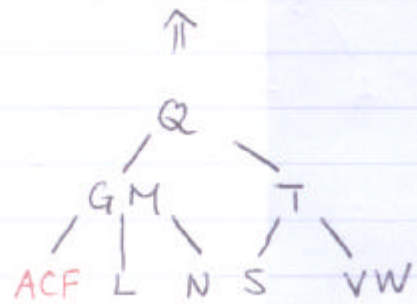
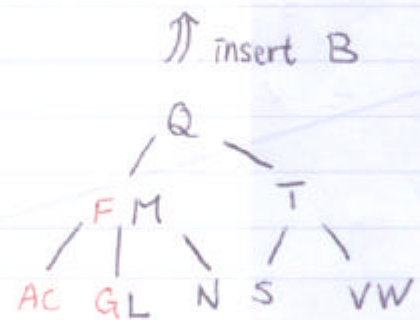
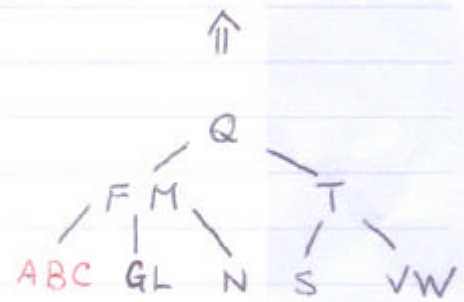
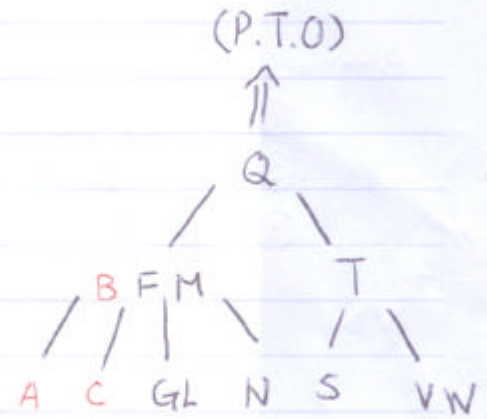
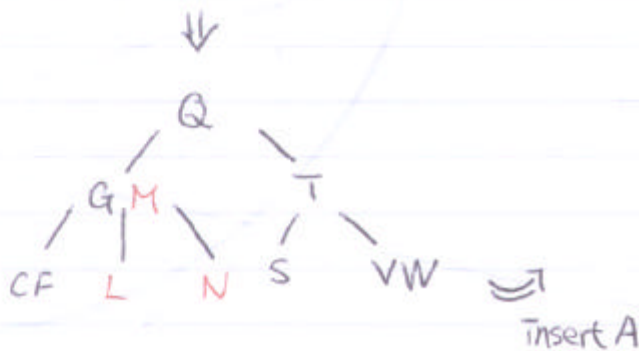
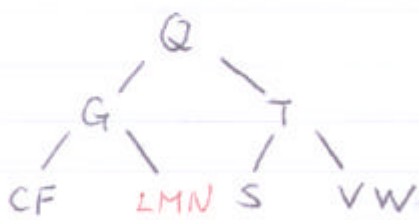
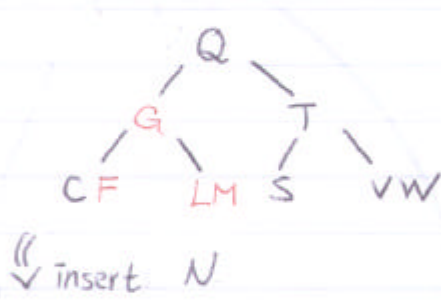
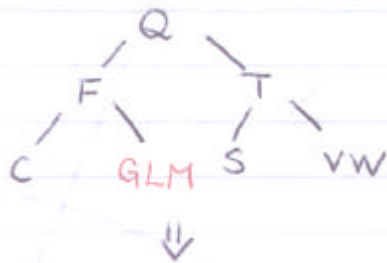
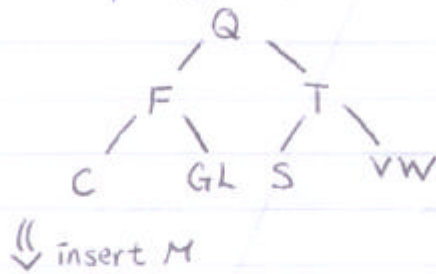
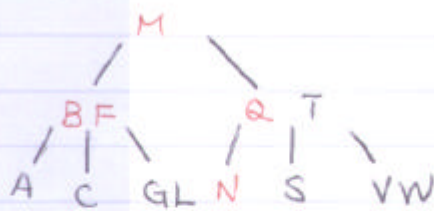



Bottom-Up-Approach :

(2-3 tree)

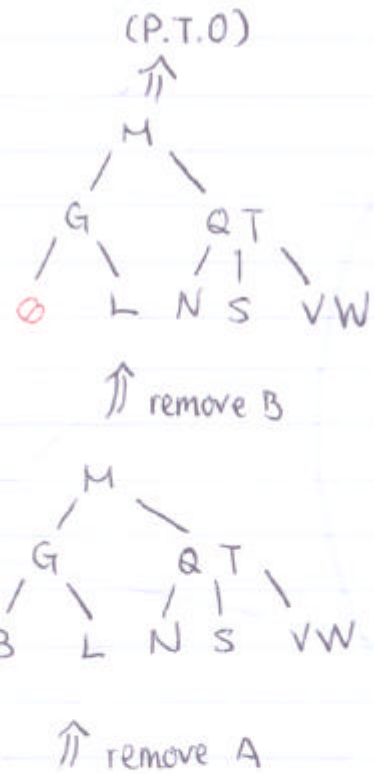
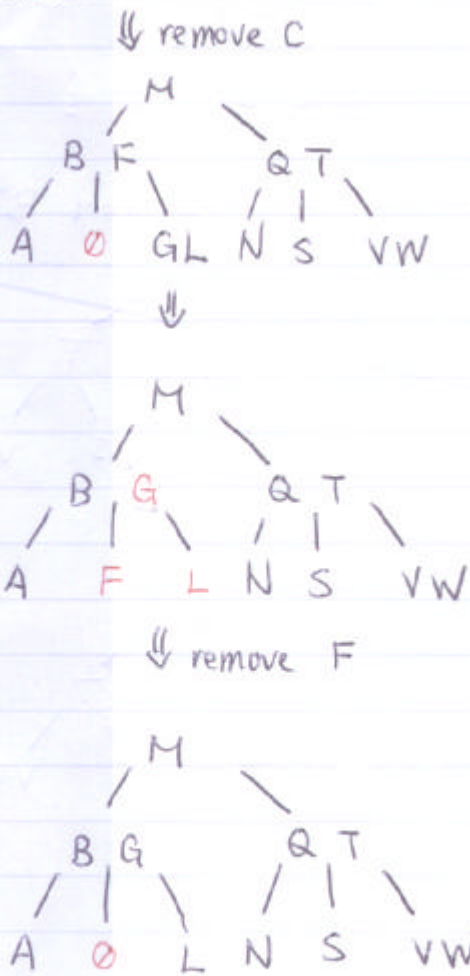


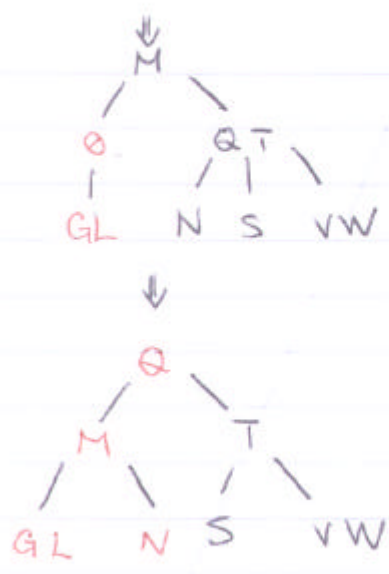


Bottom-Up-Insert:

- ① Find the location to insert, and insert it
- ② If # of keys is not exceed the limit, done!
- ③ If # of keys > limit
  - consider rotation with sibling (Left sibling, then right sibling) if sibling have space left.
  - if both sibling are full then do a split and carry one the fix-up start at the original parent.

Deletion:



**Bottom-Up-Delete:**

- ① Find the location to delete, and delete it,
- ② if the location is a leaf:
  - ②-1 if # key  $\geq$  min keys, done!
  - ②-2 if # key  $<$  min key
    - consider rotation with sibling (left then right), if sibling have  $>$  min keys
    - if both sibling have only min number of key, then do a merge with the sibling (left then right), then carry on fix-up start at the original parent.
- ③ if the location is not a leaf:
  - find predecessor  $k'$  and replace  $k$  and delete  $k'$
  - find successor  $k''$  and replace  $k$  and delete  $k''$