Red-Black Tree Insertion

This lesson will cover the insertion operation in Red-Black trees, discussing all the four insertion cases.

We'll cover the following

Insertion in Red-Black Tree

Here is a high-level description of the algorithm involved in inserting a value in a Red-Black Tree:

1. Insert the given node using the standard BST Insertion technique that we studied earlier and color it **Red**.
2. If the given node is the root, then change its color to **Black**
3. If the given node is not the root, then we will have to perform some operations to make the tree follow the Red-Black property.

Rebalancing the Tree

There are two ways to balance an unbalanced tree:

1. Recoloring Nodes
2. Rotating Nodes (left or right)

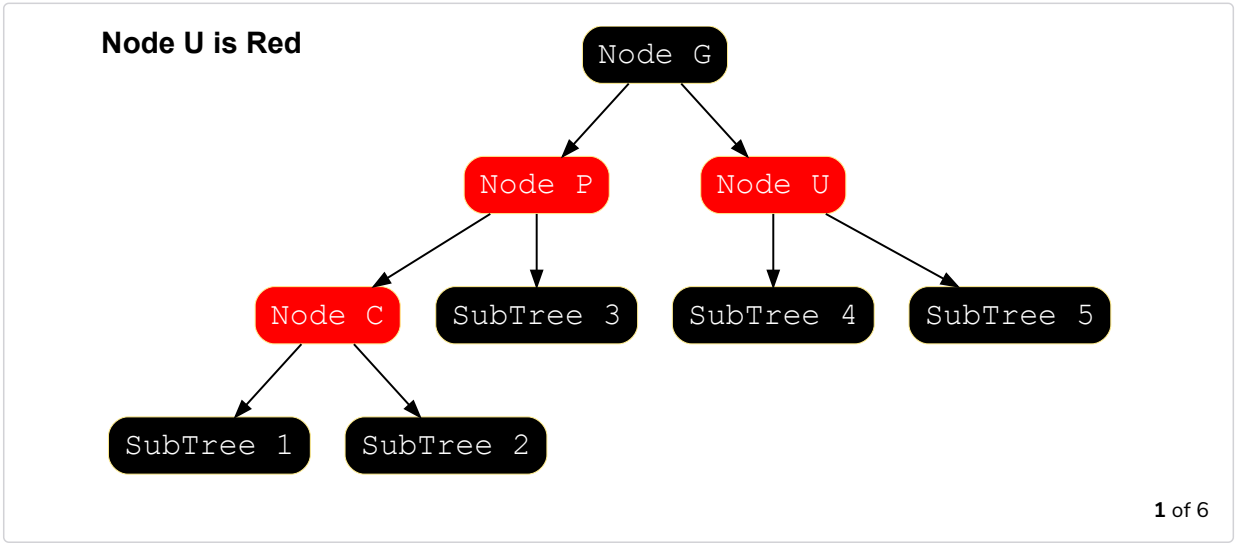
But before the details are explained, let's define the structure of the Red-Black Tree and some nodes relative to the given node, which is the node that we inserted in the Tree.

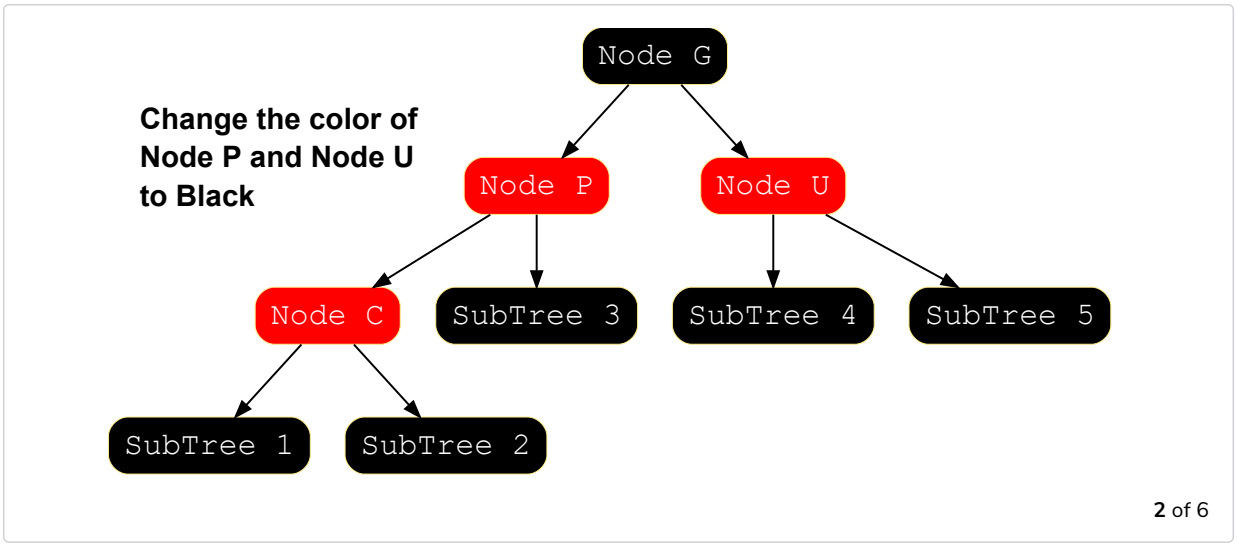
- Node C – the newly inserted node
- Node P – the parent of the newly inserted node
- Node G – the grandparent of the newly inserted node
- Node U – the sibling of the parent of the newly inserted node, i.e., the sibling of Node P / child of Node G

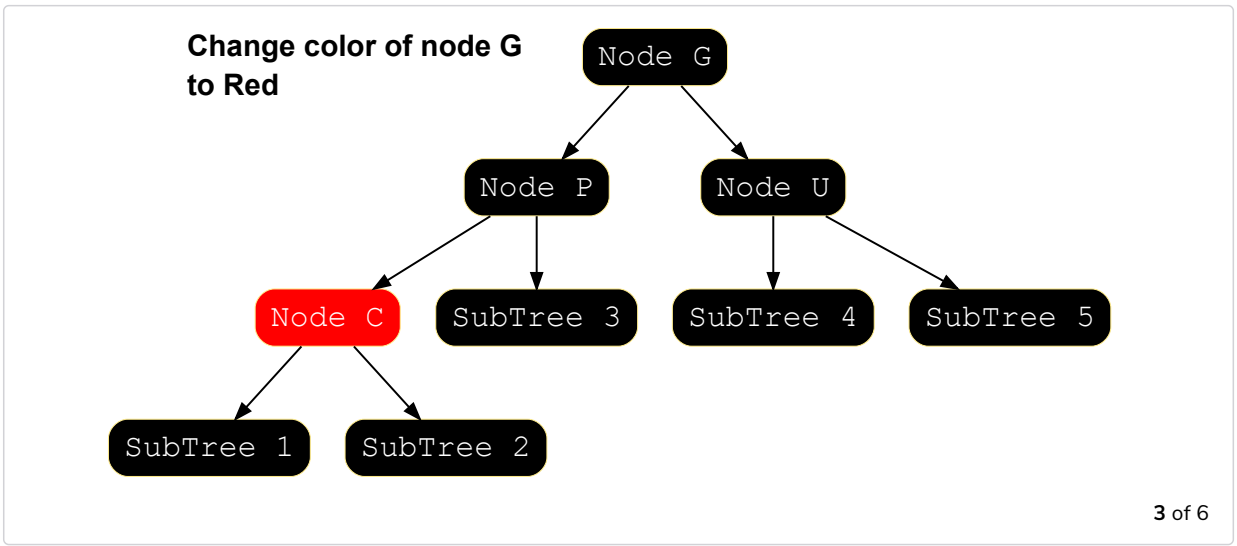
If the newly inserted node is not a root and the parent of the newly inserted node is not **Black**, first, we will check Node U which is the and based on Node U's color, we balance the tree. If

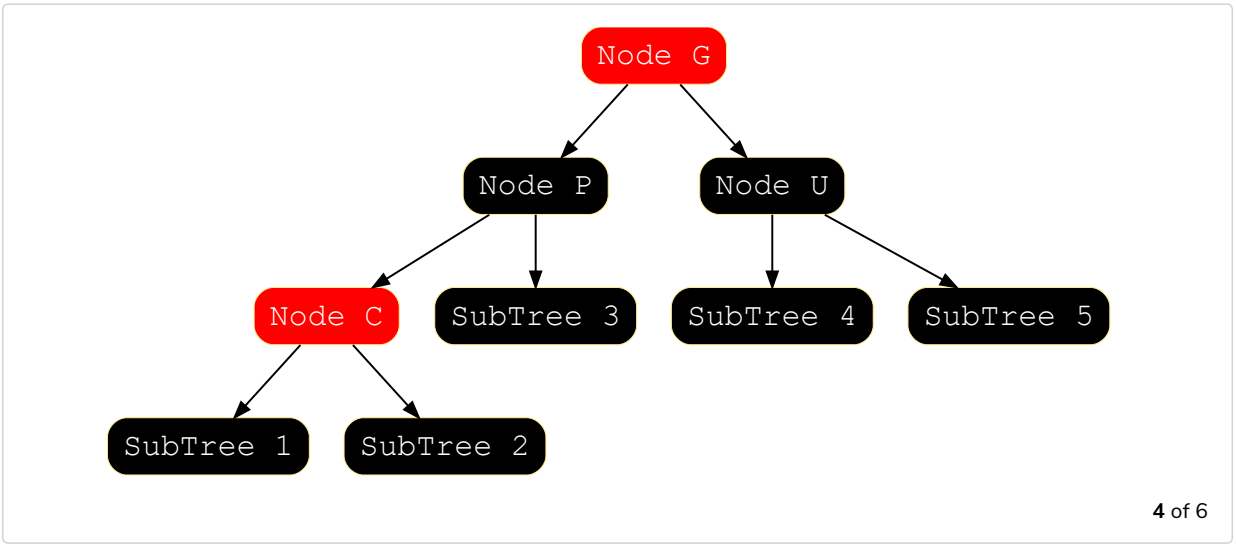
Node U is **Red**, do the following:

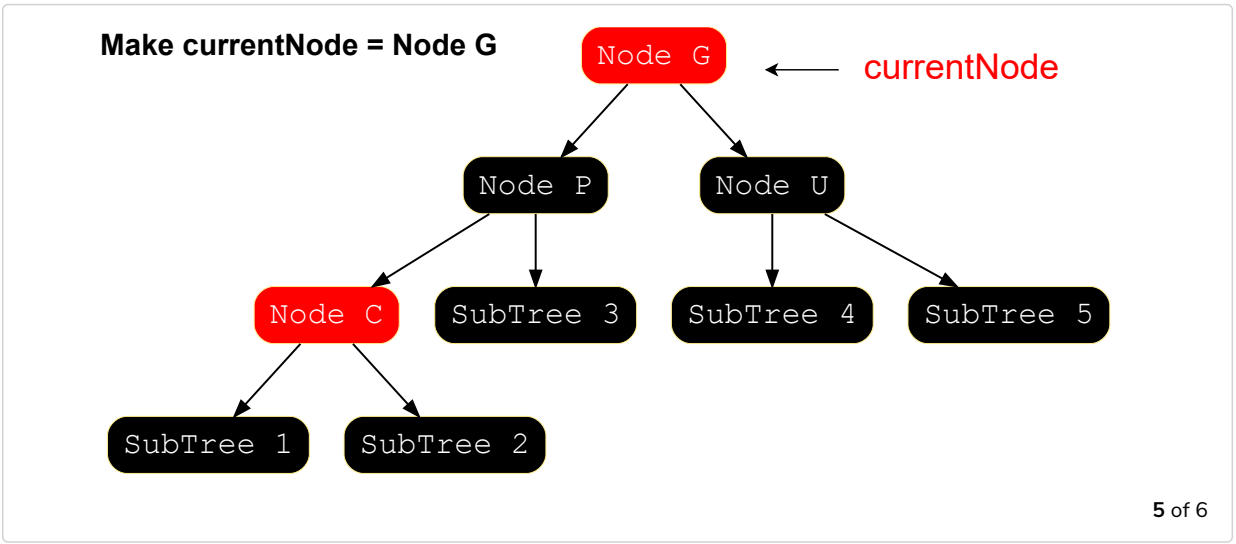
1. Change color of Node P and U to **Black**
2. Change color of Node G to **Red**
3. Make Node G the new *currentNode* and repeat the same process from step two

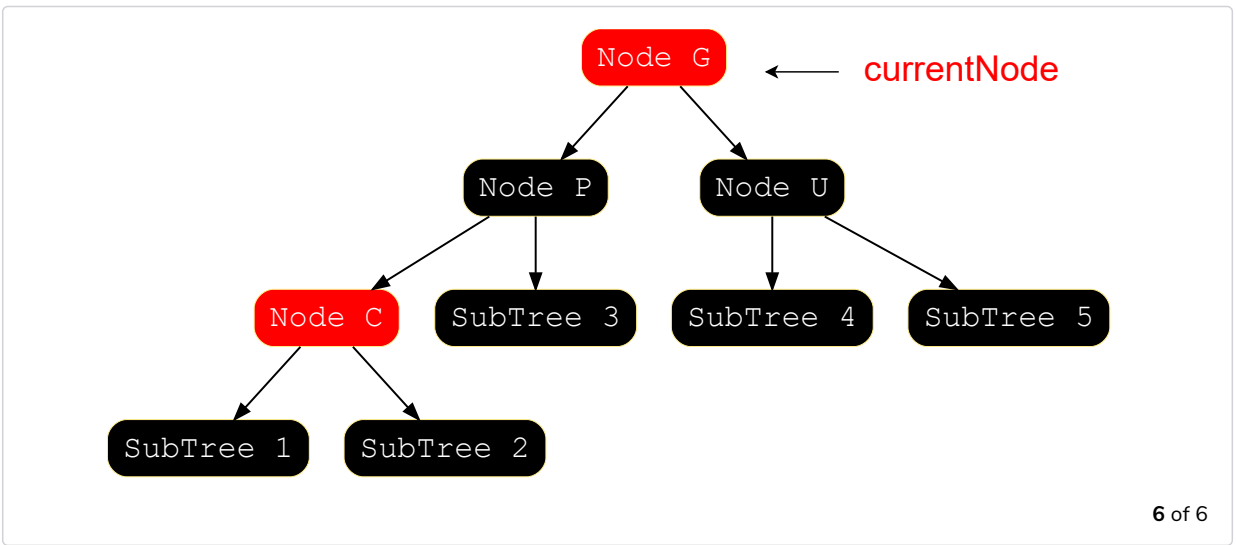












If Node U is **Black**, then we come across four different scenarios based on the arrangements of Node P and G, just like we did in AVL trees. We will cover each of these scenarios and try to help you understand through illustrations.

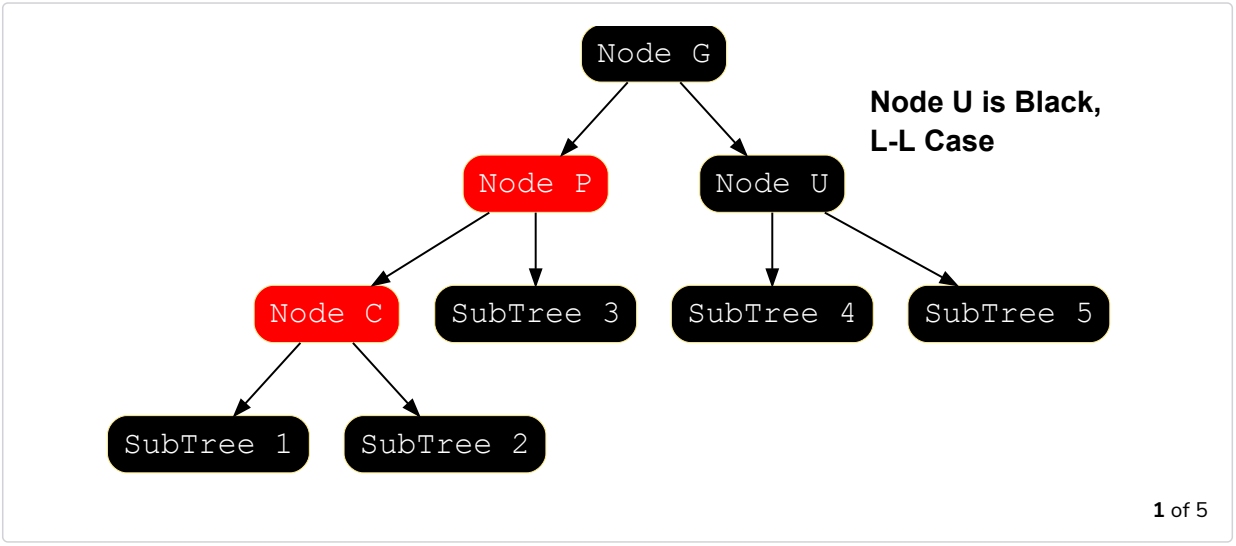
- Left-Left: Node P is the *leftChild* of Node G and *currentNode* is the *leftChild* of Node P

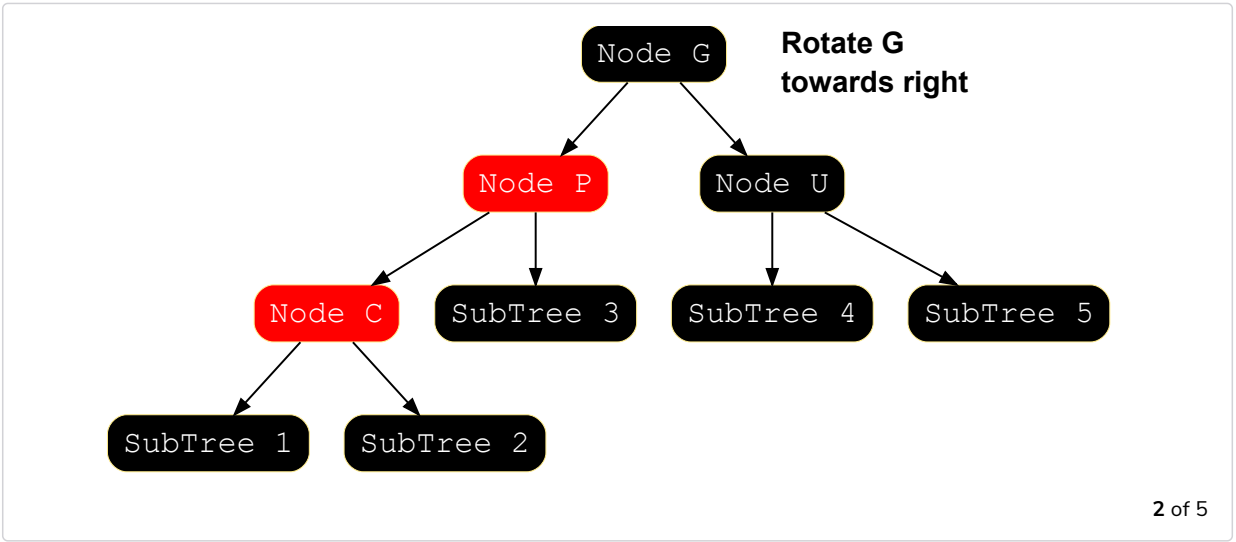
- Left-Right: Node P is the *leftChild* of Node G and *currentNode* is the *rightChild* of Node P
- Right-Right: Node P is the *rightChild* of Node G and *currentNode* is the *rightChild* of Node P
- Right-Left: Node P is the *rightChild* of Node G and *currentNode* is the *leftChild* of Node P

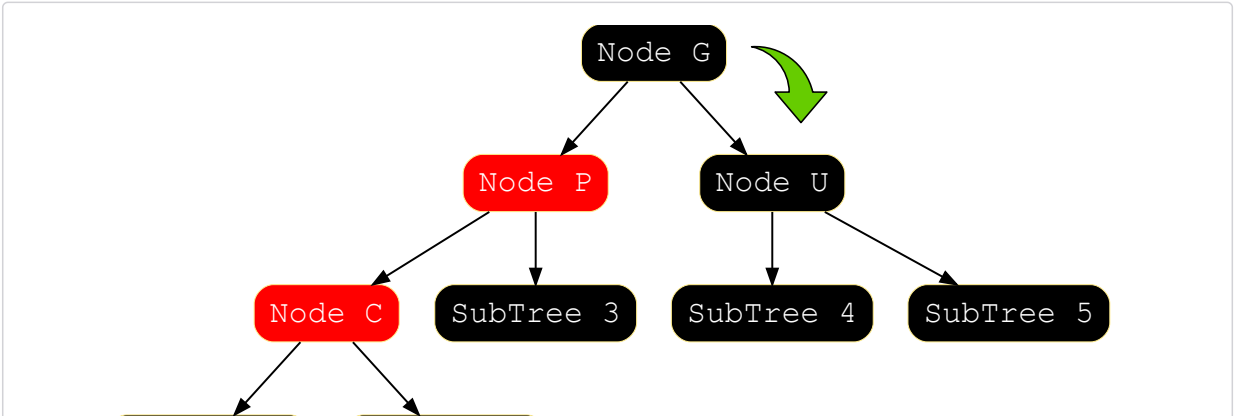
Case 1: Left-Left

In case when the Node P is the *leftChild* of Node G and *currentNode* is the *leftChild* of Node P, we perform the following steps. Look at the illustration below for a better understanding.

1. Right Rotate Node G
2. Swap the colors of Nodes G and P







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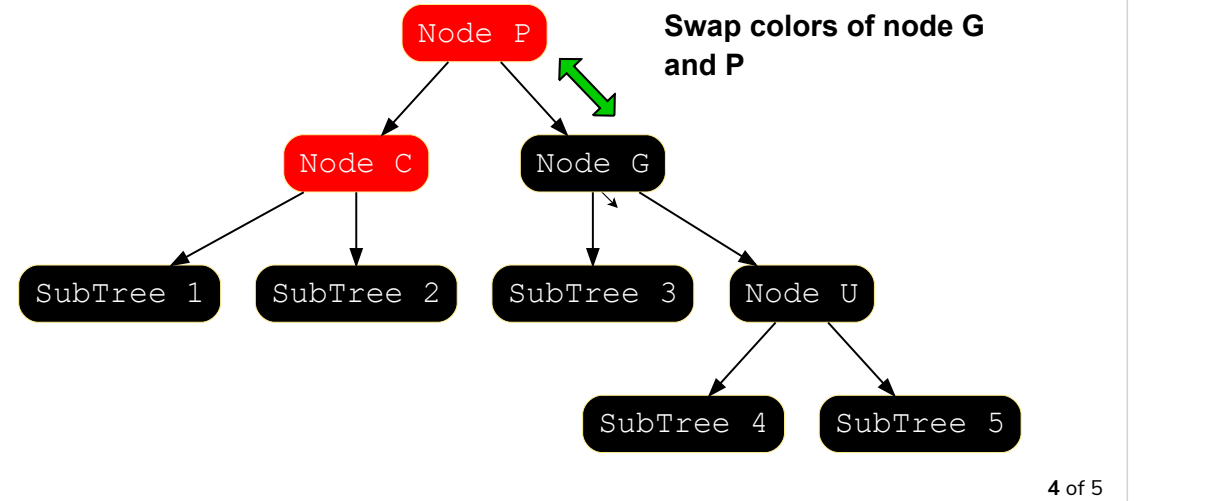

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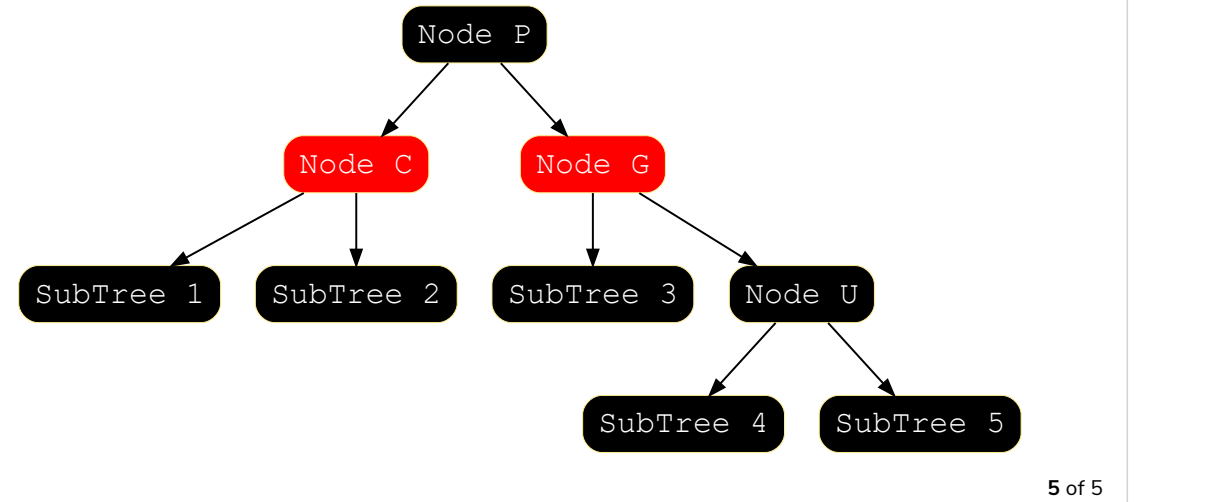

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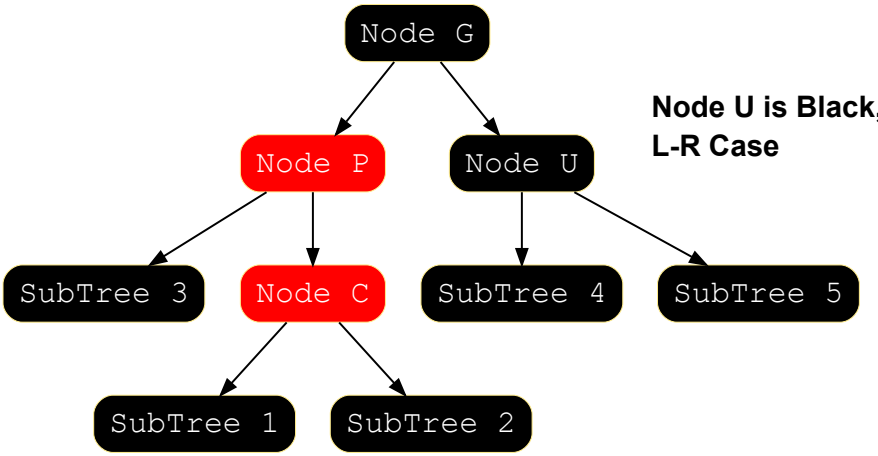
Case 2: Left-Right

In the case when the Node P is the *leftChild* of Node G and the currentNode is the *rightChild* of Node P, we perform the following steps. Look at the illustration below for better understanding:

1. Left Rotate Node P
2. After that, repeat the steps that we covered in the Left-Left case



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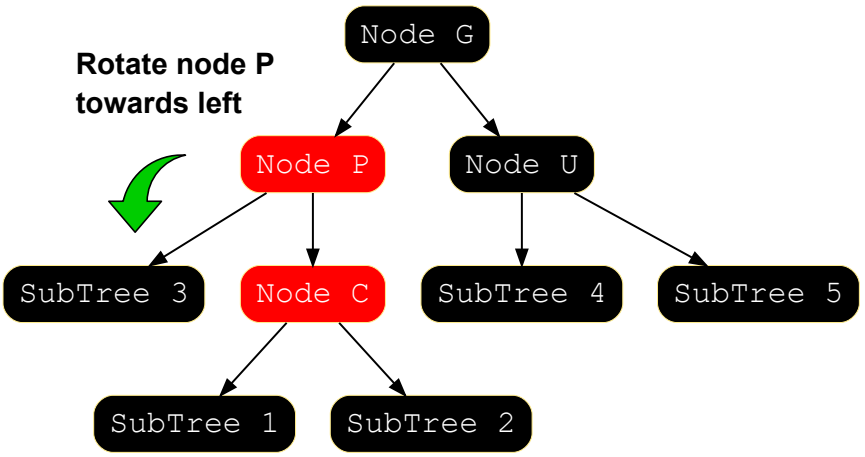

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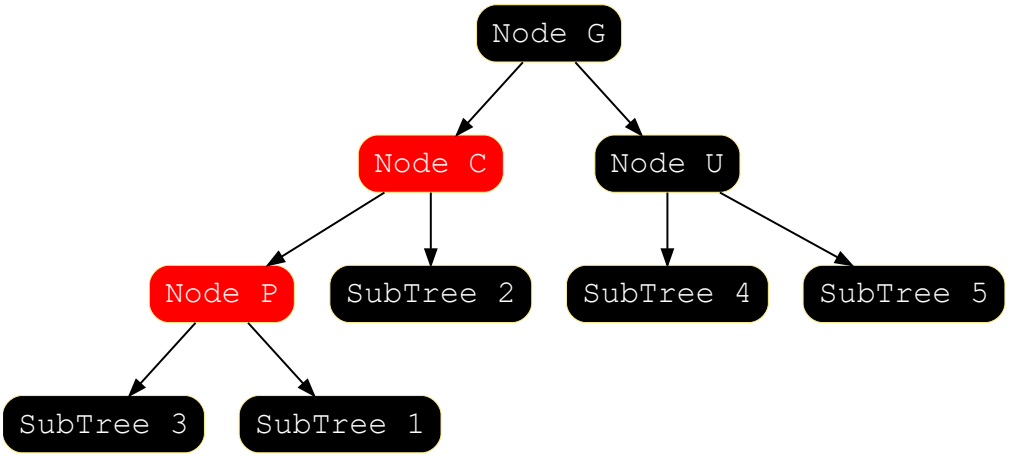

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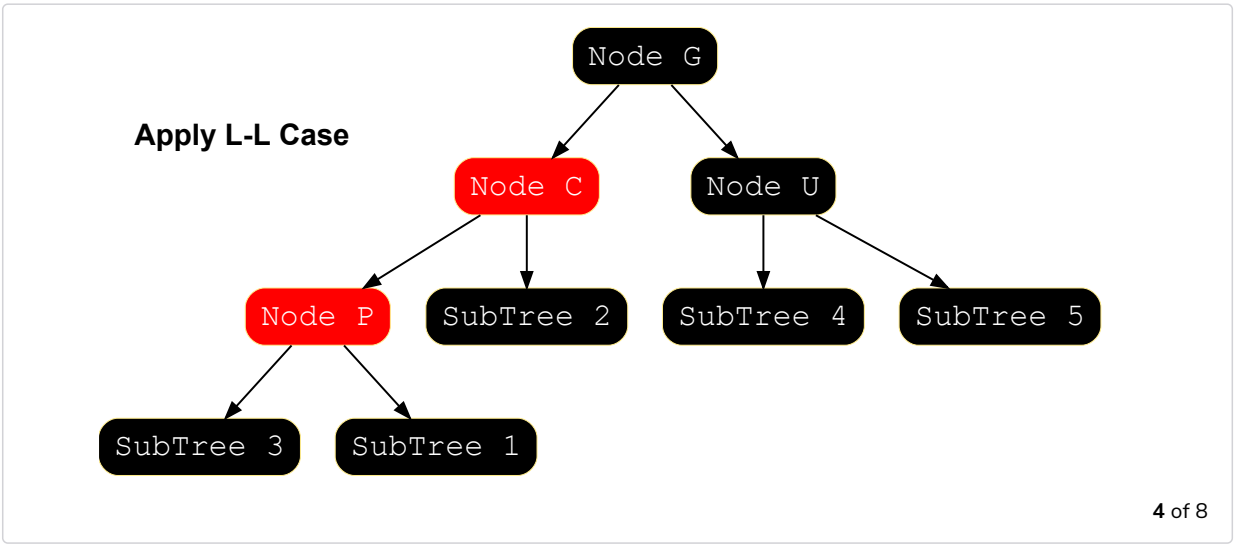
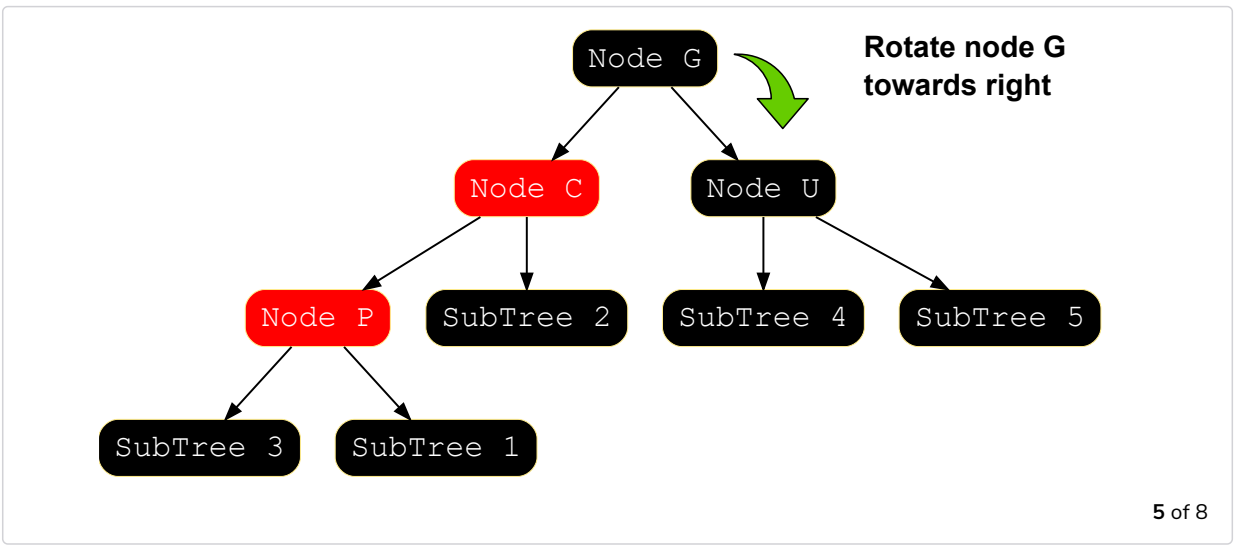
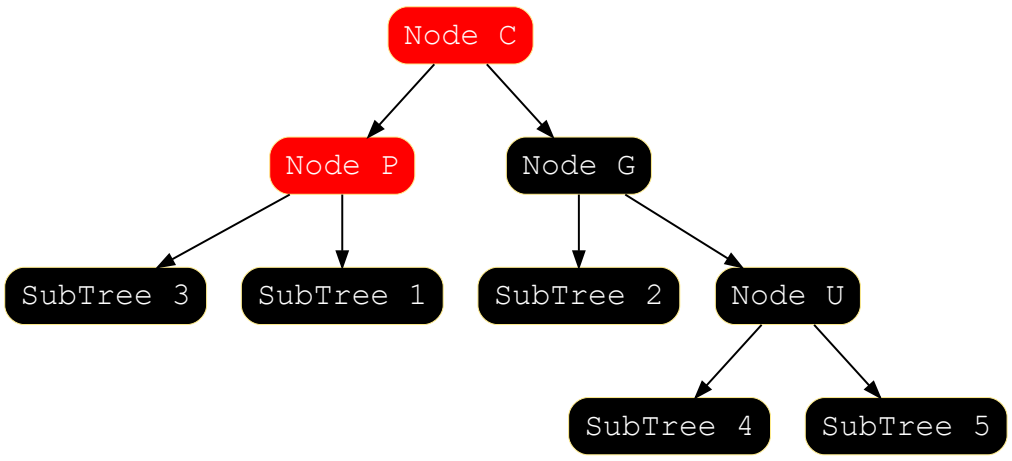
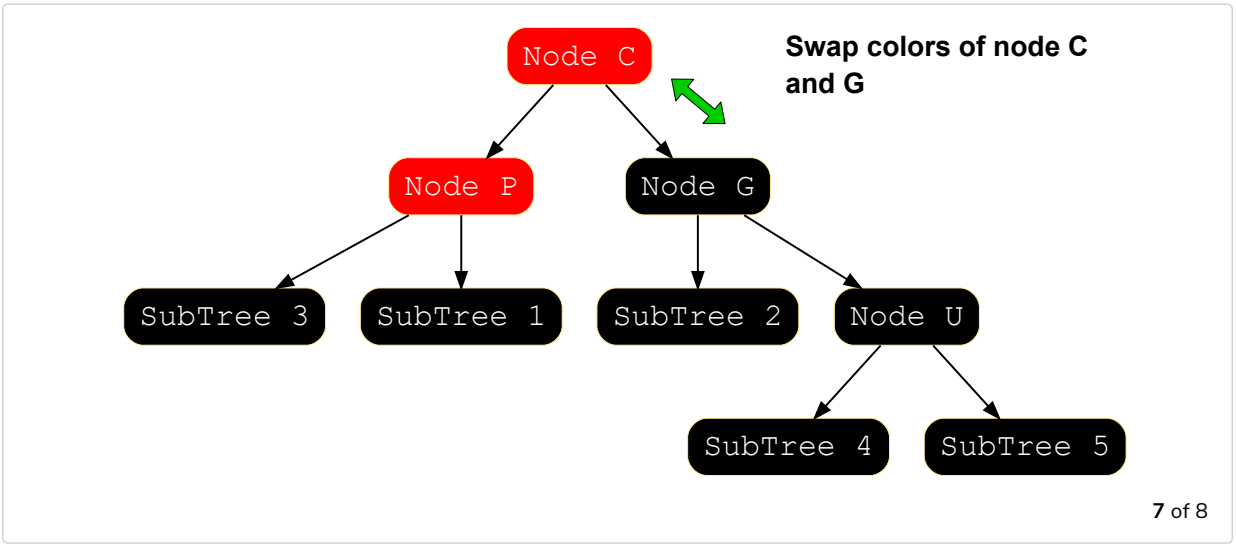
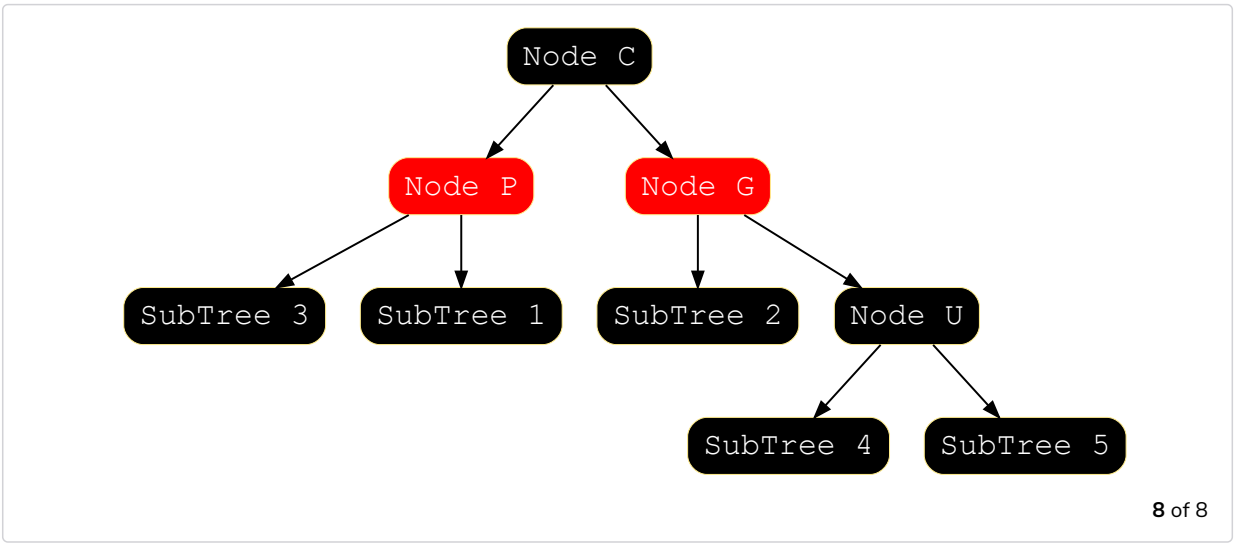

Apply L-L Case
Node G
Node C
Node U
Node P
SubTree 2
SubTree 4
SubTree 5
SubTree 3
SubTree 1


Node G
Rotate node G
towards right
Node C
Node U
Node P
SubTree 2
SubTree 4
SubTree 5
SubTree 3
SubTree 1


Node C
Node P
Node G
SubTree 3
SubTree 1
SubTree 2
Node U
SubTree 4
SubTree 5

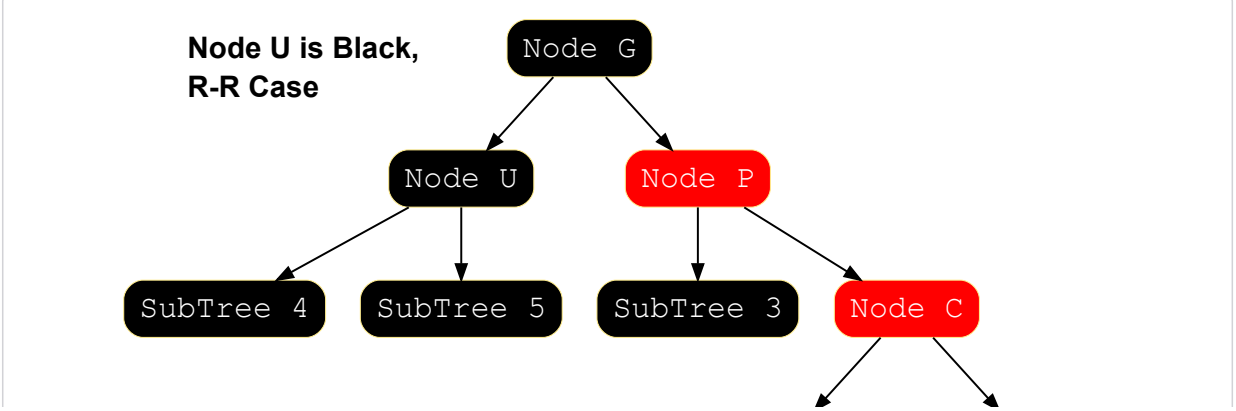




Case 3: Right-Right

In the case when Node P is the *rightChild* of Node G and the *currentNode* is the *rightChild* of Node P, we perform the following steps. Look at the illustration below for a better understanding.

1. Left Rotate Node G
2. Swap colors of Node G and P



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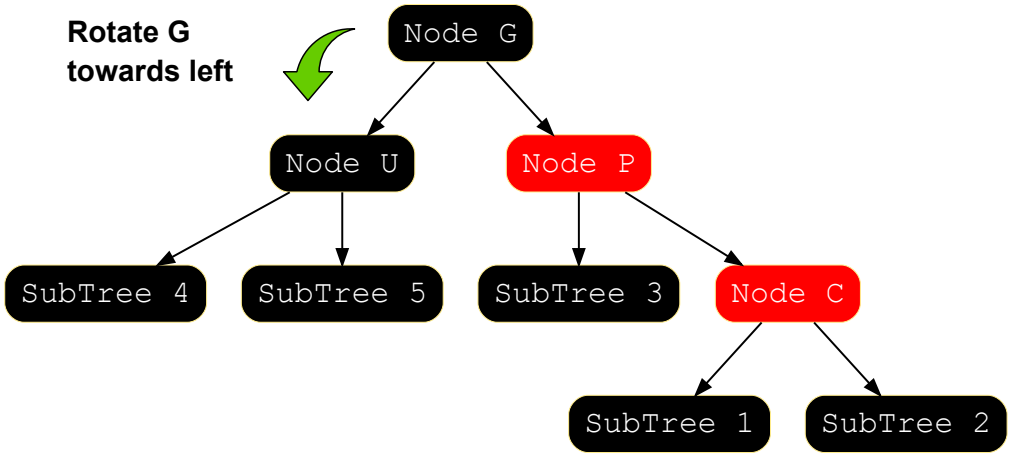

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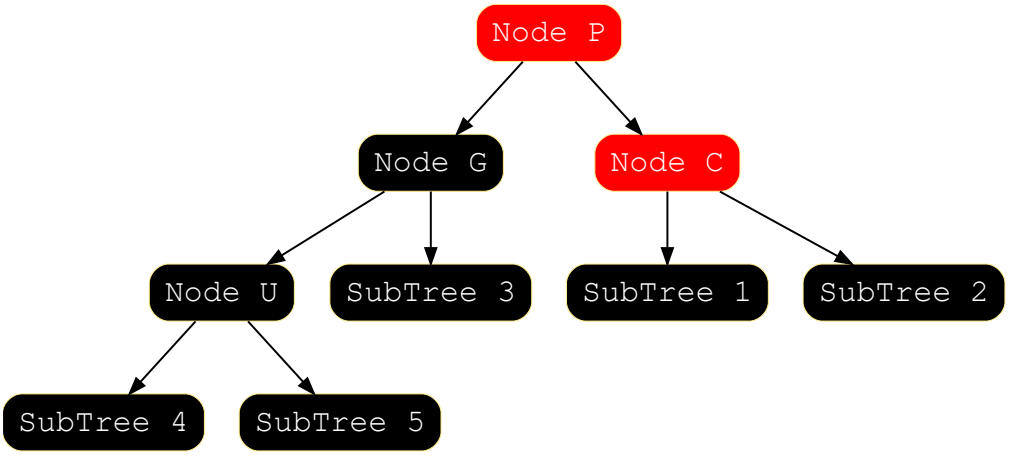

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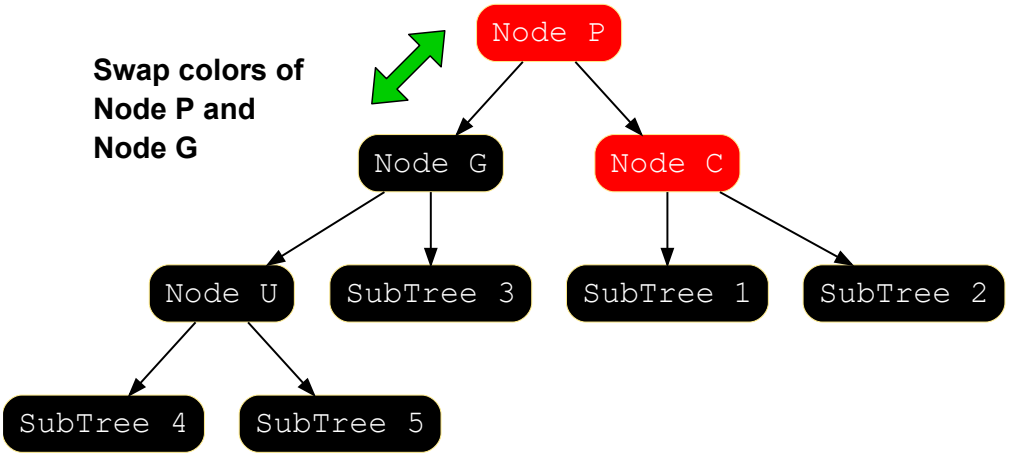

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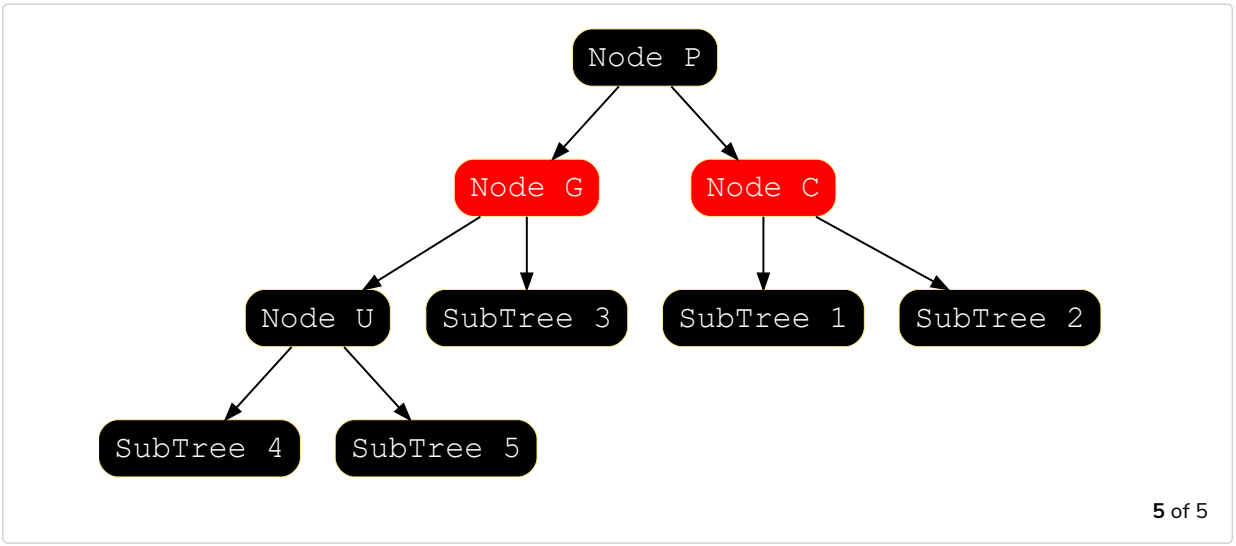
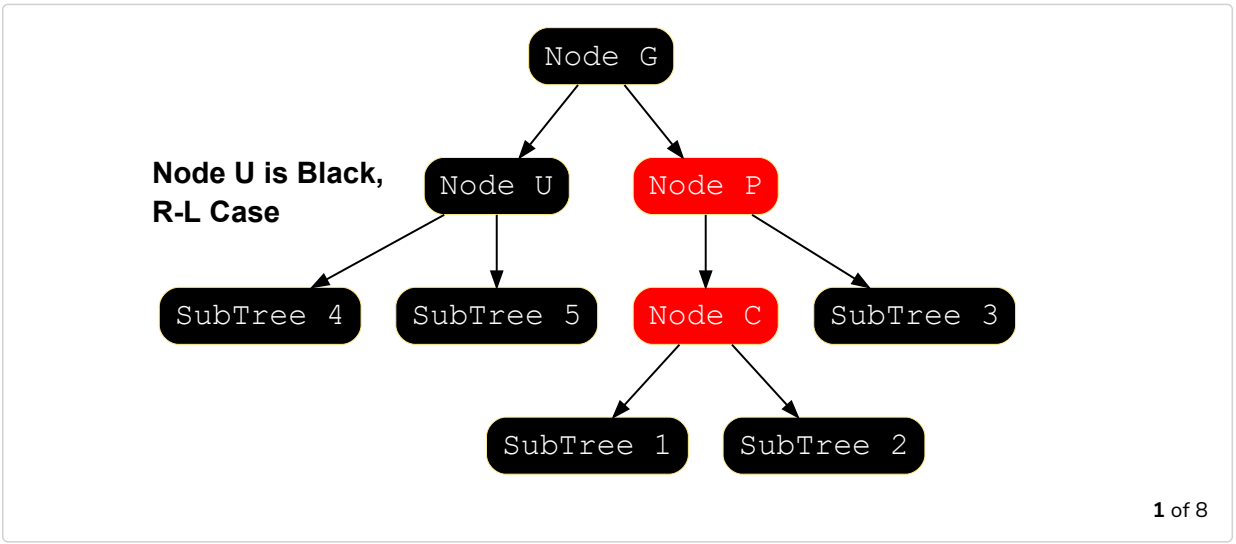
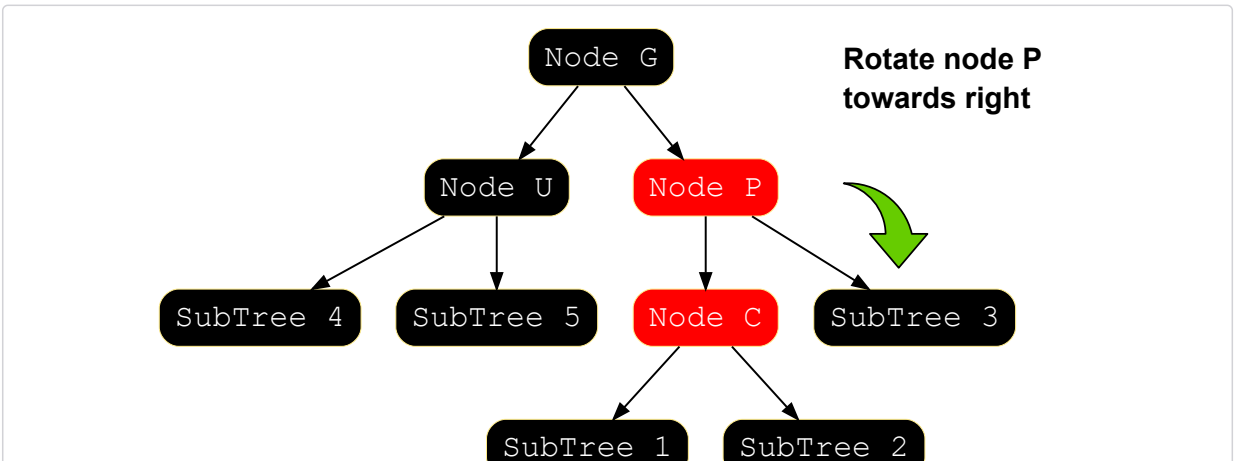


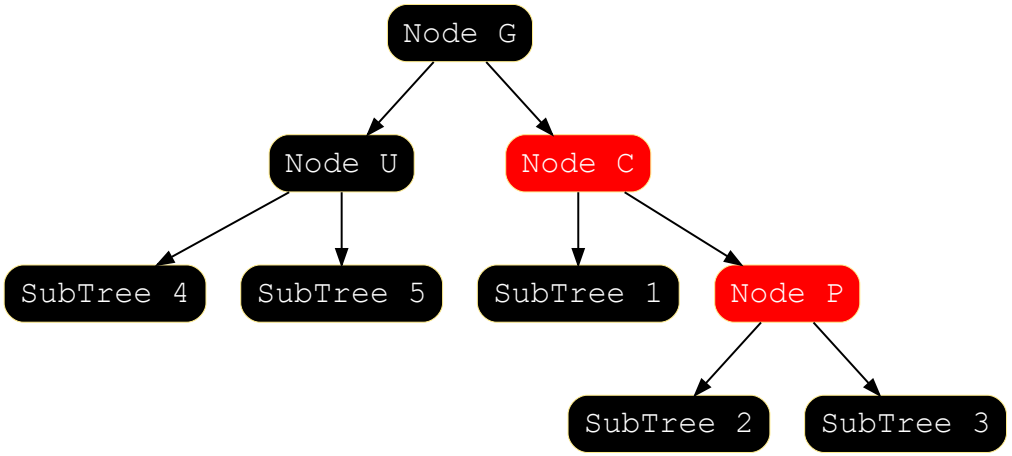
Case 4: Right-Left

In the case when Node P is the *rightChild* of Node G and the *currentNode* is the *leftChild* of Node P, we perform the following steps. Look at the illustration below for a better understanding.

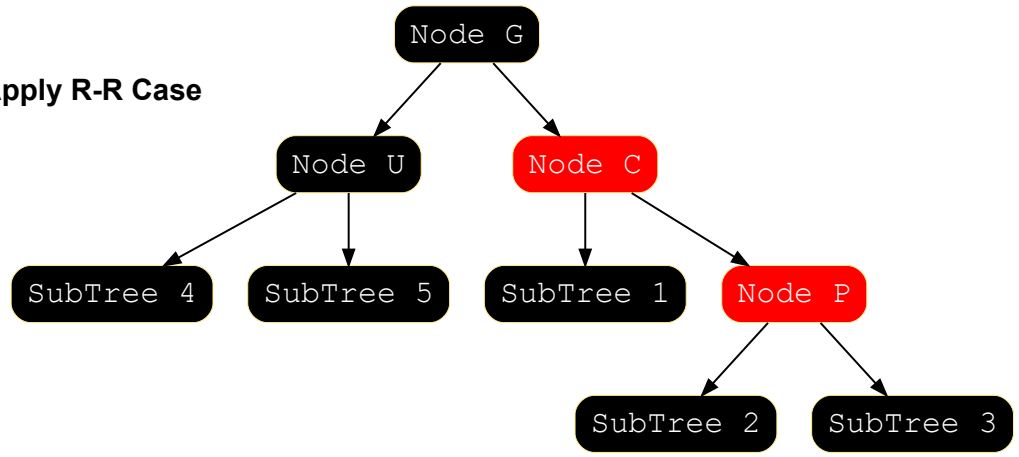
1. Right Rotate Node P
2. After that, repeat the steps that we covered in Right-Right case



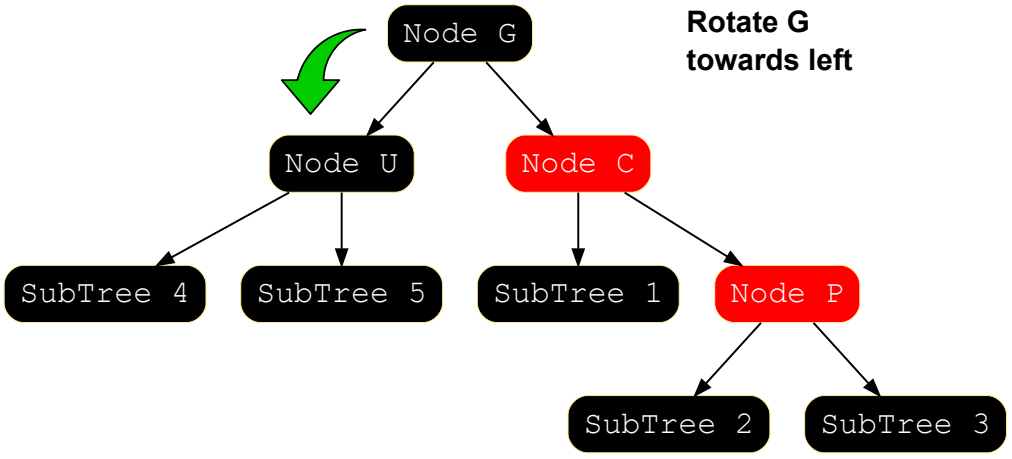


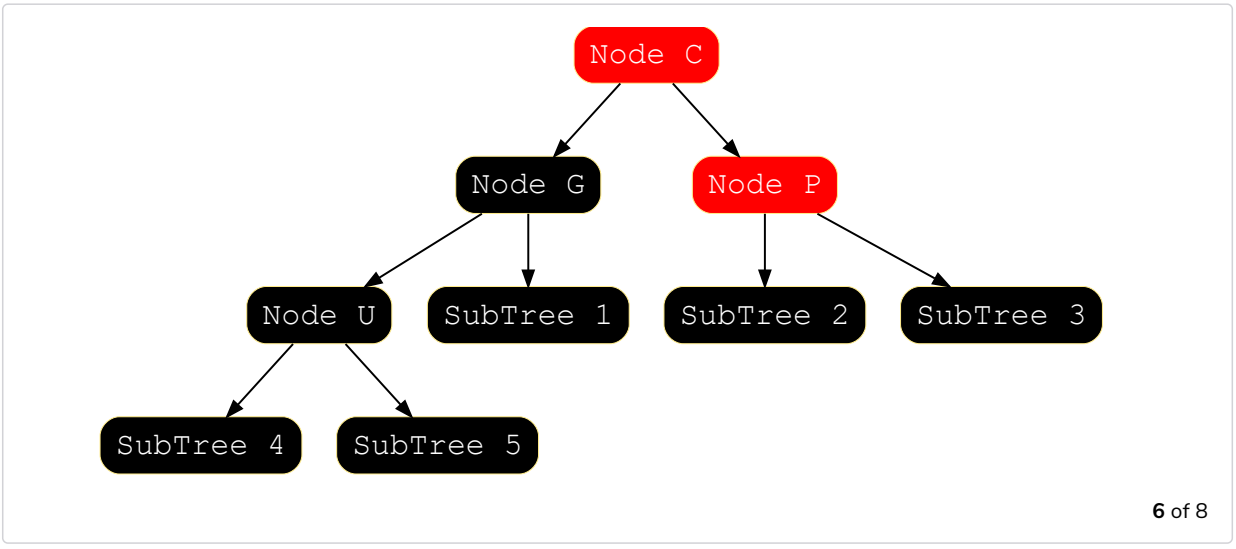


Apply R-R Case



Rotate G towards left





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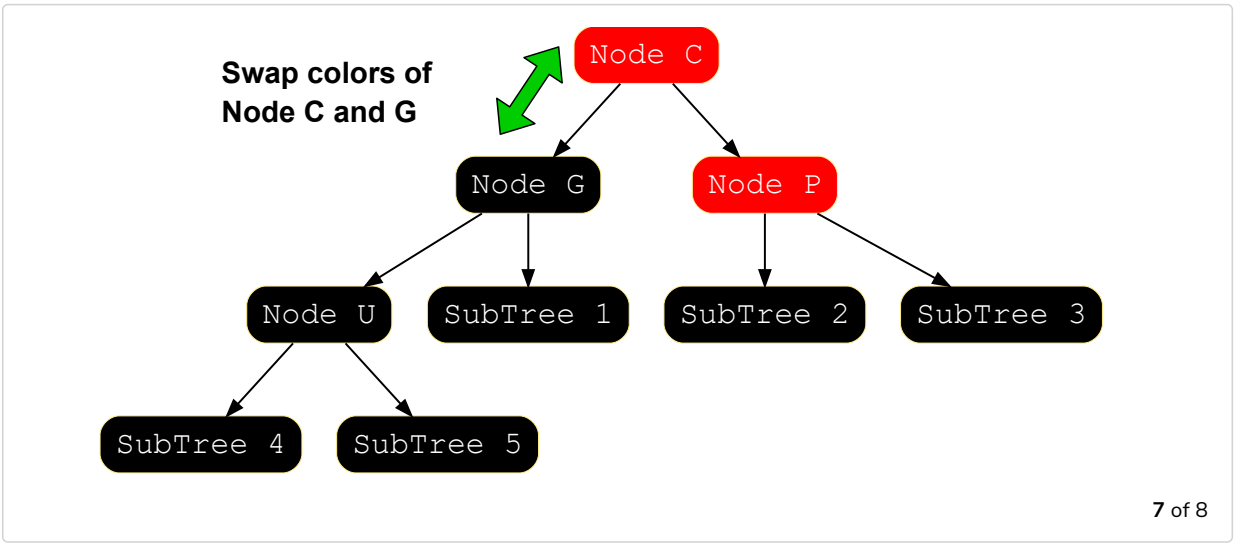

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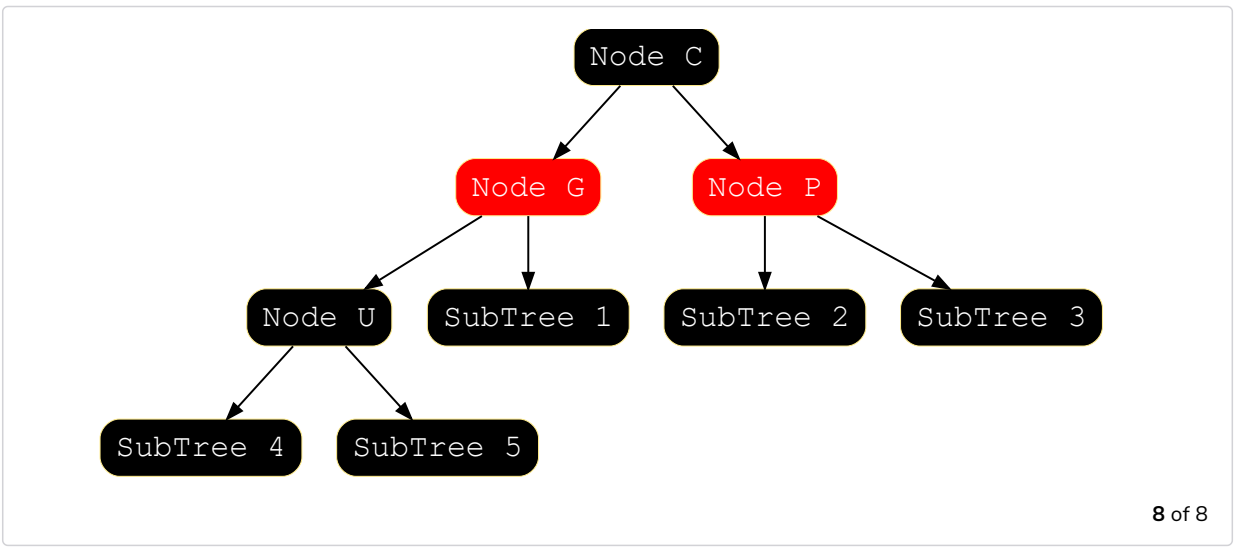

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In the next lesson, we'll study red-black tree deletion!

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