



Data Structure

Lab Session #5: Binary Trees

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Goals

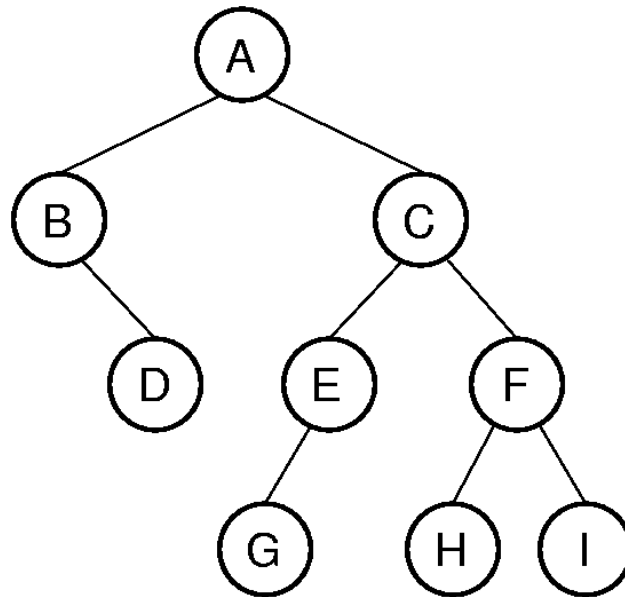
- Implement **Binary Search Tree, Traverses**
 - Fill your code in the methods in `BinaryTree.Node` class.

- Print the sample output corresponding to the sample input
 - Please carefully observe the I/O specification.



Binary Trees

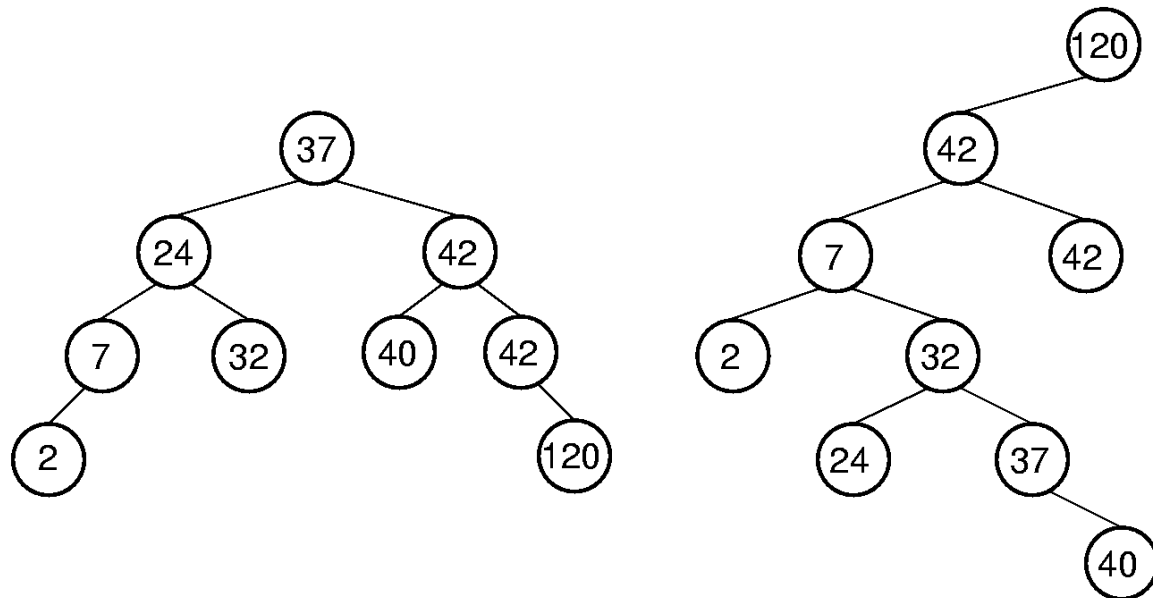
- A binary tree is made up of a finite set of nodes that is either empty or consists of a node called the root together with two binary trees, called the left and right subtrees, which are disjoint from each other and from the root.





Binary Search Trees

- **BST Property:** All elements stored in the left subtree of a node with value K have values $< K$. All elements stored in the right subtree of a node with value K have values $\geq K$.





BST insert

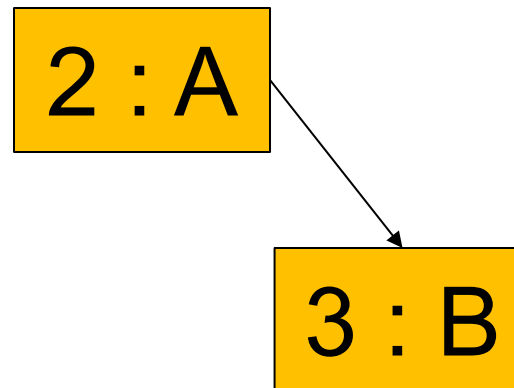
- insert 2 A

2 : A



BST insert

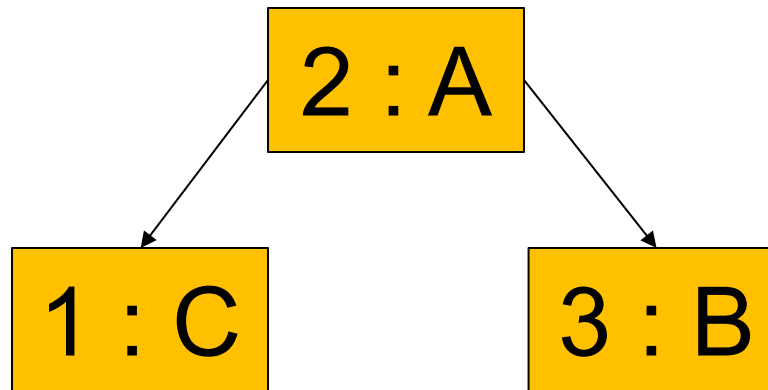
- insert 3 B





BST insert

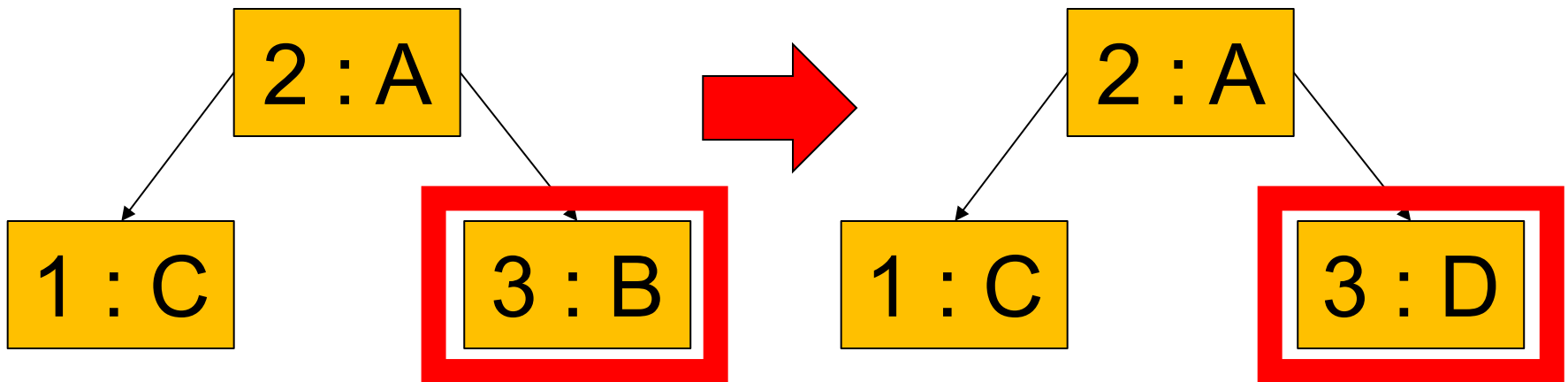
- insert 1 C





BST insert

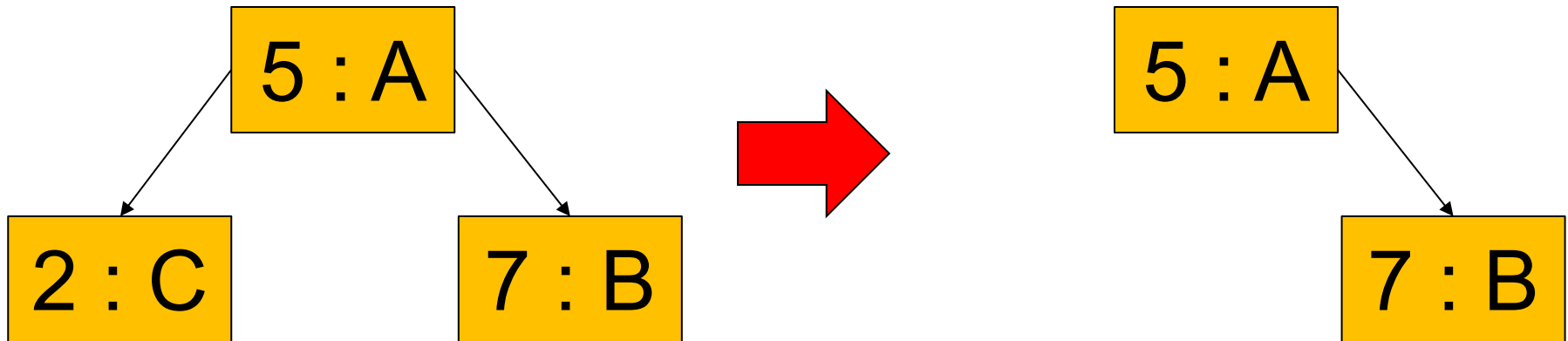
- insert 3 D
 - If BST already contains given key, replace the value.





BST delete

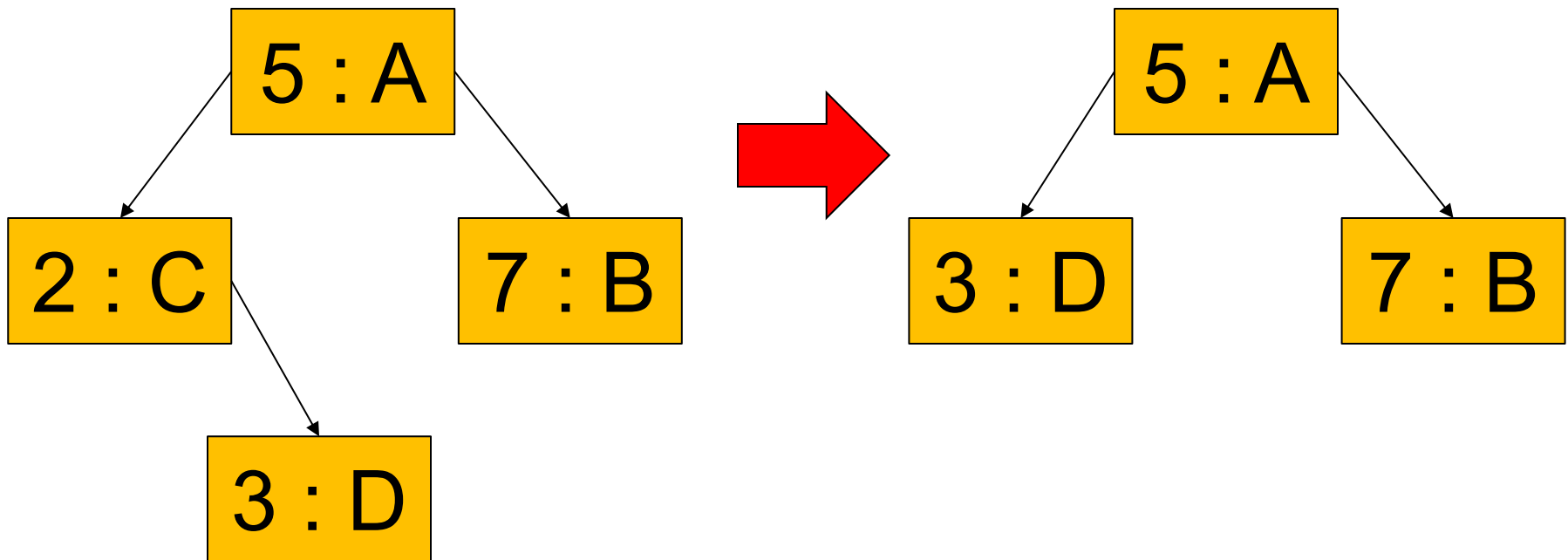
- delete 2
 - If there are no children in the node to be deleted





BST delete

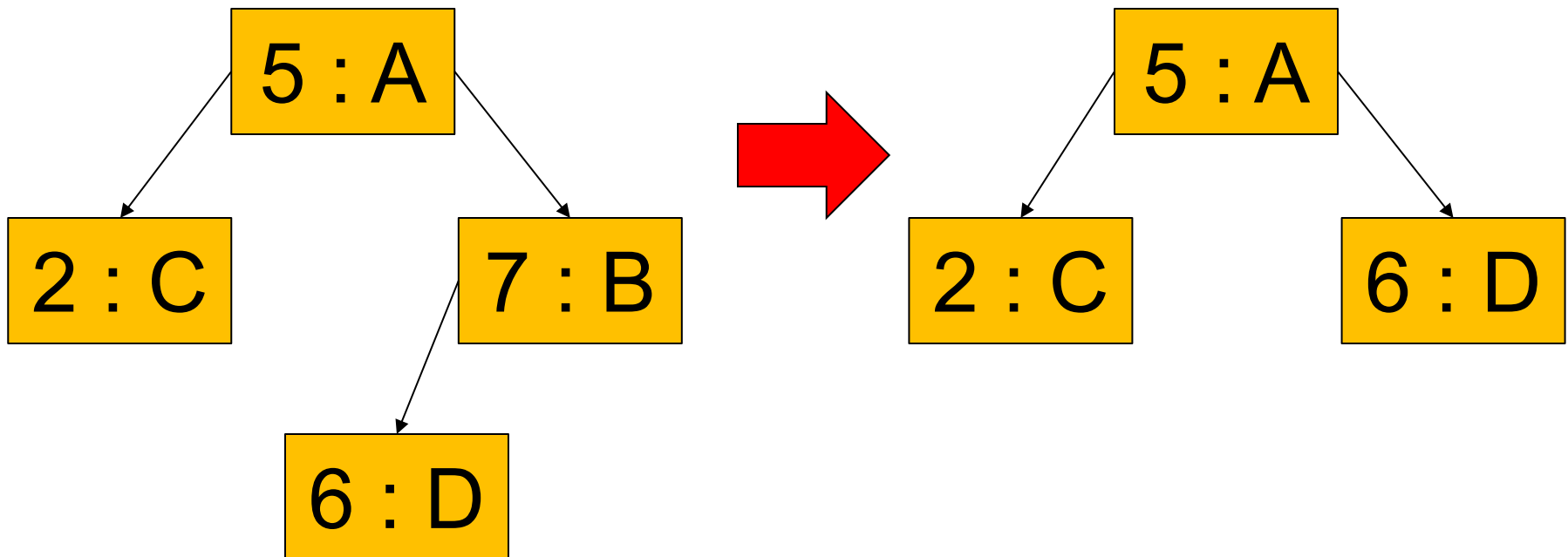
- delete 2
 - If there is a child in the node to be deleted





BST delete

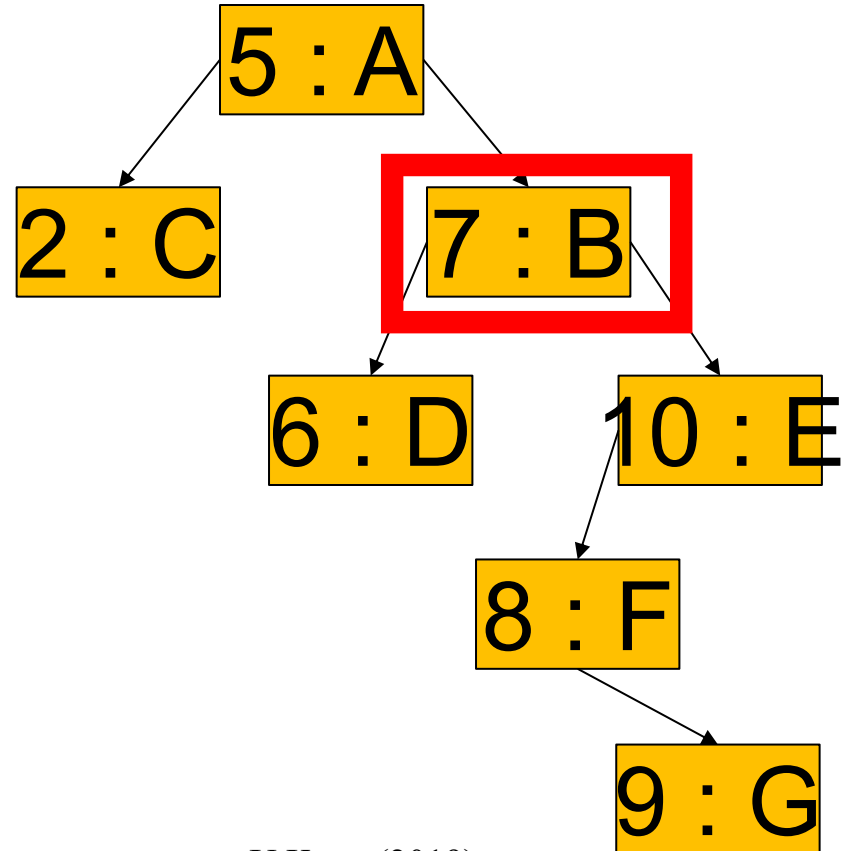
- delete 7
 - If there is a child in the node to be deleted





BST delete

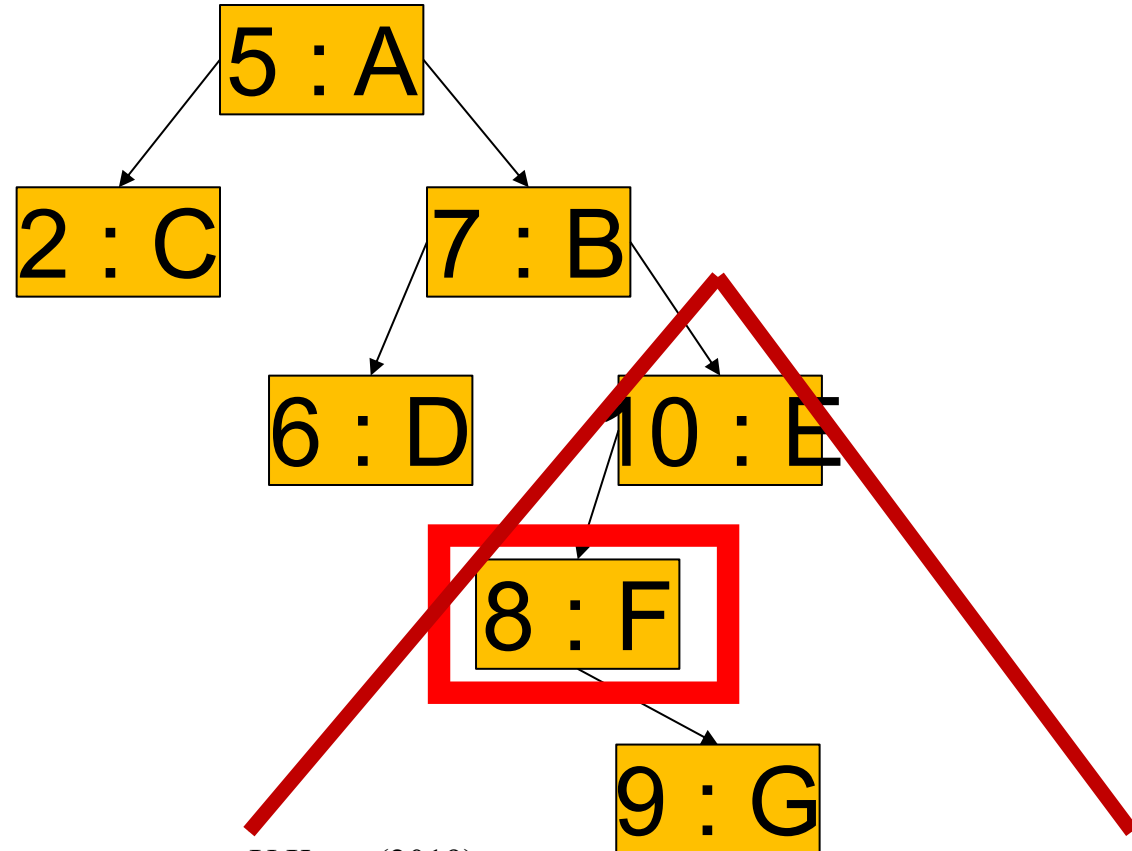
- delete 7
 - If there are two children in the node to be deleted





BST delete

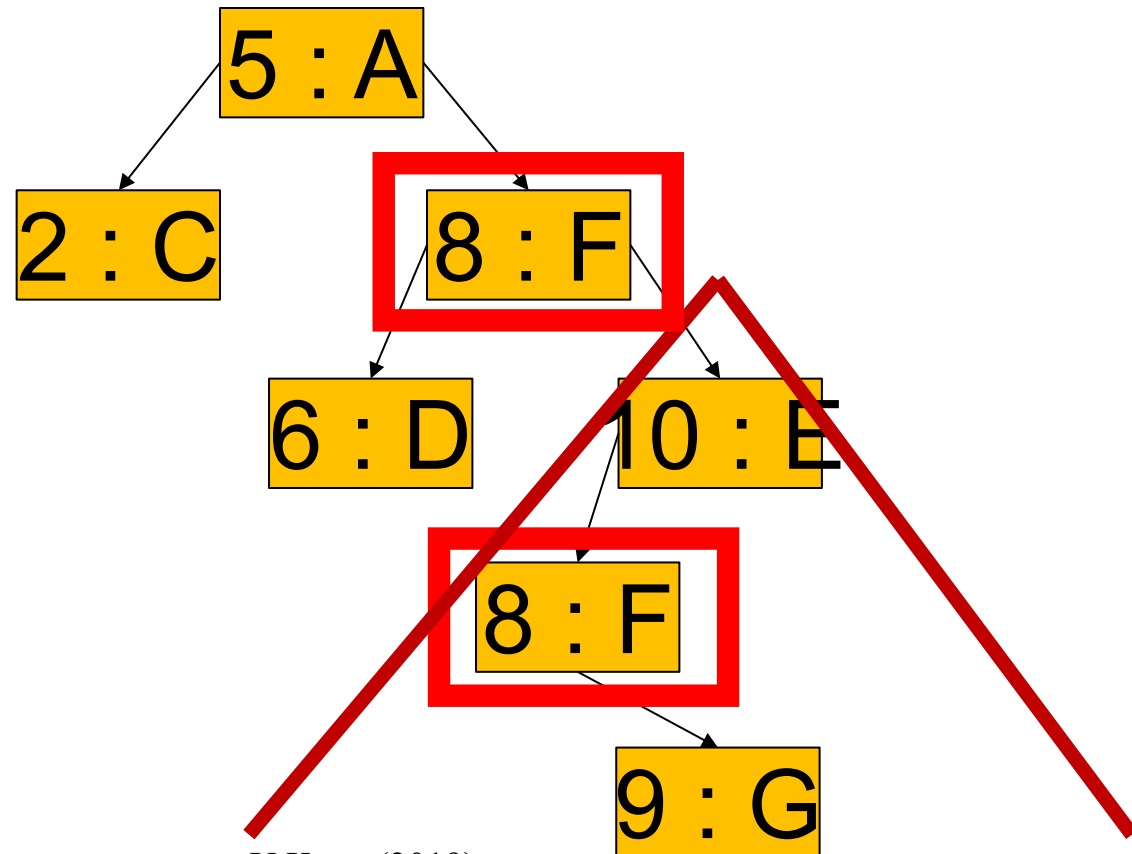
- delete 7 (continued)
 - (step1) Find the minimum-key node in the right subtree





BST delete

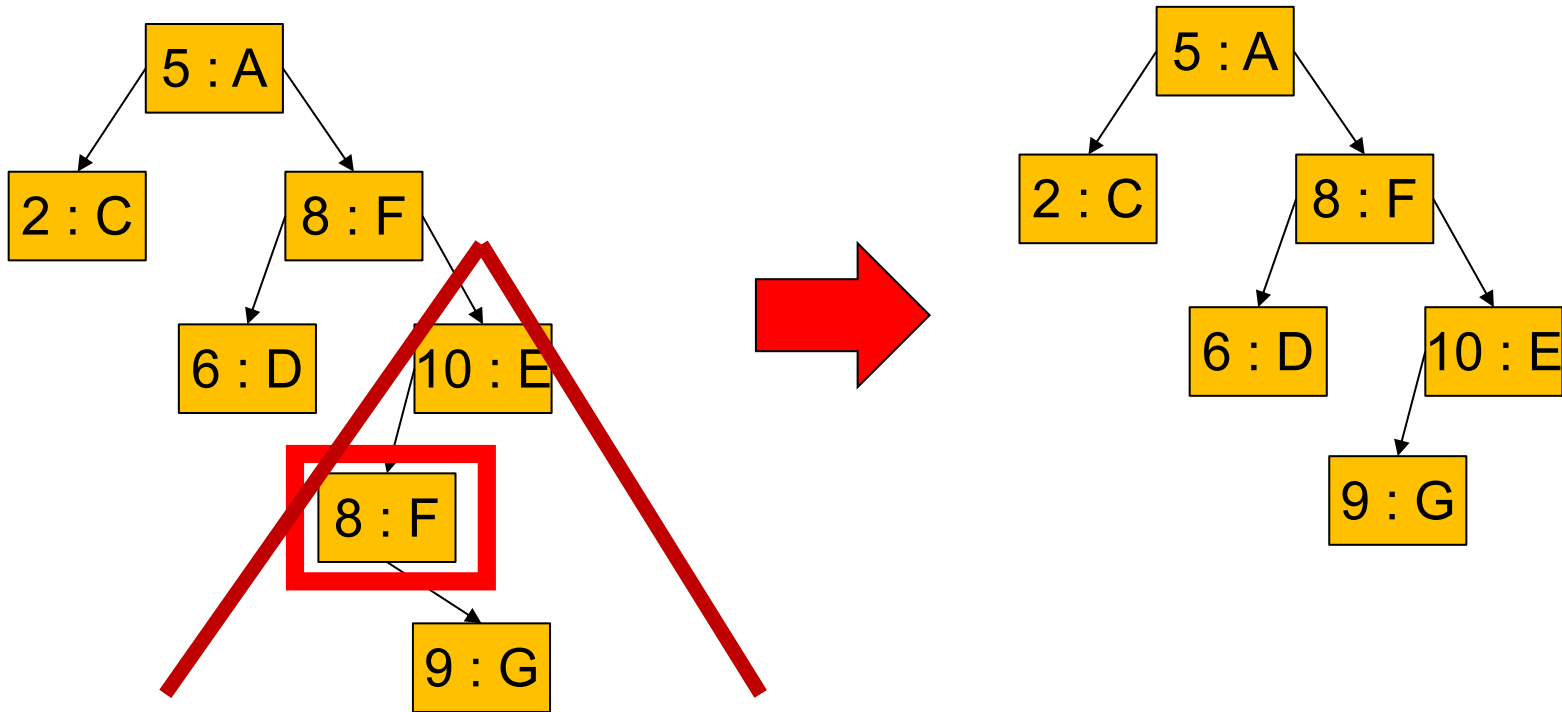
- delete 7 (continued)
 - (step2) exchange the (key, value) of node to be deleted





BST delete

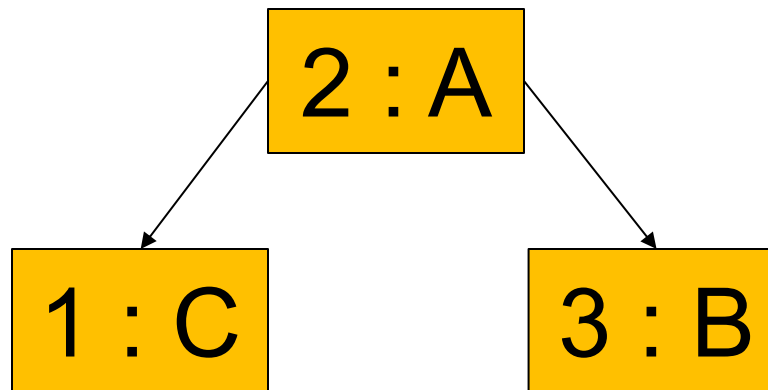
- delete 7 (continued)
 - (step3) delete the minimum node in the right subtree





BST traverse

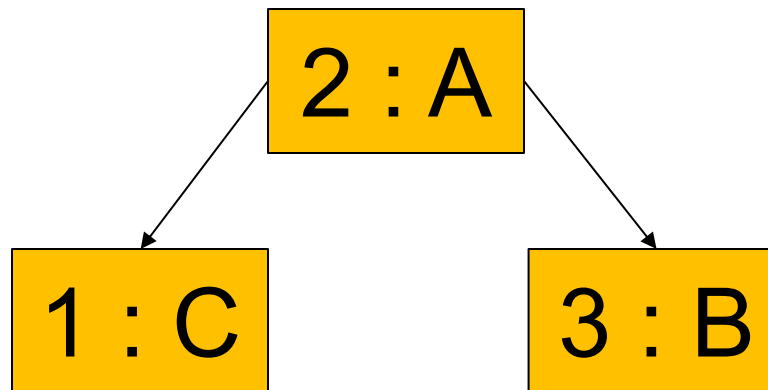
- Preorder
 - Visit the node before its children.
 - Let be the left first.
 - [2:A][1:C][3:B]





BST traverse

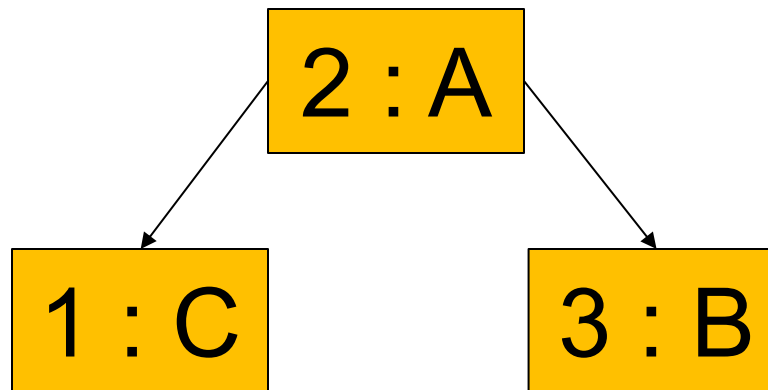
- Inorder
 - Visit the node after the left child.
 - Then, visit right child.
 - [1:C][2:A][3:B]





BST traverse

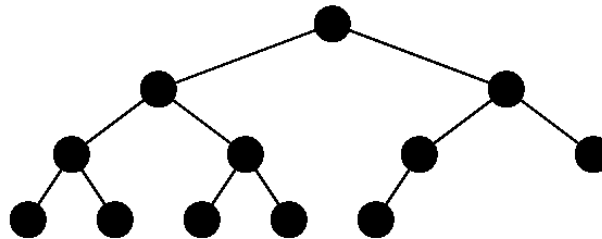
- Postorder
 - Visit the node after its children.
 - Let be the left first.
 - [1:C][3:B][2:A]





Complete Binary Trees

- Complete binary tree:
 - 1) all levels except possibly the last level are completely full
 - 2) the bottom level has all nodes to the left side.



Complete binary tree



I/O Specification

■ insert

Input form	Output form
insert (key) (value)	
Description	
<ul style="list-style-type: none">- Insert a node of (key, value) into the binary search tree.- The type of (key) is integer and (value) is string.- Each (key) is unique in the binary search tree.	
Example Input	Example Output
insert 1 BTS	



I/O Specification

■ find

Input form	Output form
<code>find (key)</code>	
Description	
<ul style="list-style-type: none">- Find a node in the binary search tree by key and return the value.- Return null if there is no matching node.	
Example Input	Example Output
<code>find 1</code>	



I/O Specification

■ preorder / inorder / postorder

Input form	Output form
preorder	(a series of key,value sets)
Description	
<ul style="list-style-type: none">- Do a preorder traversal for the binary search tree, and print out key-value sets in order of the traversal.- (a series of key-value sets) is a sequence of the key-value sets.	
Example Input	Example Output
preorder	[1:BTS][2:IOI]



I/O Specification

■ iscomplete

Input form	Output form
iscomplete	
Description	
<ul style="list-style-type: none">- Check if all levels except the last level are completely full- Check if the bottom level has all nodes to the left side- Return “True” if it’s complete binary tree, otherwise return “False”	
Example Input	Example Output
iscomplete	True



I/O Specification

■ height

Input form	Output form
height	
Description	
<ul style="list-style-type: none">- Return the height of the subtree, the root of which is this node.	
Example Input	Example Output
height	



I/O Specification

■ delete

Input form	Output form
delete (key)	
Description	
<ul style="list-style-type: none">- Delete a node by the key.- If there is no matching node in the binary search tree, do nothing.- Return the node parent should point.	
Example Input	Example Output
delete 1	



Sample Input

insert 1 BTS
iscomplete
find 1
insert 2 Blackpink
insert 3 Redvelvet
insert 4 TWICE
insert 5 IZONE
insert 6 EXO
insert 7 GFriend
preorder
height
delete 4
preorder
height
delete 1
delete 2
delete 3

delete 5
delete 6
delete 7
preorder
height
insert 4 TWICE
insert 2 Blackpink
insert 3 Redvelvet
insert 1 BTS
insert 6 EXO
insert 5 IZONE
insert 7 Gfriend
delete 4
preorder
inorder
postorder
height
find 5



Sample Output

The tree is complete binary tree.

Value for 1 is BTS

preorder : [1:BTS][2:Blackpink][3:Redvelvet][4:TWICE][5:IZONE][6:EXO][7:GFriend]

Height of this tree is 7

preorder : [1:BTS][2:Blackpink][3:Redvelvet][5:IZONE][6:EXO][7:GFriend]

Height of this tree is 6

preorder : None

Height of this tree is 0

preorder : [5:IZONE][2:Blackpink][1:BTS][3:Redvelvet][6:EXO][7:GFriend]

inorder : [1:BTS][2:Blackpink][3:Redvelvet][5:IZONE][6:EXO][7:GFriend]

postorder : [1:BTS][3:Redvelvet][2:Blackpink][7:GFriend][6:EXO][5:IZONE]

Height of this tree is 3

Value for 5 is IZONE



Questions?