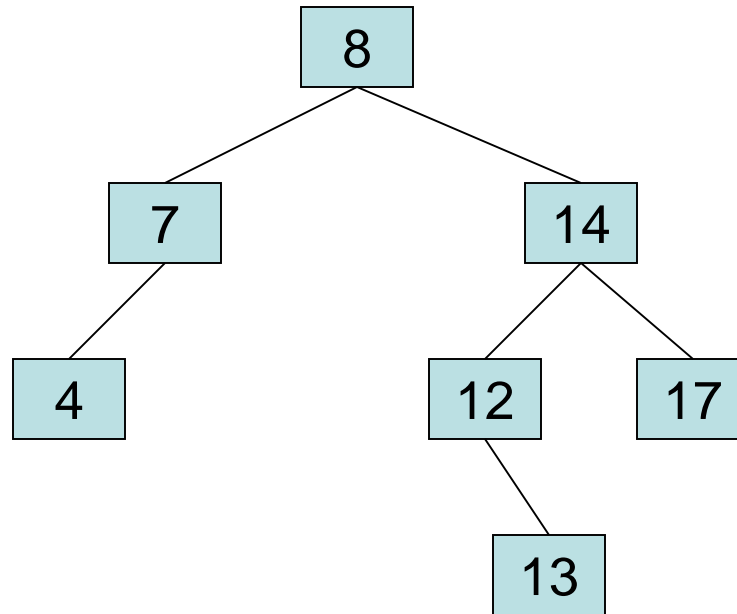
## AVL Tree Example:

- **Balanced! Remove 11**



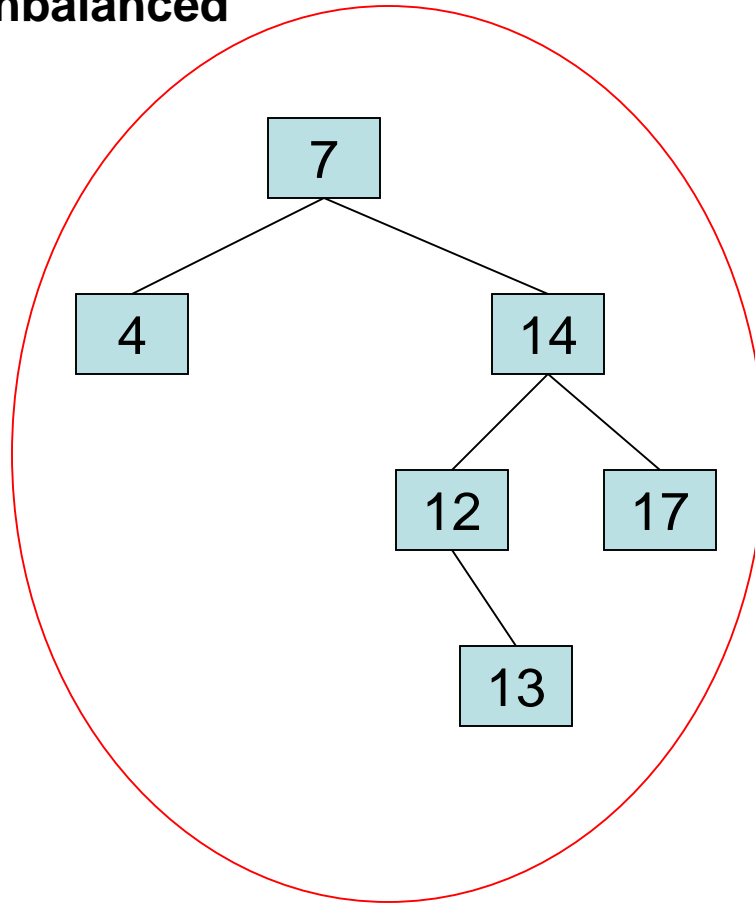
## AVL Tree Example:

- Remove 11, replace it with the largest in its left branch



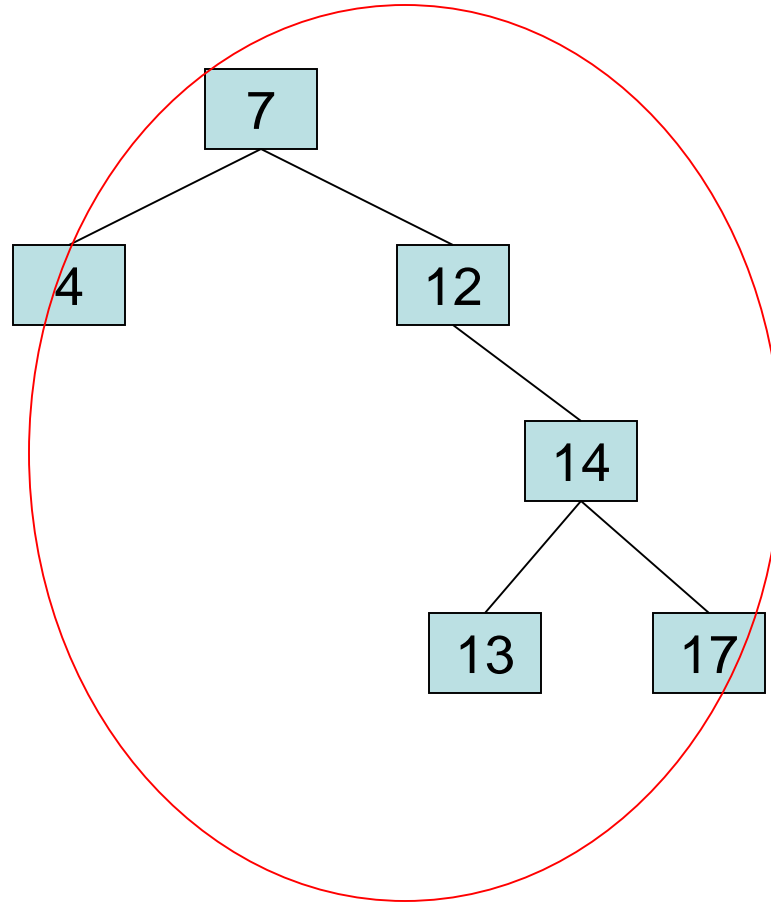
## AVL Tree Example:

- Remove 8, unbalanced



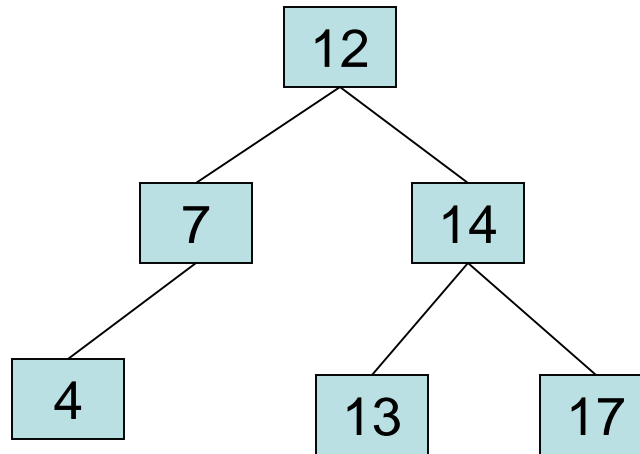
## AVL Tree Example:

- Remove 8, unbalanced



## AVL Tree Example:

- **Balanced!!**

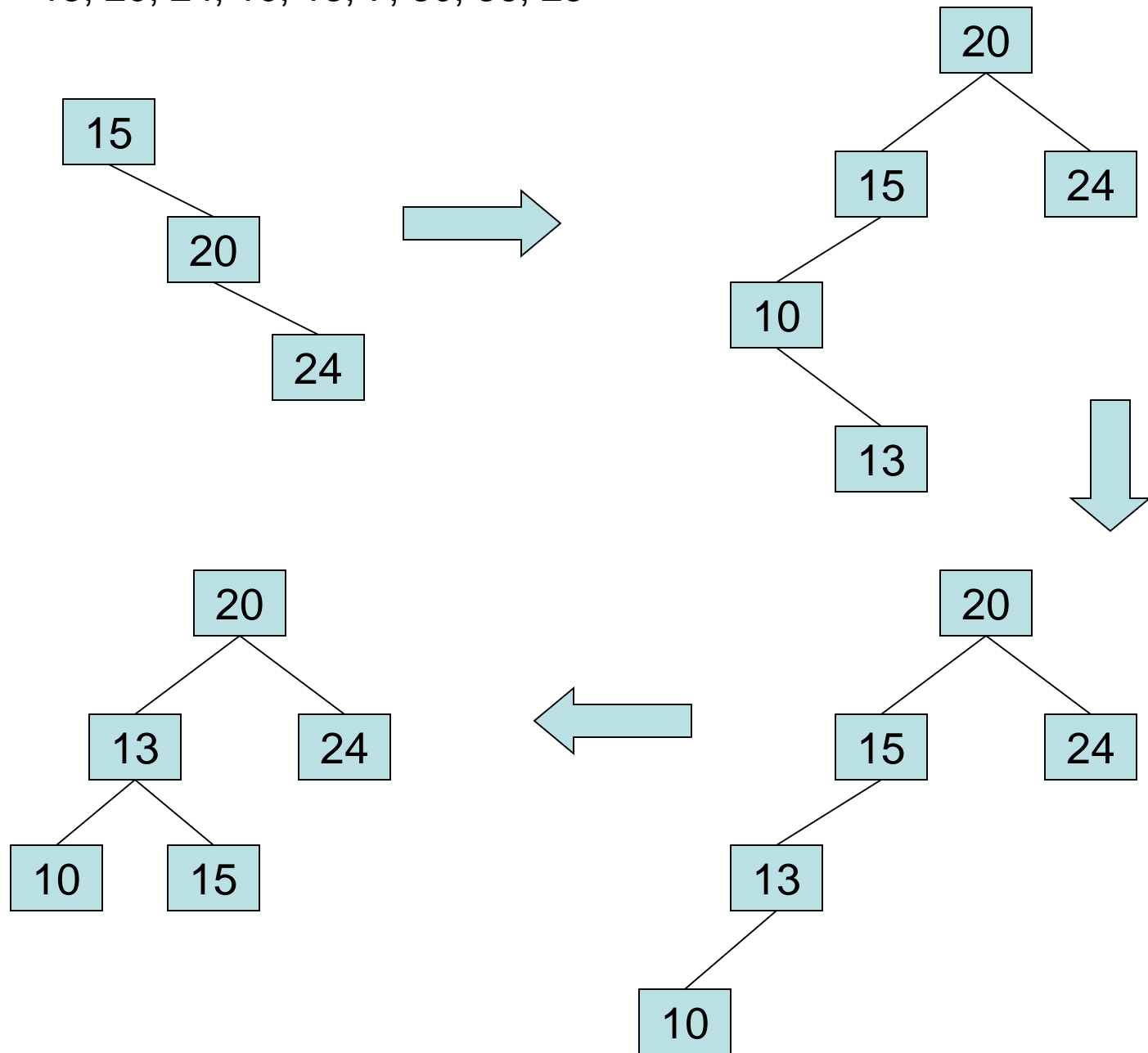


# In Class Exercises

- Build an AVL tree with the following values:  
15, 20, 24, 10, 13, 7, 30, 36, 25

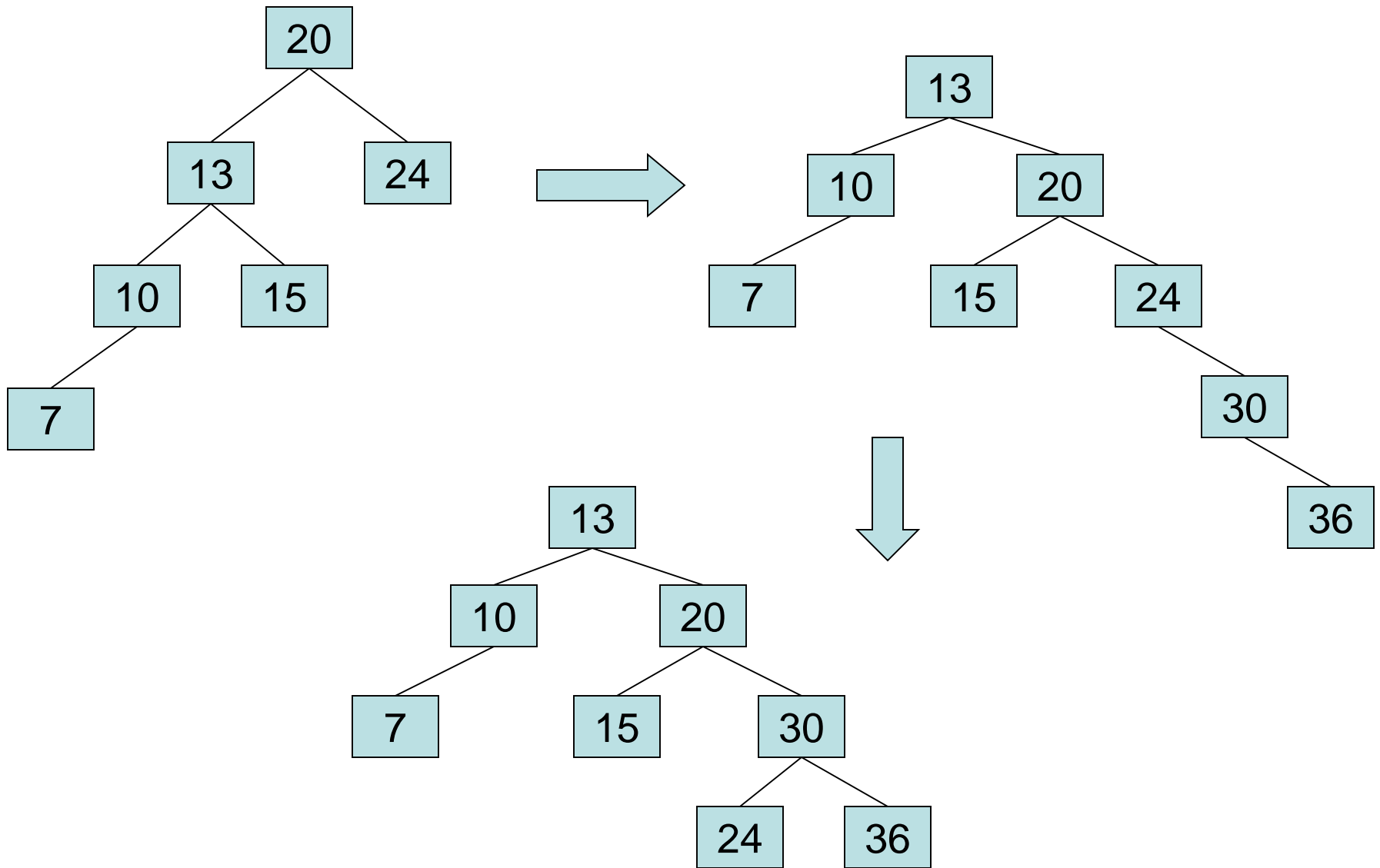
Remove 24 and 20 from the AVL tree

15, 20, 24, 10, 13, 7, 30, 36, 25

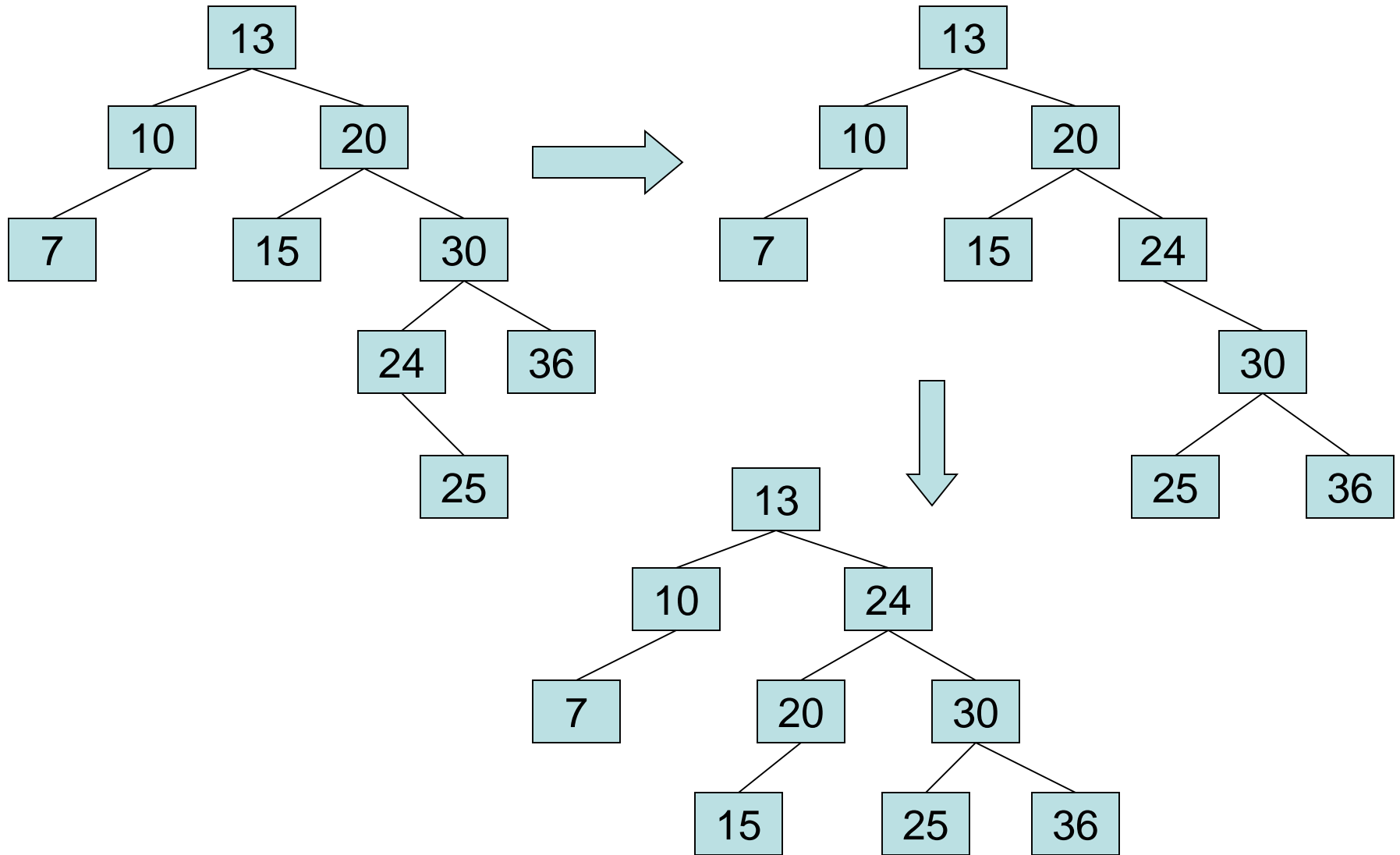




15, 20, 24, 10, 13, 7, 30, 36, 25



15, 20, 24, 10, 13, 7, 30, 36, 25



Remove 24 and 20 from the AVL tree.

