Red-Black Tree [BST with following properties]

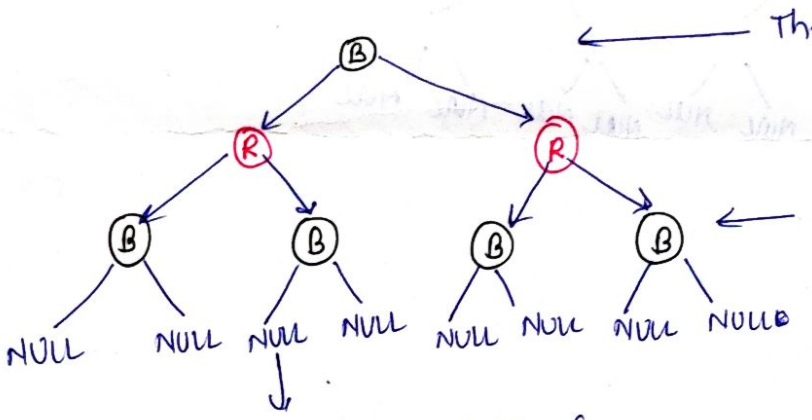
Properties of red black tree

The nodes of a red-black tree are either red or black.

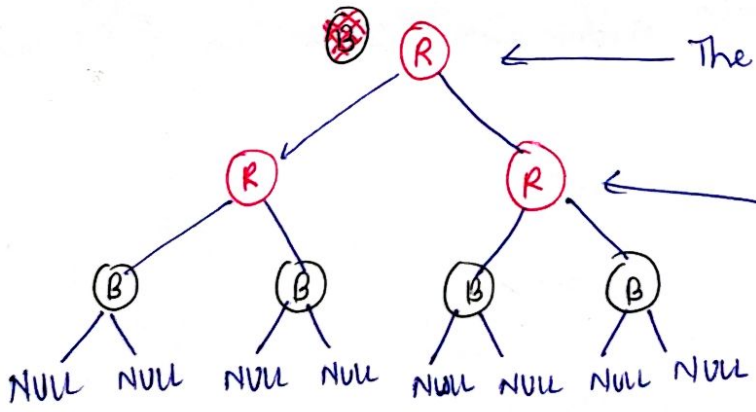
1. The root of the tree is always black.
2. A black node can have a black or a red child.
3. A red node cannot have a red child. It can only have a black child.
4. The black depth of a terminal node is the number of black nodes encountered while travelling from the terminal node to the root
5. The black depth of a terminal node is always same.

Black depth :- The number of black nodes from the terminal to the root is called the black depth of the node

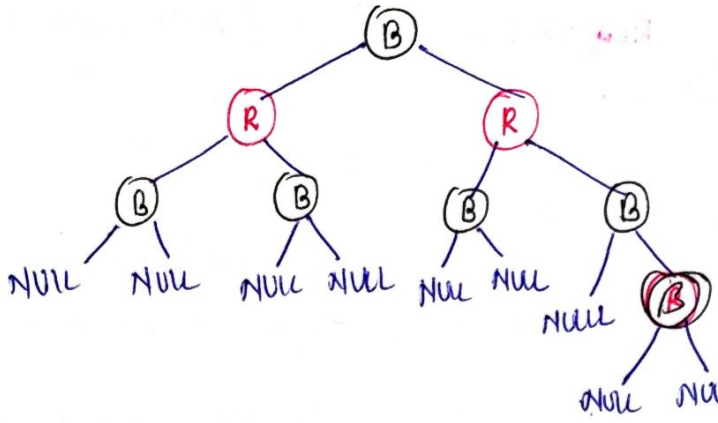
6. The leaves of a red-black tree would always be a NULL node.
7. Each black or red node last in the hierarchy will have NULL nodes as children.



a) An example of a red-black tree



b) An example of a tree which is not red-black tree

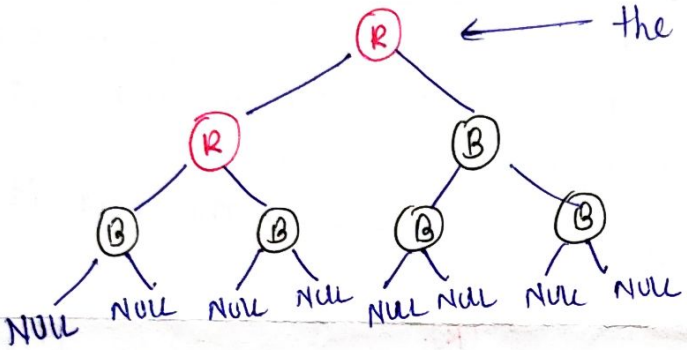


The black depth of this node & its sibling is 3, whereas for the other nodes it is 2.

c) An example of a tree which is not red-black tree

Double red problem

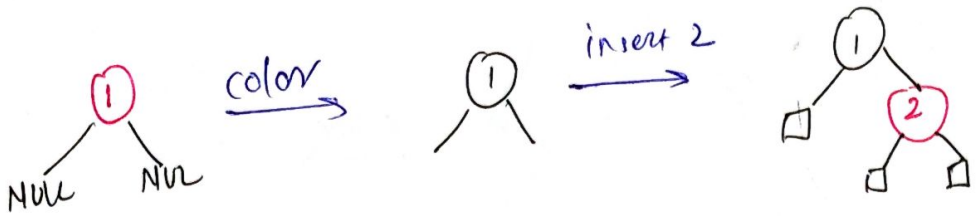
The case wherein the child of a red node is a red node is called the double red problem.



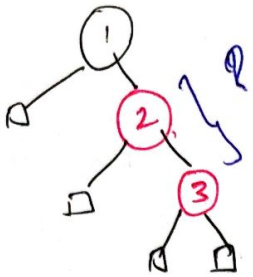
← the root is not black.

A red-black tree is a binary search tree with one extra bit of storage per node: its color which can be either RED or BLACK

1 2 3 4 5 6



insert 3



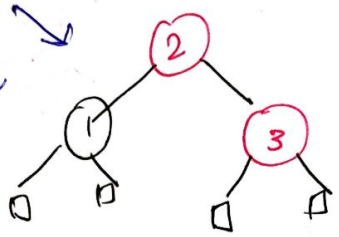
Q How to fix this?

this

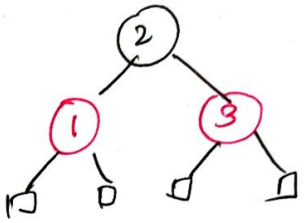
case:-3 [uncle is black & insertion is right]

left rotate around the grandparent

left rotate

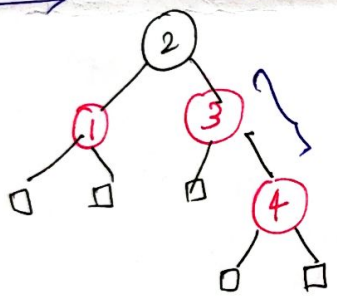


color

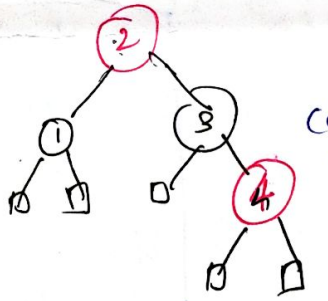


insert 4

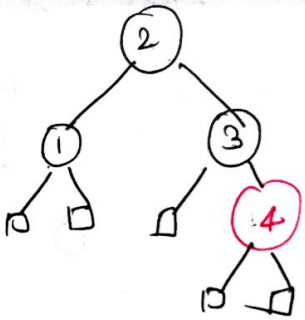
case:-4



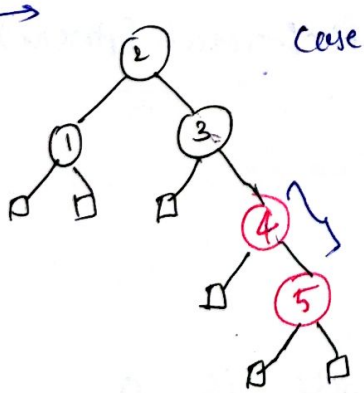
color



color

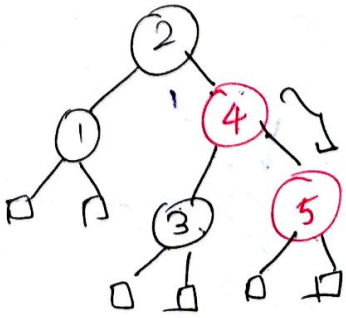


insert 5

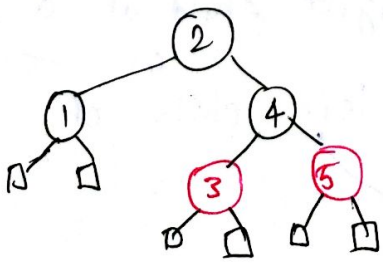


case 3 [uncle is black & insertion is at right]

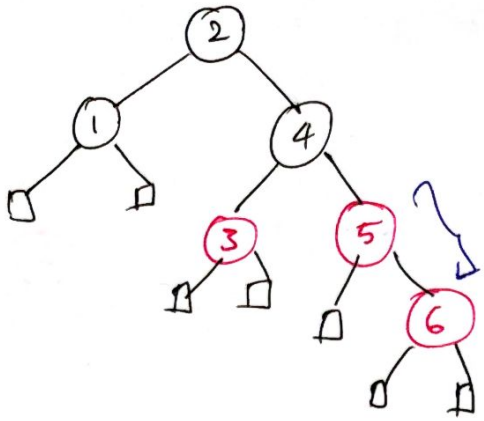
do left rotate



color change

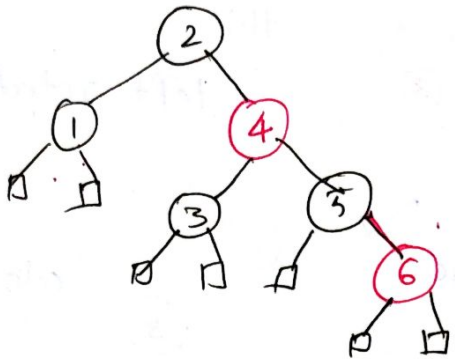


insert 6 →



Uncle is red Case 1

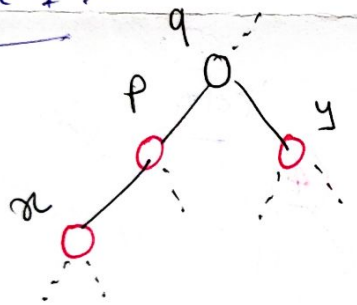
color →



Black height of this tree is 3

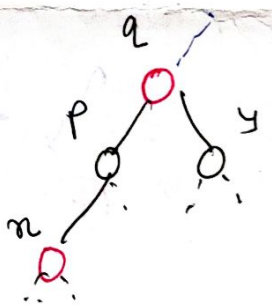
Violations

Case 1 :-

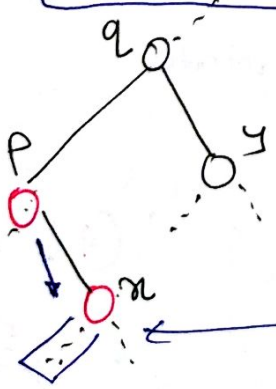


Uncle is Red

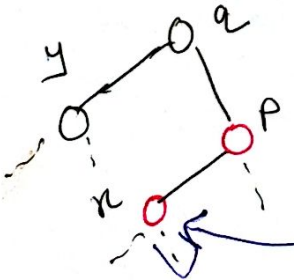
fix : color



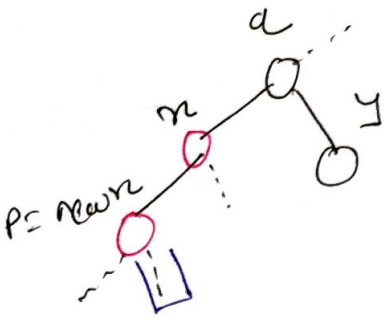
Case 2 :- Uncle is Black fix : rotate (parent)

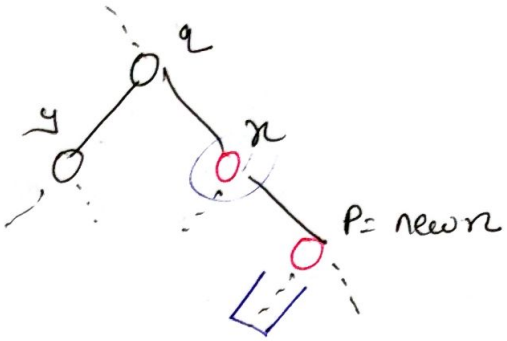


violating node is a right child of a left child or left child of a right child



to fix this rotate around the parent node.





Convert to case 3:

uncle is Black

fix rotate (grand parent)

↓

color