Chapter 19
(continued)

Binary Search Trees

Data Structures & Problem Solving
Using JAVA
Second Edition

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Figure 19.1

Two binary trees: (a) a search tree; (b) not a search tree

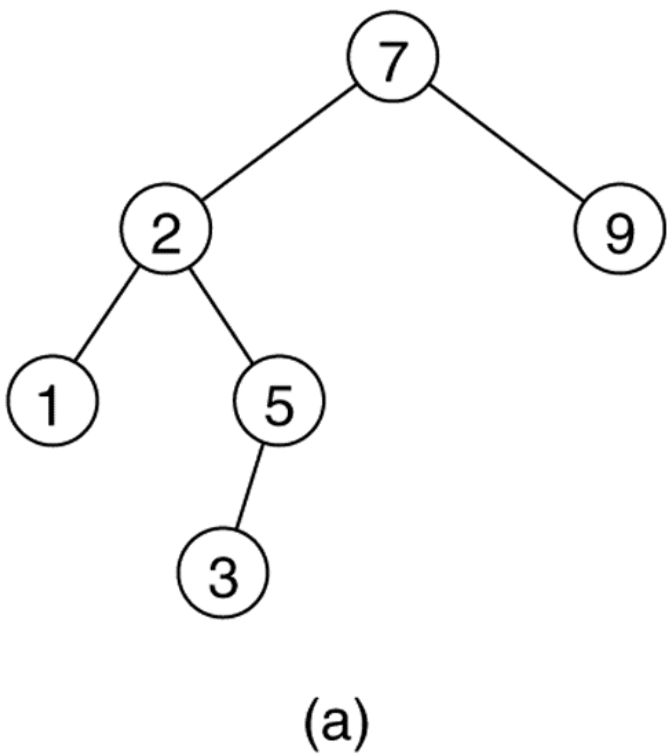


Figure 19.2
Binary search trees (a) before and (b) after the insertion of 6

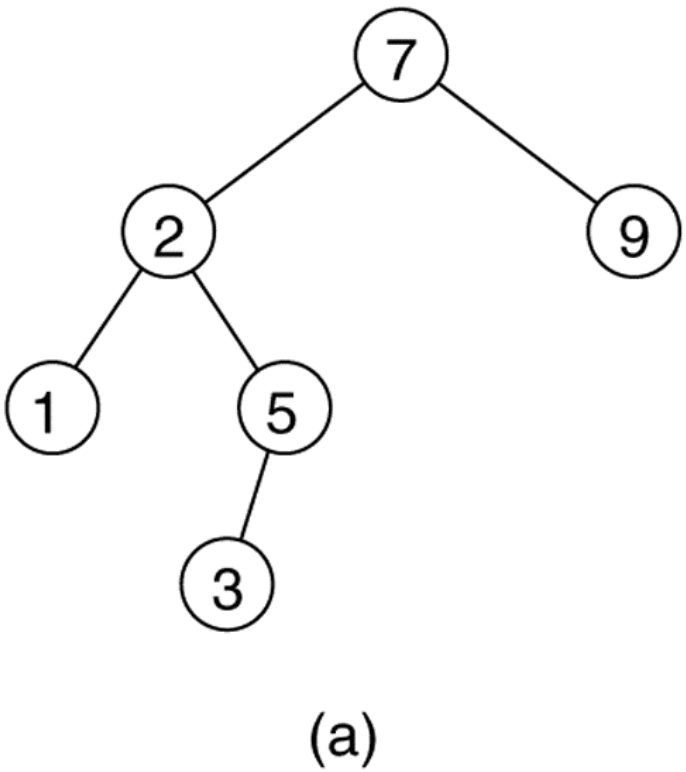


Figure 19.3

Deletion of node 5 with one child: (a) before and (b) after

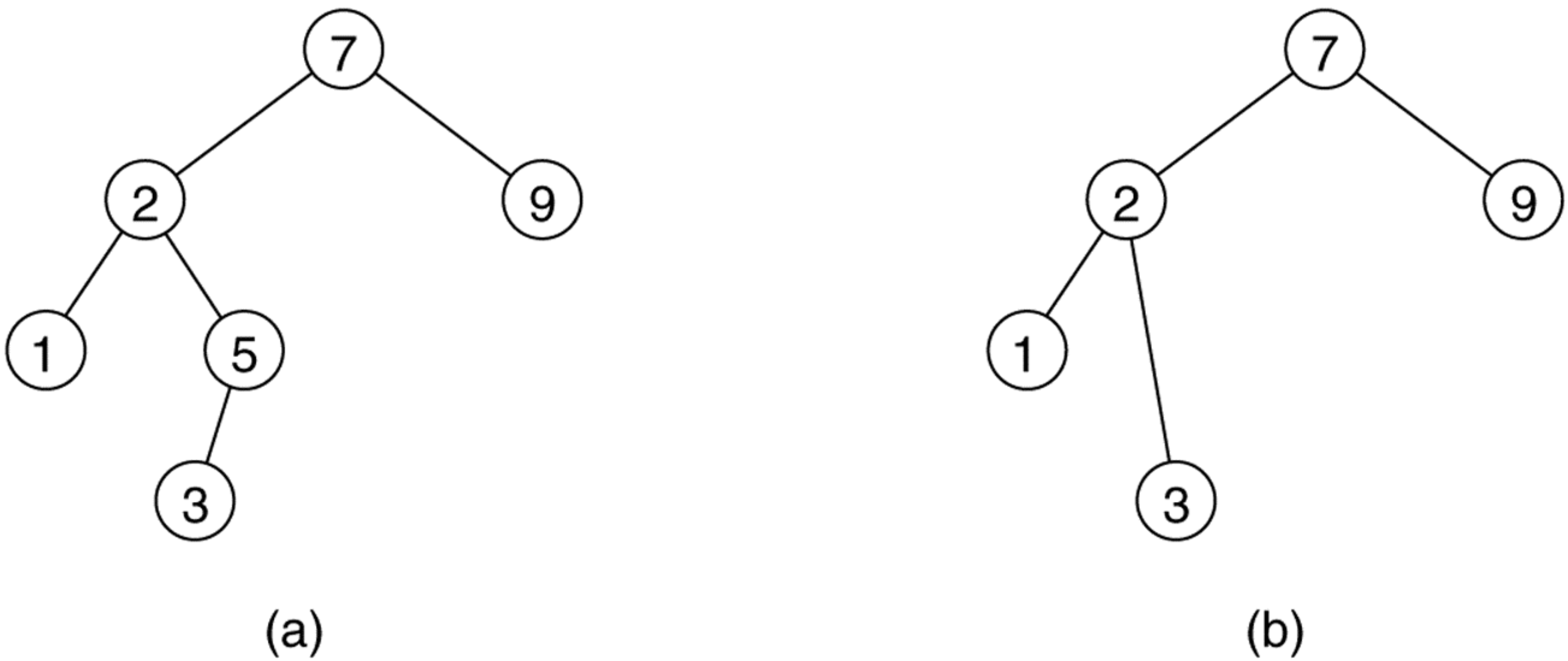


Figure 19.4

Deletion of node 2 with two children: (a) before and (b) after

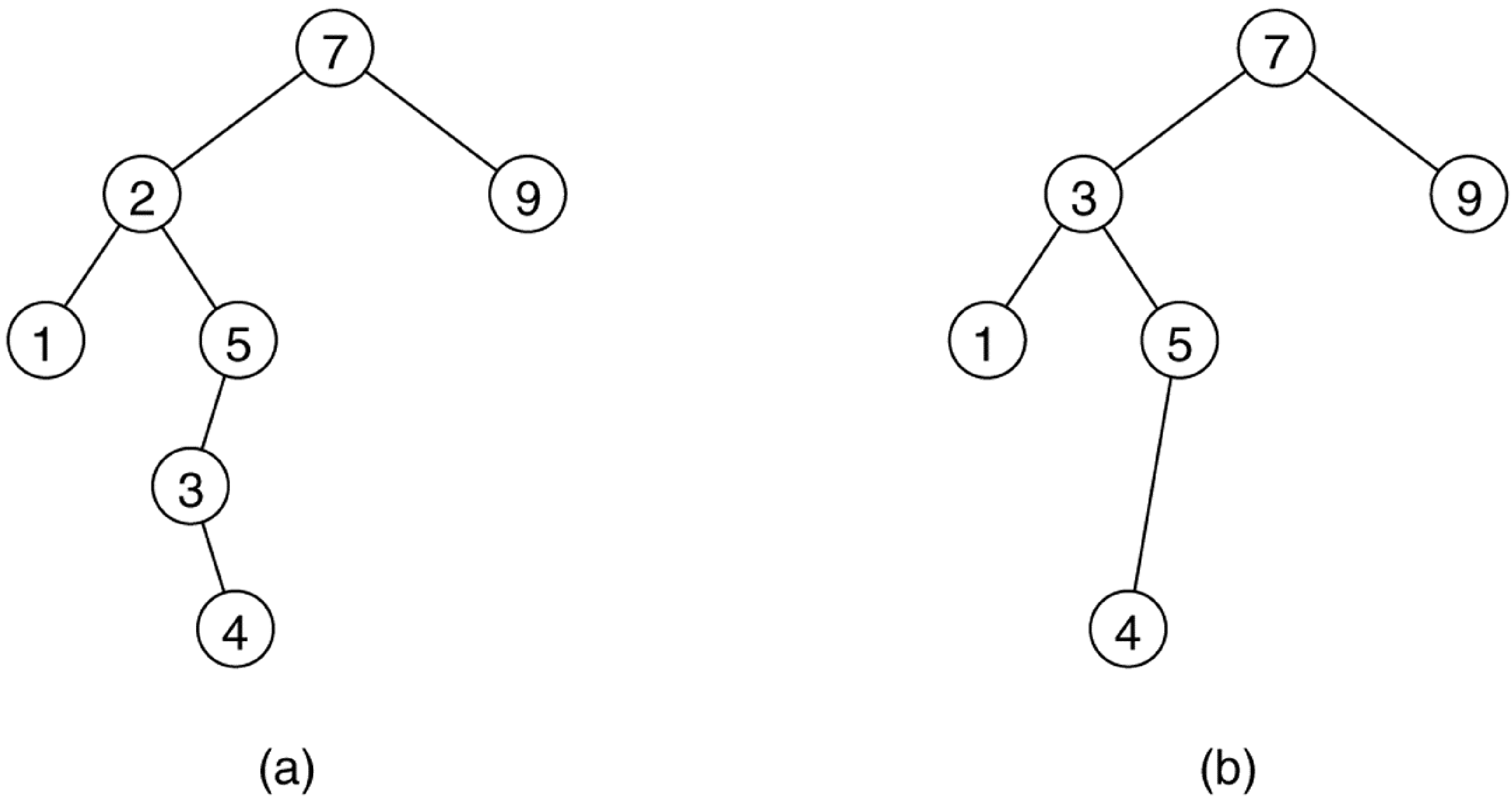


Figure 19.13

Using the size data member to implement findKth

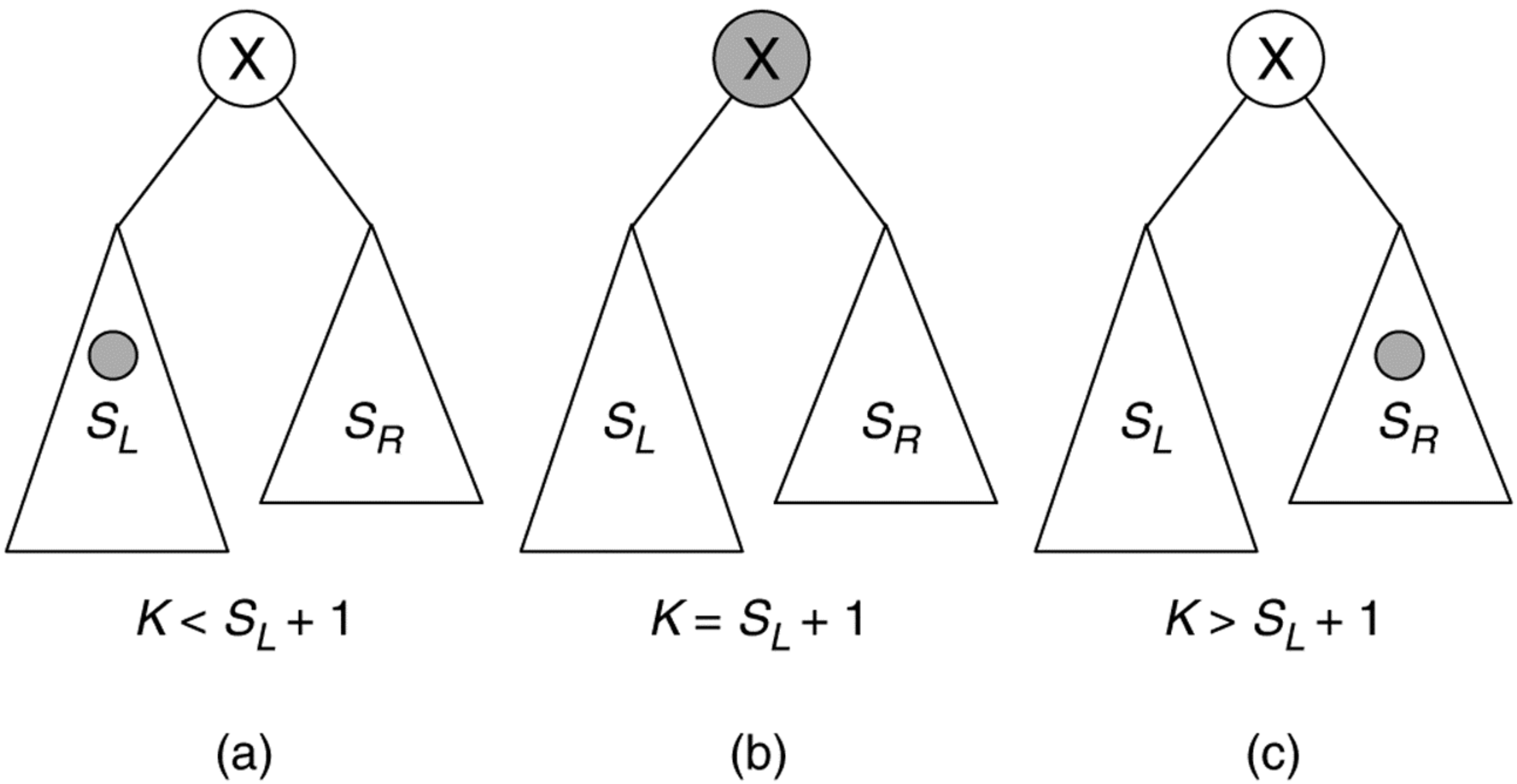


Figure 19.19

(a) The balanced tree has a depth of $\log N$; (b) the unbalanced tree has a depth of $N - 1$.

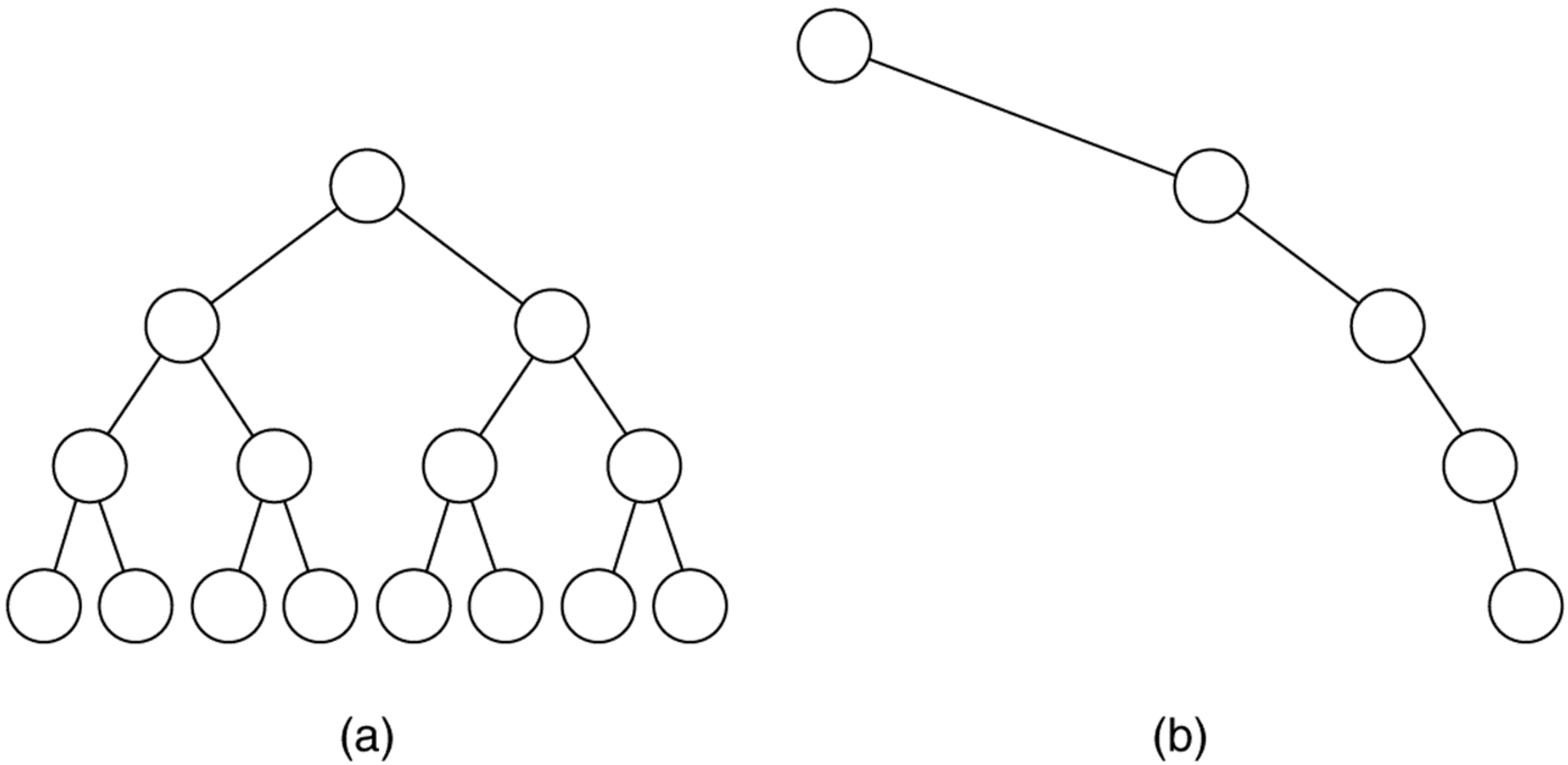


Figure 19.20

Binary search trees that can result from inserting a permutation 1, 2, and 3; the balanced tree shown in part (c) is twice as likely to result as any of the others.

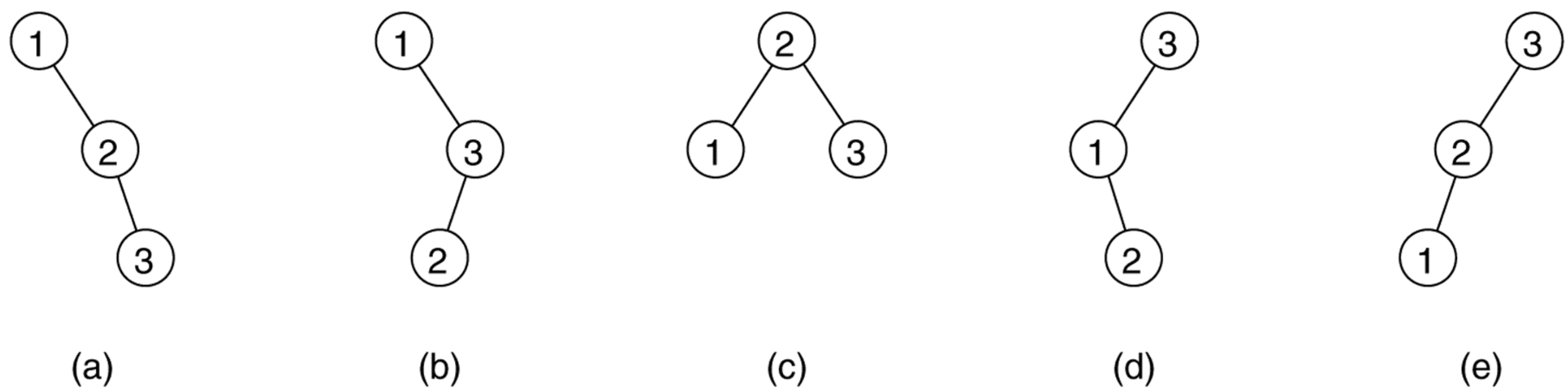


Figure 19.21

Two binary search trees: (a) an AVL tree; (b) not an AVL tree (unbalanced nodes are darkened)

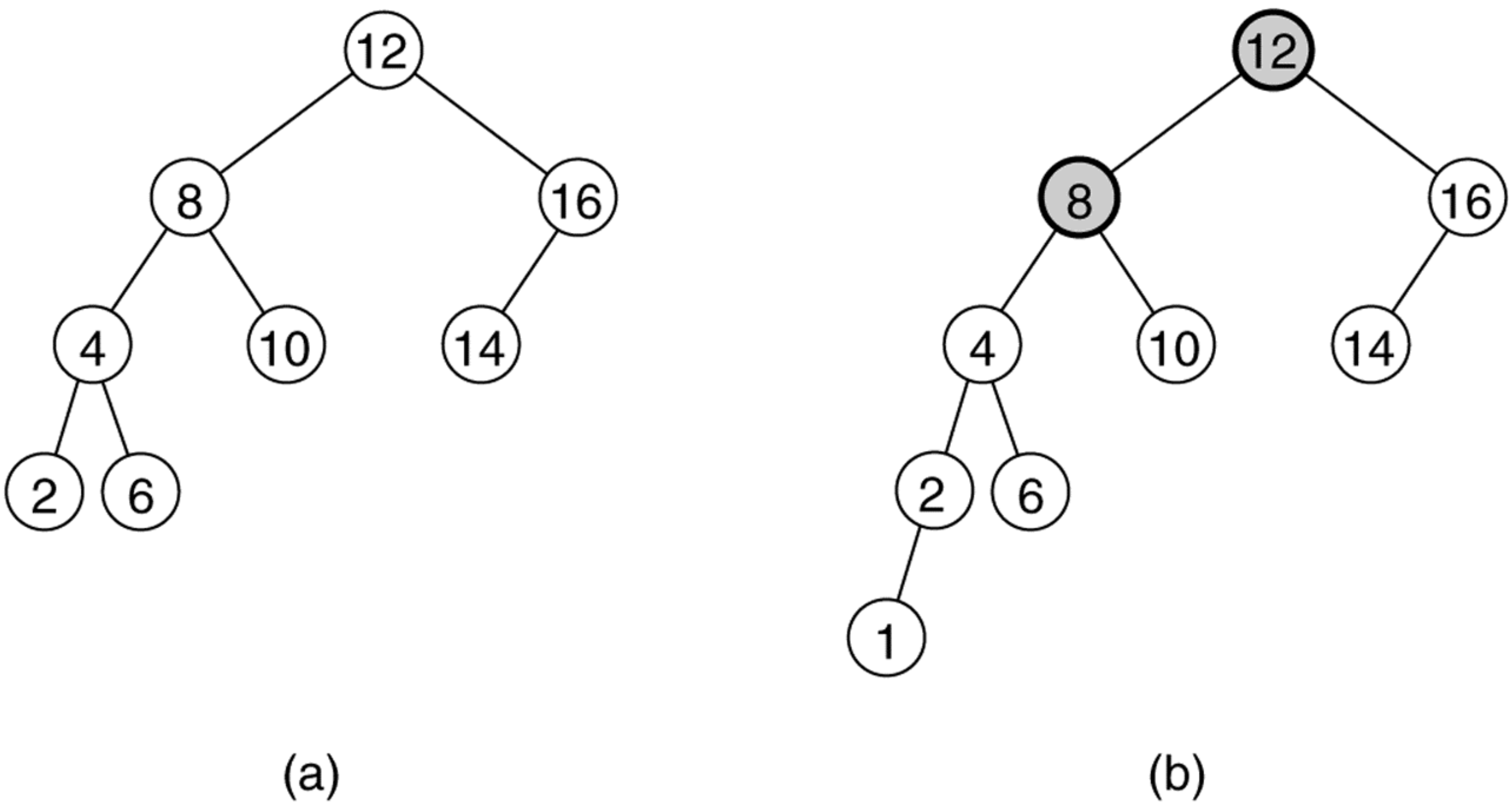


Figure 19.22

Minimum tree of height *H*

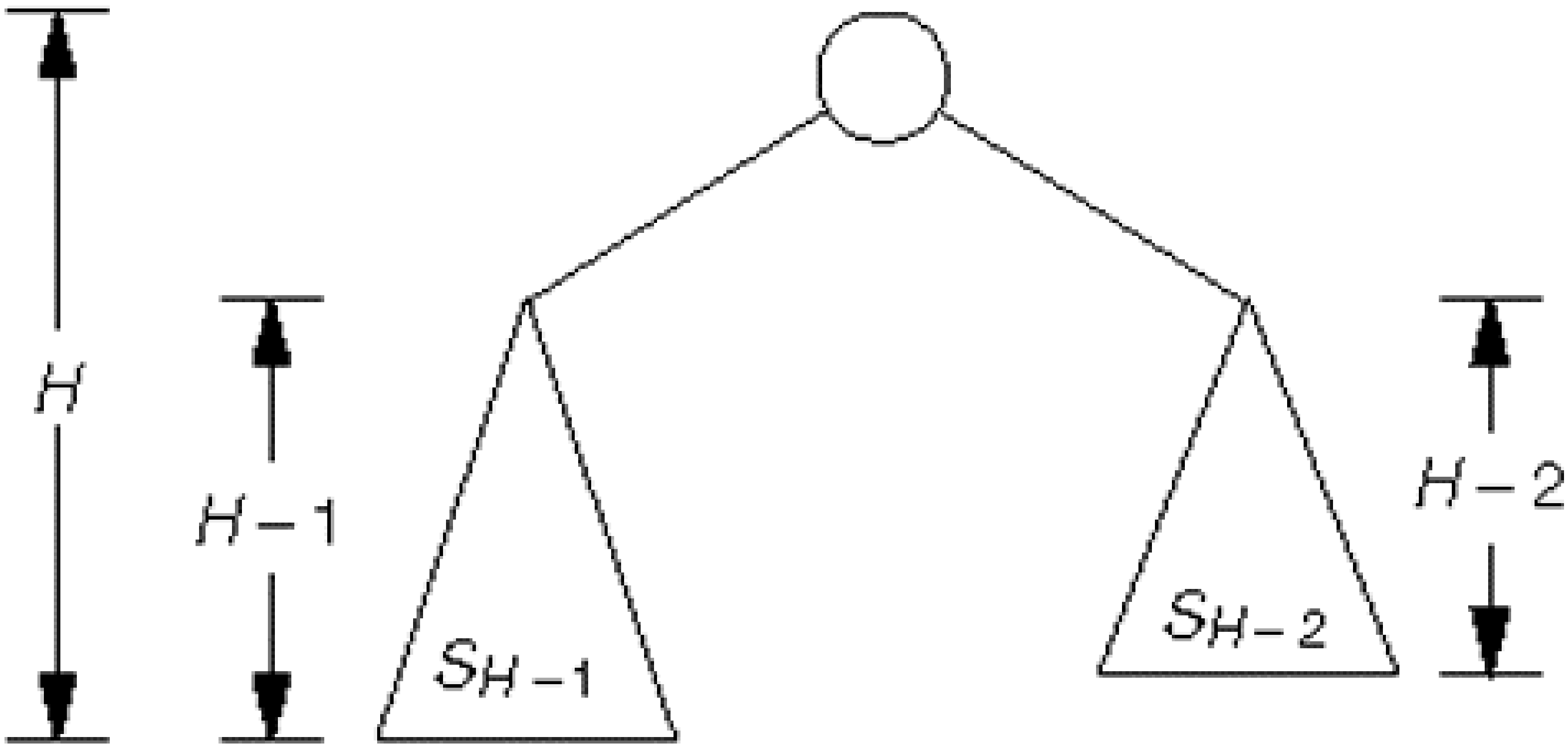
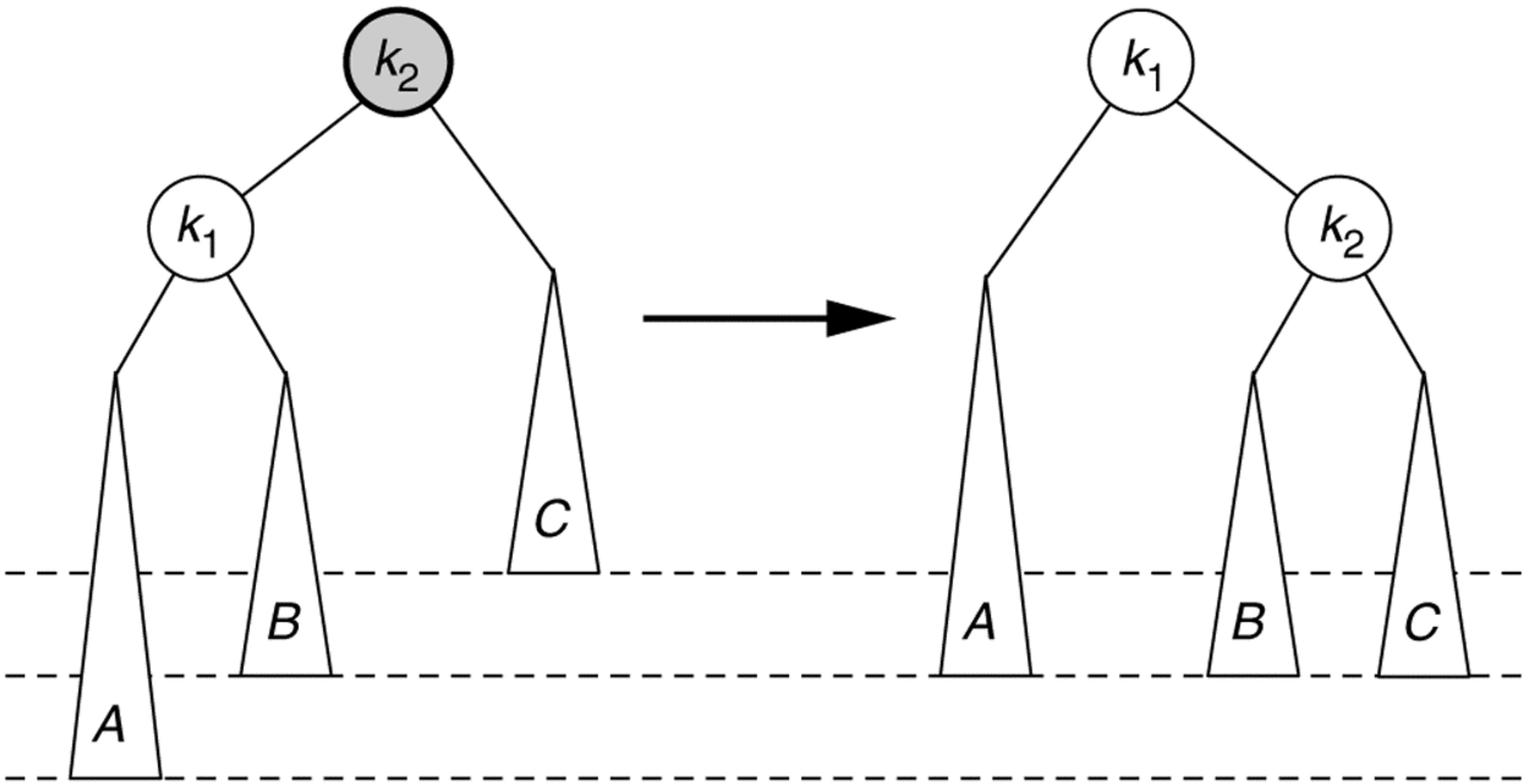


Figure 19.23

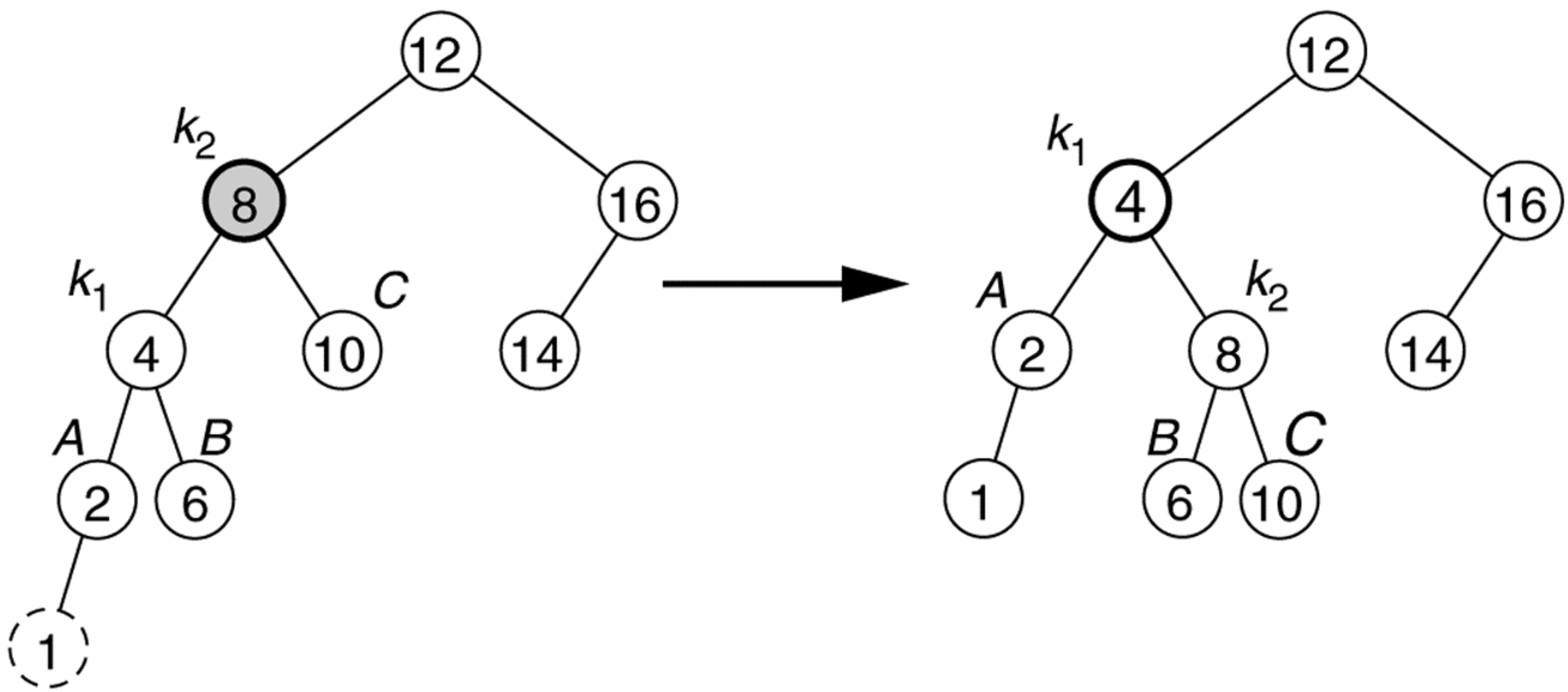
Single rotation to fix case 1



(a) Before rotation (b) After rotation

Figure 19.25

Single rotation fixes an AVL tree after insertion of 1.



(a) Before rotation (b) After rotation

Figure 19.26

Symmetric single rotation to fix case 4

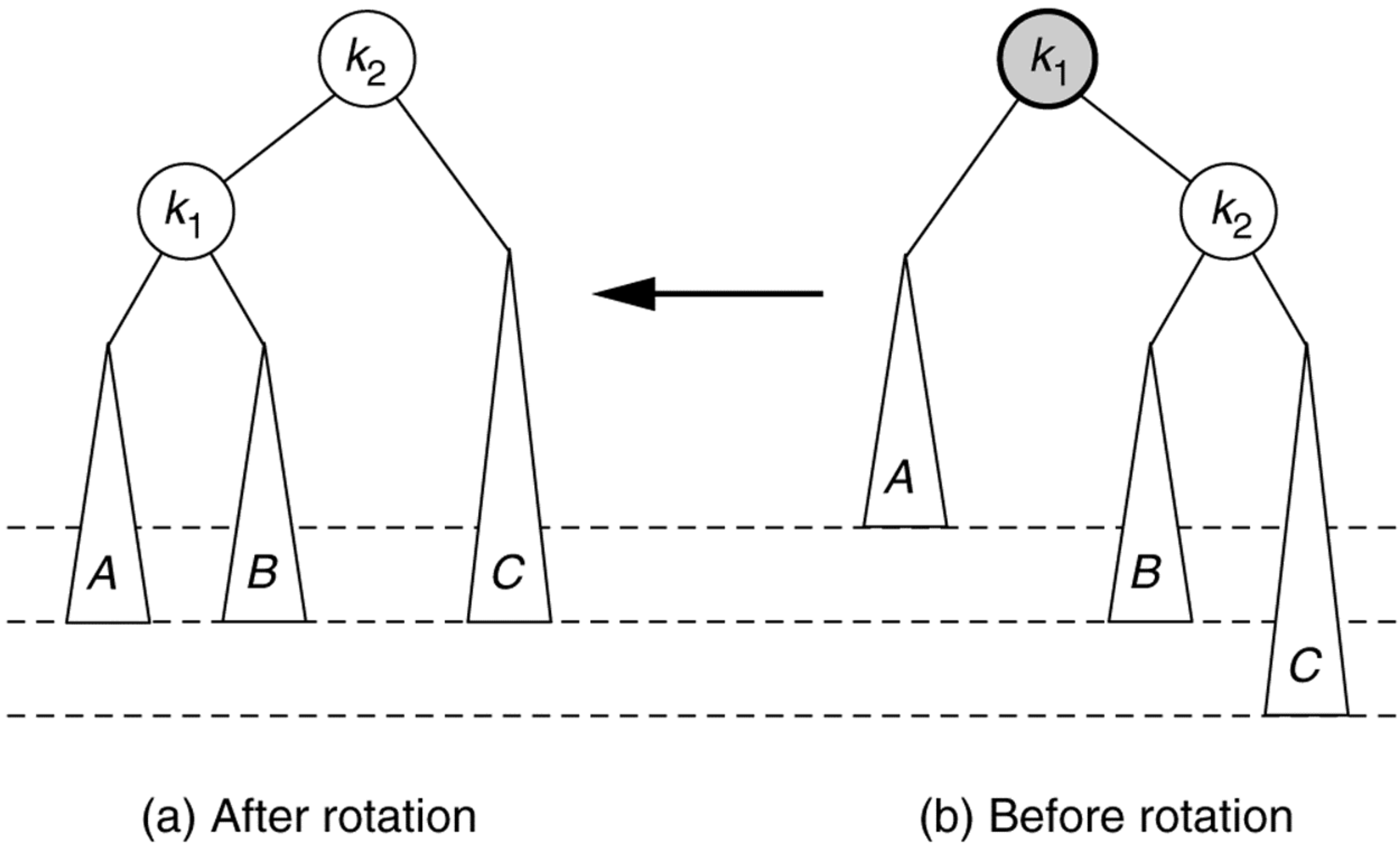


Figure 19.28

Single rotation does not fix case 2.

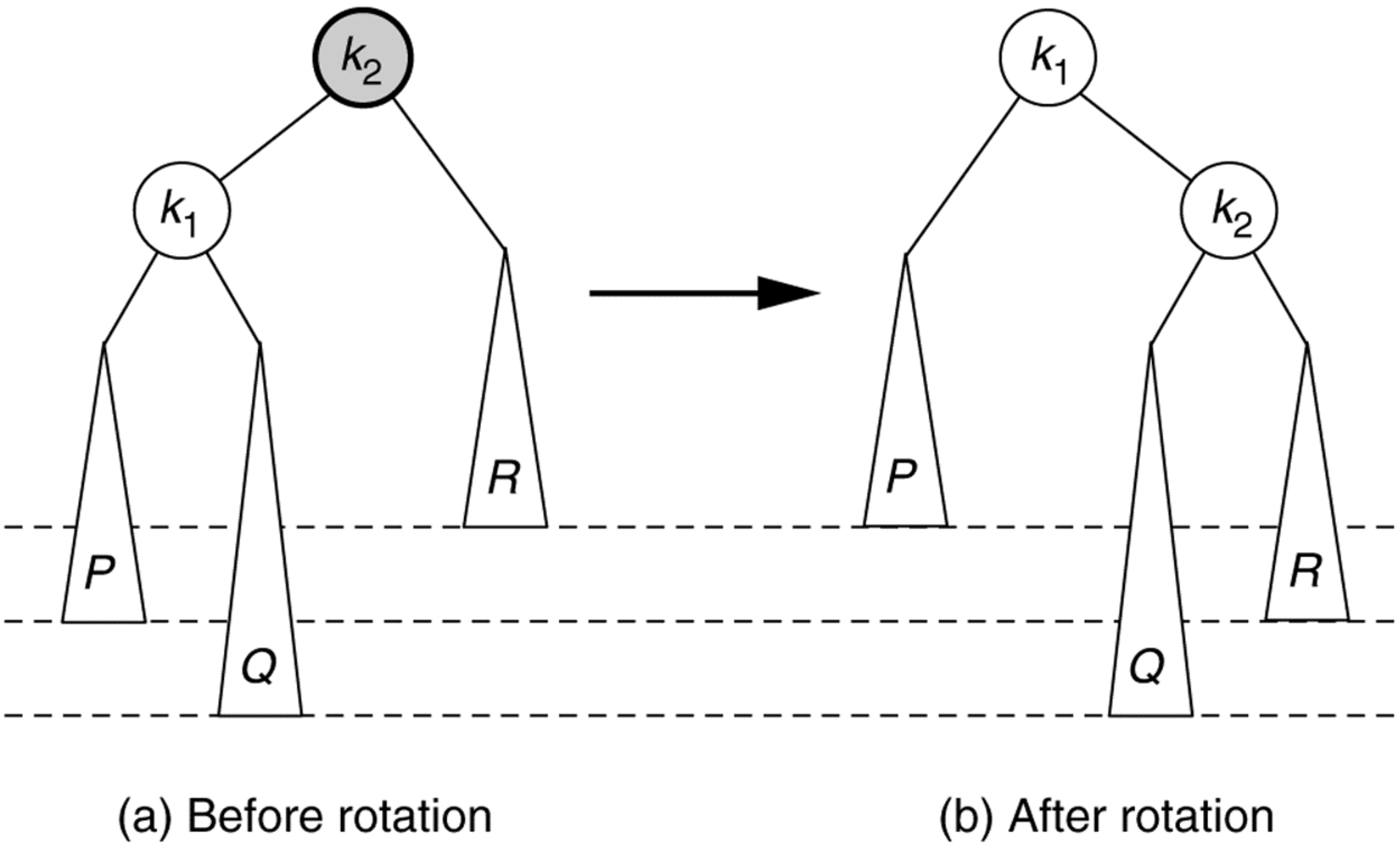


Figure 19.29

Left–right double rotation to fix case 2

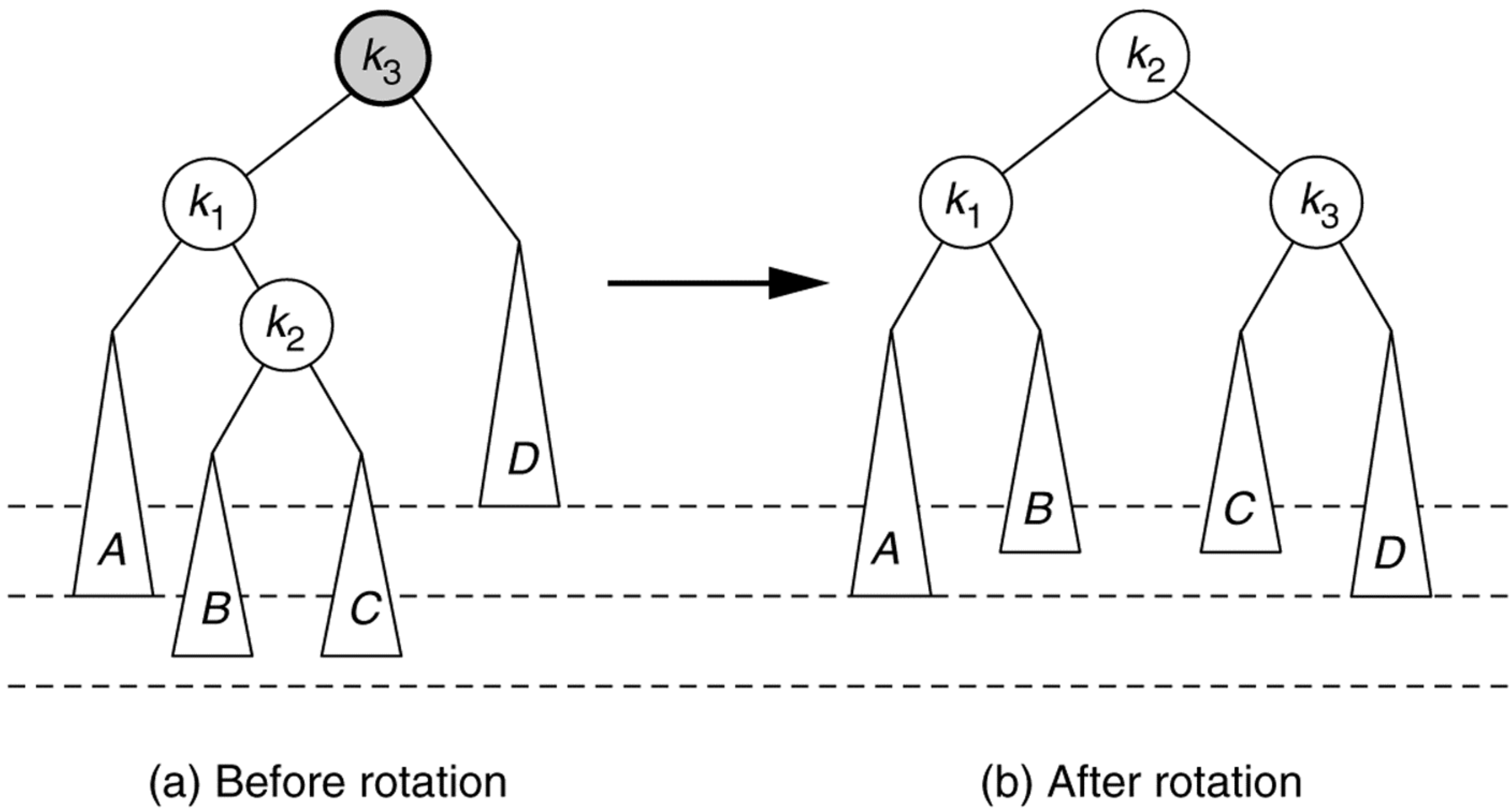
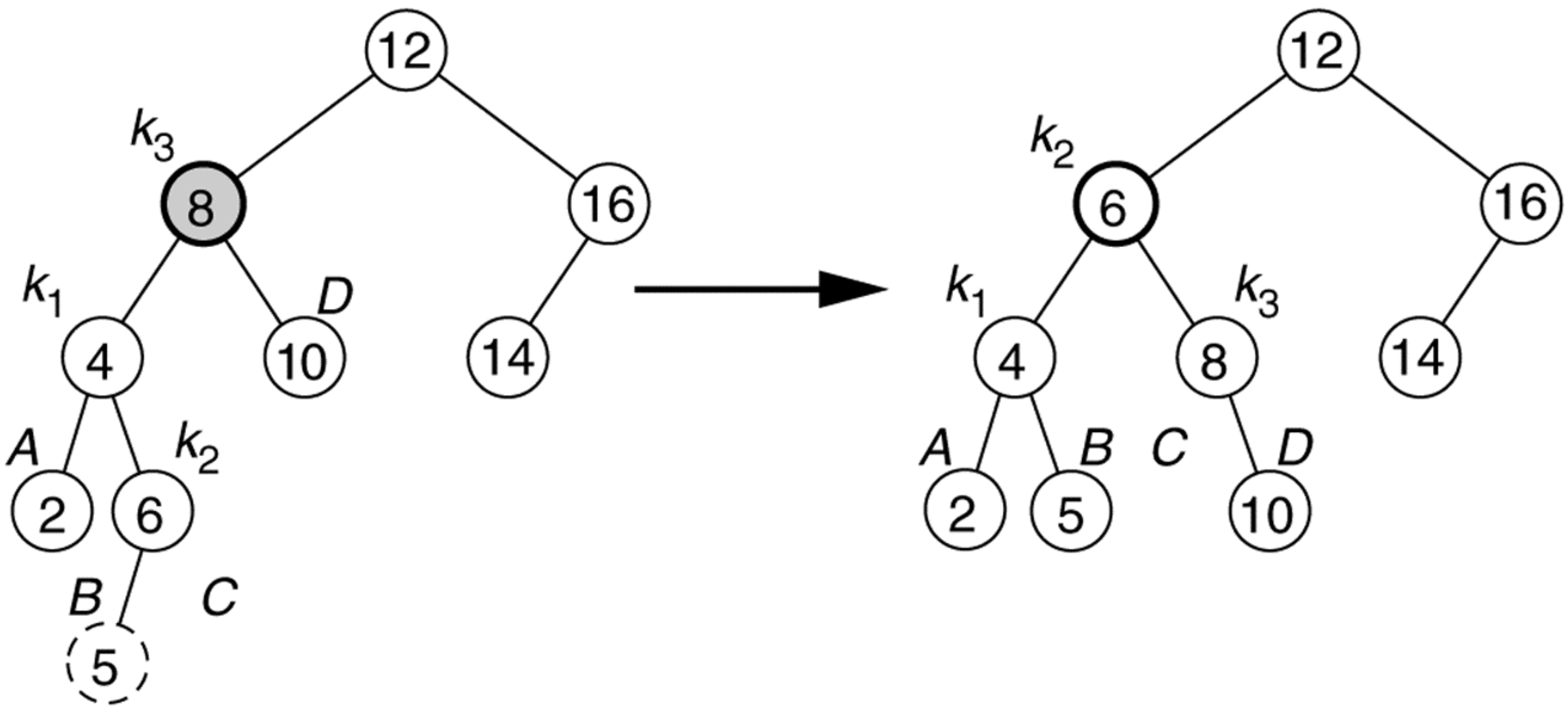


Figure 19.30

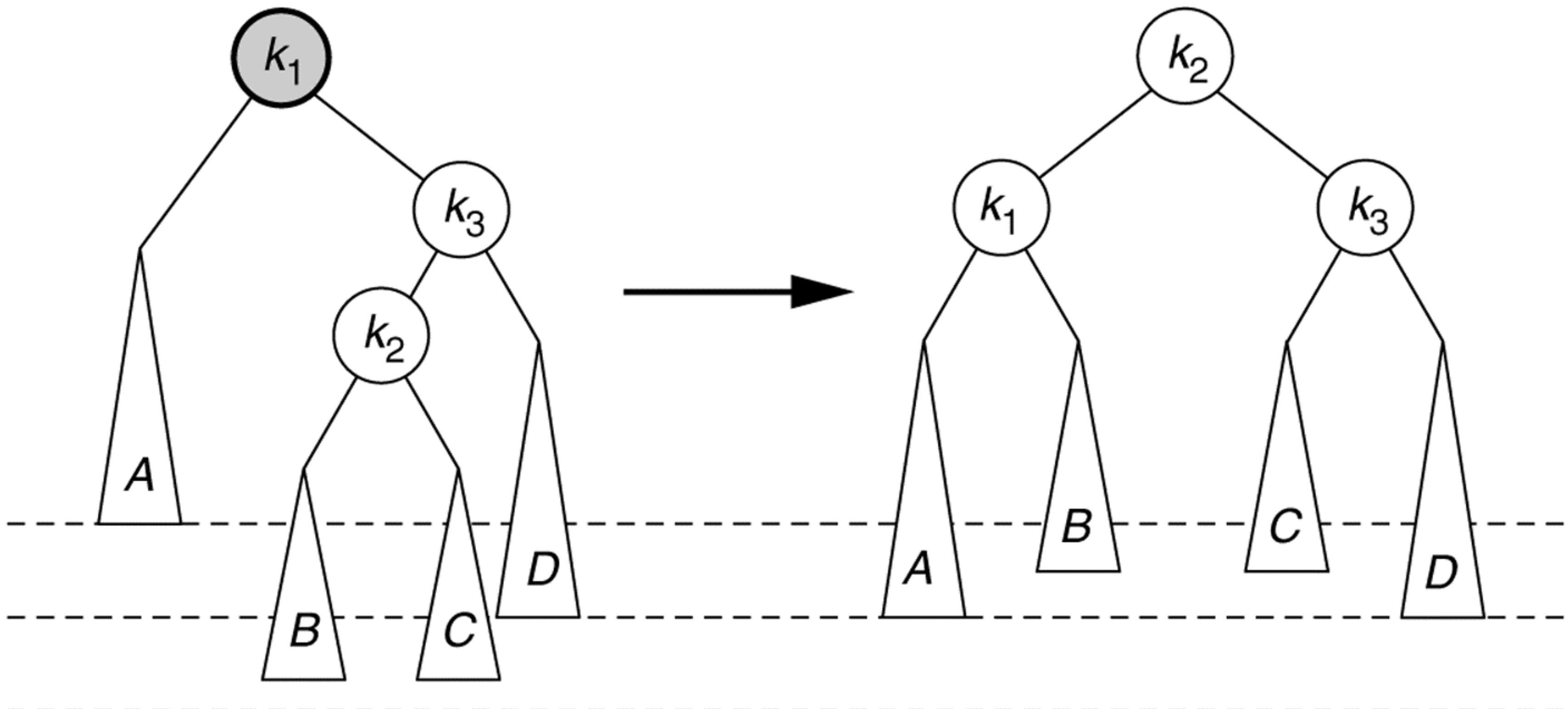
Double rotation fixes AVL tree after the insertion of 5.



(a) Before rotation (b) After rotation

Figure 19.31

Right–Left double rotation to fix case 3.



(a) Before rotation (b) After rotation

Figure 19.34

A red–black tree: The insertion sequence is 10, 85, 15, 70, 20, 60, 30, 50, 65, 80, 90, 40, 5, and 55 (shaded nodes are red).

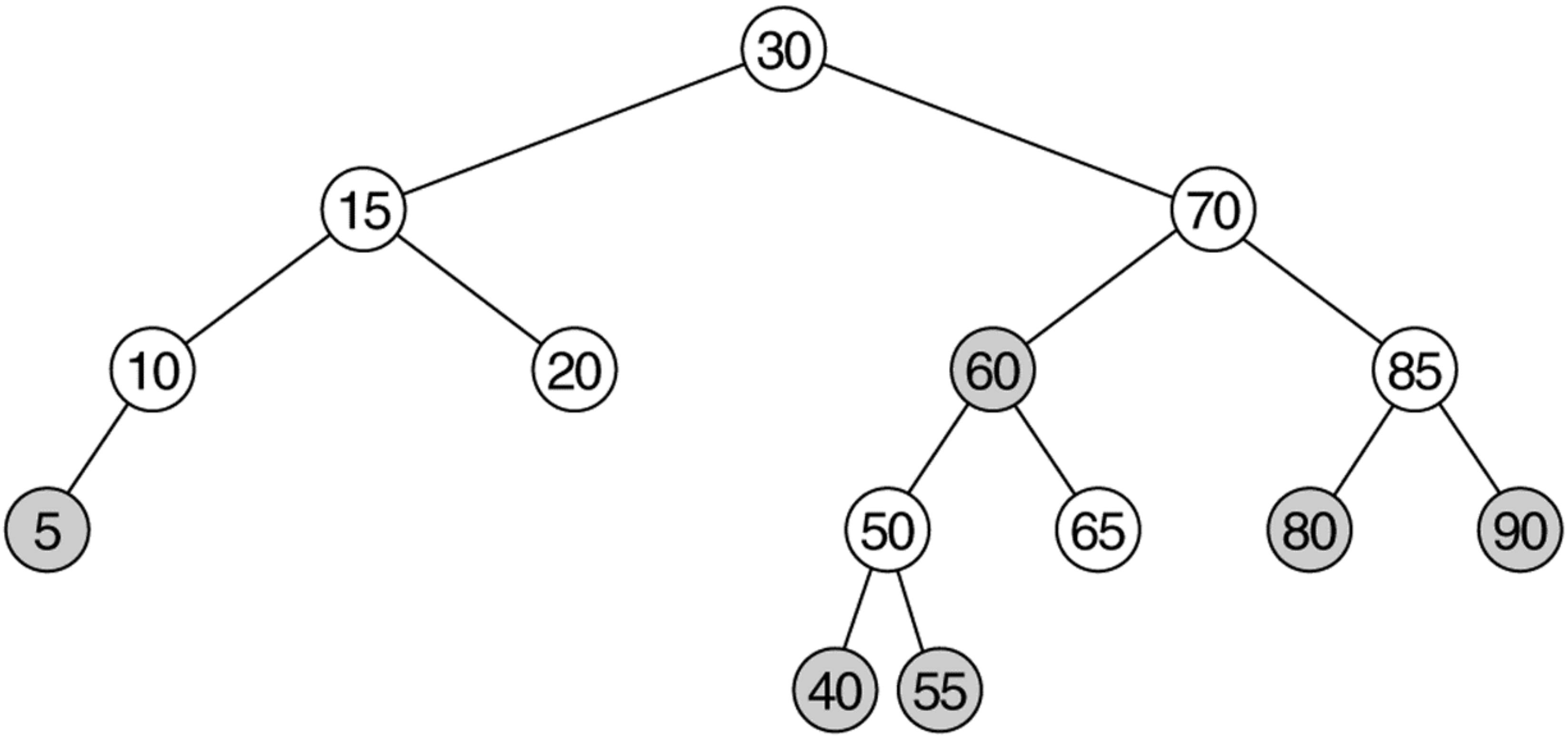
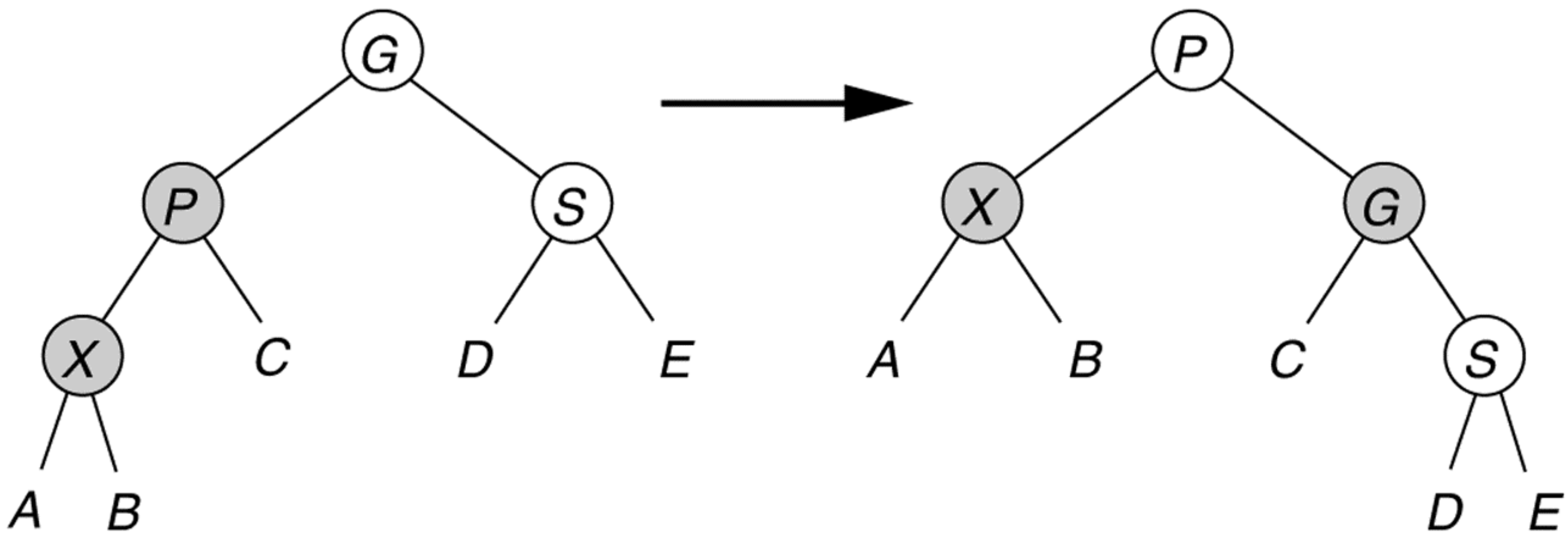


Figure 19.35

If *S* is black, a single rotation between parent and grandparent, with appropriate color changes, restores property 3 if *X* is an outside grandchild.



(a) Before rotation (b) After rotation

Figure 19.36

If *S* is black, a double rotation involving *X*, the parent, and the grandparent, with appropriate color changes, restores property 3 if *X* is an inside grandchild.

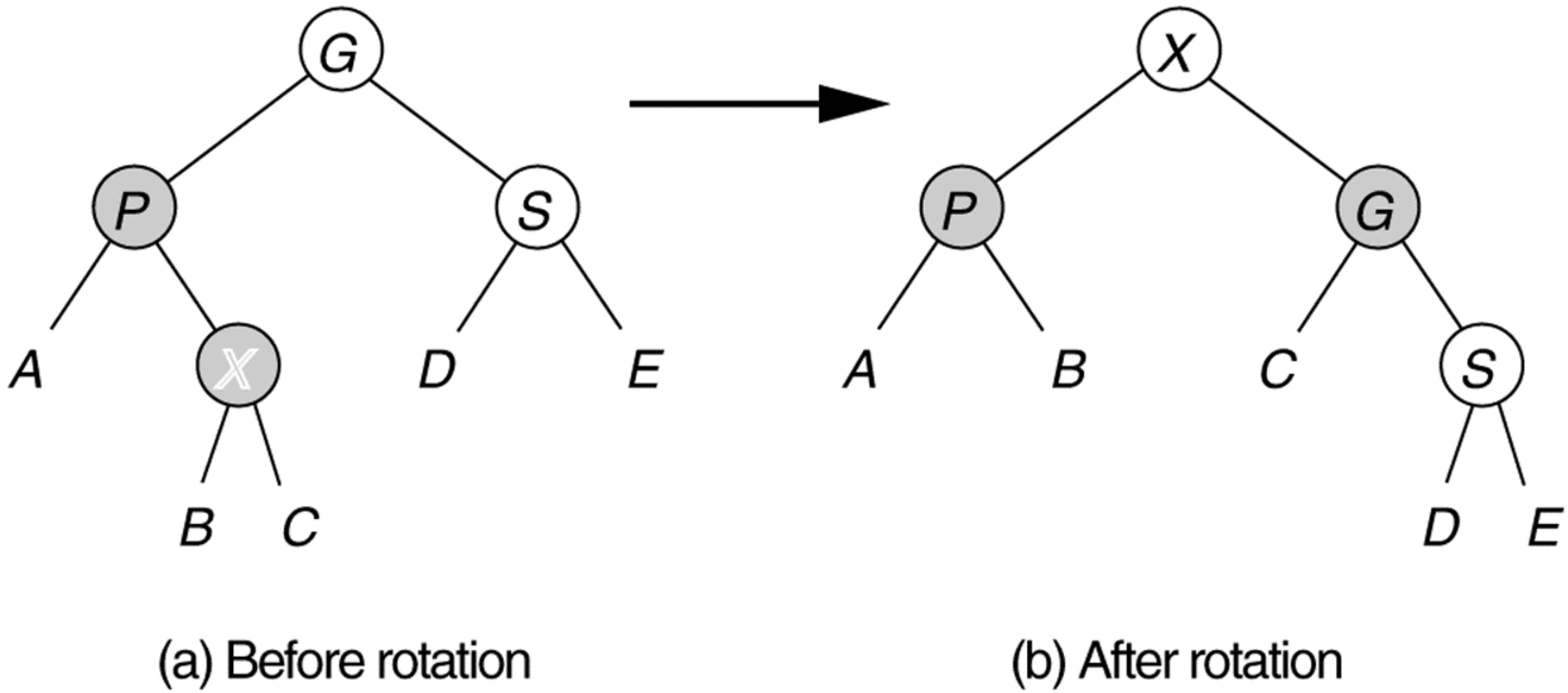


Figure 19.37

If *S* is red, a single rotation between parent and grandparent, with appropriate color changes, restores property 3 between *X* and *P*.

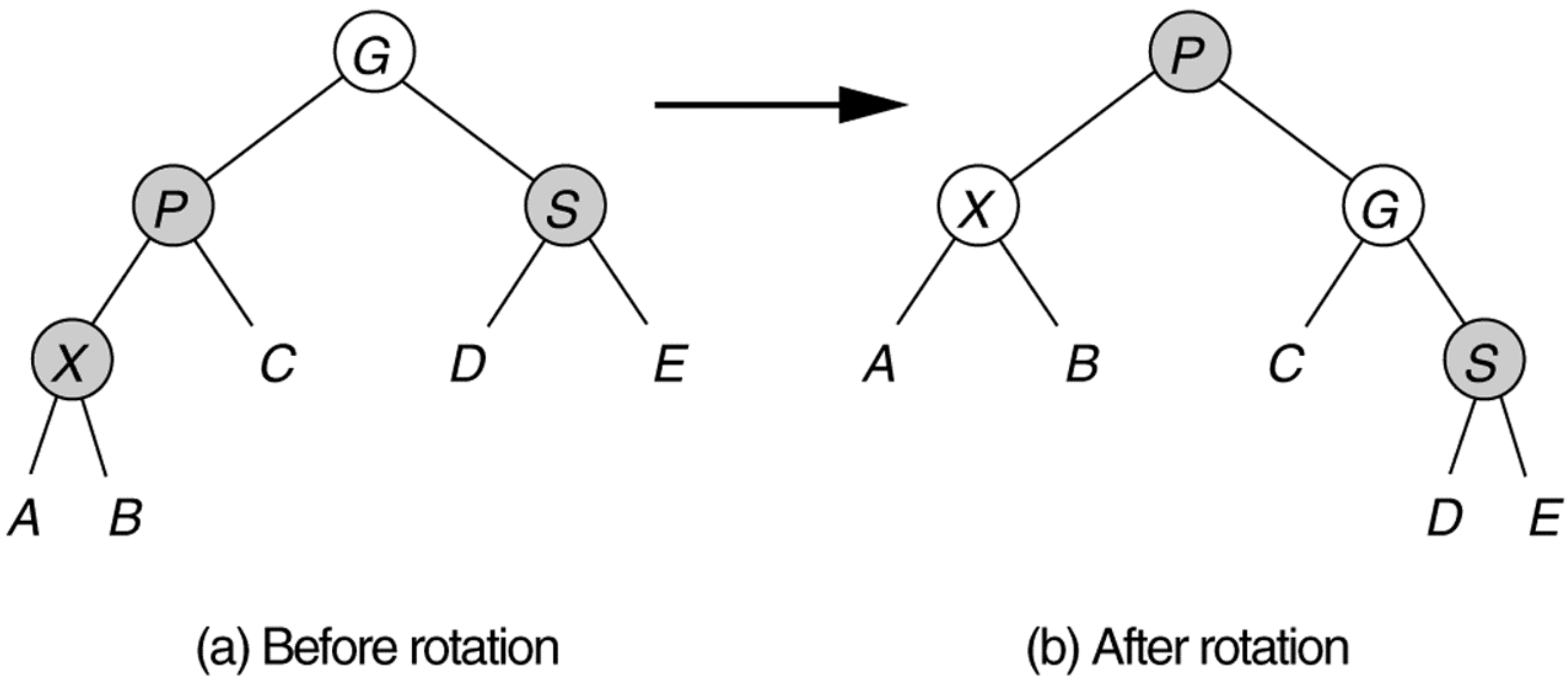
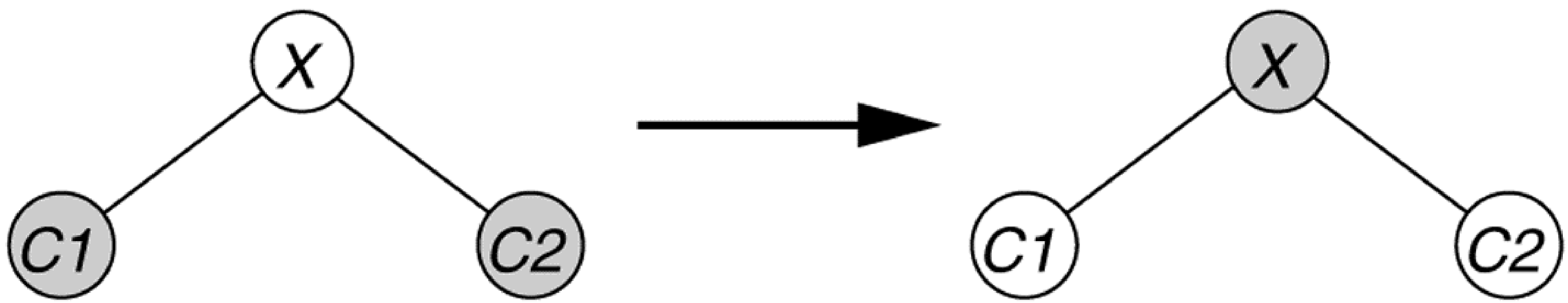


Figure 19.38
Color flip: Only if *X*'s parent is red do we continue with a rotation.



(a) Before rotation

(b) After rotation

