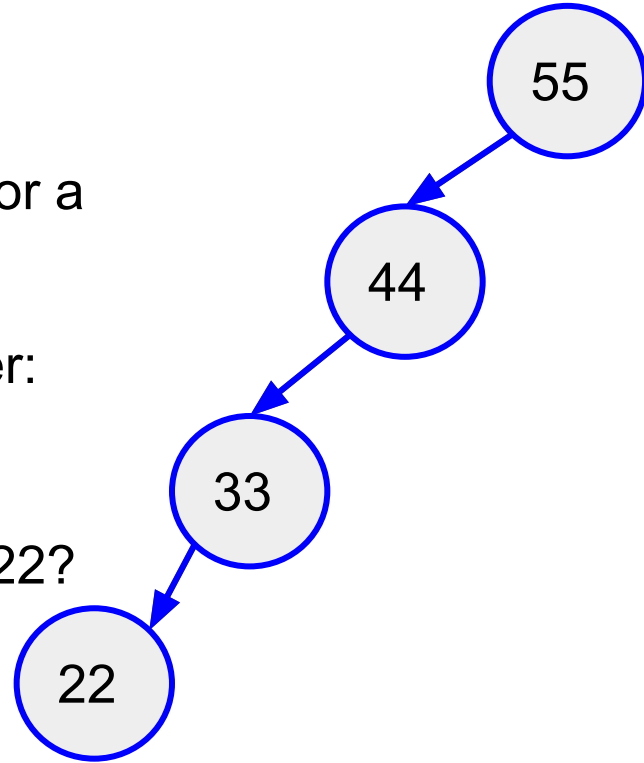


Balancing BSTs: motivation

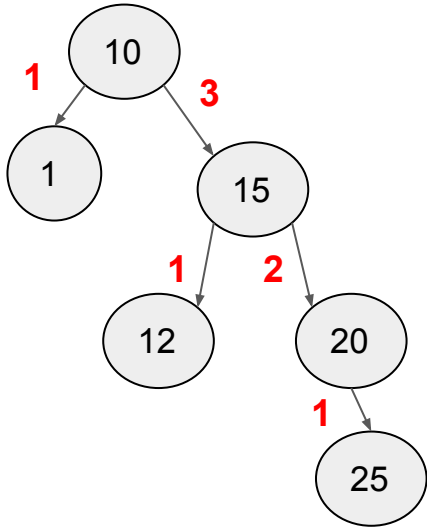
- What is the worst time complexity for a binary search here?
- Assume numbers given in this order:
 - 55, 44, 33, 22
- How many accesses to search for 22?



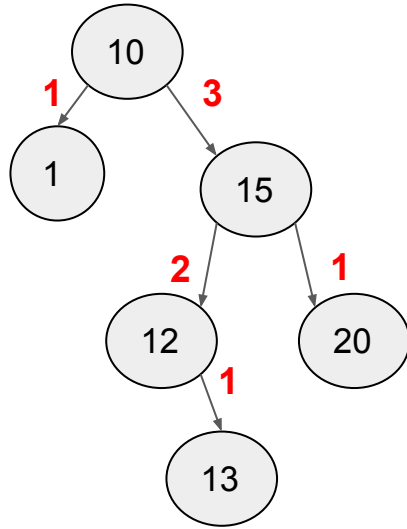
The tree is unbalanced!
Is there a fix?

When a BST is unbalanced?

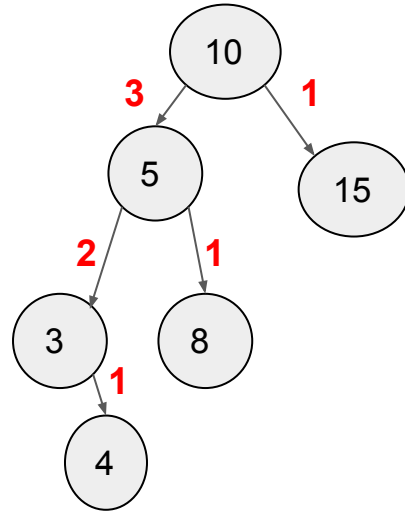
- The heights of left and right subtrees differ by at least 2



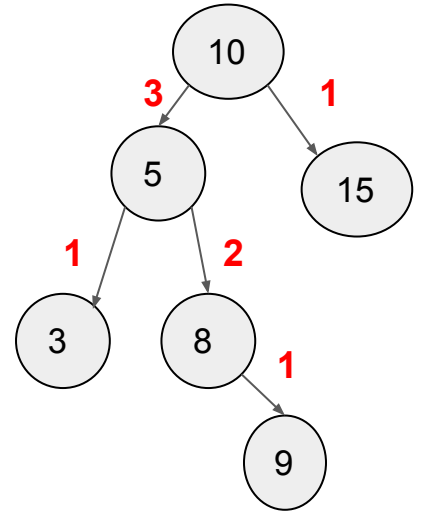
Right-right case



Right-left case



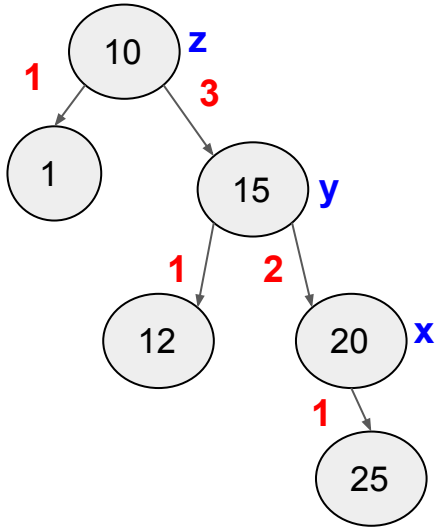
Left-left case



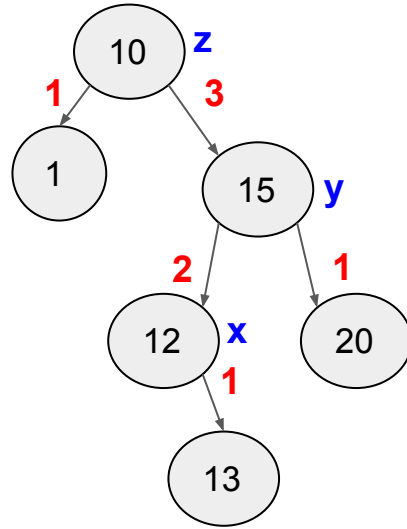
Left-right case

When a BST is unbalanced?

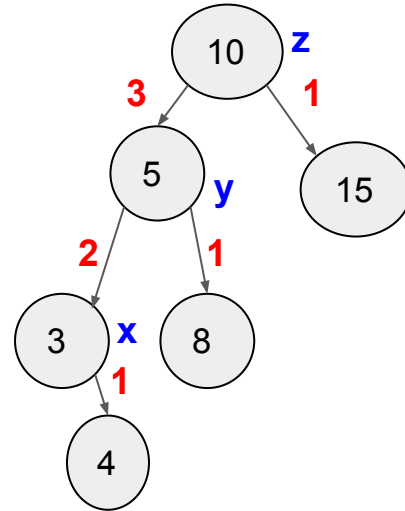
- The heights of left and right subtrees differ by at least 2



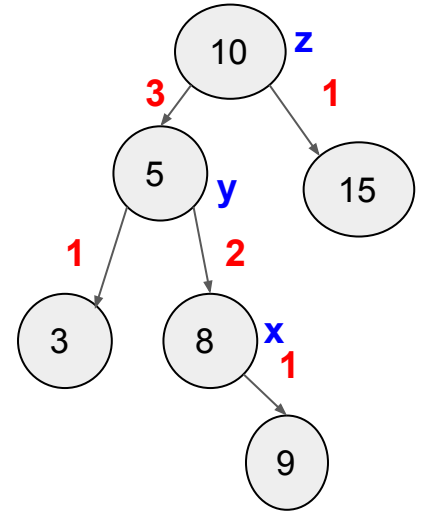
Right-right case



Right-left case

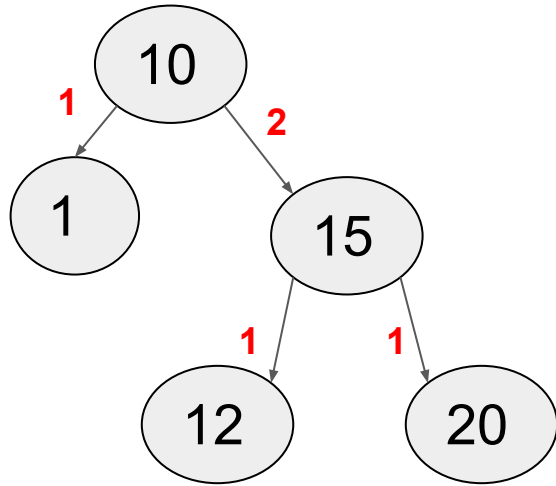


Left-left case

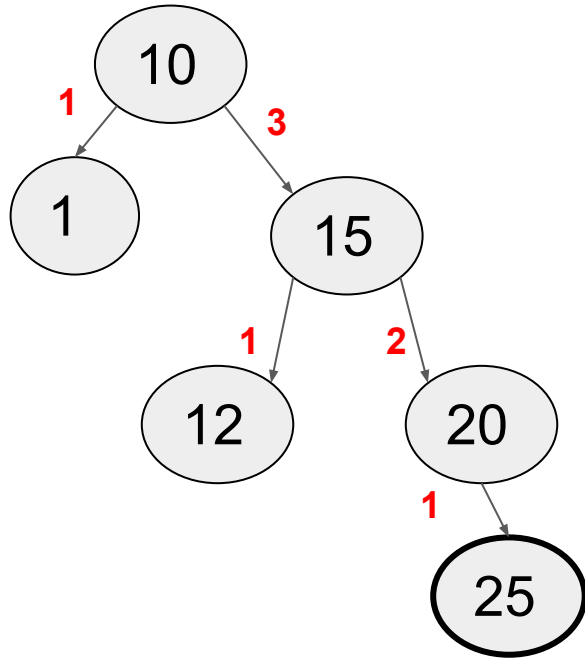


Left-right case

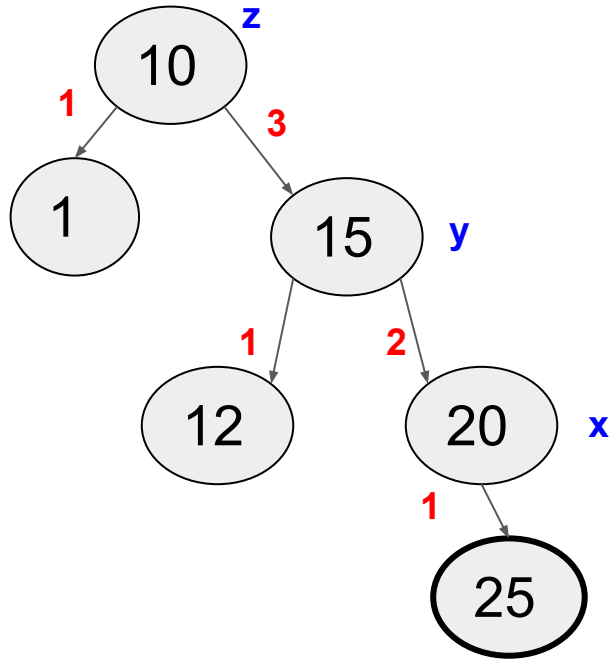
Right-right grandchild



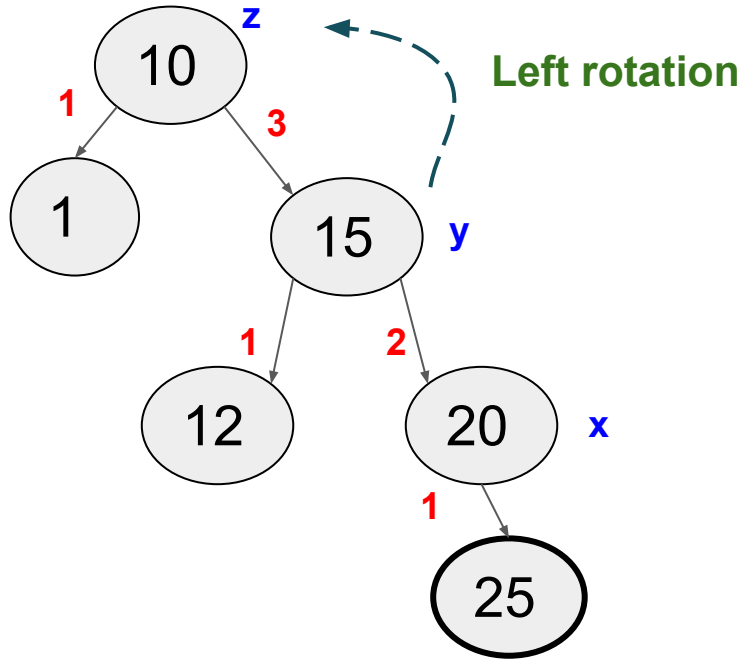
Right-right grandchild



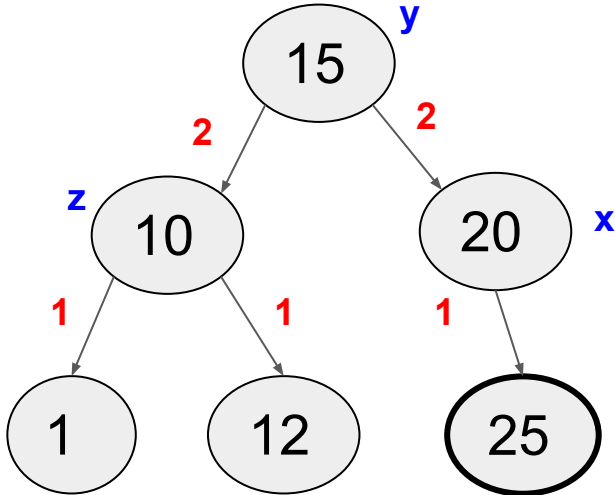
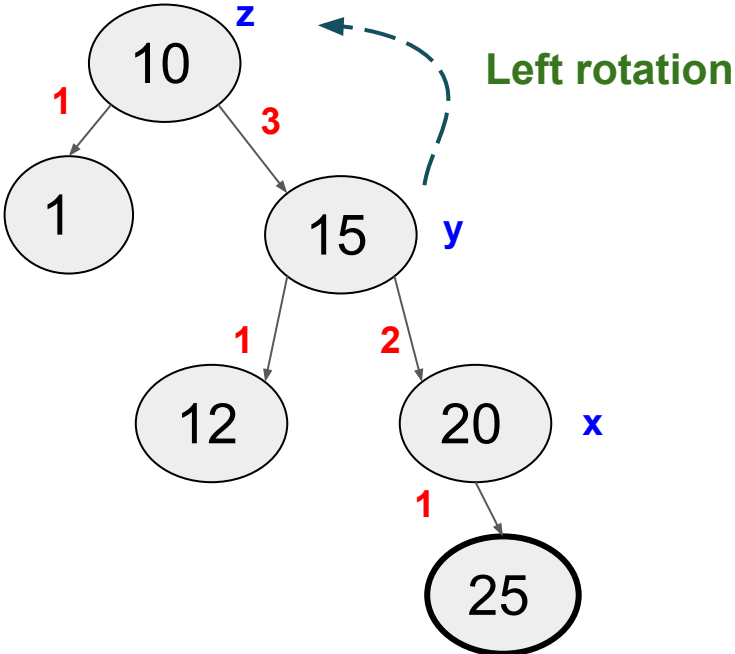
Right-right grandchild



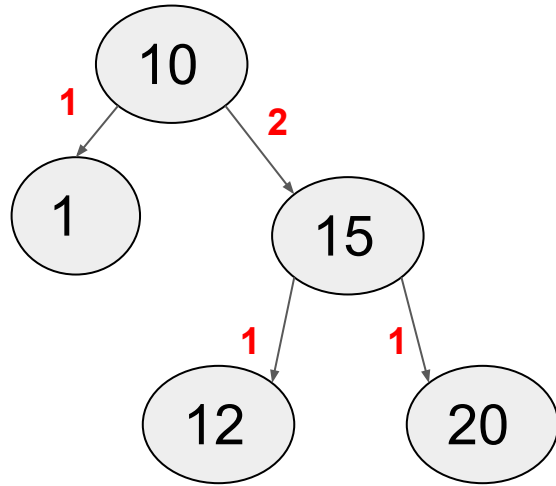
Right-right grandchild



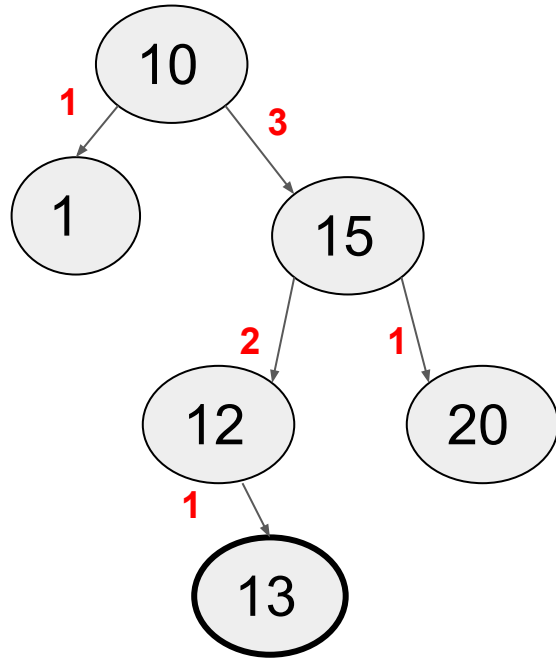
Right-right grandchild



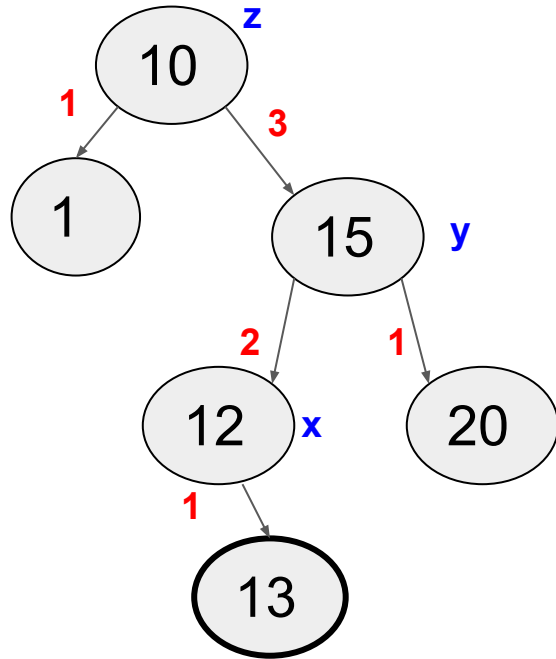
Right-left grandchild



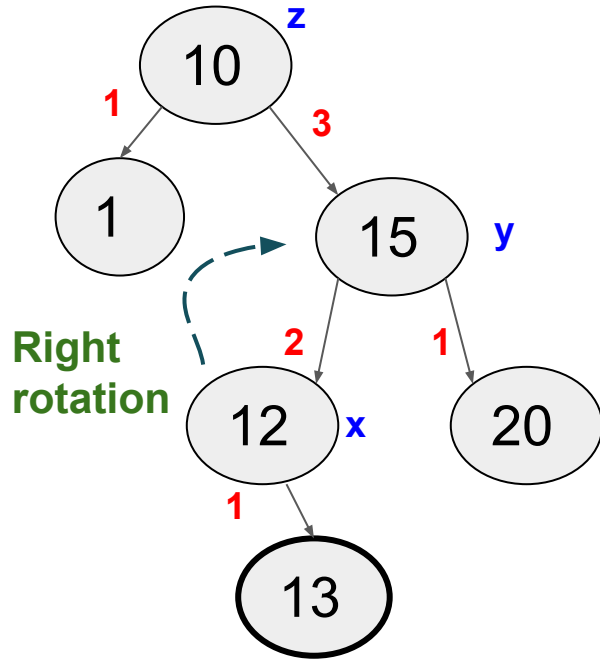
Right-left grandchild



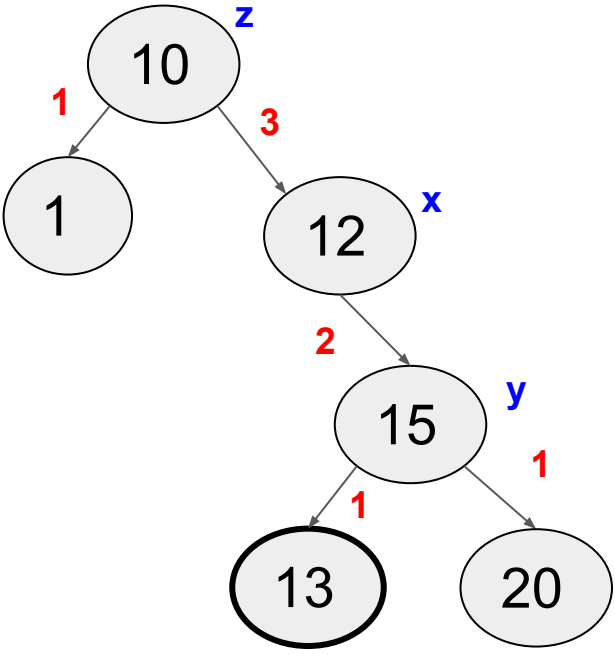
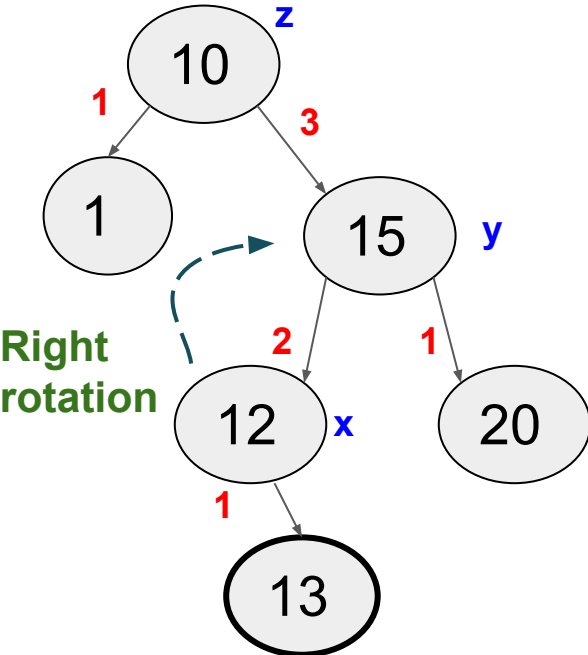
Right-left grandchild



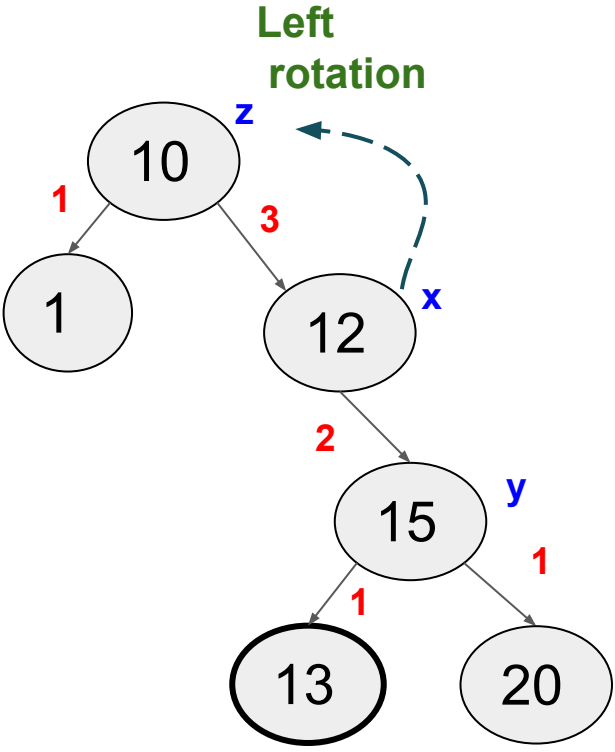
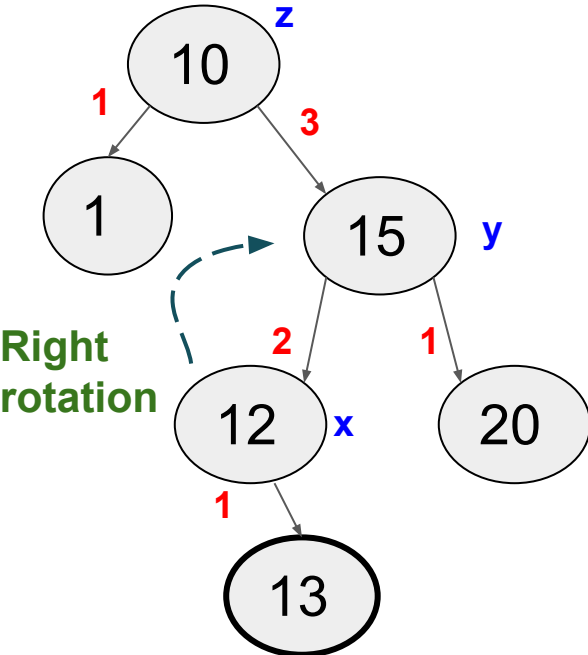
Right-left grandchild



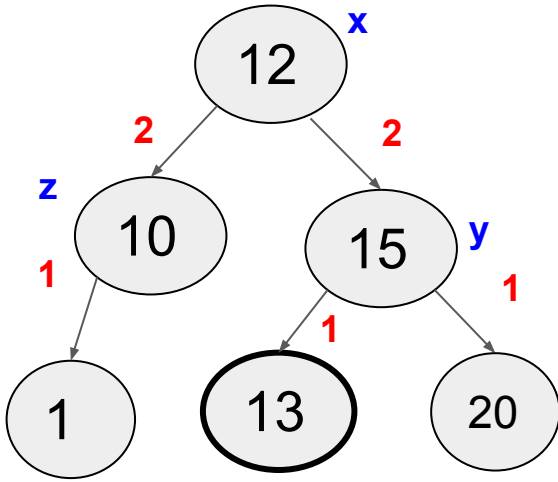
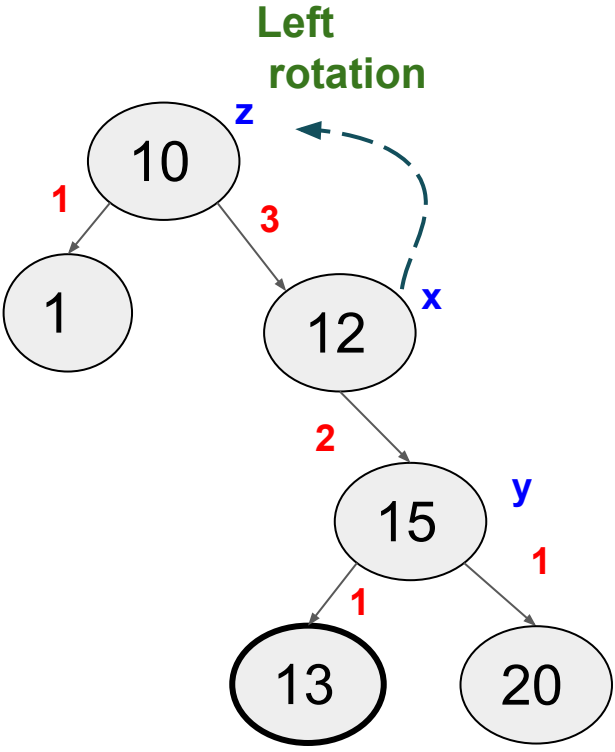
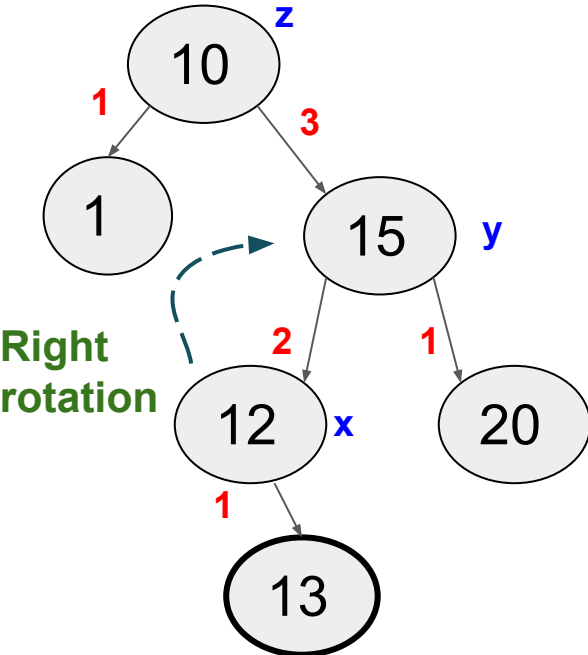
Right-left grandchild



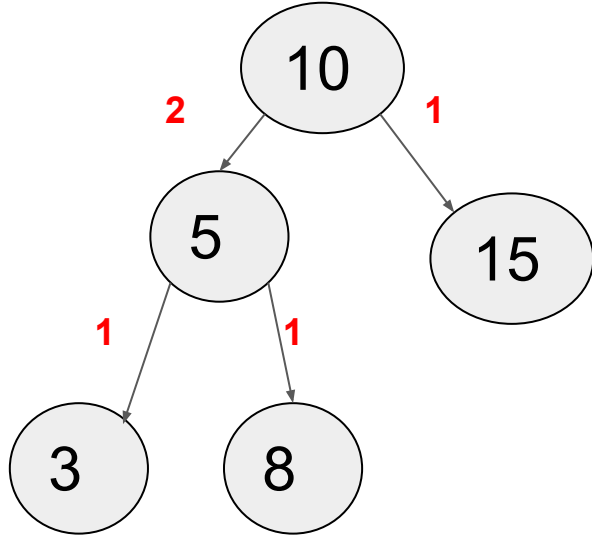
Right-left grandchild



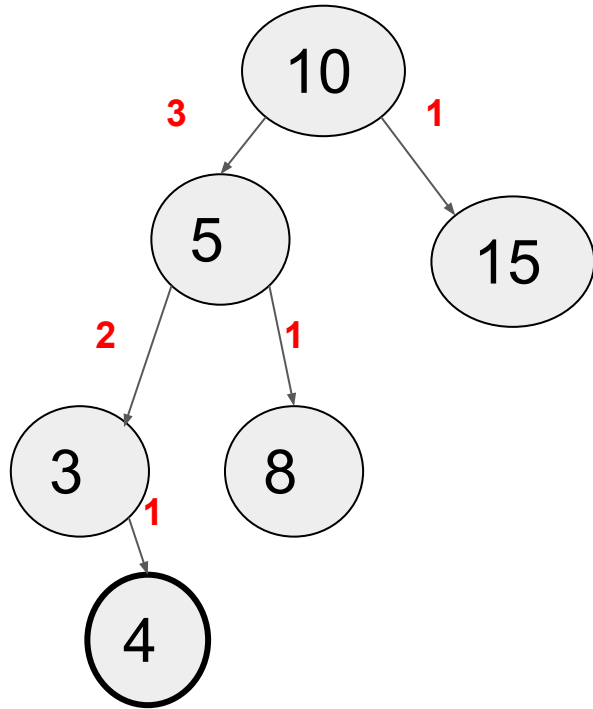
Right-left grandchild



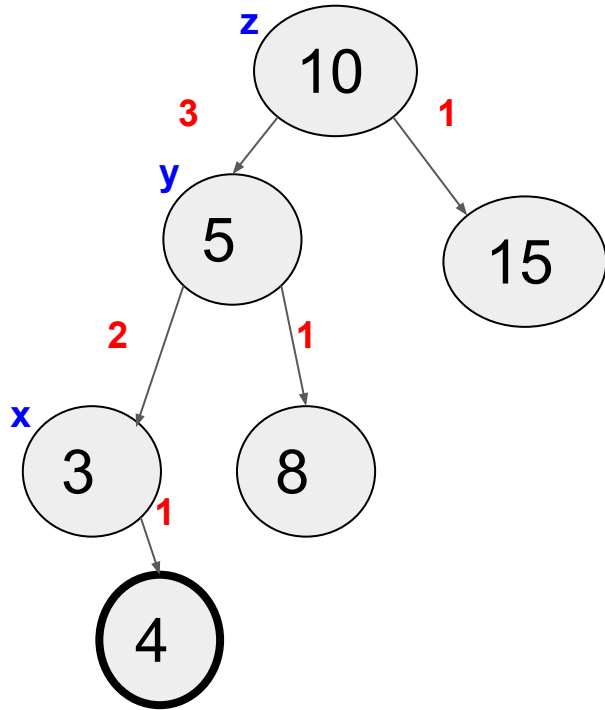
Left-left grandchild



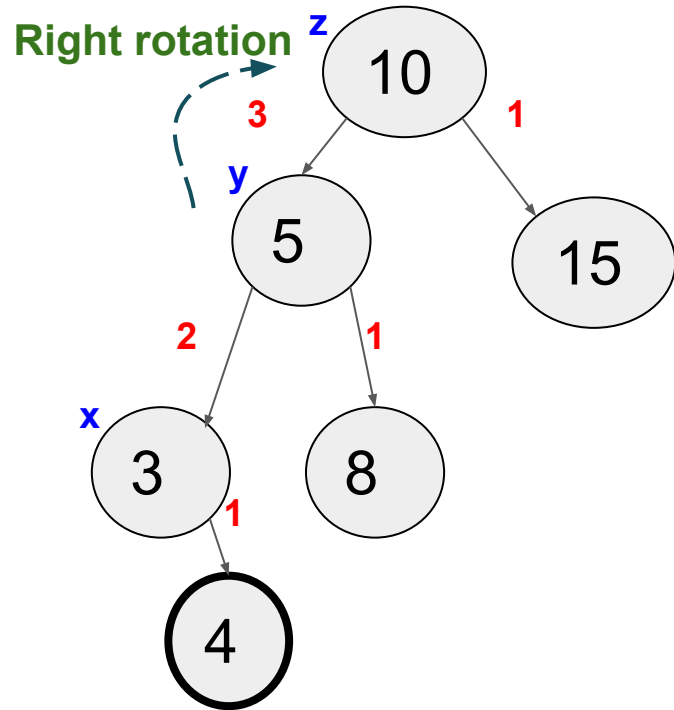
Left-left grandchild



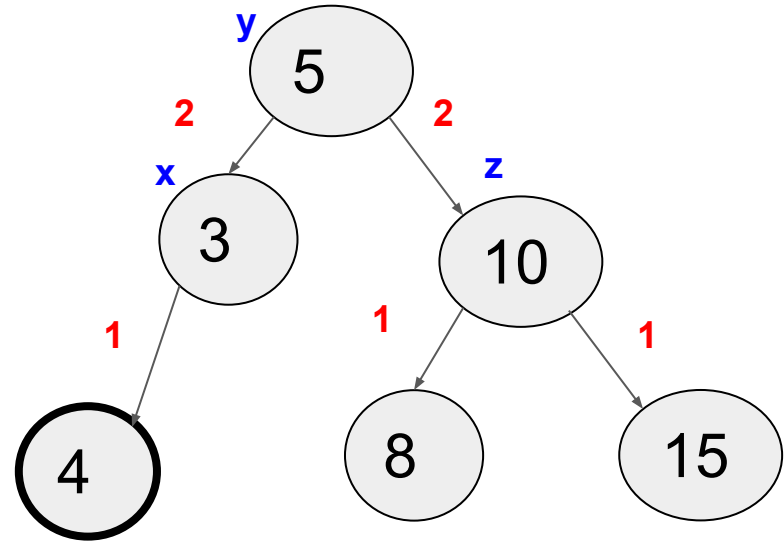
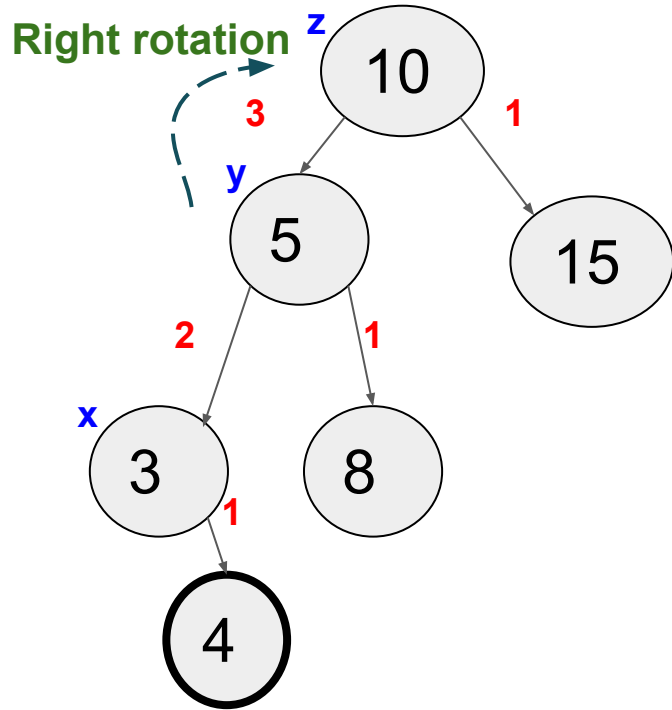
Left-left grandchild



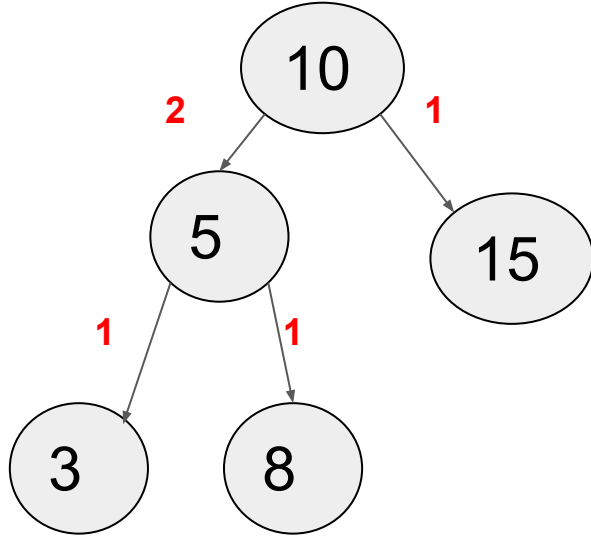
Left-left grandchild



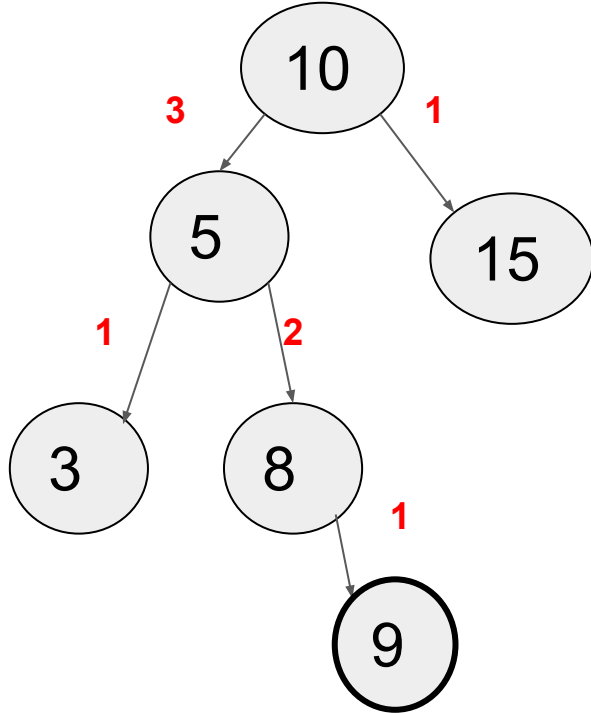
Left-left grandchild



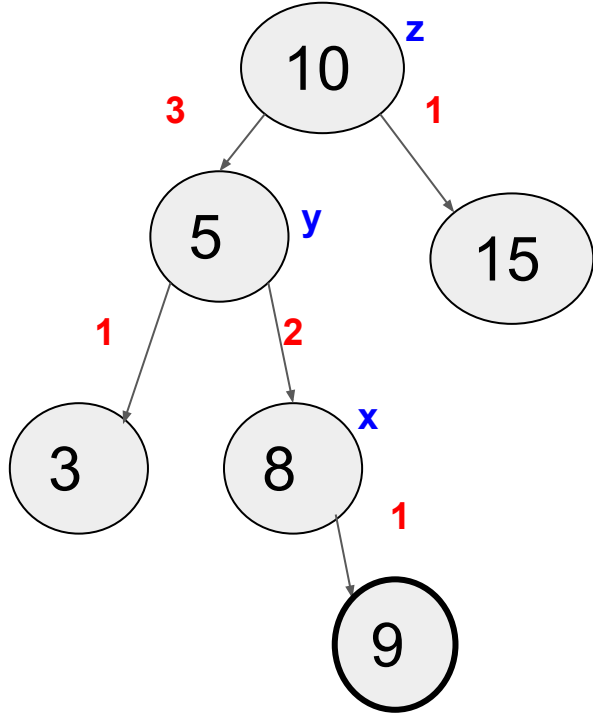
Left-right grandchild



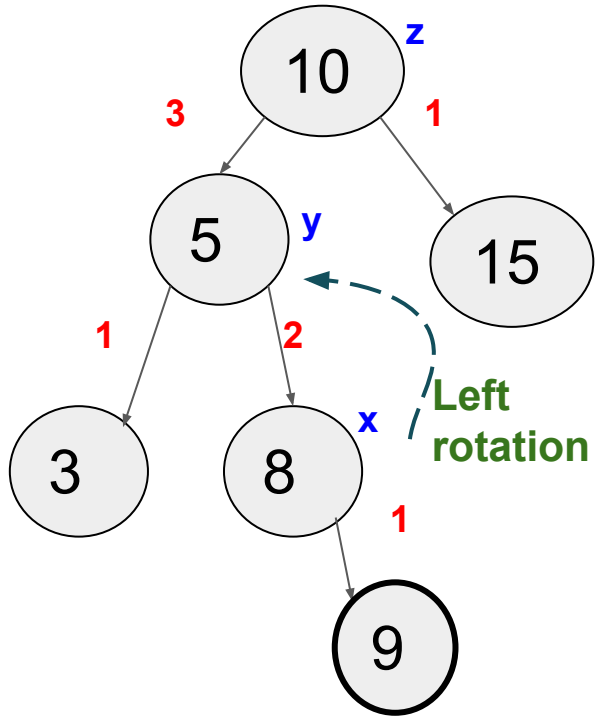
Left-right grandchild



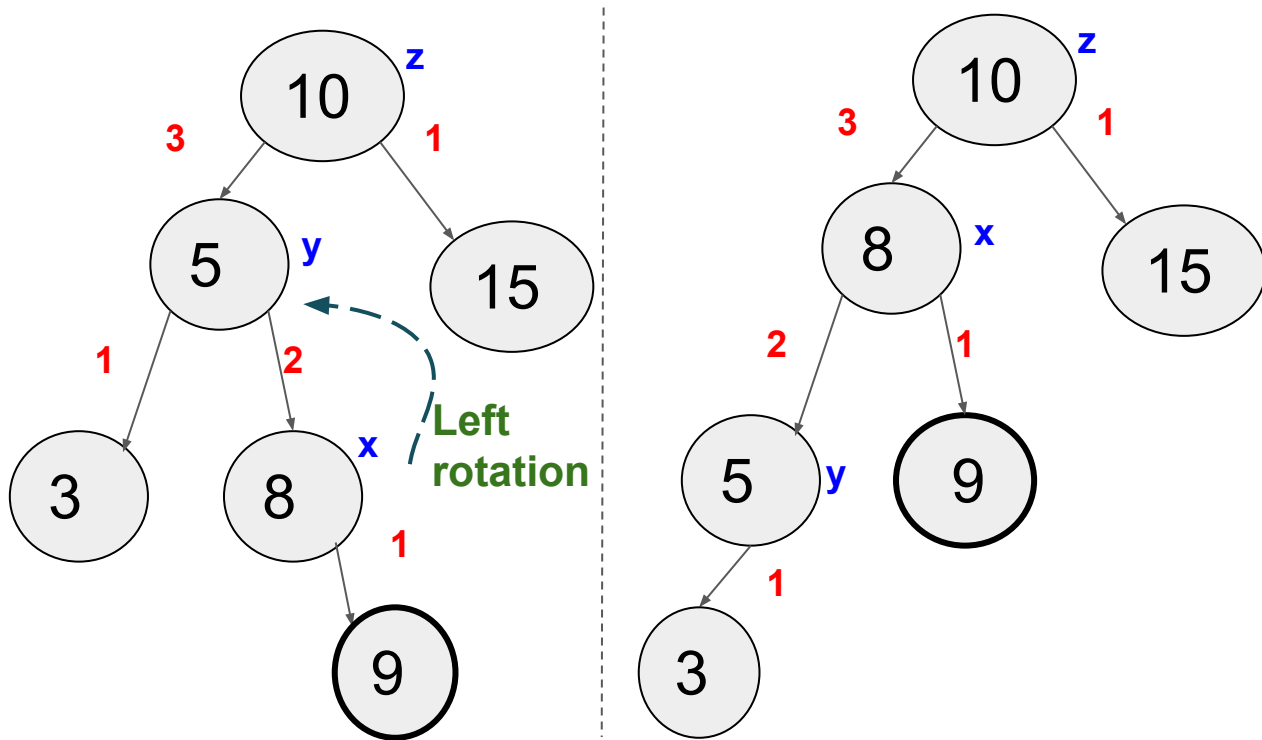
Left-right grandchild



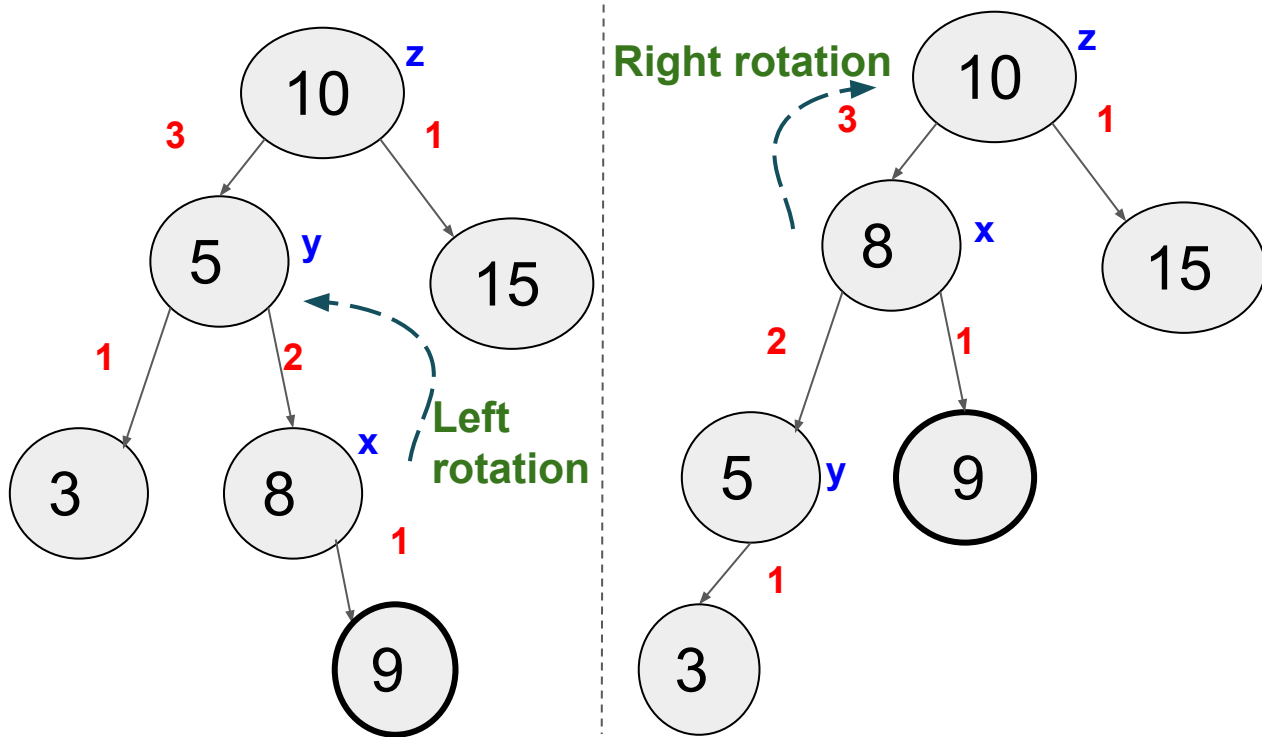
Left-right grandchild



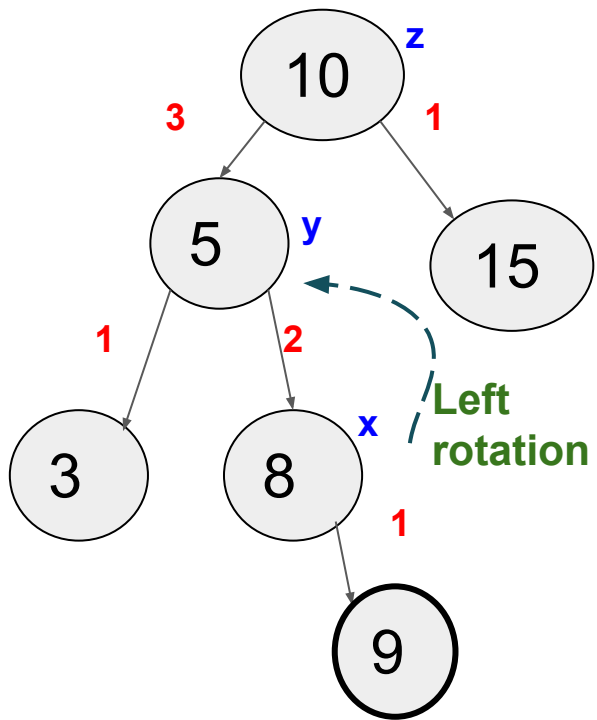
Left-right grandchild



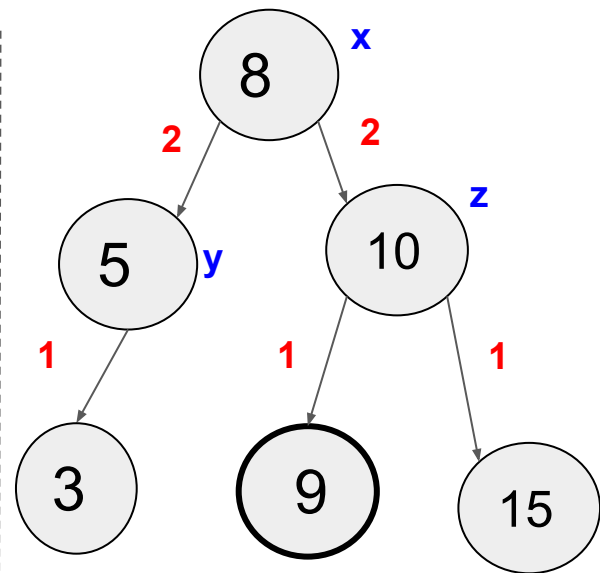
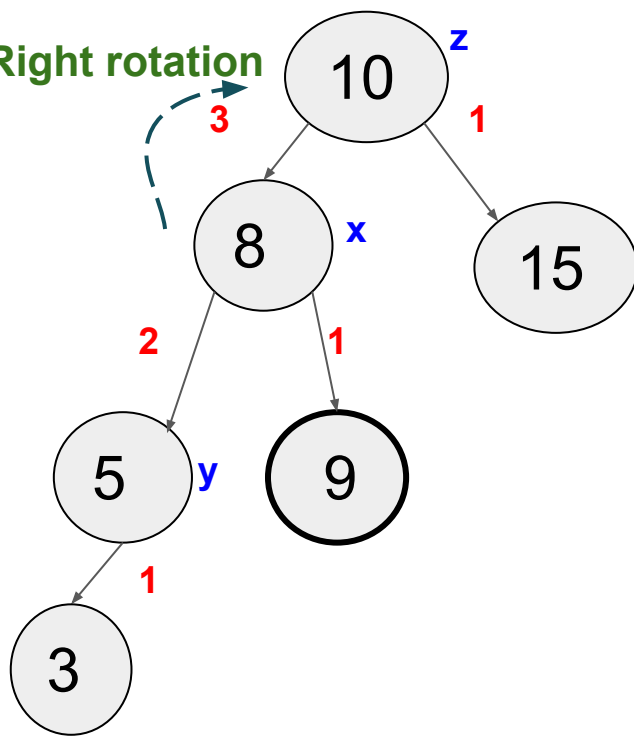
Left-right grandchild



Left-right grandchild

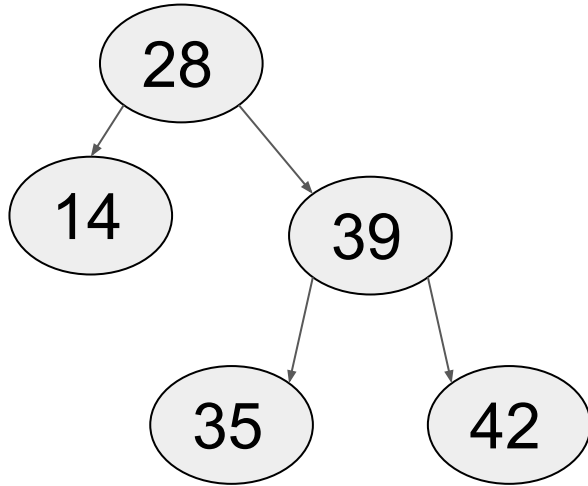


Right rotation

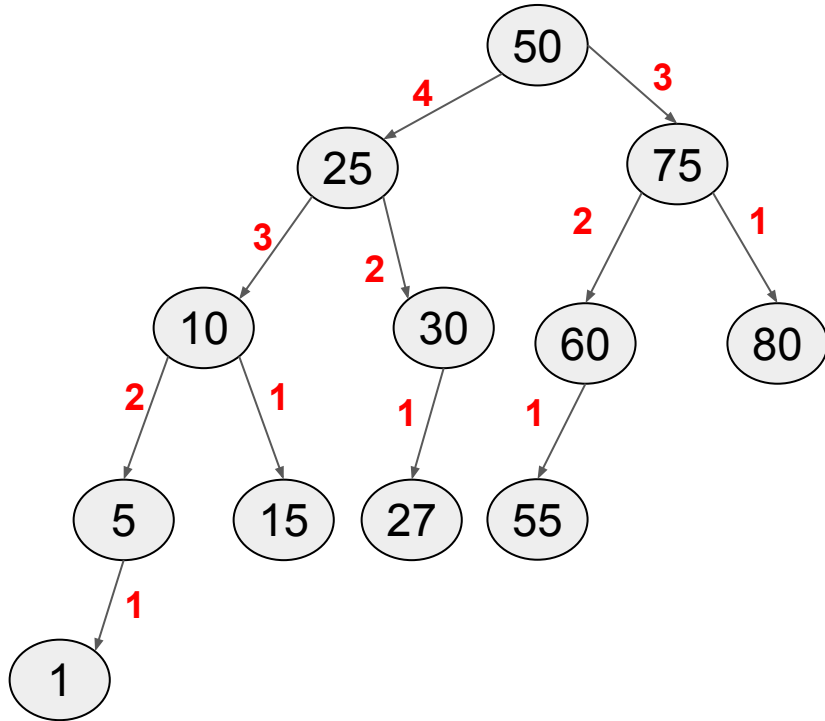


Practice

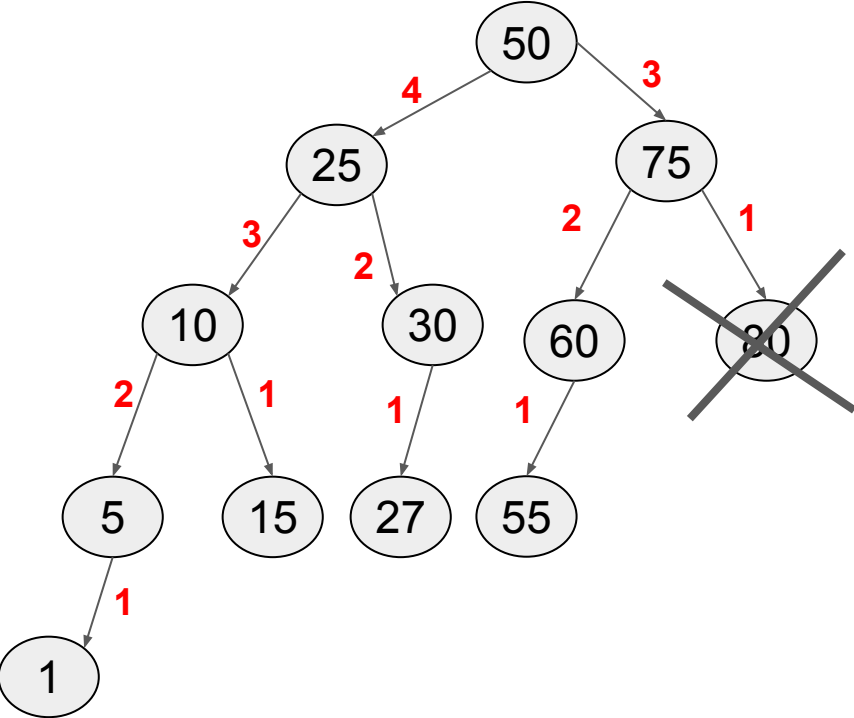
What will this AVL tree look like after inserting node 30?



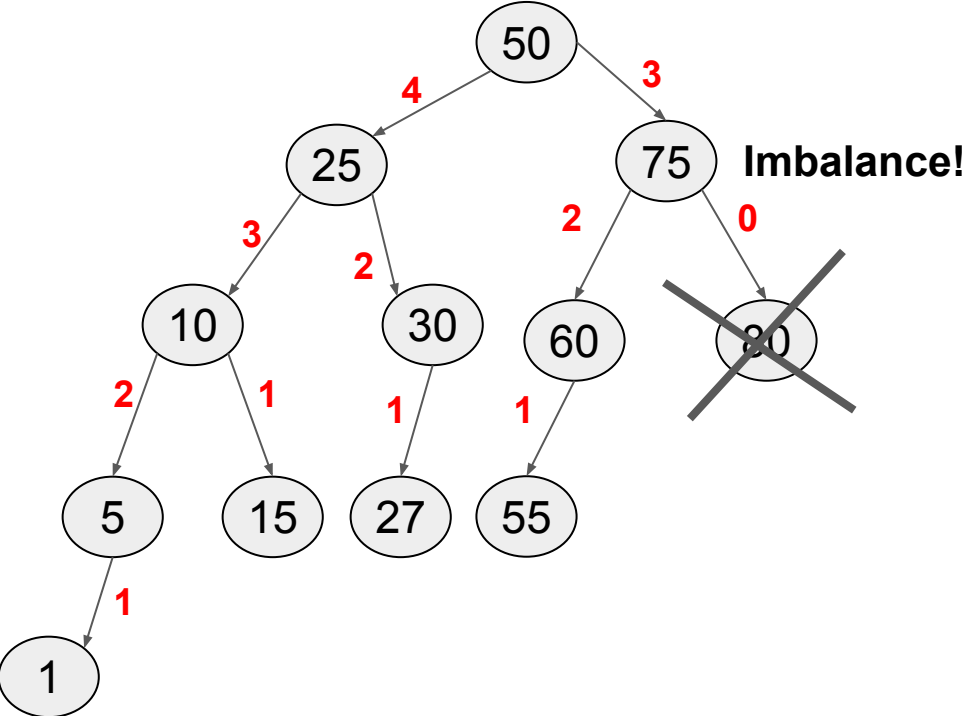
Deletion example



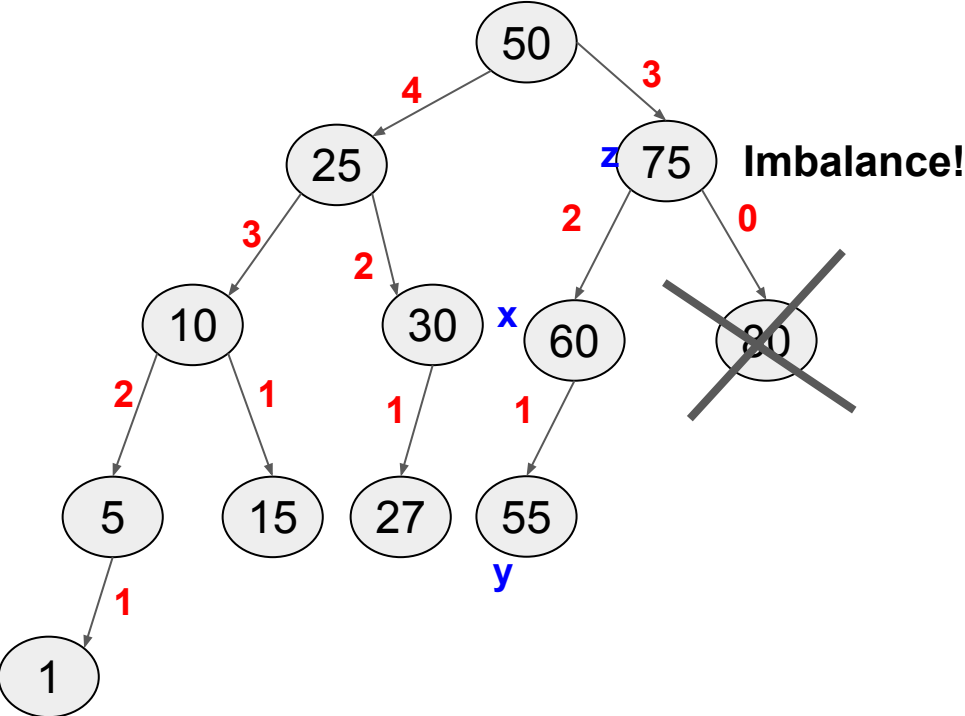
Deletion example



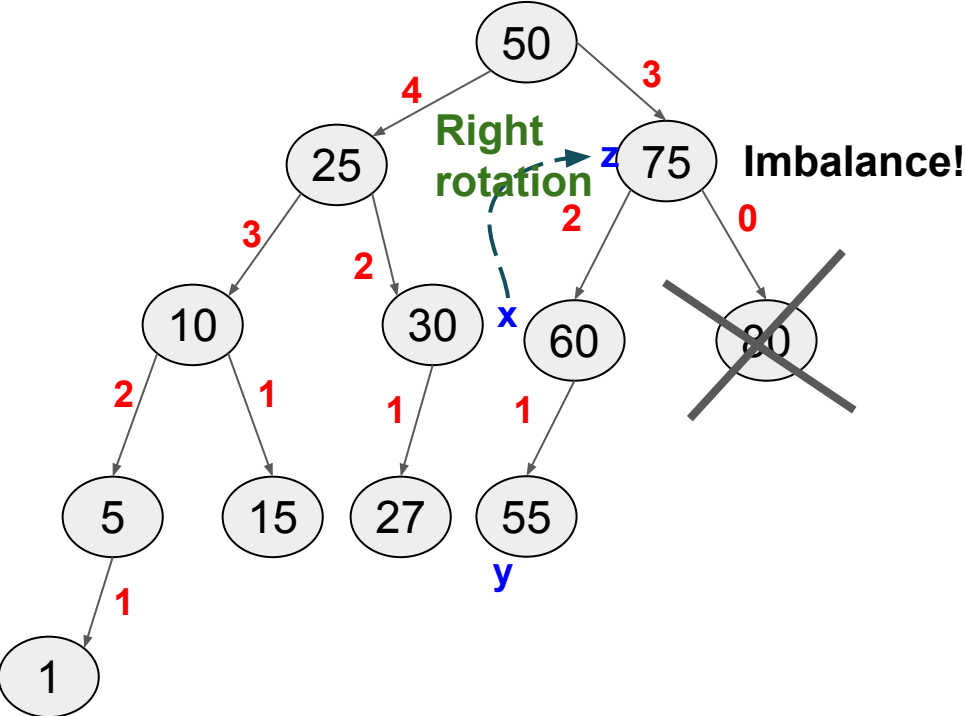
Deletion example



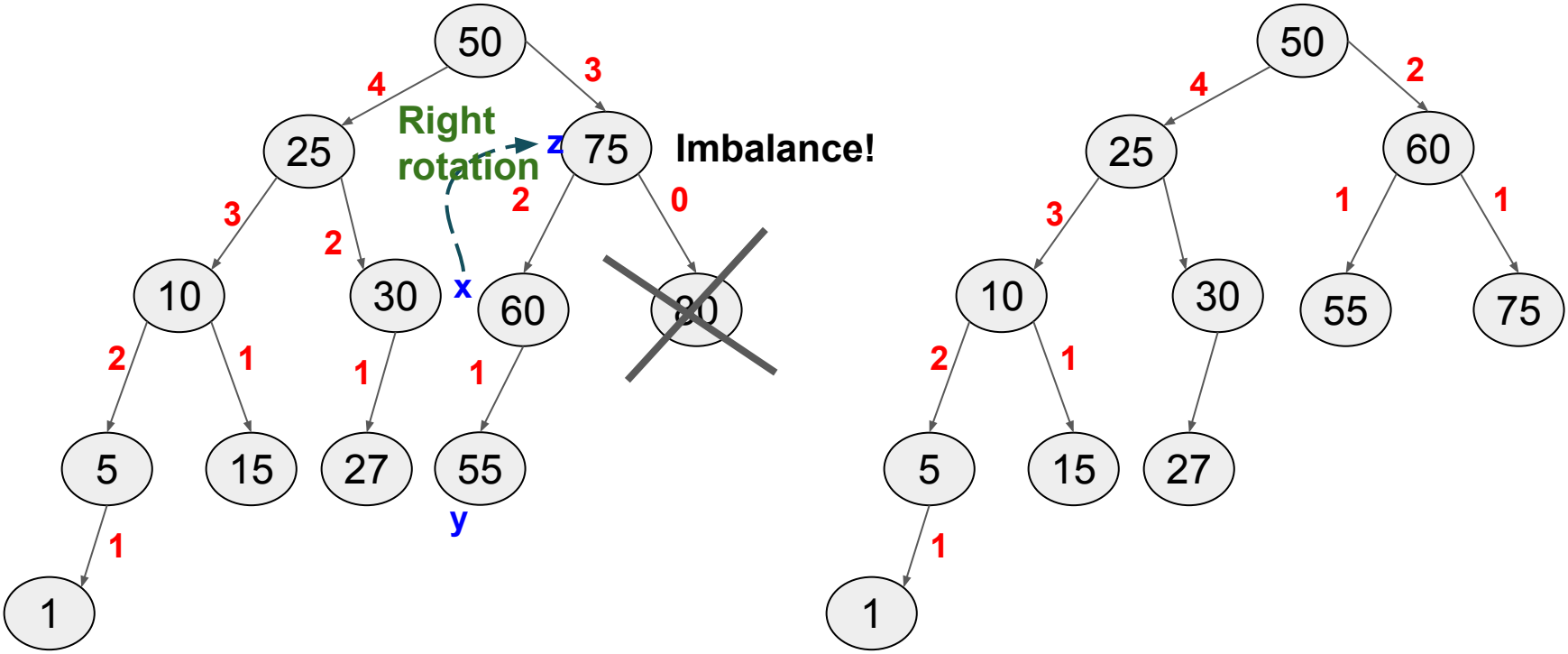
Deletion example



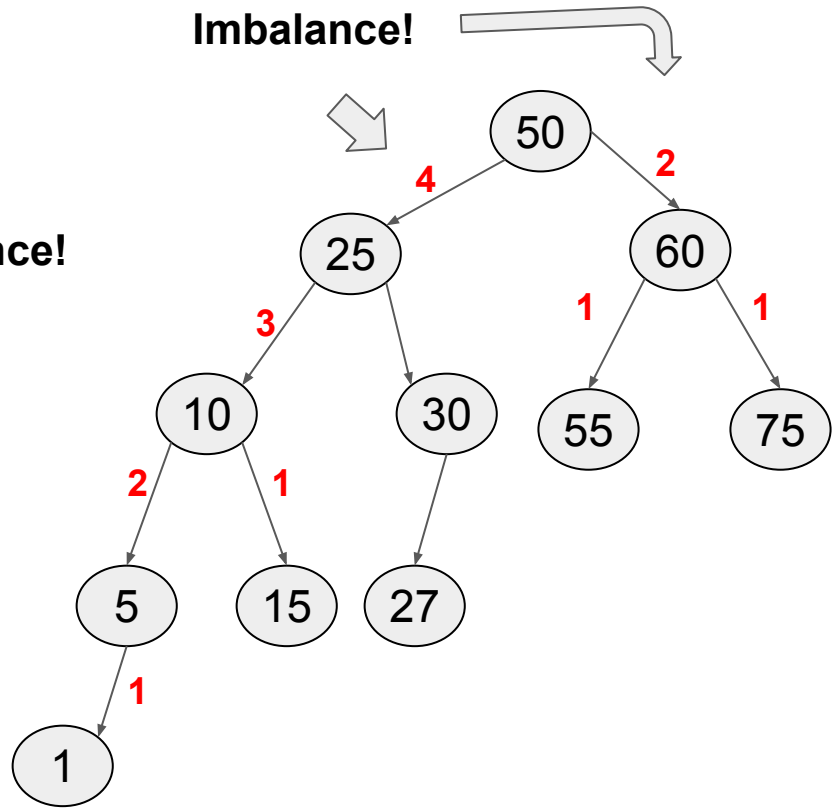
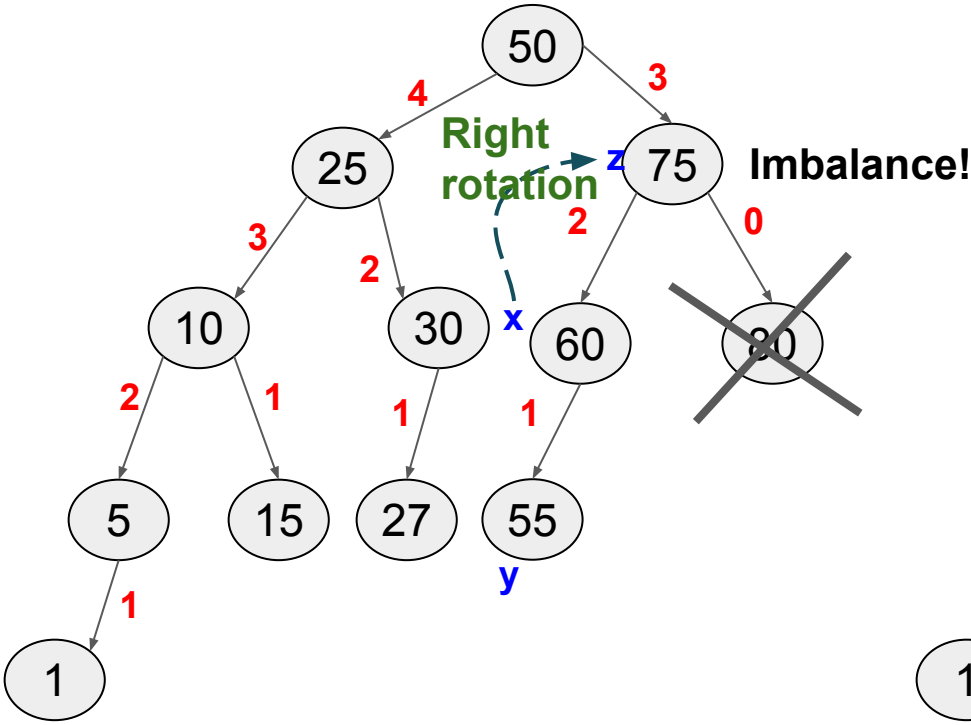
Deletion example



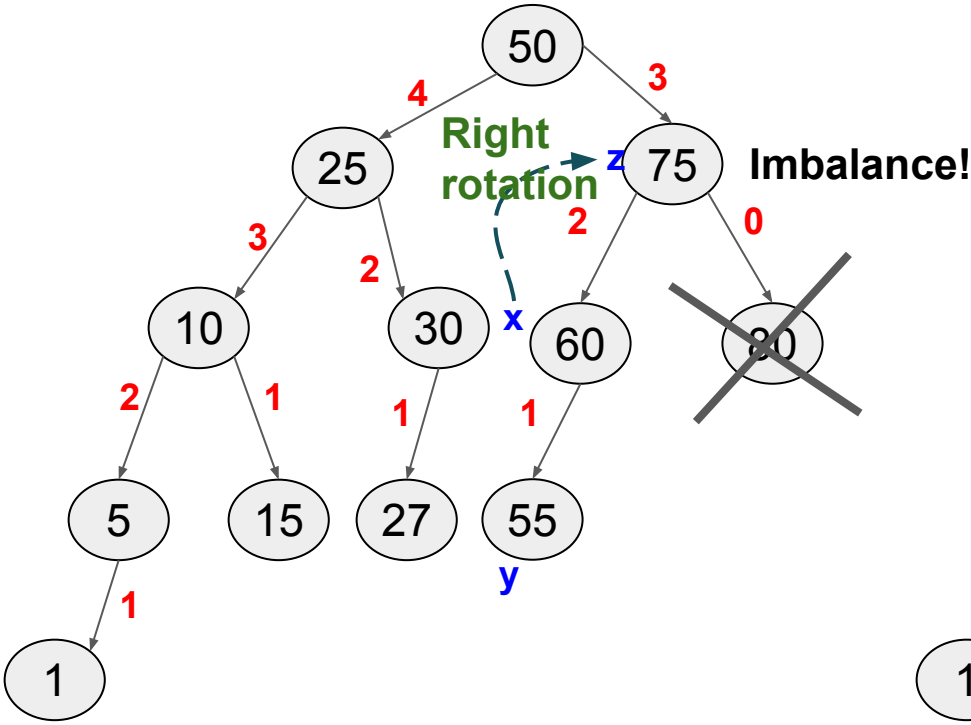
Deletion example



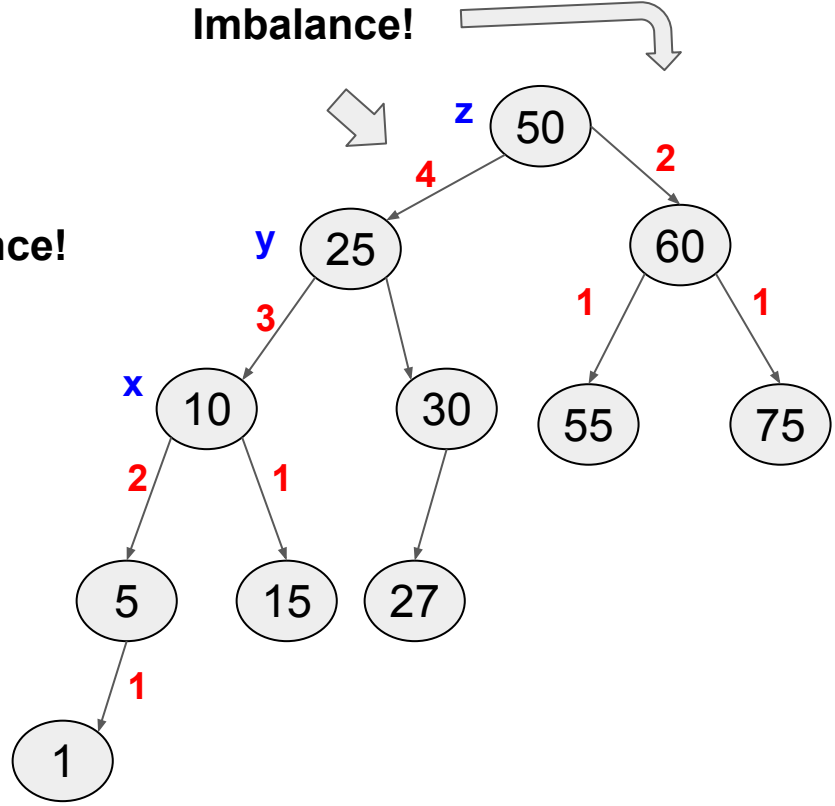
Deletion example



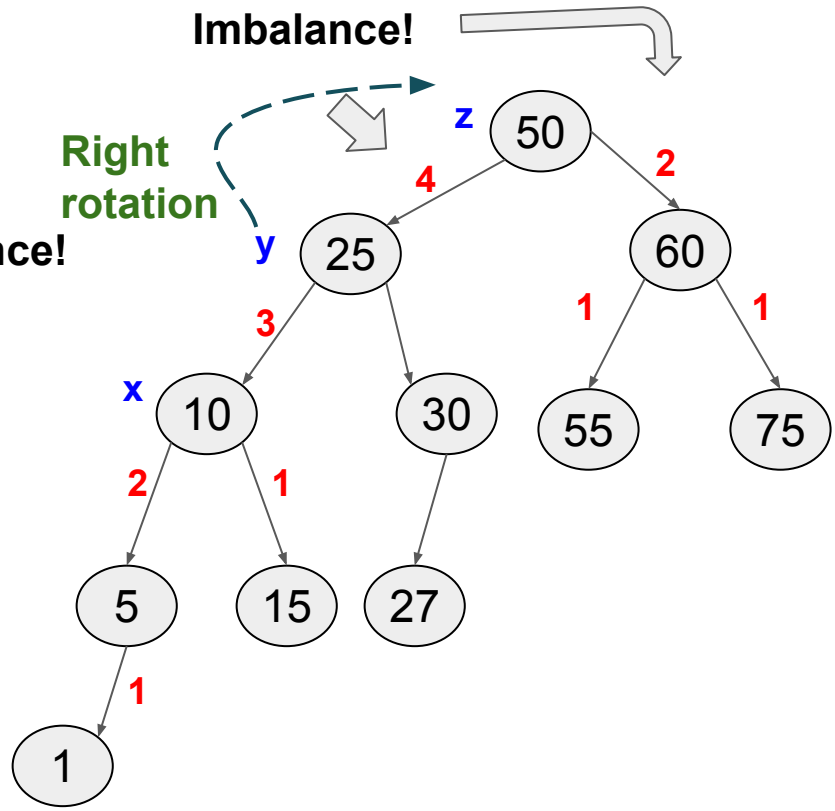
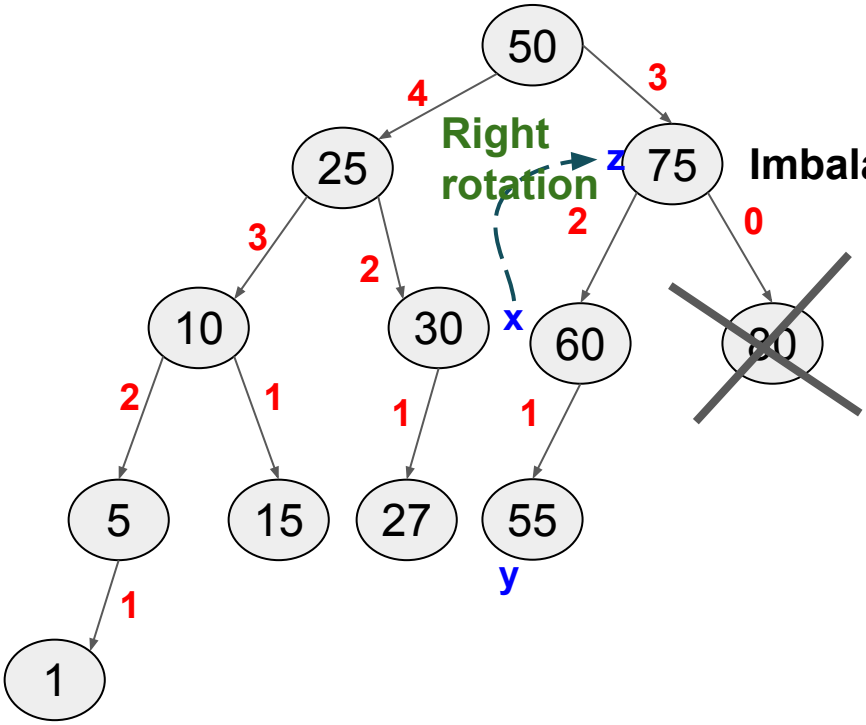
Deletion example



Imbalance!



Deletion example



Deletion example

