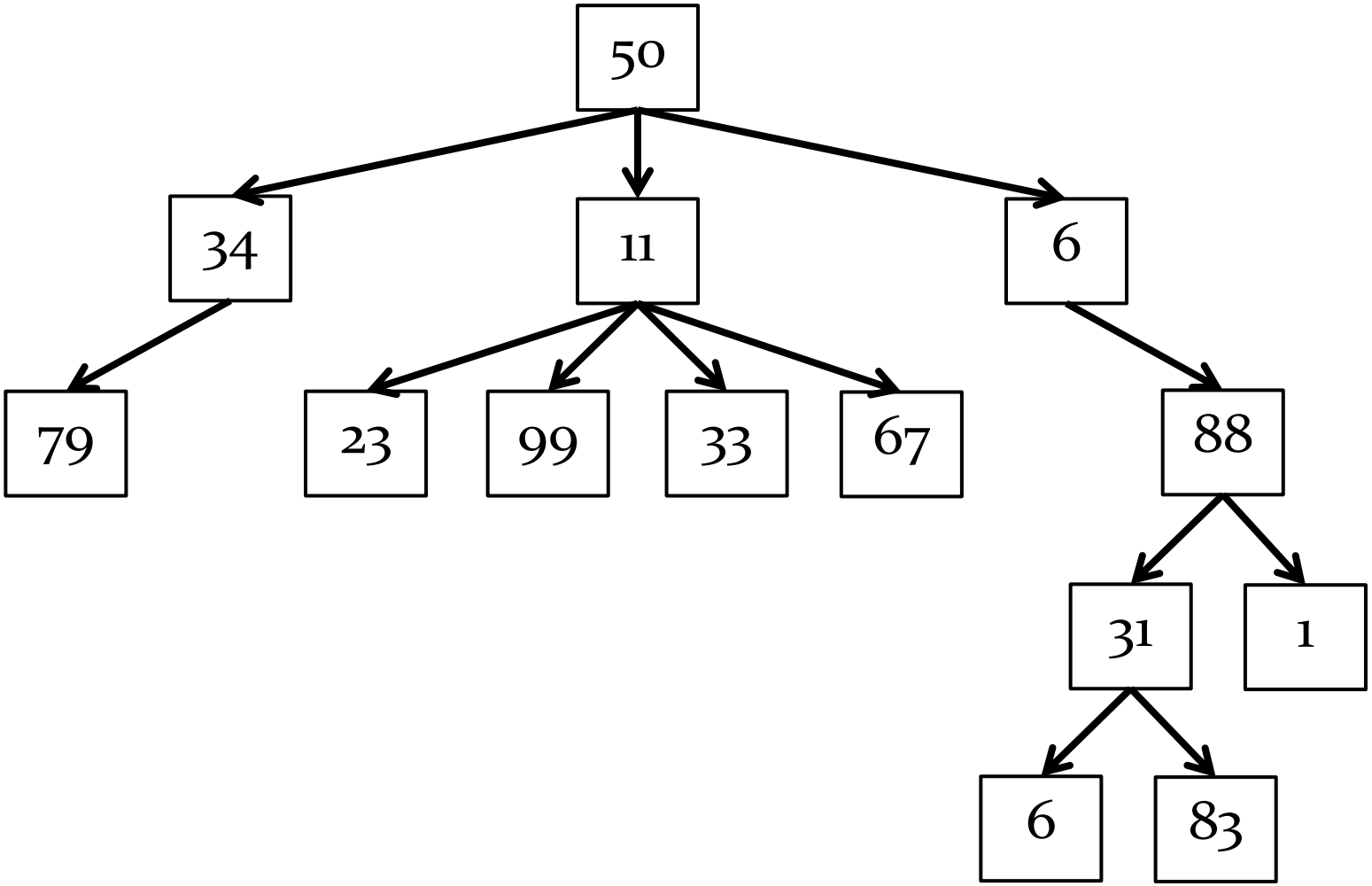
Trees

Graphs

- a graph is a data structure made up of nodes
  - each node stores data
  - each node has links to zero or more nodes
    - in graph theory the links are normally called *edges*
- graphs occur frequently in a wide variety of real-world problems
  - social network analysis
    - e.g., six-degrees-of-Kevin-Bacon, Facebook Friend Wheel
  - transportation networks
    - e.g., http://ac.fltmaps.com/en
  - many other examples
    - http://www.visualcomplexity.com/vc/

Trees

- trees are special cases of graphs
- a tree is a data structure made up of nodes
  - each node stores data
  - each node has links to zero or more nodes in the next level of the tree
    - children of the node
  - each node has exactly one parent node
    - except for the root node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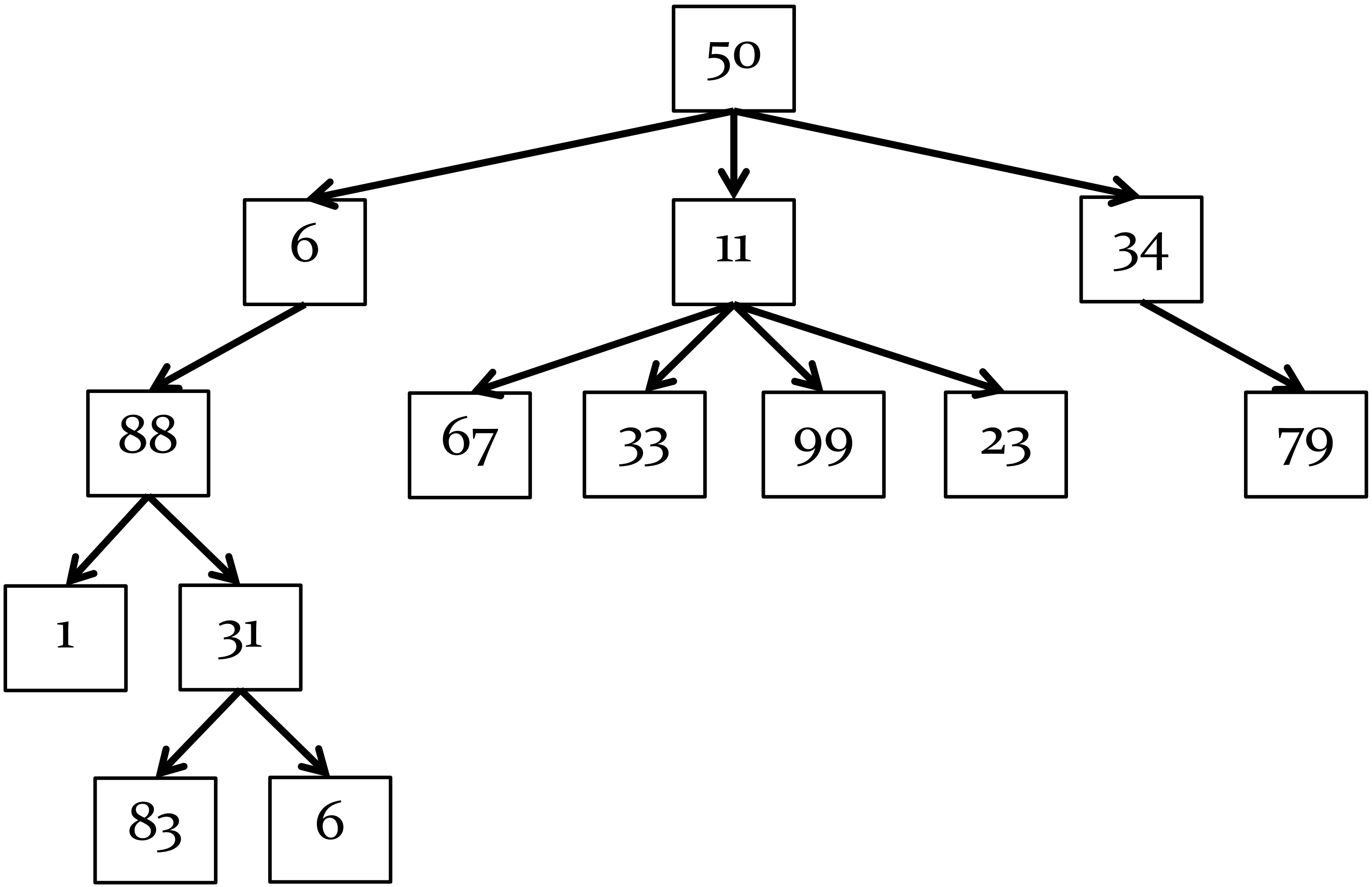
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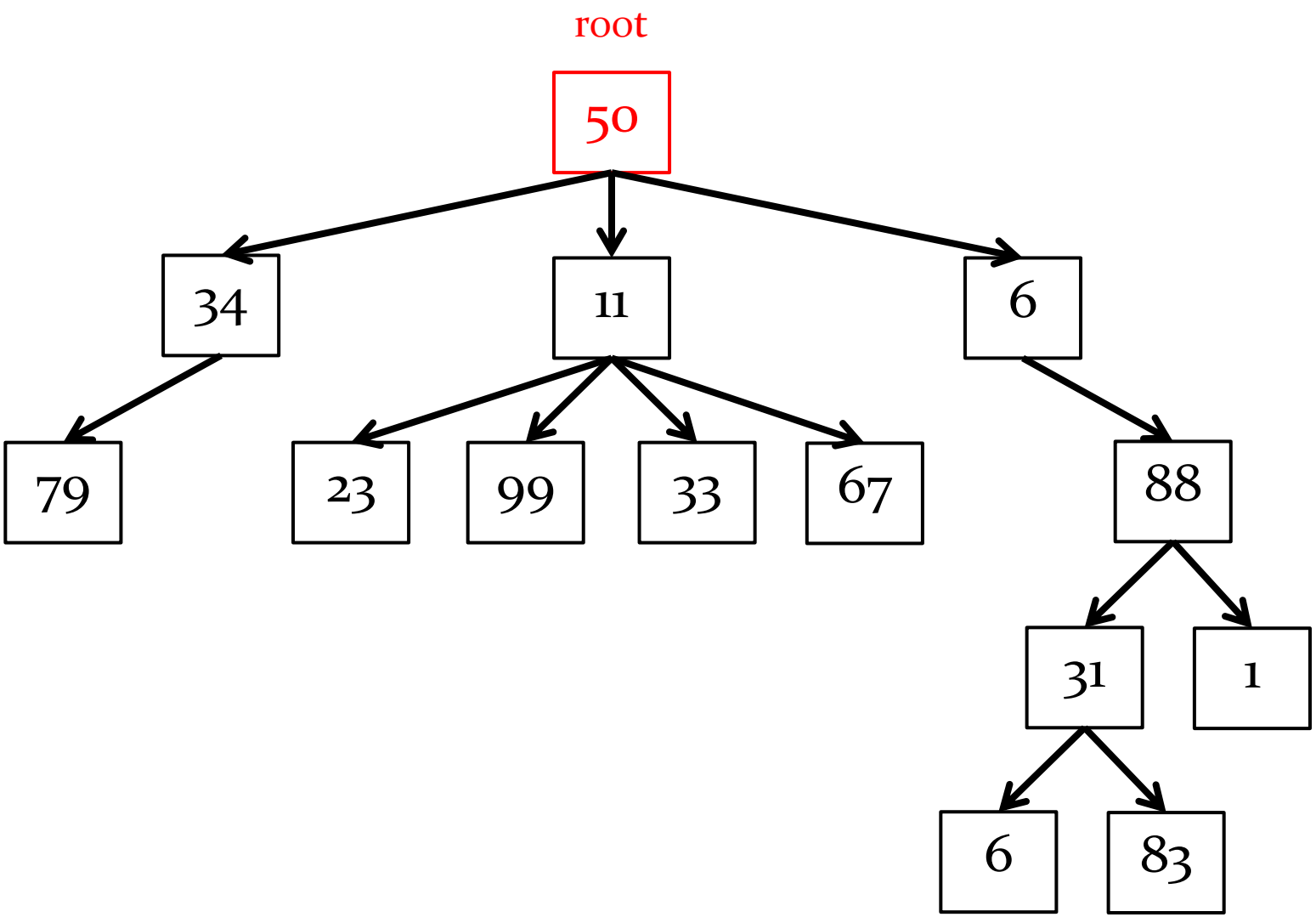
Trees

- the root of the tree is the node that has no parent node
- all algorithms start at the root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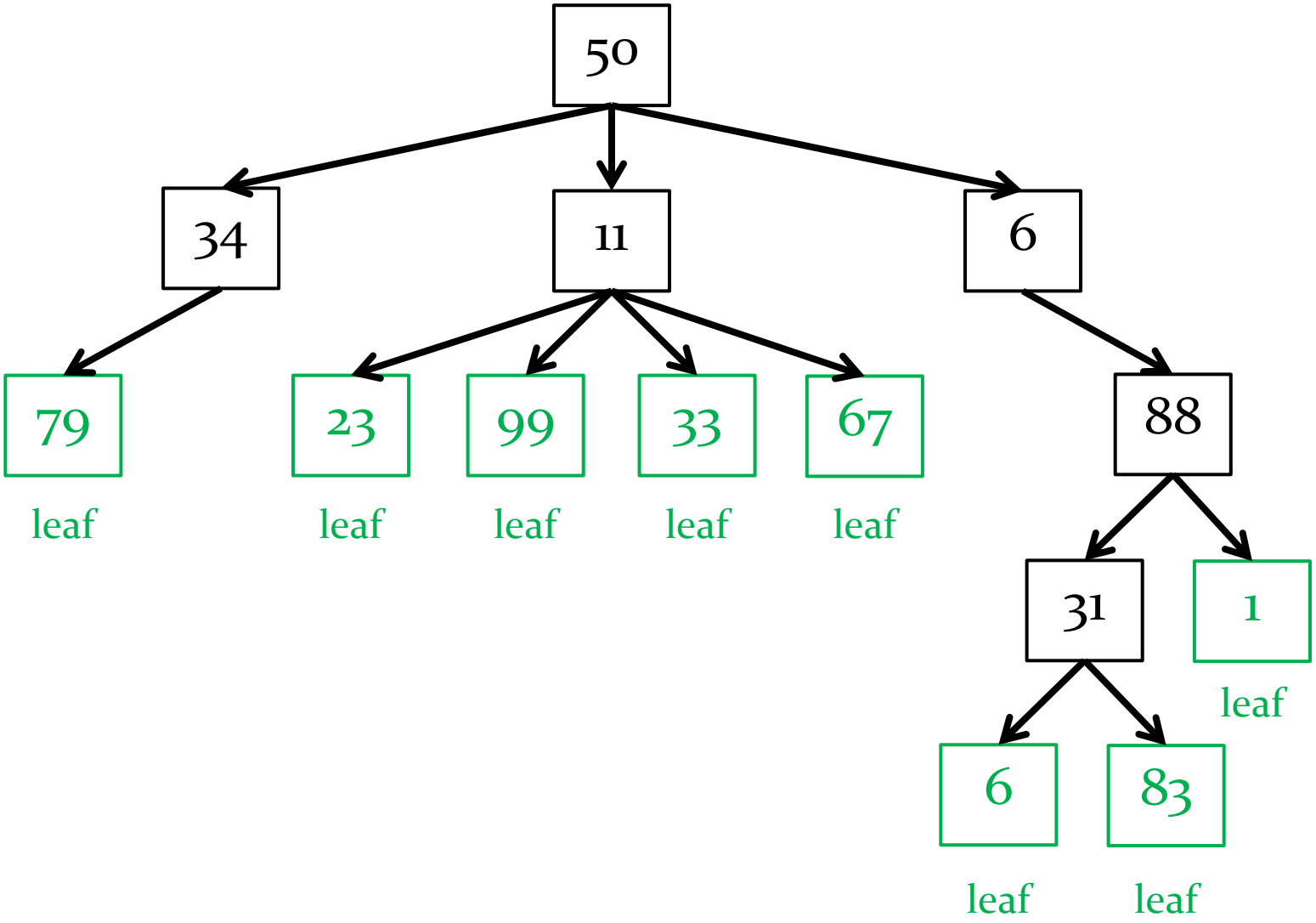
Trees

- a node without any children is called a leaf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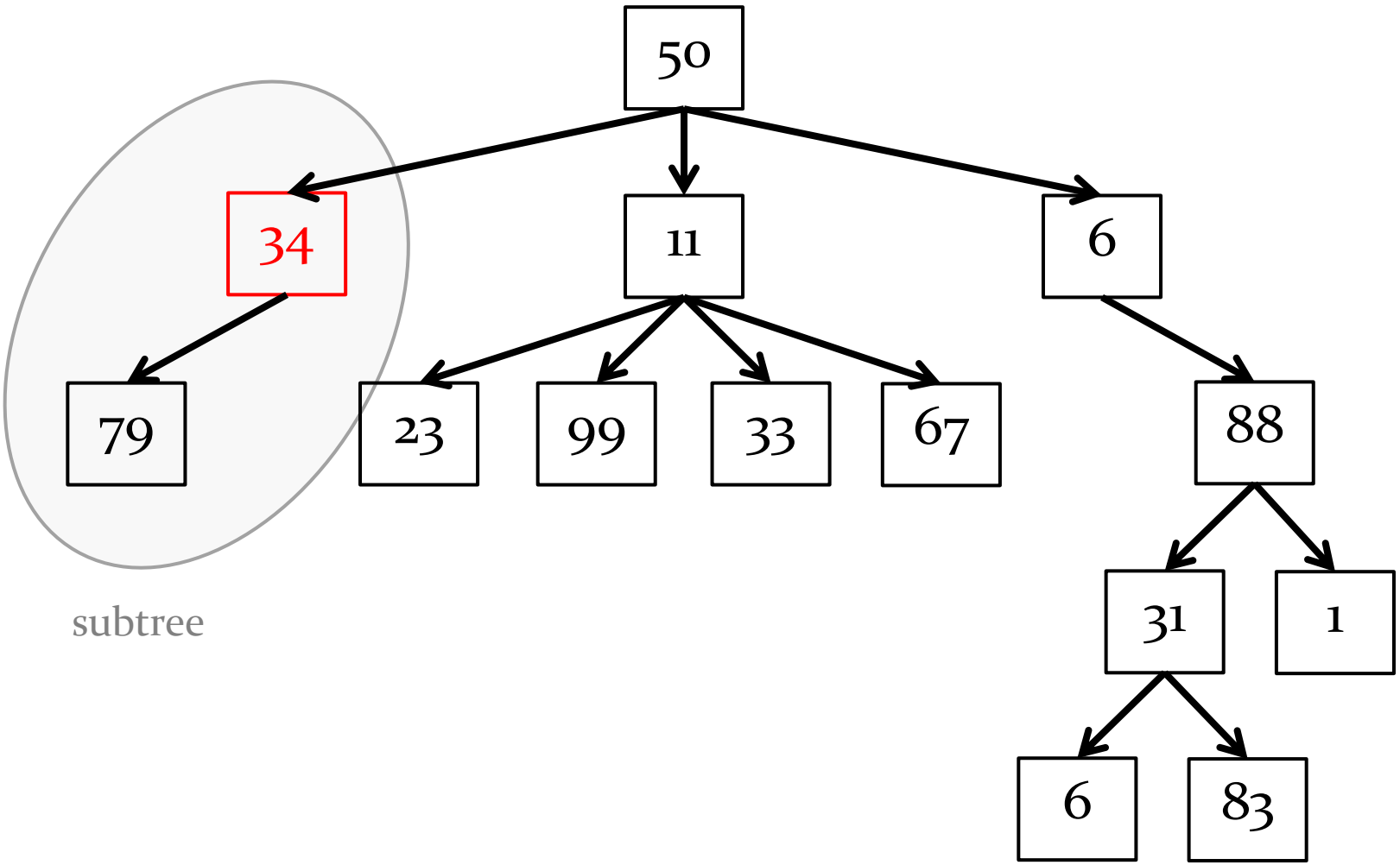
leaf

Trees

- the recursive structure of a tree means that every node is the root of a tree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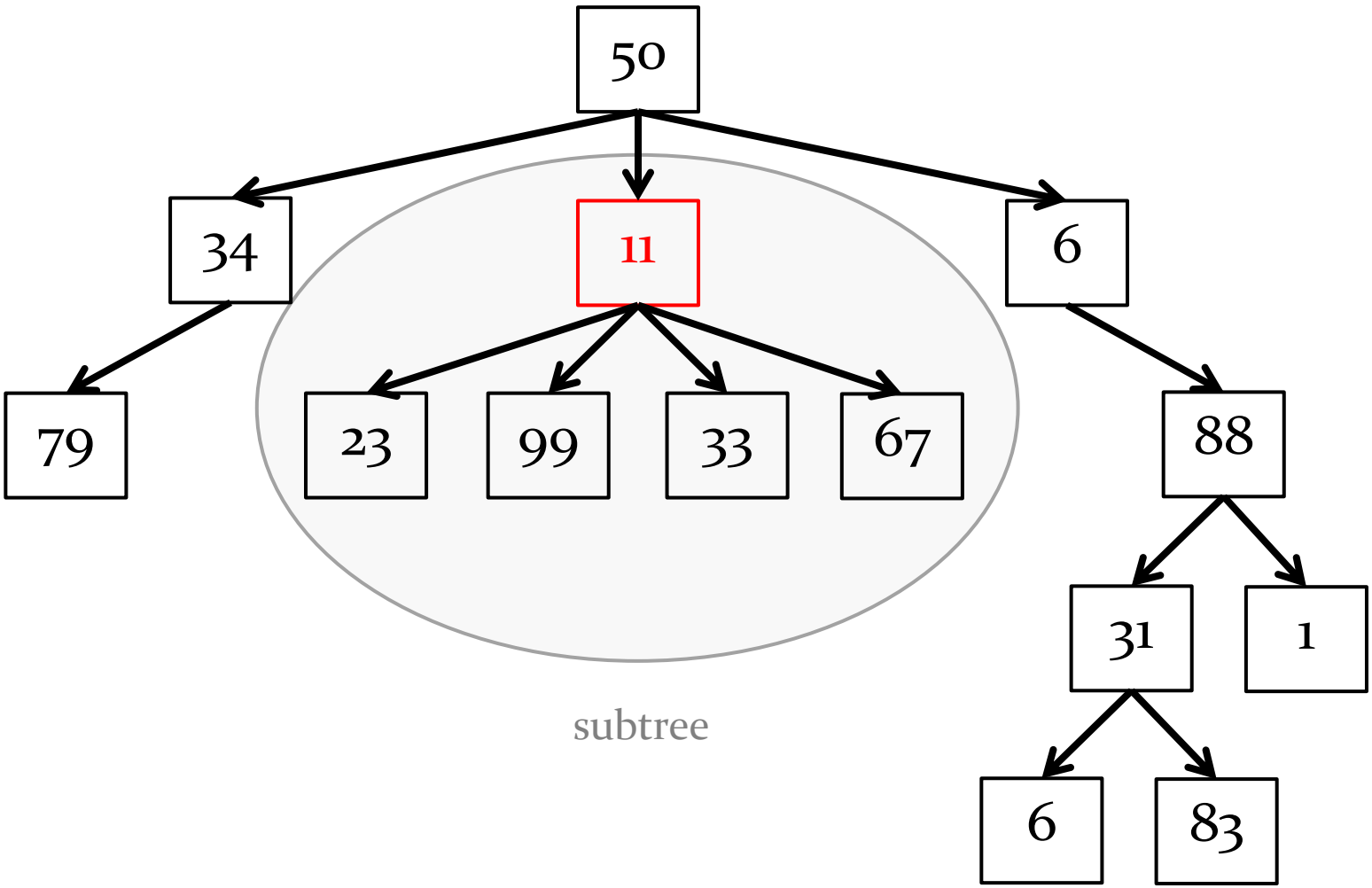
subtree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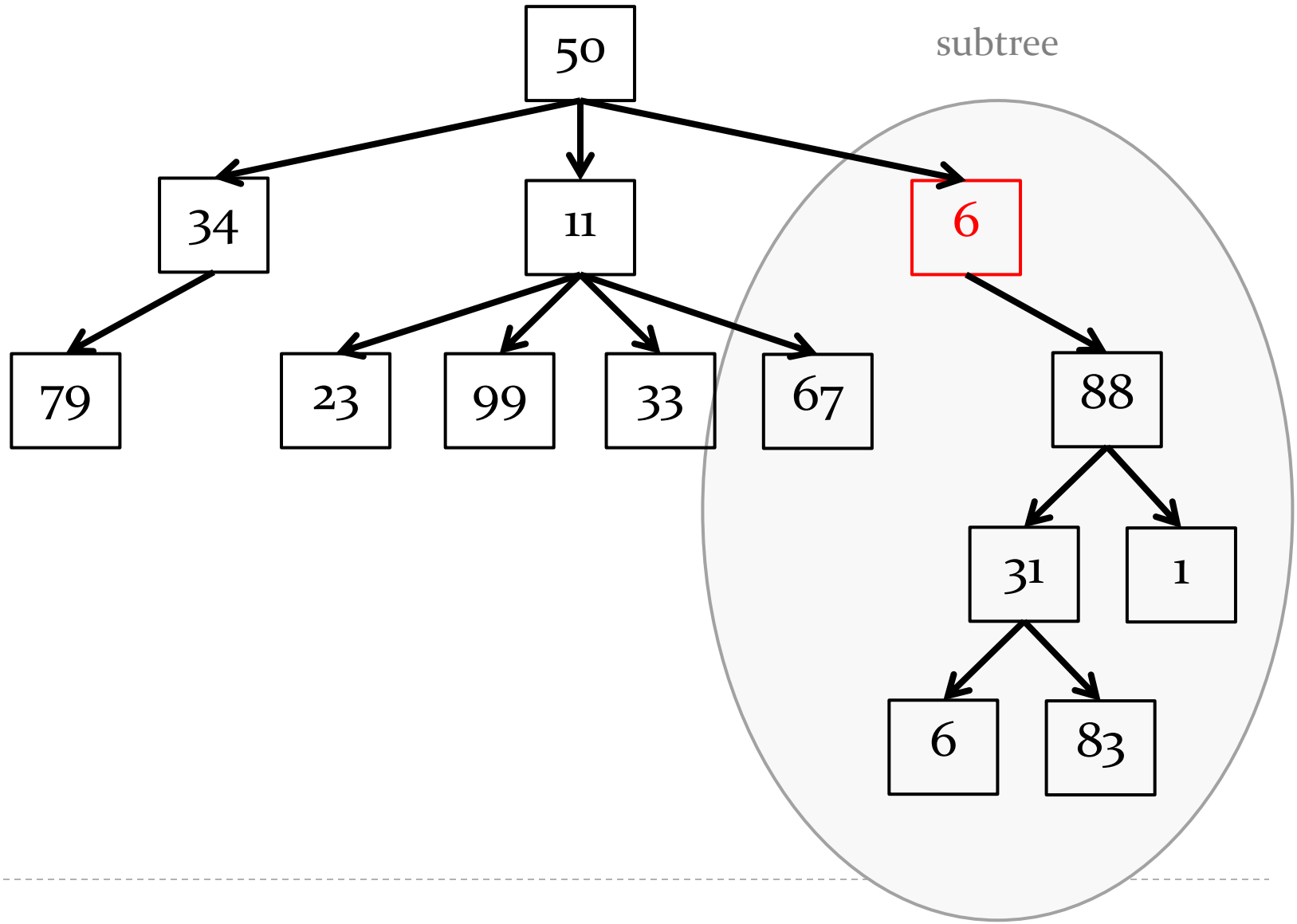
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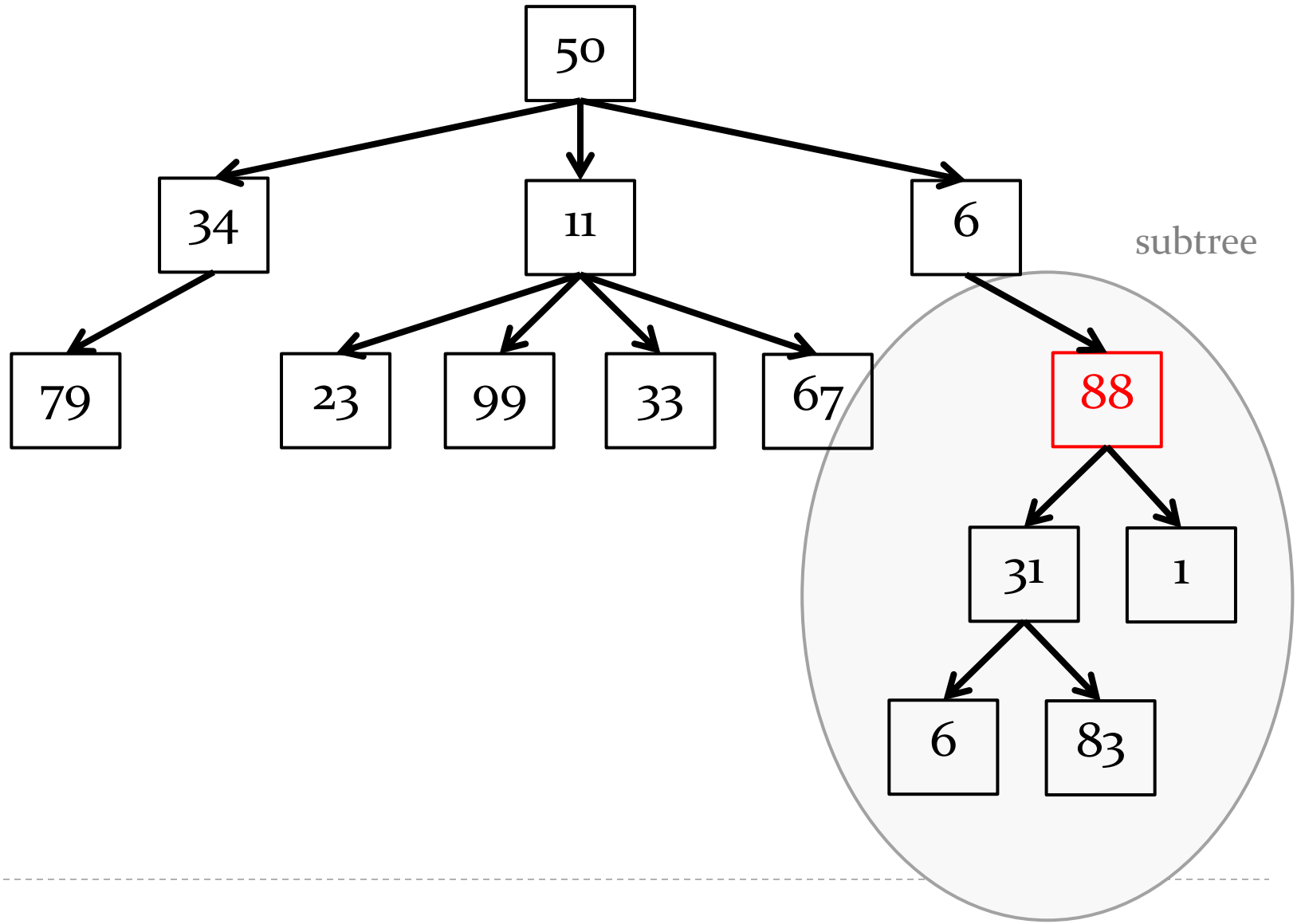
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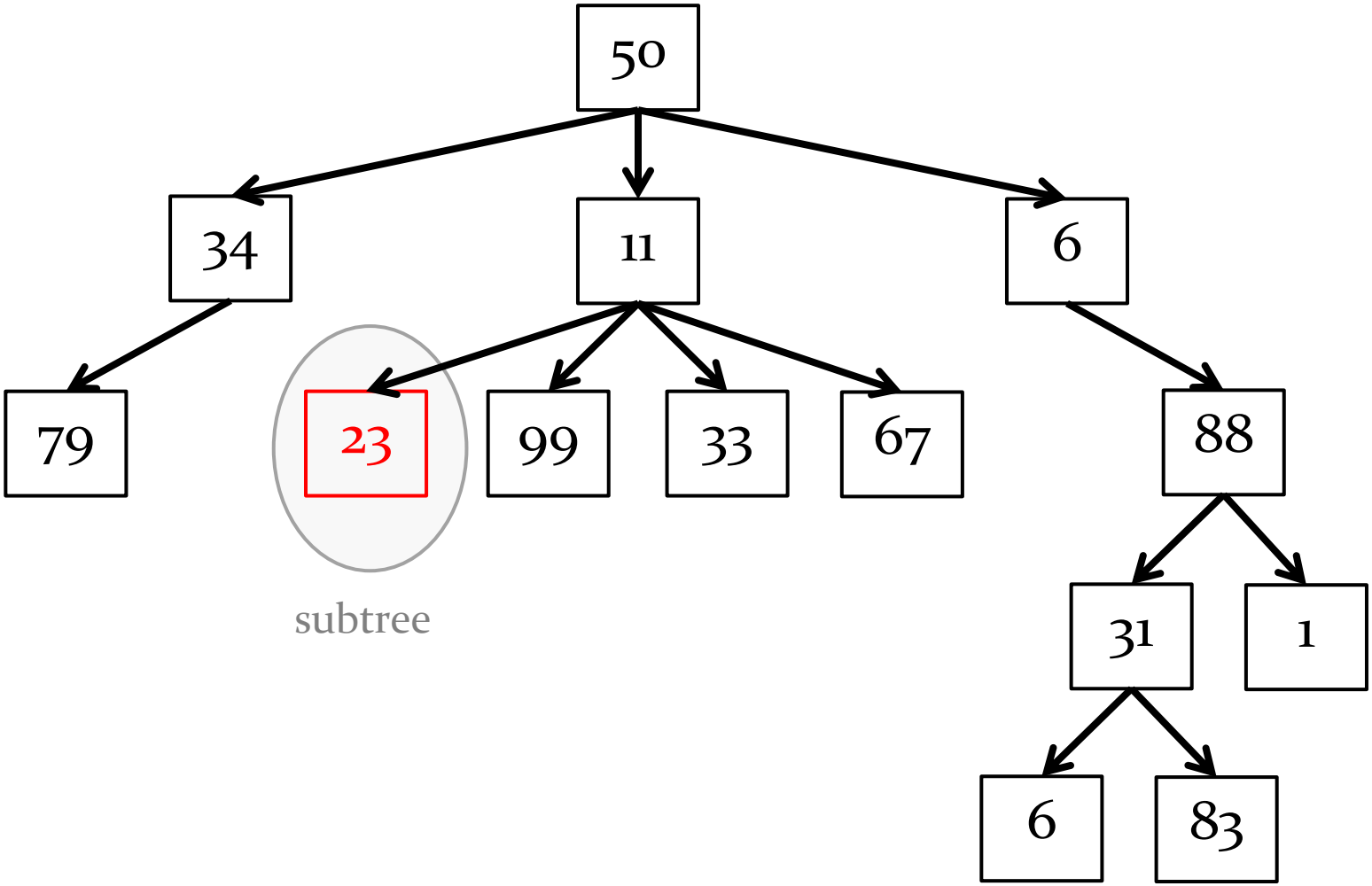
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subtree
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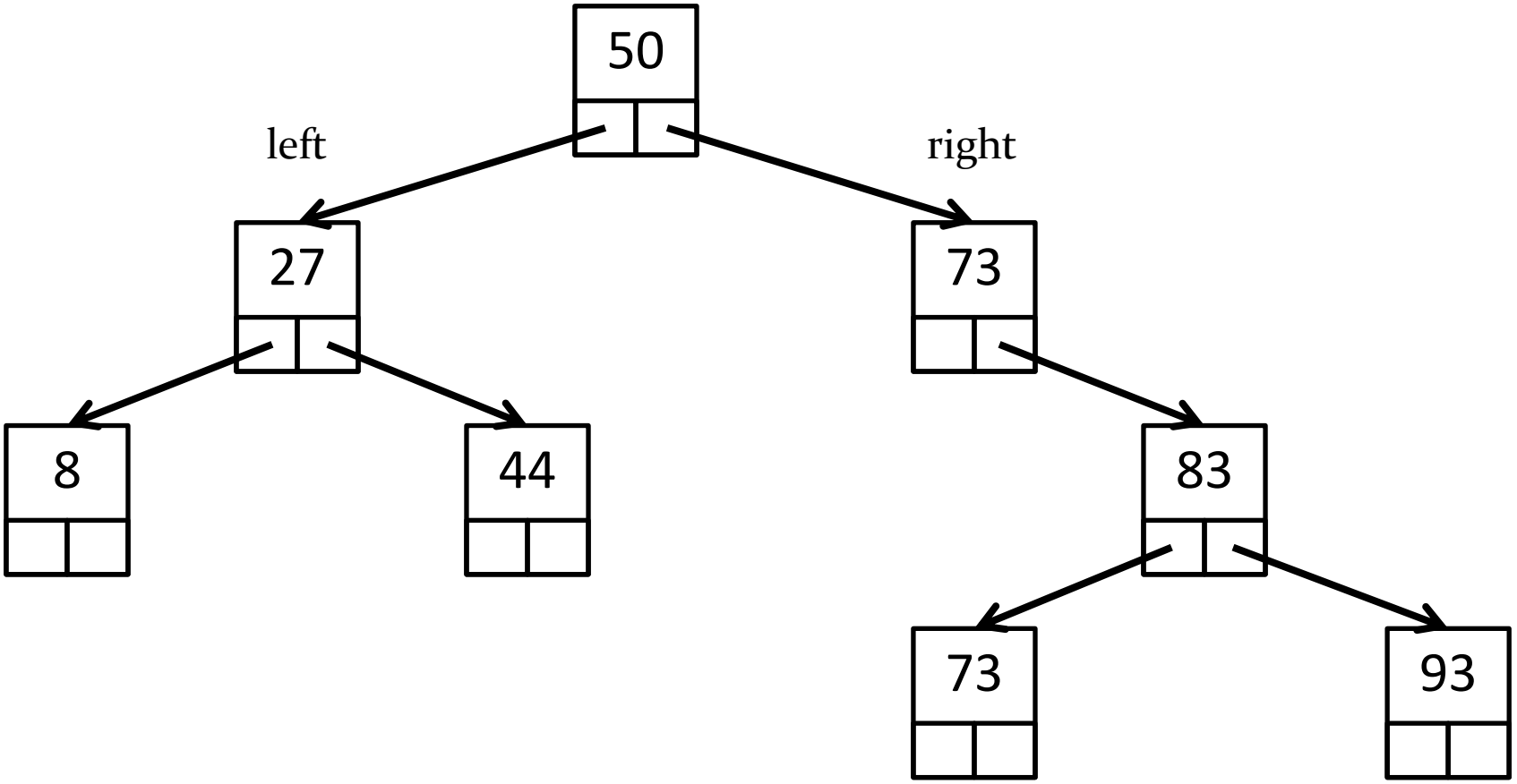
83

Binary Tree

- a binary tree is a tree where each node has at most two children
  - very common in computer science
  - many variations
- traditionally, the children nodes are called the left node and the right node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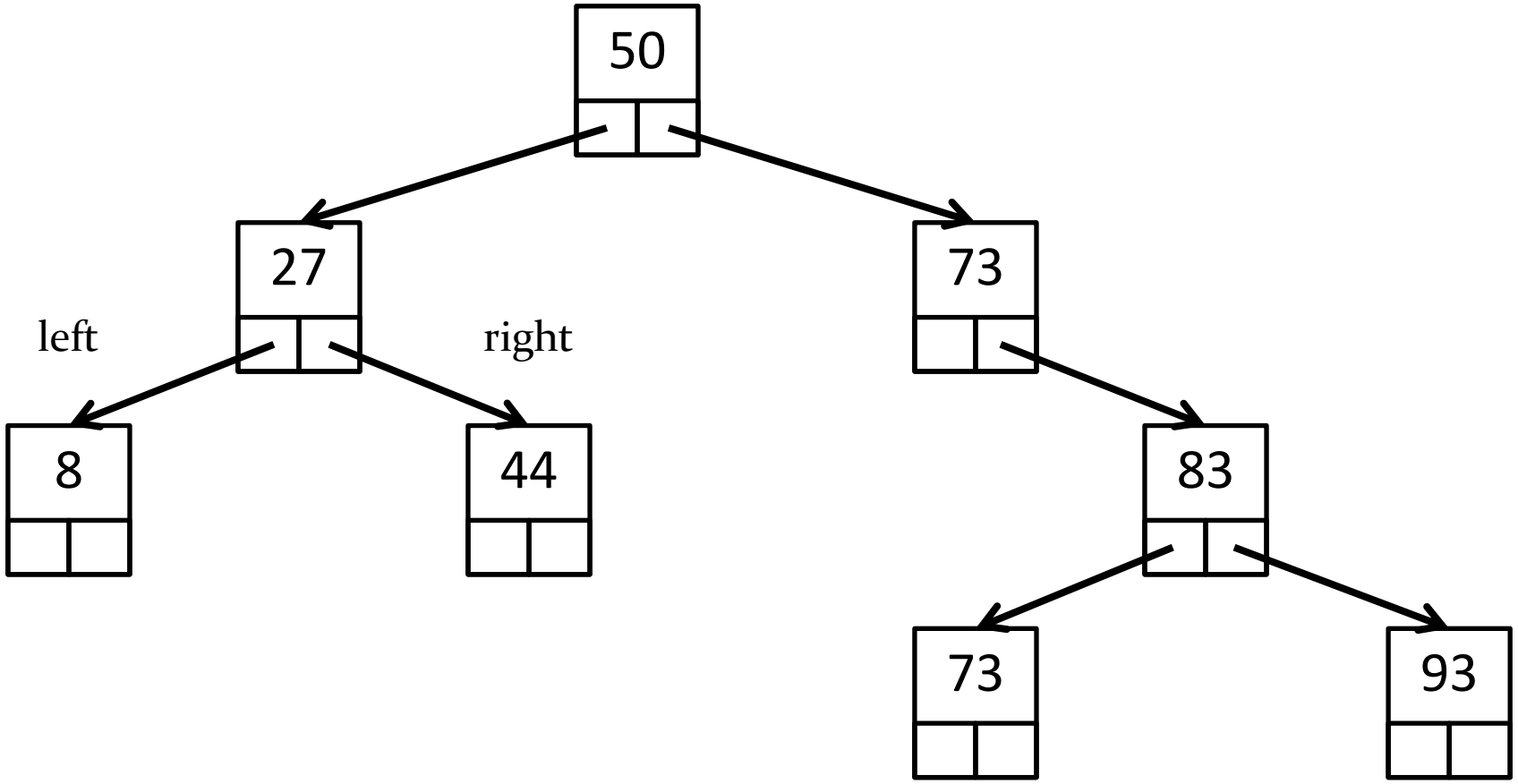
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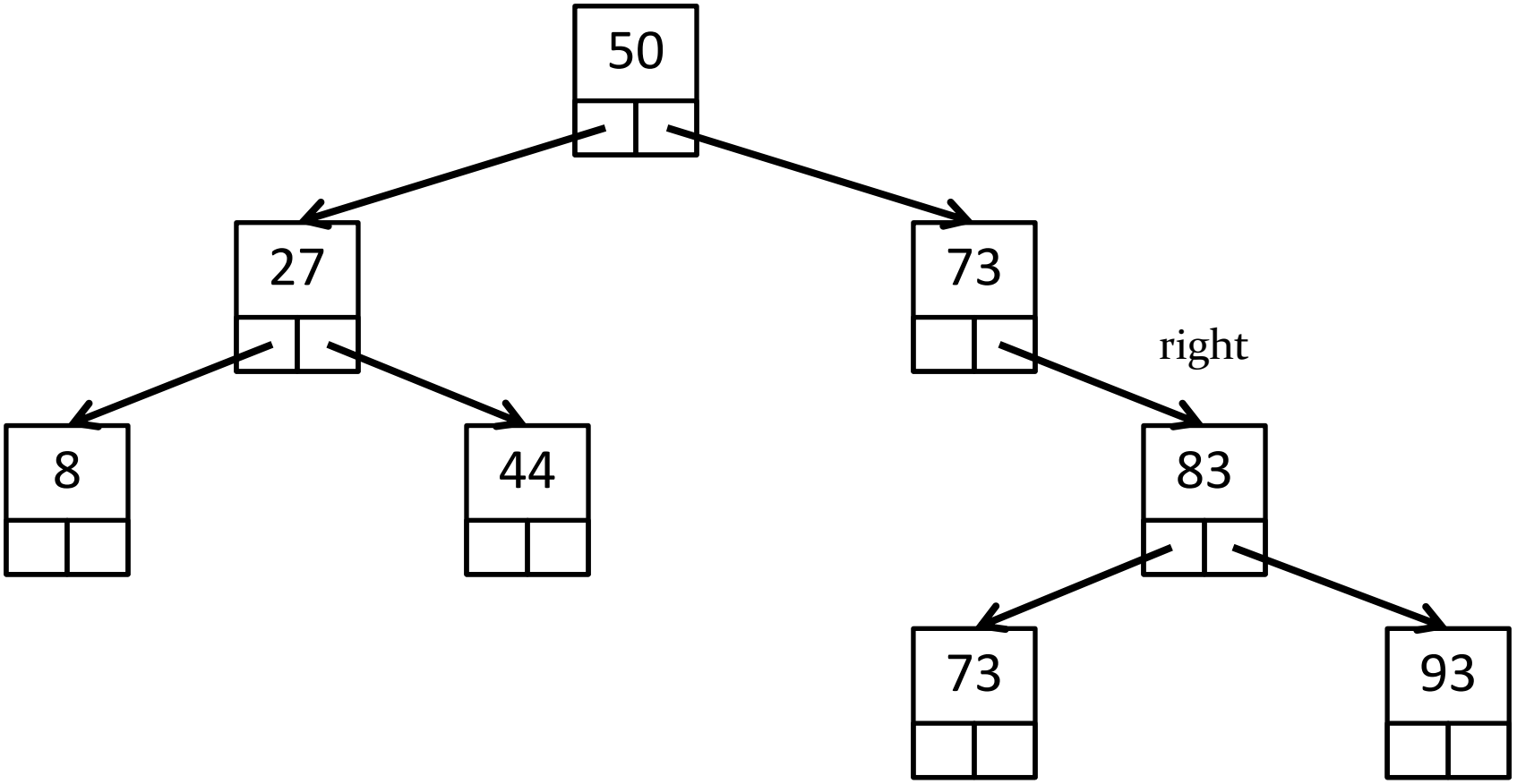
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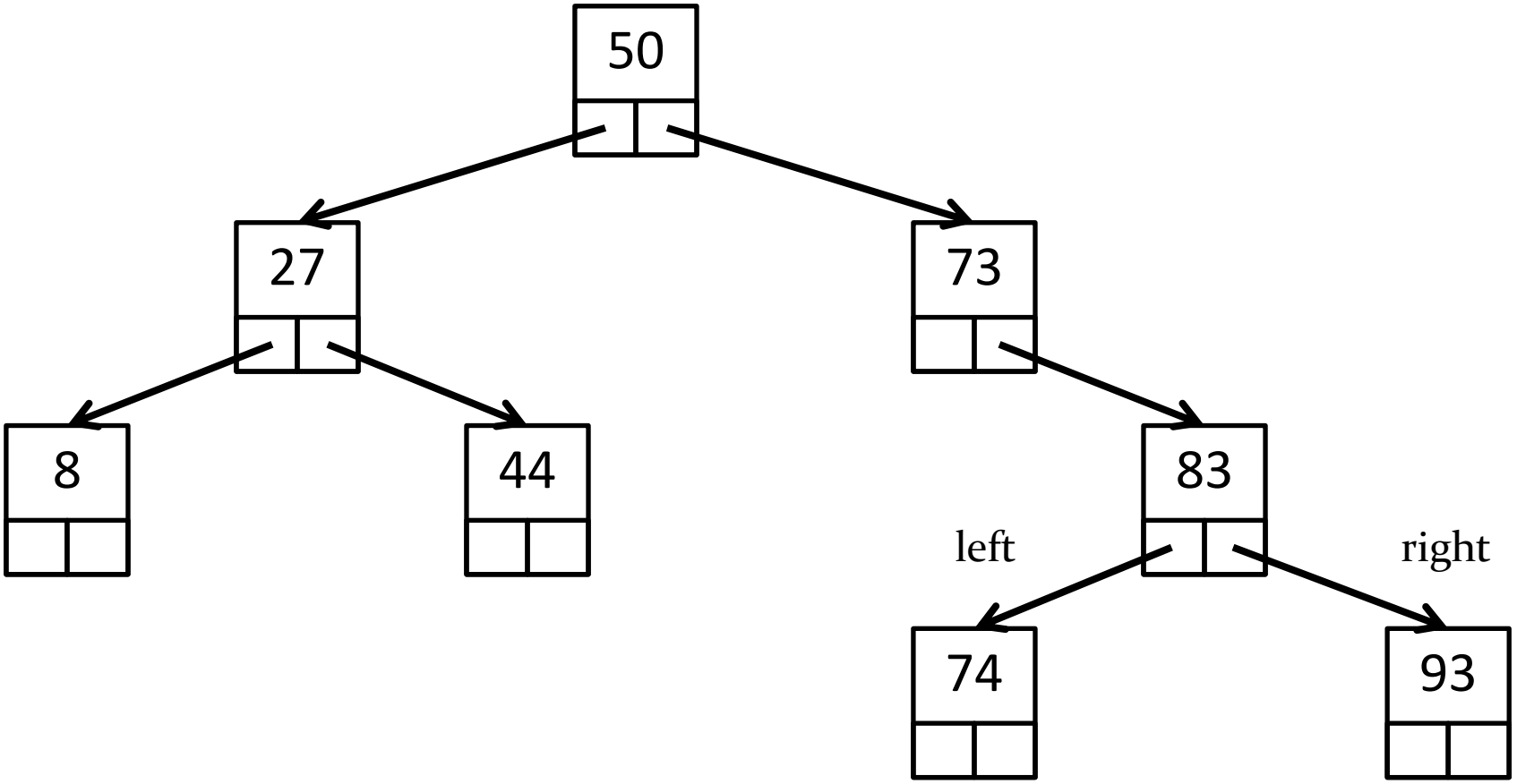
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left
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Binary Tree Algorithms

- the recursive structure of trees leads naturally to recursive algorithms that operate on trees
- for example, suppose that you want to search a binary tree for a particular element

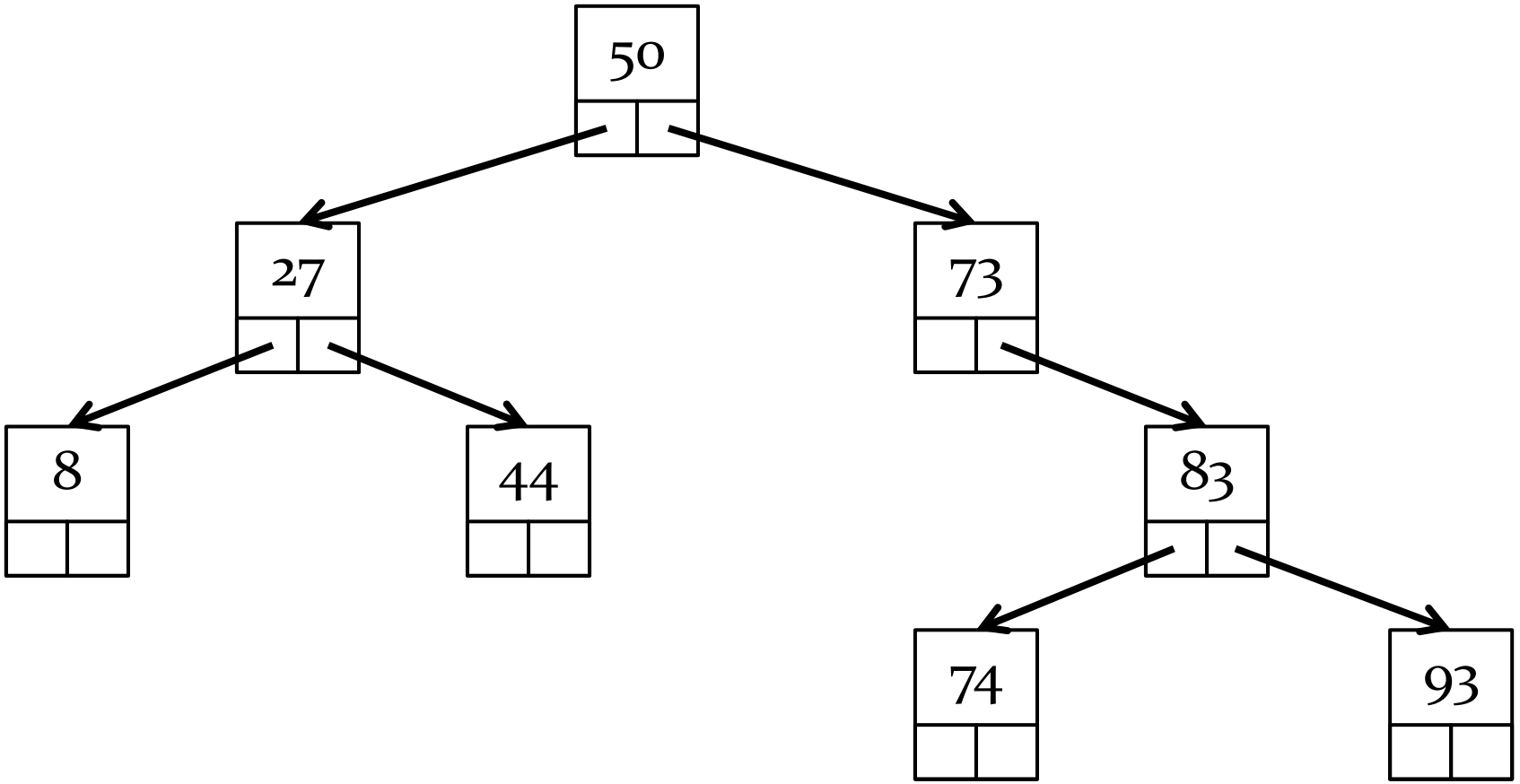
```
public static <E> boolean contains(E element, Node<E> node) {
  if (node == null) {
    return false;
  }
  if (element.equals(node.data)) {
    return true;
  }
  boolean inLeftTree = contains(element, node.left);
  if (inLeftTree) {
    return true;
  }
  boolean inRightTree = contains(element, node.right);
  return inRightTree;
}
```

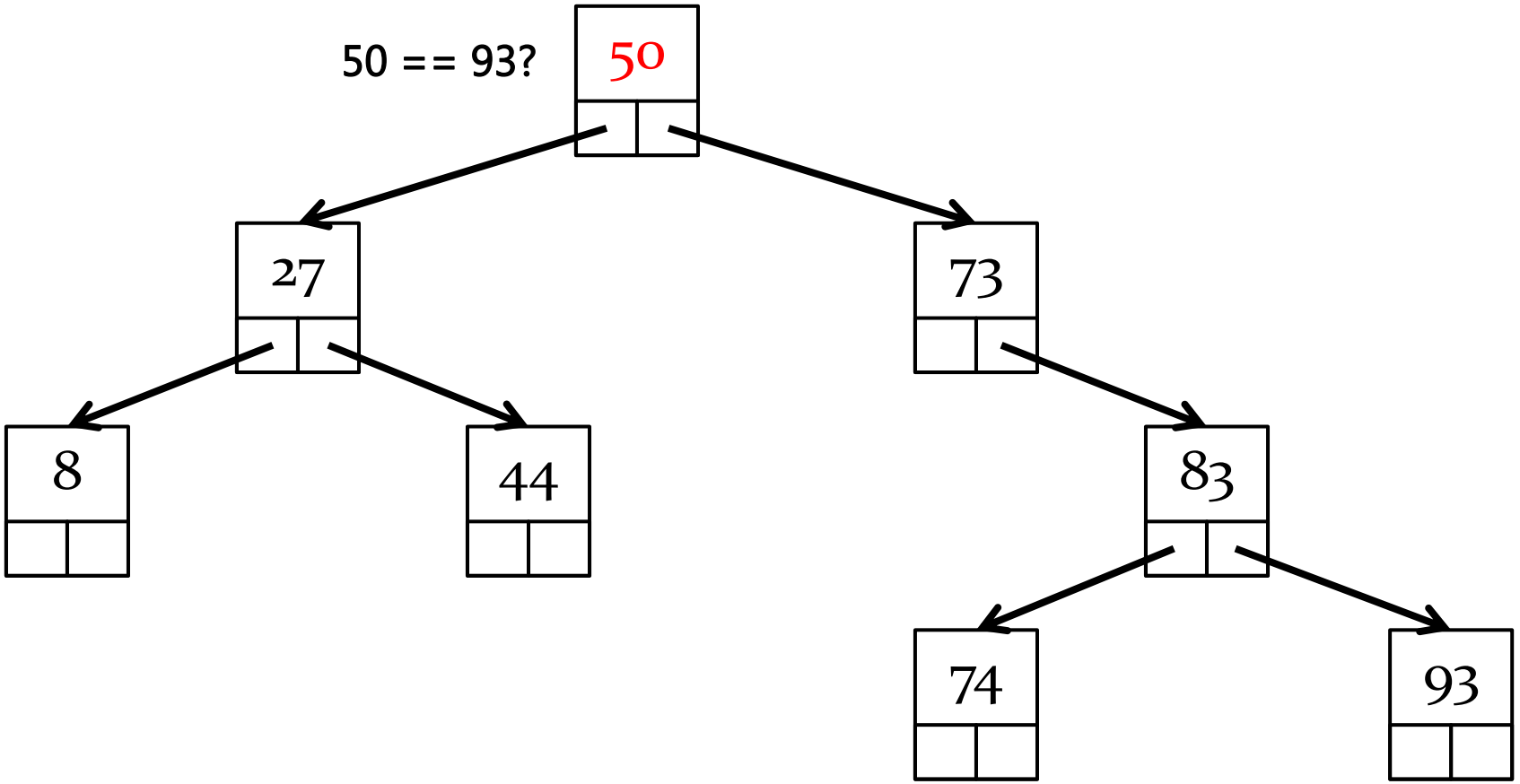
examine root

examine left subtree

examine right subtree

t.contains(93)




50 == 93?
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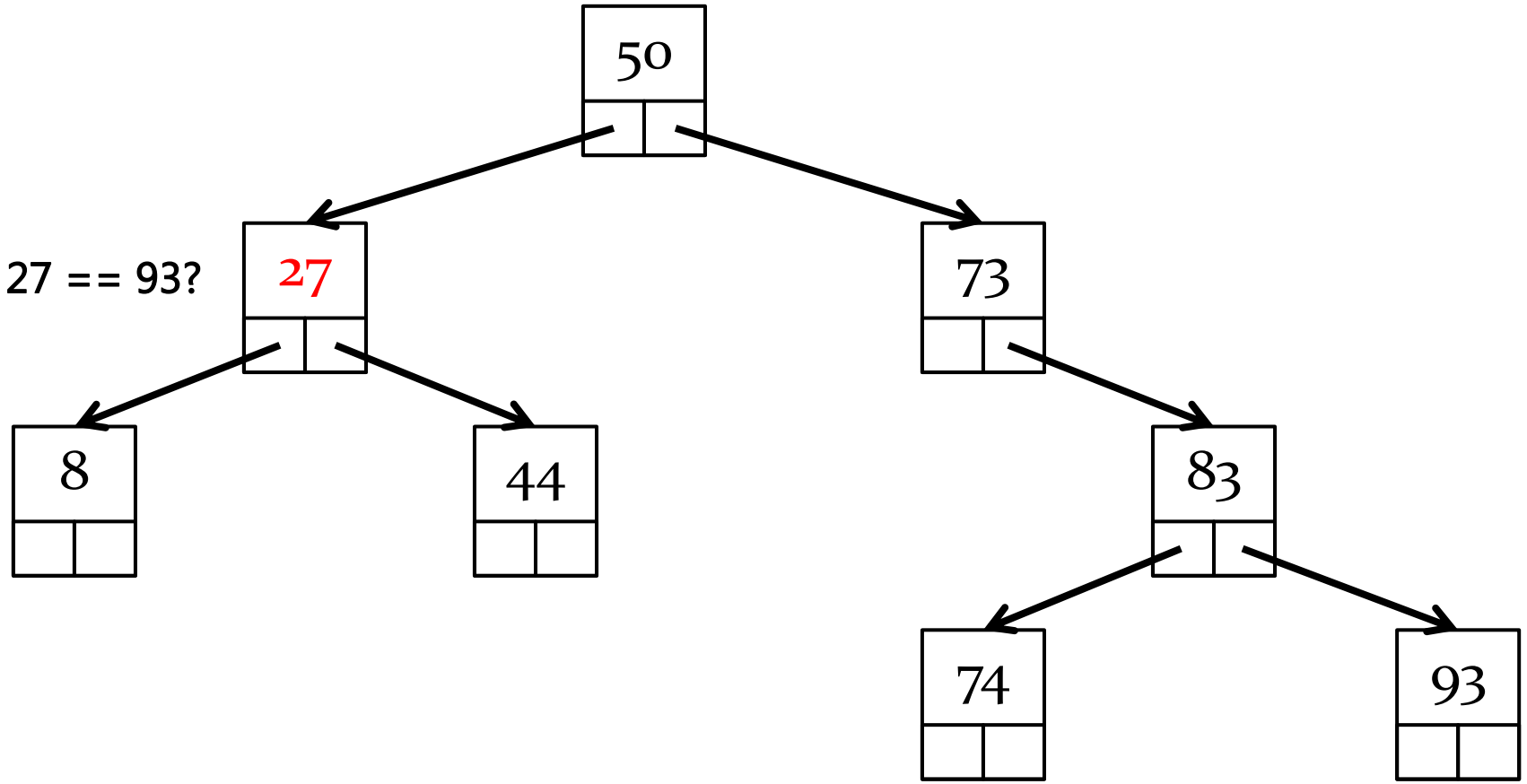
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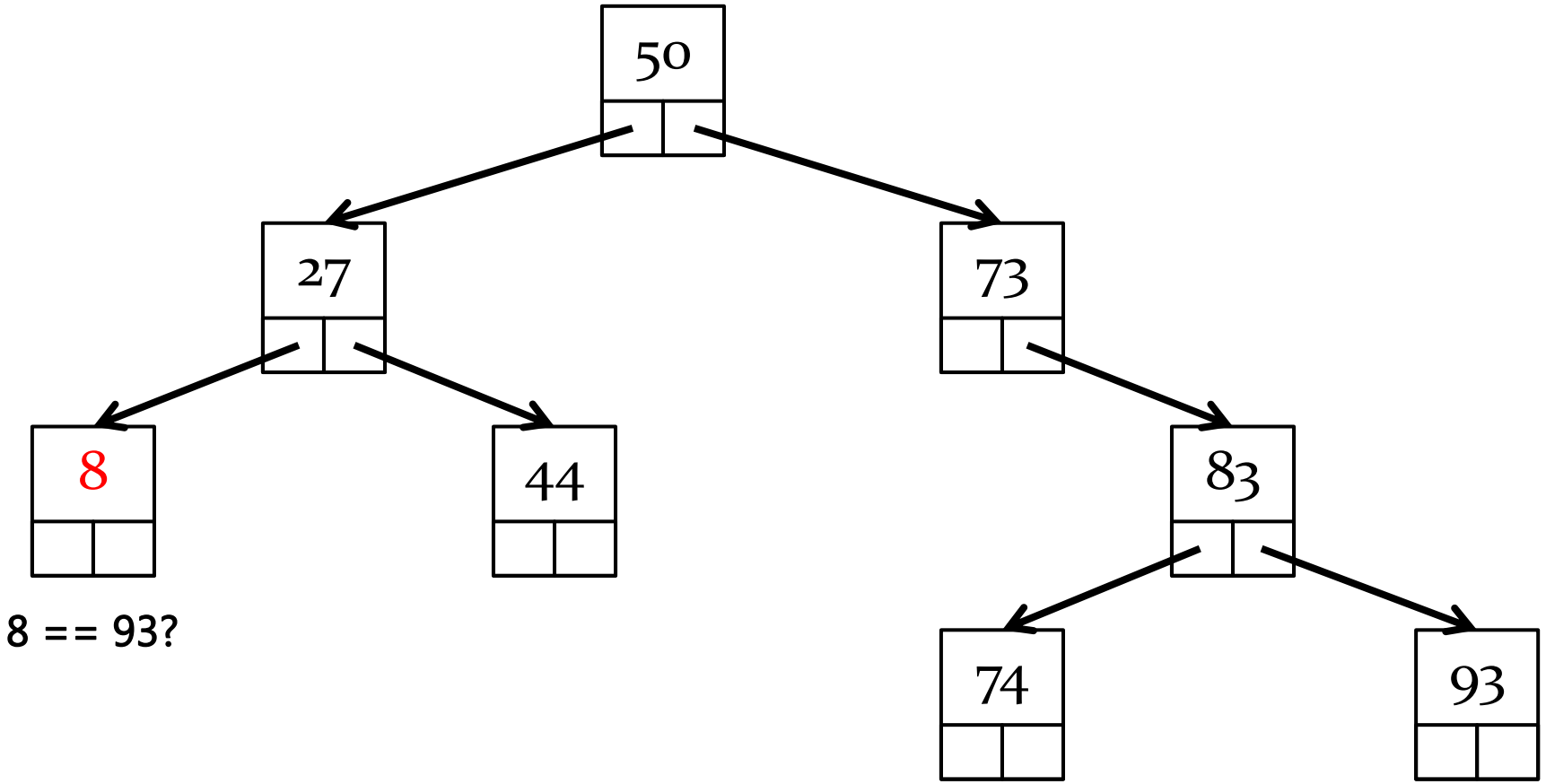
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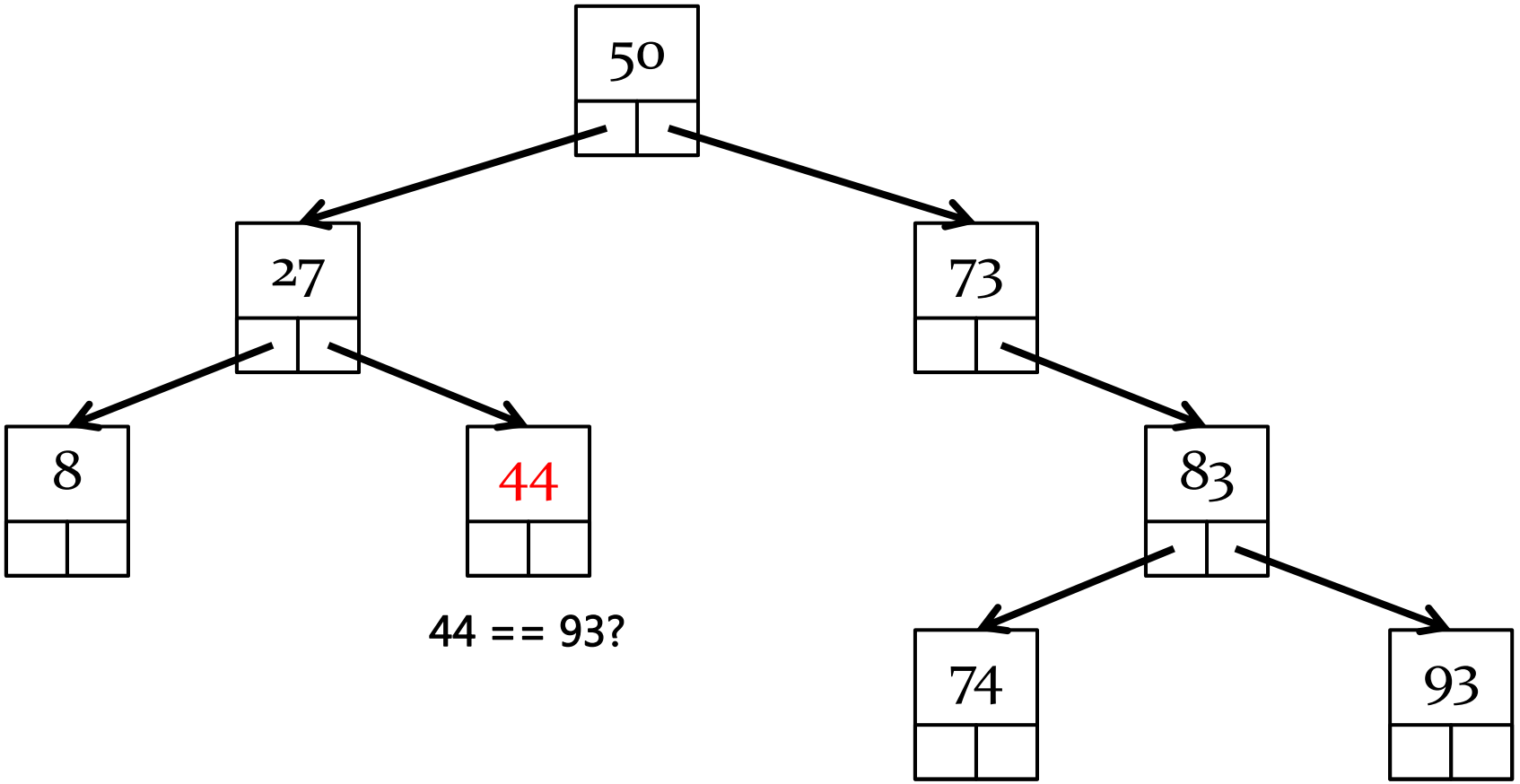
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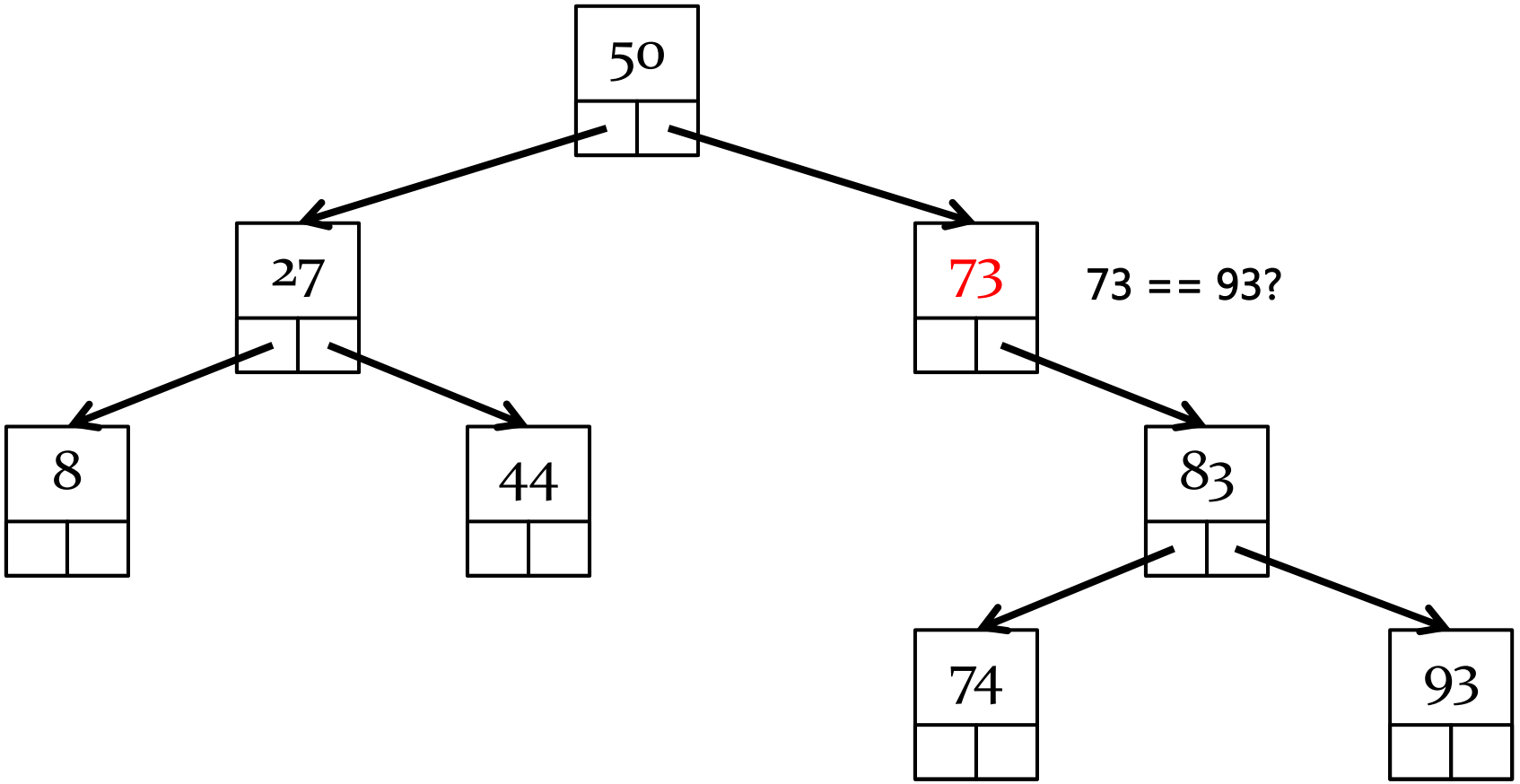
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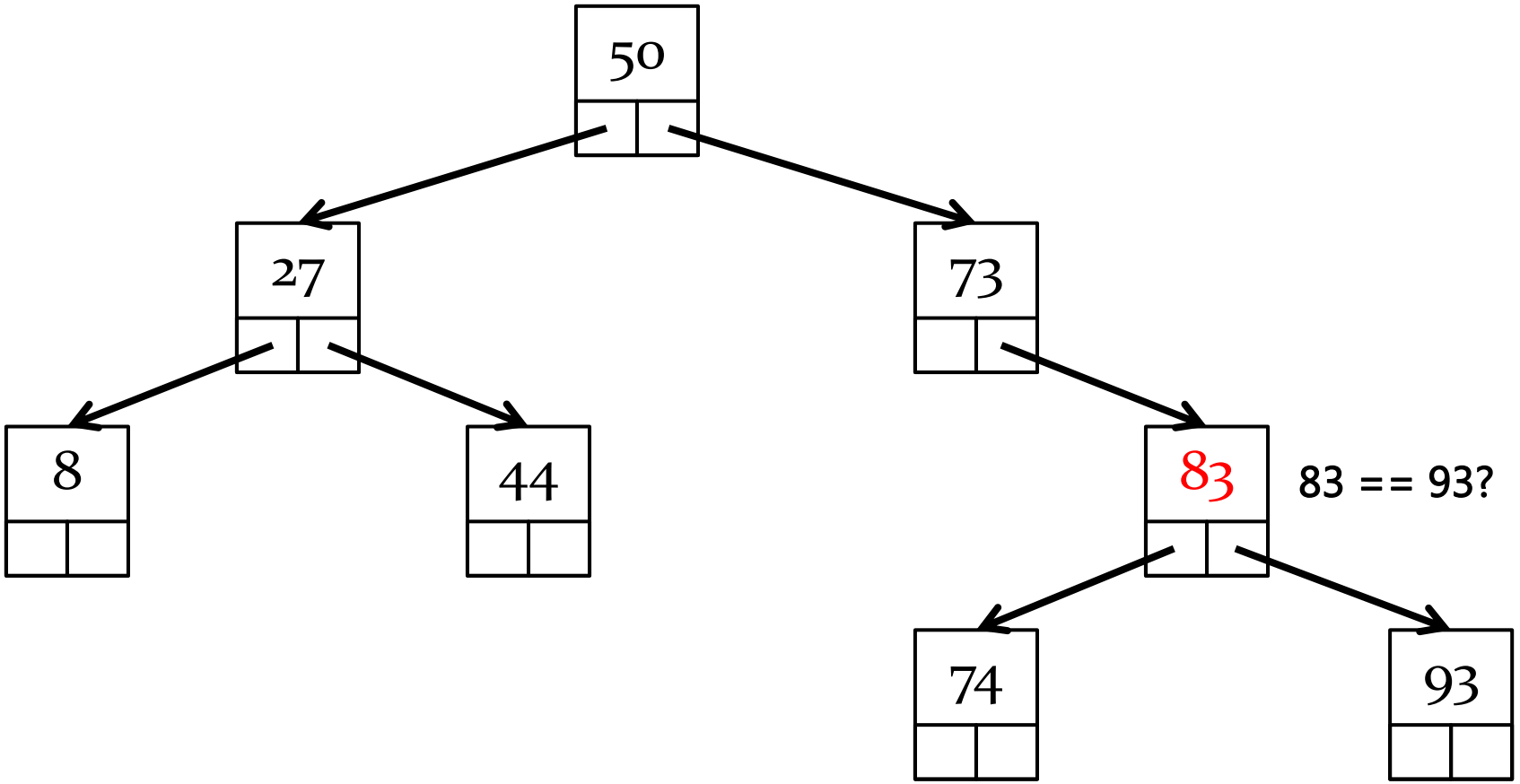
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83 == 93?
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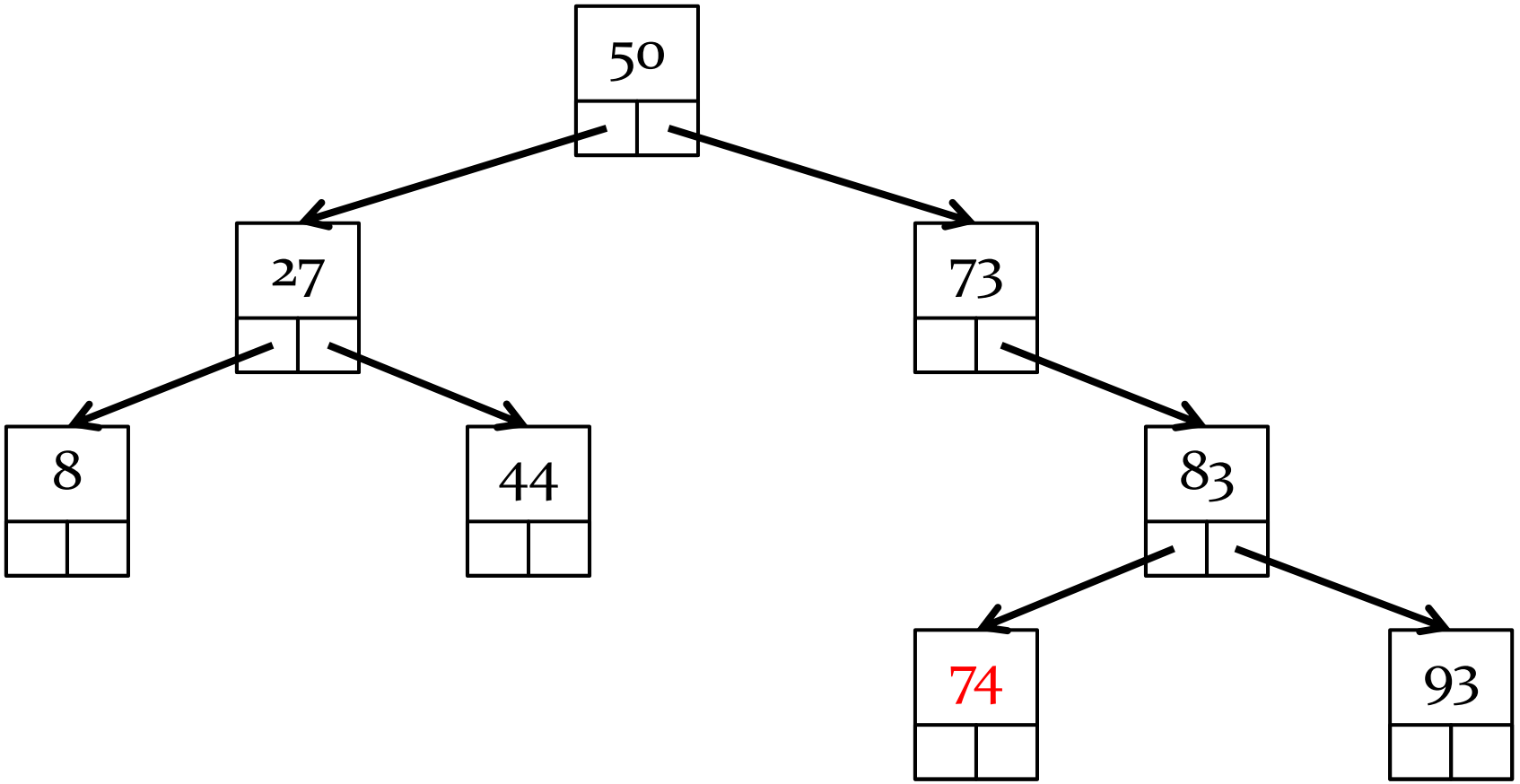
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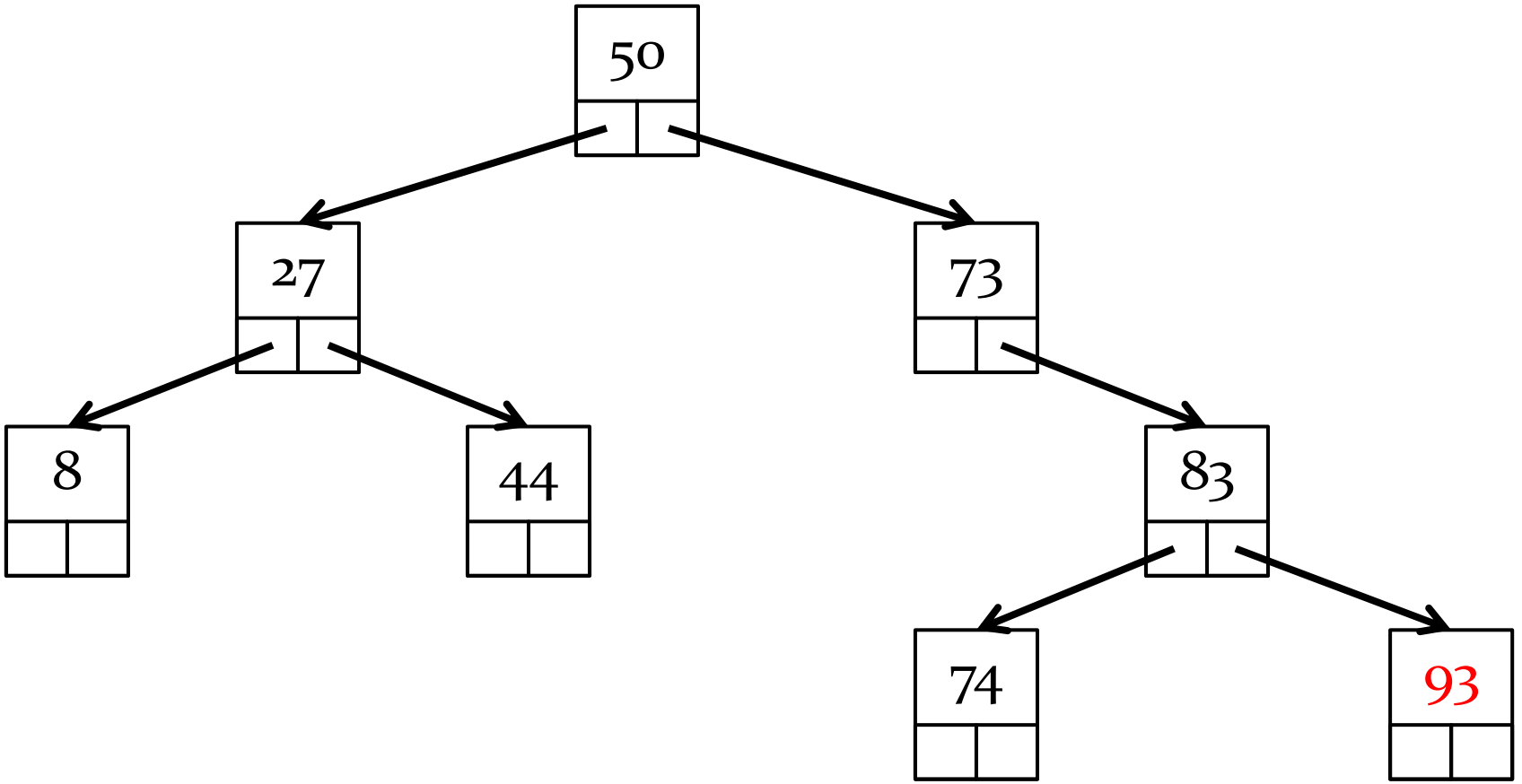
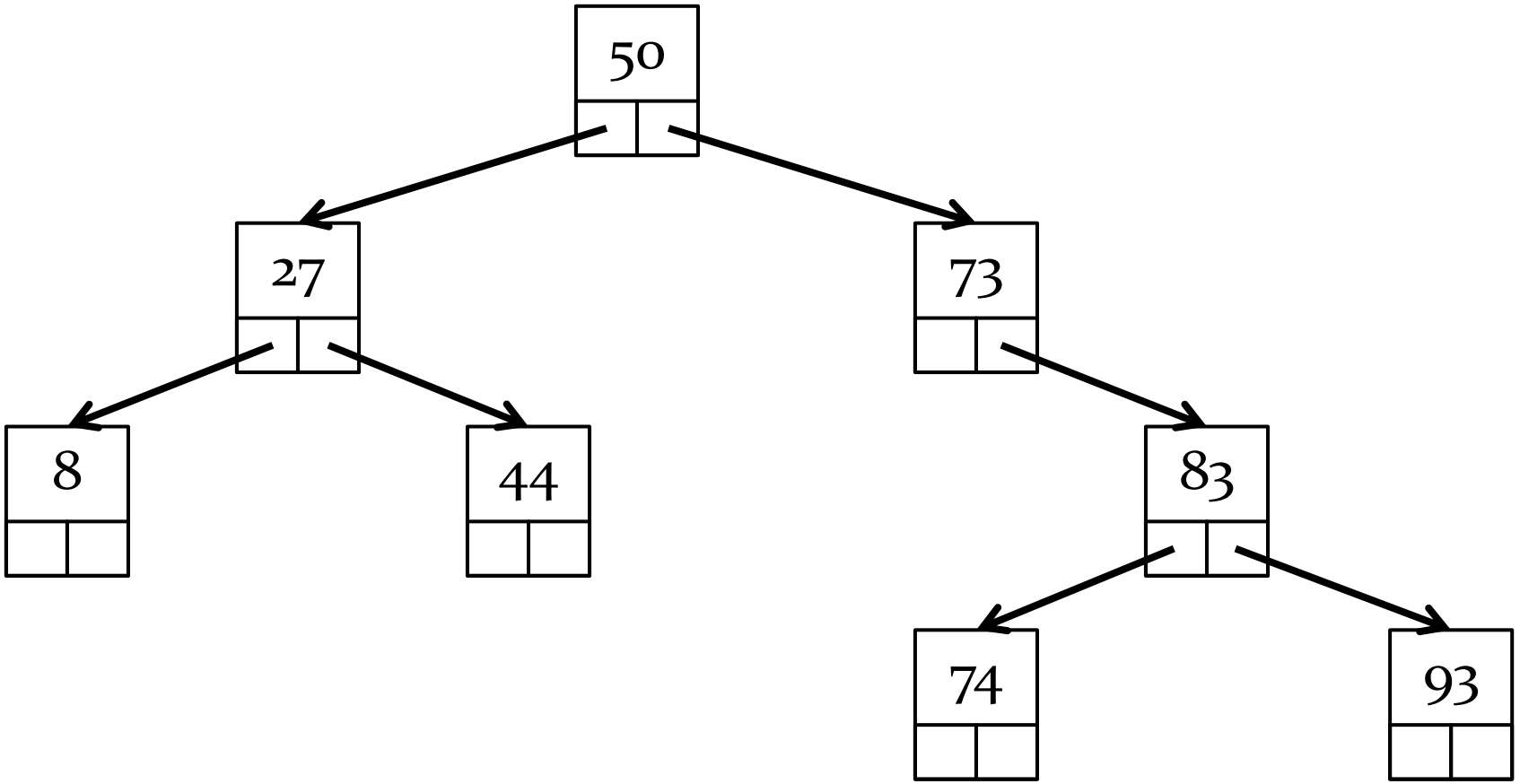
74 == 93?



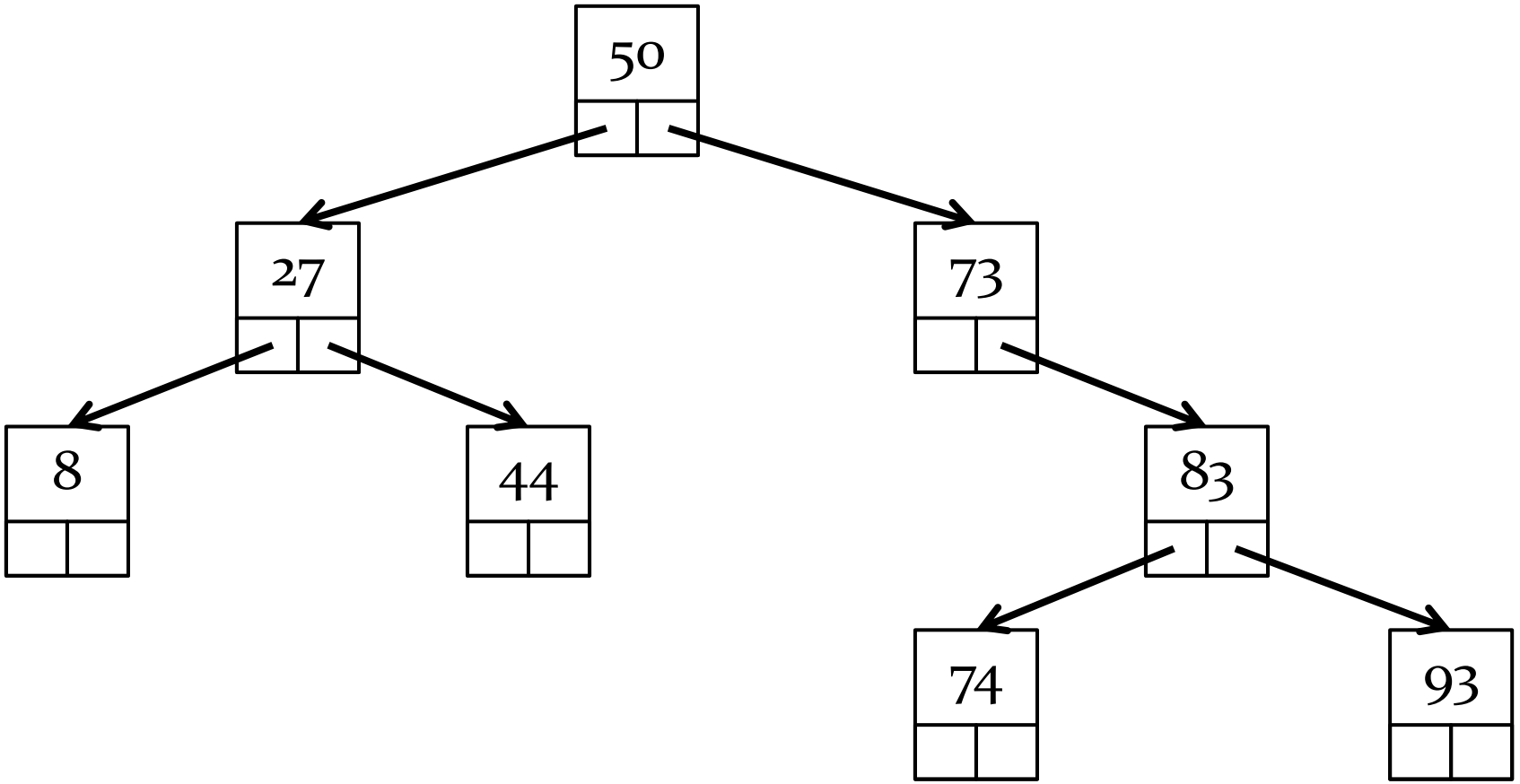
93 == 93?

Iteration

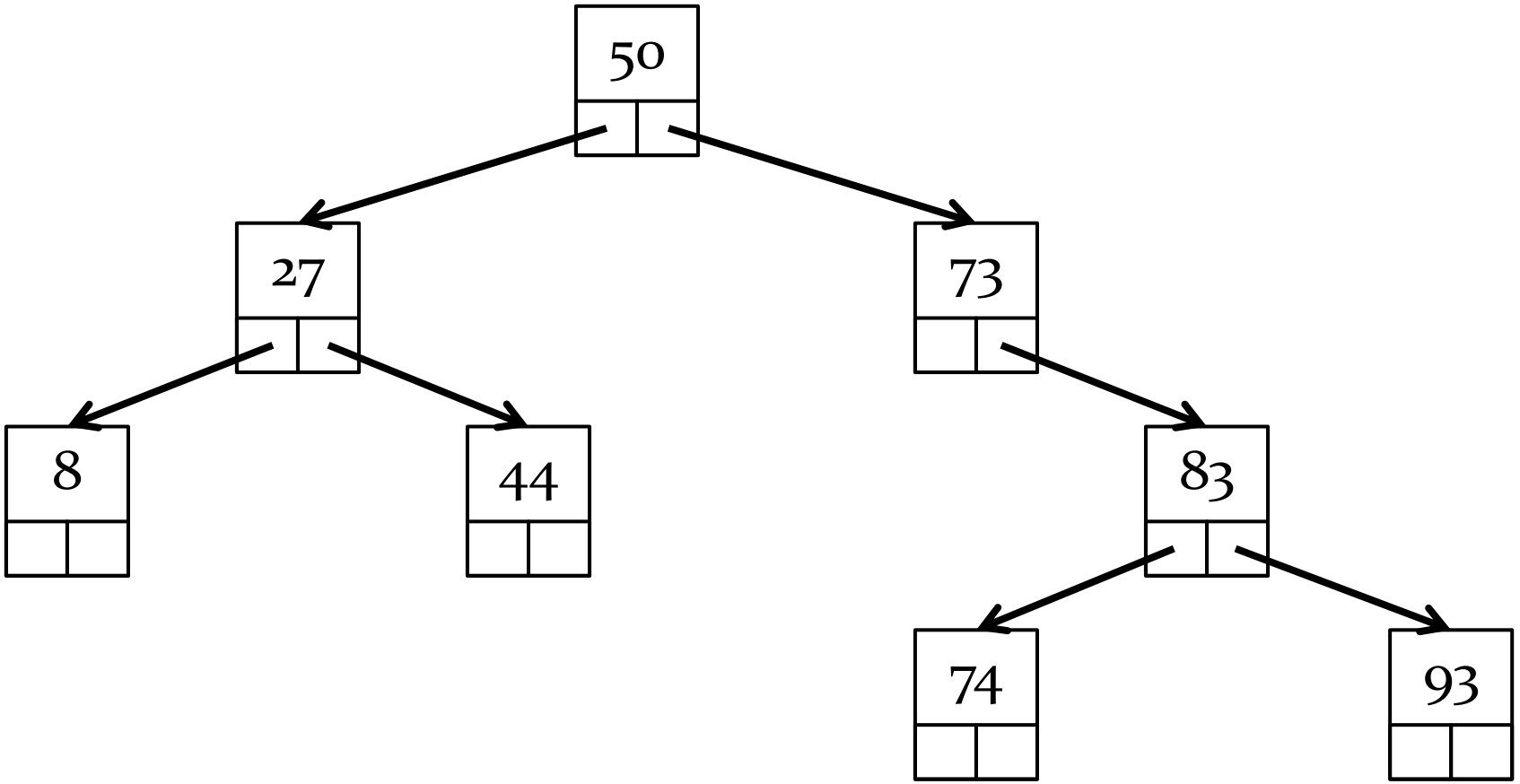
- visiting every element of the tree can also be done recursively
- 3 possibilities based on when the root is visited
  - inorder
    - visit left child, then root, then right child
  - preorder
    - visit root, then left child, then right child
  - postorder
    - visit left child, then right child, then root



inorder: 8, 27, 44, 50, 73, 74, 83, 93



preorder: 50, 27, 8, 44, 73, 83, 74, 93



postorder: 8, 44, 27, 74, 93, 83, 73, 50