COSC 2436: Binary Search Trees (BST)

What is a BST?

- A BST is a type of binary tree
- The left nodes' values are less than the value of the parent node
- The right nodes' values are greater than the value of the parent node
- Best Case Time Complexity: **O(logn)**
- Worst Case Time Complexity: **O(n)**

BST: Terms to know

- Edge - the link from a parent node to a child node

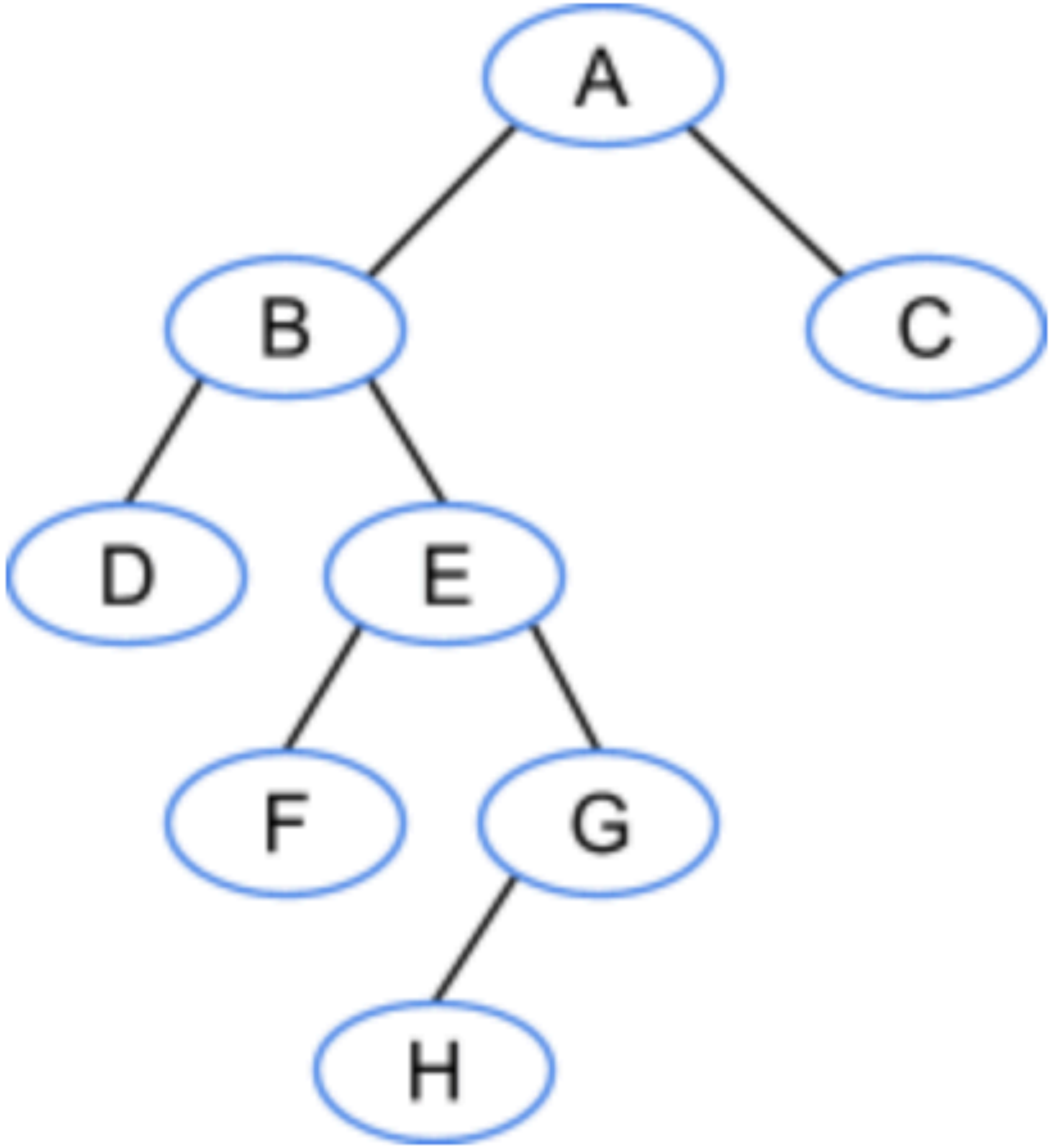
- Depth - the number of edges on the path from the root to the node (the root node has depth 0)

- Level - all the nodes that have the same depth

- Height - the largest depth of any node (tree with one node has height 0)

BST: Terms to know (review)

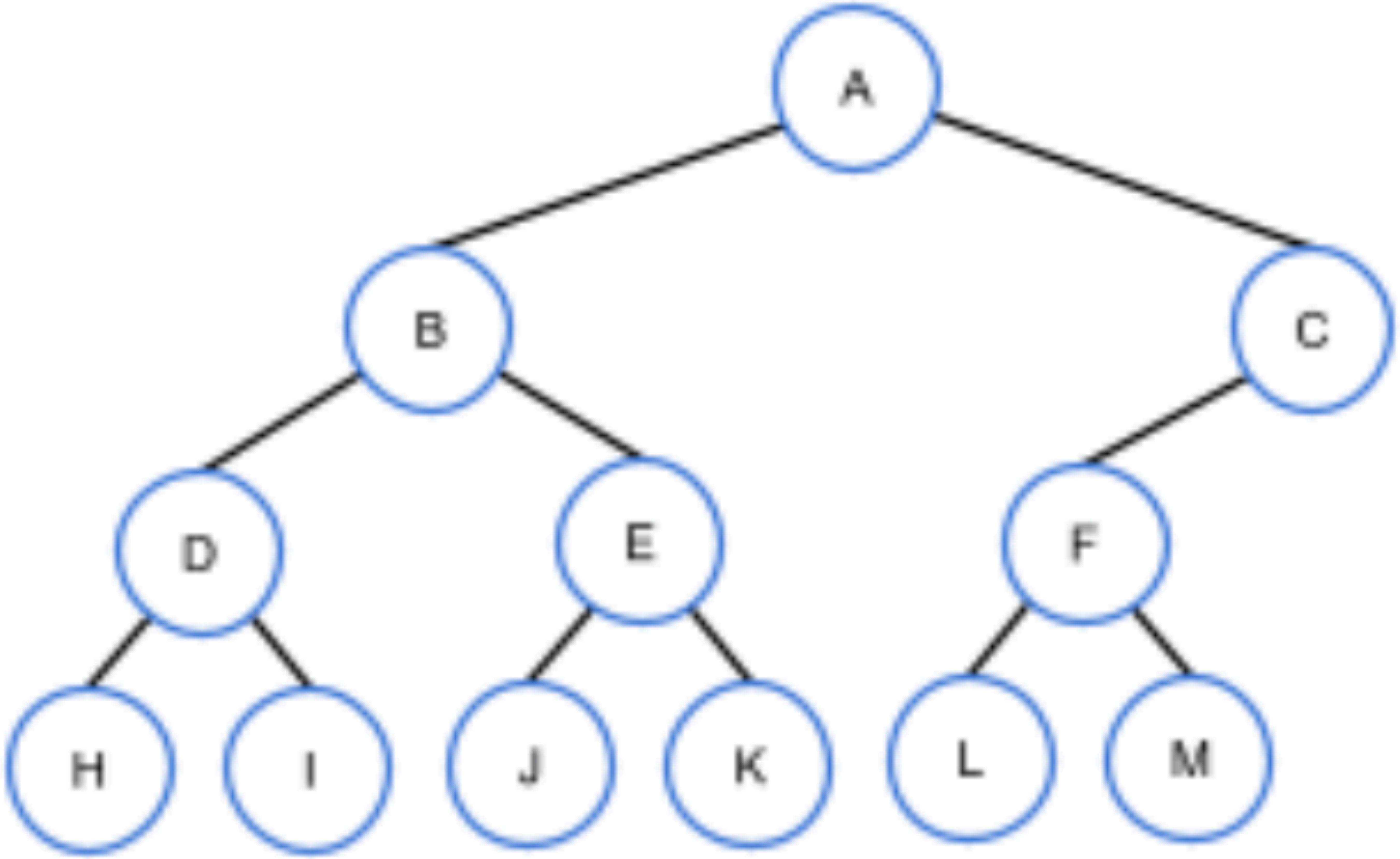
- Node *E* has depth 2
- Node *A* has depth 0
- Node *G* has depth 3
- Nodes *B* and *C* form level 1
- The tree's height is 4



BST: full, complete, perfect

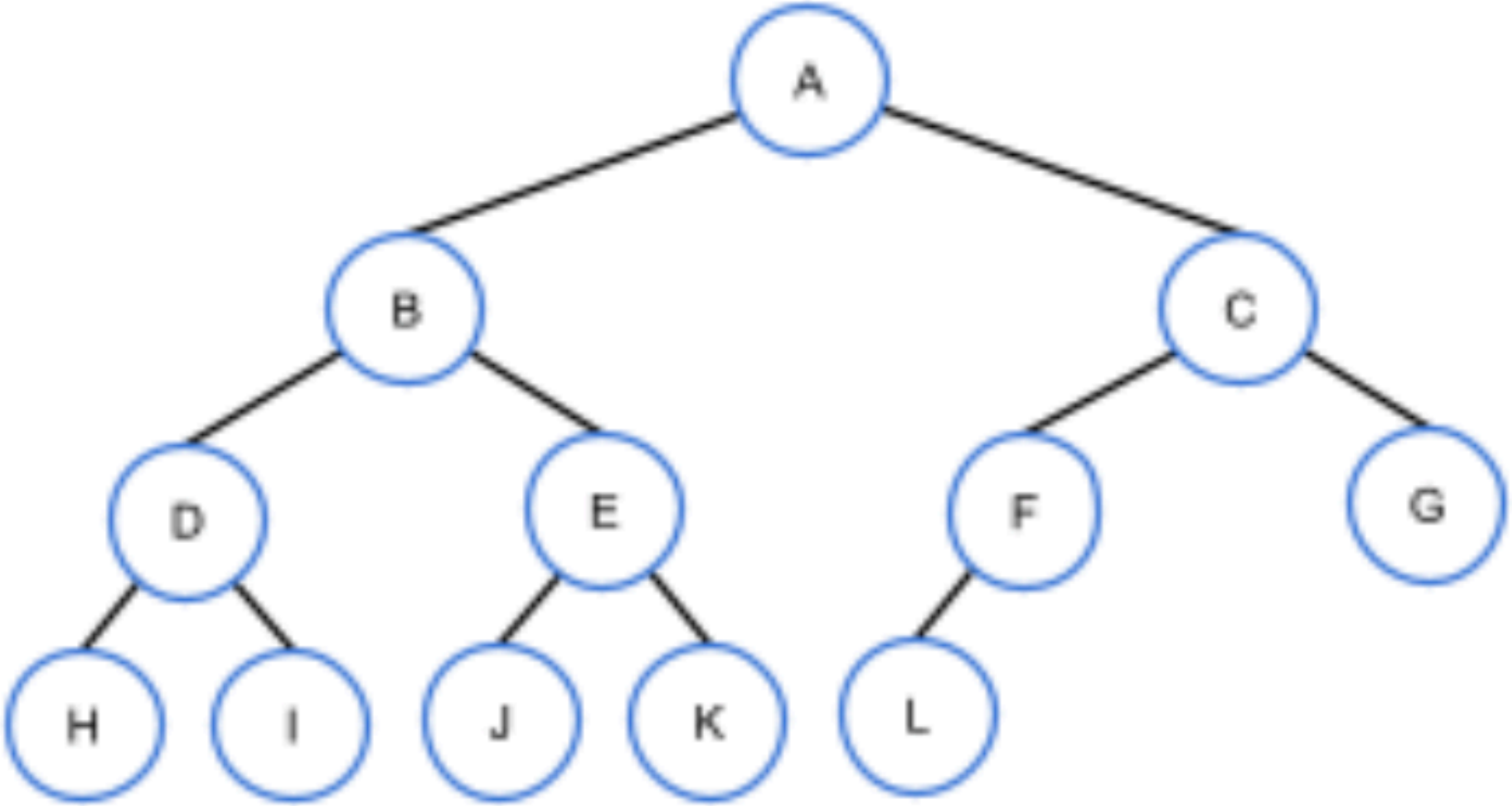
- A **full** tree means that every node contains 0 or 2 children.
- A **complete** tree means that all levels contain all possible nodes. *note that for the last level must have all the nodes as far left as possible for it to be complete.
- A **perfect** tree means that all internal nodes have 2 children and all leaf nodes are at the same level

not full, not complete, not perfect



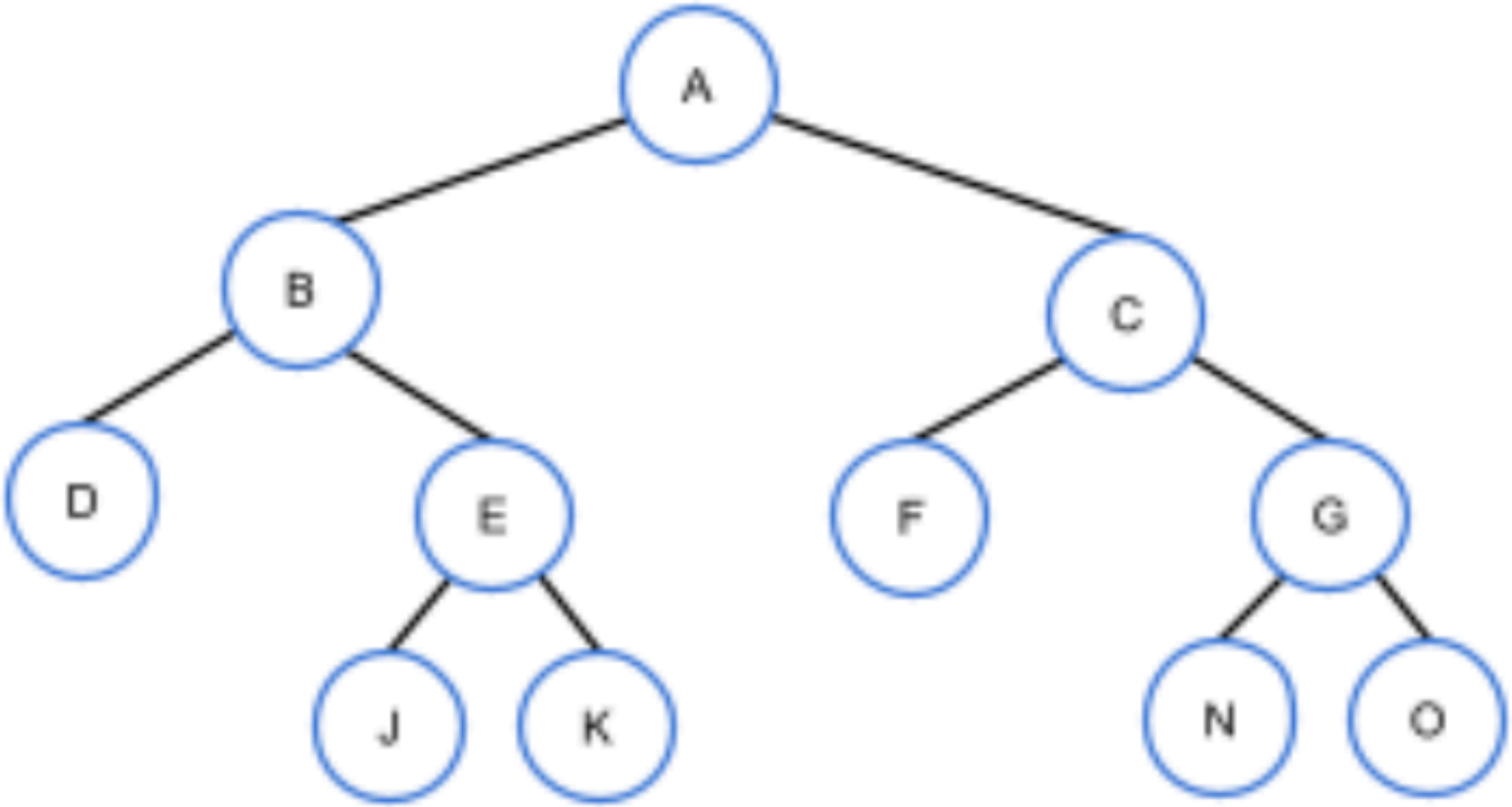
Not full, not complete, not perfect

not full, complete, not perfect



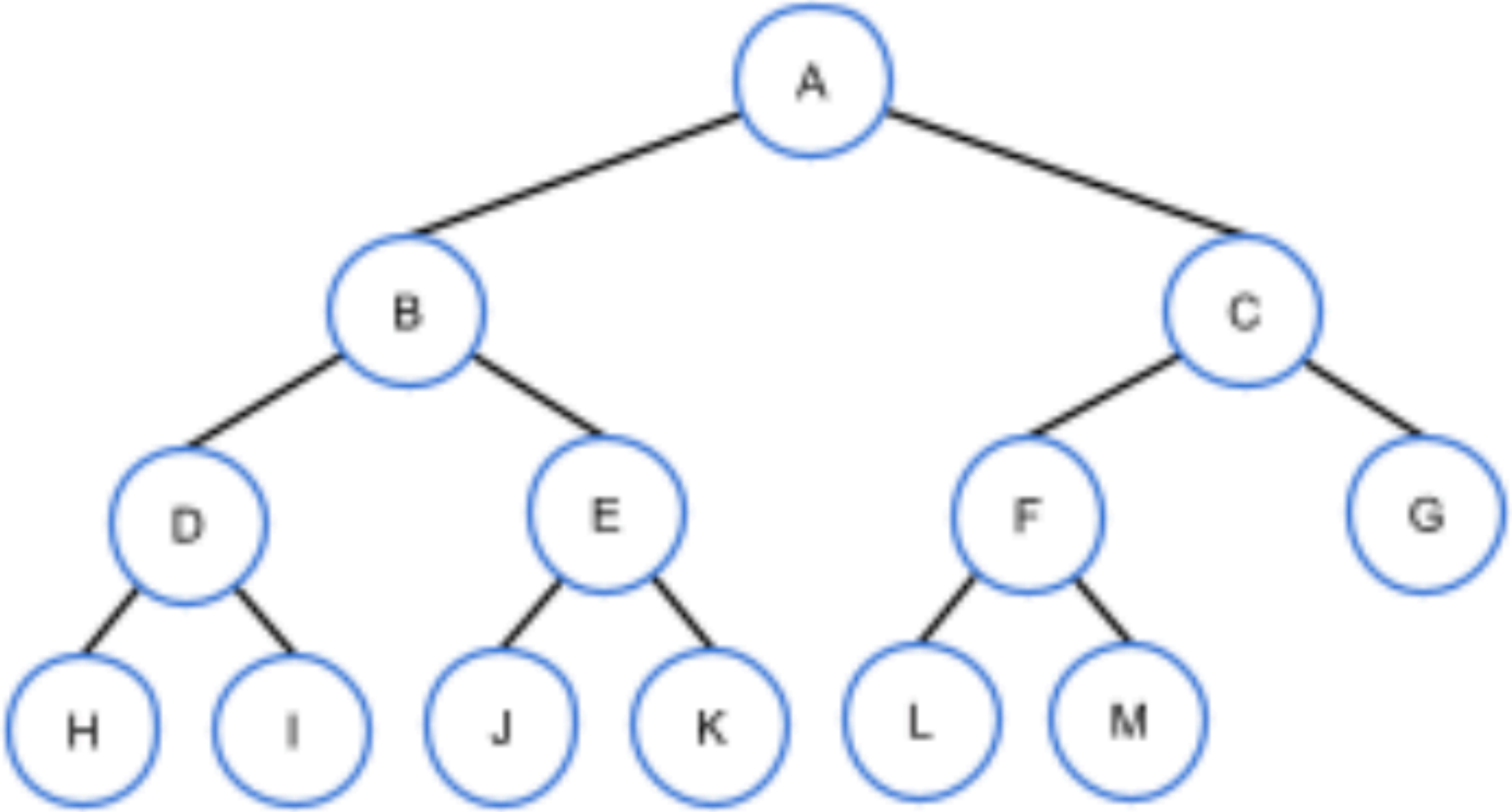
Not full, complete, not perfect

full, not complete, not perfect



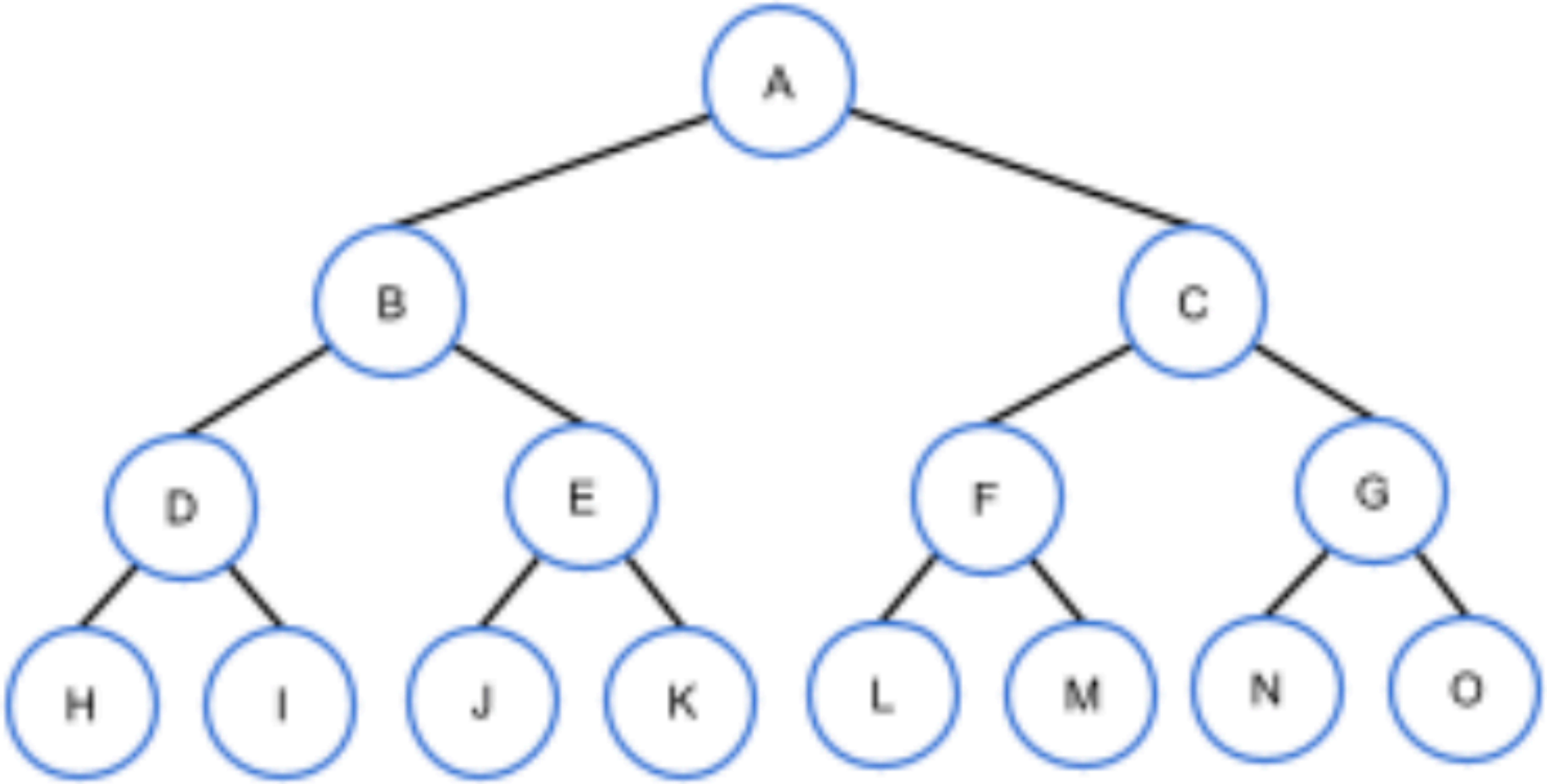
Full, not complete, not perfect

full, complete, not perfect



Full, complete, not perfect

full, complete, perfect

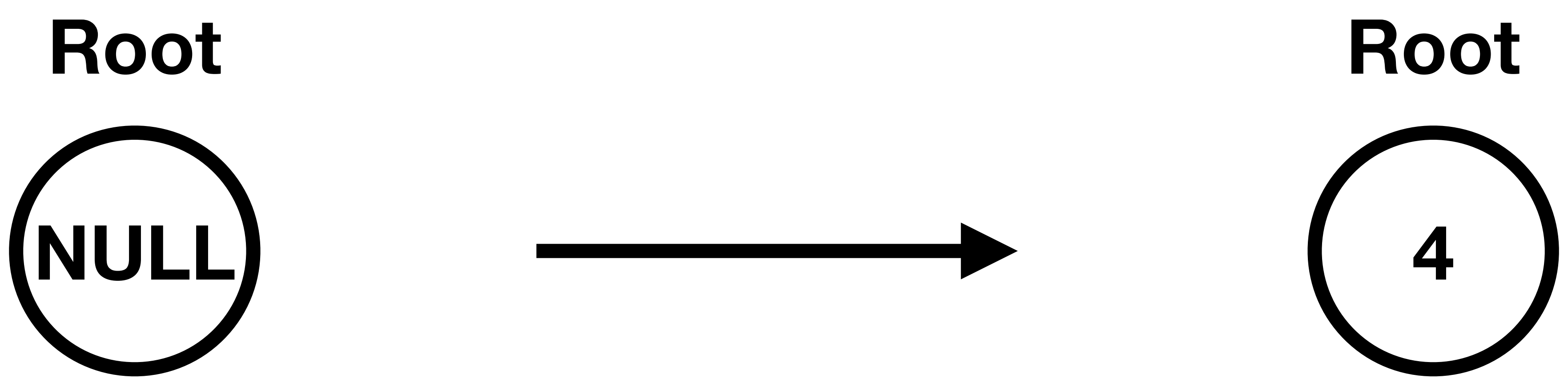


Full, complete, perfect

BST: Insert

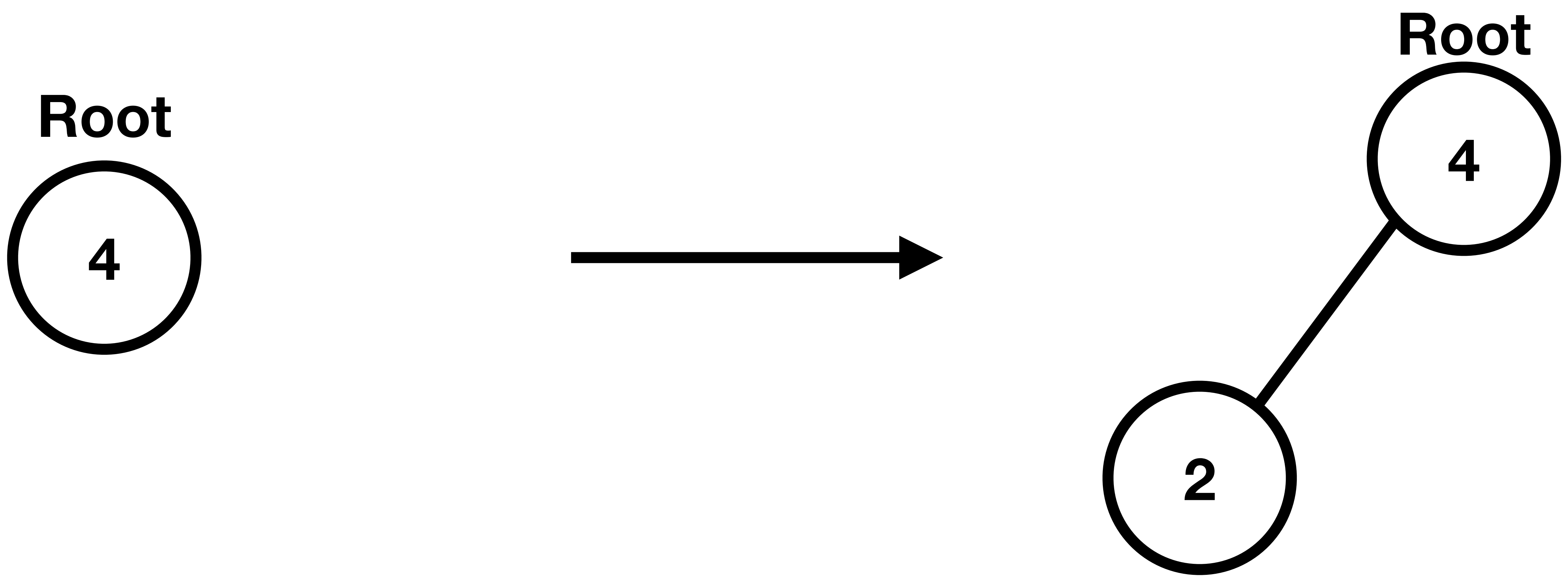
Insert 4

Root is NULL so insert 4 at root



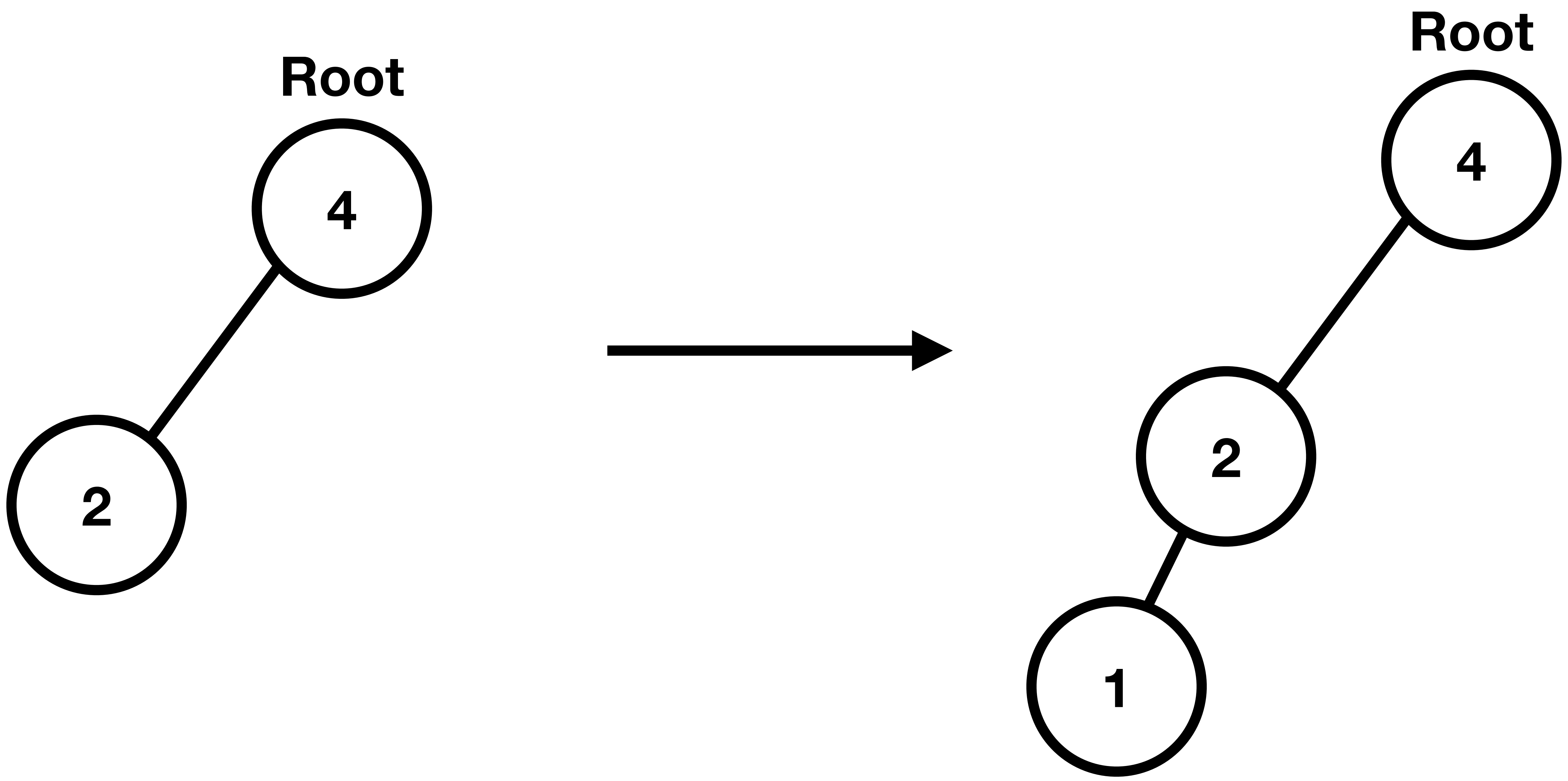
BST: Insert

Insert 2
Root is not NULL
2 is less than 4 so go to left



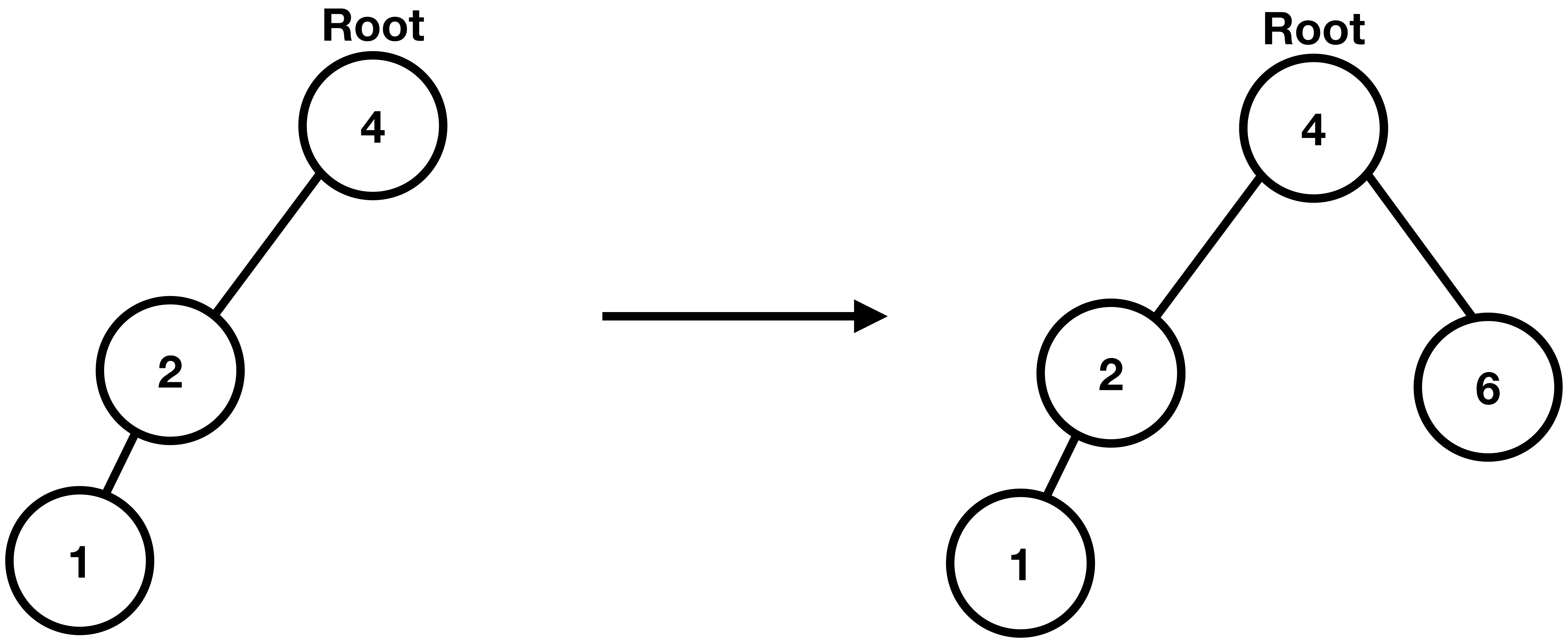
BST: Insert

Insert 1
Root is not NULL
1 is less than 4 so go to left
1 is less than 2 so go to left



BST: Insert

Insert 6
Root is not NULL
6 is greater than 4 so go to right



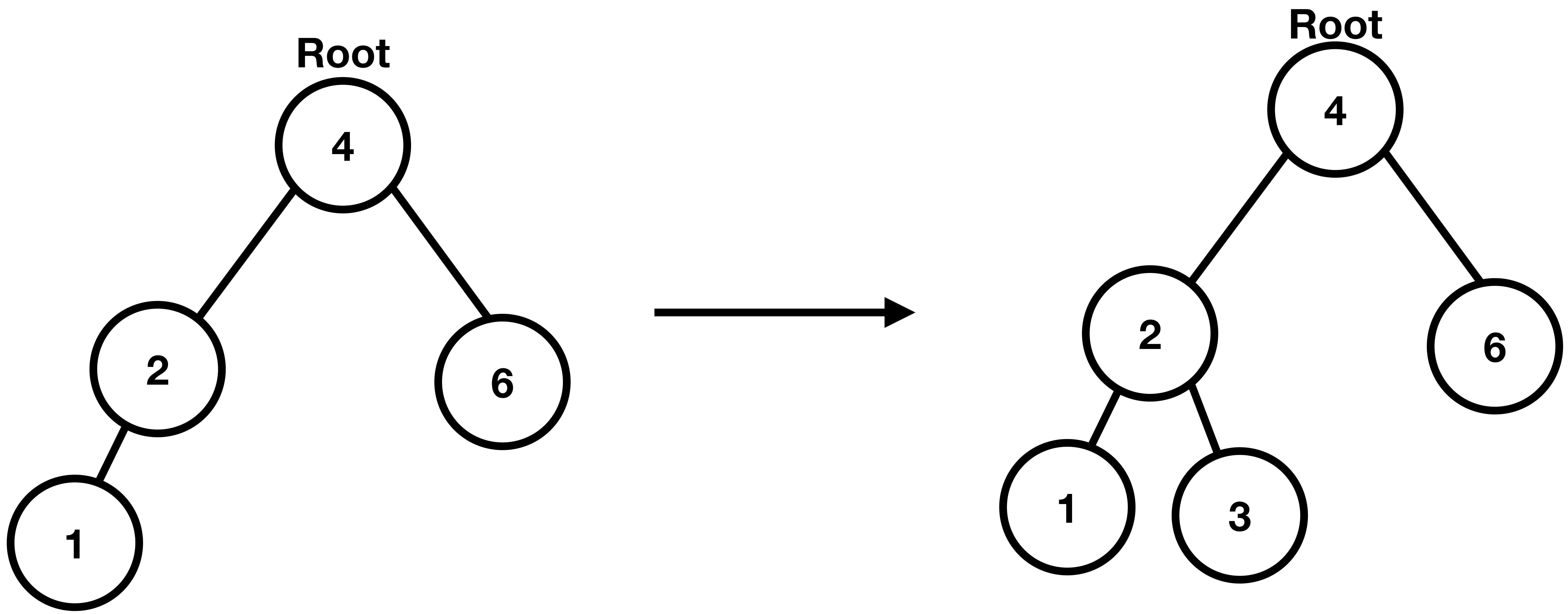
BST: Insert

Insert 3

Root is not NULL

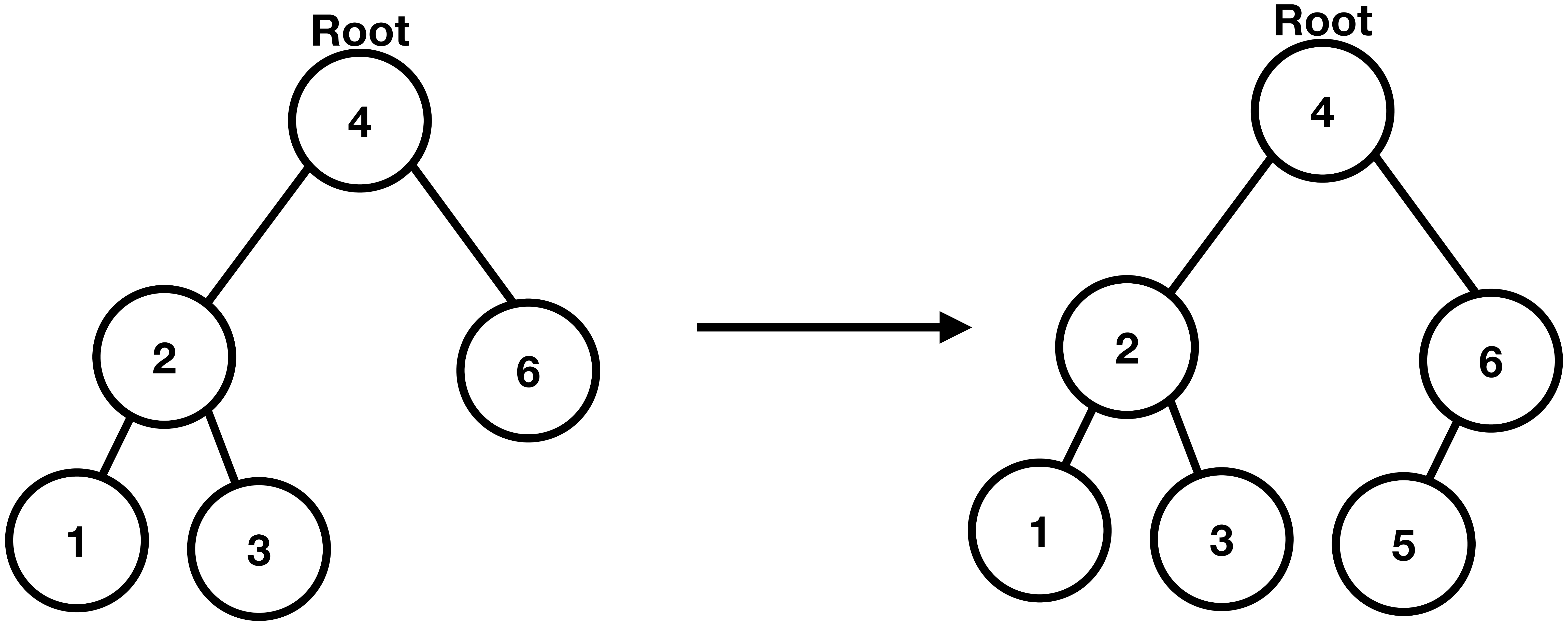
3 is less than 4 so go to left

3 is greater than 2 so go to right



BST: Insert

Insert 5
Root is not NULL
5 is greater than 4 so go to right
5 is less than 6 so go to left



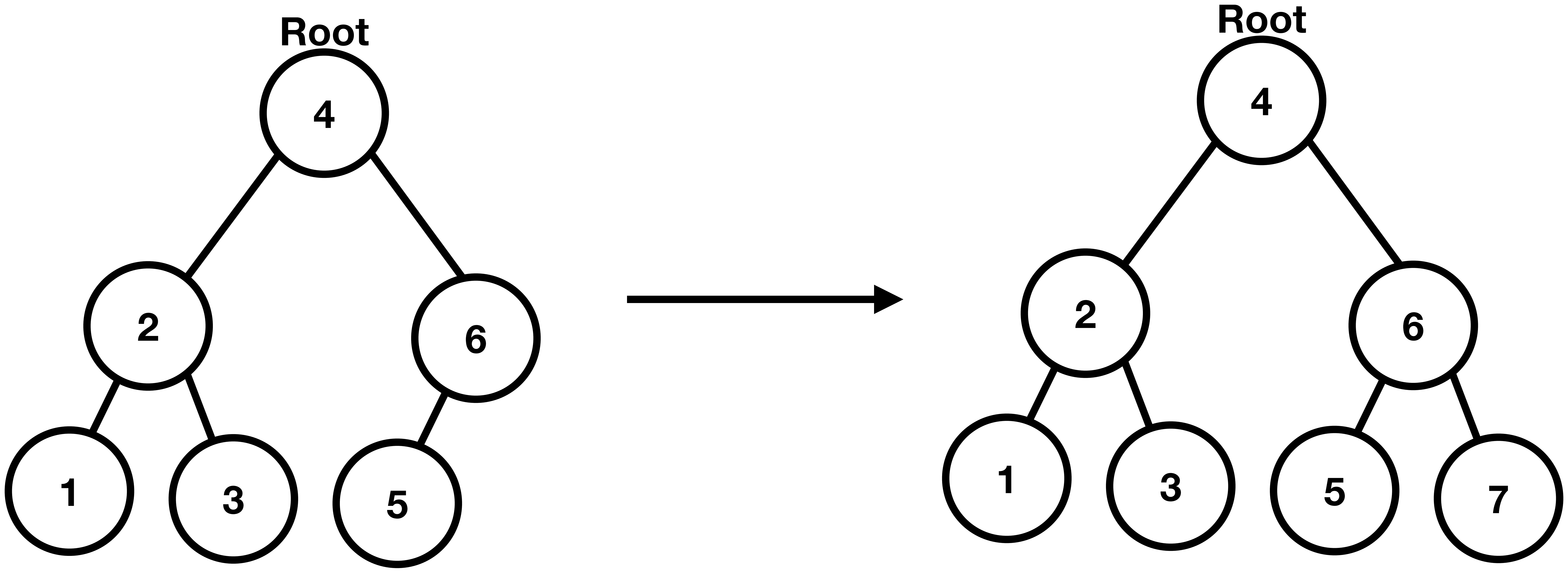
BST: Insert

Insert 7

Root is not NULL

7 is greater than 4 so go to right

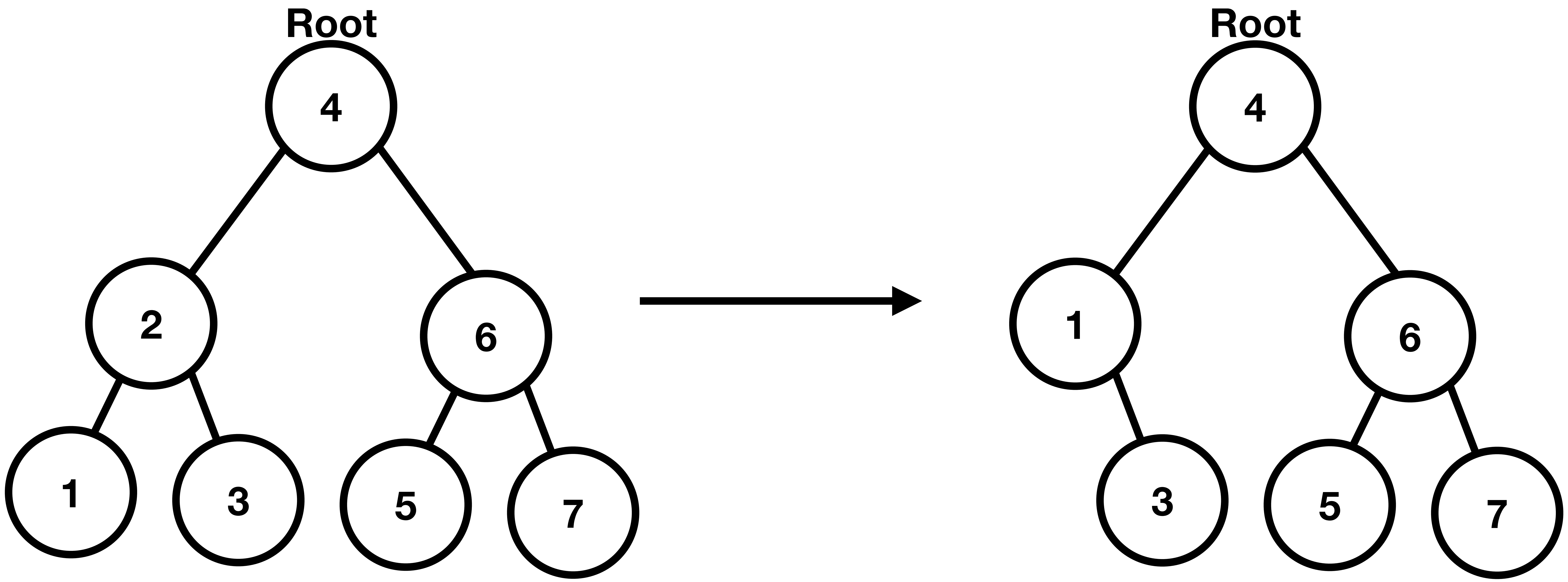
7 is greater than 6 so go to right



BST: Remove

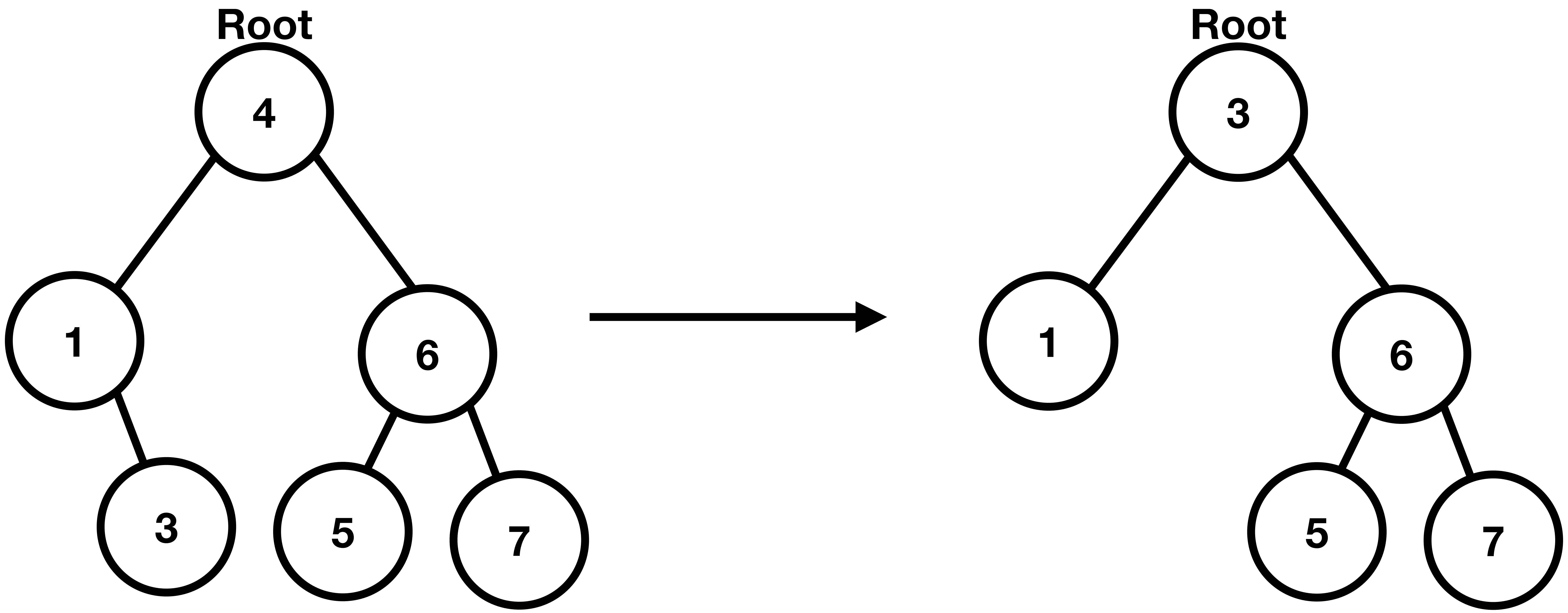
Remove 2

Replace 2 with in-order predecessor (which is 1)



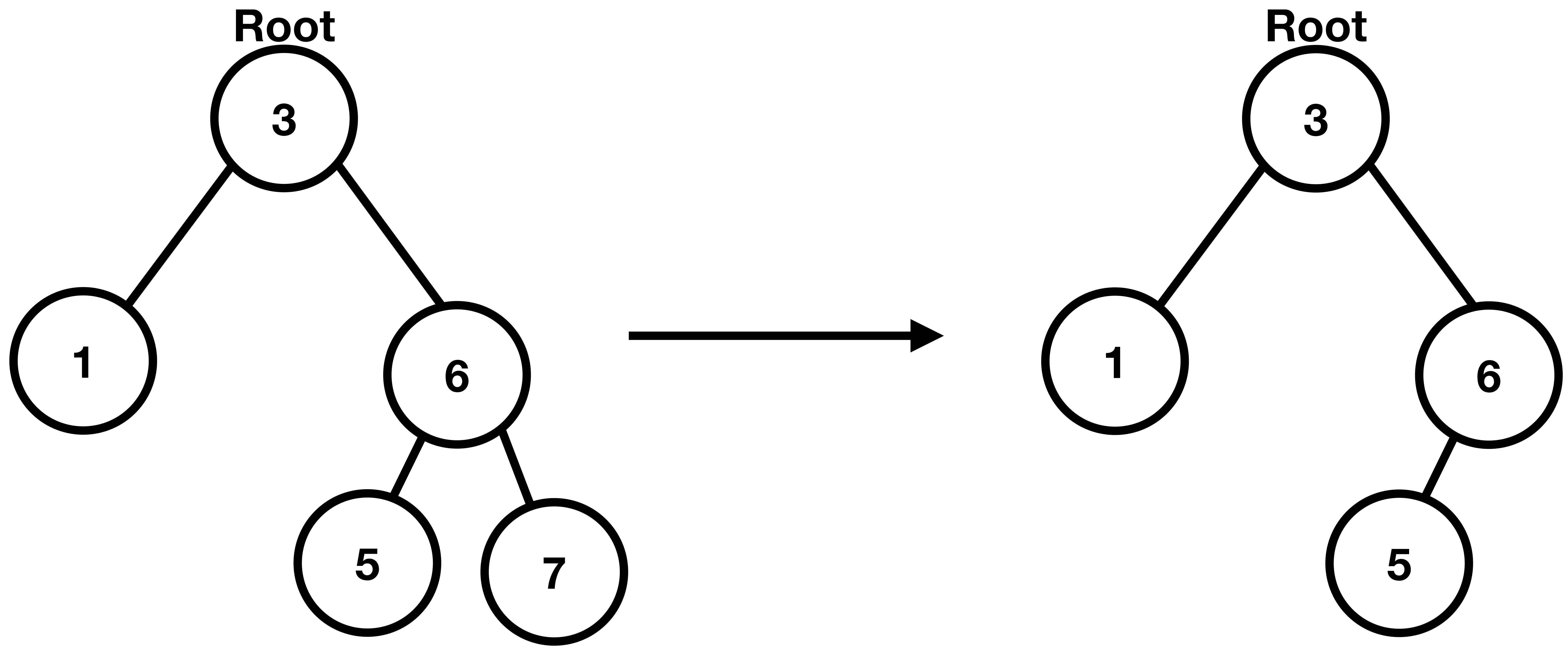
BST: Remove

Remove 4
Replace 4 with in-order predecessor (which is 3)



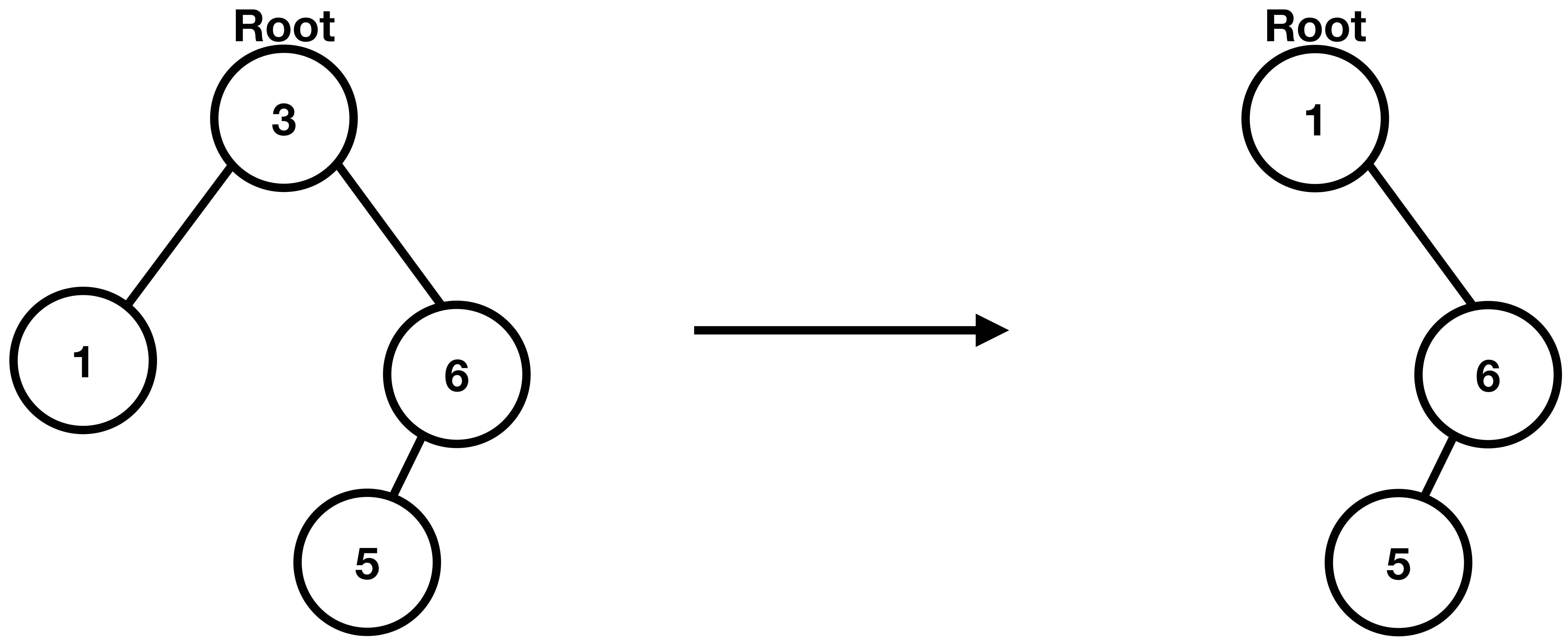
BST: Remove

Remove 7
7 is a leaf so nothing to replace



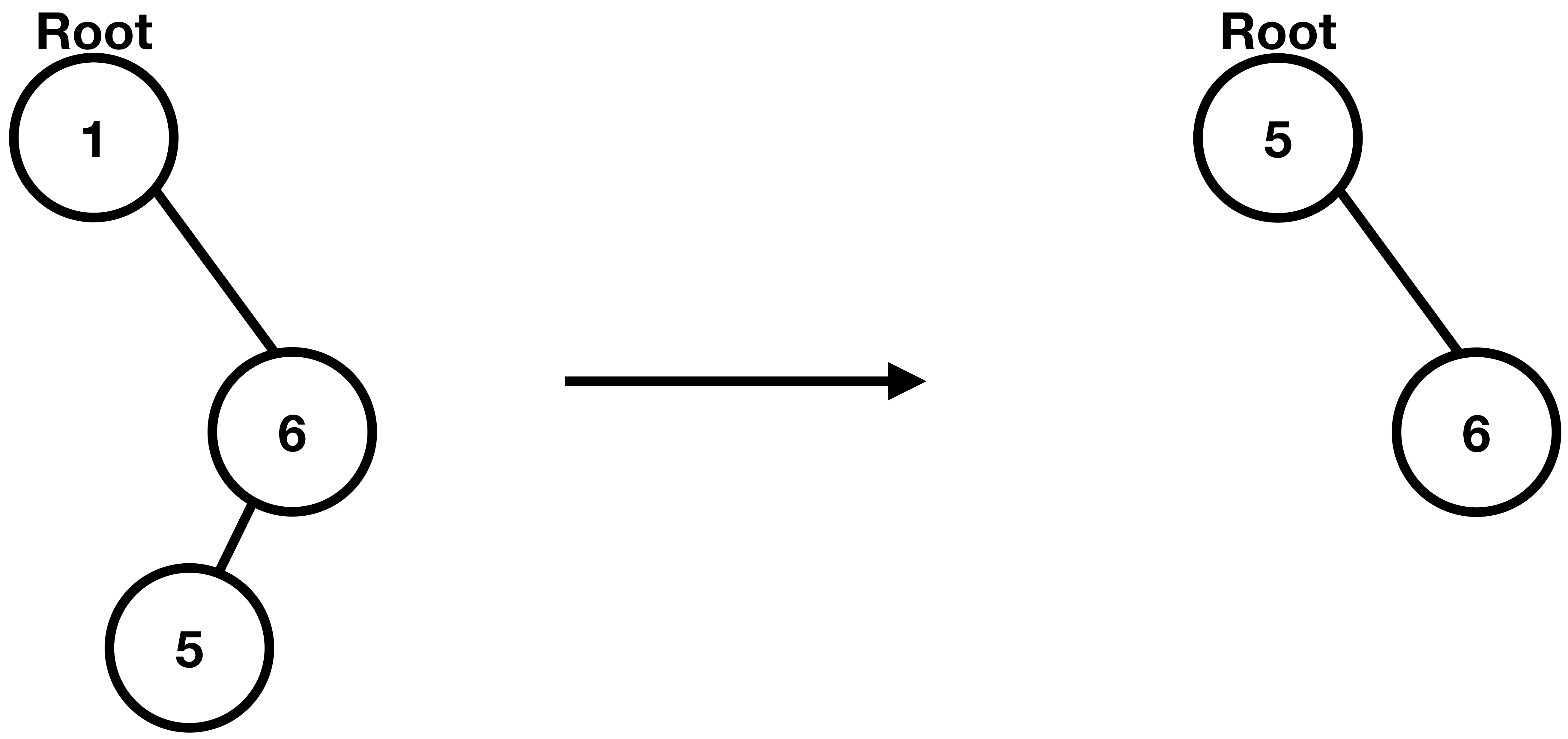
BST: Remove

Remove 3
Replace 3 with in-order predecessor (which is 1)



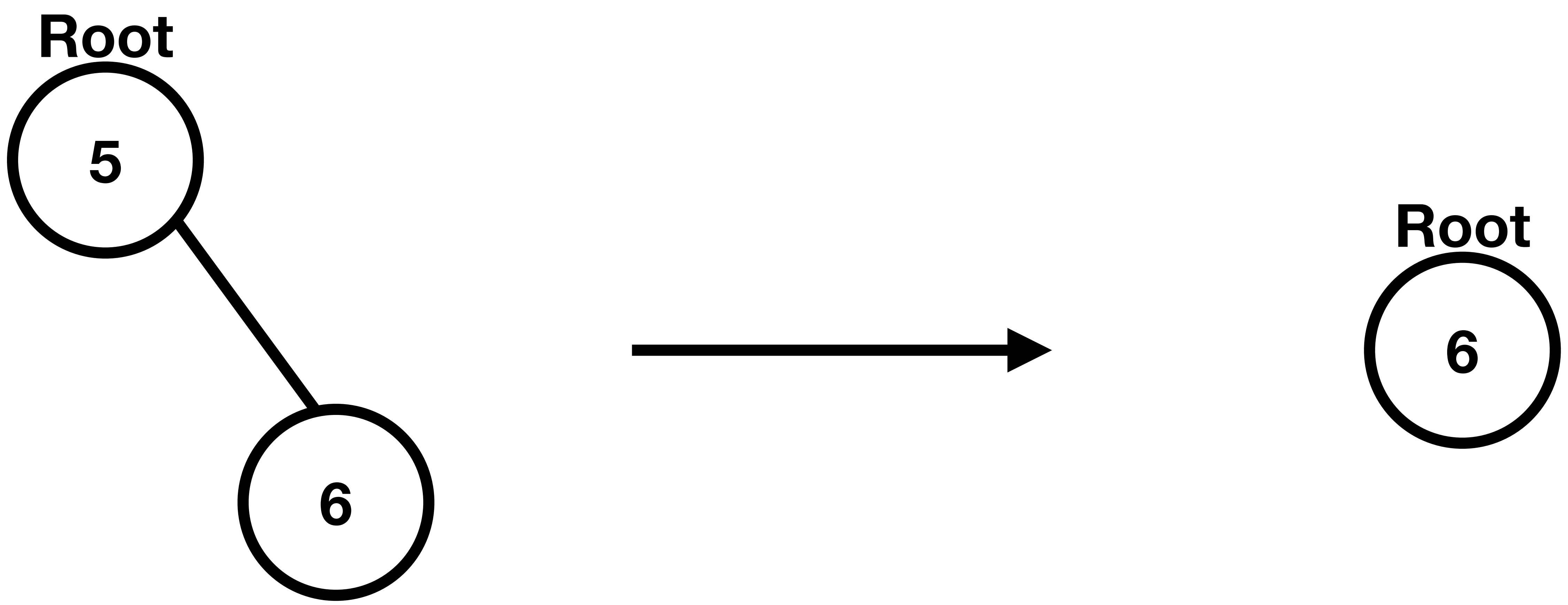
BST: Remove

Remove 1
Replace 1 with in-order predecessor
Since 1 has no in-order predecessor, replace 1 with in-order successor (which is 5)



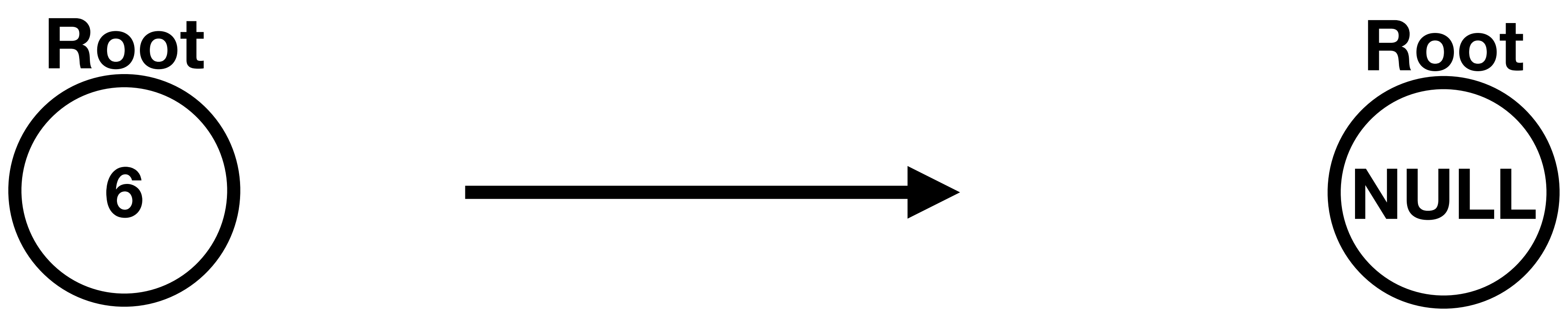
BST: Remove

Remove 5
Replace 5 with in-order predecessor
Since 5 has no in-order predecessor, replace 5 with in-order successor (which is 6)



BST: Remove

Remove 6
Replace 6 with in-order predecessor
Since 6 has no in-order predecessor, replace 6 with in-order successor
Since 6 has no in-order predecessor set root to NULL



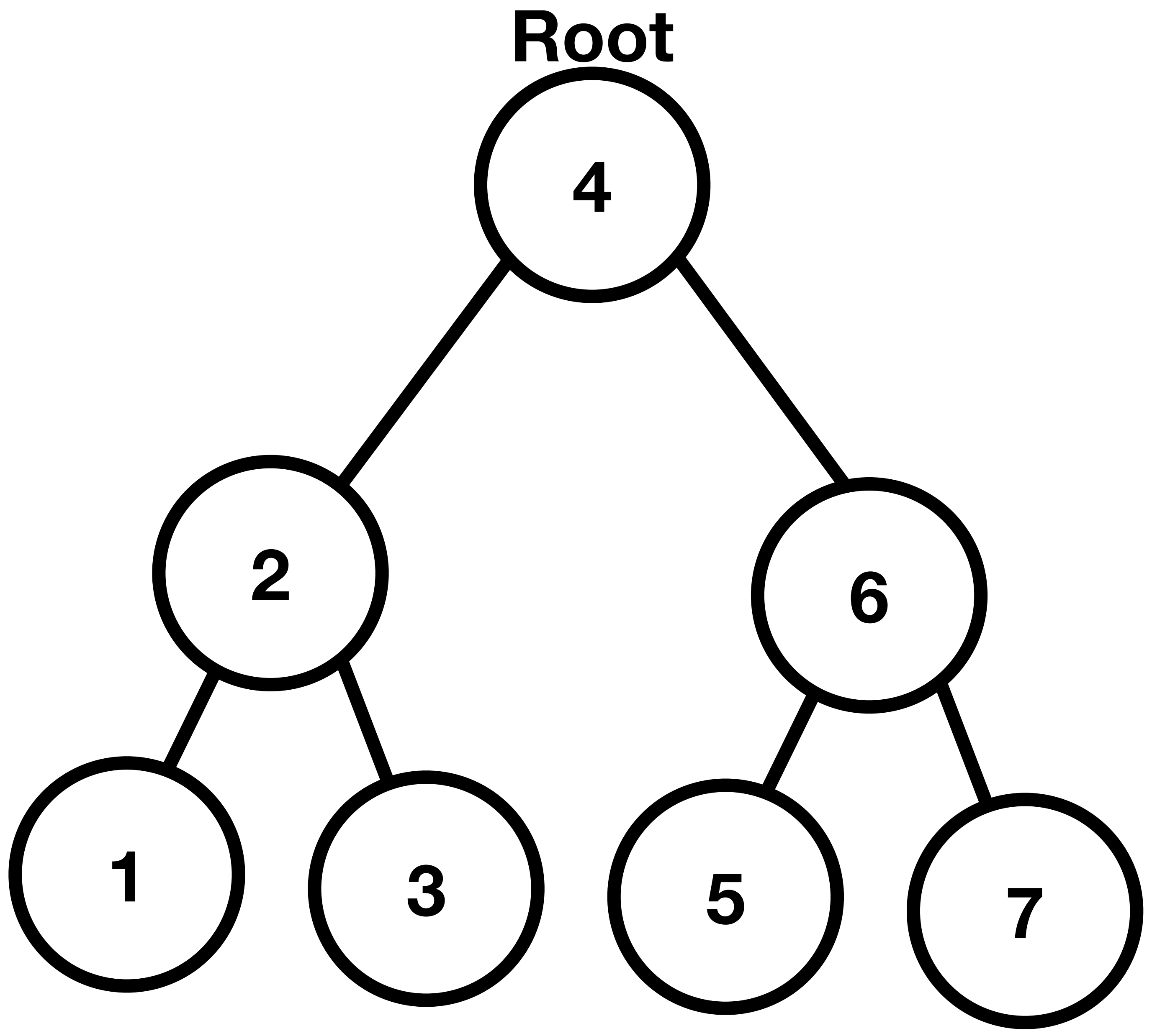
BST: Level Order

Level Order:

4

2 6

1 3 5 7



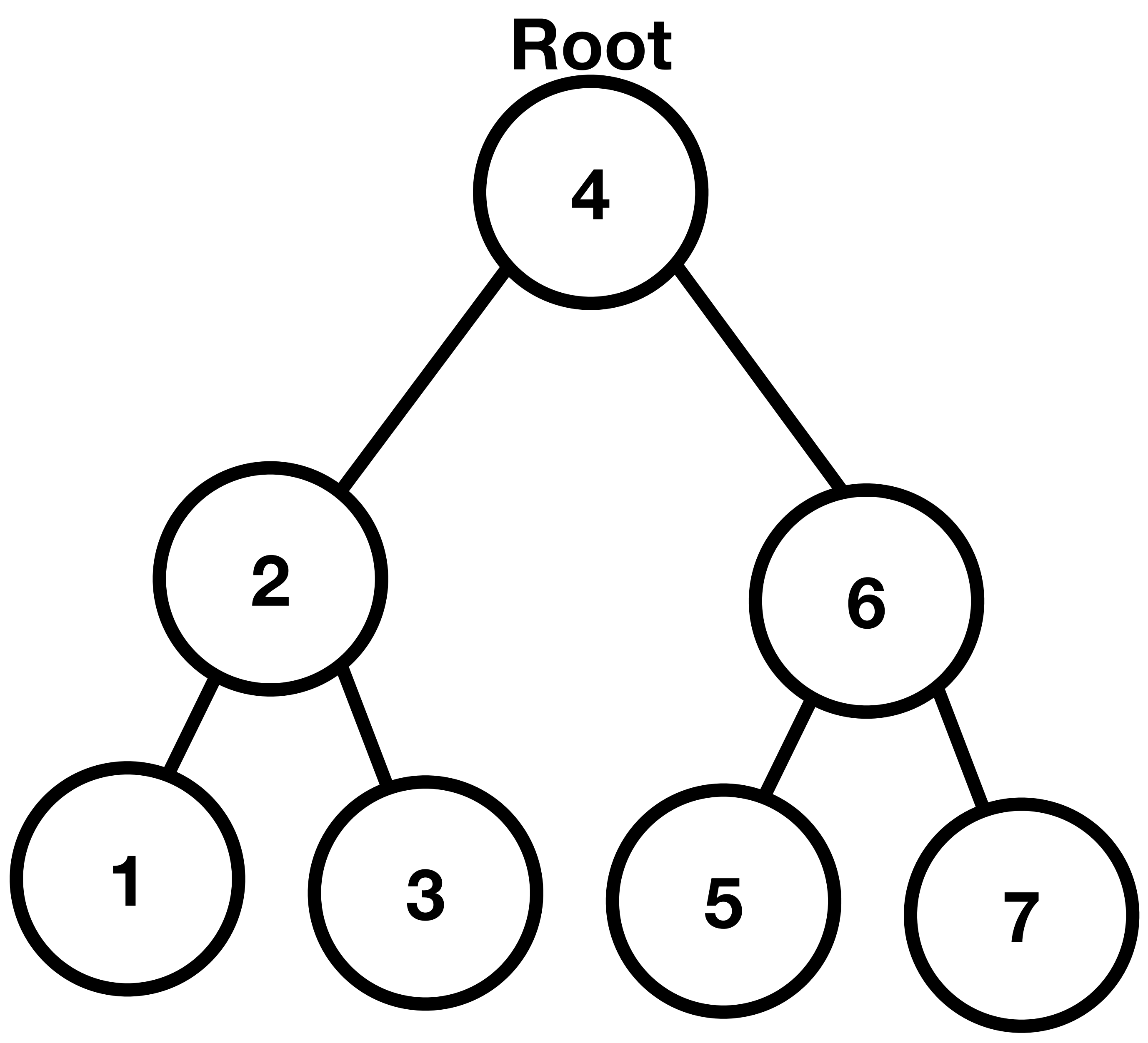
BST: Level Order

```
void levelorder(node *n){
  if(n == nullptr){
    cout << "BST is empty" << endl;
    return;
  }
  queue<node*> q;
  q.push(n);
  while(!q.empty()){
    int levelSize = q.size();
    for(int i = 0; i < levelSize; i++){
      node *cu = q.front();
      q.pop();
      cout << cu->value << " ";
      if(cu->left != nullptr)
        q.push(cu->left);
      if(cu->right != nullptr)
        q.push(cu->right);
    }
    cout << endl;
  }
}
```

BST: Inorder

Inorder:

1 2 3 4 5 6 7

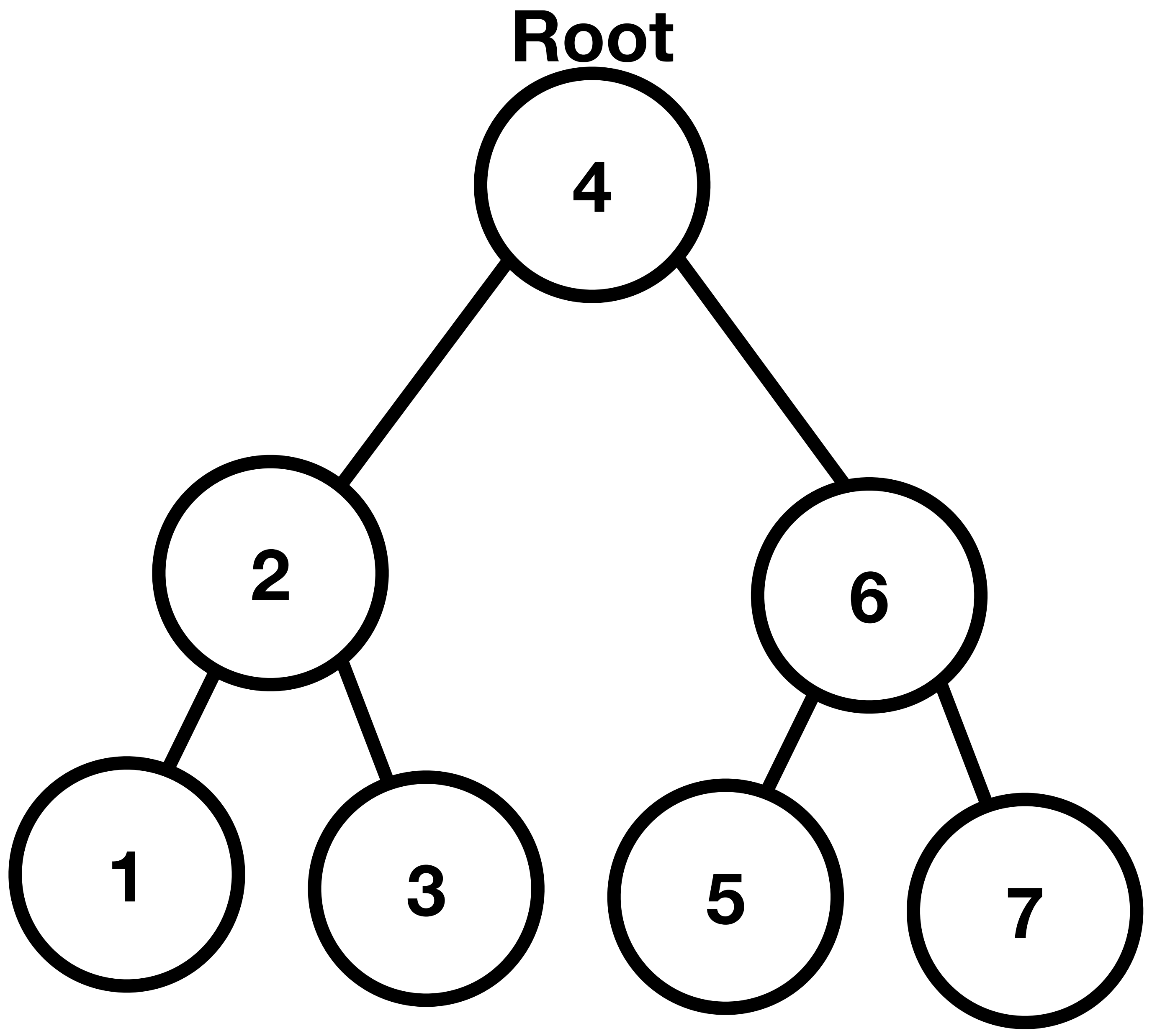


BST: Inorder

```cpp
void inorder(node *n){
  if(n == nullptr)
    return;
  inorder(n->left);
  cout << n->value << " ";
  inorder(n->right);
}
```

BST: Reverse Order

Reverse Order:
7 6 5 4 3 2 1



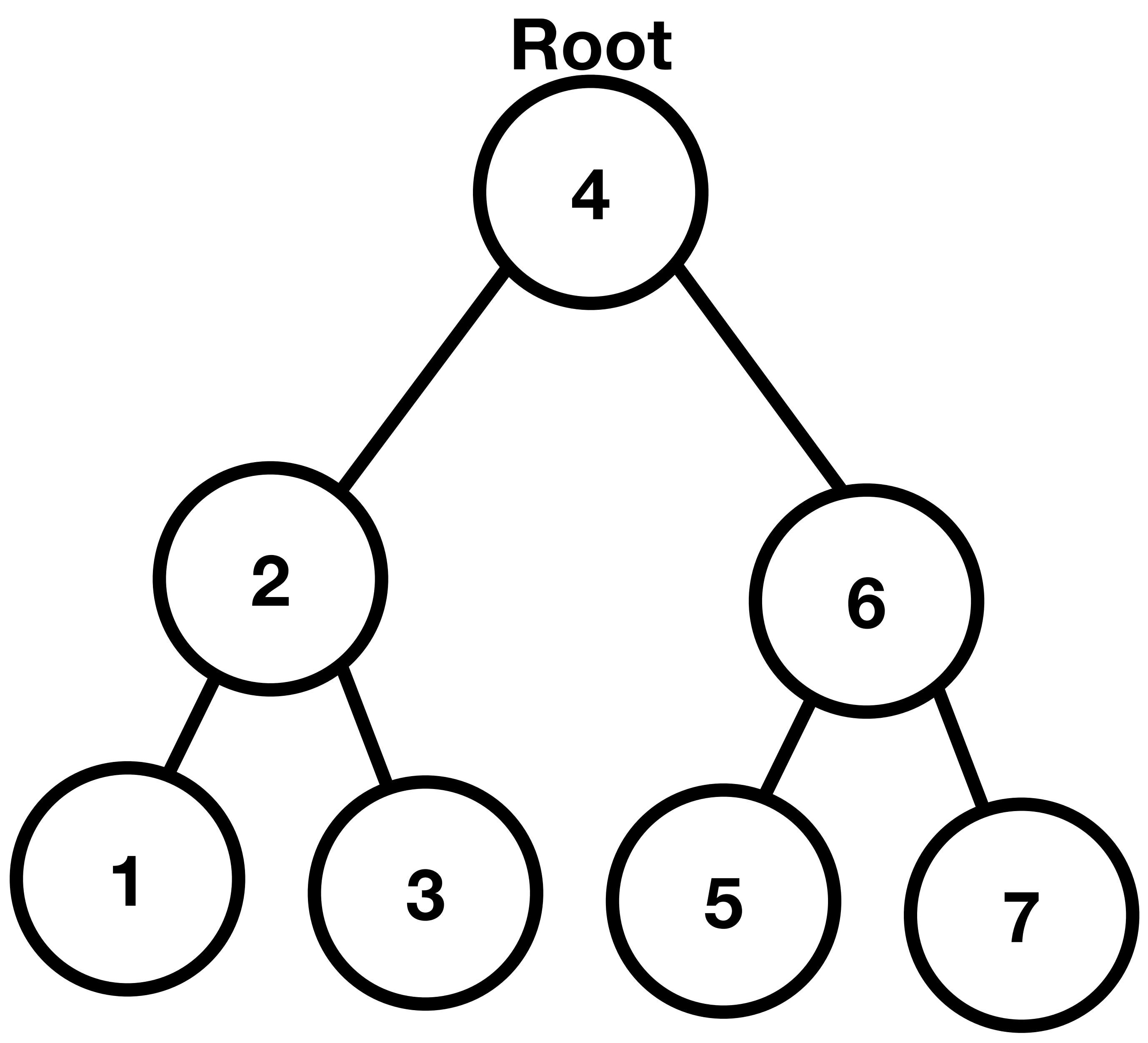
BST: Reverse Order

```
void reverseorder(node *n){
  if(n == nullptr)
    return;
  reverseorder(n->right);
  cout << n->value << " ";
  reverseorder(n->left);
}
```

BST: Preorder

Preorder:

4 2 1 3 6 5 7



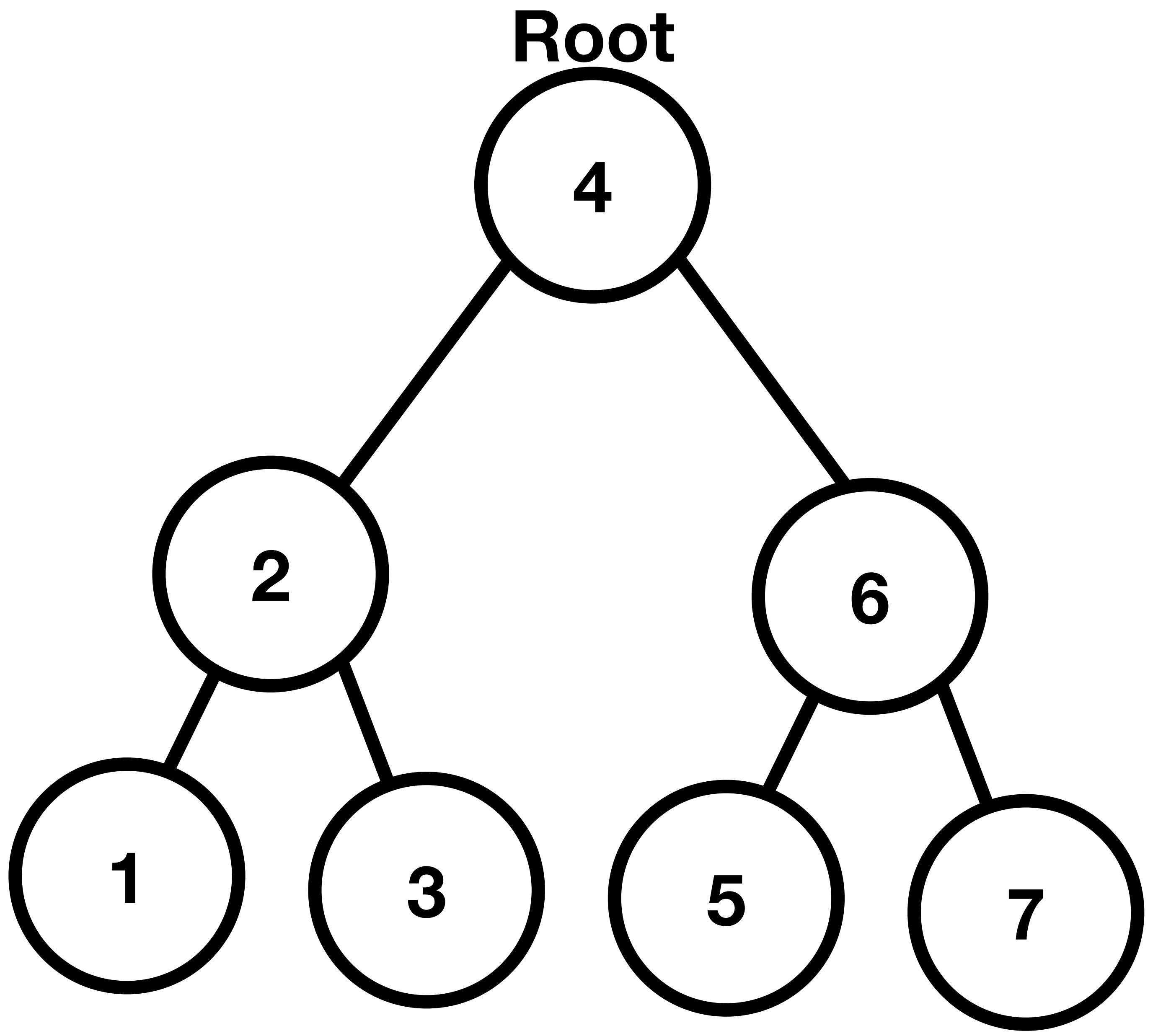
BST: Preorder

```
void preorder(node *n){
  if(n == nullptr)
    return;
  cout << n->value << " ";
  preorder(n->left);
  preorder(n->right);
}
```

BST: Postorder

Postorder:

1 3 2 5 7 6 4

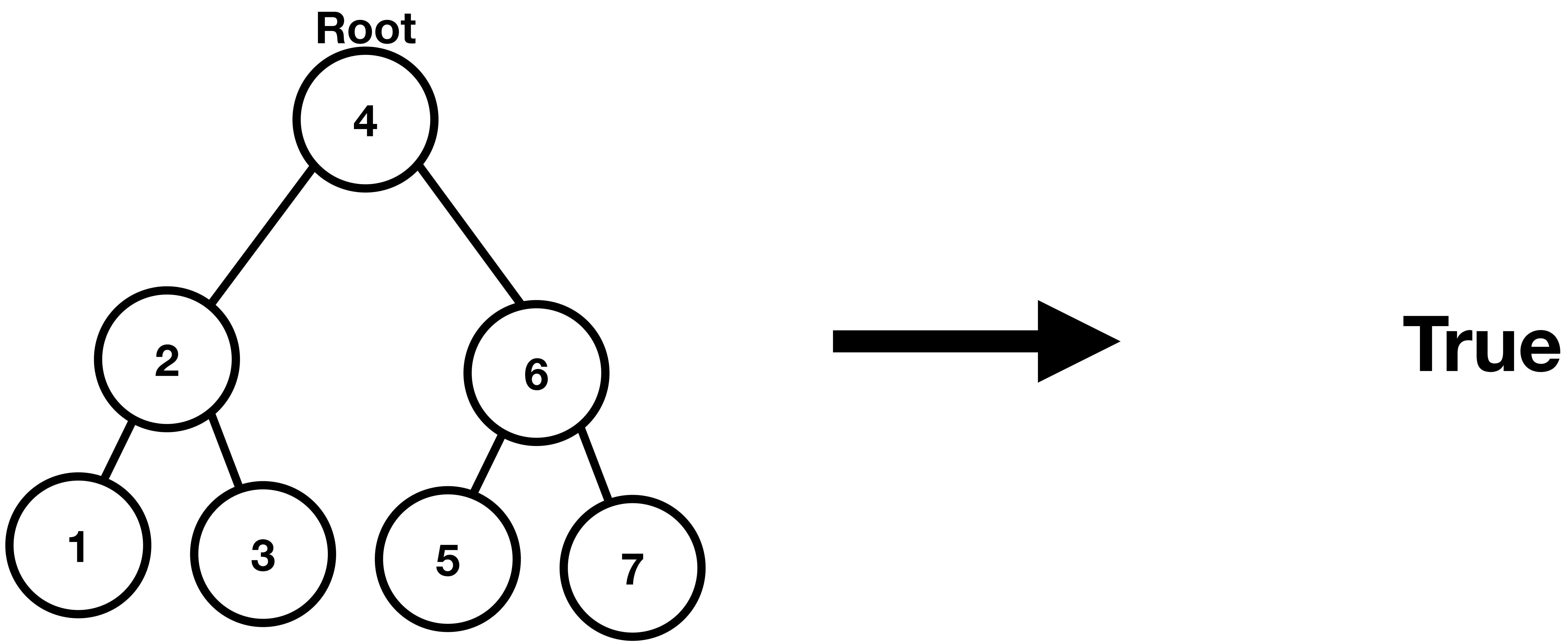


BST: Postorder

```
void postorder(node *n){
  if(n == nullptr)
    return;
  postorder(n->left);
  postorder(n->right);
  cout << n->value << " ";
}
```

BST: isBST()

Write a function that returns **true** if a tree is a BST and **false** otherwise.

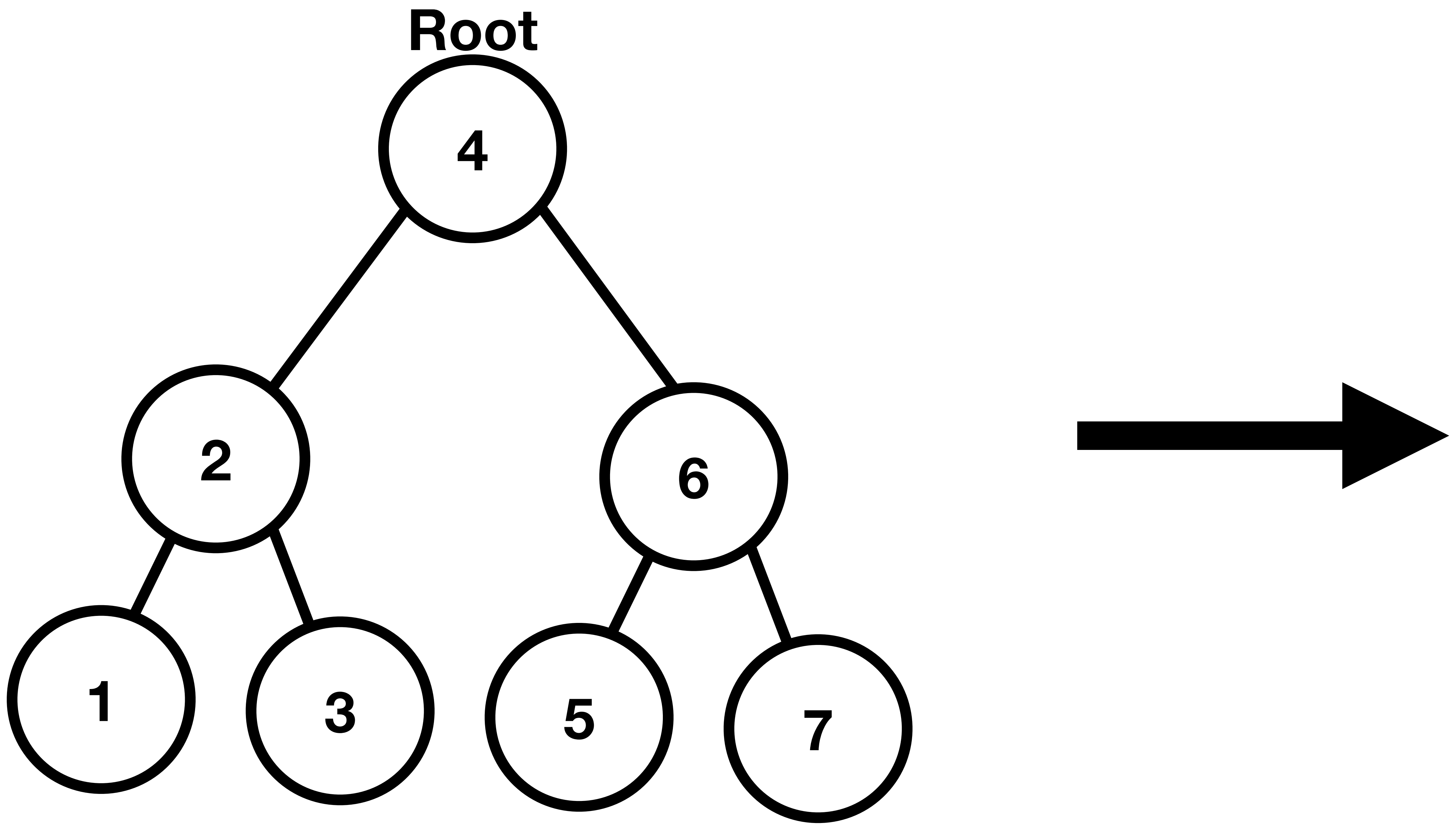


BST: isBST()

```
bool isBST(node *n){
  if(n == nullptr)
    return true;
  else if(n->left != nullptr && n->left->value > n->value)
    return false;
  else if(n->right != nullptr && n->right->value < n->value)
    return false;
  else
    return (isBST(n->left) && isBST(n->right));
}
```

BST: printLeaves()

Write a function to print all of the leaf values of a binary tree.



1 3 5 7

BST: printLeaves()

```
void printLeaves(node *n){
  if(n == nullptr)
    return;
  if(n->left == nullptr && n->right == nullptr){
    cout << n->value << " ";
    return;
  }
  printLeaves(n->left);
  printLeaves(n->right);
}
```