CS 261 – Data Structures

BST Iterator

or

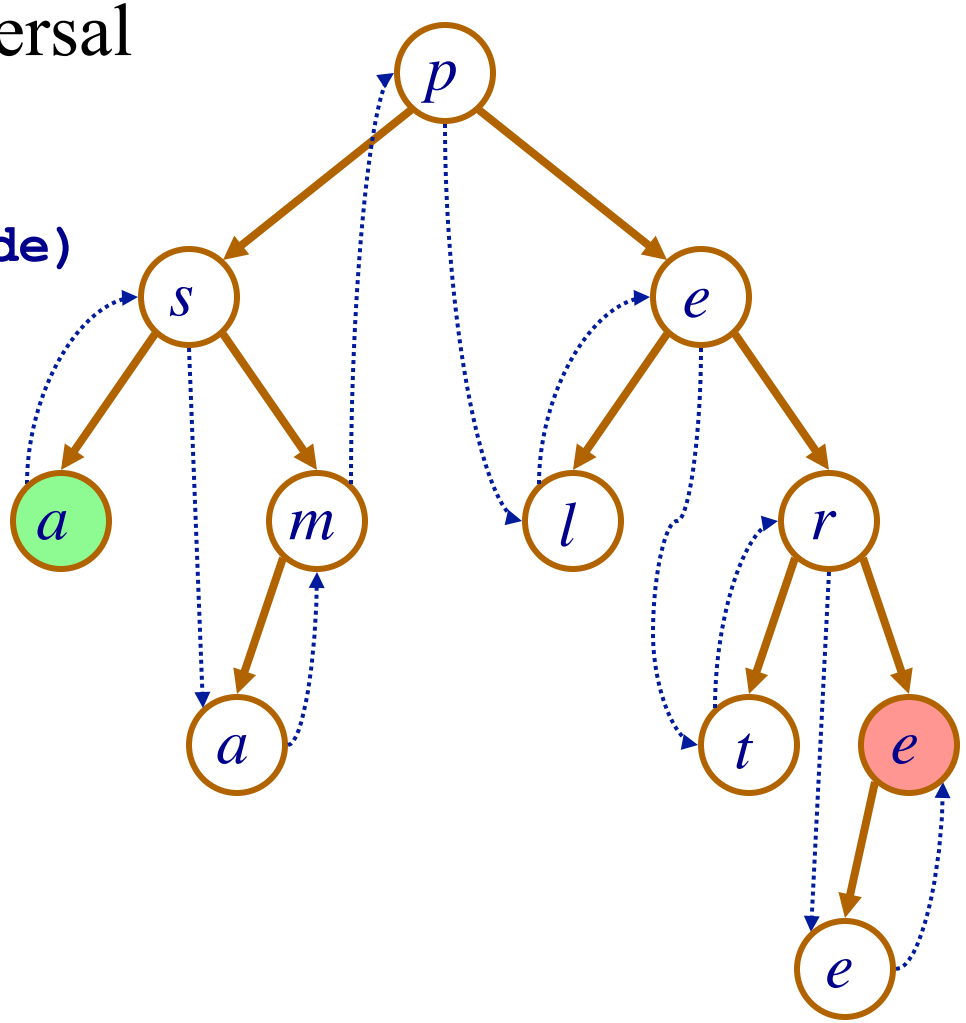
How to traverse the tree

without recursion?

Example: In-Order Traversal

- We can traverse the tree using a recursion
- For example: in-order traversal

```
void inorder(BinaryNode node)
{
    if (node != null){
      inorder(node.left);
      process (node.obj);
      inorder(node.rght);
    }
  }
```



Example result: a sample tree

Iterator Implementation

But, what if we cannot use recursion?
For example, the end user is not familiar

```
Initialize(&tree, &itr);
while( HasNext(&itr) ){
    Process( Next(&itr) );
}
```

Simple Iterator

- Recursively traverse the tree, placing all node values into a linked list,
- Then, use a linked list iterator
- Problem: duplicates data, uses twice as much space
- Can we do better?

Yes → Use a Stack

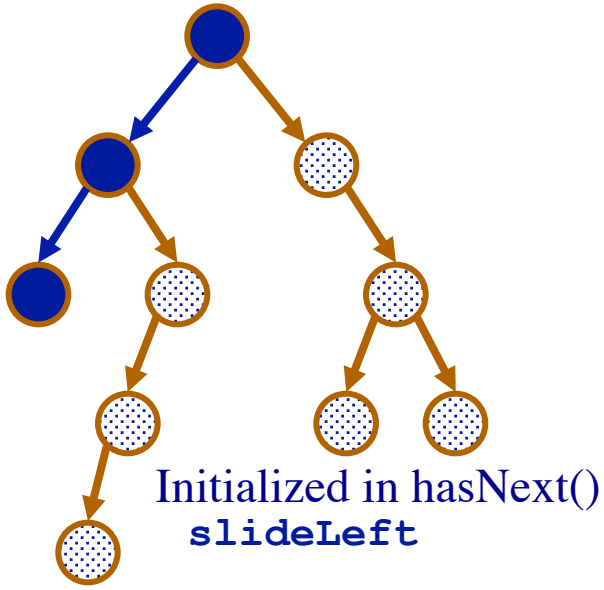
- **Simulate recursion using a stack**
- Suppose we want to iterate as **in-order**
- **Then:** Stack a path as we traverse down to the smallest (leftmost) element
- Other iterations (post-order, pre-order) can also be implemented

In-Order: Example

On stack (lowest node at top).

Not yet visited.

Enumerated (order indicated).

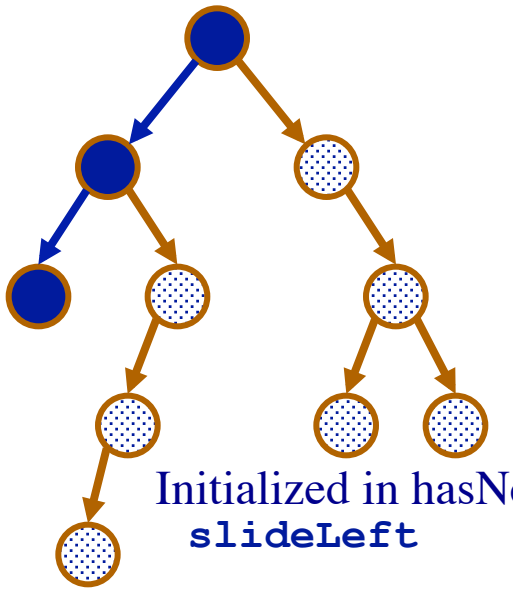


In-Order: Example

On stack (lowest node at top).

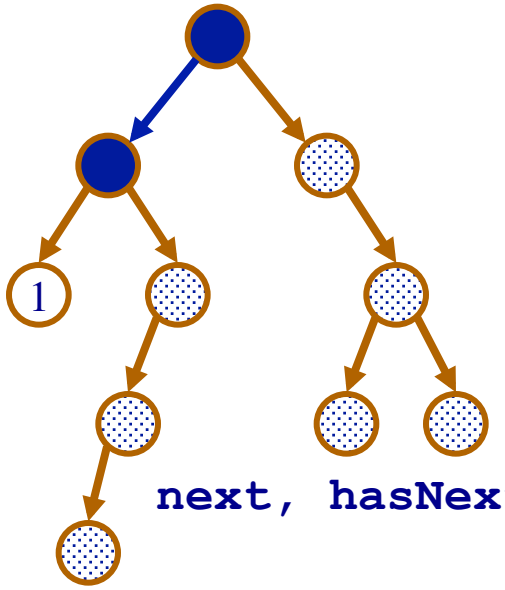
Not yet visited.

Enumerated (order indicated).



Initialized in hasNext()

`slideLeft`



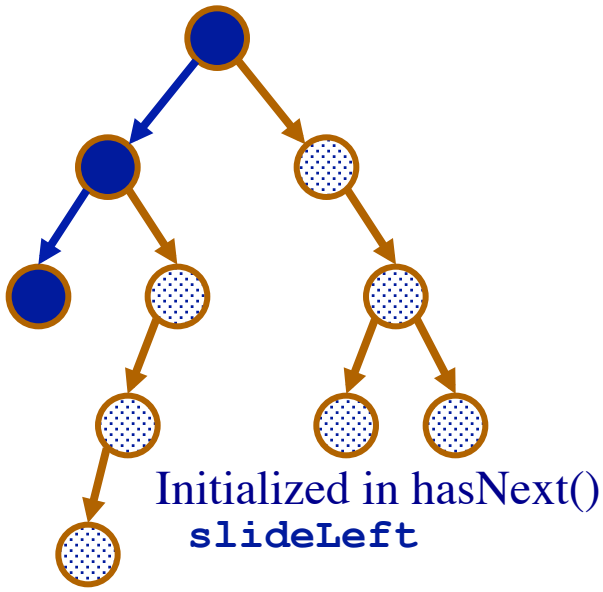
`next, hasNext`

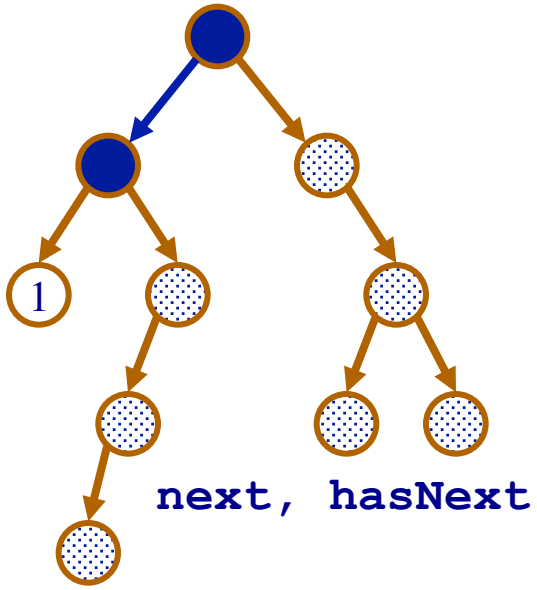
In-Order: Example

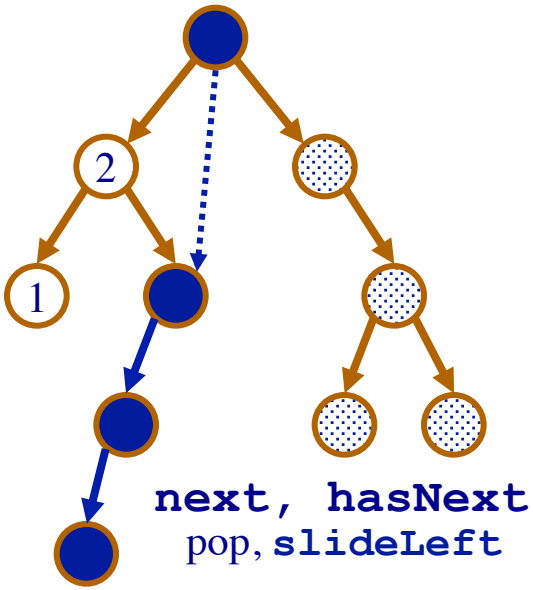
On stack (lowest node at top).

Not yet visited.

Enumerated (order indicated).





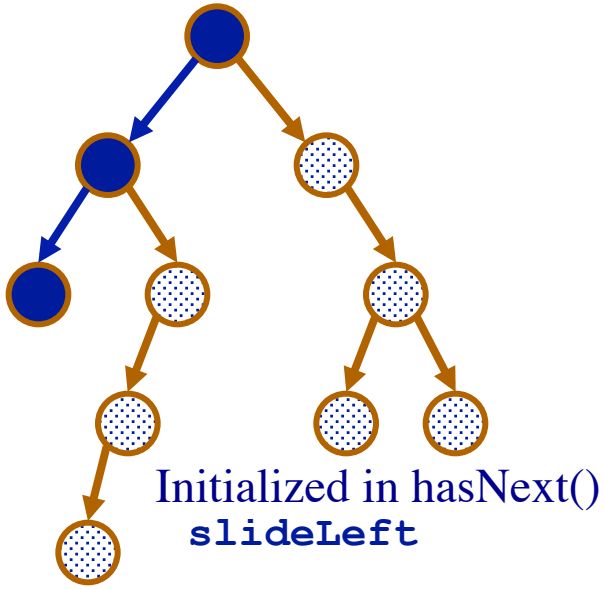


In-Order: Example

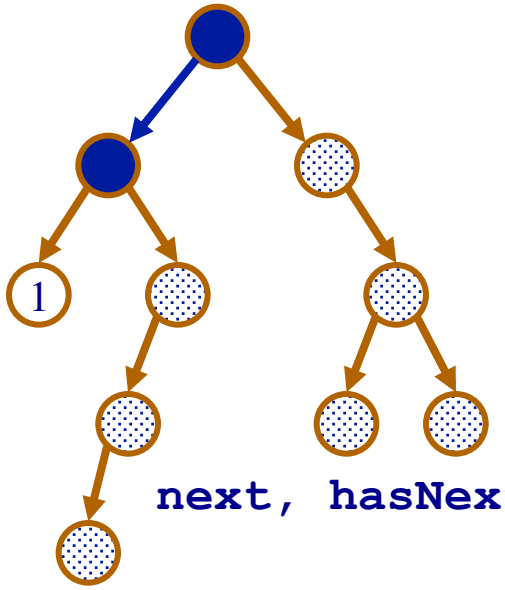
On stack (lowest node at top).

Not yet visited.

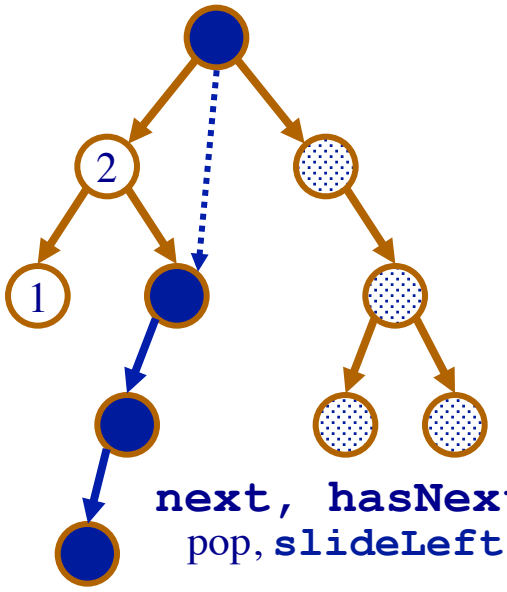
Enumerated (order indicated).



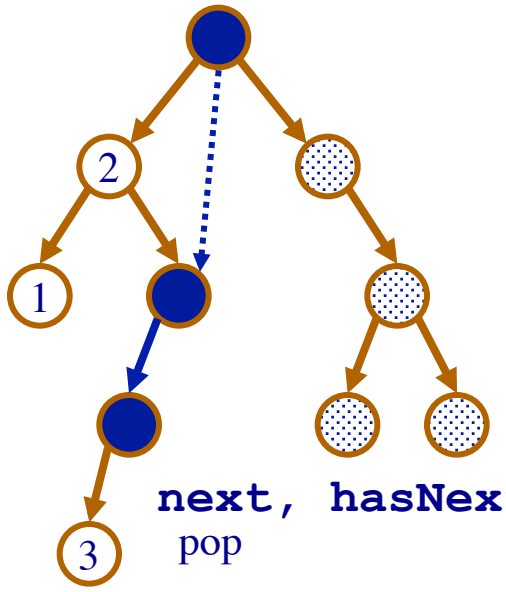
Initialized in hasNext()
`slideLeft`



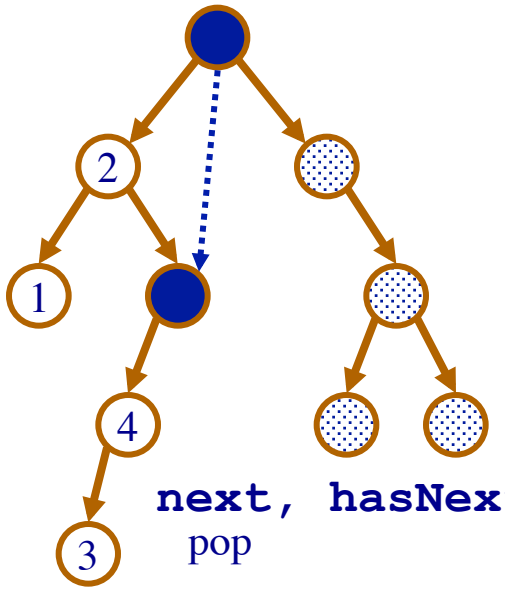
`next, hasNext`



`next, hasNext`
pop, `slideLeft`



`next, hasNext`
pop



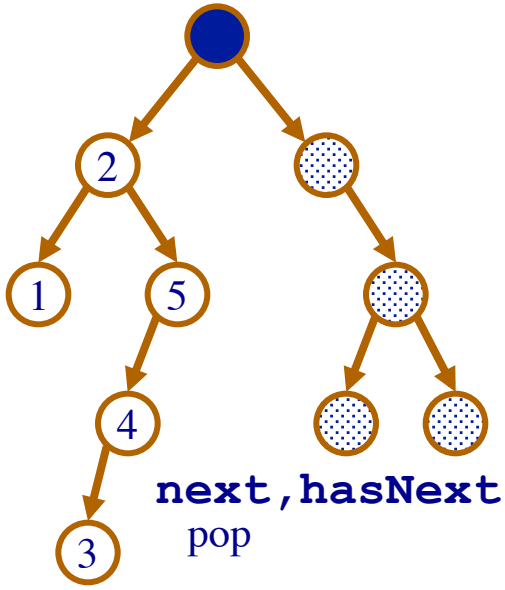
`next, hasNext`
pop

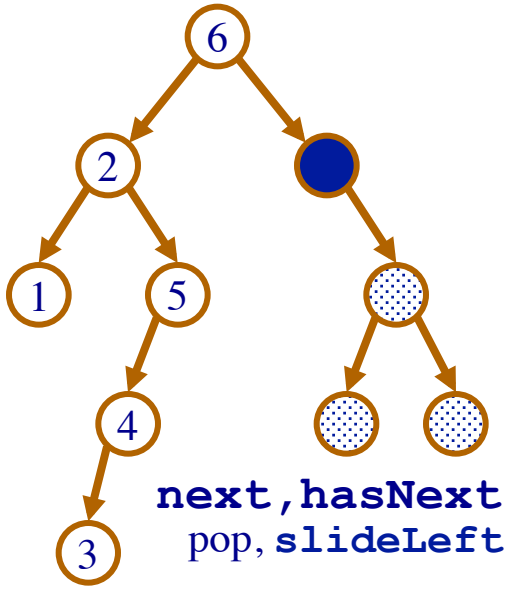
In-Order: Example (cont.)

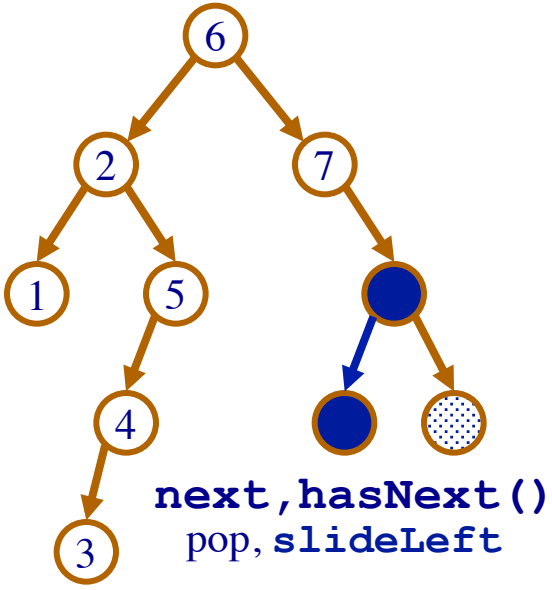
On stack (lowest node at top).

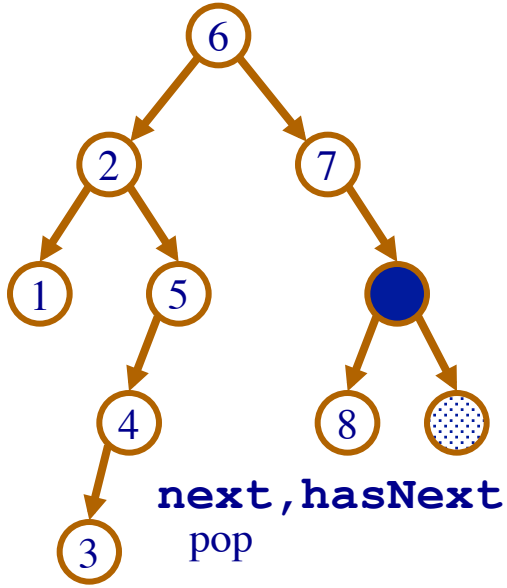
Not yet visited.

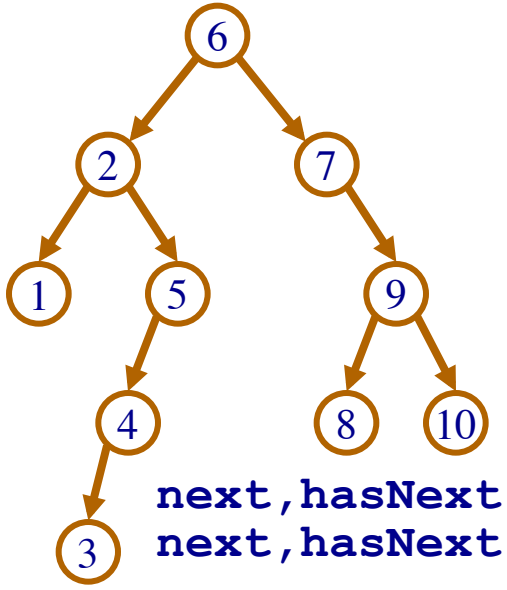
Enumerated (order indicated).











Iterator Implementation

```
Initialize(&tree, &itr);
while( HasNext(&itr) )
{
        /* Do something */
    Process( Next(&itr) );
}
```

Implementation

```
struct BSTIterator {
    struct DynArr *stk;
    struct BSTree *tree;
};

struct DynArray {
    struct Node *nodes;
    int size;
    int capacity;
};
```

```
struct BSTree {
    struct Node *root;
    int size;
};

struct Node {
    TYPE val;
    struct Node *lft;
    struct Node *rght;
};
```

BST Iterator -- Initialize

```
void initBSTIter (struct BSTree *tree,
                          struct BSTIterator *itr)
{
    /* Stack as dynamic array */
   int capacity = log(tree->size); /*saves memory*/
   itr->tree = tree;
   InitStack(itr->stk, capacity);
}
```

Iterator Implementation

```
Initialize(&tree, &itr);
while( HasNext(&itr) )
{
        /* Do something */
    Process( Next(&itr) );
}
```

BST Iterator -- Next( )

Returns the top of the stack

```
topStack(itr->stk)
```

/*this does not remove the top node*/

Iterator Implementation

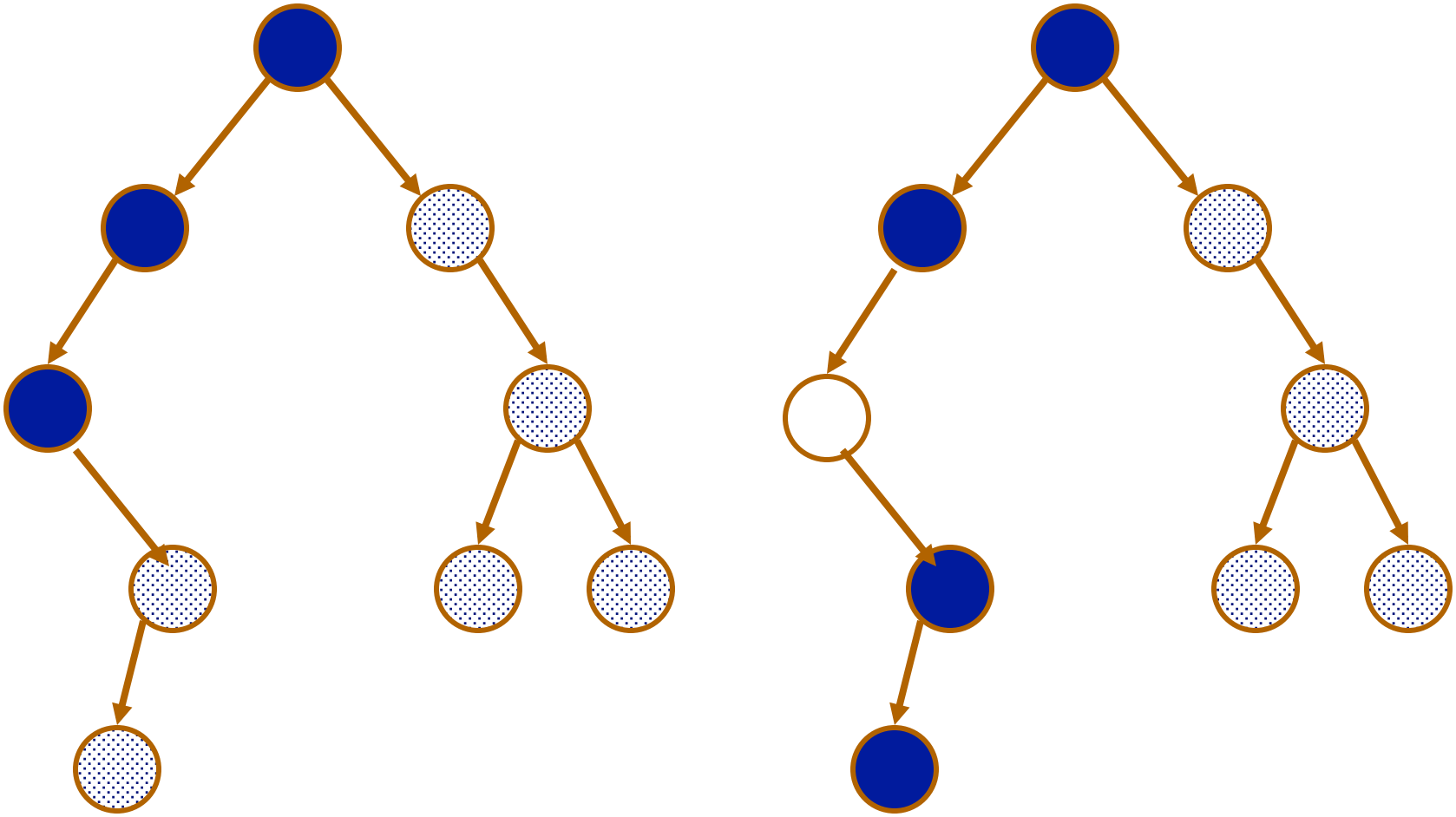
```
Initialize(&tree, &itr);
while( HasNext(&itr) )
{
        /* Do something */
    Process( Next(&itr) );
}
```

BST Iterator – HasNext ( )

Two purposes:

- Check if Stack is empty
- Forming Stack
  - When the top of Stack is processed,
  - Insert its right-child's left branch

Sliding Left



Stack holds the path to the leftmost node

BST Iterator – HasNext ( )

```
if ( isEmpty(itr->stk) )
```

Push new nodes into Stack

from the root down left

```
else{
```

- Pop the top element of Stack
- Push left descendants of the right child into Stack

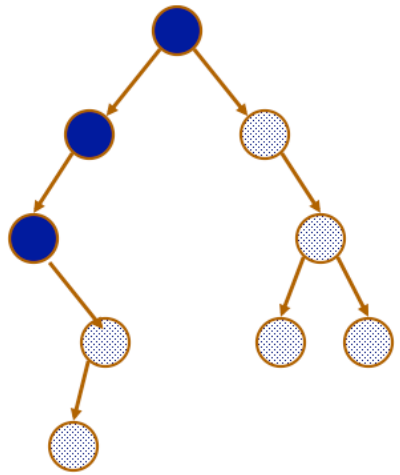
```
}
if (! isEmpty(itr->stk) )
   return TRUE;
else
   return FALSE;
```

BST Iterator – HasNext ( )

```
if ( isEmpty(itr->stk) )
    /* push into Stack */
    slideLeft(itr->tree->root);
else{
   current = topStack(itr->stk) read top elem.
   popStack(itr->stk)   remove top element
   /* push into Stack */
   slideLeft(current->rght) from right child
}...
```

Sliding Left

```
void _slideLeft(struct DynArray *stk,
                struct Node *current)
{
    while (current != 0) {
      pushStack(stk, current);
      current = current->left;
    }
}
```



Other Traversal Types

- Pre-order and post-order traversals can also use a stack
- Breadth-first traversal uses a queue – how?
- Depth-first traversal uses a stack – how?

Breadth-Frist Traversal

```
void PrintBreadthFirstBST(struct BSTree *tree){
   struct listQueue *q;
   struct BSTNode *current = tree->root;
   initListQueue(q);
   addBackListQueue (q, current);
   while(!isEmptyListQueue(q)){
      current = getFrontListQueue(q);
      removeFrontListQueue(q);
      printf("%f  ",current->val);
      if(current->left != 0)
         addBackListQueue (q, current->left);
      if(current->right != 0)
         addBackListQueue (q, current->right);
   }
}
```