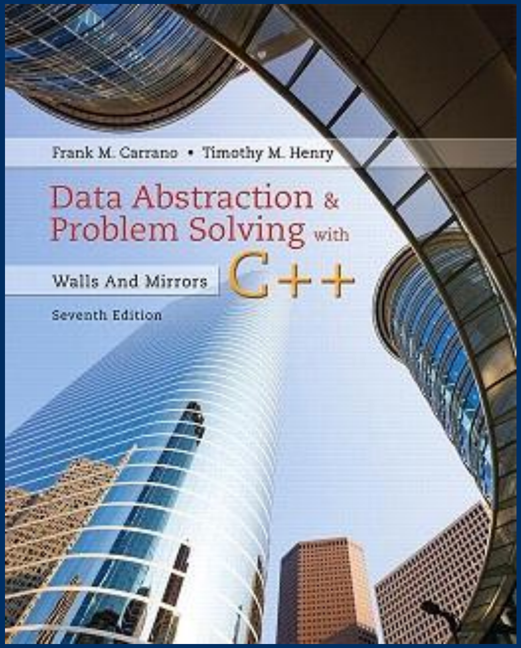
Chapter 19

Balanced Search Trees

CS 302 - Data Structures

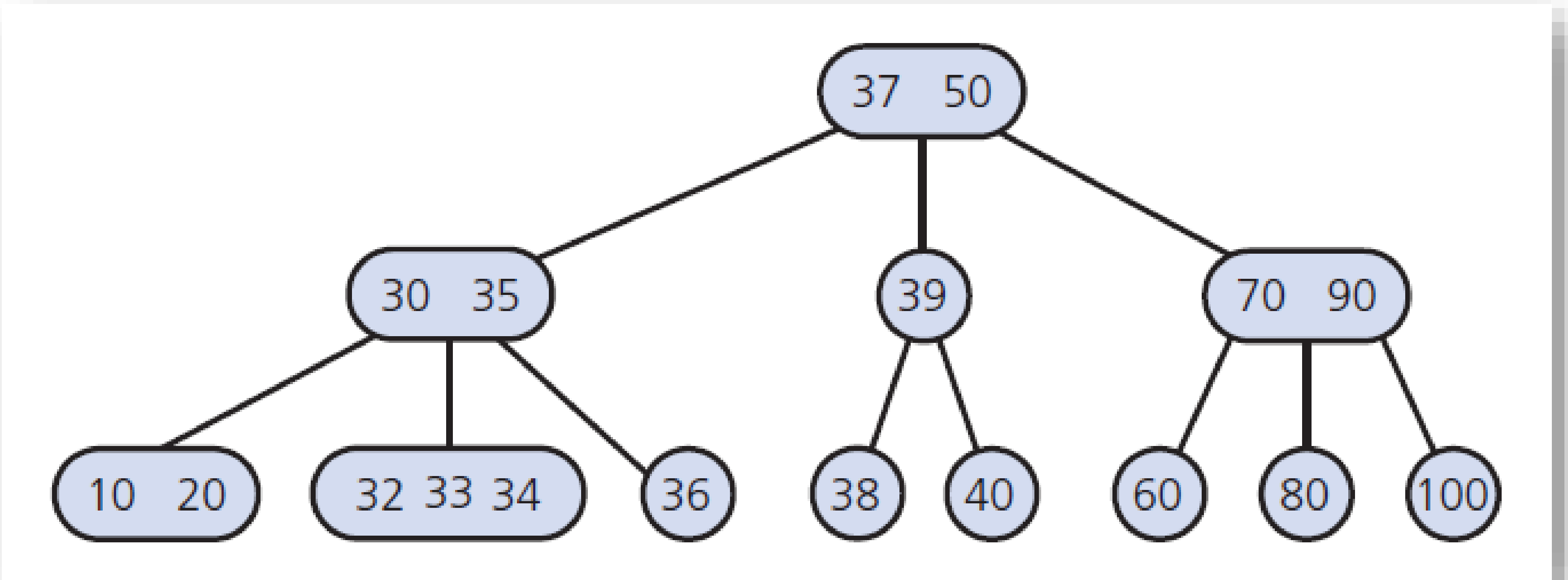
M. Abdullah Canbaz



Modified from authors' slides

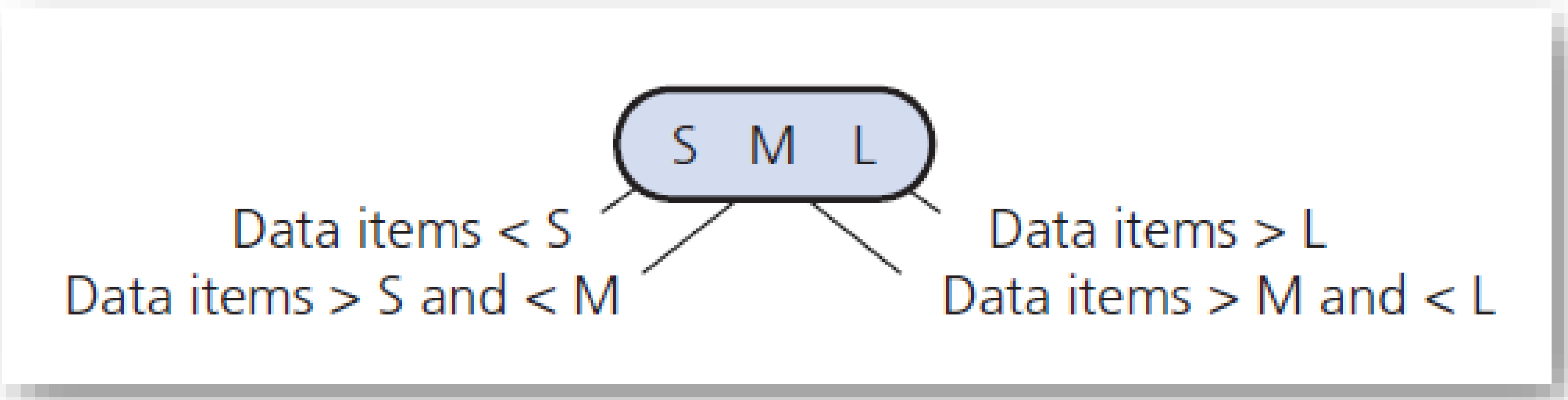
2-3-4 Trees

2-3-4 Trees



- A 2-3-4 tree with the same data items as the 2-3 tree

2-3-4 Trees



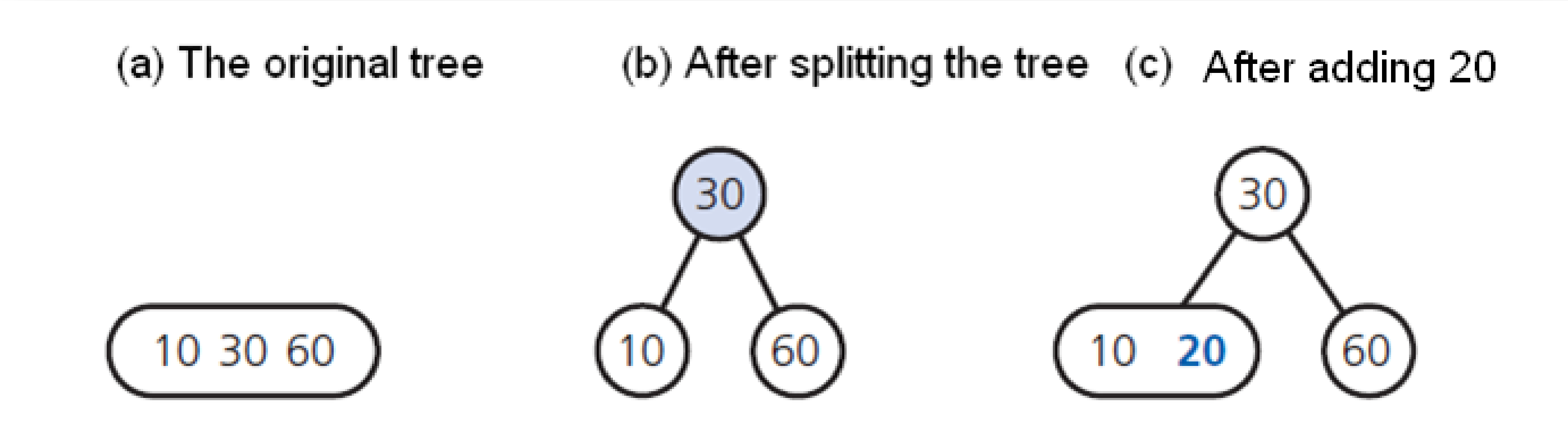
- A 4-node in a 2-3-4 tree

2-3-4 Trees

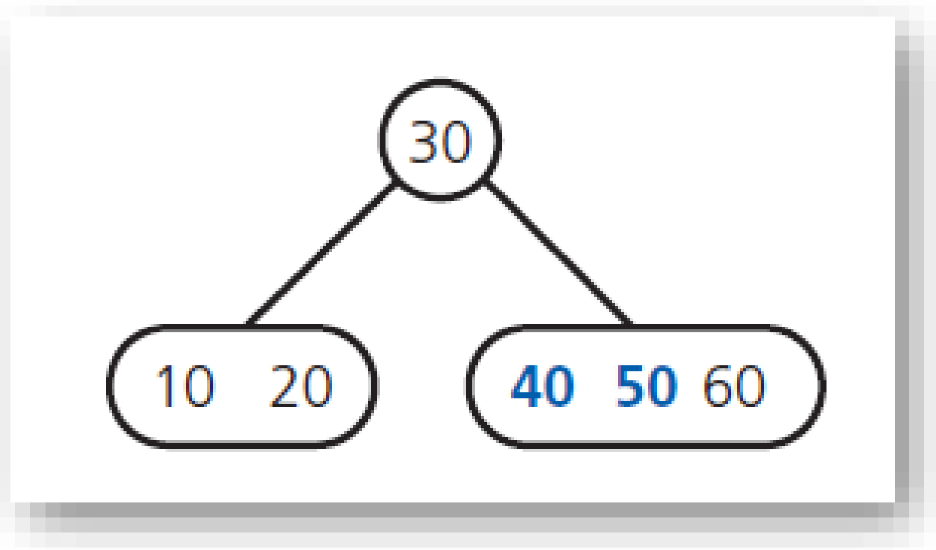
- Searching and traversing
  - Simple extensions of corresponding algorithms for a 2-3 tree
- Adding data
  - Like addition algorithm for 2-3 tree
  - Splits node by moving one data item up to parent node

Adding Data to 2-3-4 Trees

- Adding 20 to a one-node 2-3-4 tree

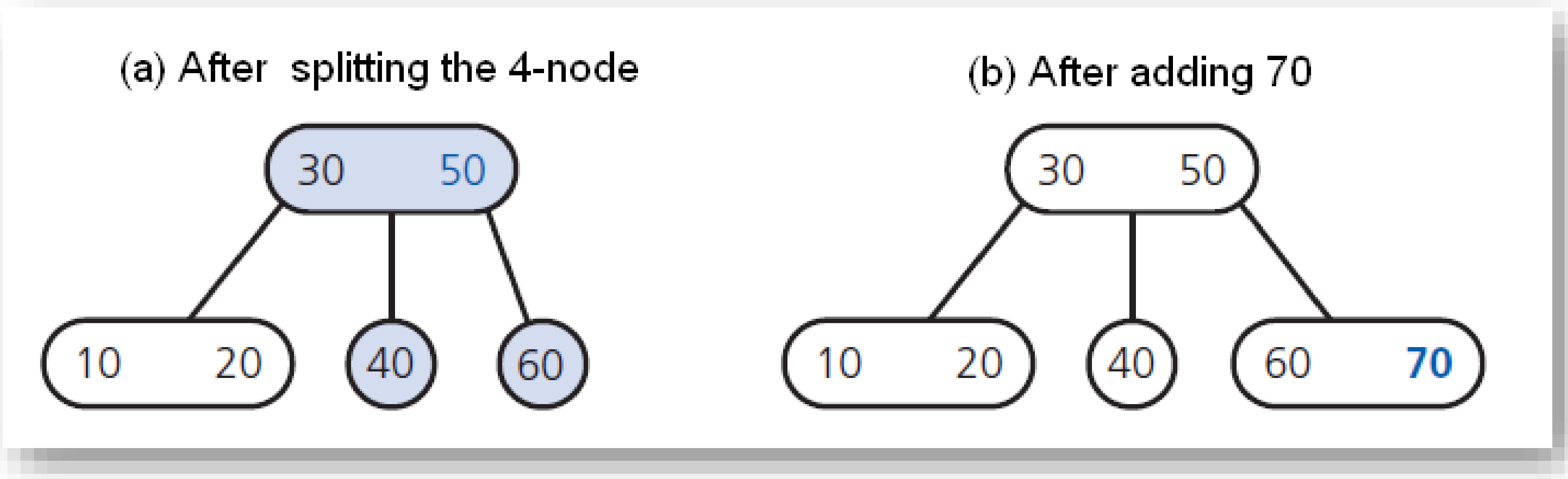


Adding Data to 2-3-4 Trees



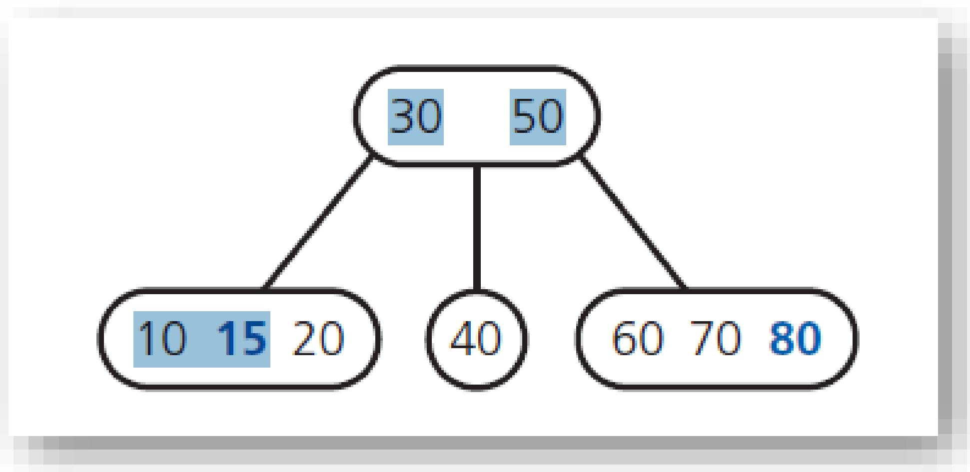
- After adding 50 and 40 to the tree

Adding Data to 2-3-4 Trees



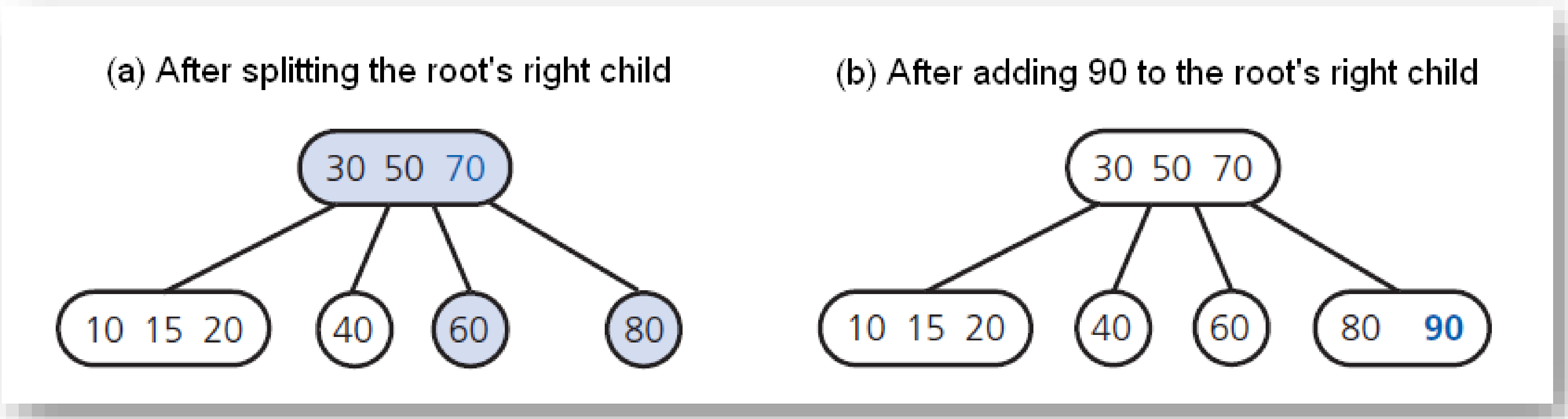
- The steps for adding 70 to the tree

Adding Data to 2-3-4 Trees



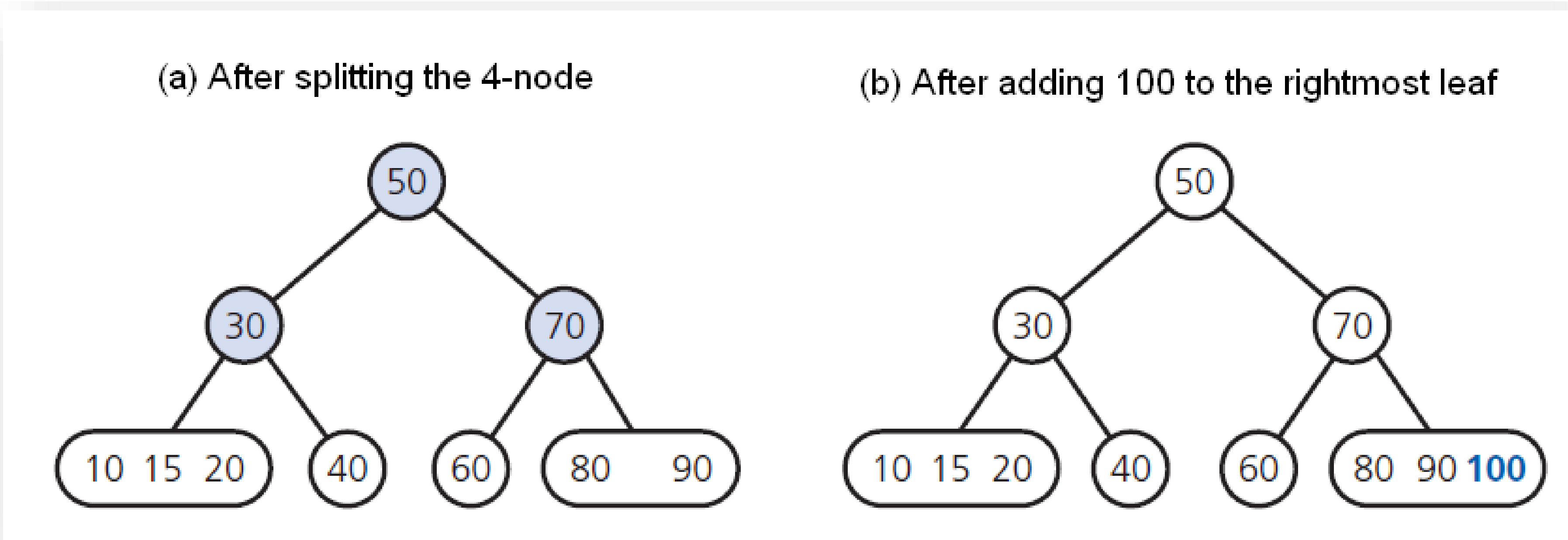
- After adding 80 and 15 to the tree

Adding Data to 2-3-4 Trees



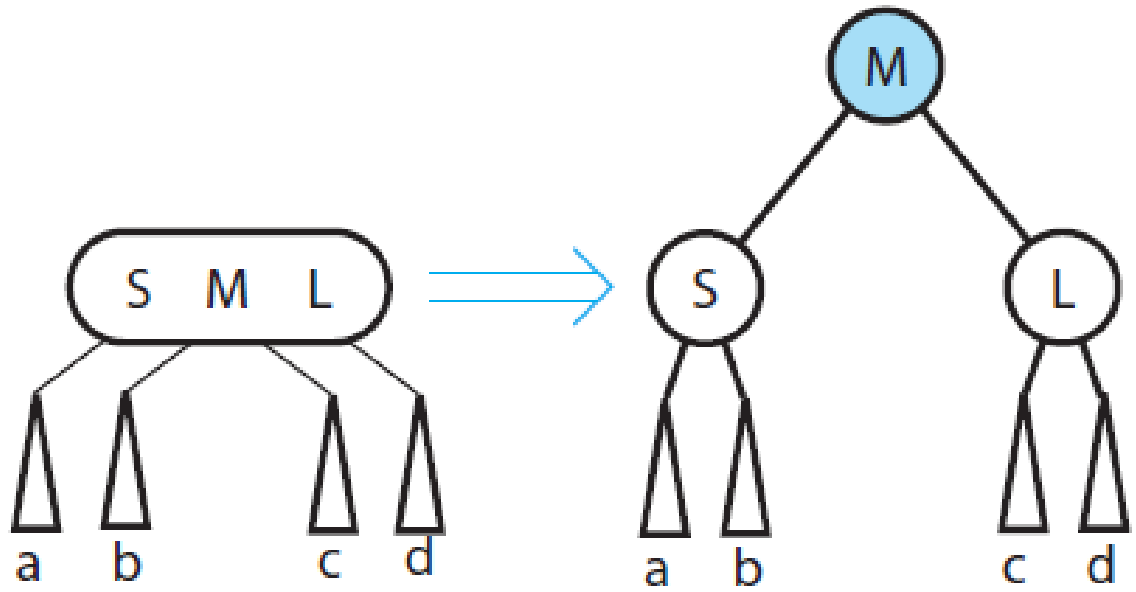
- The steps for adding 90 to the tree

Adding Data to 2-3-4 Trees



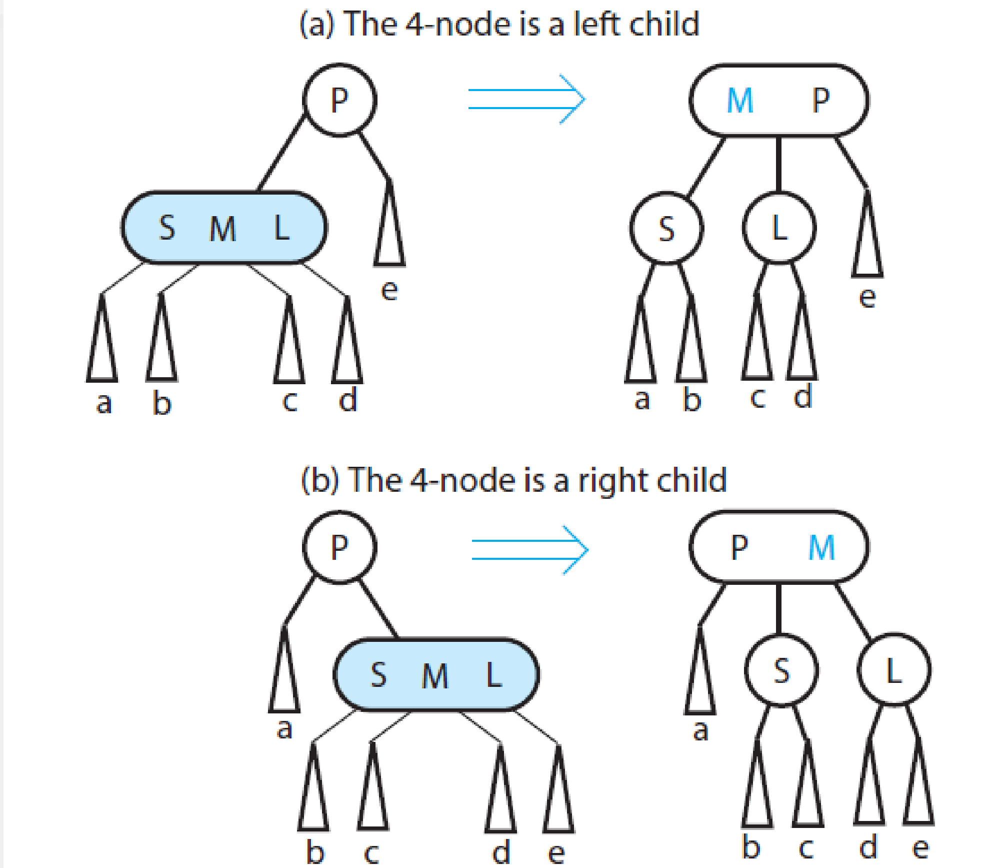
- The steps for adding 100 to the tree

Adding Data to 2-3-4 Trees



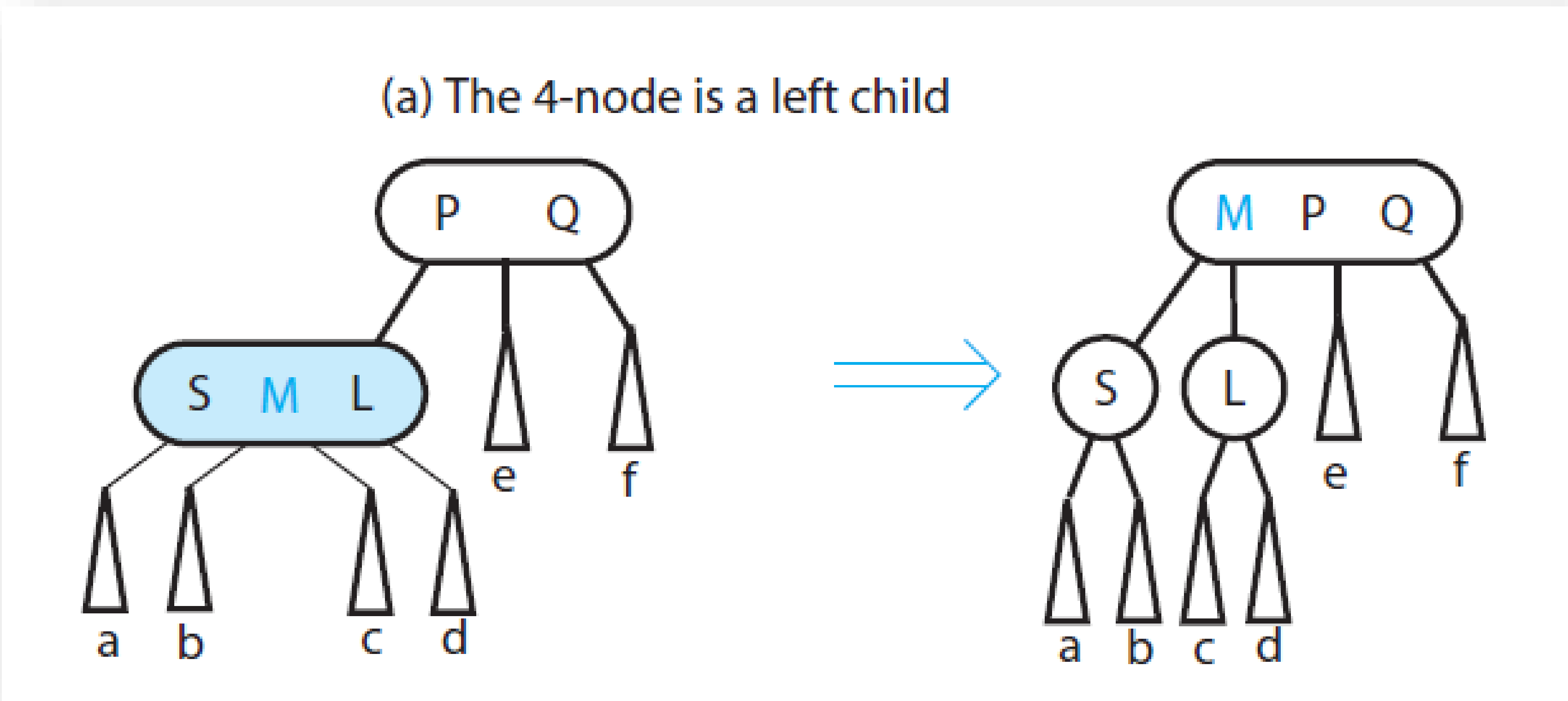
- Splitting a 4-node root when adding data to a 2-3-4 tree

Adding Data to 2-3-4 Trees



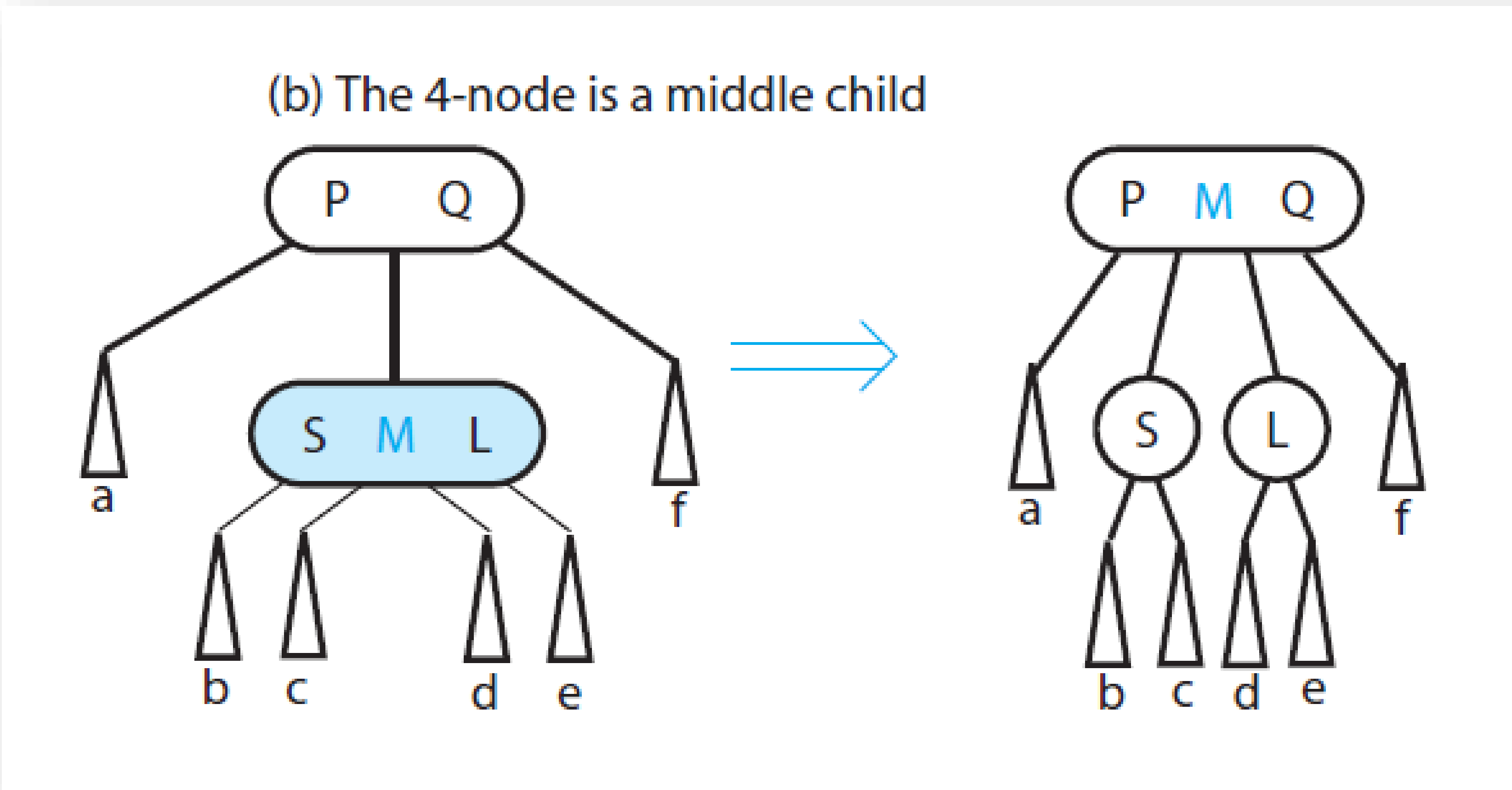
- Splitting a 4-node whose parent is a 2-node when adding data to a 2-3-4 tree

Adding Data to 2-3-4 Trees



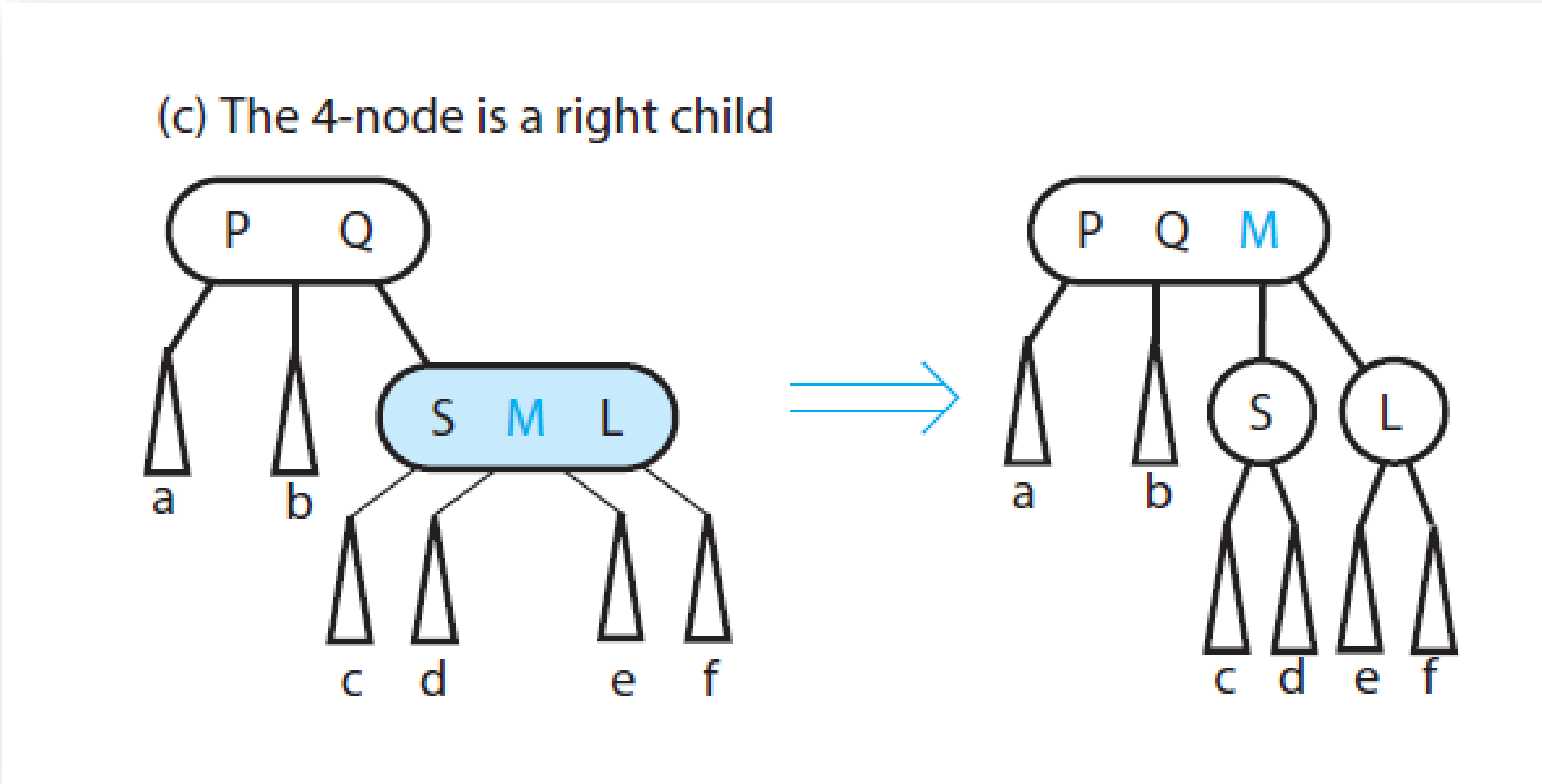
- Splitting a 4-node whose parent is a 3-node when adding data to a 2-3-4 tree

Adding Data to 2-3-4 Trees



- Splitting a 4-node whose parent is a 3-node when adding data to a 2-3-4 tree

Adding Data to 2-3-4 Trees



- Splitting a 4-node whose parent is a 3-node when adding data to a 2-3-4 tree

Removing Data from a 2-3-4 Tree

- Has same beginning as removal algorithm for a 2-3 tree

- Transform each 2-node into a 3-node or a 4-node

- Insertion and removal algorithms for 2-3-4 tree require fewer steps than for 2-3 tree

Red-Black Trees

Modified from Dr Monica Nicolescu

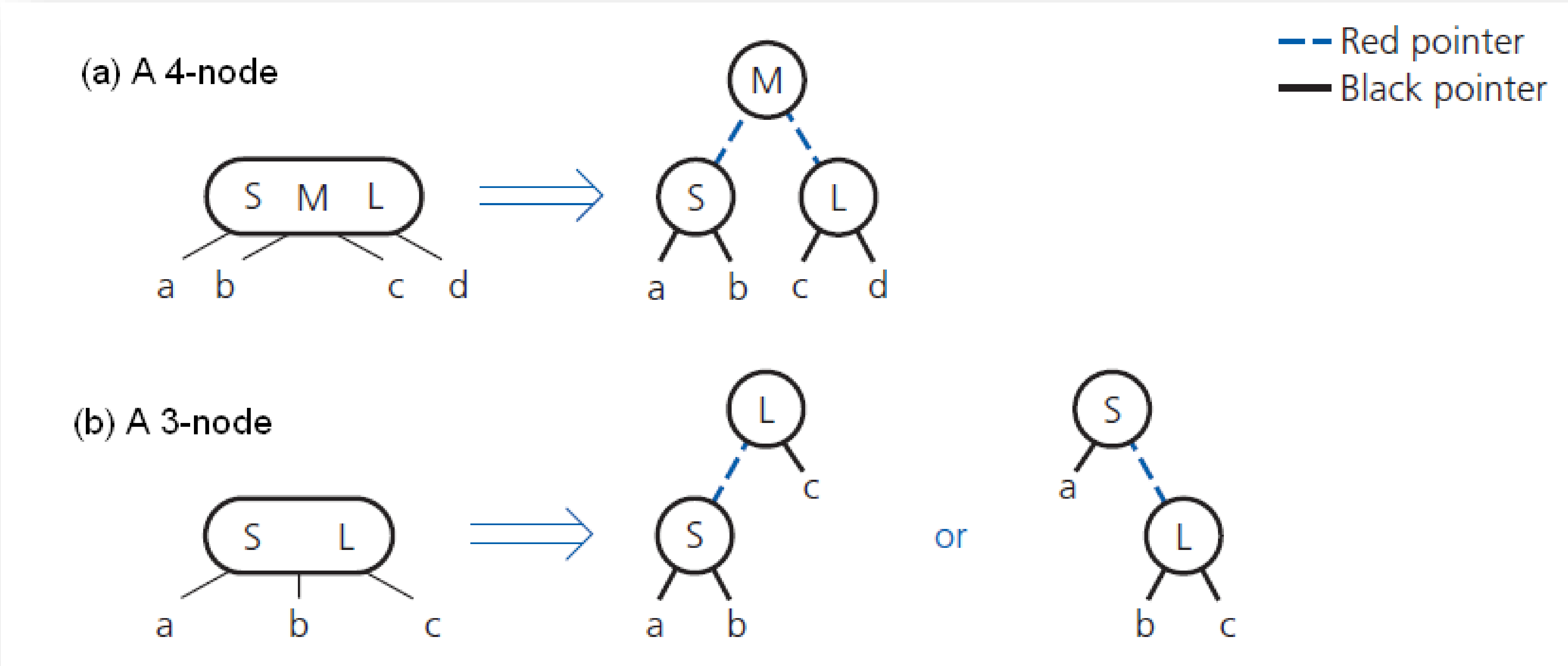
Red-Black Trees

- A 2-3-4 tree requires more storage than binary search tree

- Red-black tree has advantages of a 2-3-4 tree but requires less storage

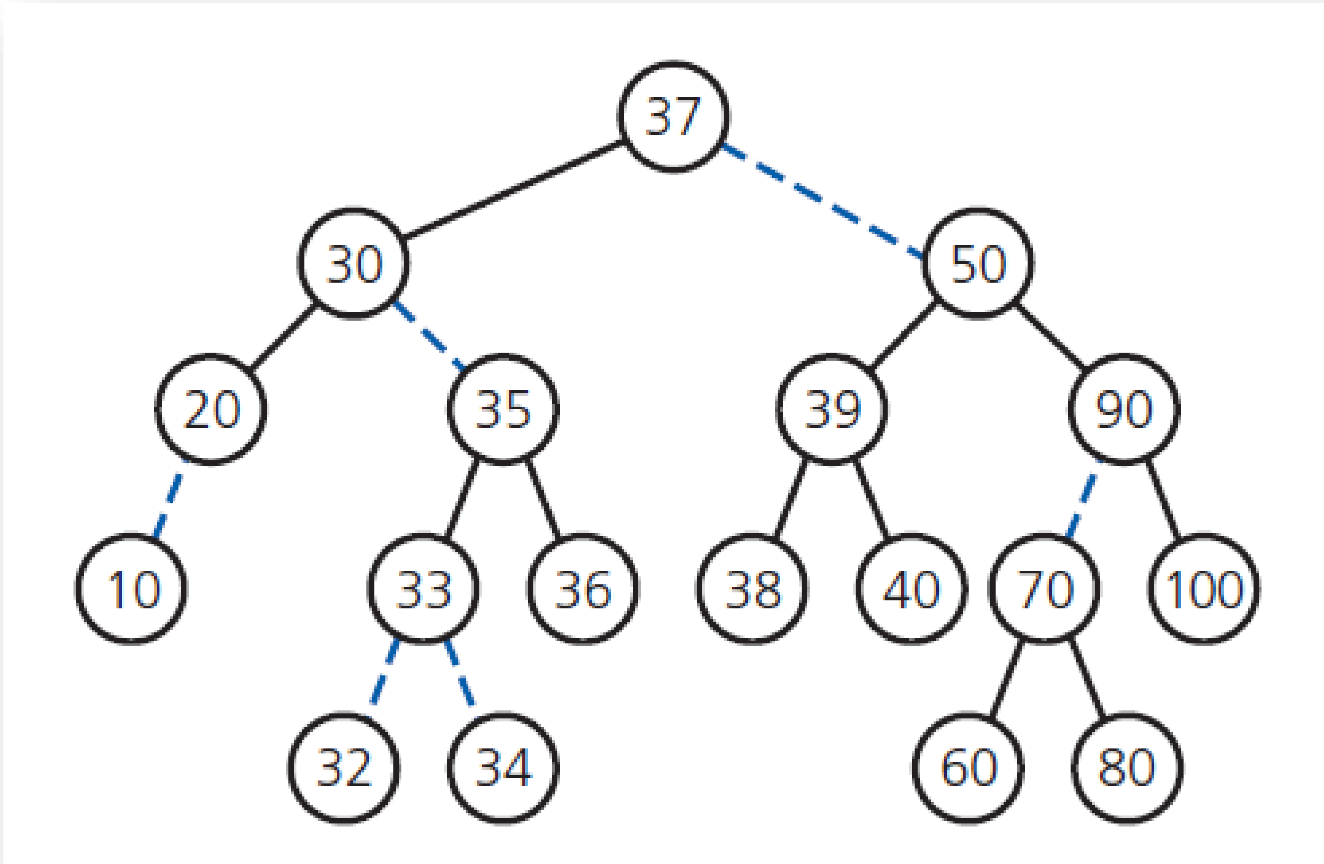
- In a red-black tree,
  - Red pointers link 2-nodes that now contain values that were in a 3-node or a 4-node

Red-Black Trees



- Red-black representation s of a 4-node and a 3-node

Red-Black Trees



- A red-black tree that represents the 2-3-4 tree

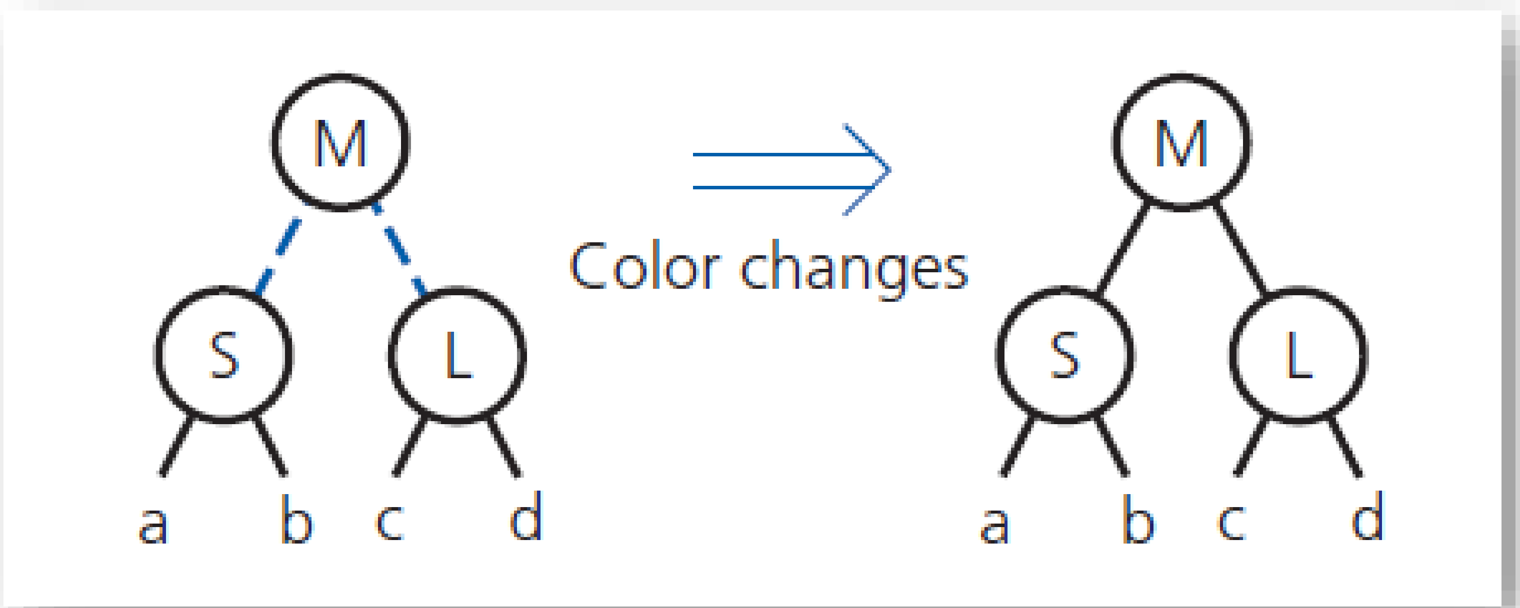
Searching and Traversing a Red-Black Tree

- A red-black tree is a binary search tree
- Thus, search and traversal
  - Use algorithms for binary search tree
  - Simply ignore color of pointers

Adding to and Removing from a Red-Black Tree

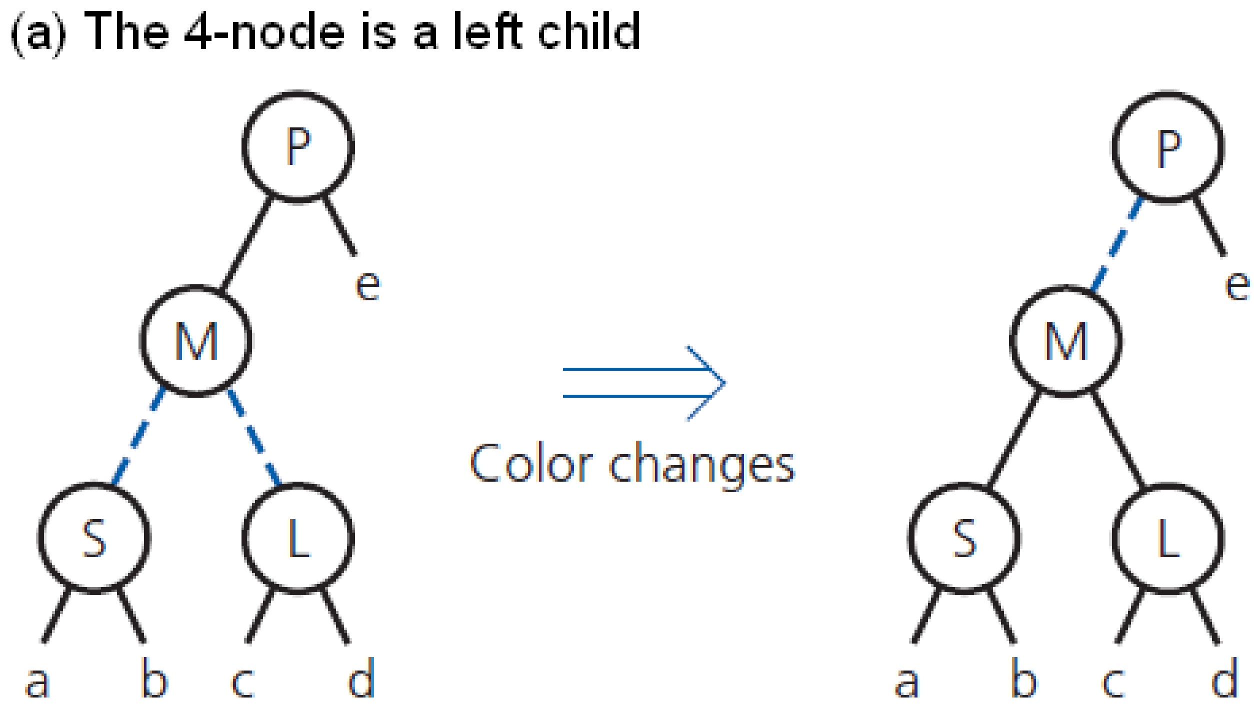
- Red-black tree represents a 2-3-4 tree
  - Simply adjust 2-3-4 addition algorithms
  - Accommodate red-black representation
- Splitting equivalent of a 4-node requires simple color changes
  - Pointer changes called rotations result in a shorter tree

Adding to and Removing from a Red-Black Tree



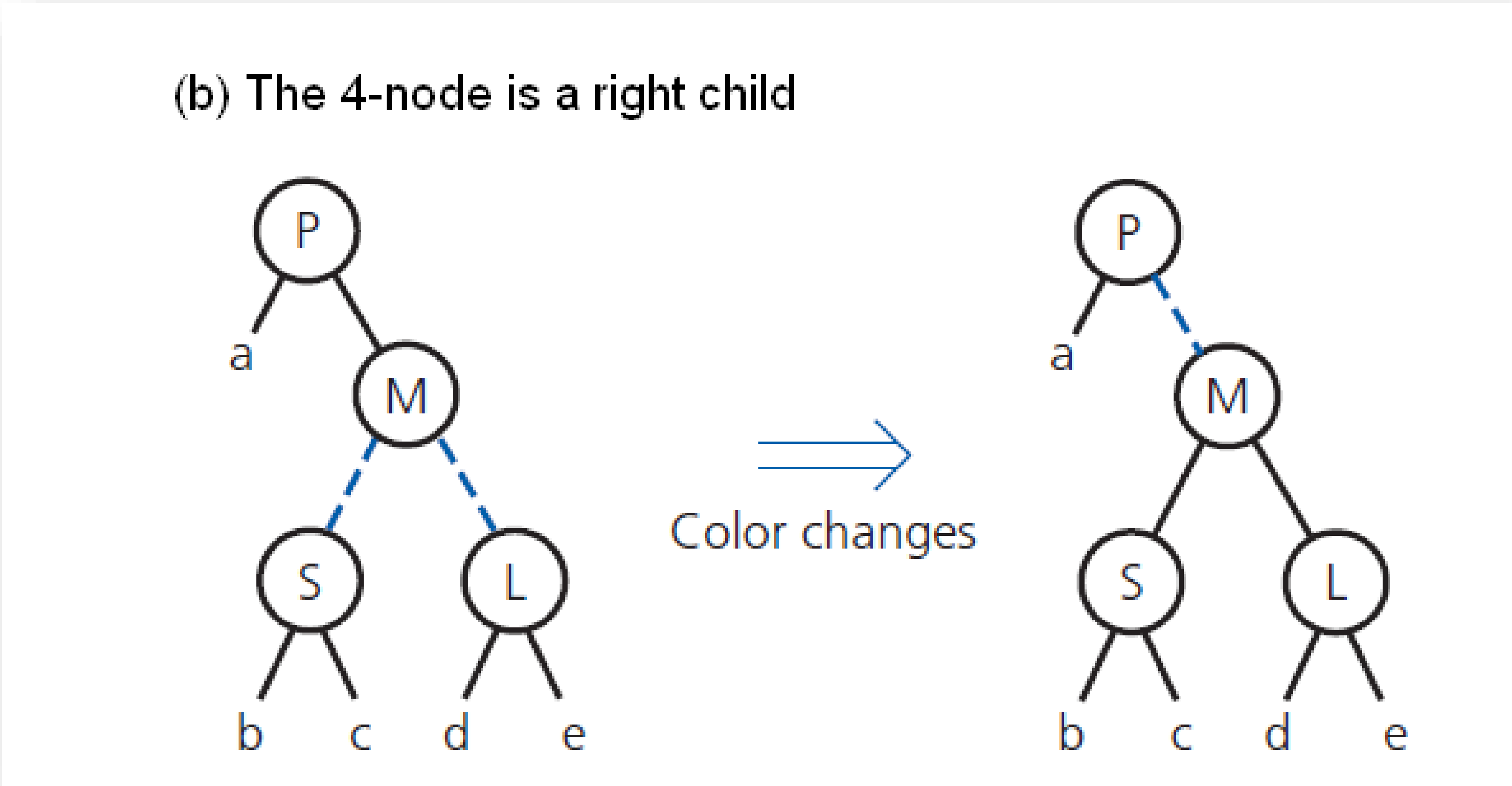
- Splitting a red-black representation of a 4-node root

Adding to and Removing from a Red-Black Tree



- Splitting a red-black representation of a 4-node whose parent is a 2-node

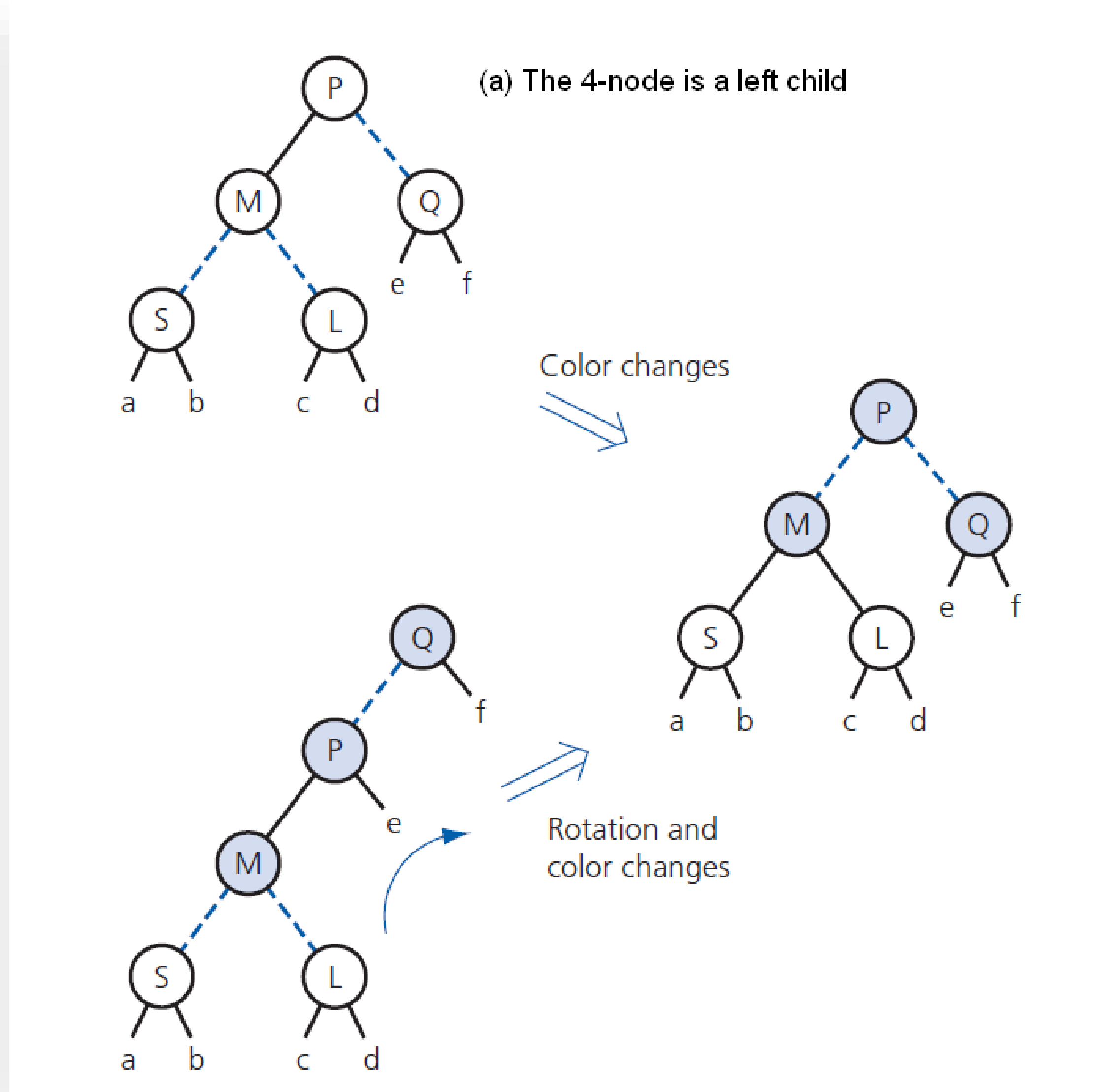
Adding to and Removing from a Red-Black Tree



- Splitting a red-black representation of a 4-node whose parent is a 2-node

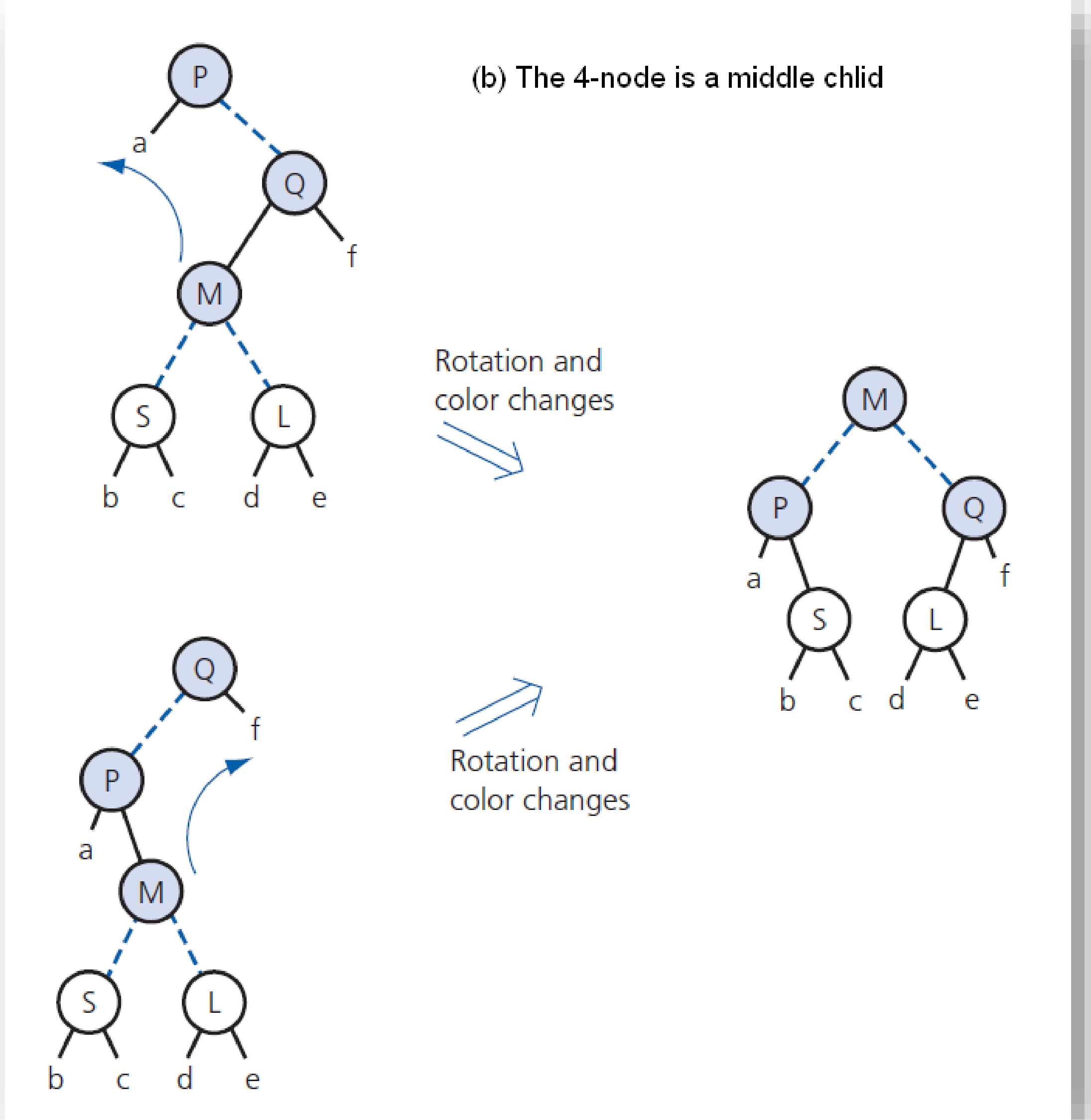
Adding to and Removing from a Red-Black Tree

- Splitting a red-black representation of a 4-node whose parent is a 3-node



Adding to and Removing from a Red-Black Tree

- Splitting a red-black representation of a 4-node whose parent is a 3-node



Adding to and Removing from a Red-Black Tree

- Splitting a red-black representation of a 4-node whose parent is a 3-node