Faculty of Engineering and Tecnology

Computer Science Department

Trees_2

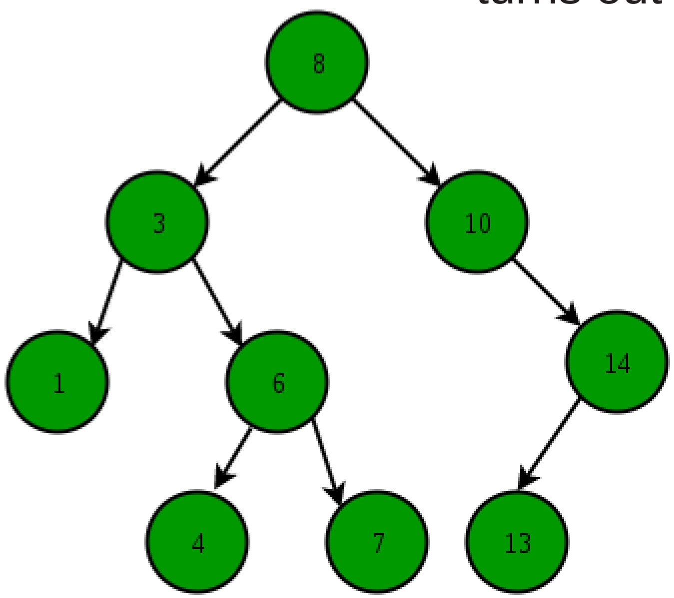
Binary Search Tree

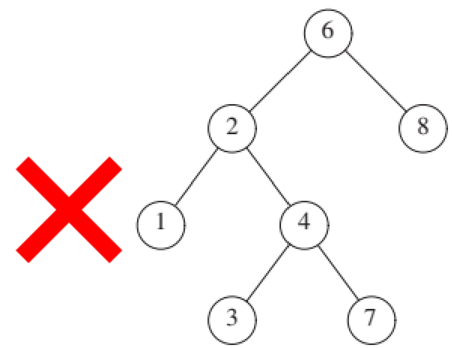
Binary Search Trees (BST)

- BST: is a binary tree that satisfies the following properties:
  - The left subtree of any node contains only nodes with keys (values) less than the node's key.
  - The right subtree of any node contains only nodes with keys greater than the node's key.
  - The left and right subtree each must also be a binary search tree.

BST

the average depth of a binary search tree turns out to be **O(log N)**





Operations on BST

- Creation
- Insertion
- Deletion
- Searching
- Traversing

BST: Implementation

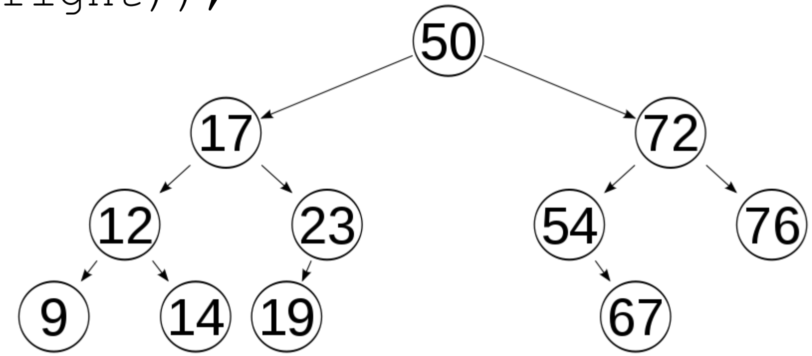
```
typedef struct tree_node *tree_ptr;
struct tree_node
{
    element_type element;
    tree_ptr left;
    tree_ptr right;
};
typedef tree_ptr BST;
```

- Routine to make an empty tree

```
BST Make_null ( void)
{
return NULL;
}
```

BST: Find

```
tree_ptr find( element_type x, BST T)
{
   if ( T == NULL)
return NULL;

if ( x < T->element)//greater than x move to right
     return ( find (x, T->left));
else                    //Less than x move to left
     if ( x > T->element )
return ( find ( x, T->right));
    else

return T;
}
```



BST: Traversal

```
//inorder
void traversal(BST T)
{
  if ( T == NULL)
       return ;
     traversal(T->left);
       printf("%d ",T->element );
     traversal(T->right);
}
```

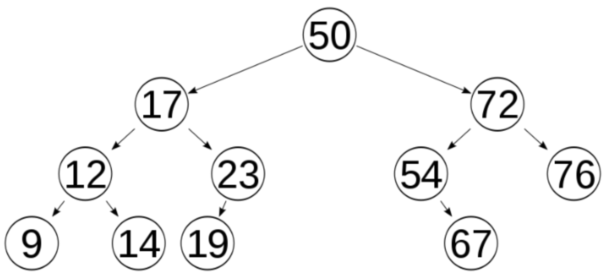
```
//Preorder
void traversal(BST T)
{
  if ( T == NULL)
       return ;
     printf("%d ",T->element );
     traversal(T->left);
     traversal(T->right);
}
```

```
//Postorder
void traversal(BST T)
{
  if ( T == NULL)
       return ;
     traversal(T->left);
     traversal(T->right);
     printf("%d ",T->element );
}
```

None- traversal (post order) :

```
struct Node {
    int data;
    struct Node *left, *right;
    bool visited;
};

void postorder(struct Node* root)
{
    struct Node* temp = root;  // Save head in temp tree

     while (temp && temp->visited == false) {

        // Visited left subtree
        if (temp->left && temp->left->visited == false)
            temp = temp->left;

        // Visited right subtree
        else if (temp->right && temp->right->visited == false)
            temp = temp->right;

        // Print node
        else {
            printf("%d ", temp->data);
            temp->visited = true;
            temp = root;        }
    }
}
```

```
struct Node* newNode(int data)
{
    struct Node* node = new
Node;
    node->data = data;
    node->left = NULL;
    node->right = NULL;
    node->visited = false;
    return (node);
}
```



BST: Insertion

The idea is to do iterative level order traversal of the given tree.

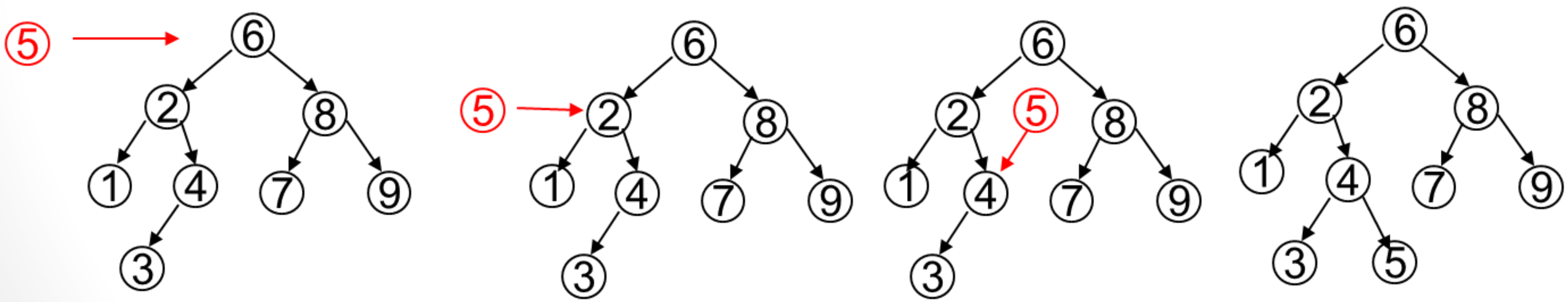
- **If we find a node whose left child is empty**

  we make new key **as left child** of the node.

- **Else if we find a node whose right child is empty**

  we make new key **as right child**.

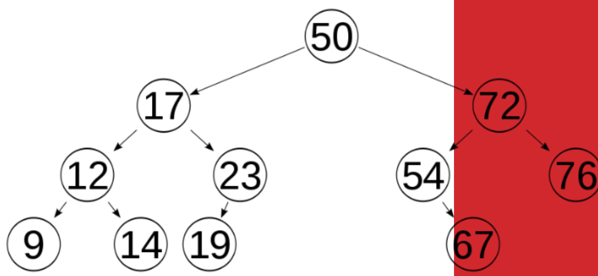
- We keep traversing the tree until we find a node whose either left or right is empty.



BST: Insertion

```
BST insert ( BST T, element_type x)
{                                        //Tree empty, insert first element

    if ( T == NULL ) {
                  T = ( BST) malloc (sizeof(struct tree_node));

                 if ( T == NULL )
                        printf (" Out of space!!!");
                else
                {
                       T->element = x;
                       T->left = T->right = NULL;
                 }
          }
else                                 //Tree not empty, check to insert to left or right.
    if ( x < T->element)
      T->left = insert ( T->left , x);
else
      if ( x > T->element)
         T->right = insert(T->right, x);
return T;

}
```

Example: Insert 8,28,52



BST: Deletion

When we delete a node, three possibilities arise.

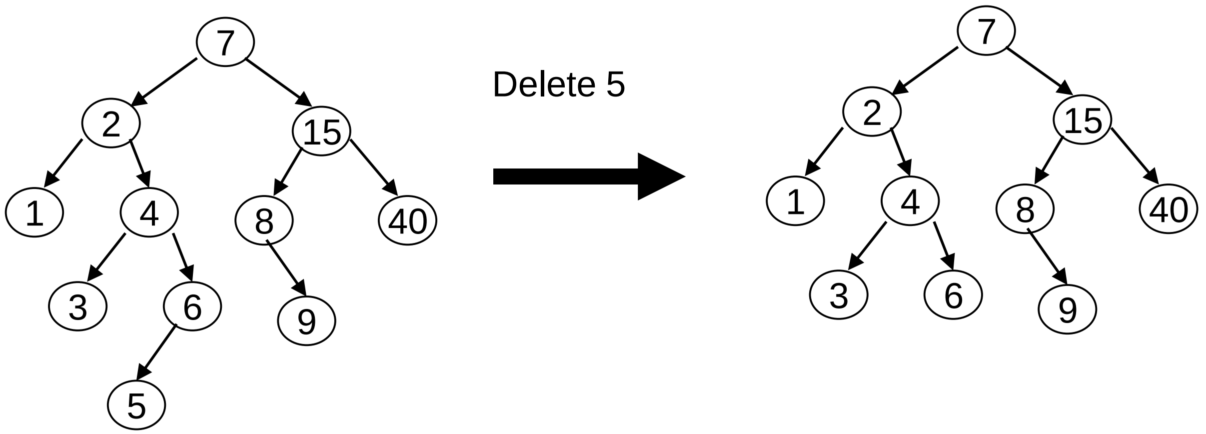
1) Node to be deleted is leaf: Simply remove from the tree.

2) Node to be deleted has only one child: Copy the child to the node and delete the child

3) Node to be deleted has two children*:* Find **in order successor of the node**. Copy contents of the **in order** successor to the node and delete the **in order successor**. Note that in order predecessor can also be used.

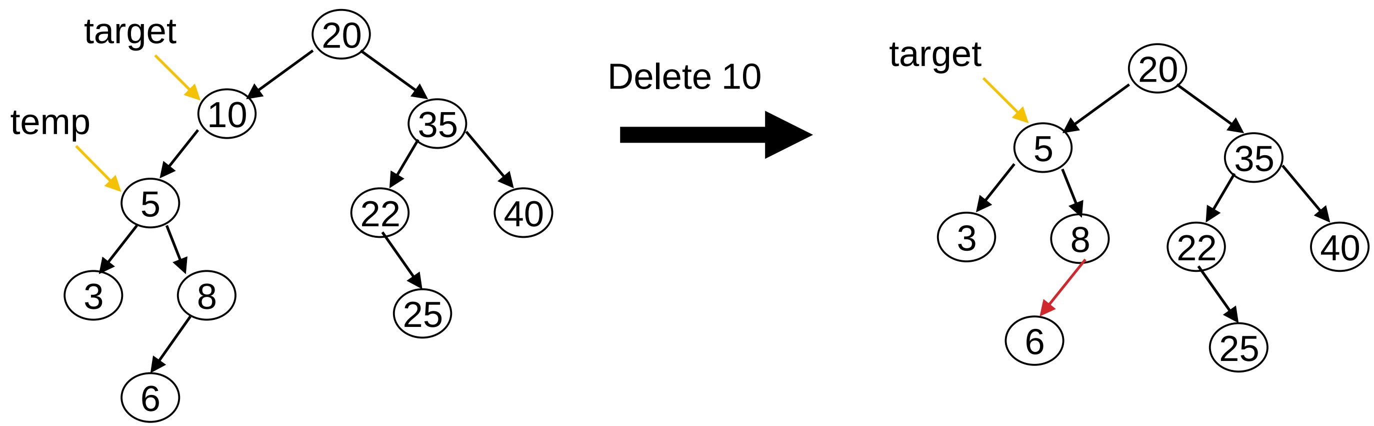
BST: Deletion a leaf

- Example: Delete 5 in the tree below:



BST: Deleting a one-child node

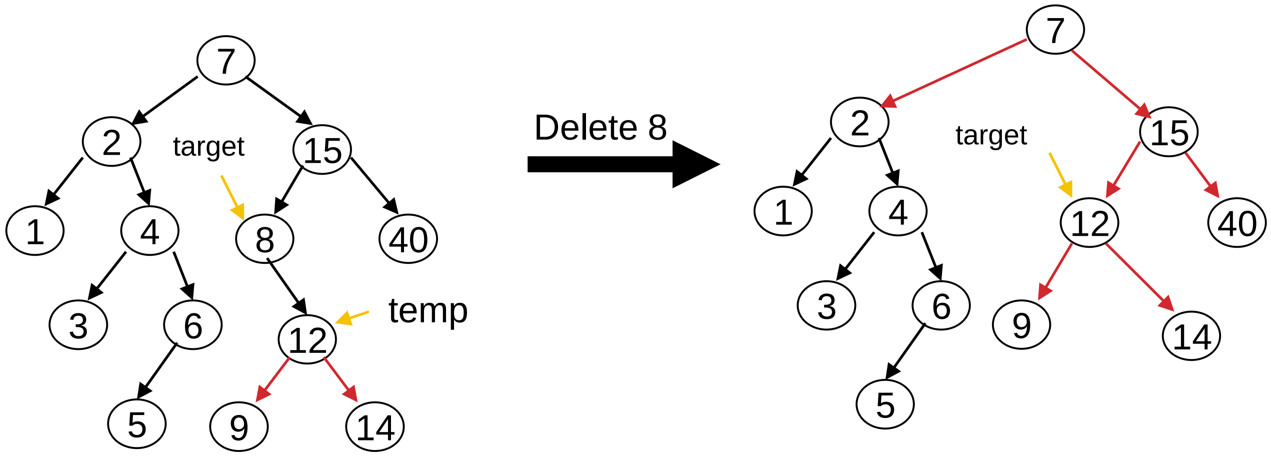
- CASE 2: THE NODE TO BE DELETED HAS ONE NON-EMPTY CHILD
  (a) The right subtree of the node x to be deleted is empty.
- Example:



BST: Deleting a one-child node

(b) The left subtree of the node x to be deleted is empty.

Example:

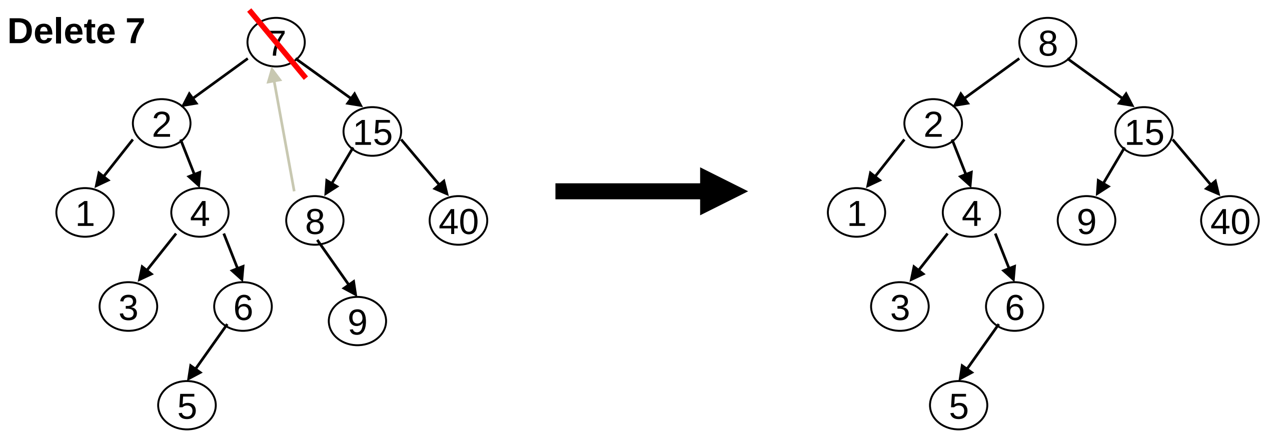


BST: Deleting a two-child node

METHOD#1: DELETION BY COPYING the minimum:

Copy the **minimum** key in the **right** subtree of x to the node x, then delete the one-child or leaf-node with this minimum key.

- Example:

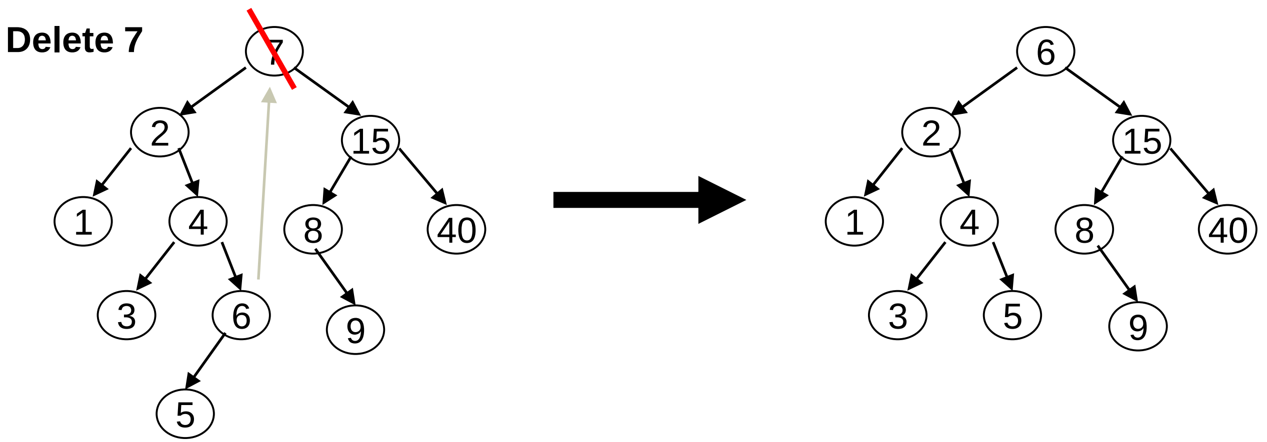


BST: Deleting a two-child node

METHOD#2: DELETION BY COPYING the maximum

Copy the **maximum** key in the **left** subtree of x to the node x, then delete the one-child or leaf-node with this **maximum** key.

- Example:



BST: Finding the minimum

Recursive implementation of find_min for binary search trees

```
tree_ptr find_min( BST T)
   {
     if ( T == NULL )        //empty tree
      return NULL;
  else
    if ( T->left == NULL )   //node itself
     return ( T );
  else
    return ( find_min ( T->left )); //find min recursive

}
```

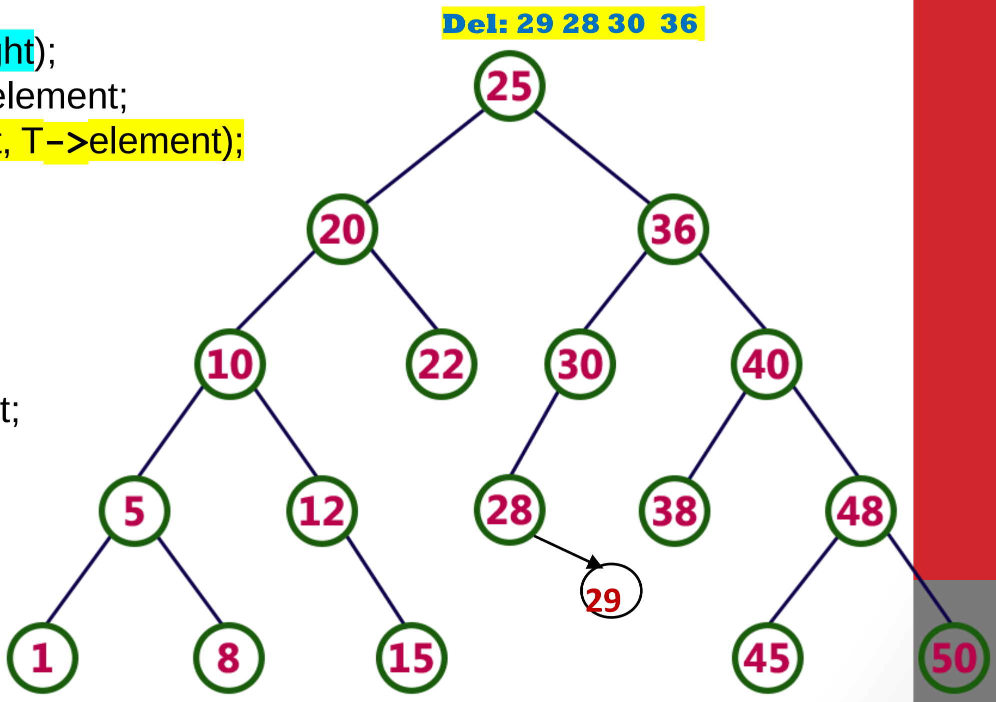
Nonrecursive implementation of find_max for binary search trees

```
tree_ptr find_max( BST T)
{
     if ( T != NULL )

     while ( T->right != NULL )
         T = T->right;
     return T;
}
```

Home Work: Rebuild two above functions in alternative way

BST: Delete function

```
tree_ptr delete ( BST T, int x)
    {
        tree_ptr    tmp_cell, child;
            if ( T == NULL )
                    printf(" Element not found" );
            else if ( x < T->element)
                    T->left = delete(T->left, x);
            else if ( x > T->element)
                    T->right = delete(T->right, x);
            else if ( T->left && T->right )        //found element and has (right ,left) elements
            {
                    tmp_cell = find_min(T->right);
                    T->element = tmp_cell->element;
                    T->right = delete(T->right, T->element);
            }
            else
            {
                    tmp_cell = T;
                    if ( T->left == NULL)
                            child = T->right;
                    if (T->right == NULL)
                            child = T->left;
                    free ( tmp_cell);
                    return child;
            }
        return T;
}
```



Exercise :Constructing binary tree from in order and post order traversals

Post-order : 17 40 38 48 47 45 53 58 65 62 55 50

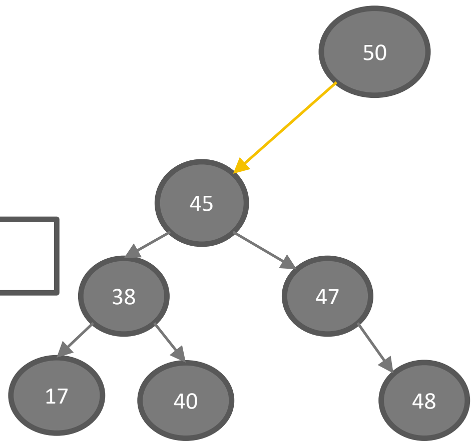
In-order : 17 38 40 45 47 48 50 53 55 58 62 65

Left Subtree

Post-order : 17 40 38 48 47 45

In-order :17 38 40 45 47 48

Post-order : 17 40 38



Exercise :Constructing binary tree from in order and post order traversals

Post-order : 17 40 38 48 47 45 53 58 65 62 55 50

In-order : 17 38 40 45 47 48 50 53 55 58 62 65

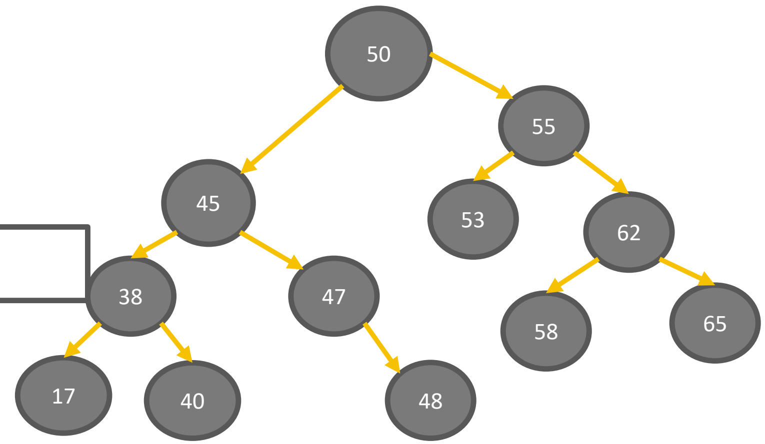
Right Subtree

Post-order 53 58 65 62 55

In-order : 53 55 58 62 55

Post-order 58 65 62

In order : 58 62 55



THANK YOU