Threaded Trees

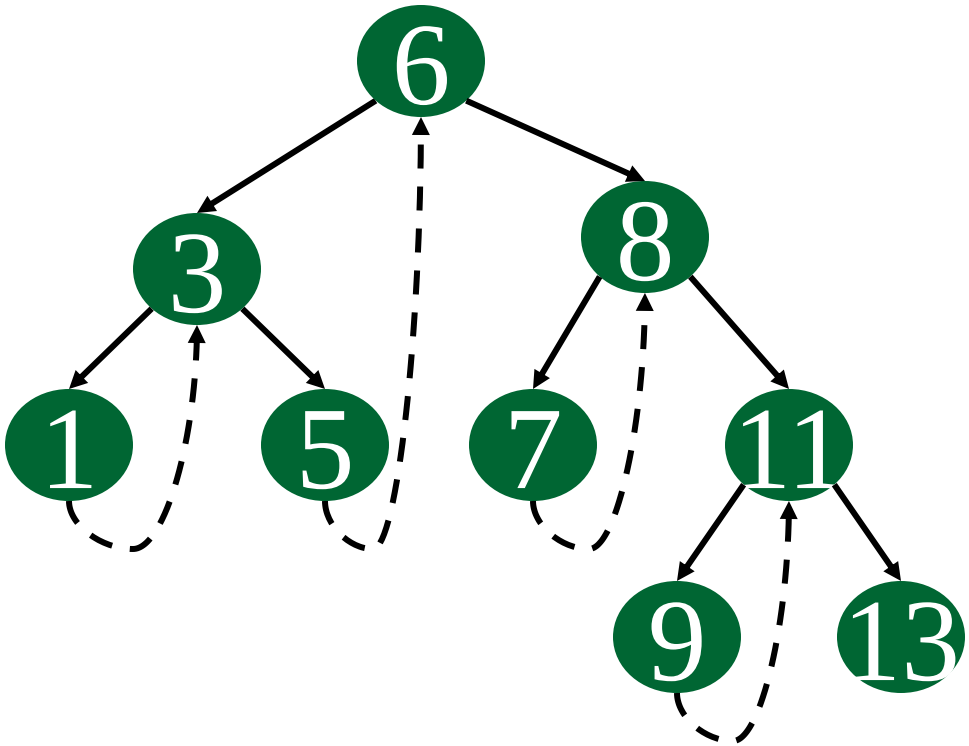
- Binary trees have a lot of wasted space: the leaf nodes each have 2 null pointers
- We can use these pointers to help us in inorder traversals
- We have the pointers reference the next node in an inorder traversal; called *threads*
- We need to know if a pointer is an actual link or a thread, so we keep a boolean for each pointer

Threaded Tree Code

- Example code:

```
class Node {
    Node left, right;
    boolean leftThread, rightThread;
}
```

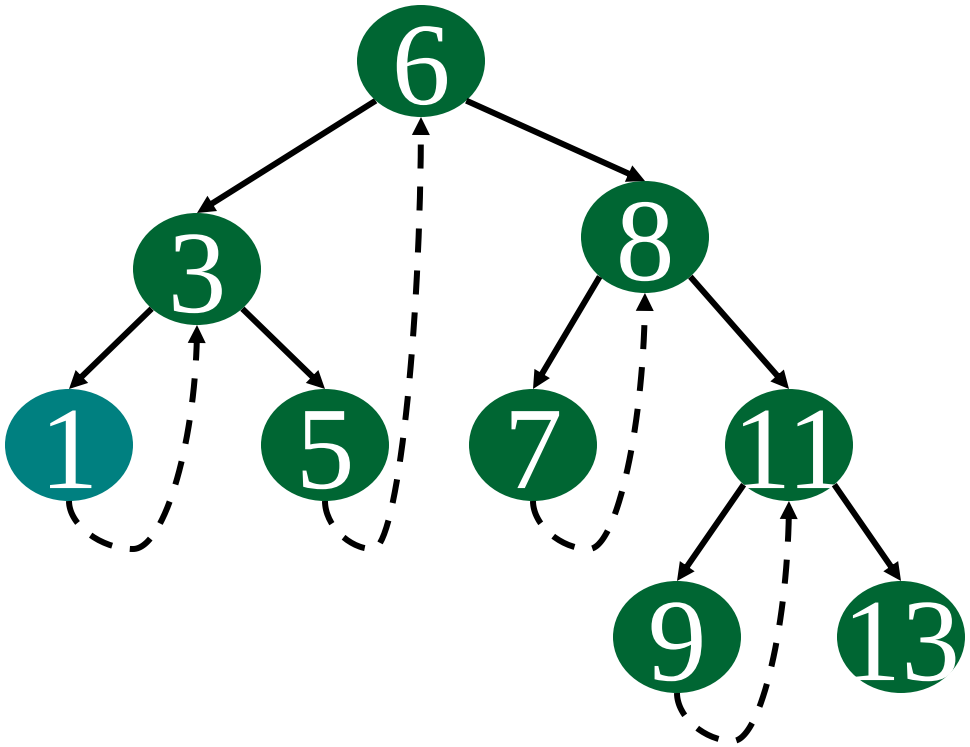
Threaded Tree Example



Threaded Tree Traversal

- We start at the leftmost node in the tree, print it, and follow its right thread
- If we follow a thread to the right, we output the node and continue to its right
- If we follow a link to the right, we go to the leftmost node, print it, and continue

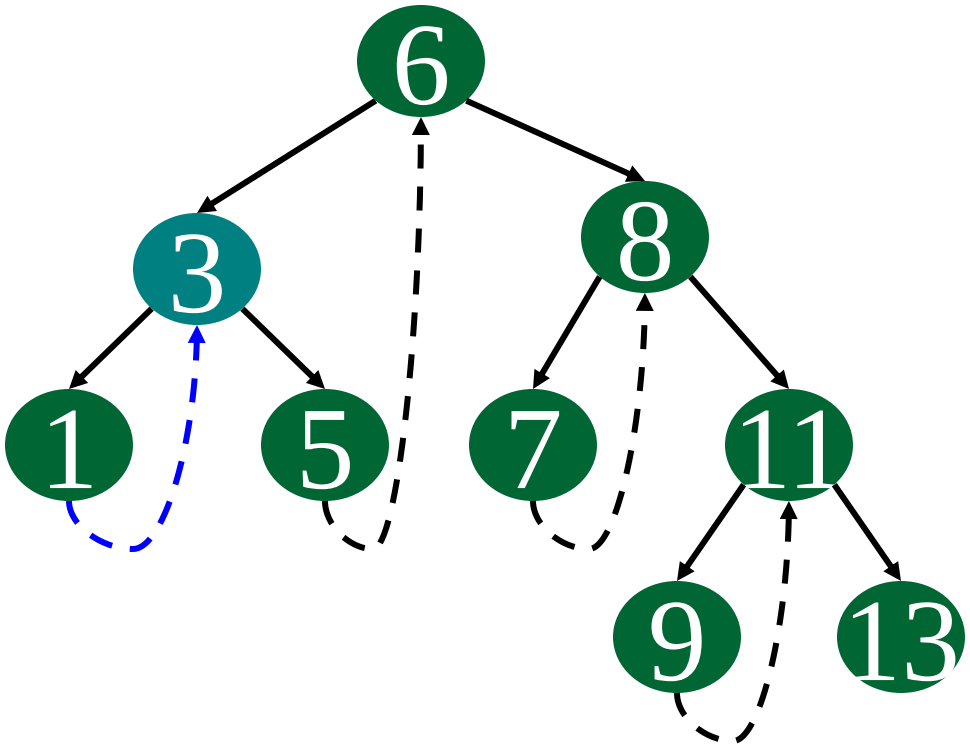
Threaded Tree Traversal



Output
1

Start at leftmost node, print it

Threaded Tree Traversal



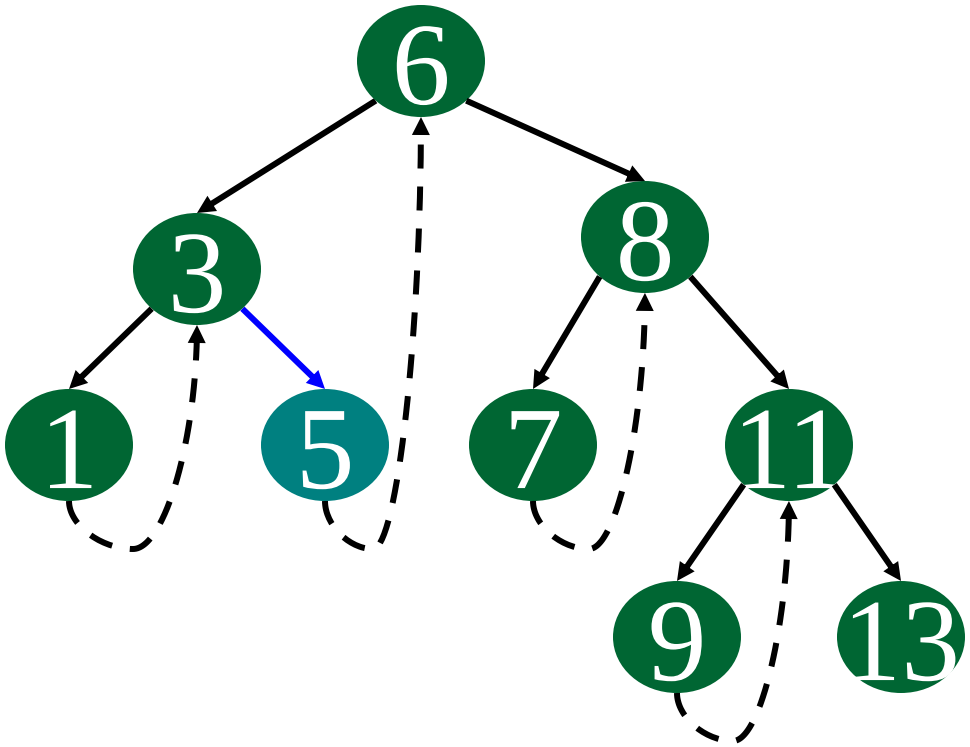
Output

1

3

Follow thread to right, print node

Threaded Tree Traversal



Output

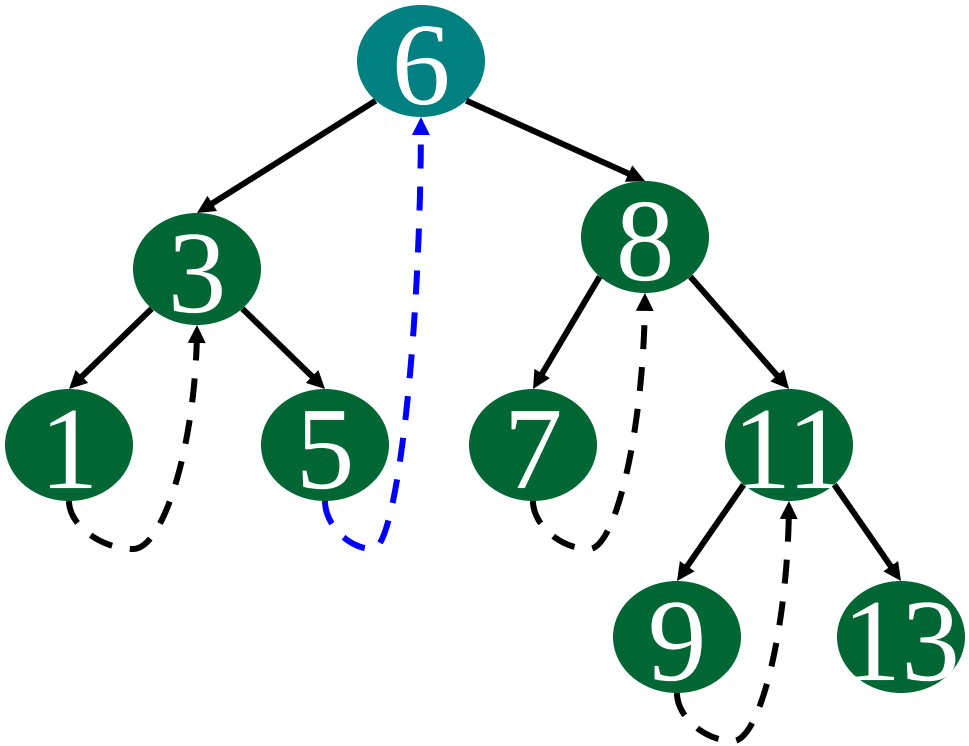
1

3

5

Follow link to right, go to leftmost node and print

Threaded Tree Traversal

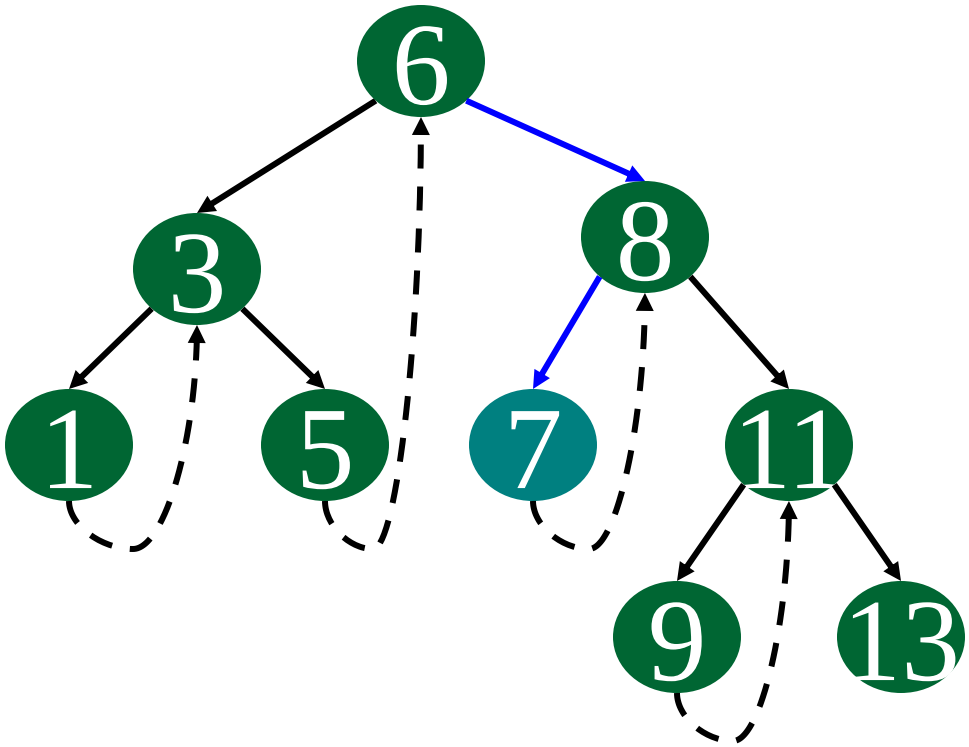


Output

1
3
5
6

Follow thread to right, print node

Threaded Tree Traversal

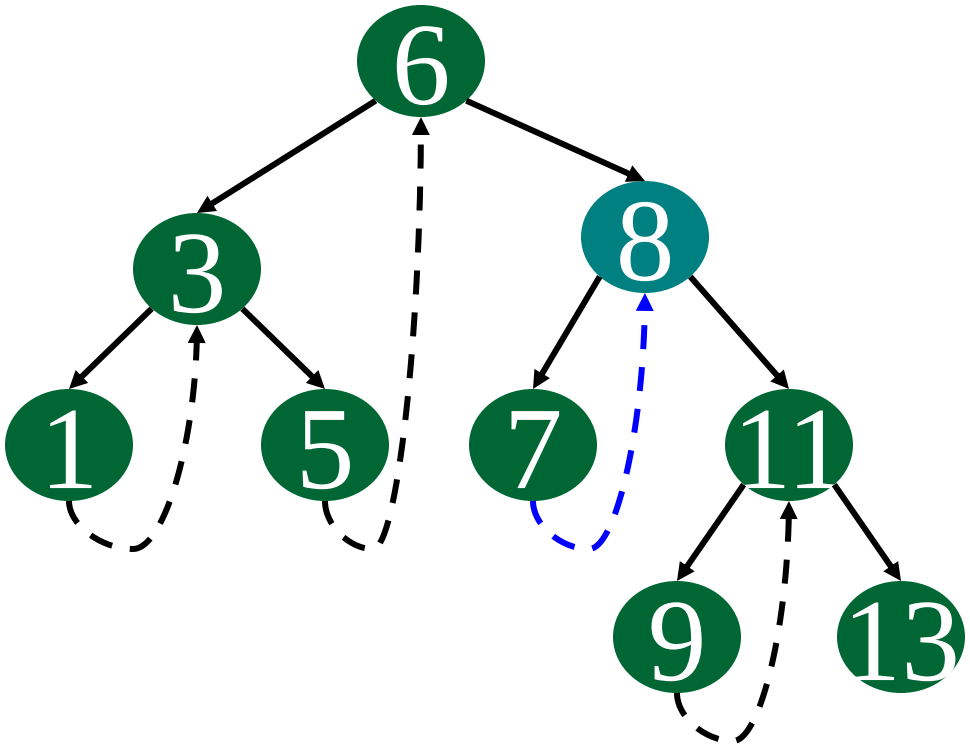


Output

1
3
5
6
7

Follow link to right, go to leftmost node and print

Threaded Tree Traversal

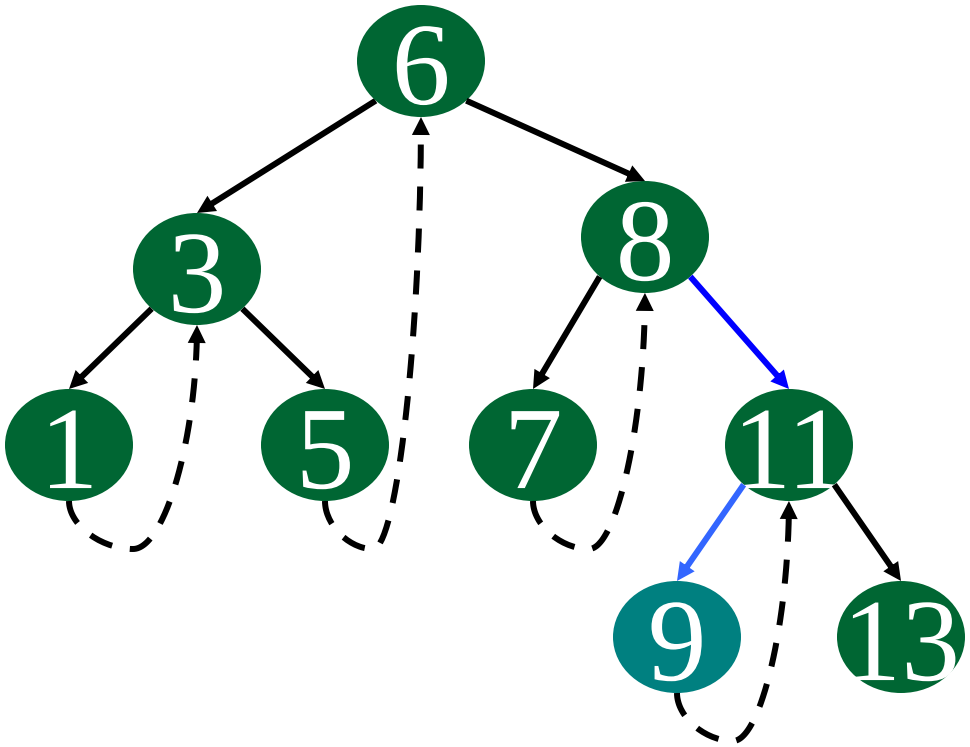


Output

1
3
5
6
7
8

Follow thread to right, print node

Threaded Tree Traversal

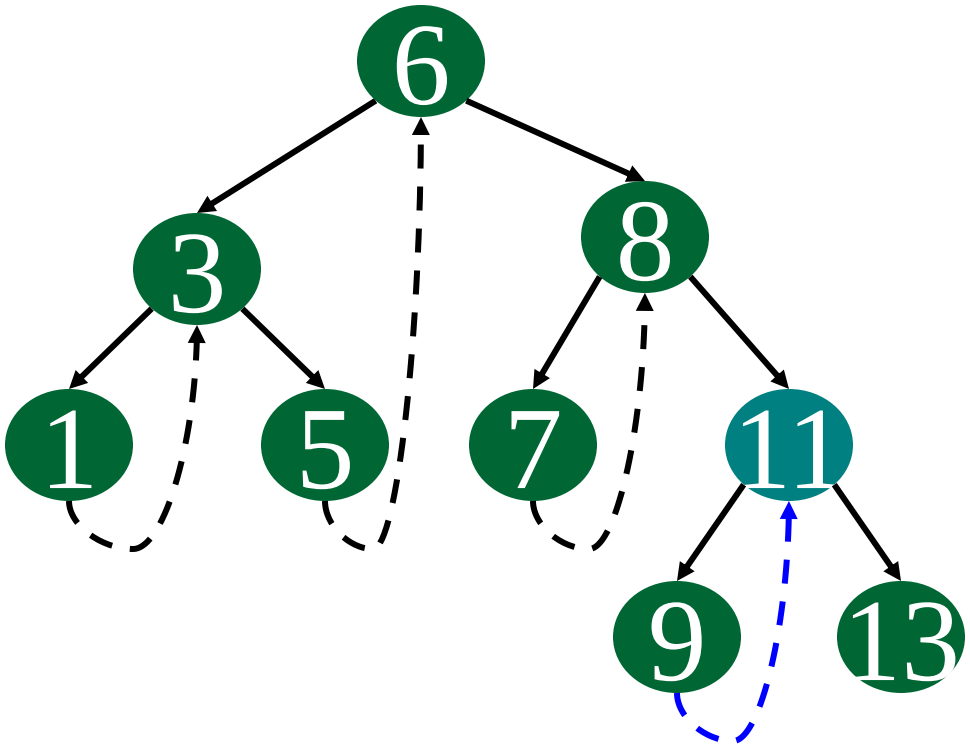


Output

1
3
5
6
7
8
9

Follow link to right, go to leftmost node and print

Threaded Tree Traversal

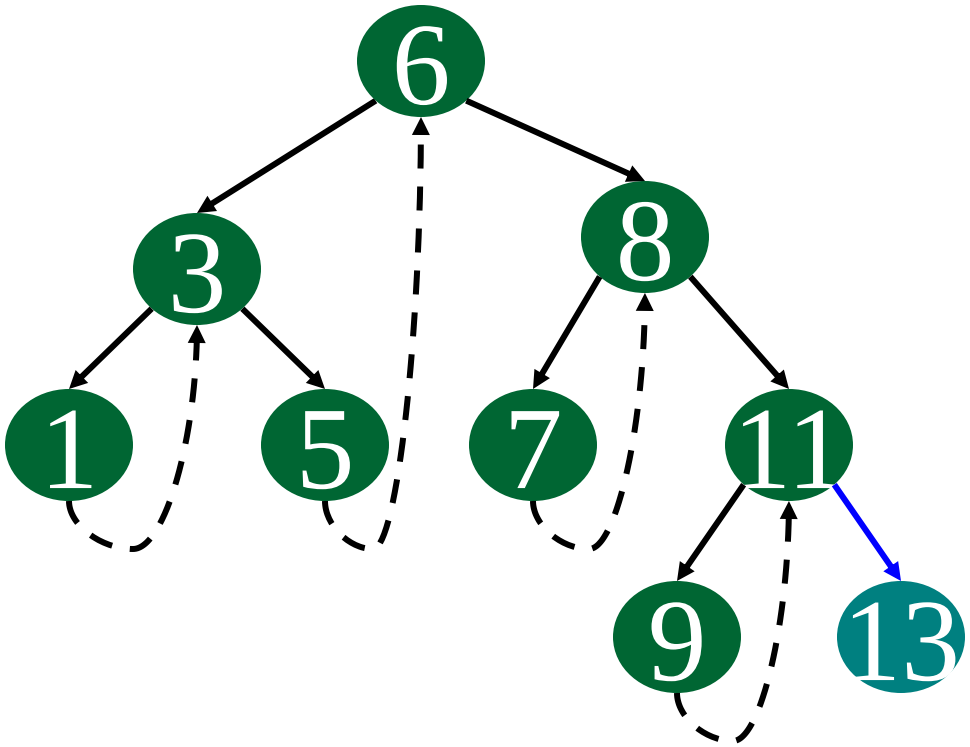


Output

1
3
5
6
7
8
9
11

Follow thread to right, print node

Threaded Tree Traversal



Output

1
3
5
6
7
8
9
11
13

Follow link to right, go to leftmost node and print

Threaded Tree Traversal Code

```
Node leftMost(Node n) {
    Node ans = n;
    if (ans == null) {
        return null;
    }
    while (ans.left != null) {
        ans = ans.left;
    }
    return ans;
}
```

```
void inOrder(Node n) {
    Node cur = leftmost(n);
    while (cur != null) {
        print(cur);
        if (cur.rightThread) {
            cur = cur.right;
        } else {
            cur = leftmost(cur.right);
        }
    }
}
```

Threaded Tree Modification

- We're still wasting pointers, since half of our leafs' pointers are still null
- We can add threads to the previous node in an inorder traversal as well, which we can use to traverse the tree backwards or even to do postorder traversals

Threaded Tree Modification