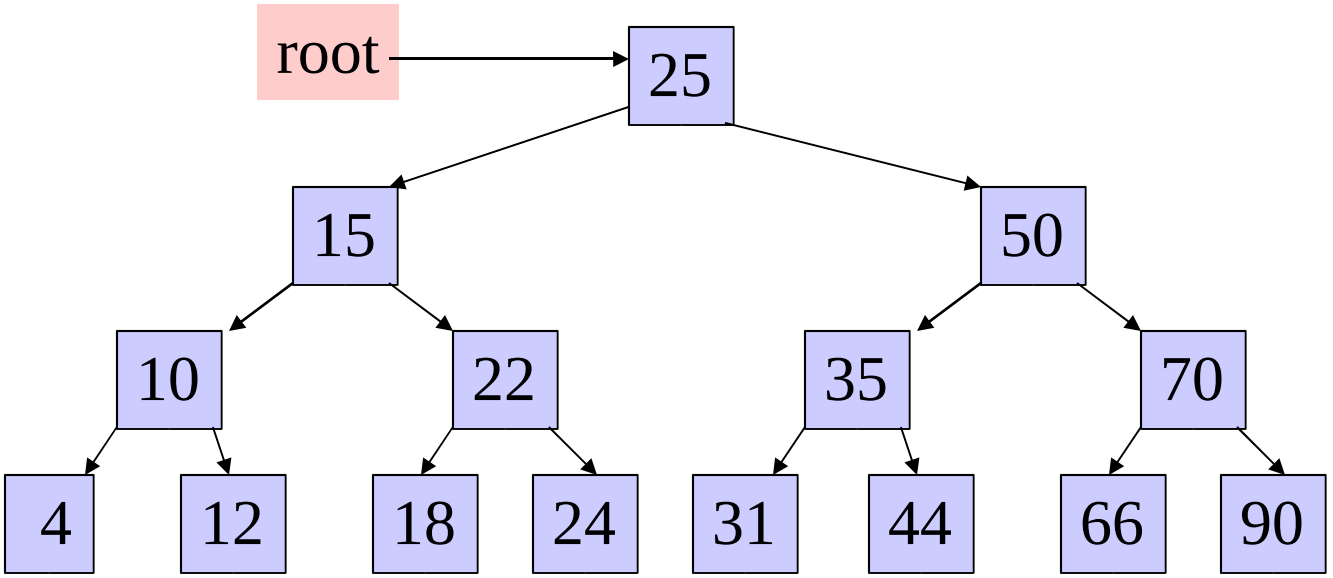
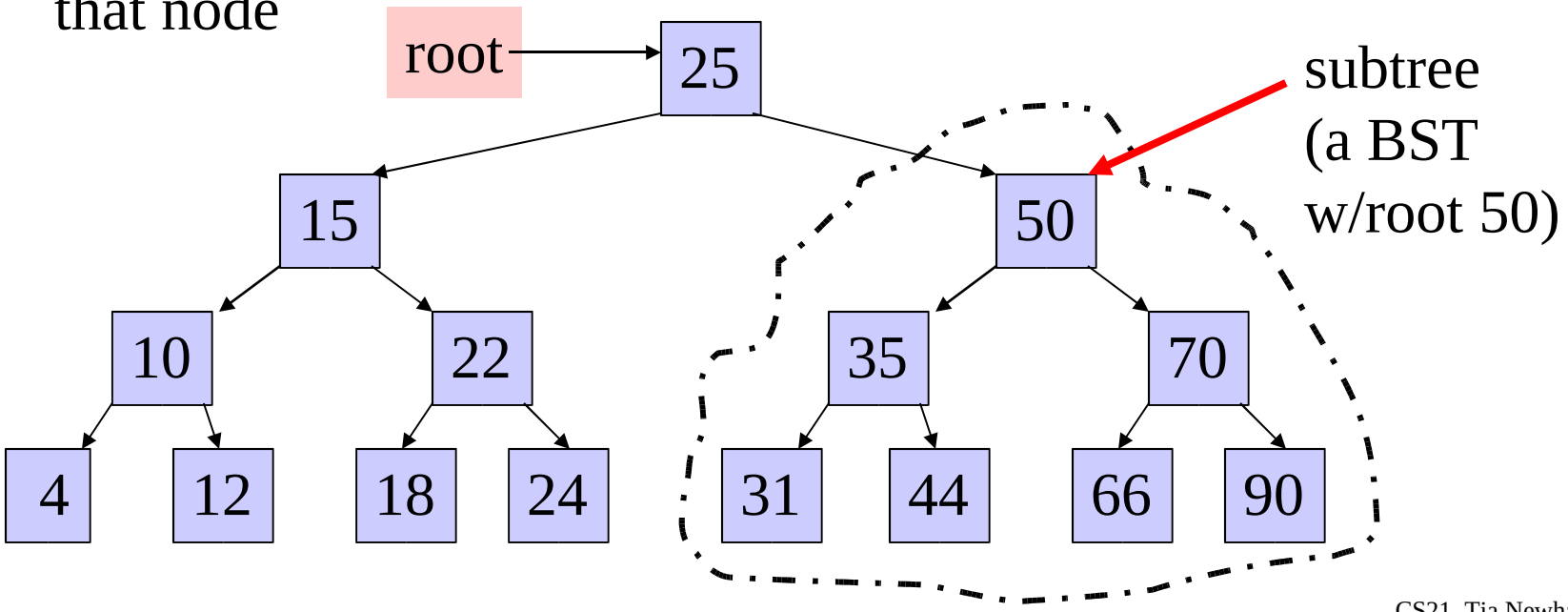
Binary Search Trees (BST)

1. Hierarchical data structure with a single pointer to root node
2. Each node has at most two child nodes (a left and a right child)
3. Nodes are organized by the Binary Search property:
   - Every node is ordered by some key data field(s)
   - For every node in the tree, its key is greater than its left child's key and less than its right child's key



Some BST Terminology

1. The Root node is the top node in the hierarchy
2. A Child node has exactly one Parent node, a Parent node has at most two child nodes, Sibling nodes share the same Parent node (ex. node 22 is a child of node 15)
3. A Leaf node has no child nodes, an Interior node has at least one child node (ex. 18 is a leaf node)
4. Every node in the BST is a Subtree of the BST rooted at that node



Implementing Binary Search Trees

Self-referential struct is used to build Binary Search Trees

```
struct bst_node {
        int data;
        struct bst_node *left;
        struct bst_node *right;
};
typedef struct bst_node bst_node;
```

- **`left`** holds the address of the left child
- **`right`** holds the address of the left child
- one or more data fields, a subset of which are the key fields on which the nodes are ordered in the BST
- Single pointer to the root of the BST
  - All BST nodes can be accessed through root pointer by traversing left and right bst_node pointers

Operations on BST

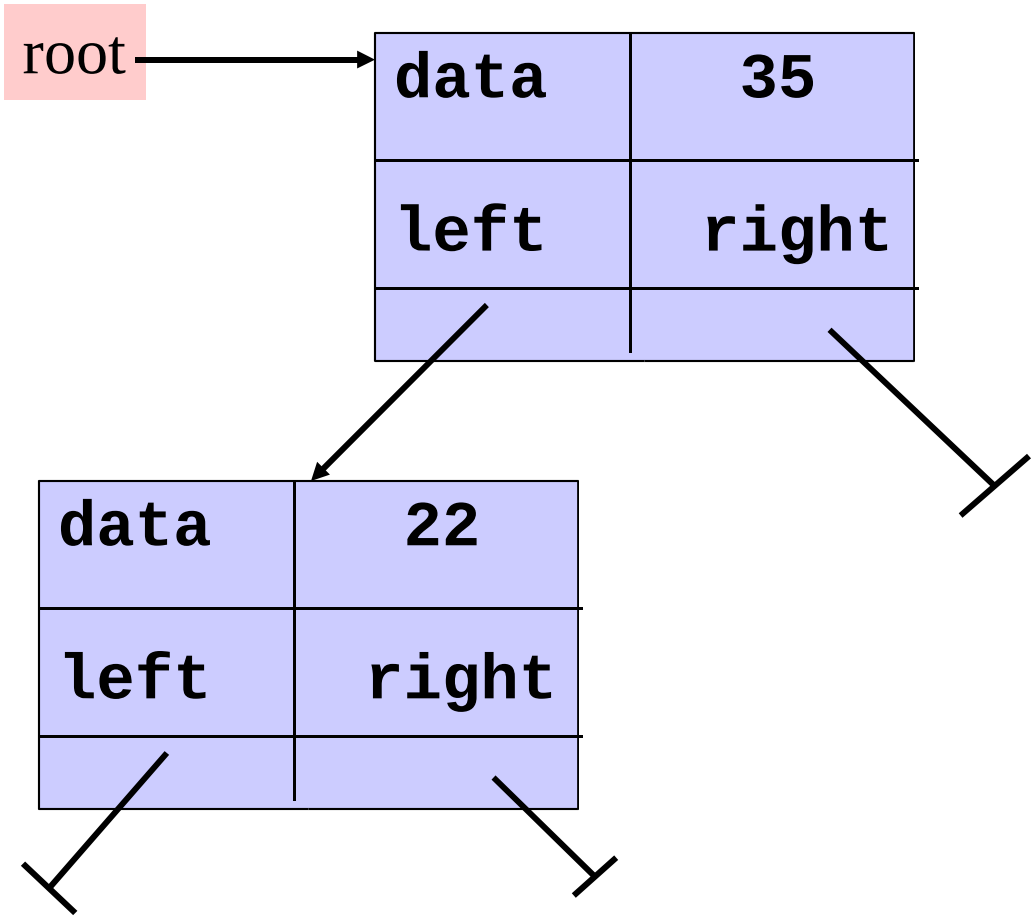
- Naturally recursive:
  - Each node in the BST is itself a BST
- Some Operations:
  - Create a BST
  - Find node in BST using its key field
  - Add a node to the BST
  - Traverse the BST
    visit all the tree nodes in some order

Create a BST

```
/* a function that creates, initializes,
 * and returns a new bst_node
 */
bst_node *CreateANode(int val) {
   bst_node *newnode;

   newnode = malloc(sizeof(bst_node);
   if( newnode == NULL) {
         return NULL;
   }
   newnode->data = val;
   newnode->right = newnode->left = NULL;
   return newnode;
}
```

```
bst_node *root = NULL;   // an empty BST
root = CreateANode(35);  // a BST w/one node
If(root != NULL) {       // add a left child
  root->left = CreateANode(22);
}
```



Find a Node into the BST

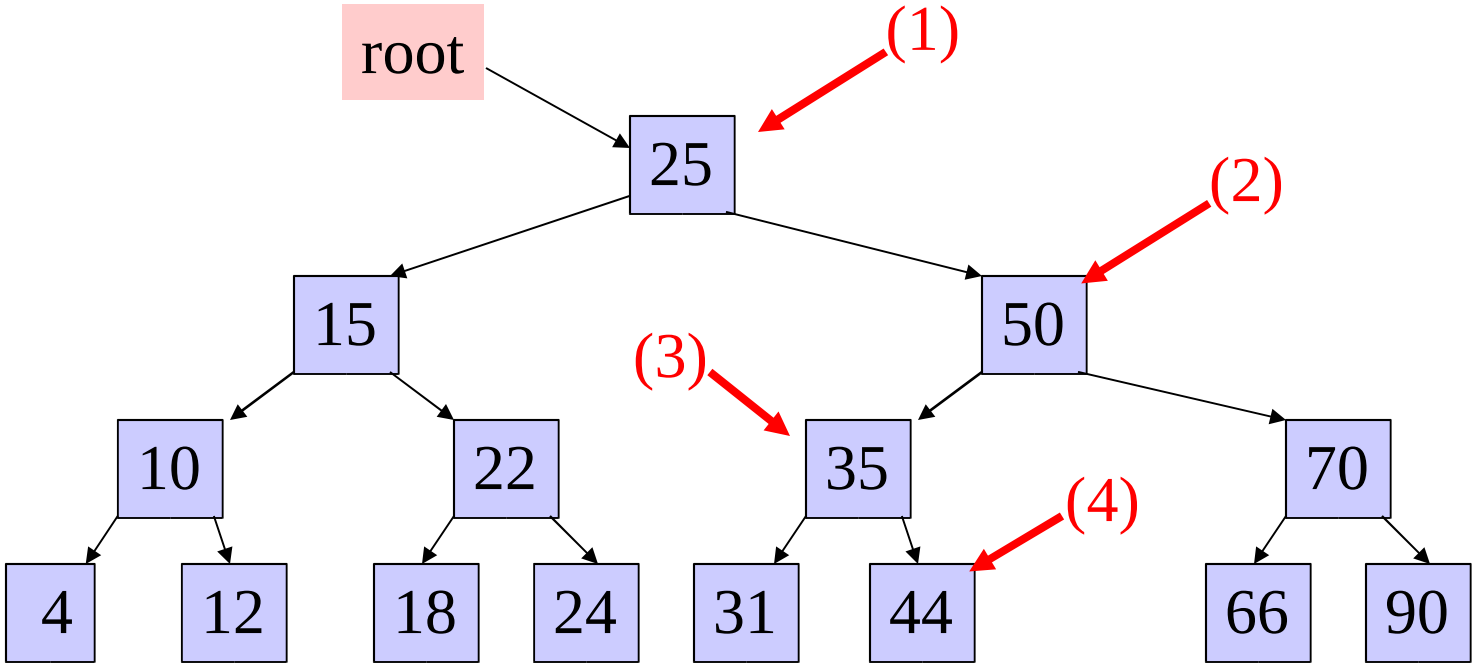
- Use the search key to direct a recursive binary

  search for a matching node

  1. Start at the root node as current node
  2. If the search key's value matches the current node's key then found a match
  3. If search key's value is greater than current node's
     1. If the current node has a right child, search right
     2. Else, no matching node in the tree
  4. If search key is less than the current node's
     1. If the current node has a left child, search left
     2. Else, no matching node in the tree

Example: search for 45 in the tree:

1. start at the root, 45 is greater than 25, search in right subtree
2. 45 is less than 50, search in 50's left subtree
3. 45 is greater than 35, search in 35's right subtree
4. 45 is greater than 44, but 44 has no right subtree so 45 is not
   in the BST



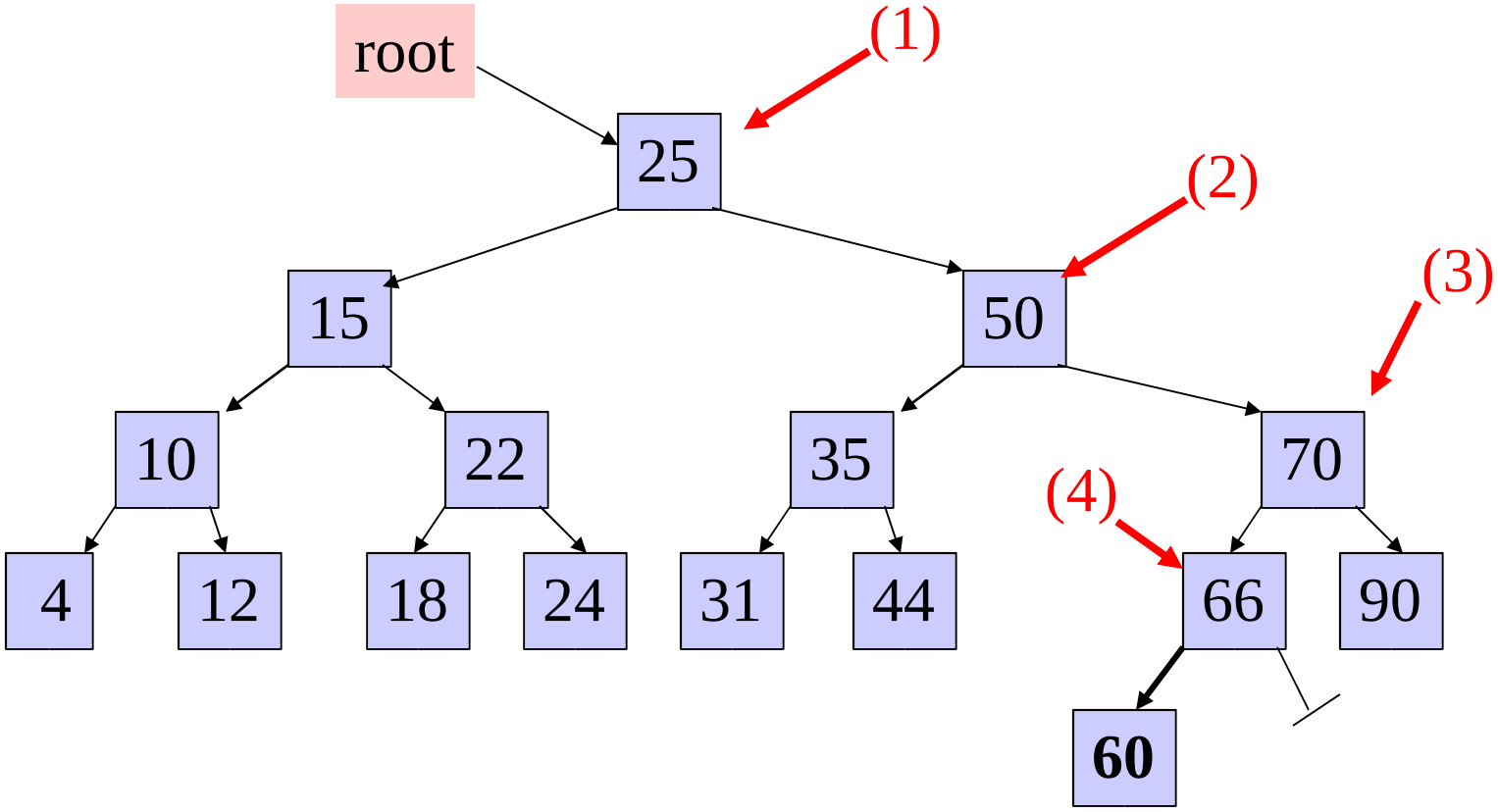
Insert Node into the BST

Always insert new node as leaf node

2. Start at root node as current node
3. If new node's key < current's key
    1. If current node has a left child, search left
    2. Else add new node as current's left child
4. If new node's key > current's key
    1. If current node has a right child, search right
    2. Else add new node as current's right child

Example: insert 60 in the tree:

1. start at the root, 60 is greater than 25, search in right subtree
2. 60 is greater than 50, search in 50's right subtree
3. 60 is less than 70, search in 70's left subtree
4. 60 is less than 66, add 60 as 66's left child



Traversals

- Visit every node in the tree and perform some operation on it

  (ex) print out the data fields of each node

- Three steps to a traversal
  1. Visit the current node
  2. Traverse its left subtree
  3. Traverse its right subtree
- The order in which you perform these three steps results in different traversal orders:
  - Pre-order traversal: (1) (2) (3)
  - In-order traversal: (2) (1) (3)
  - Post-order traversal: (2) (3) (1)

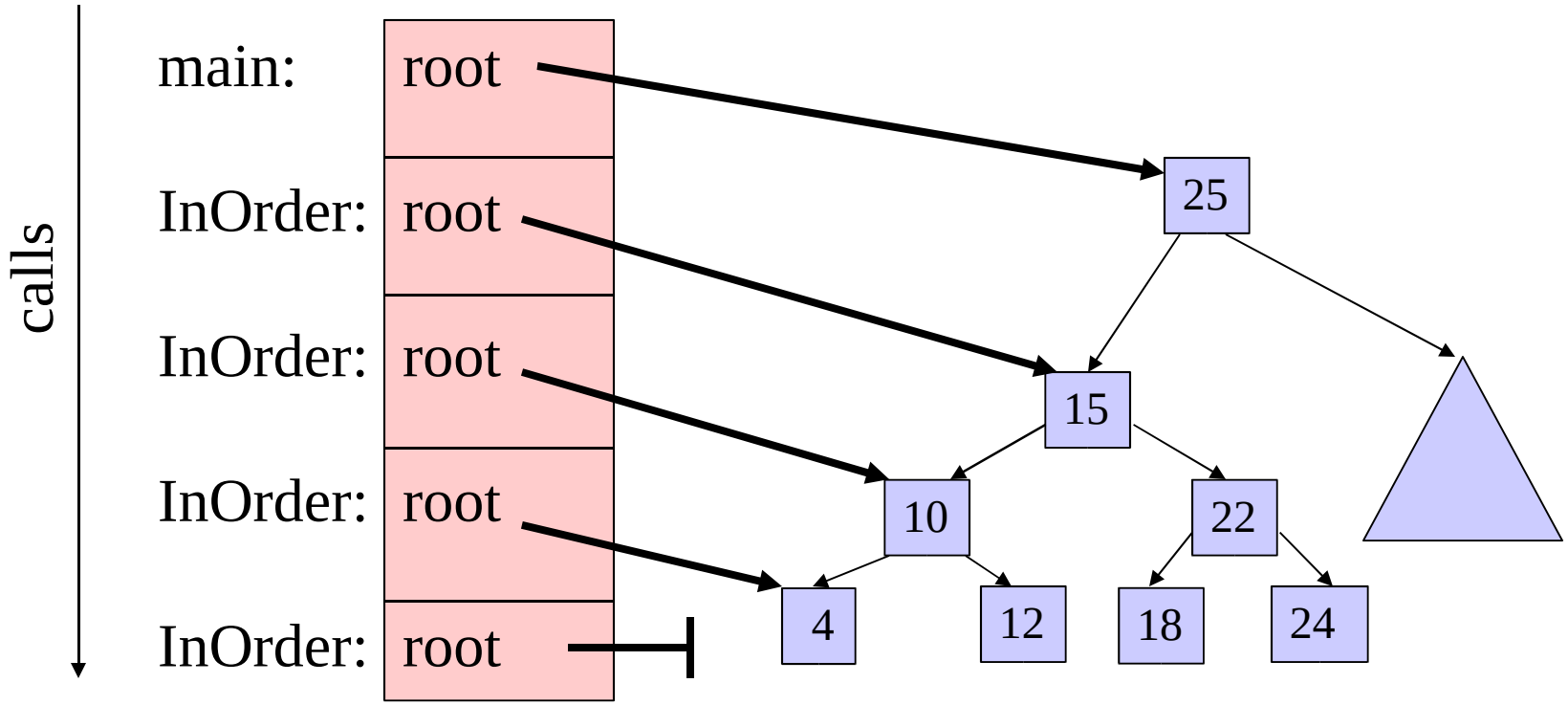
Traversal Code

```
/* recursive version of in-order traversal
 * the iterative version is ugly
 */
void InOrder(bst_node *root) {
  if(root == NULL) {
     return;
  }
  InOrder(root->left);// traverse lft subtree
  Visit(root);        // visit node
  InOrder(root->right);// traverse rt subtree
}
```

```
// in main: a call to InOrder passing root
InOrder(root);

// The call stack after the first few
// recursive calls to InOrder(root->left):
```

Call Stack (drawn upside down):



Traversal Examples

InOrder(root) visits nodes in the following order:

4, 10, 12, 15, 18, 22, 24, 25, 31, 35, 44, 50, 66, 70, 90

A Pre-order traversal visits nodes in the following order:

25, 15, 10, 4, 12, 22, 18, 24, 50, 35, 31, 44, 70, 66, 90

A Post-order traversal visits nodes in the following order:

4, 12, 10, 18, 24, 22, 15, 31, 44, 35, 66, 90, 70, 50, 25