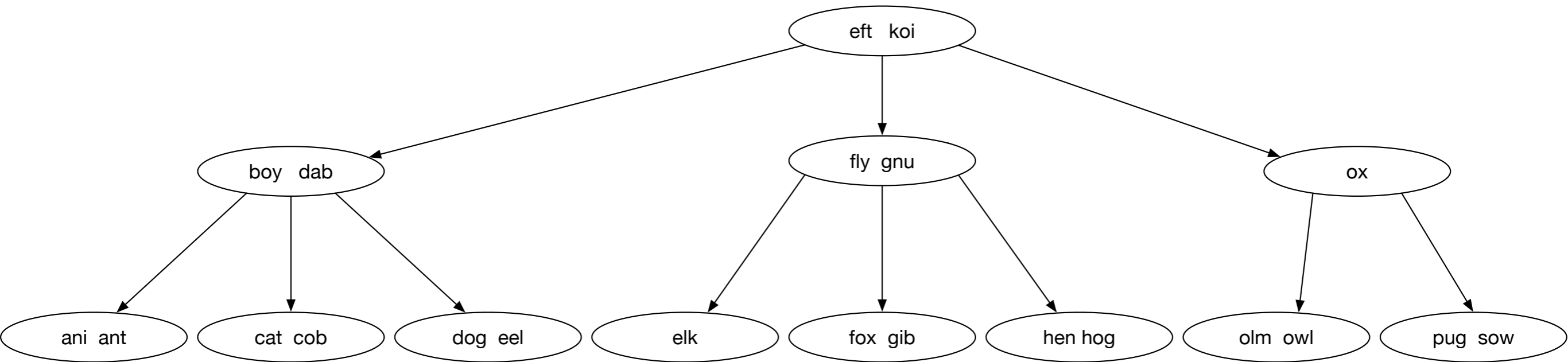


Activity: B-tree Operations

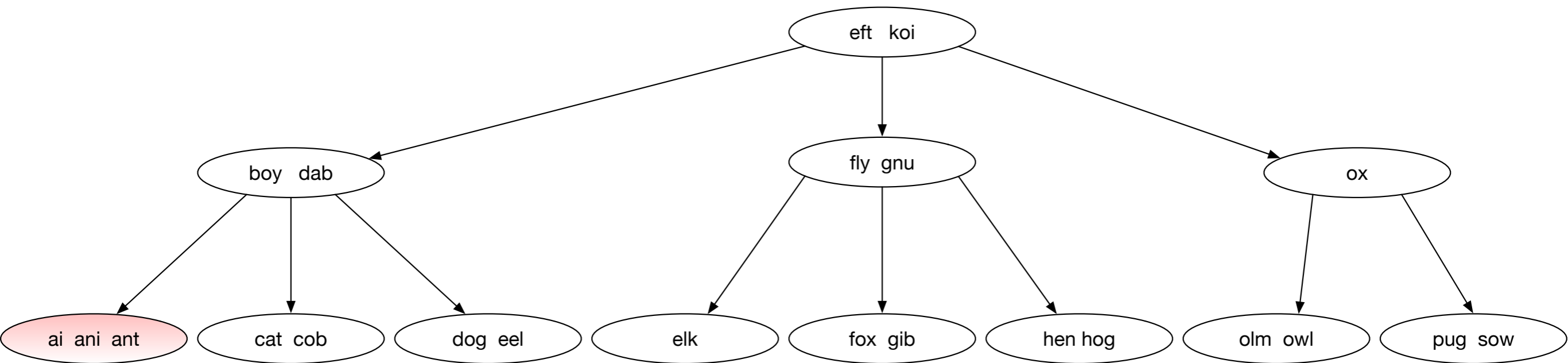
How do we insert 'ai'?

- Rules:
 - Prefer left rotate over right rotate over split / merge



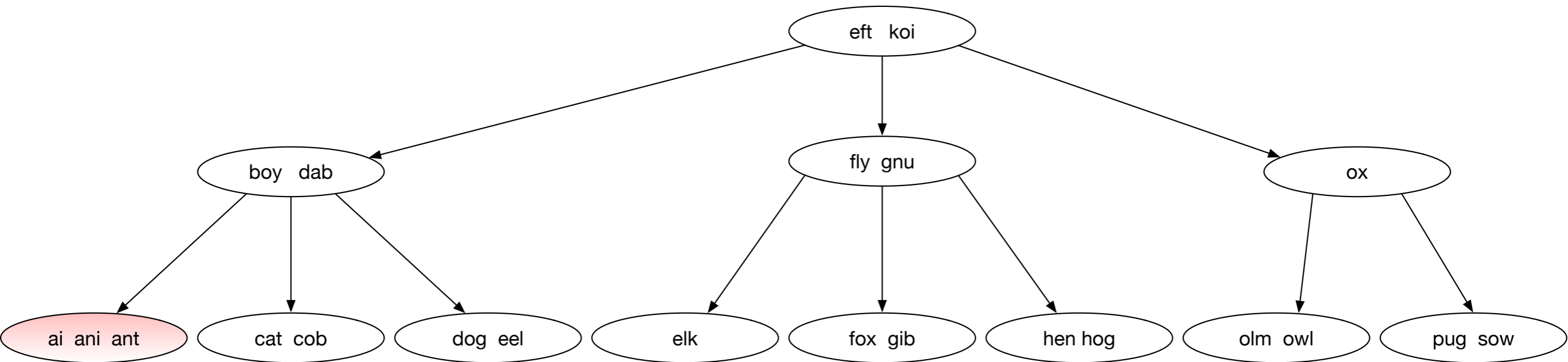
Solution

- Insert into leaf and diagnose an overflow



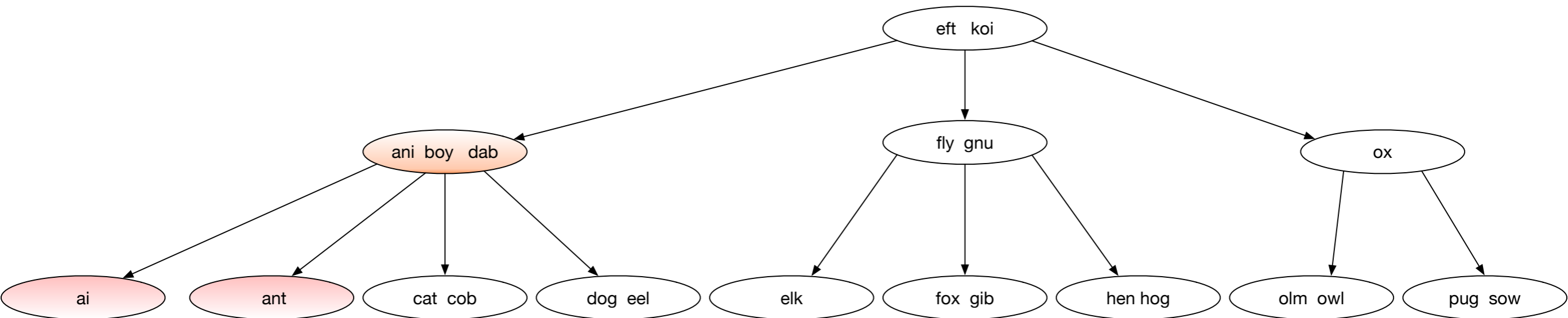
Solution

- Only neighbor is at capacity, need to split



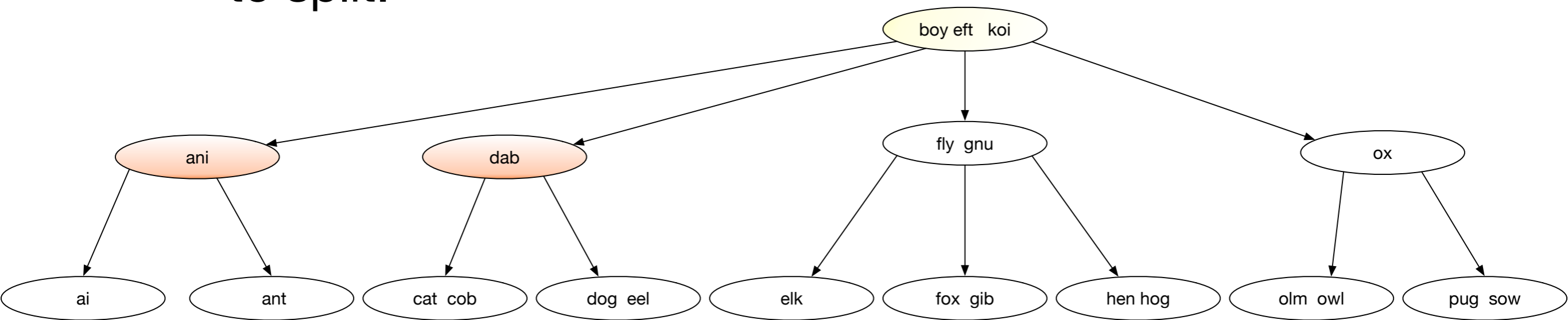
Solution

- The split results in another overflow



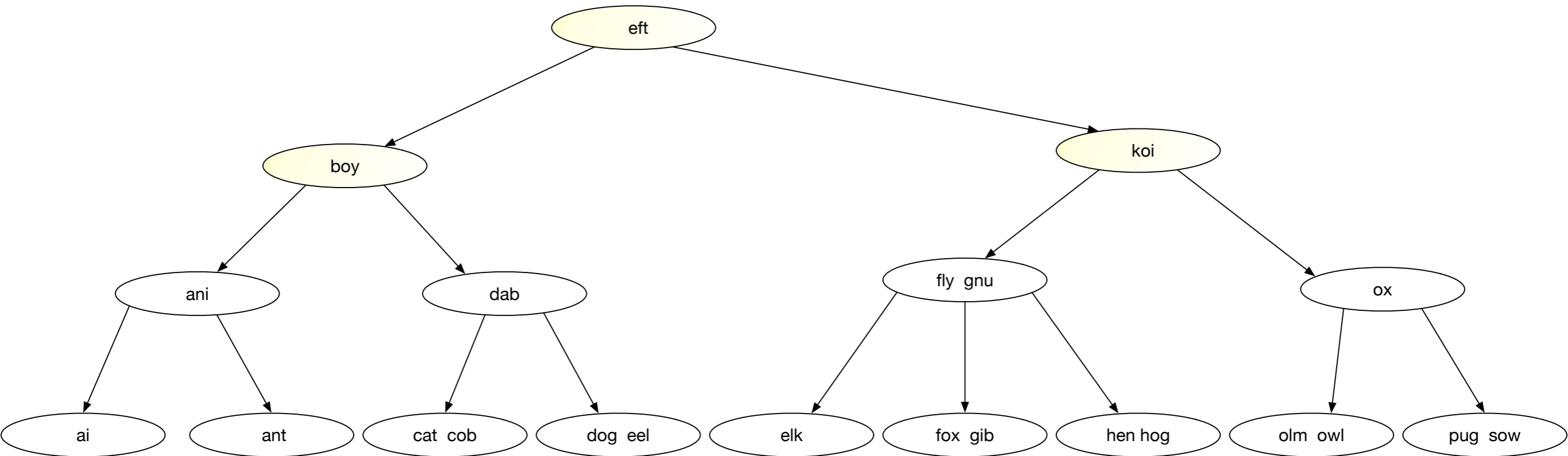
Solution

- The only neighbor is at capacity, therefore split
 - The parent is at capacity, has no neighbor, so we need to split.



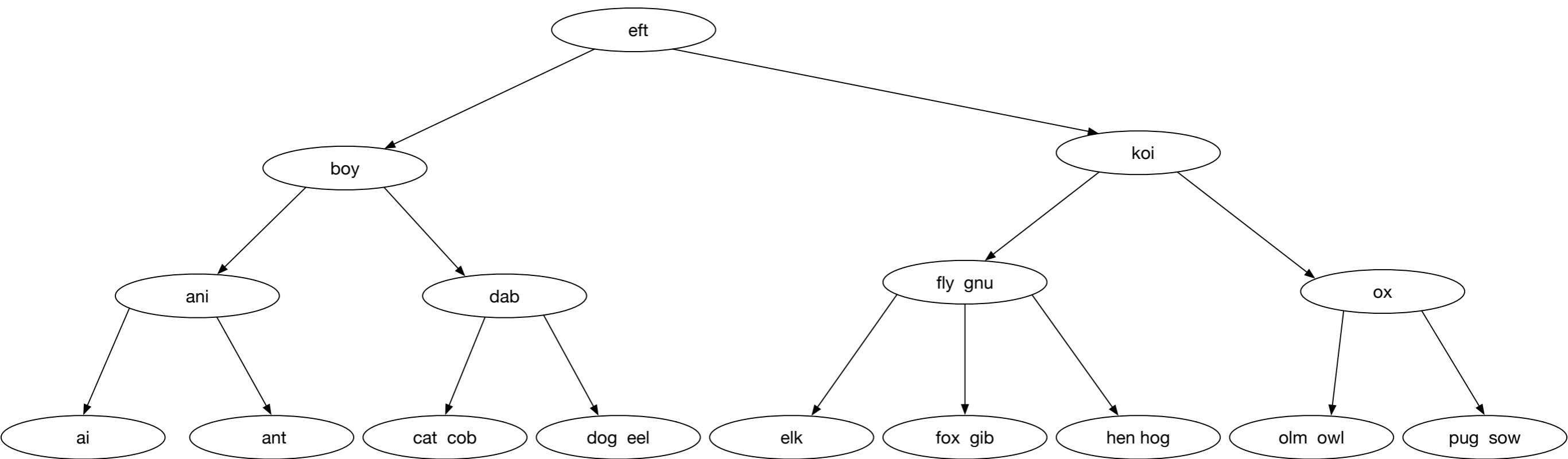
Solution

- Final result



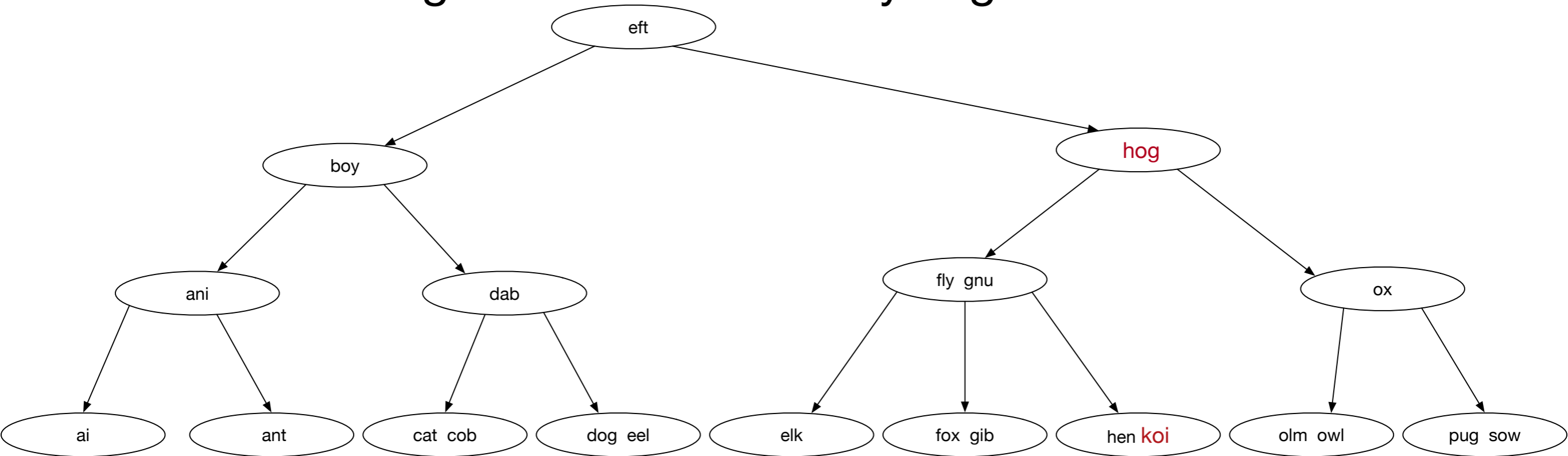
Problem

- Delete 'koi' from this tree
 - Rules: Use always the predecessor
 - Prefer left rotate over right rotate over merge



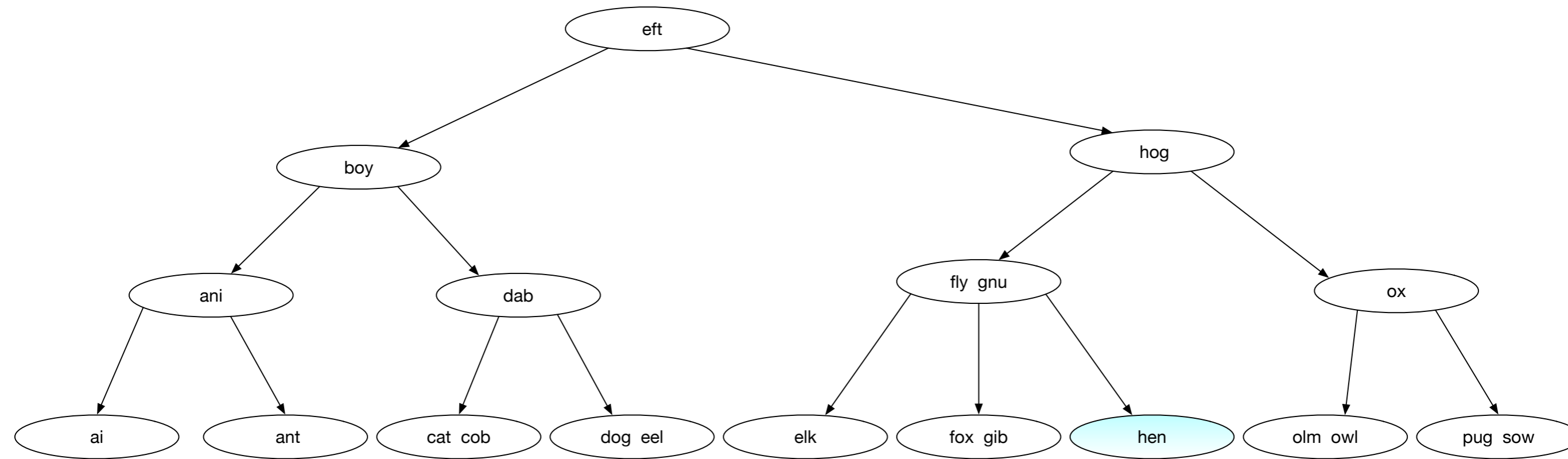
Solution

- Locate "koi", then the predecessor of "koi" and switch
- From "koi" go left and then always right



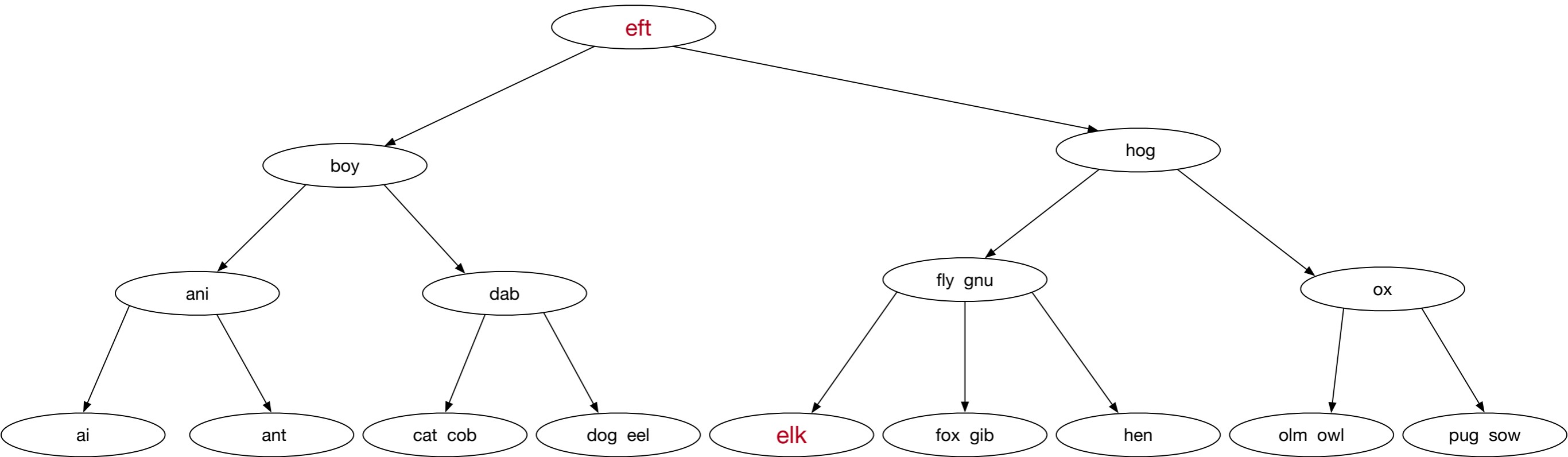
Solution

- The deletion does not lead to an underflow, so we have the final state of the 2-3 tree



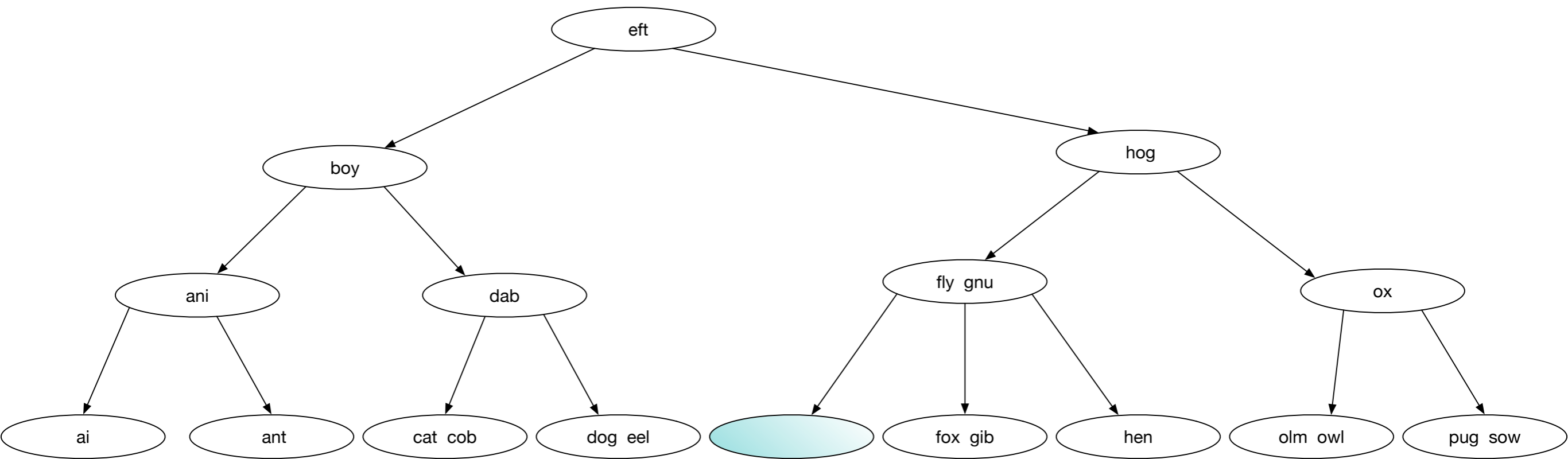
Problem

- Now use the successor to delete "eft" from the previous tree



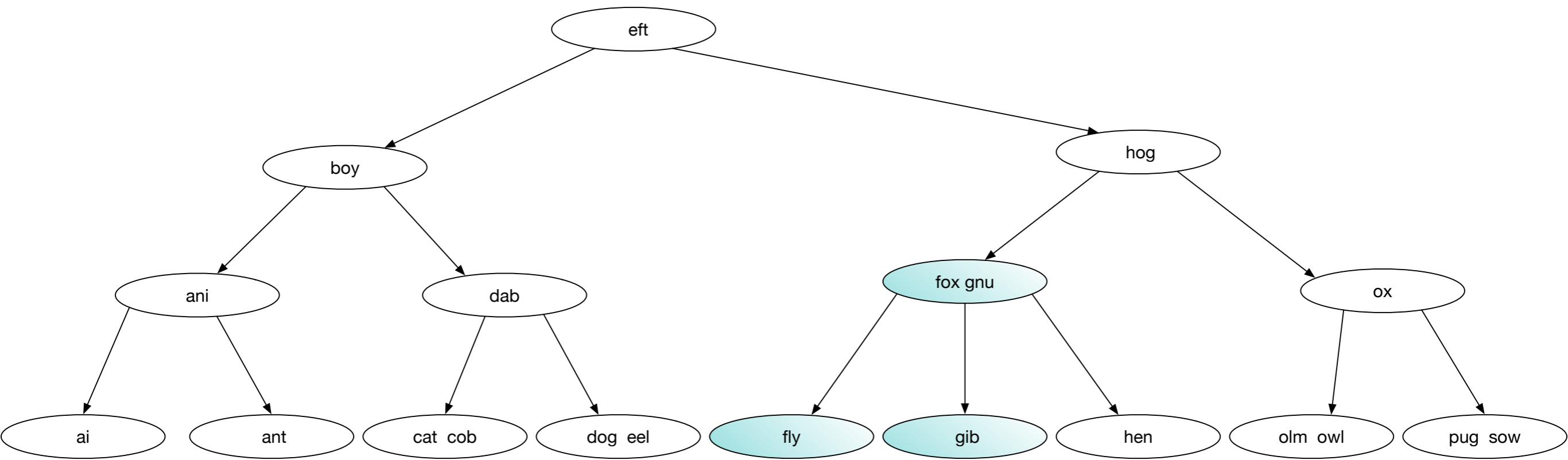
Solution

- Now the delete gives an empty (underflowing) node



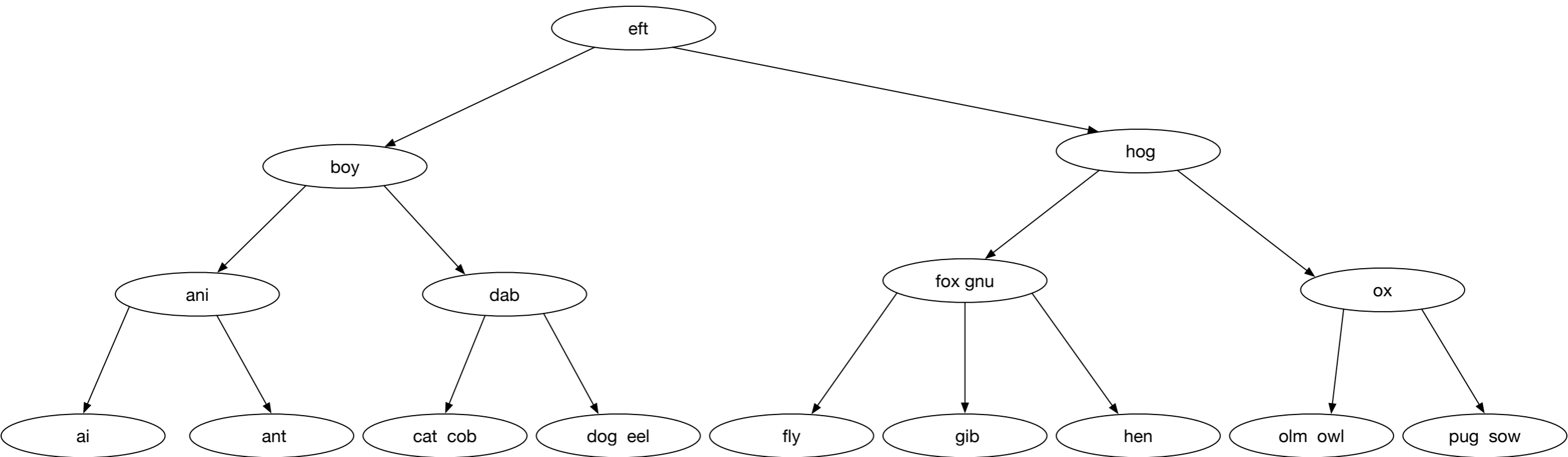
Solution

- There is only one neighbor, which is over minimum capacity, so we rotate
- "fox" goes up, "fly" goes down



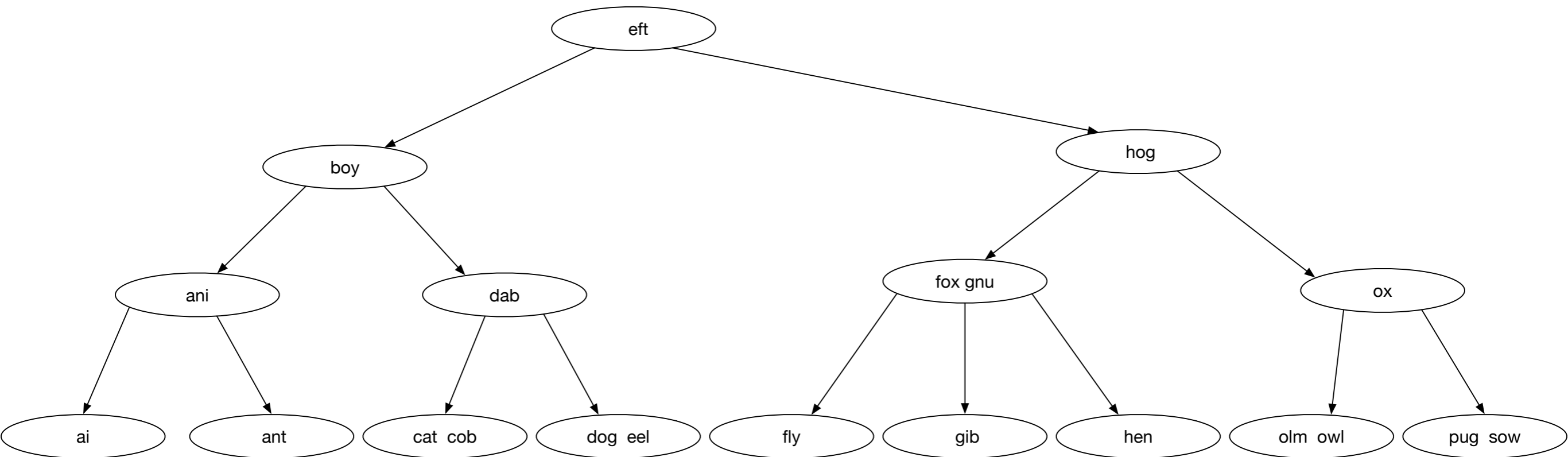
Solution

- The result is a valid 2-3 tree



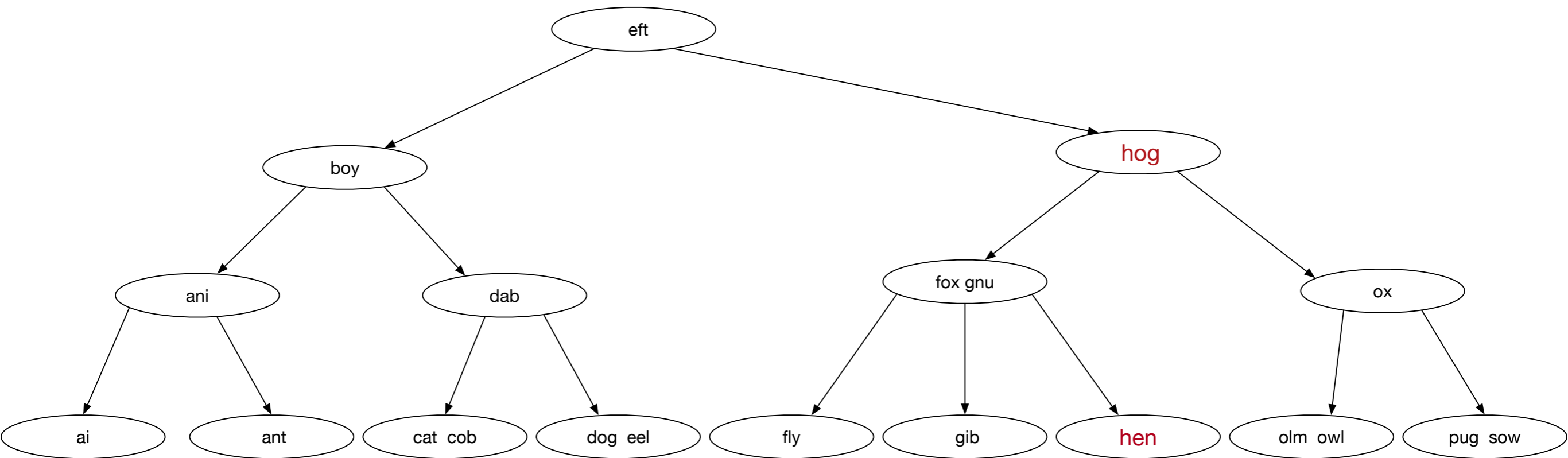
Problem

- Delete hog using the predecessor



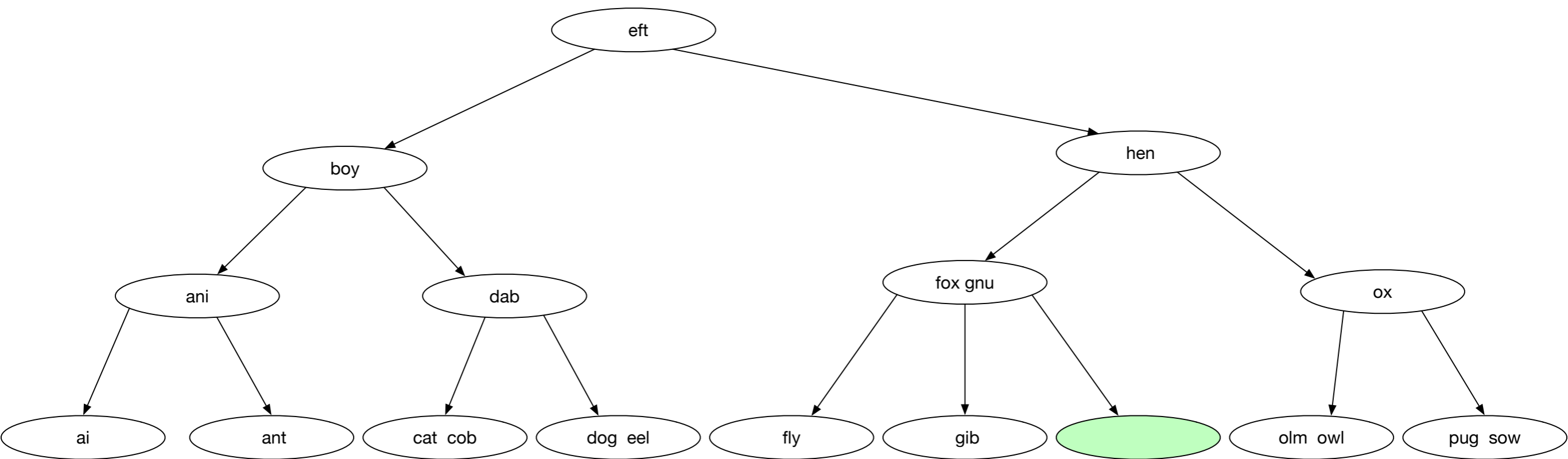
Solution

- We find 'hog', then we locate the predecessor



Solution

- We switch and delete from the leaf
- The result is an empty node

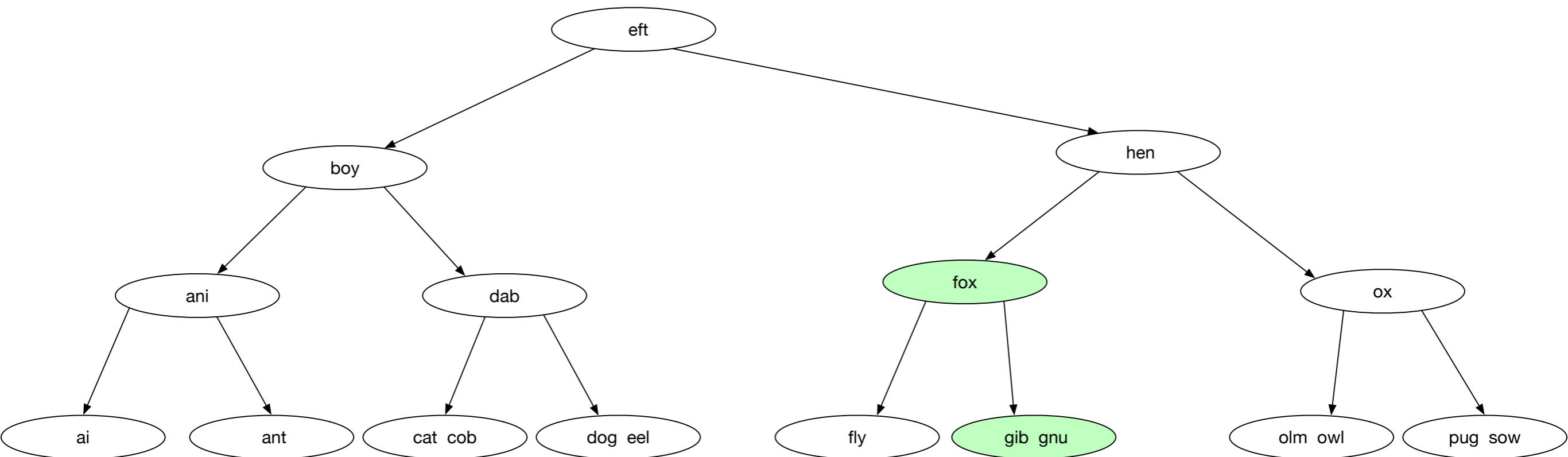


Solution

- Because we cannot do a rotate, we need to do a merge
- A merge is easiest remembered as the inverse operation of the split
 - "gnu" goes down into the united node

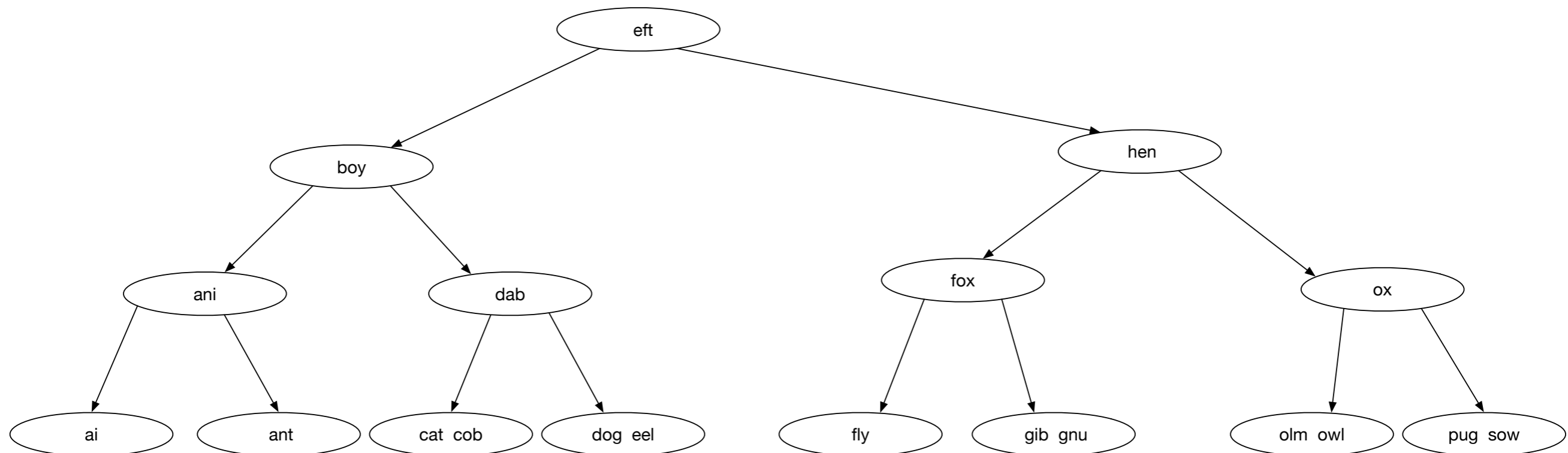
Solution

- The resulting tree complies with all requirements and we are done



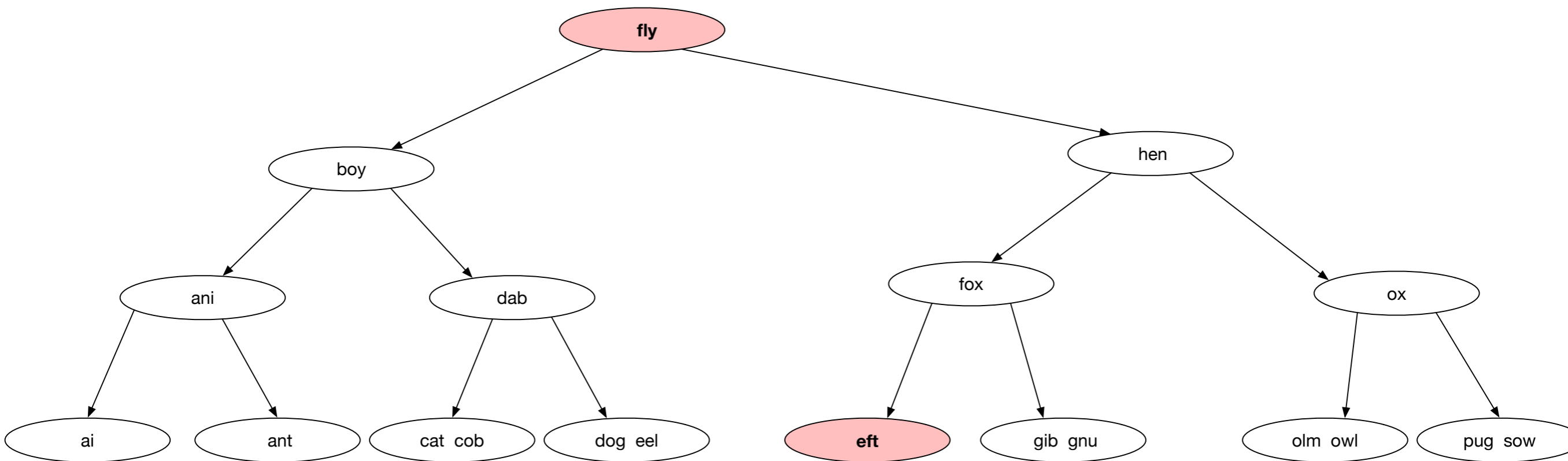
Homework Problem

- Submit by Wednesday:
 - Show the steps and the result of the deletion of "eft" using the successor!
 - Then show the steps and the result of the deletion of "fox" using the predecessor!



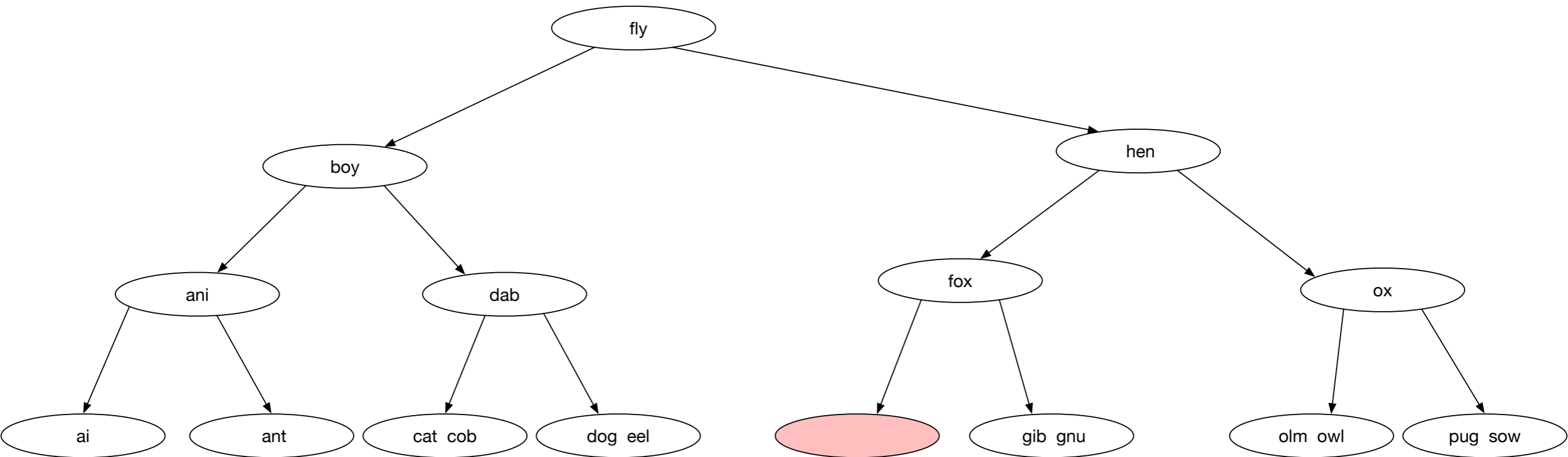
Solution

- Identify "eft" and its predecessor



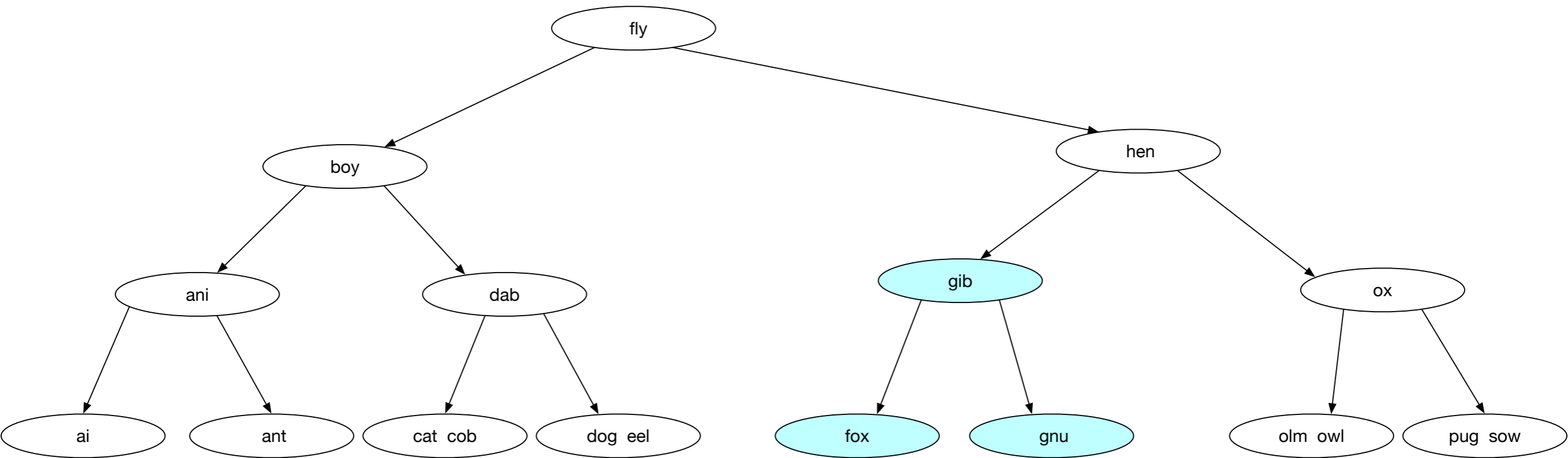
Solution

- Delete from the leaf — Find an underflow



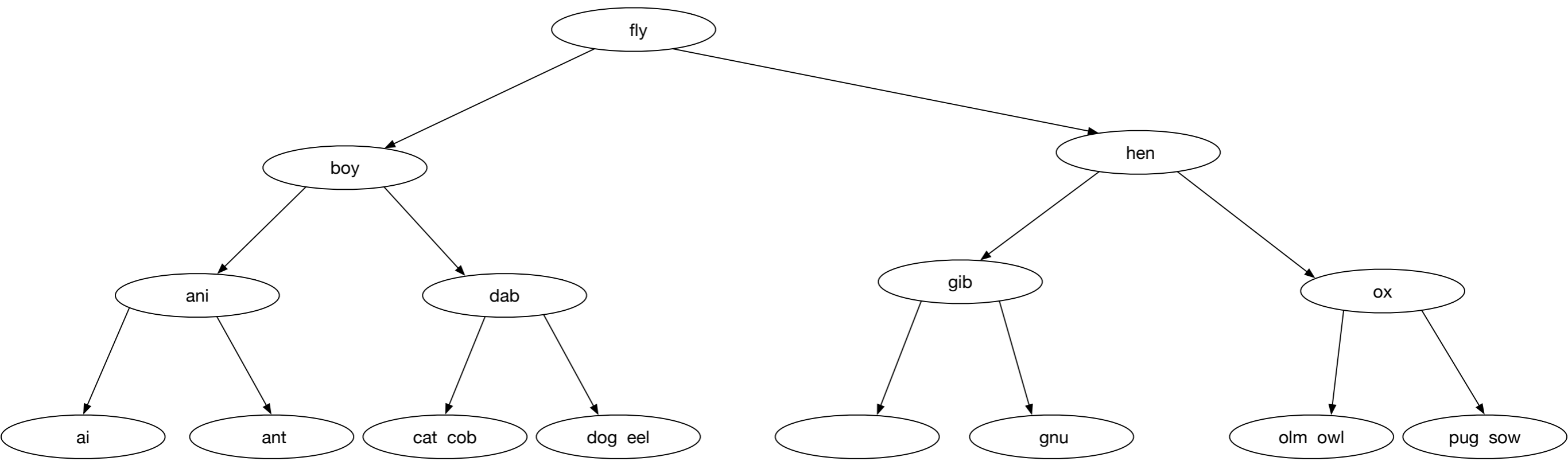
Solution

- Use a left rotate



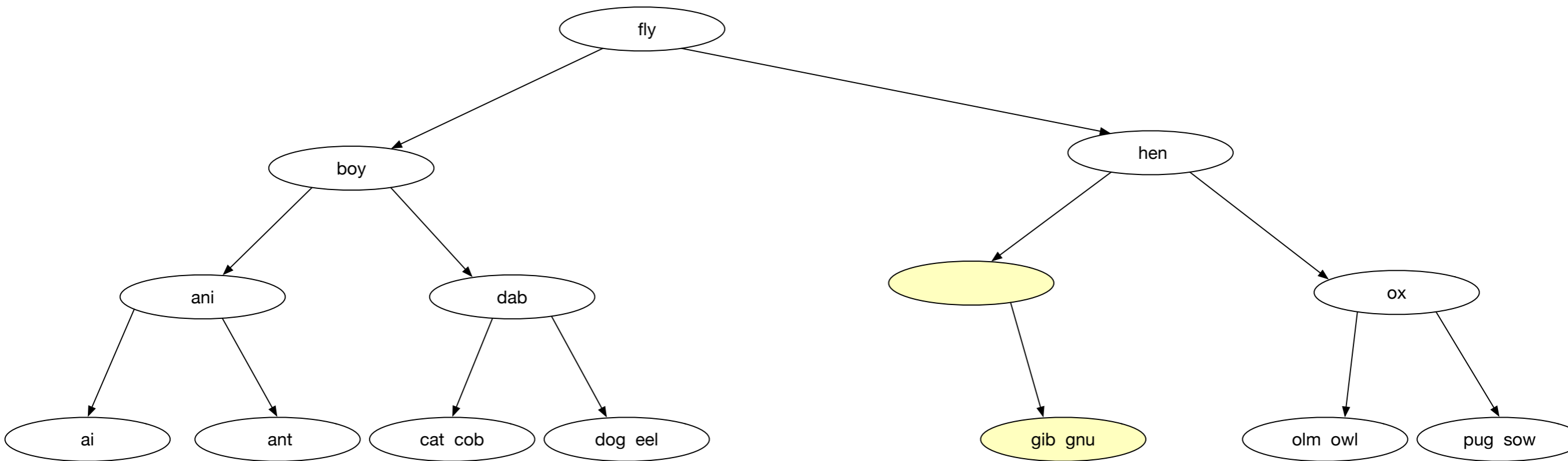
Solution

- To delete fox, first identify it and its predecessor
- However, it is already in a leaf, so we can just delete it without swapping



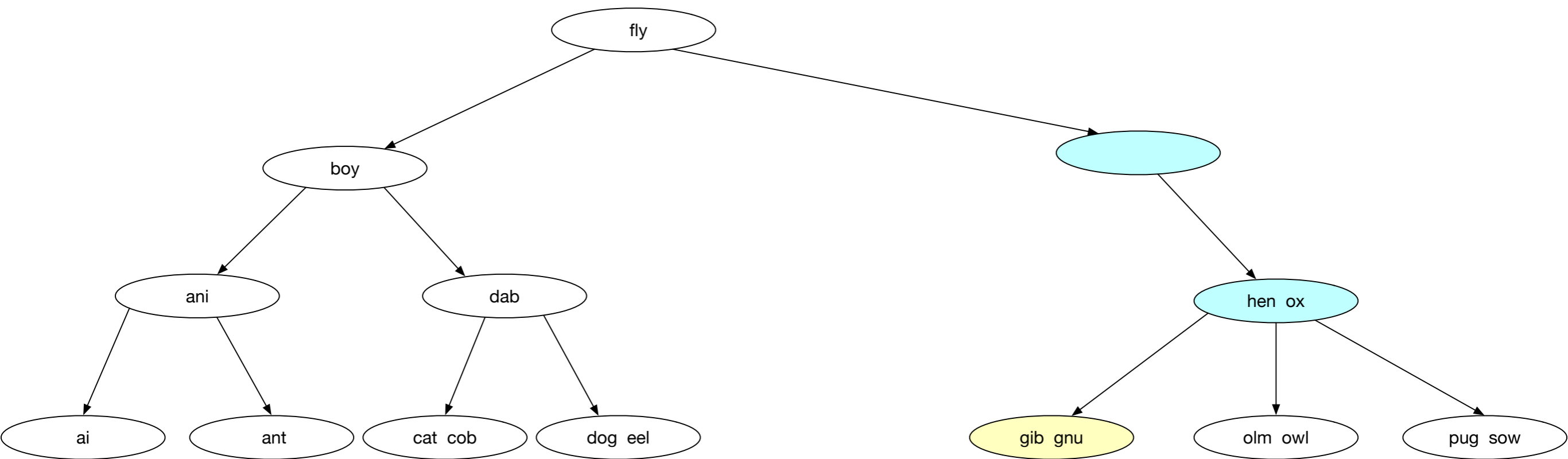
Solution

- The resulting underflow can not be solved with a rotate
- Need to merge



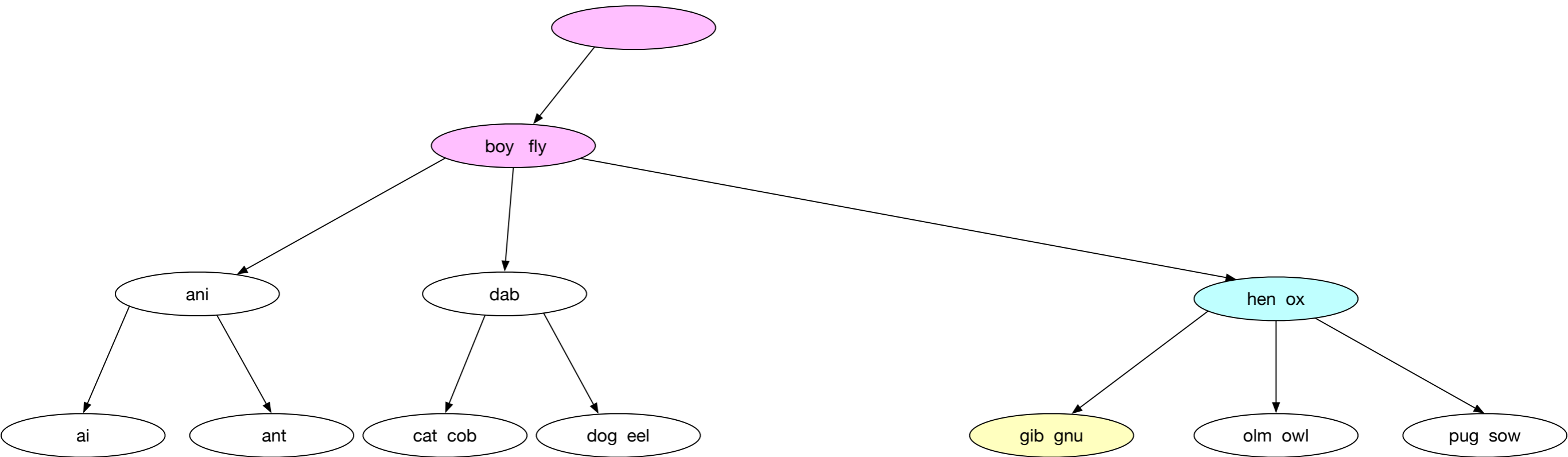
Solution

- The new parent now has an underflow
 - Need to merge again



Solution

- Again, the parent has an underflow
- No sibling for rotation, need to merge



Solution

- The root node has become empty and will be deleted

