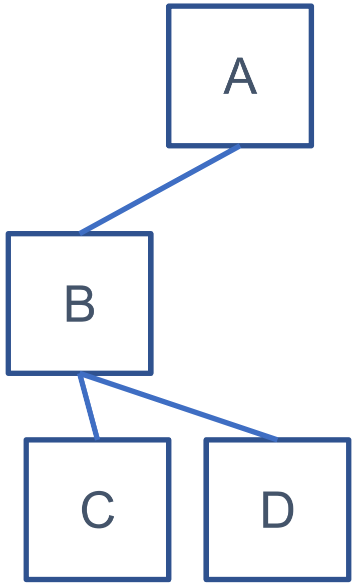
Review

- Tree
- Rooted tree
- Rooted binary tree
- Binary search tree



Computing Bootcamp

Trees

Lecture 17

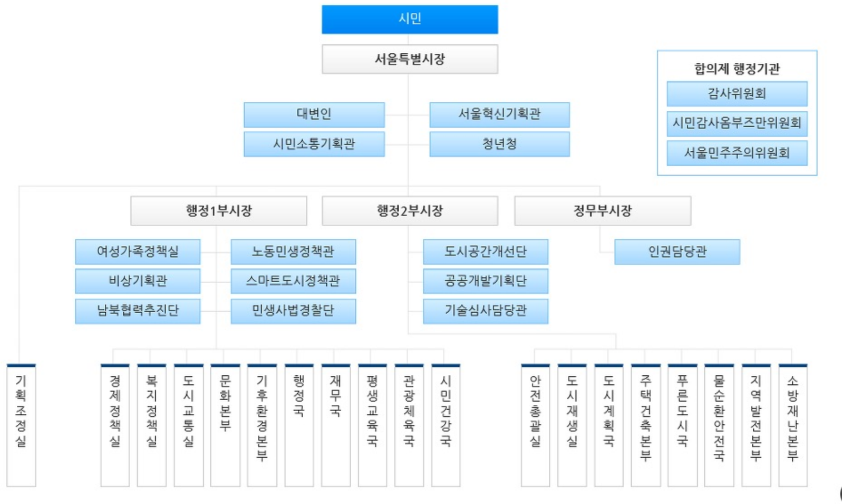
Hyung-Sin Kim

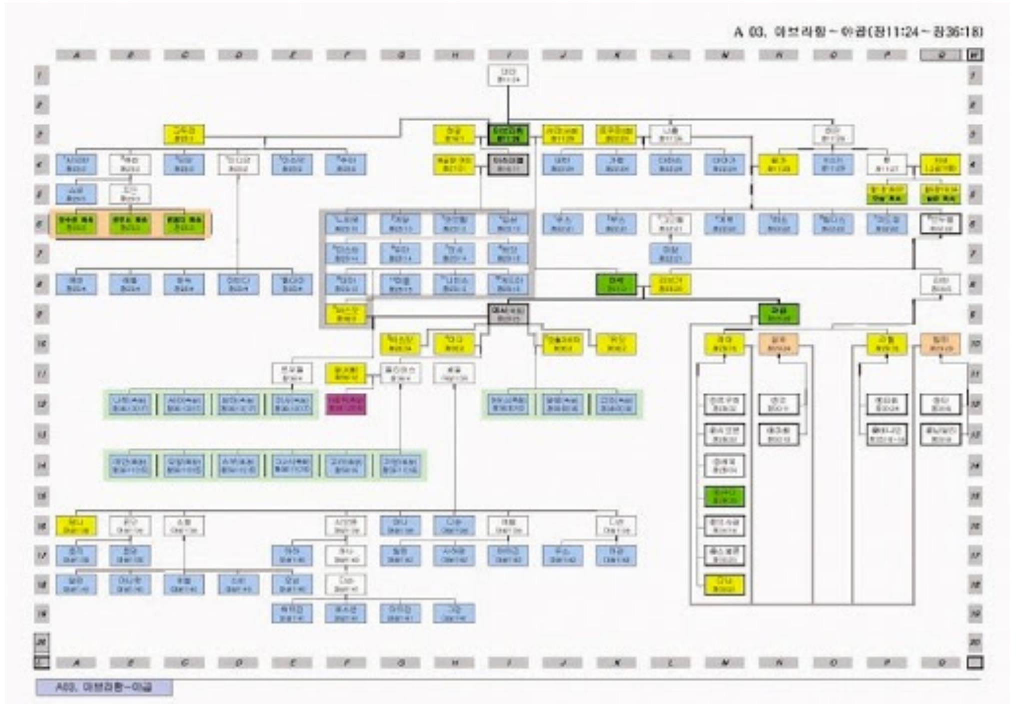
SNU Graduate School of Data Science

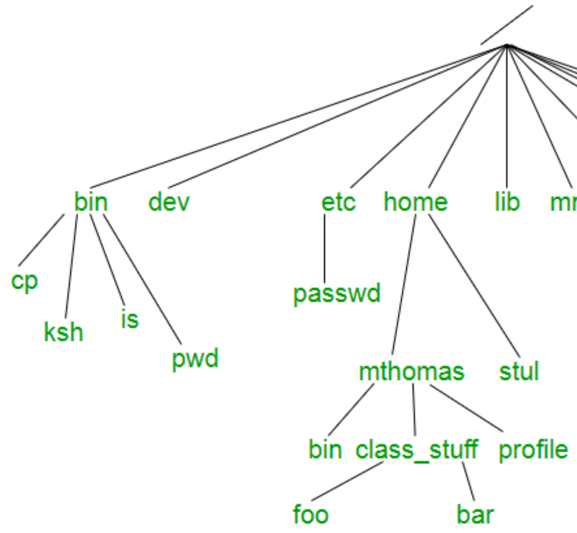
Contents

Trees are Everywhere

- Organization chart
- Genealogy (family tree)
- File system







K-ary Trees

- A general tree node does not have to have only two children nodes

- A tree that allows each node to have up to k children nodes is called **k-ary tree**

```
class TreeNode():
    def __init__(self, x: int, k: int) -> None:
        self.val = x
        self.arity = k
        self.child = [None]*k
```

How to navigate the whole tree conveniently?

Breadth-First Traversal

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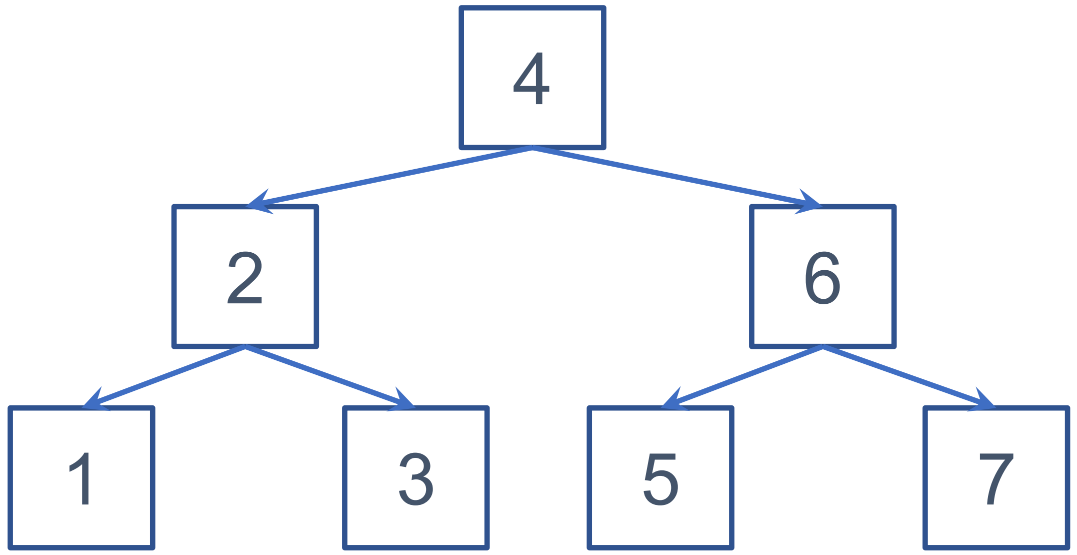
Level-order (Breadth-First) Traversal

- Visit nodes from left to right, and from top to bottom



Level-order (Breadth-First) Traversal

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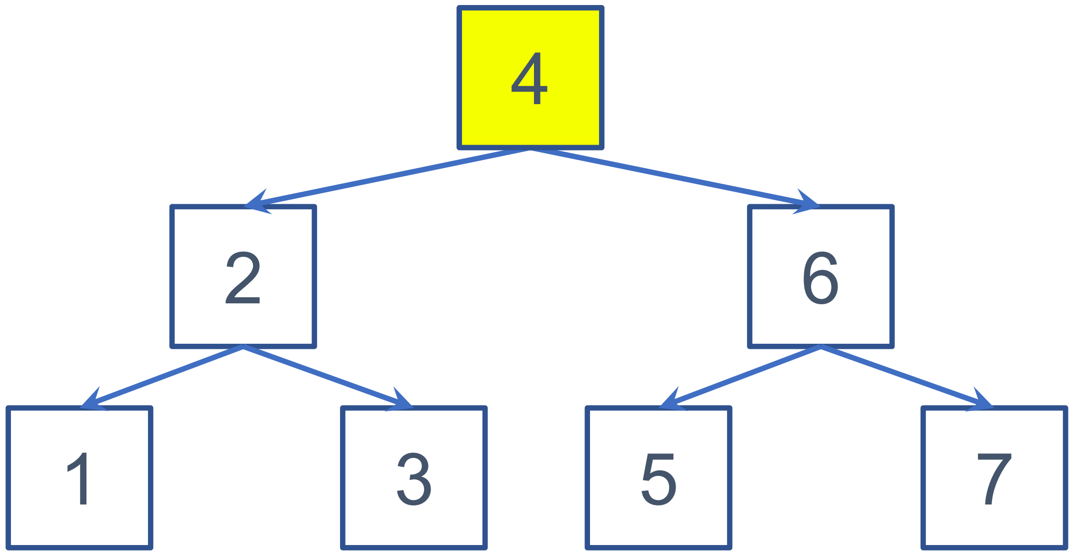

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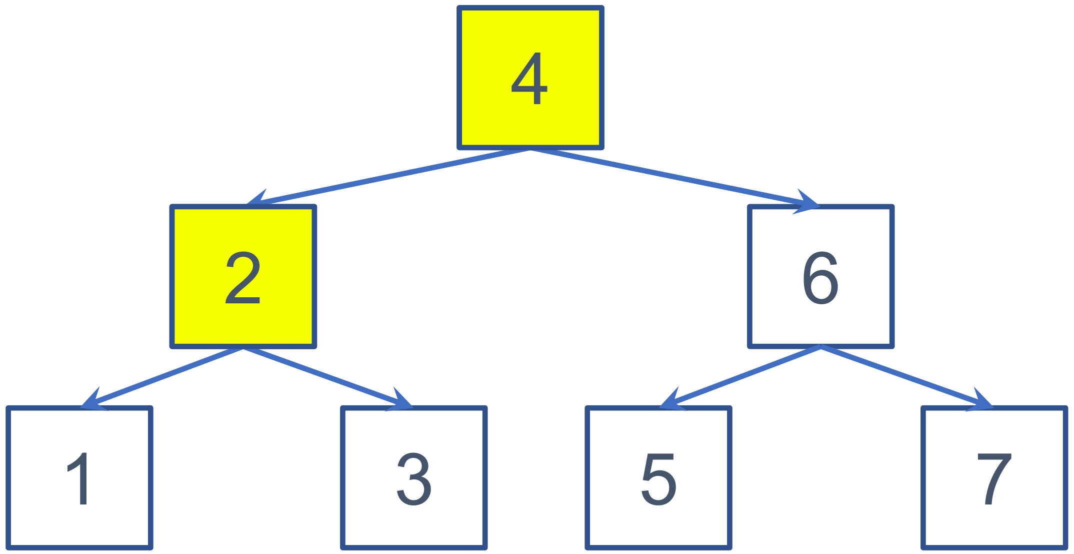

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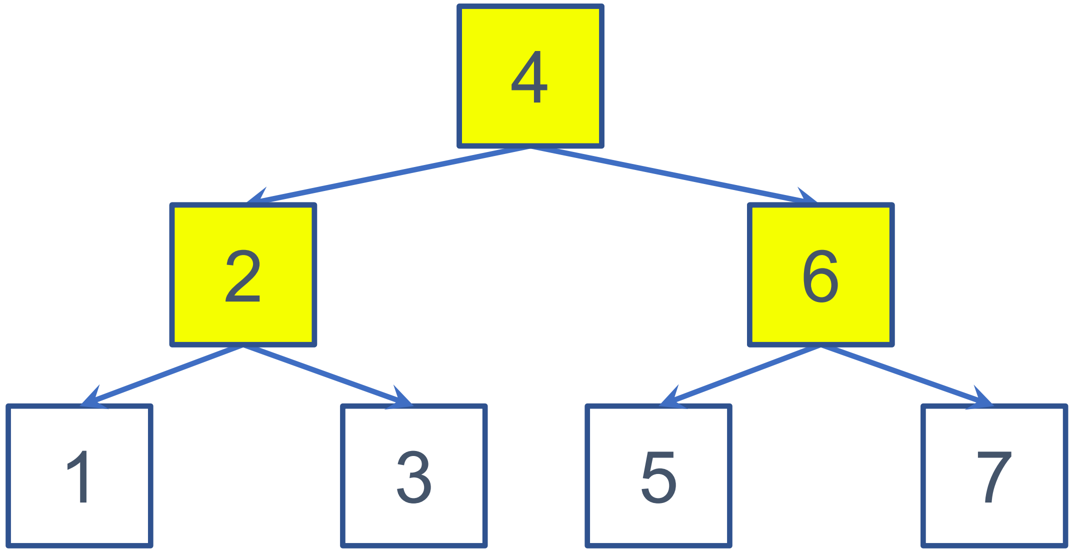

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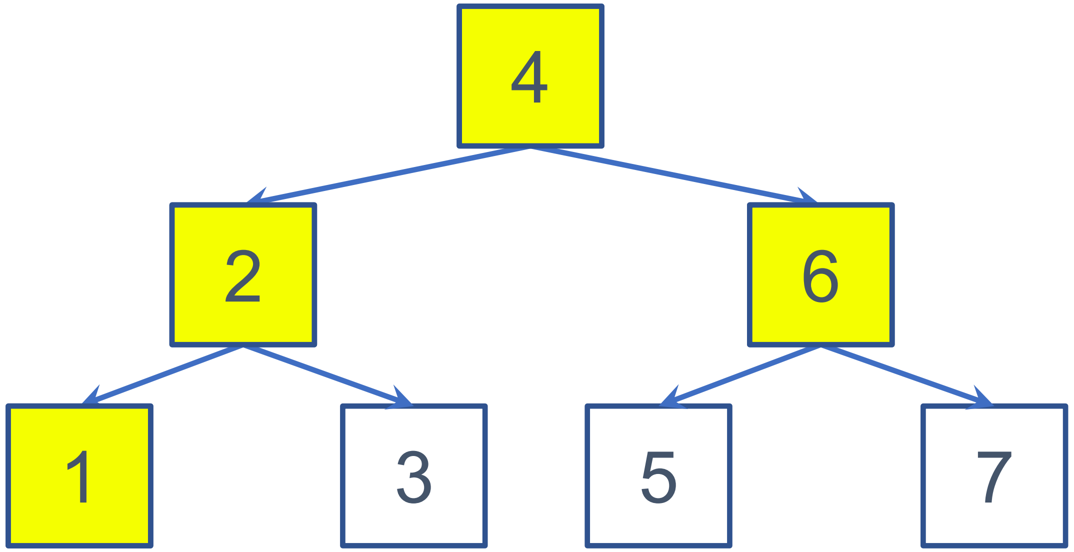

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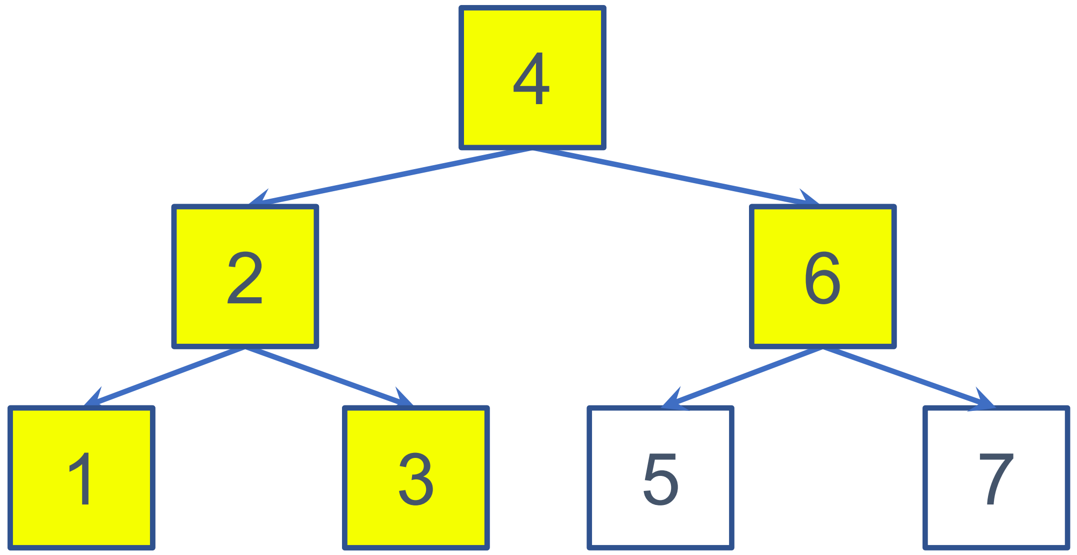

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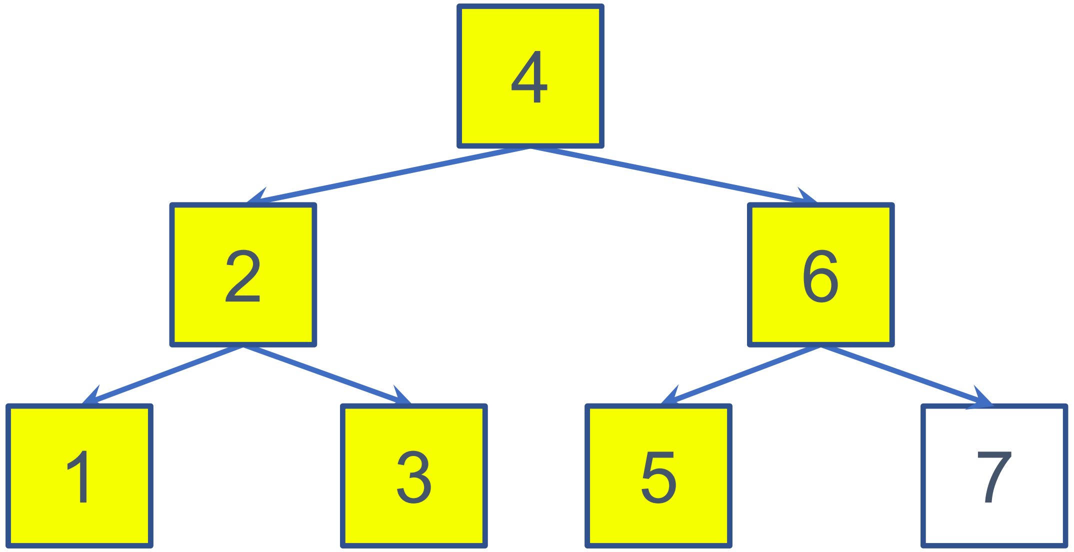

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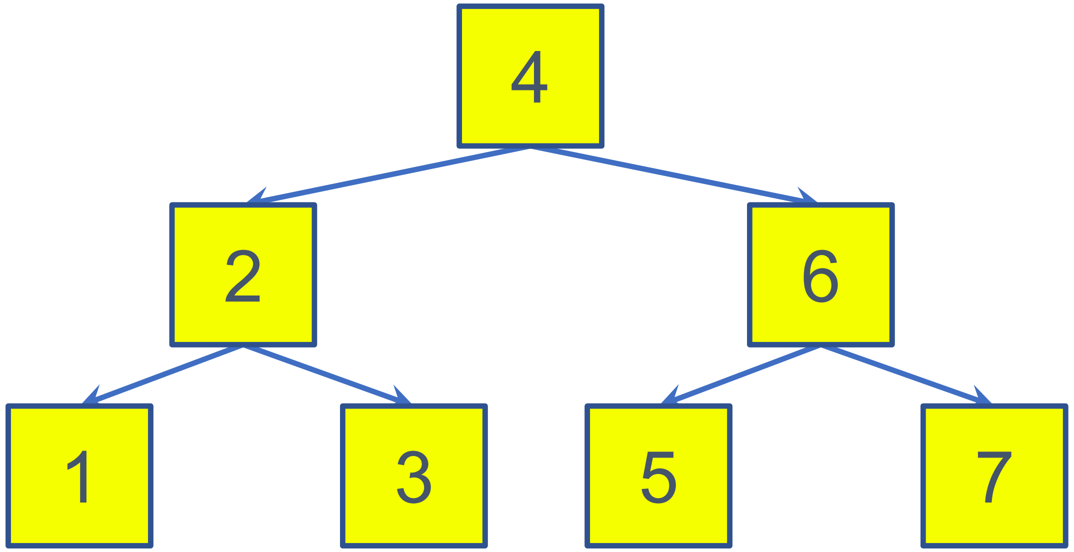

Level-order (Breadth-First) Traversal

- Visit nodes from left to right, and from top to bottom

```
class Tree():
    def visit(self, node: TreeNode):
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    def BFT(self):
        if self.root == None:
            return
        q = [self.root]
        while q:
            curNode = q.pop(0)
            self.visit(curNode)
            for childNode in curNode.child:
                if childNode:
                    q.append(childNode)
```

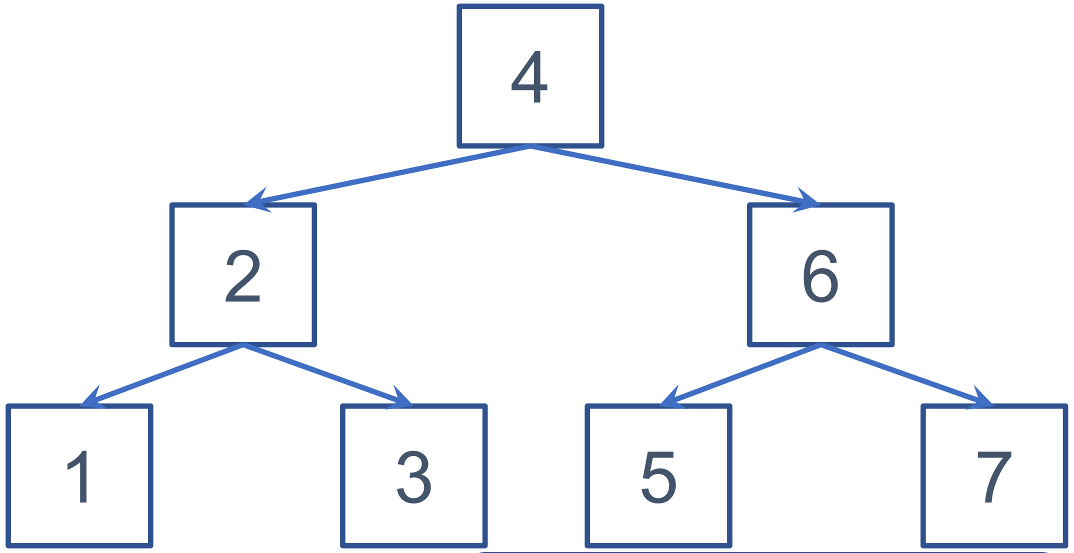

Out:

Level-order (Breadth-First) Traversal

- Visit nodes from left to right, and from top to bottom

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class Tree():
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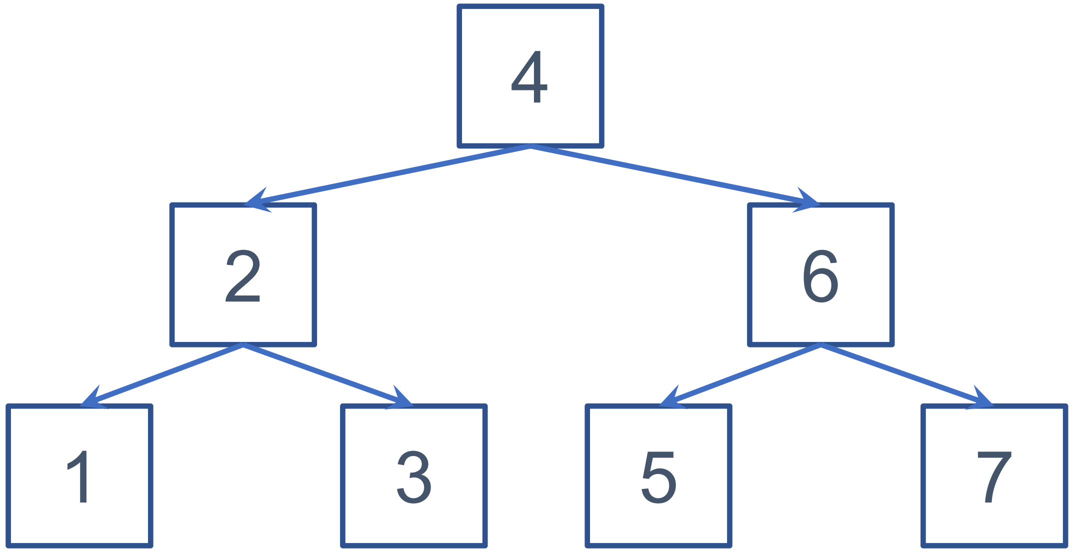
        while q:
            curNode = q.pop(0)
            self.visit(curNode)
            for childNode in curNode.child:
                if childNode:
                    q.append(childNode)
```

q = [T(4)]



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Level-order (Breadth-First) Traversal

- Visit nodes from left to right, and from top to bottom

```
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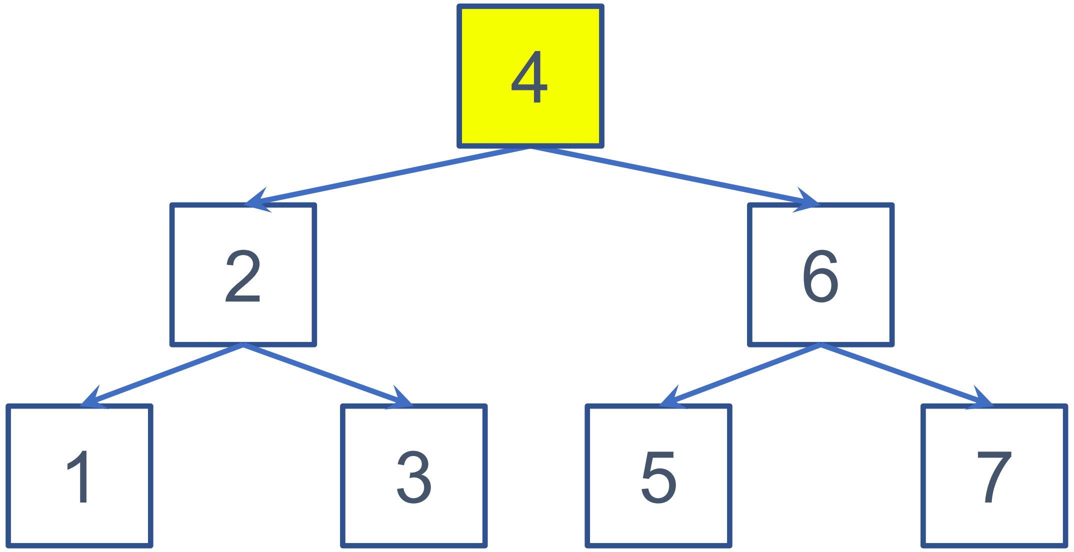
        q = [self.root]
        while q:
            curNode = q.pop(0)
            self.visit(curNode)
            for childNode in curNode.child:
                if childNode:
                    q.append(childNode)
```

q = []



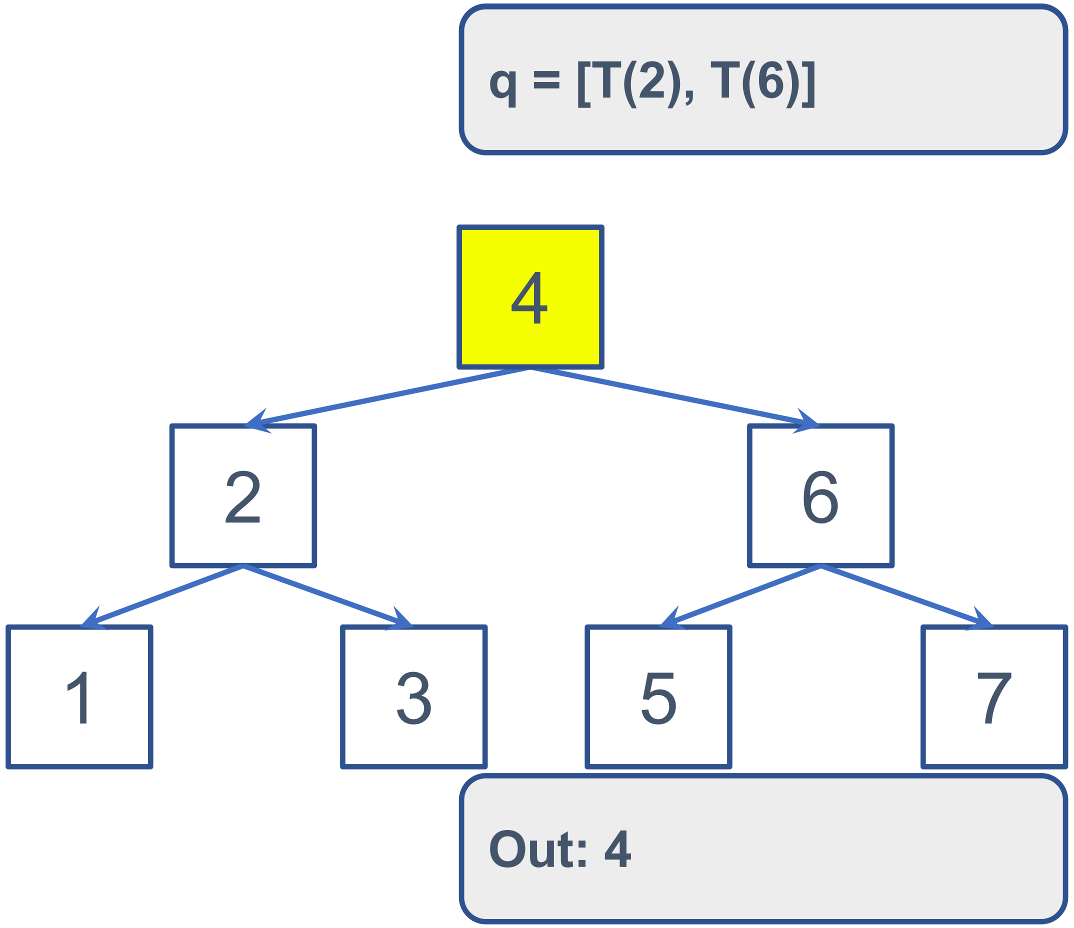
Out: 4

Level-order (Breadth-First) Traversal

- Visit nodes from left to right, and from top to bottom

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def BFT(self):
        if self.root == None:
            return
        q = [self.root]
        while q:
            curNode = q.pop(0)
            self.visit(curNode)
            for childNode in curNode.child:
                if childNode:
                    q.append(childNode)
```



Level-order (Breadth-First) Traversal

- Visit nodes from left to right, and from top to bottom

```
class Tree():
    def visit(self, node: TreeNode):
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    def BFT(self):
        if self.root == None:
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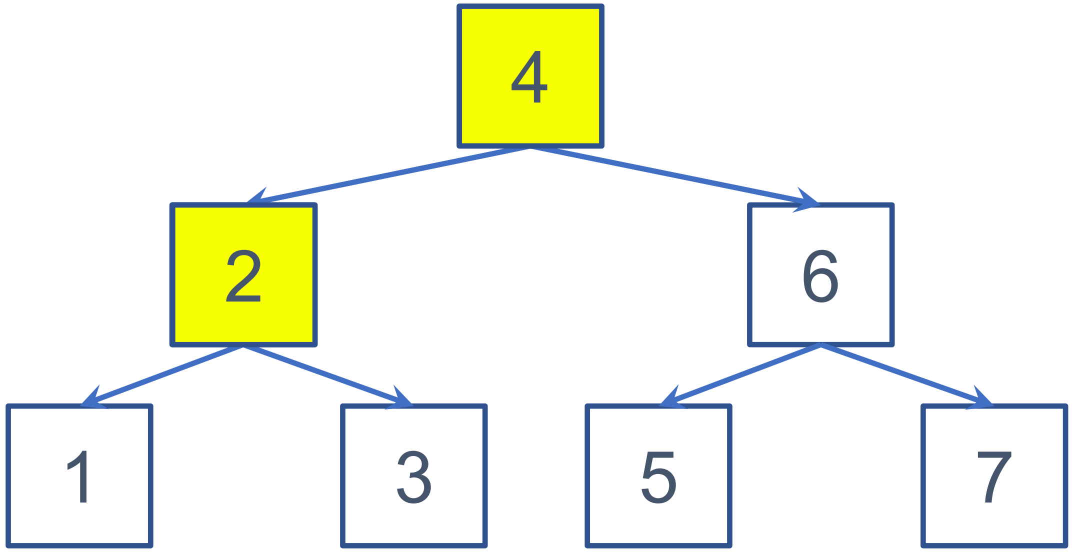
        q = [self.root]
        while q:
            curNode = q.pop(0)
            self.visit(curNode)
            for childNode in curNode.child:
                if childNode:
                    q.append(childNode)
```

q = [T(6)]



Out: 4 2

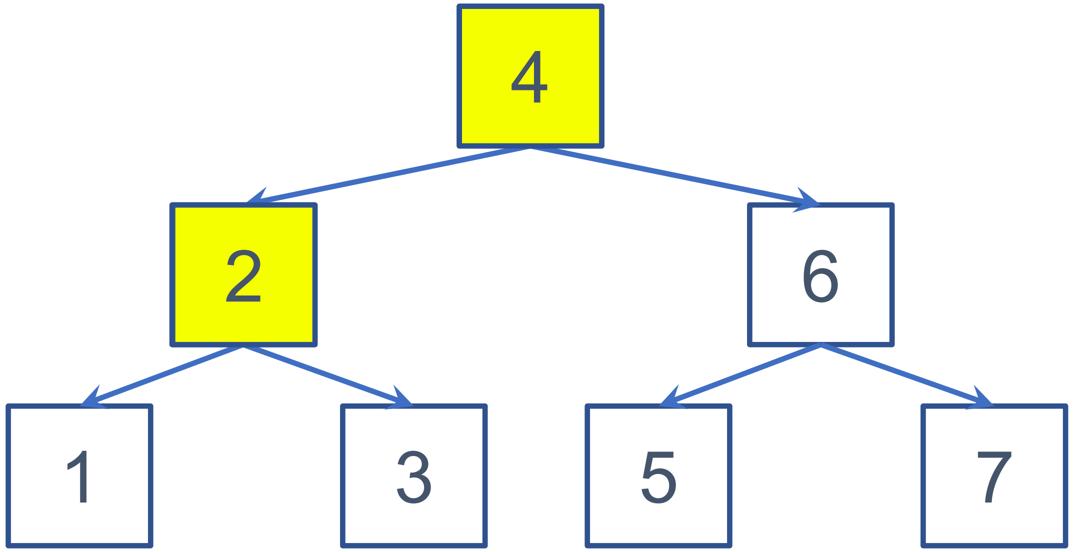
Level-order (Breadth-First) Traversal

- Visit nodes from left to right, and from top to bottom

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def BFT(self):
        if self.root == None:
            return
        q = [self.root]
        while q:
            curNode = q.pop(0)
            self.visit(curNode)
            for childNode in curNode.child:
                if childNode:
                    q.append(childNode)
```

q = [T(6), T(1), T(3)]



Out: 4 2

Level-order (Breadth-First) Traversal

- Visit nodes from left to right, and from top to bottom

```
class Tree():
    def visit(self, node: TreeNode):
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    def BFT(self):
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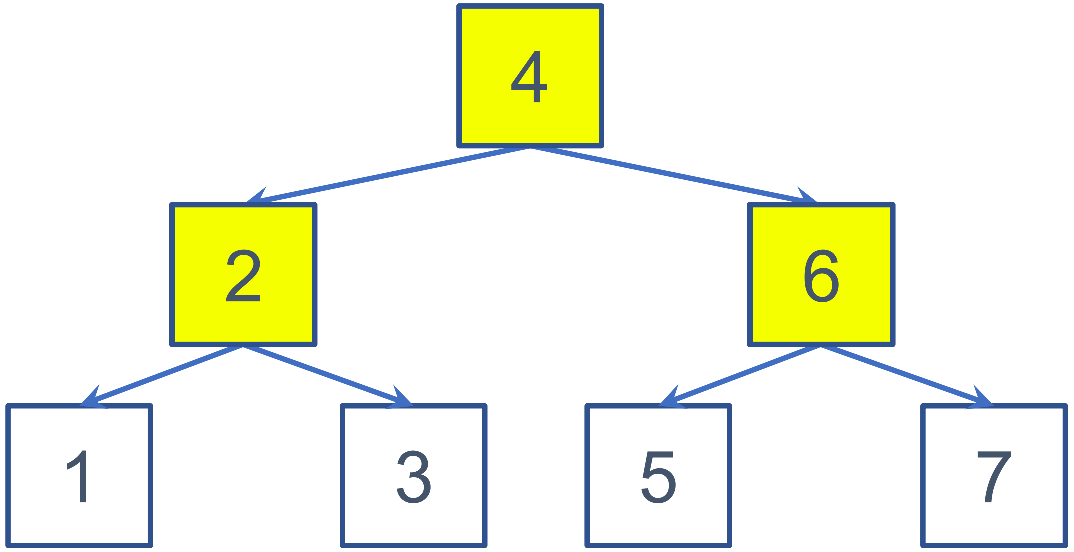
        q = [self.root]
        while q:
            curNode = q.pop(0)
            self.visit(curNode)
            for childNode in curNode.child:
                if childNode:
                    q.append(childNode)
```

q = [T(1), T(3)]



Out: 4 2 6

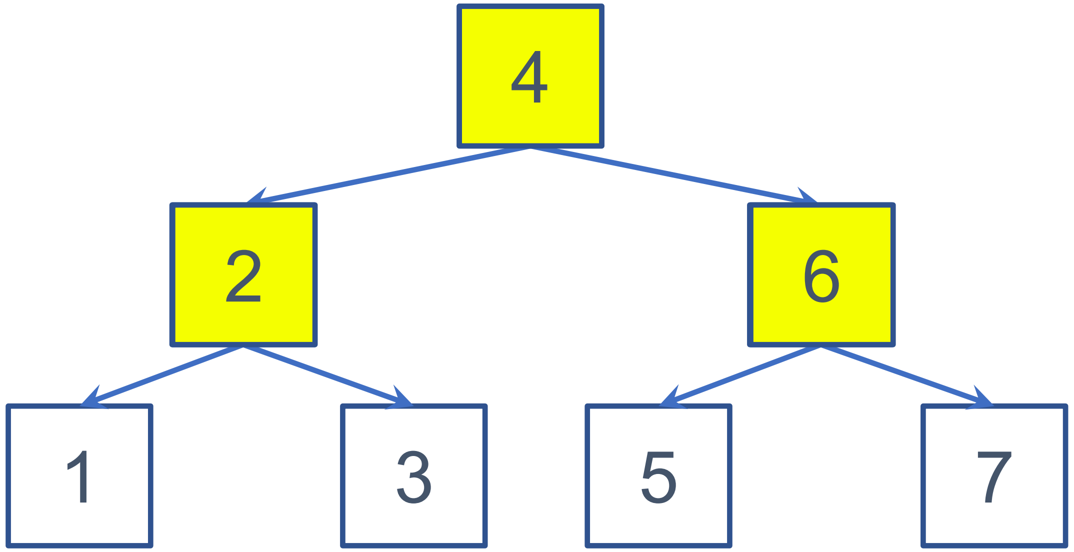
Level-order (Breadth-First) Traversal

- Visit nodes from left to right, and from top to bottom

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def BFT(self):
        if self.root == None:
            return
        q = [self.root]
        while q:
            curNode = q.pop(0)
            self.visit(curNode)
            for childNode in curNode.child:
                if childNode:
                    q.append(childNode)
```

q = [T(1), T(3), T(5), T(7)]



Out: 4 2 6

Level-order (Breadth-First) Traversal

- Visit nodes from left to right, and from top to bottom

```
class Tree():
    def visit(self, node: TreeNode):
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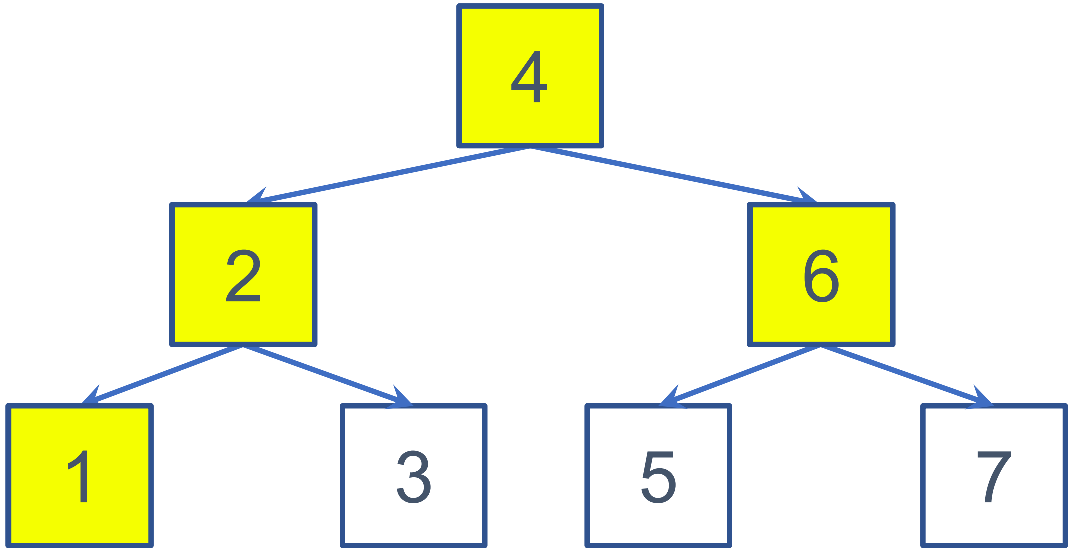
        while q:
            curNode = q.pop(0)
            self.visit(curNode)
            for childNode in curNode.child:
                if childNode:
                    q.append(childNode)
```

q = [T(3), T(5), T(7)]



Out: 4 2 6 1

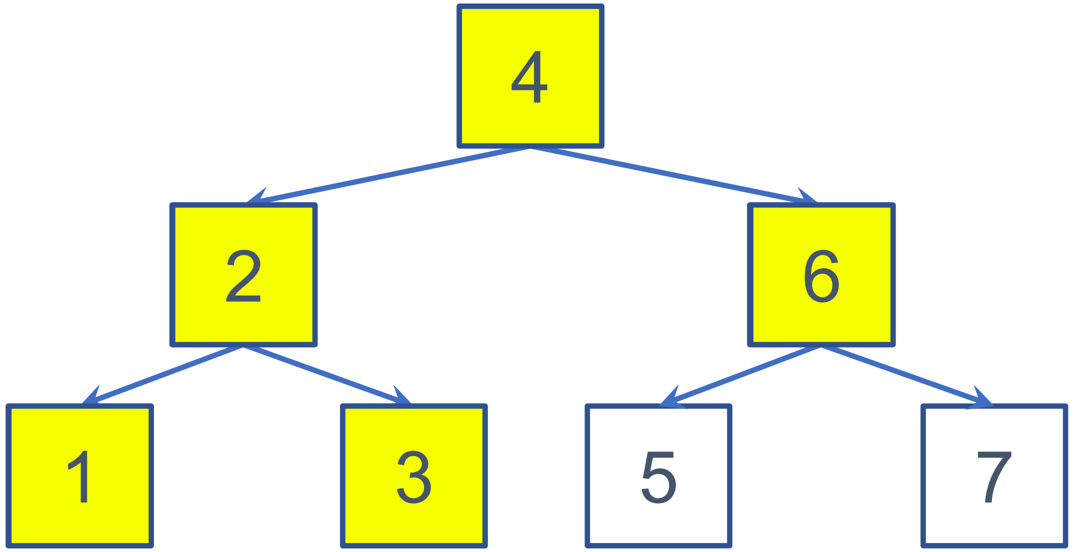
Level-order (Breadth-First) Traversal

- Visit nodes from left to right, and from top to bottom

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def BFT(self):
        if self.root == None:
            return
        q = [self.root]
        while q:
            curNode = q.pop(0)
            self.visit(curNode)
            for childNode in curNode.child:
                if childNode:
                    q.append(childNode)
```

q = [T(5), T(7)]



Out: 4 2 6 1 3

Level-order (Breadth-First) Traversal

- Visit nodes from left to right, and from top to bottom

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def BFT(self):
        if self.root == None:
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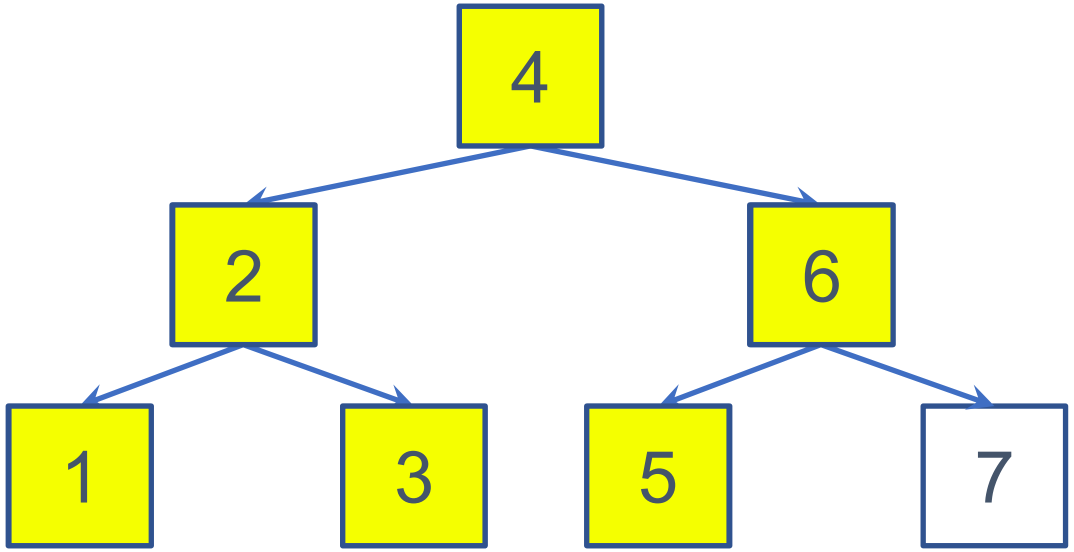
        while q:
            curNode = q.pop(0)
            self.visit(curNode)
            for childNode in curNode.child:
                if childNode:
                    q.append(childNode)
```

q = [T(7)]



Out: 4 2 6 1 3 5

Level-order (Breadth-First) Traversal

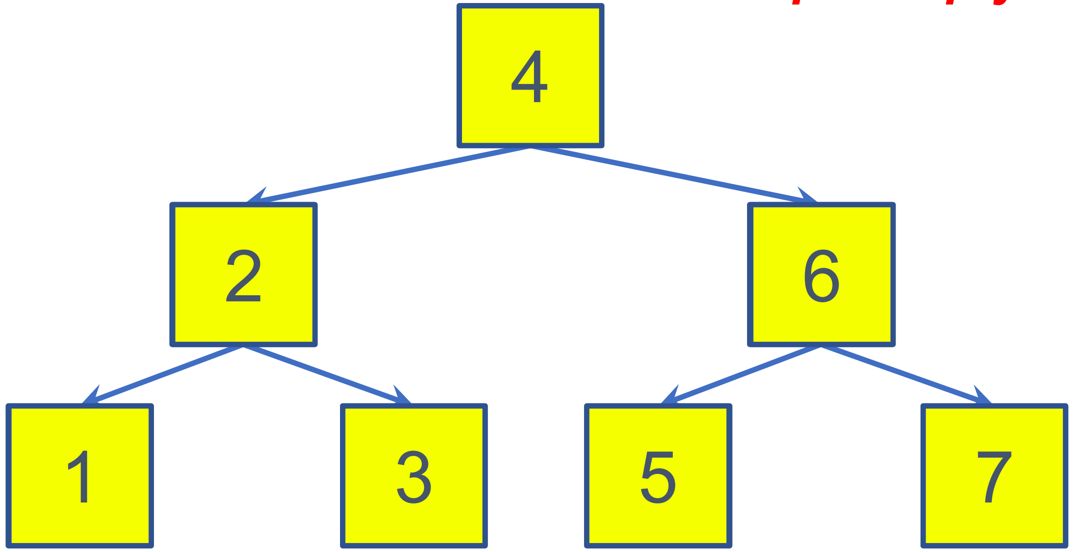
- Visit nodes from left to right, and from top to bottom

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def BFT(self):
        if self.root == None:
            return
        q = [self.root]
        while q:
            curNode = q.pop(0)
            self.visit(curNode)
            for childNode in curNode.child:
                if childNode:
                    q.append(childNode)
```

q = []

Now q is empty!



Out: 4 2 6 1 3 5 7

Level-order (Breadth-First) Traversal – Deque

- Visit nodes from left to right, and from top to bottom

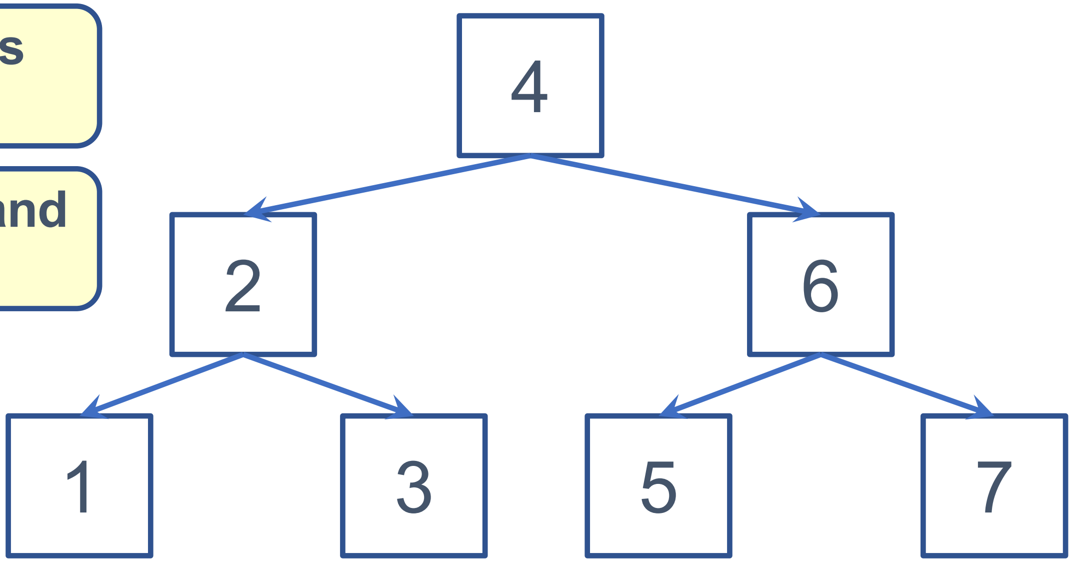
```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def BFT(self):
        if self.root == None:
            return
        q = deque([self.root])
        while q:
            curNode = q.popleft()
            self.visit(curNode)
            for childNode in curNode.child:
                if childNode:
                    q.append(childNode)
```

Doubly-linked list that provides
- append(x), appendleft(x),
- pop(), popleft()

from **collections** import **deque**

Faster pushing and popping!



Depth-First Traversal

Depth-First Traversal

- **Depth-First Traversal**
- **Preorder**
- **Inorder**
- **Postorder**

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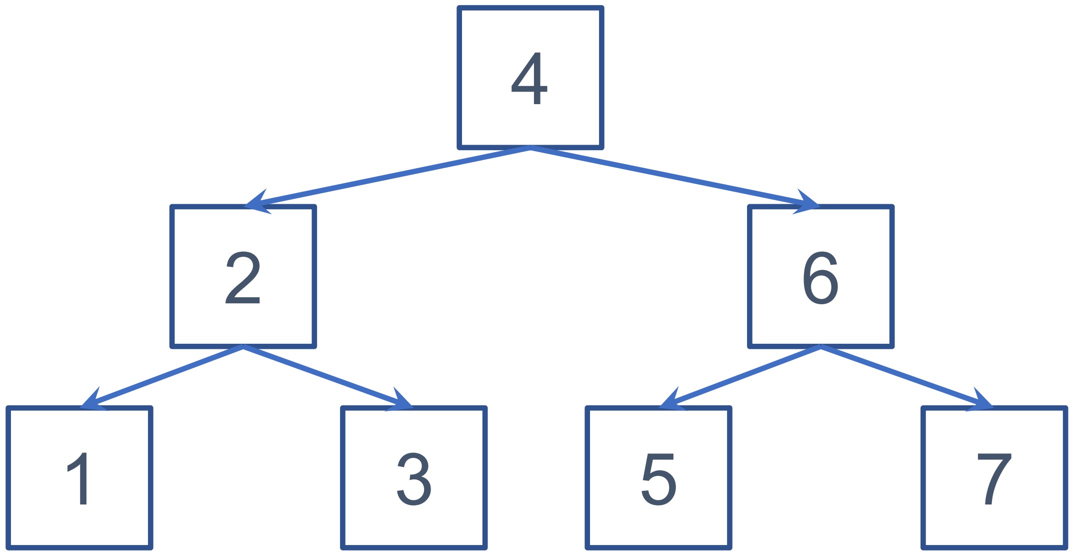
Depth First Traversals



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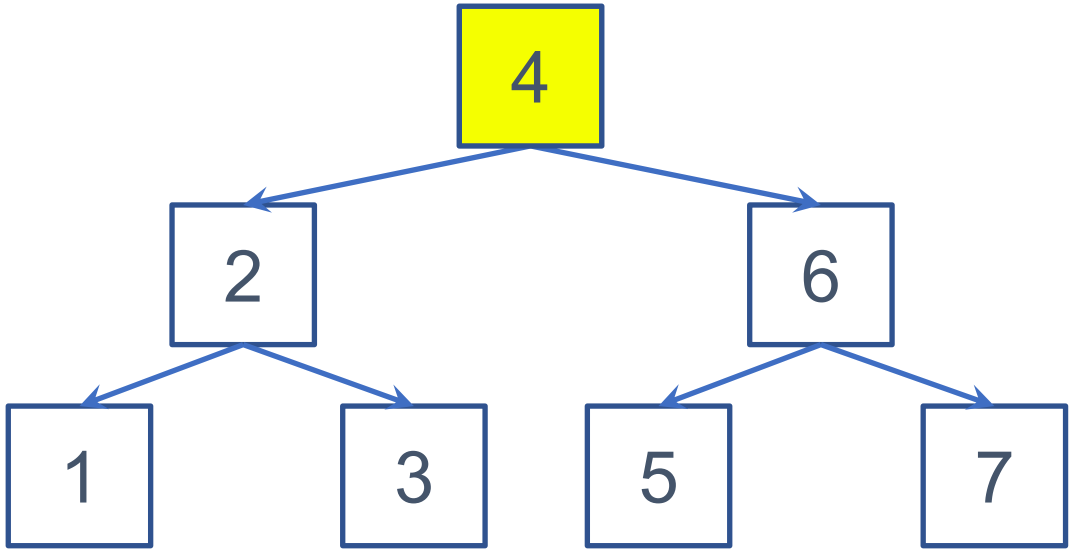

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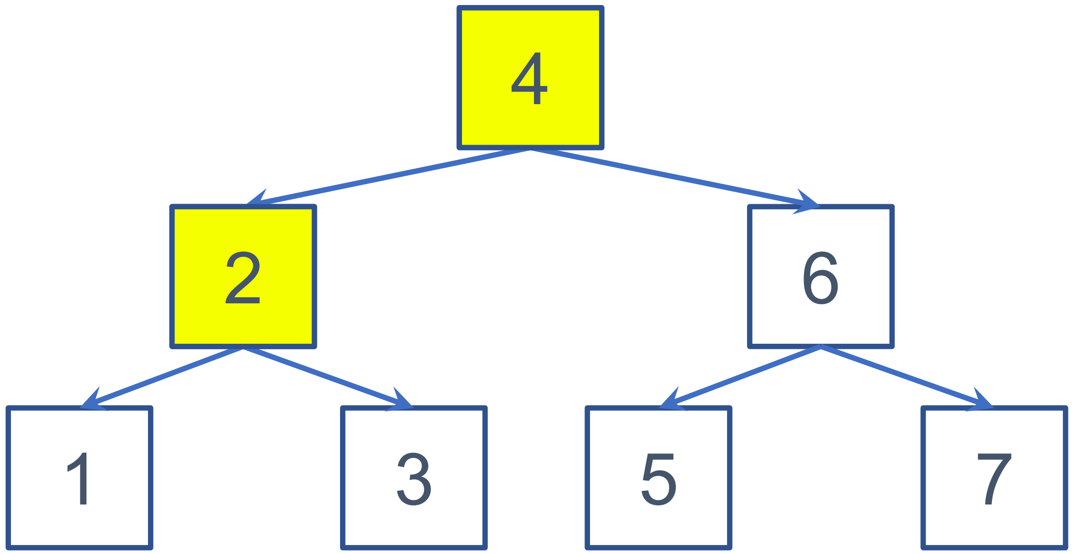

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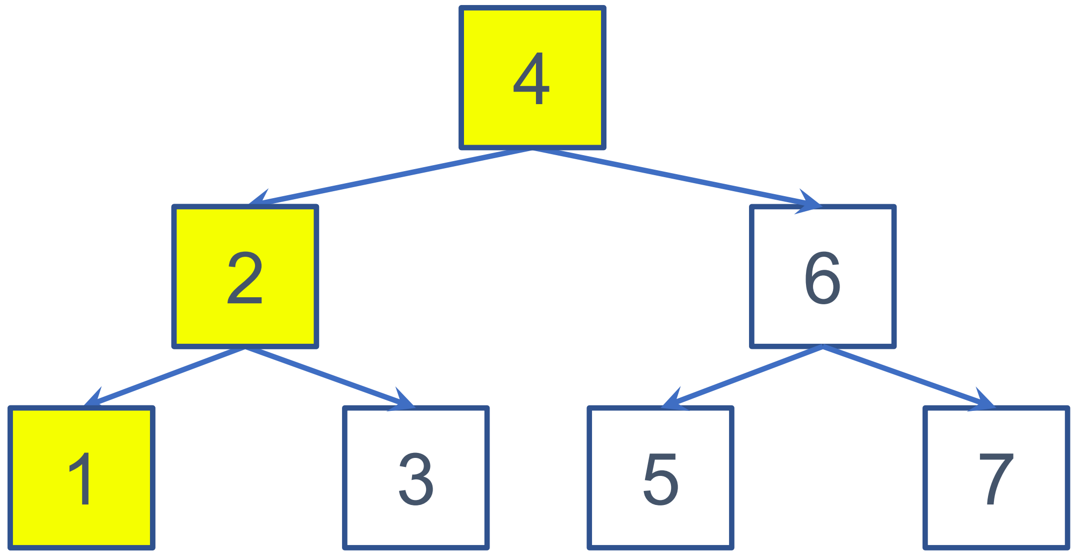
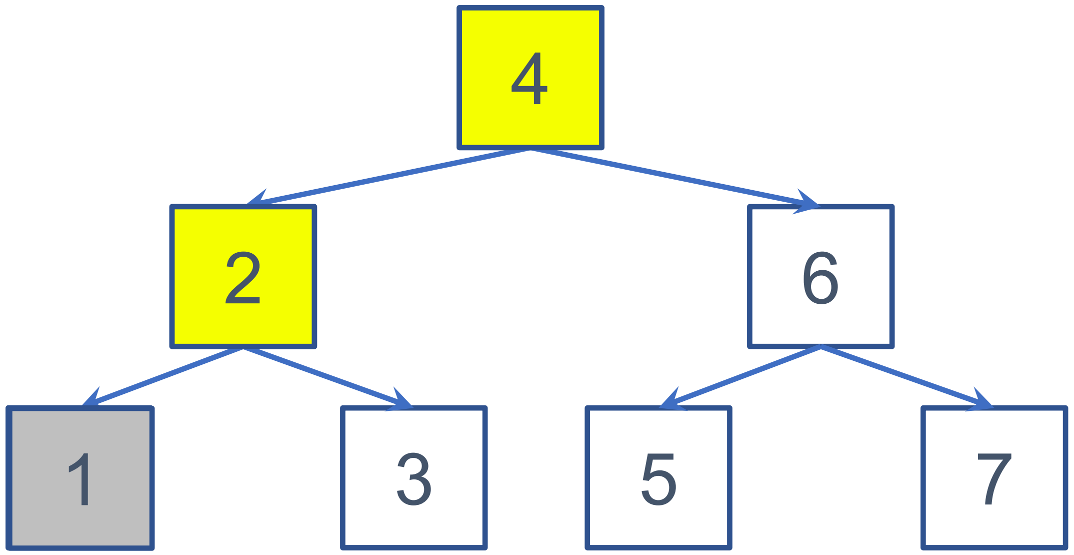


Depth First Traversals



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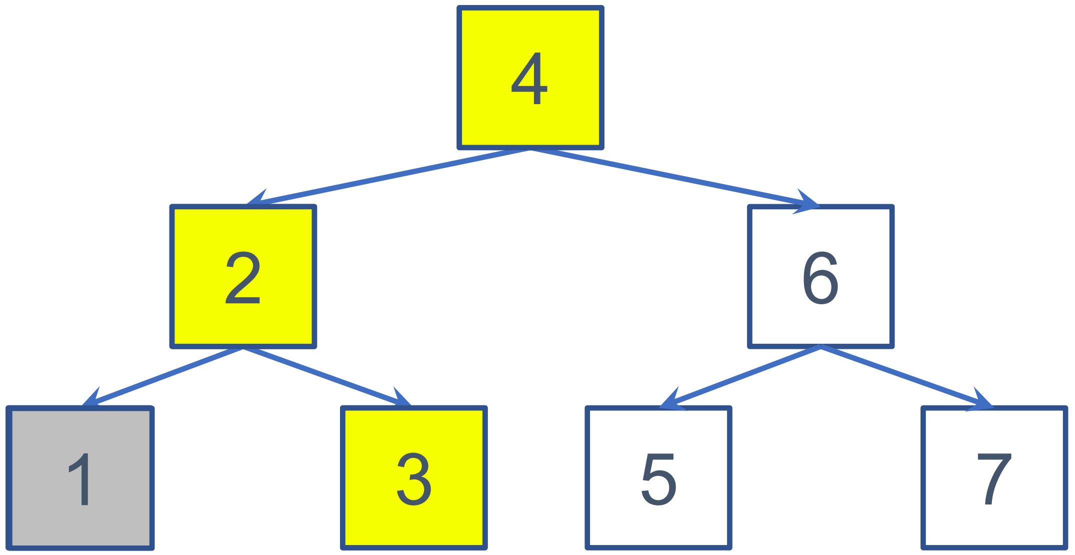

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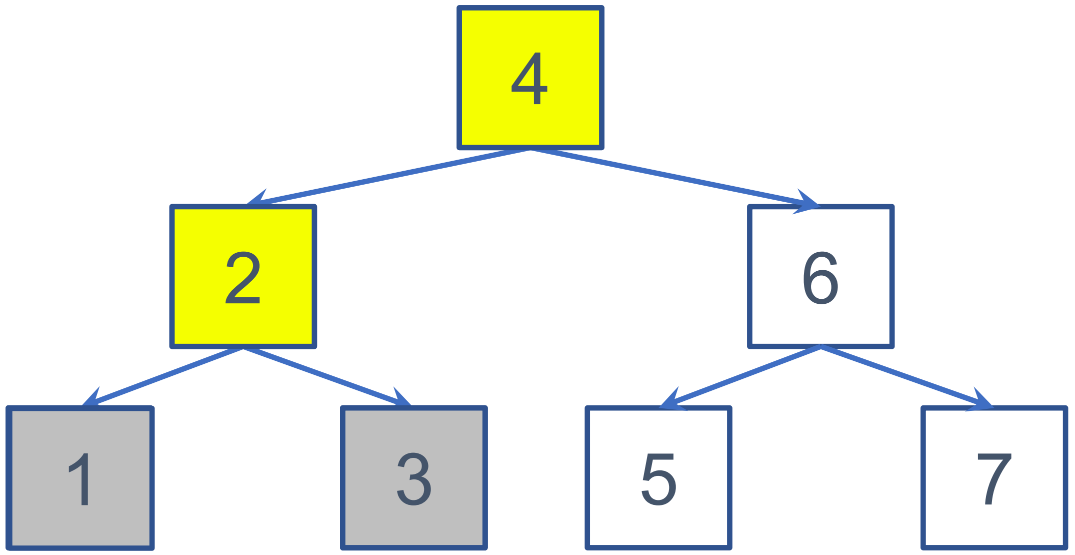

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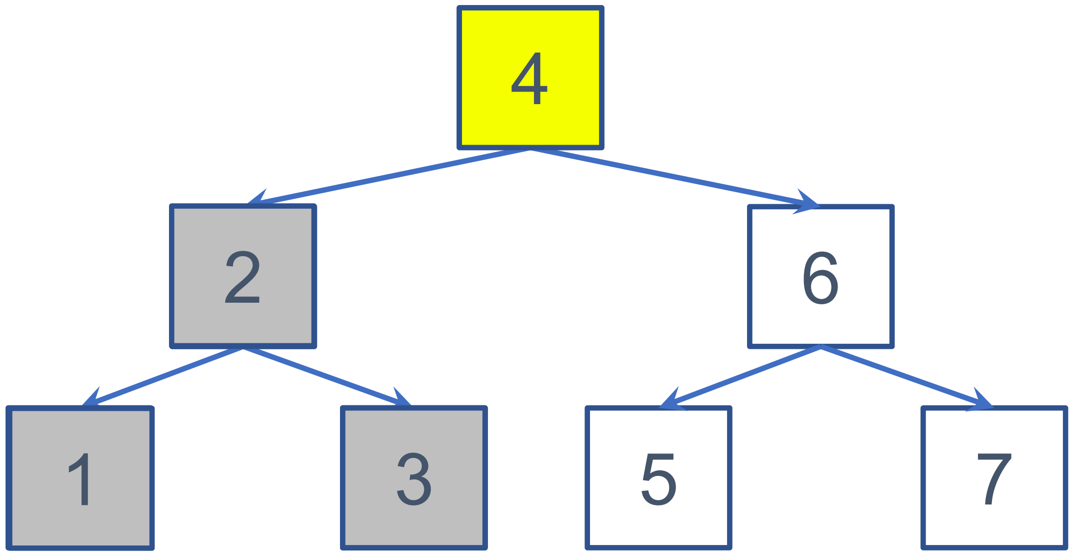

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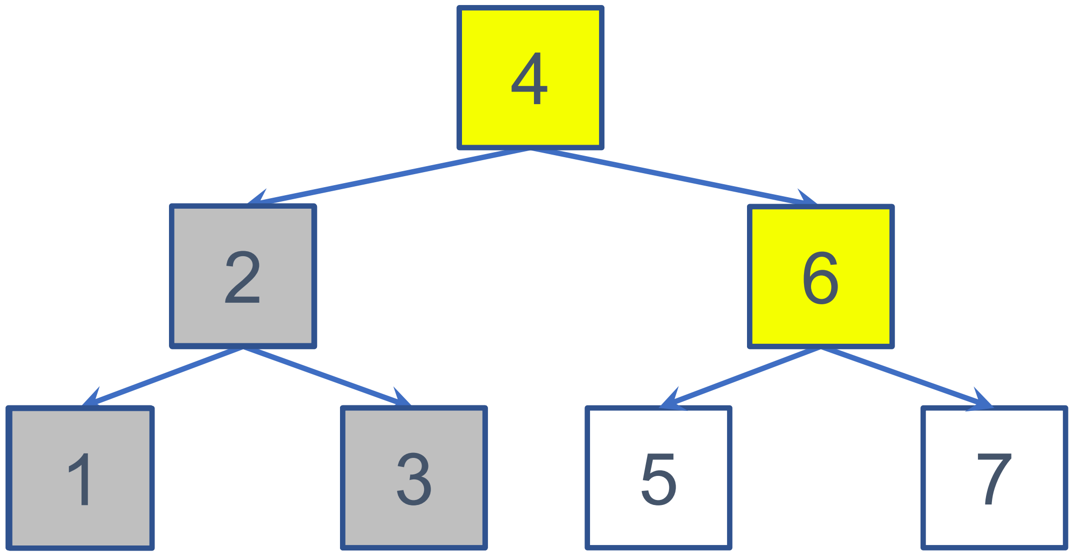

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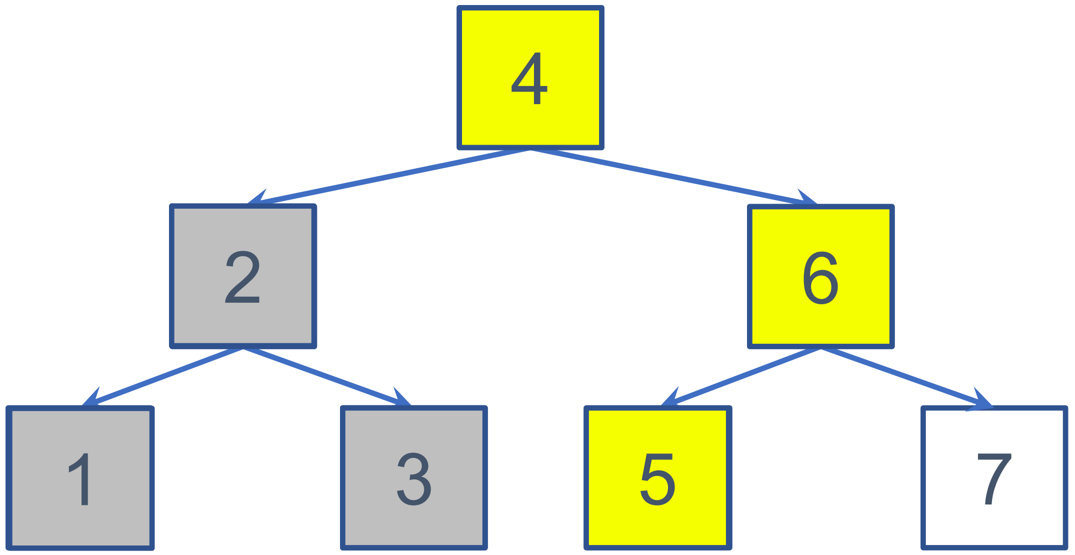
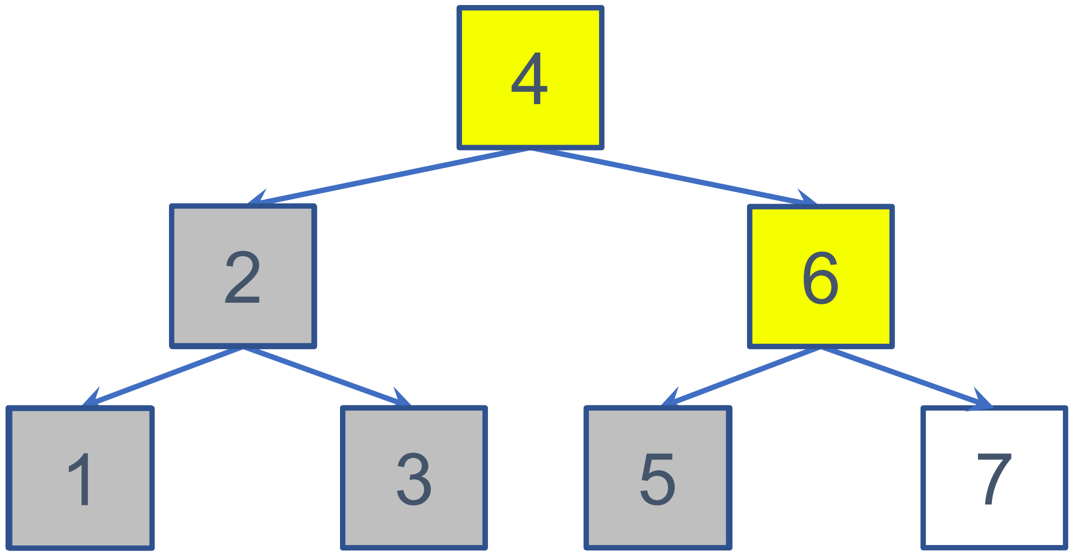


Depth First Traversals



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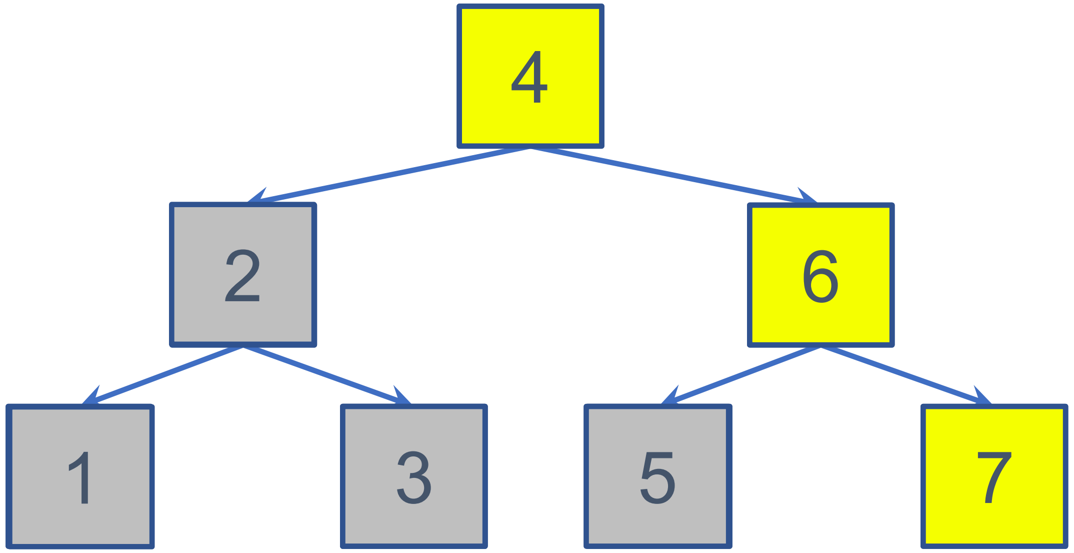
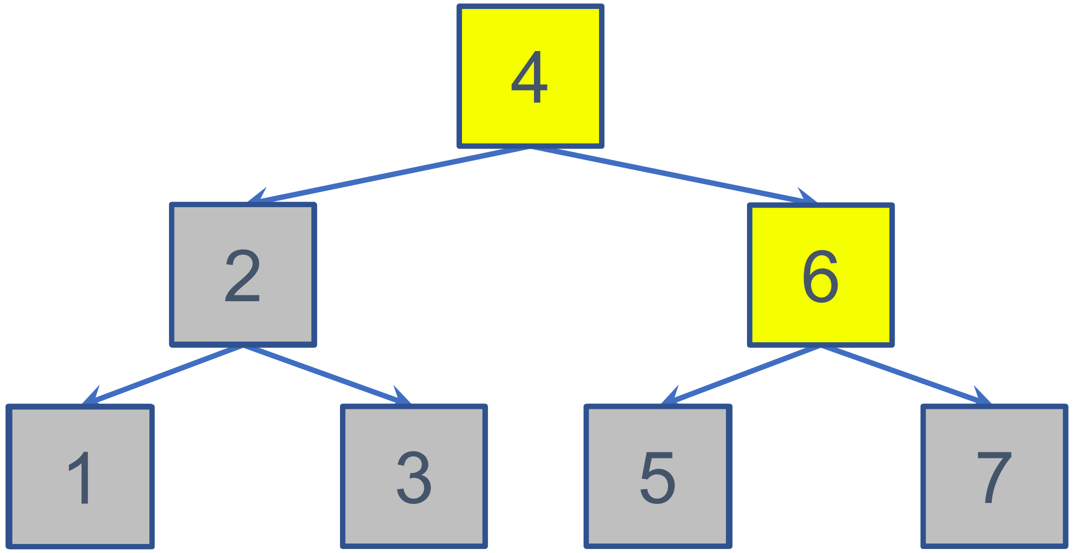
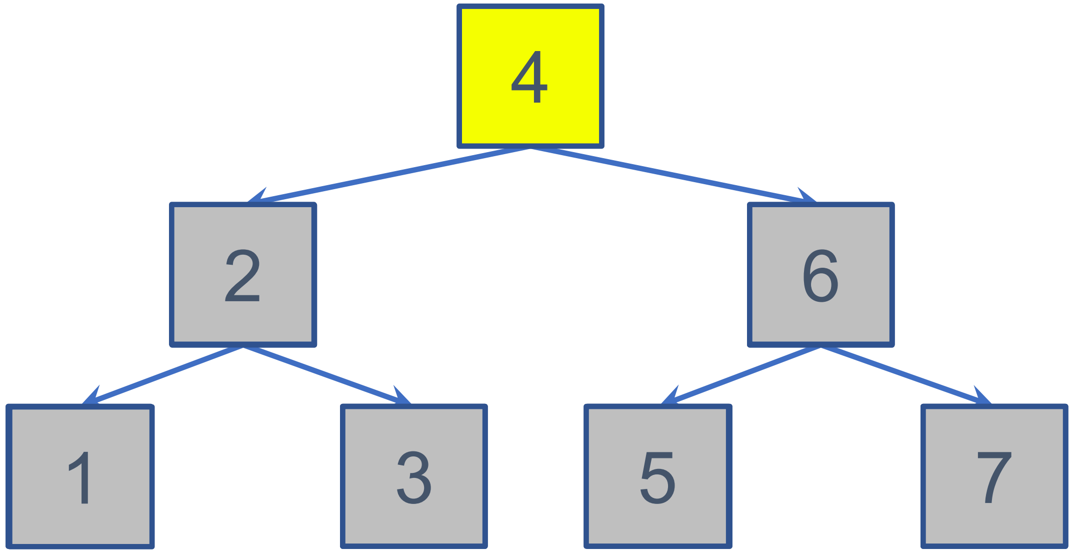


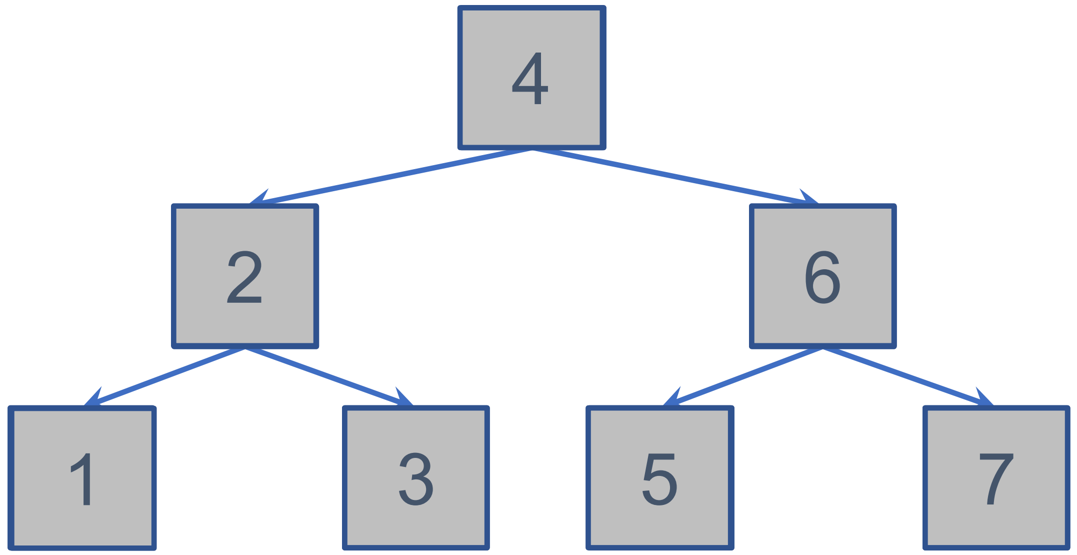
Depth First Traversals



Depth First Traversals

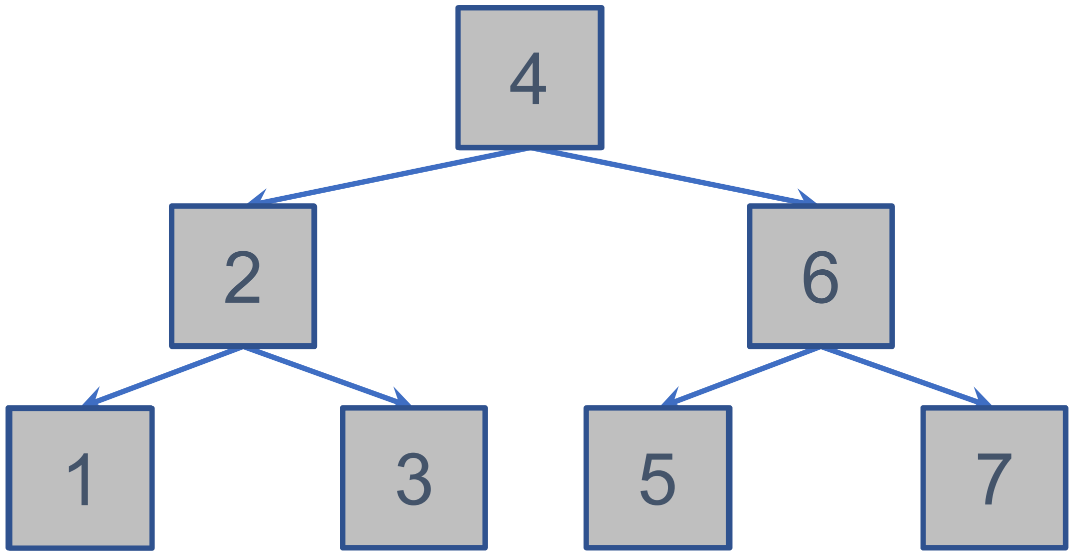


Depth First Traversals



Depth First Traversals

- Three types
  - Preorder, inorder, and postorder



Depth-First Traversal

- Depth-First Traversal
- **Preorder**
- Inorder
- Postorder

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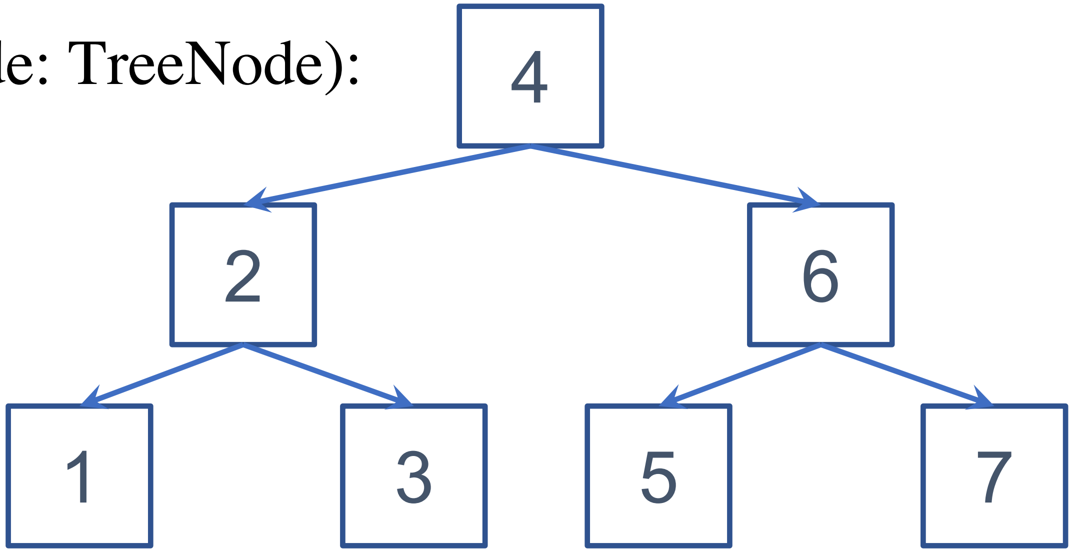
Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```



Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

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class Tree():
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        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

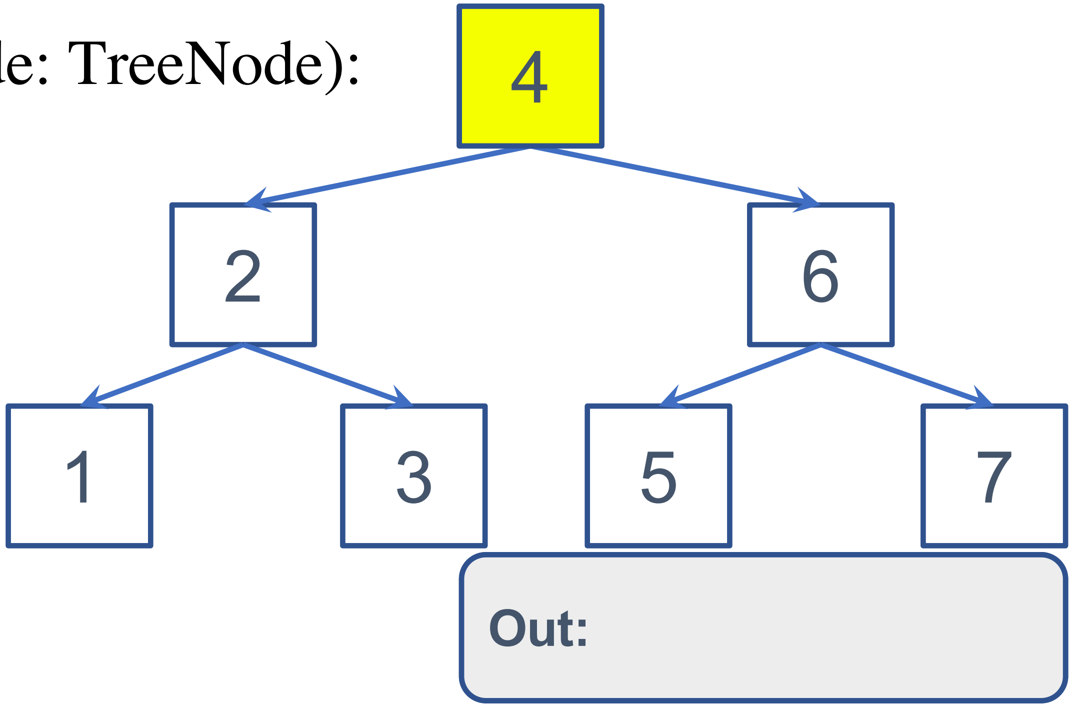

Depth First Traversals – Preorder

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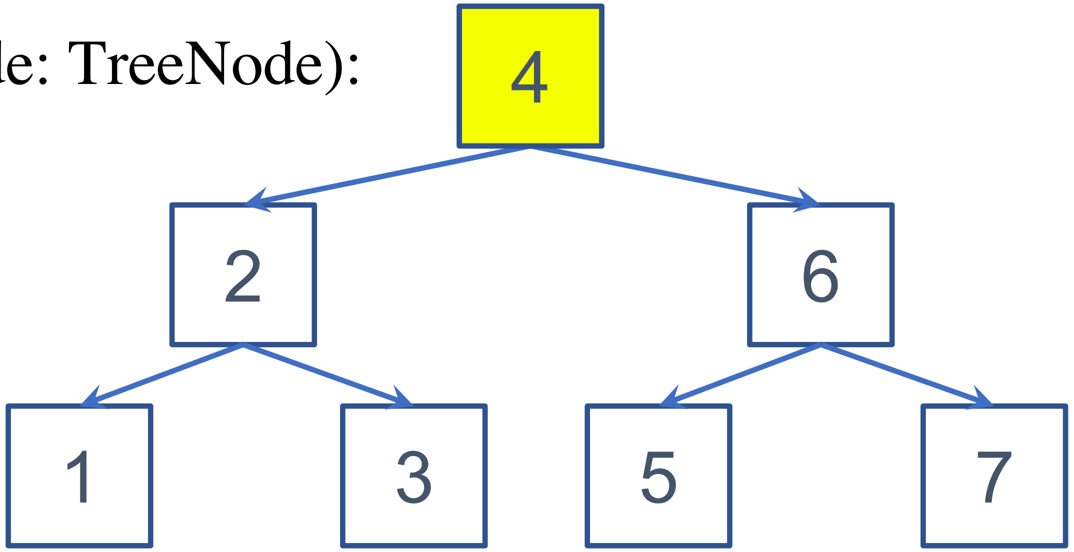

Out: 4

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
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    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```
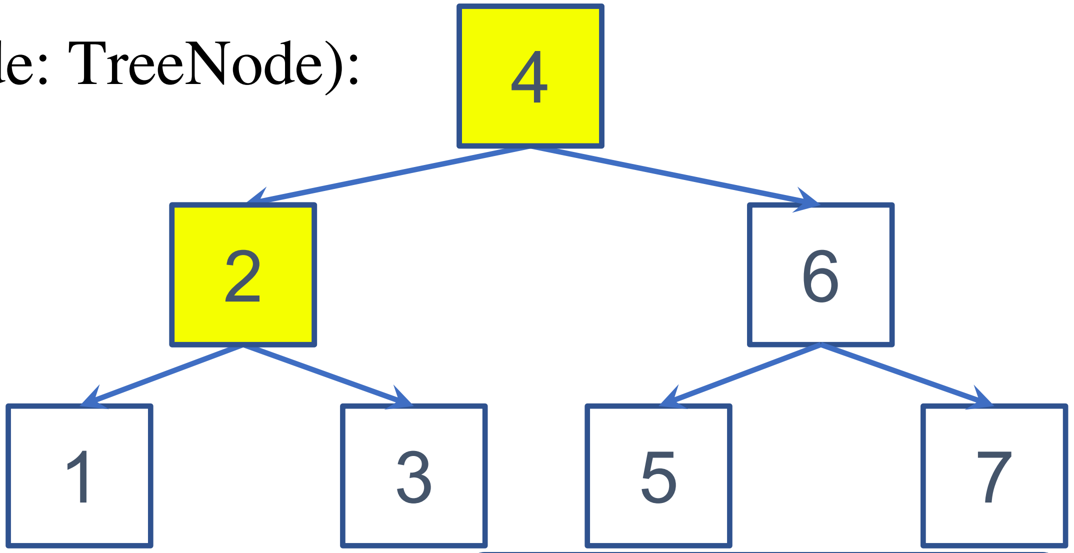
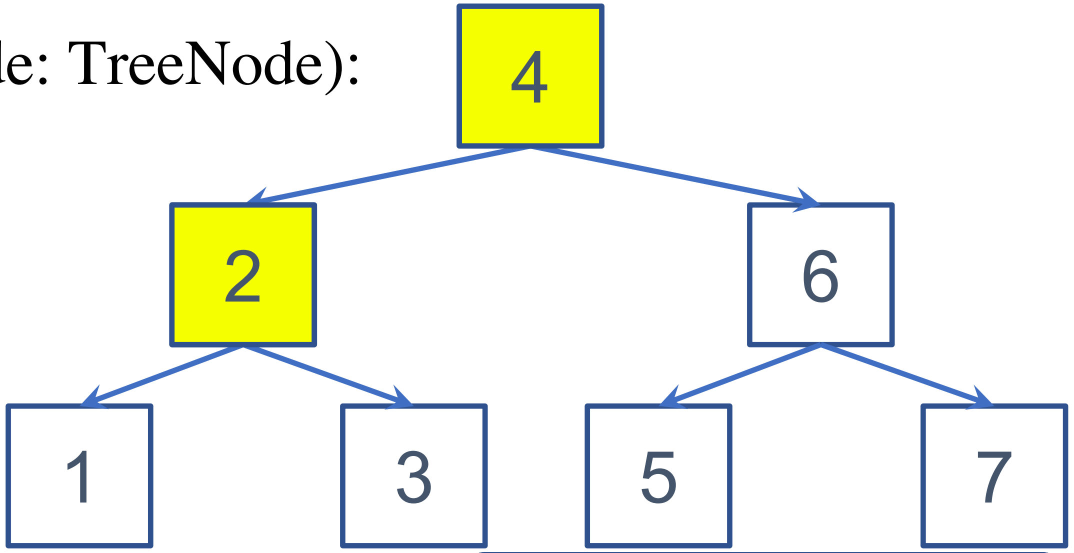



Out: 4

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

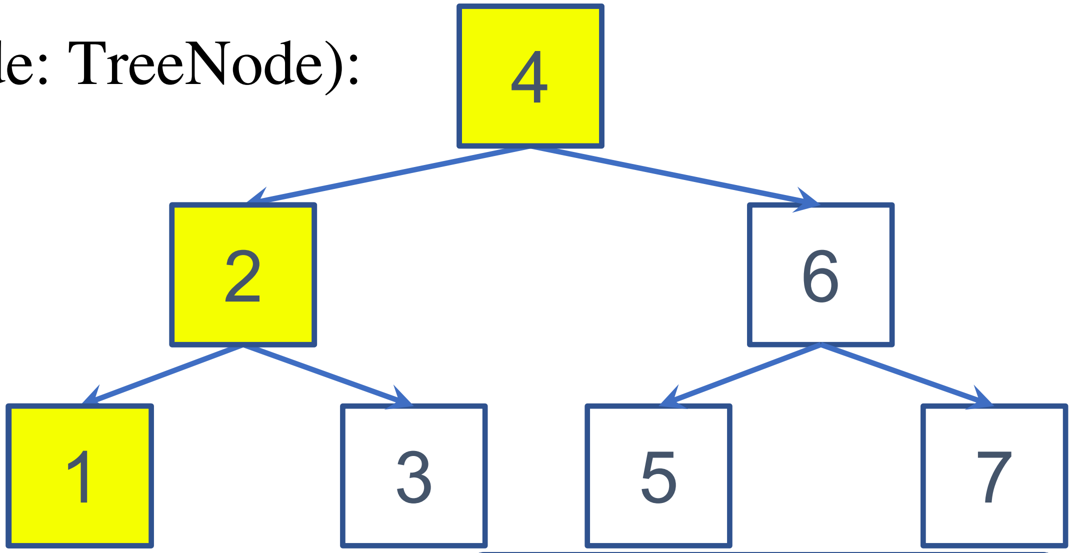


Out: 4 2

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

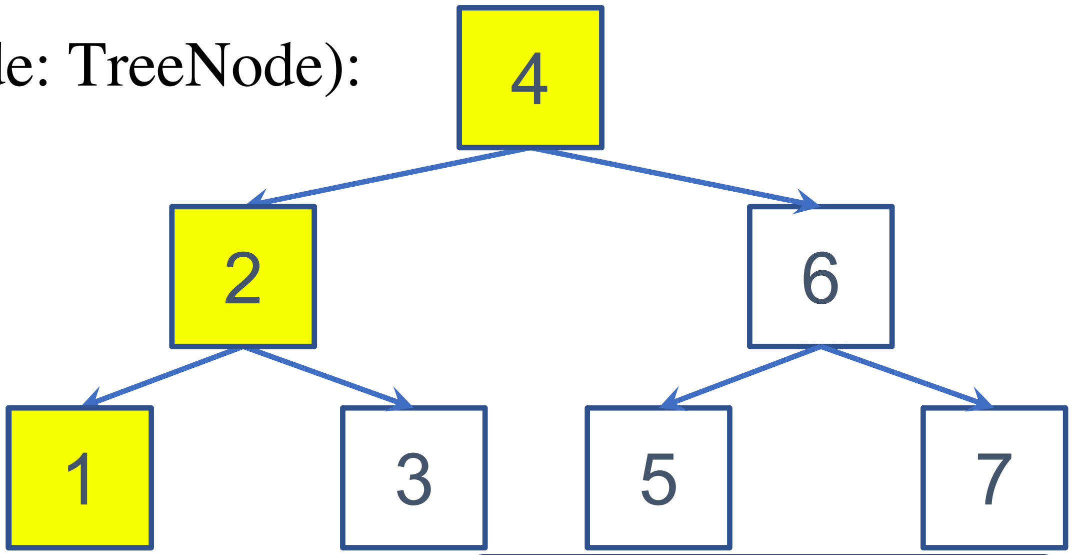


```
Out: 4 2
```

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

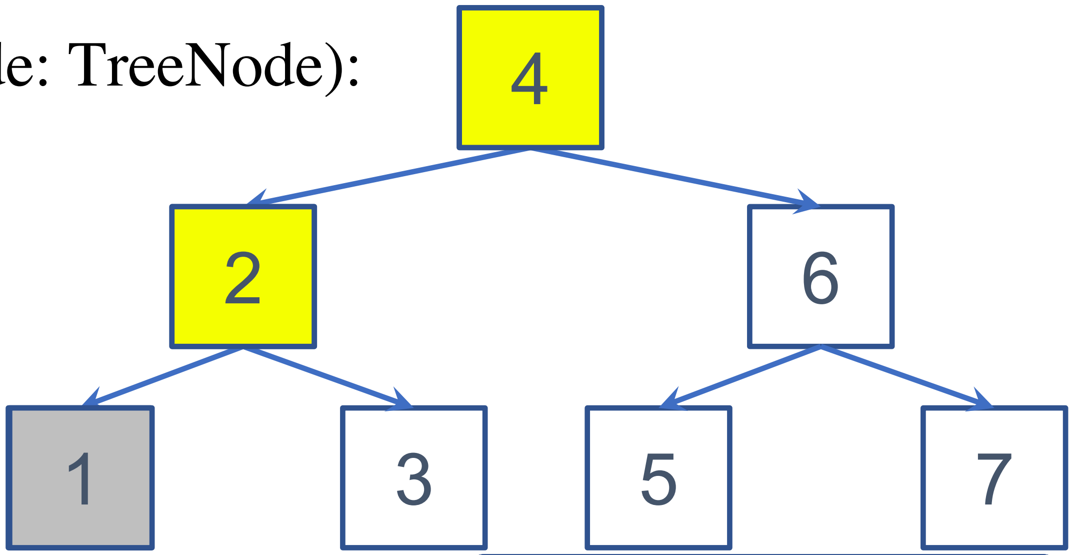


Out: 4 2 1

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

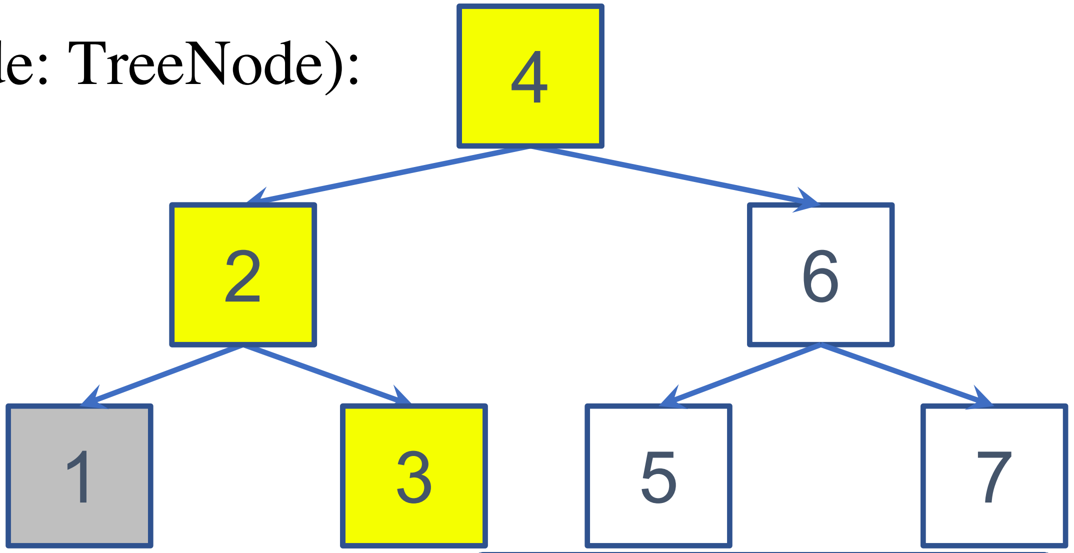


Out: 4 2 1

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

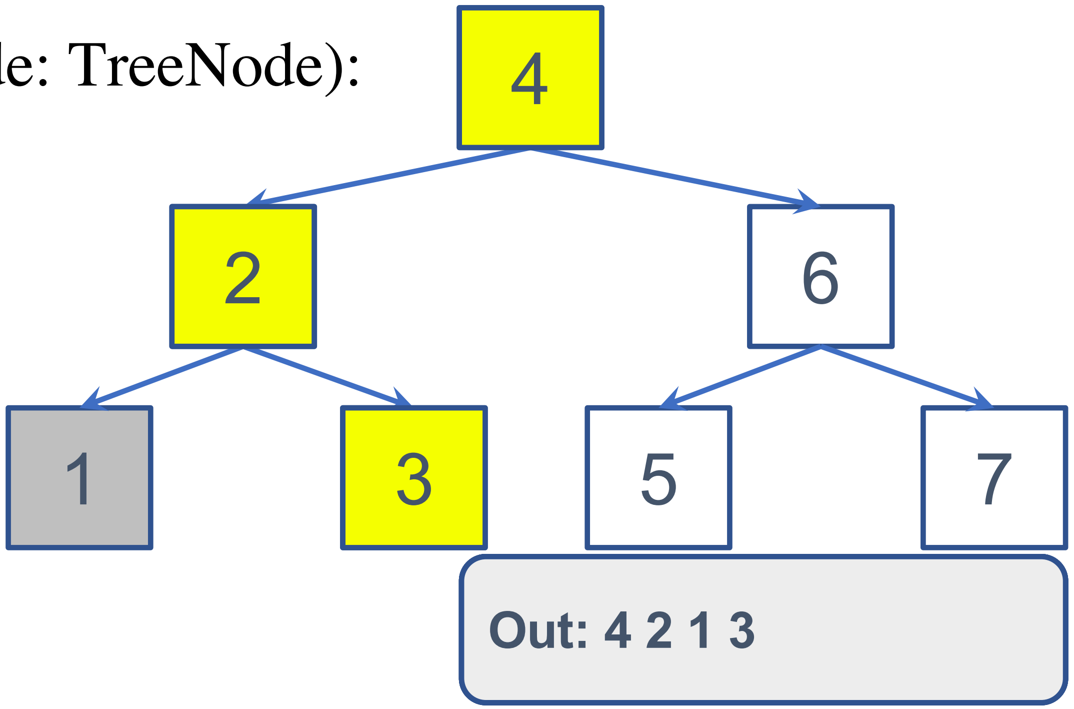


```
Out: 4 2 1
```

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

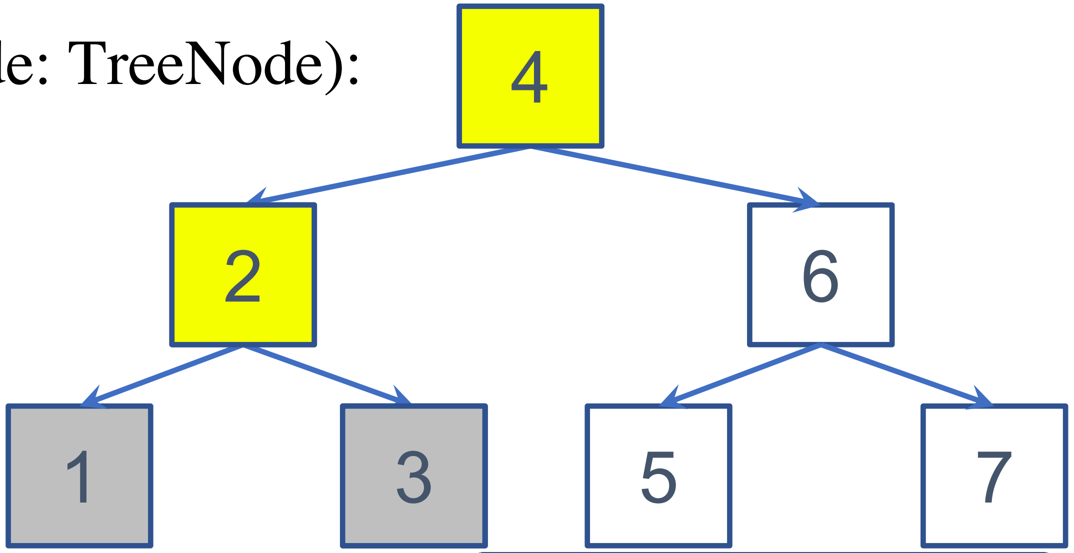


Out: 4 2 1 3

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

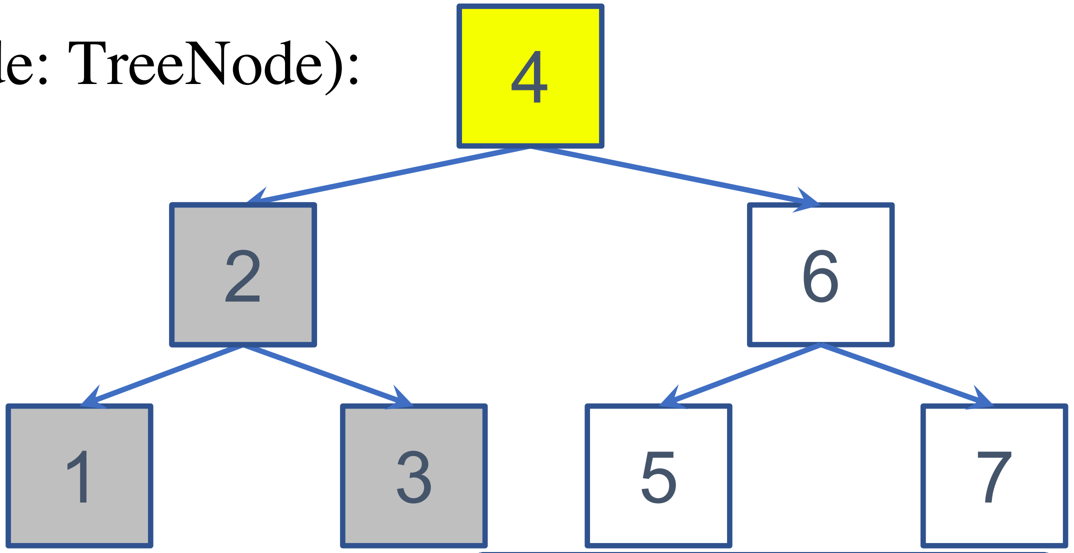


```
Out: 4 2 1 3
```

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

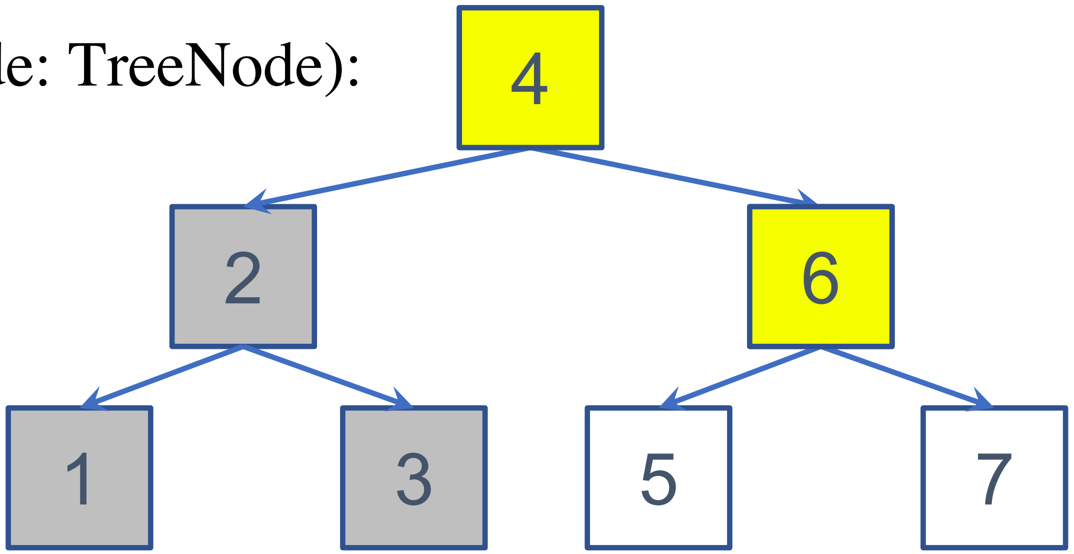


Out: 4 2 1 3

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

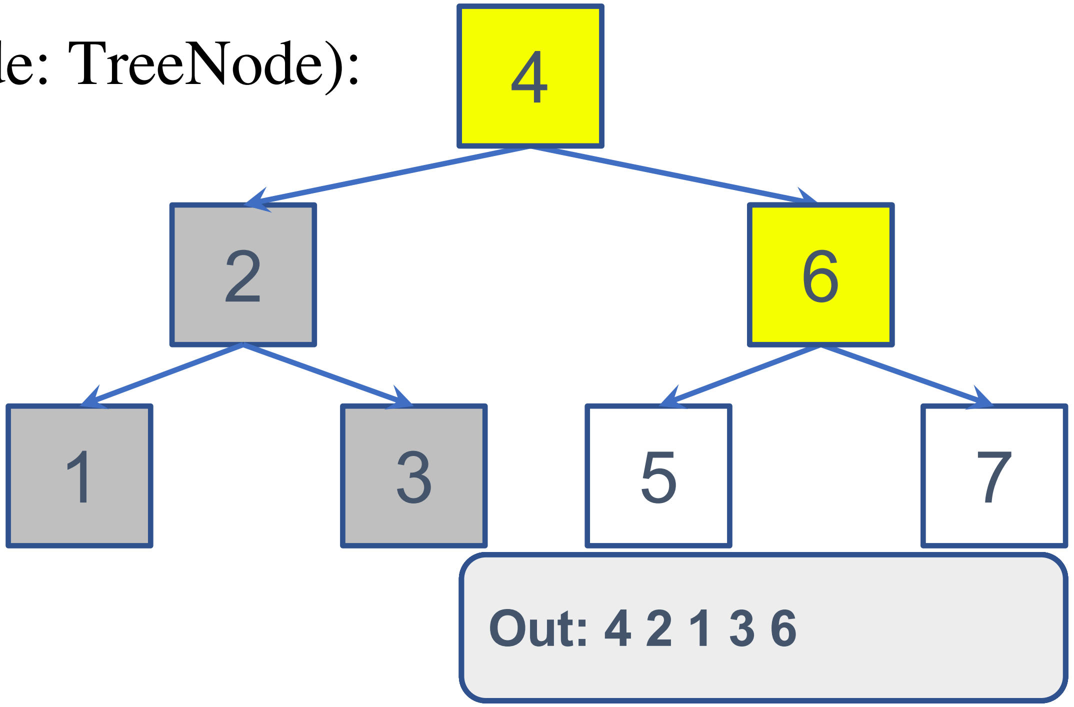


```
Out: 4 2 1 3
```

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

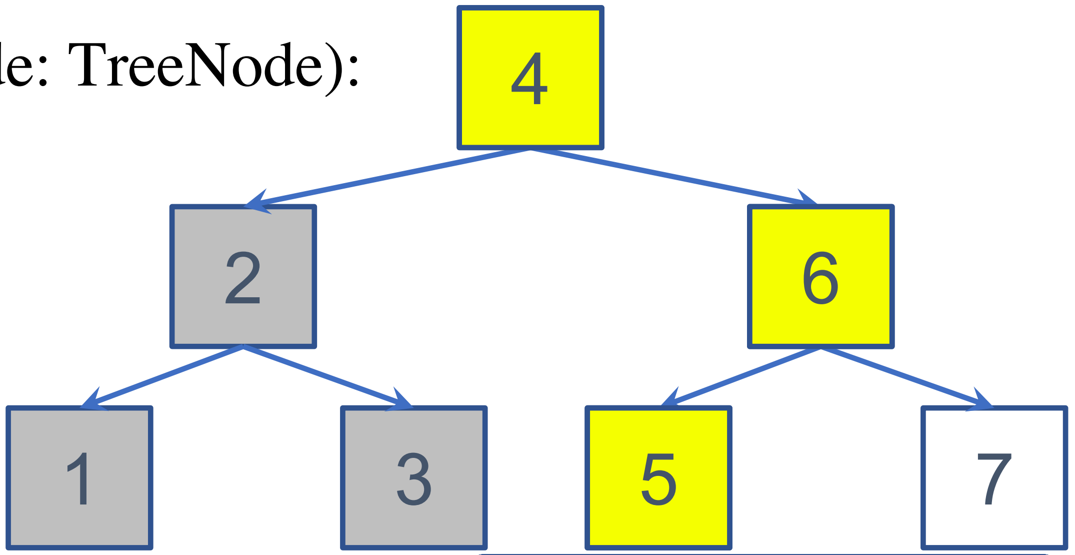


Out: 4 2 1 3 6

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

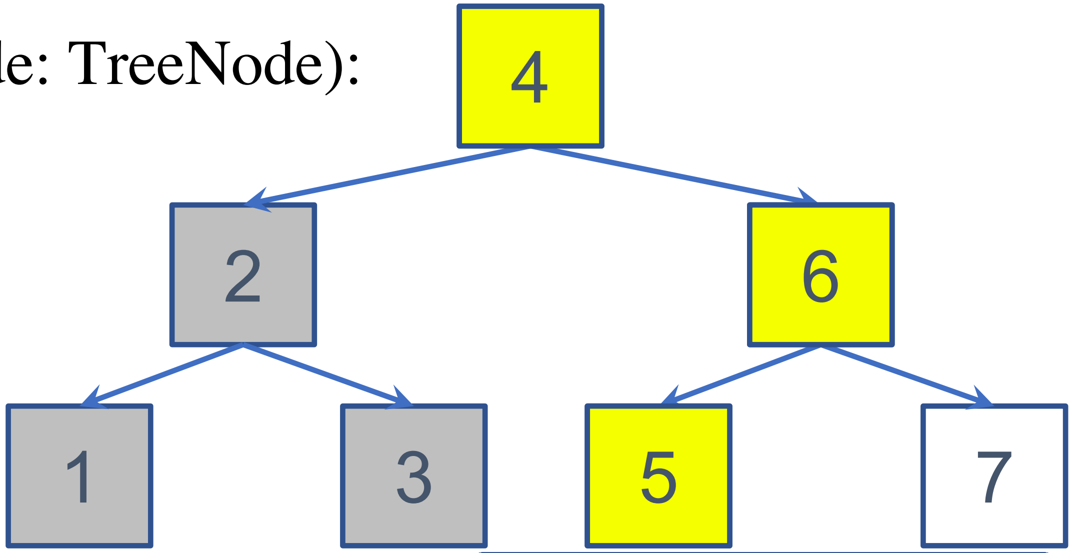


```
Out: 4 2 1 3 6
```

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

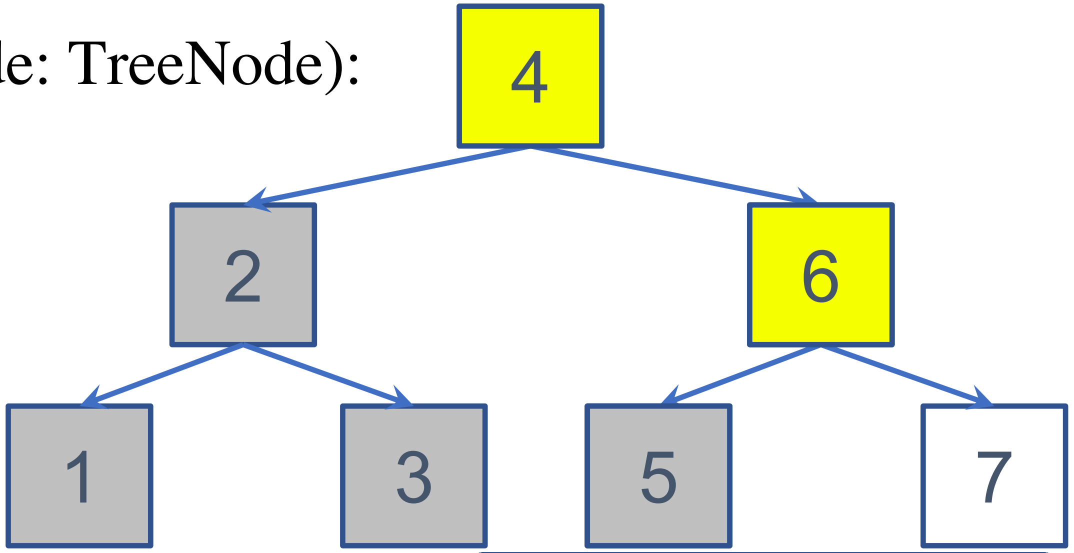


```
Out: 4 2 1 3 6 5
```

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

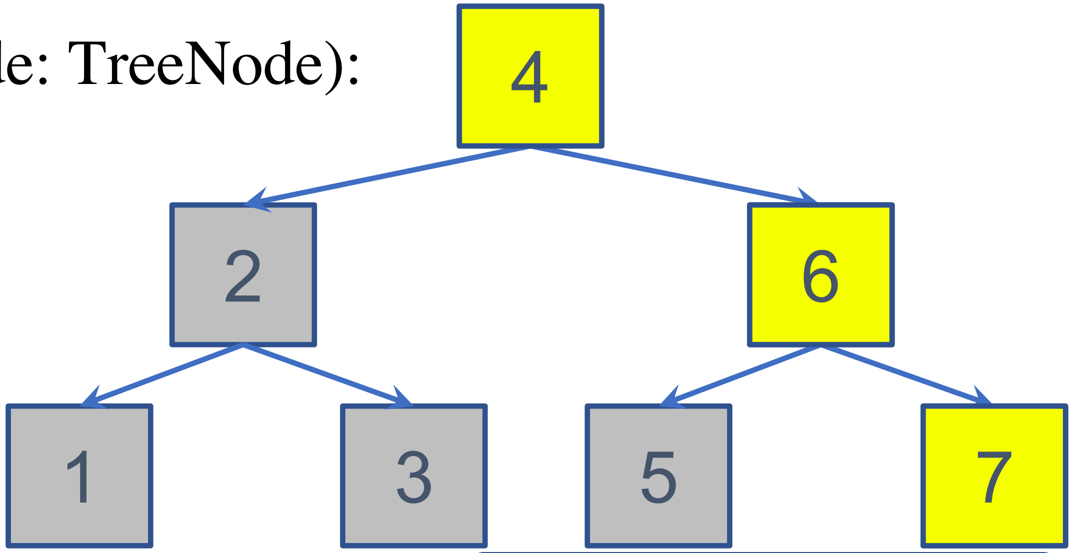


```
Out: 4 2 1 3 6 5
```

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

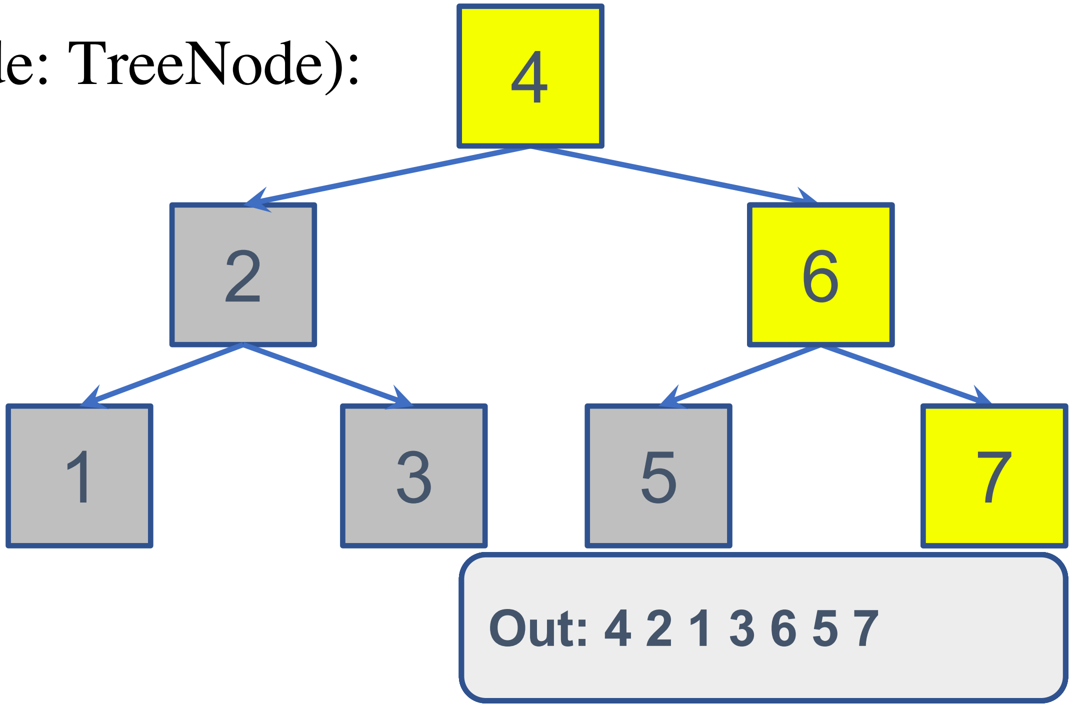


```
Out: 4 2 1 3 6 5
```

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

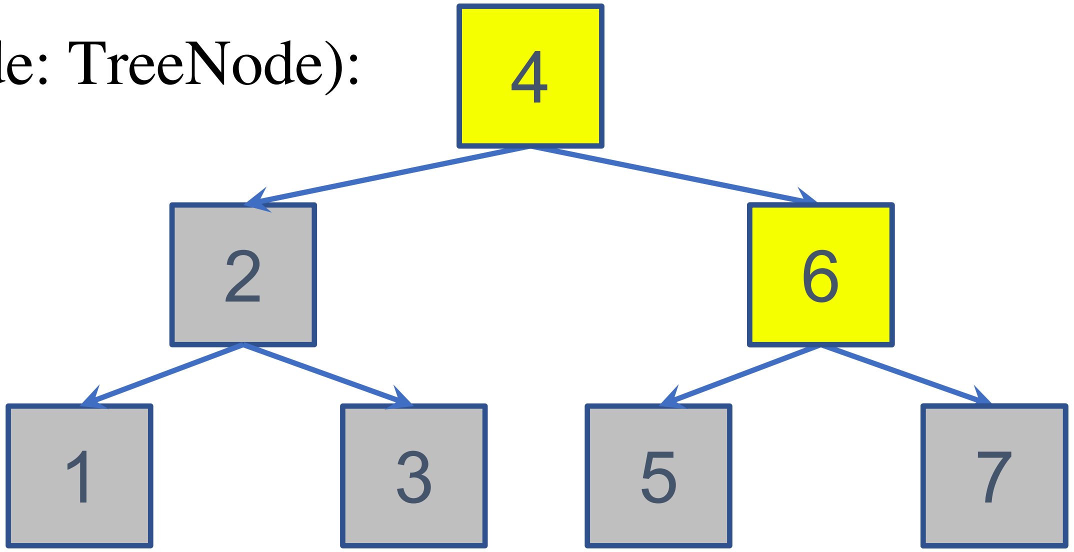
```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```



Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

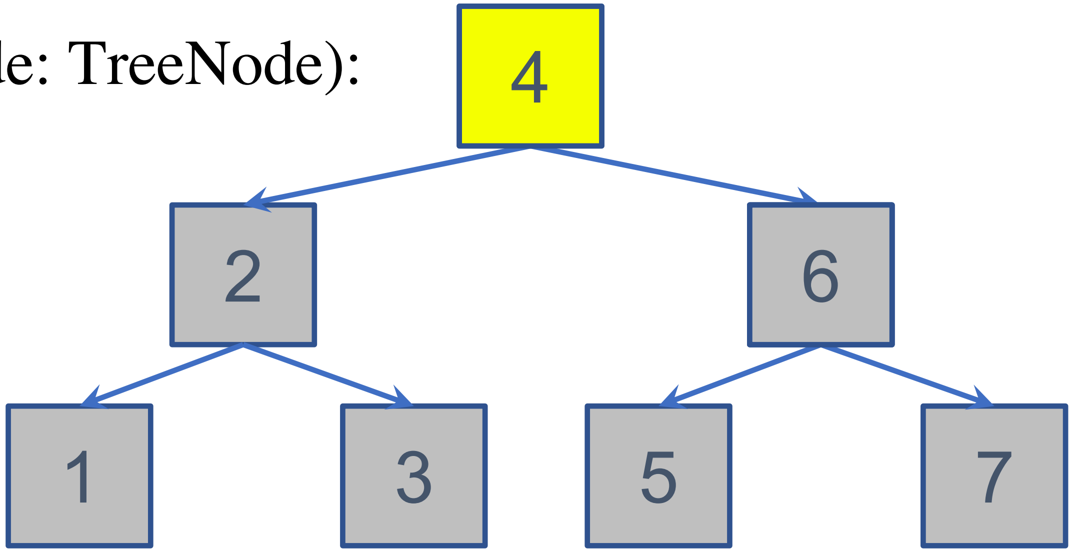


Out: 4 2 1 3 6 5 7

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```



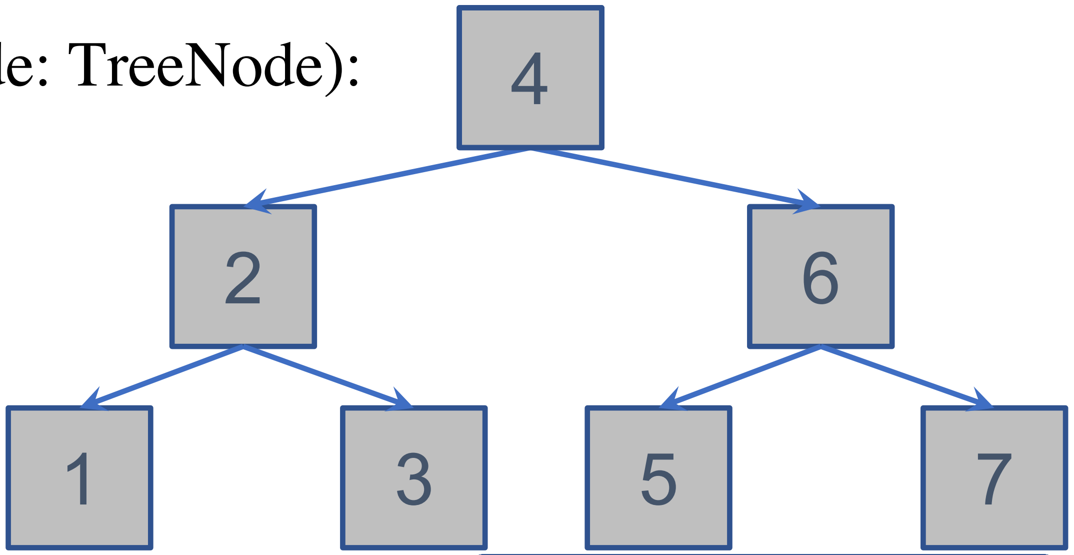
Out: 4 2 1 3 6 5 7

Depth First Traversals – Preorder

- Visit a node **before** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_preorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        self.visit(curNode)
        for childNode in curNode.child:
            self.__DFT_preorderHelp(childNode)

    def DFT_preorder(self):
        self.__DFT_preorderHelp(self.root)
```

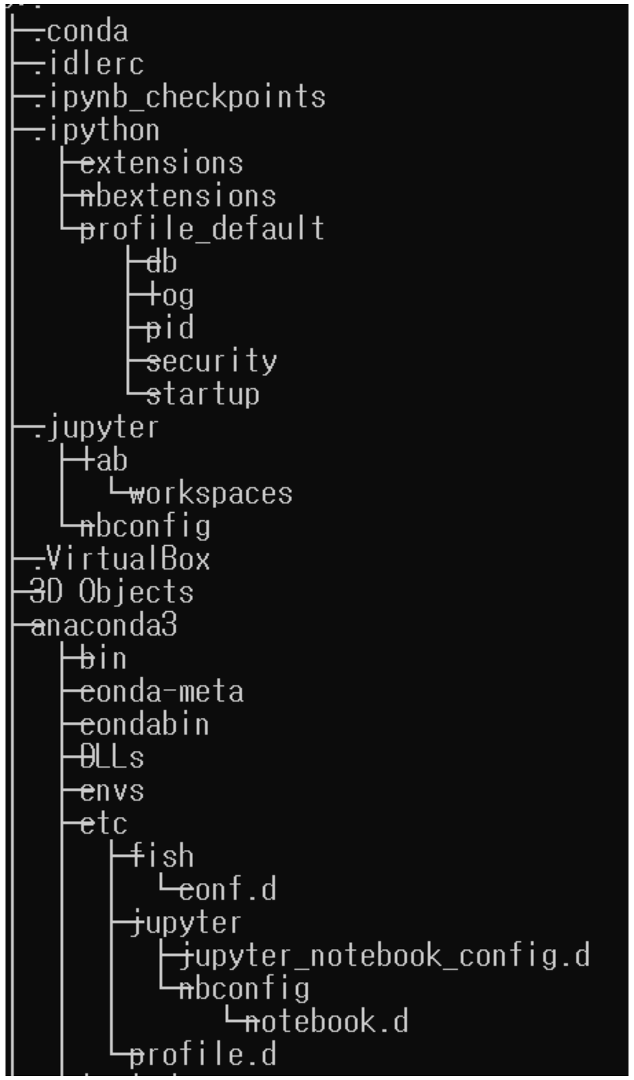
Done!



Out: 4 2 1 3 6 5 7

Depth First Traversals – Preorder

- **Application**: Directory listing (type "Tree" for fun)



```
├─.conda
├─.idlerc
├─.ipynb_checkpoints
├─.ipython
│  ├─extensions
│  ├─nbextensions
│  └─profile_default
│      ├─db
│      ├─log
│      ├─pid
│      ├─security
│      └─startup
├─.jupyter
│  ├─lab
│  │  └─workspaces
│  └─nbconfig
├─.VirtualBox
├─3D Objects
├─anaconda3
│  ├─bin
│  ├─conda-meta
│  ├─condabin
│  ├─DLLs
│  ├─envs
│  ├─etc
│  │  ├─fish
│  │  │  └─conf.d
│  │  ├─jupyter
│  │  │  ├─jupyter_notebook_config.d
│  │  │  └─nbconfig
│  │  │      └─notebook.d
│  │  └─profile.d
```

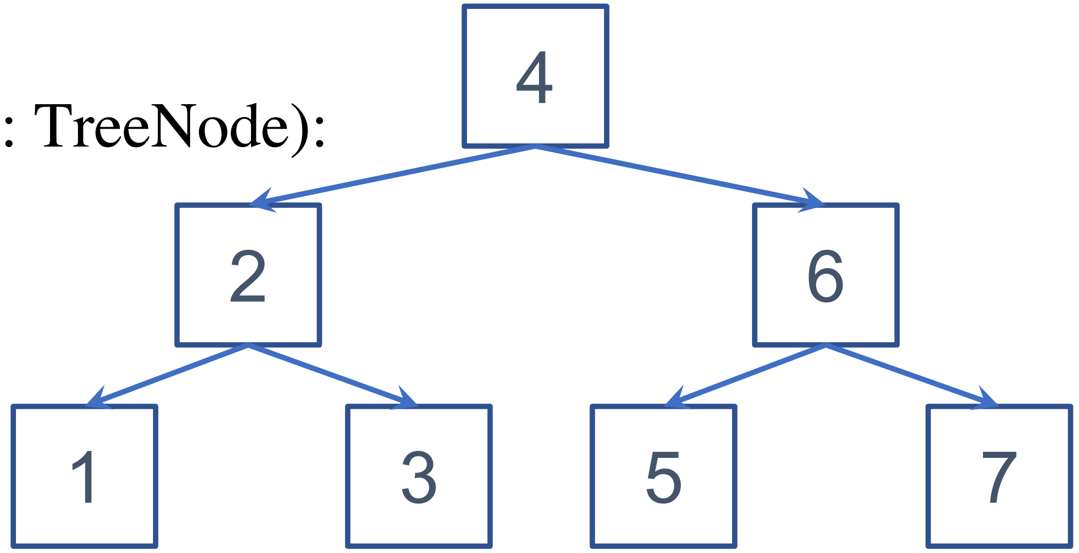
Depth-First Traversal

- Depth-First Traversal
- Preorder
- **Inorder**
- Postorder

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```

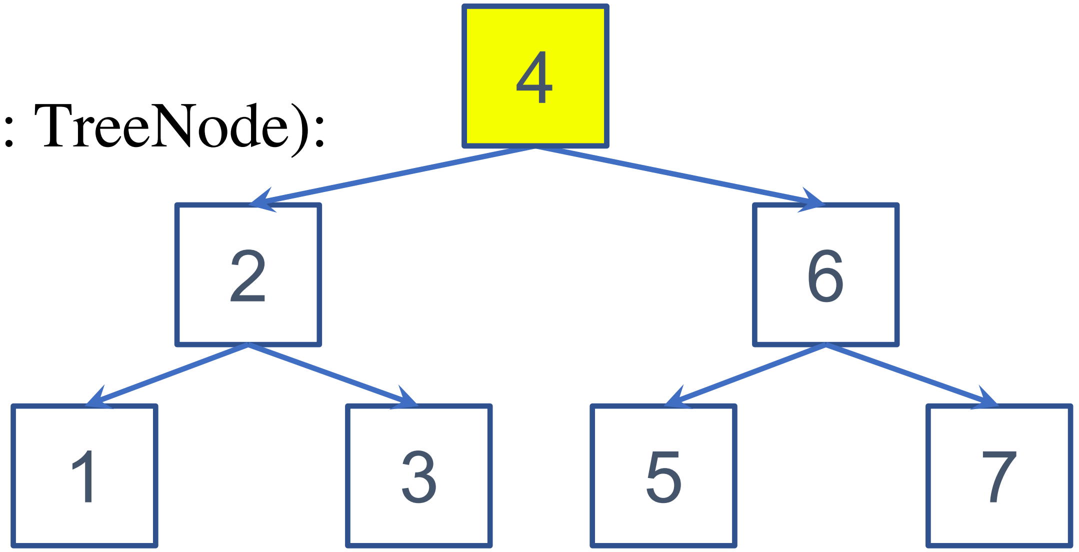


Out:

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```

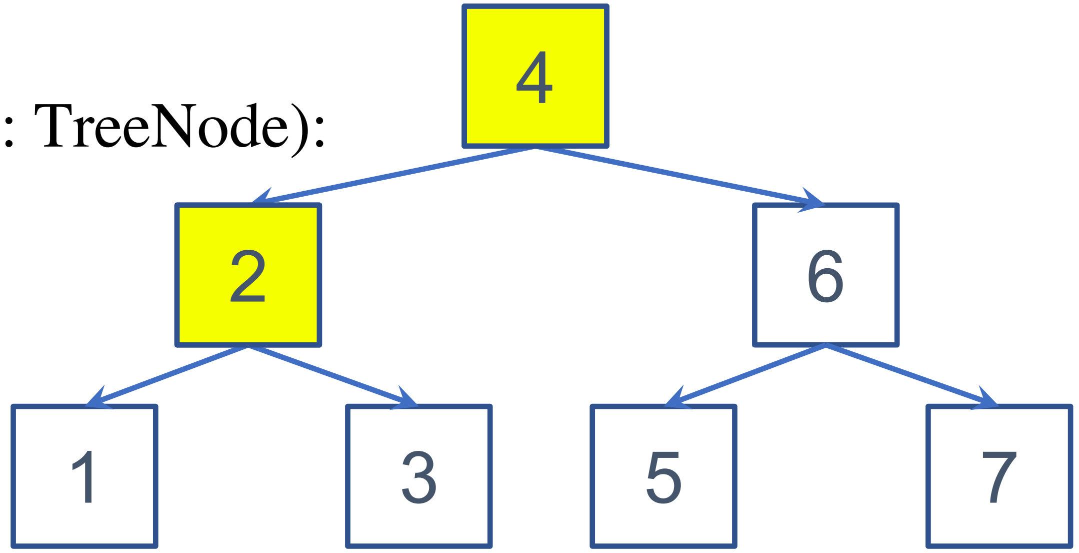


Out:

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```

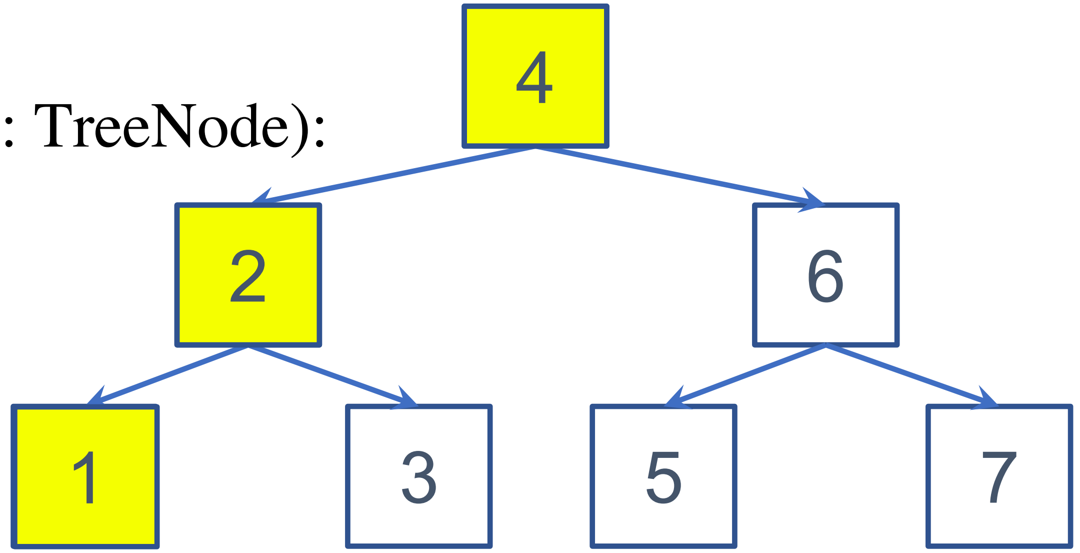


Out:

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```

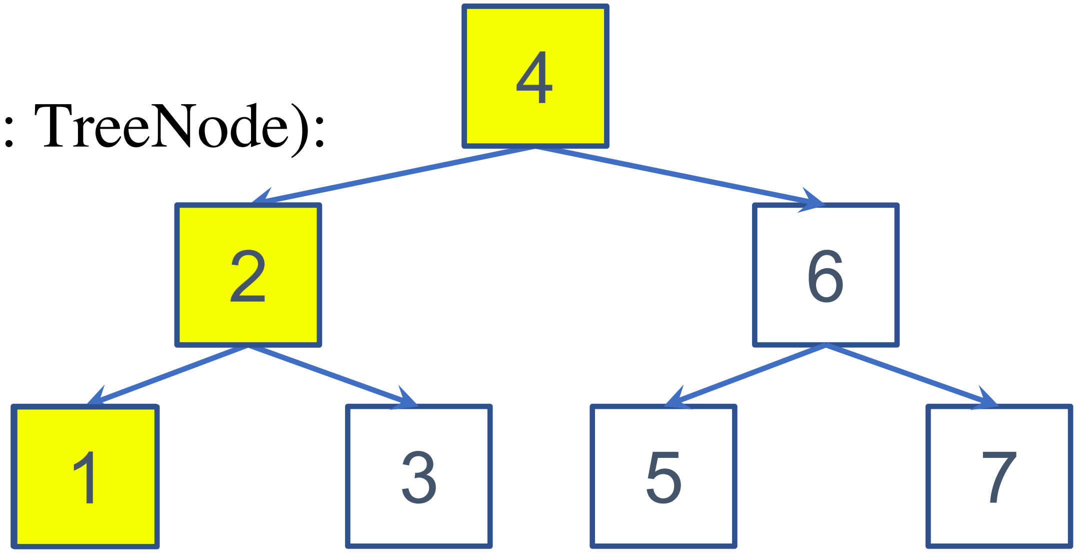


Out:

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```

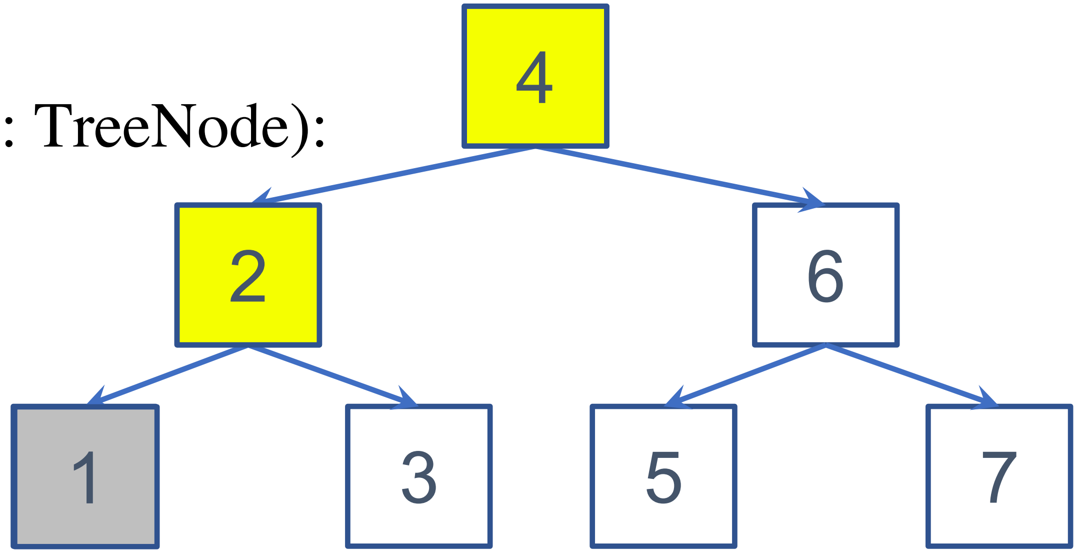


Out: 1

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```

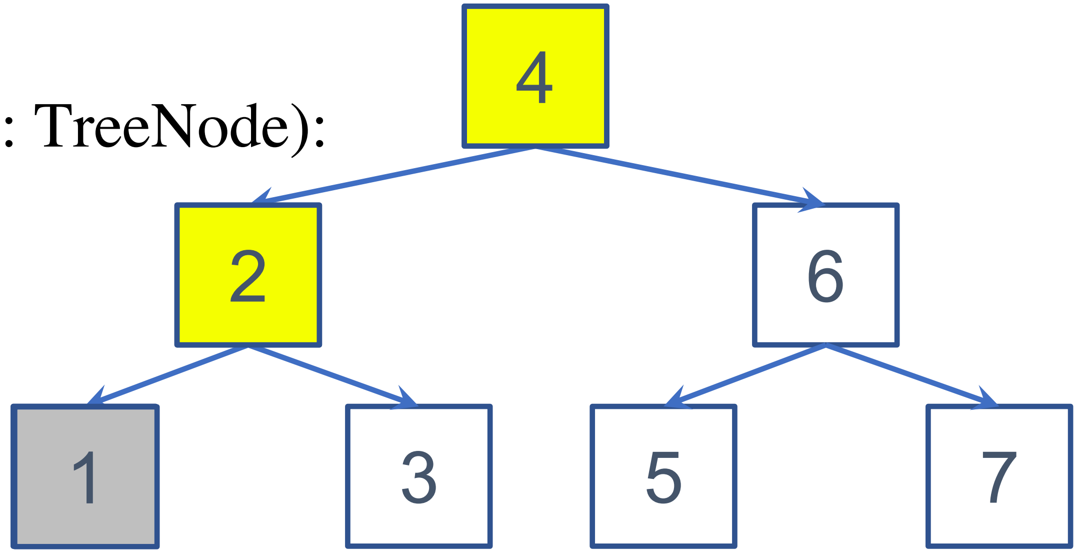


Out: 1

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```

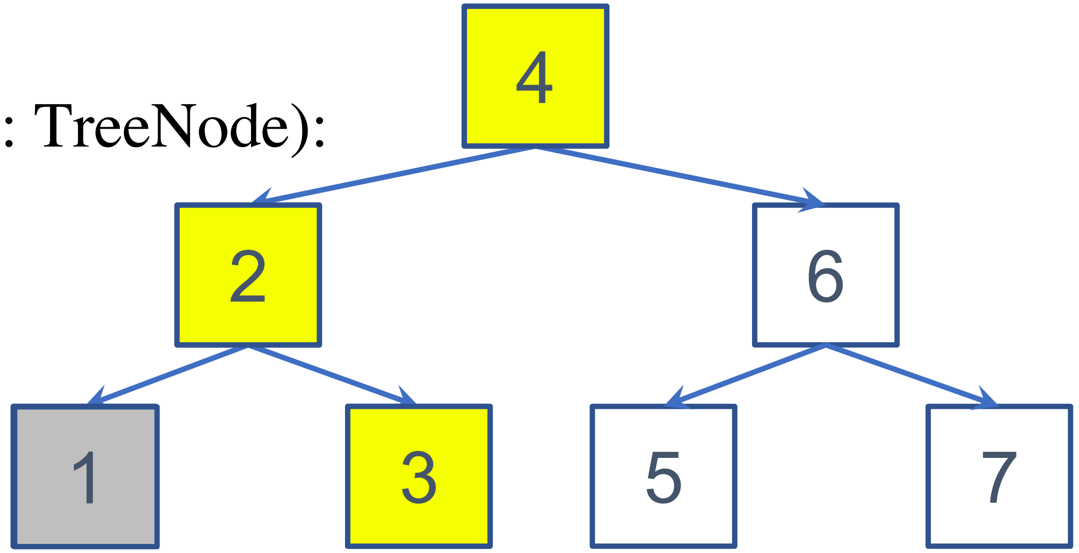


Out: 1 2

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```

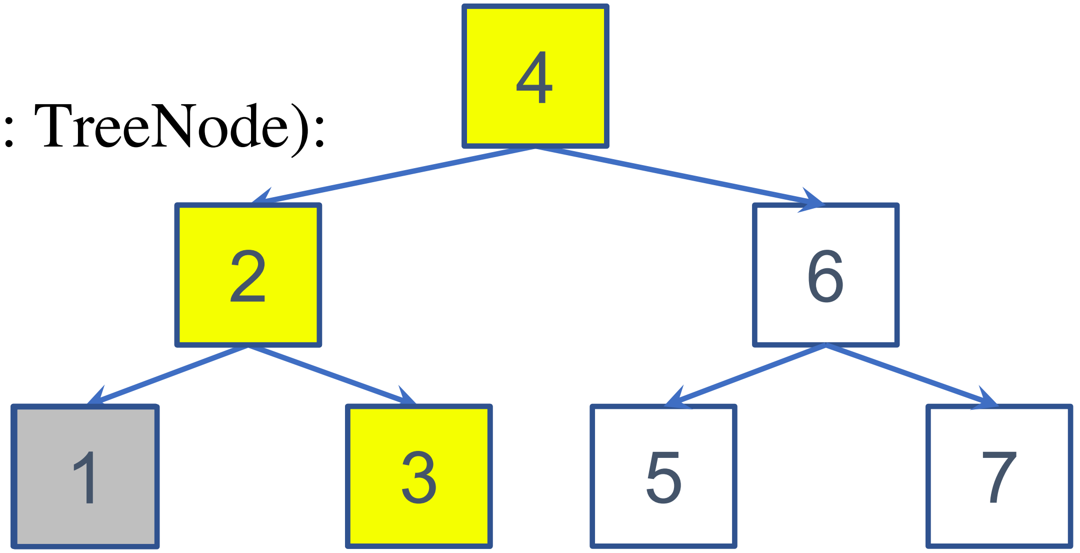


Out: 1 2

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```

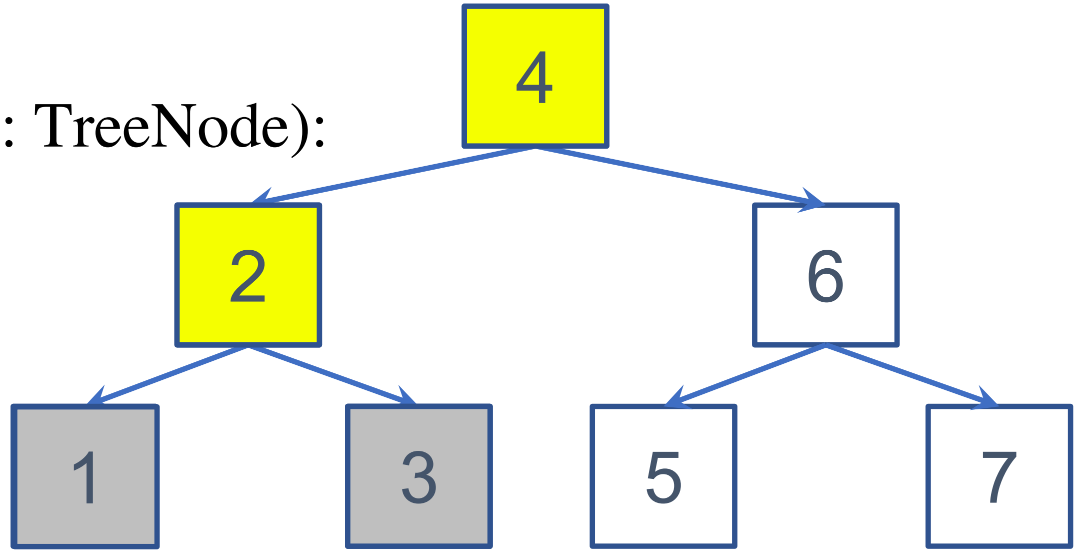


Out: 1 2 3

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```

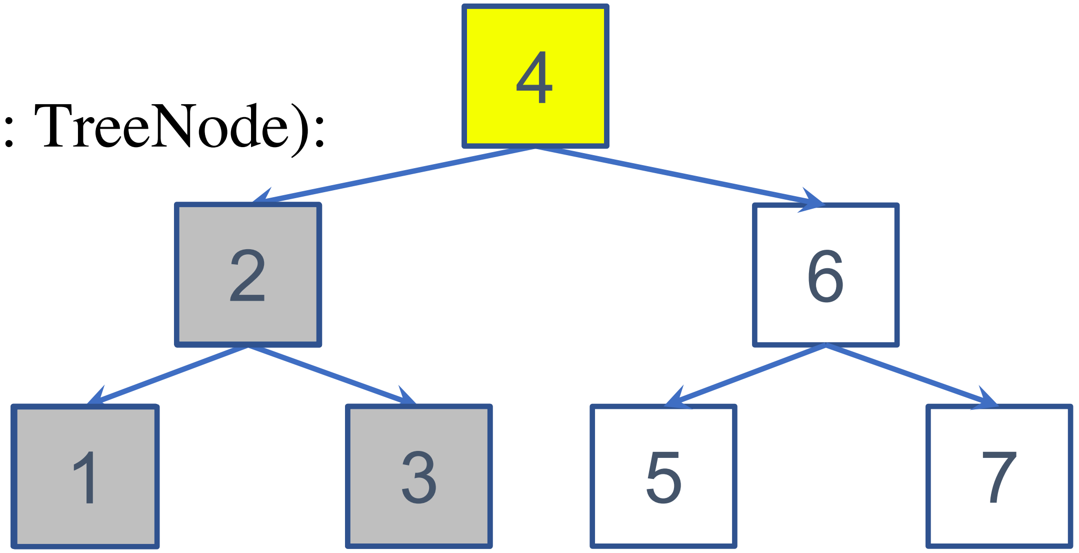


Out: 1 2 3

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```

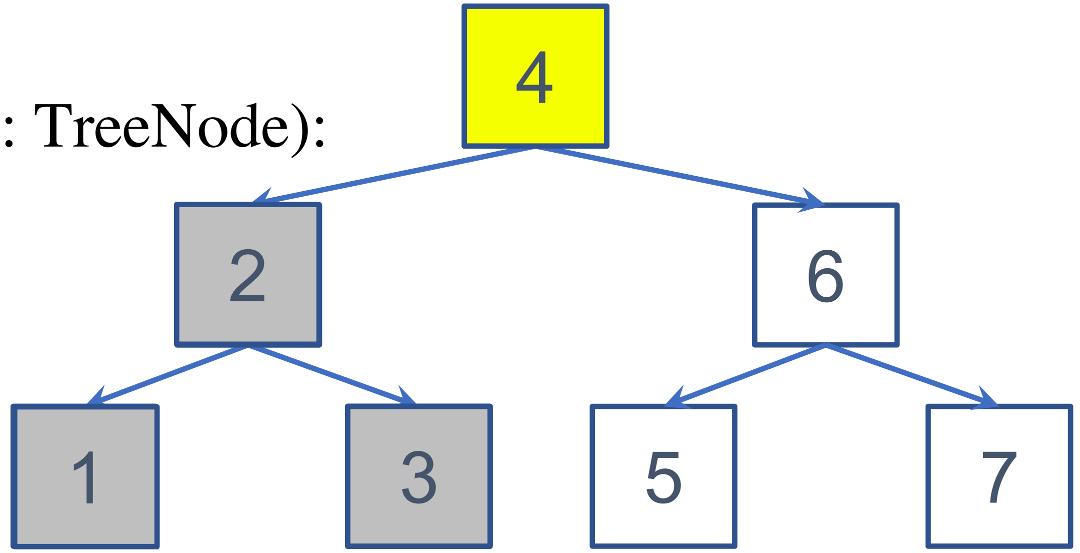


Out: 1 2 3

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```

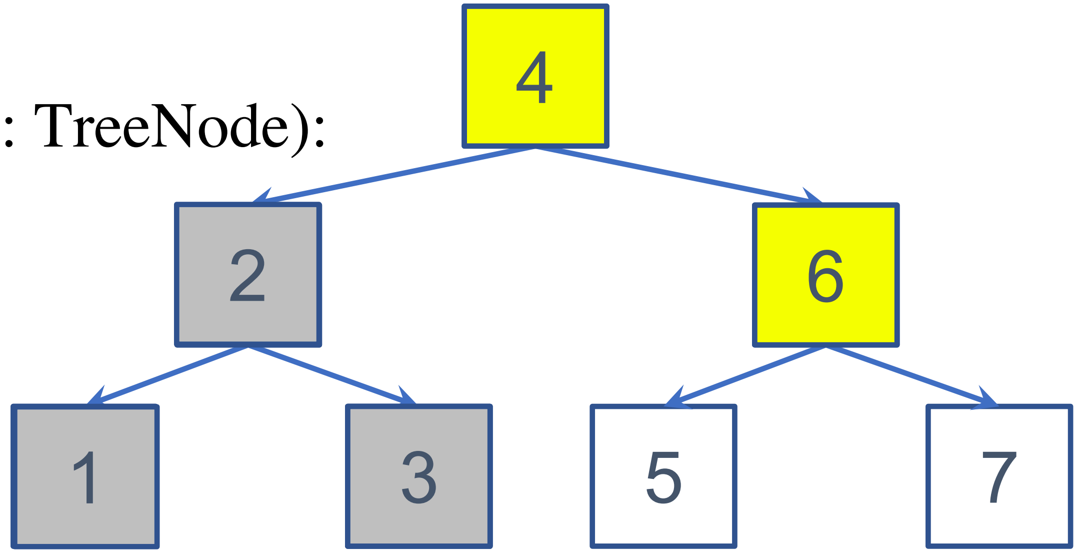


```
Out: 1 2 3 4
```

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```



```
Out: 1 2 3 4
```

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
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            if i == 1:
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    def DFT_inorder(self):
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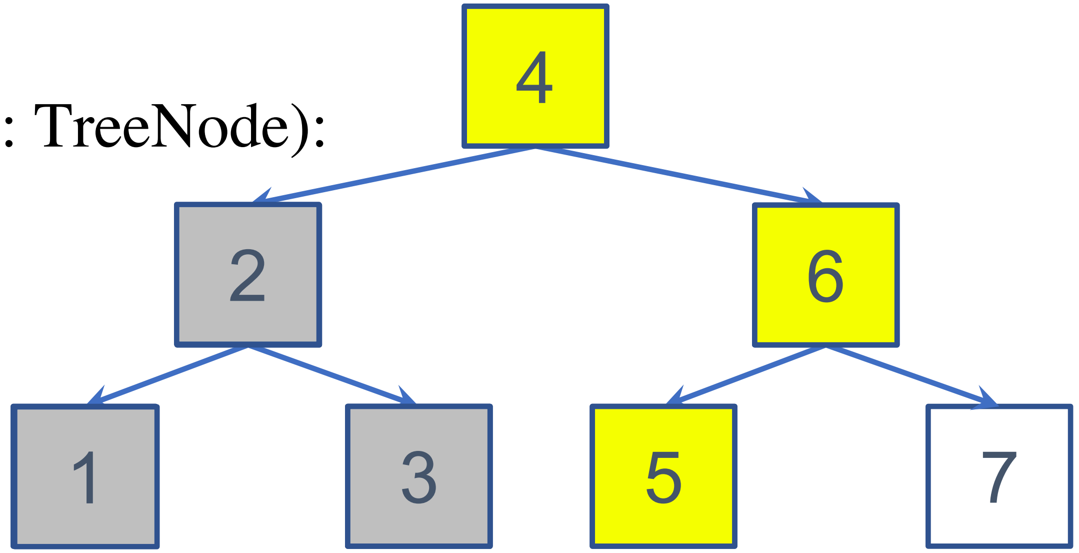


Out: 1 2 3 4

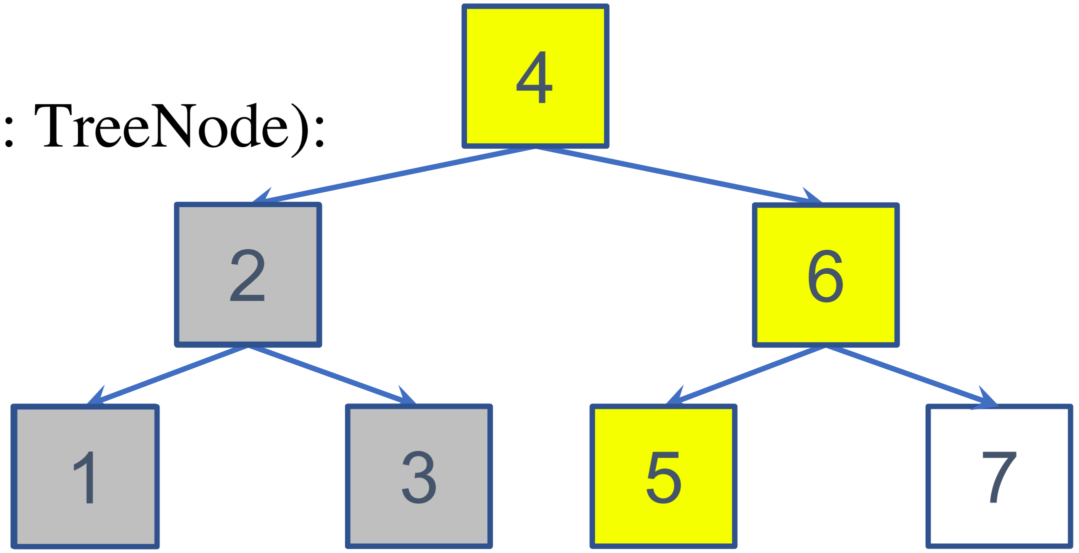
Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```



Out: 1 2 3 4 5

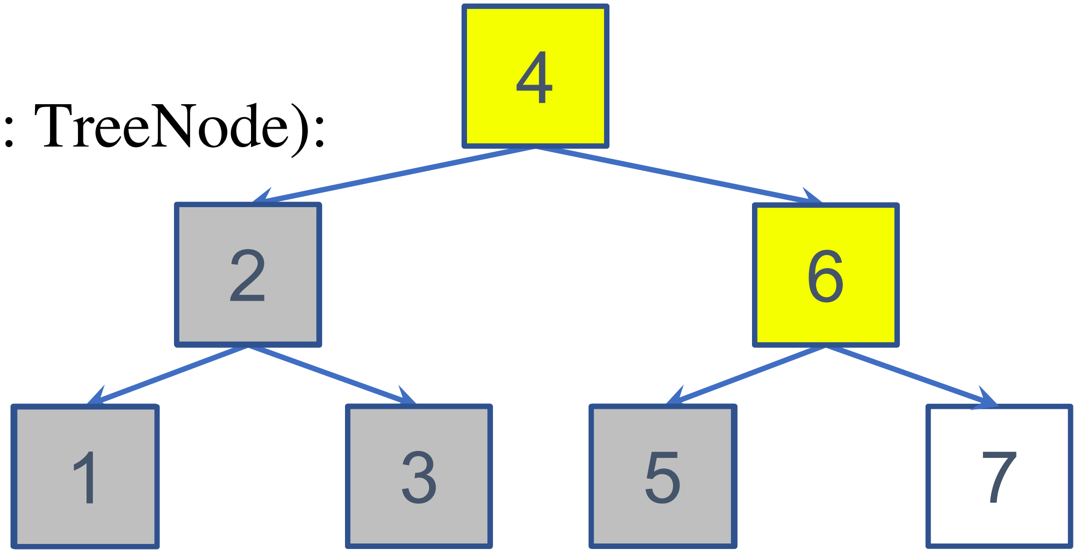
Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```



Out: 1 2 3 4 5

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

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            if i == 1:
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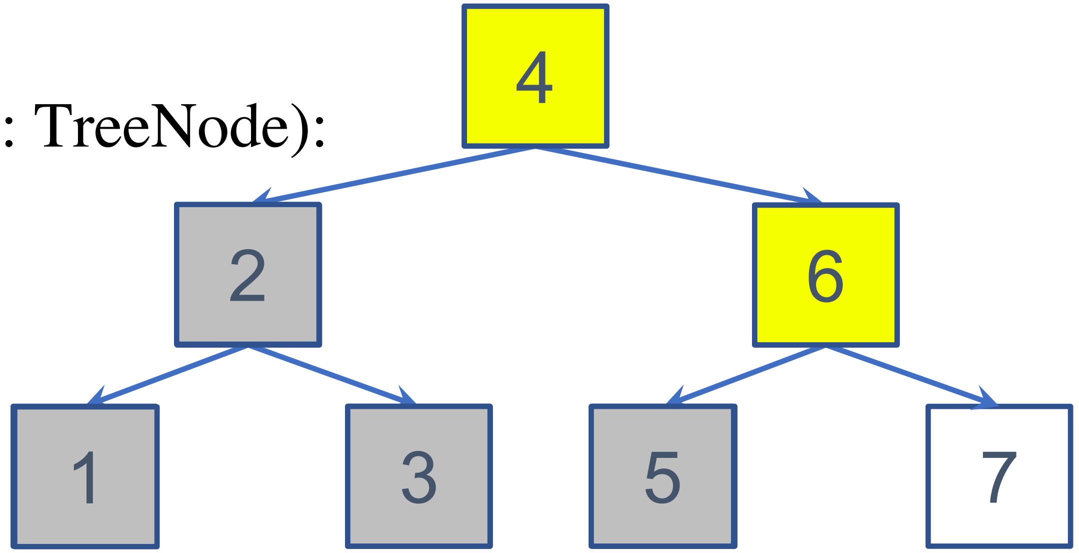
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```



Out: 1 2 3 4 5 6

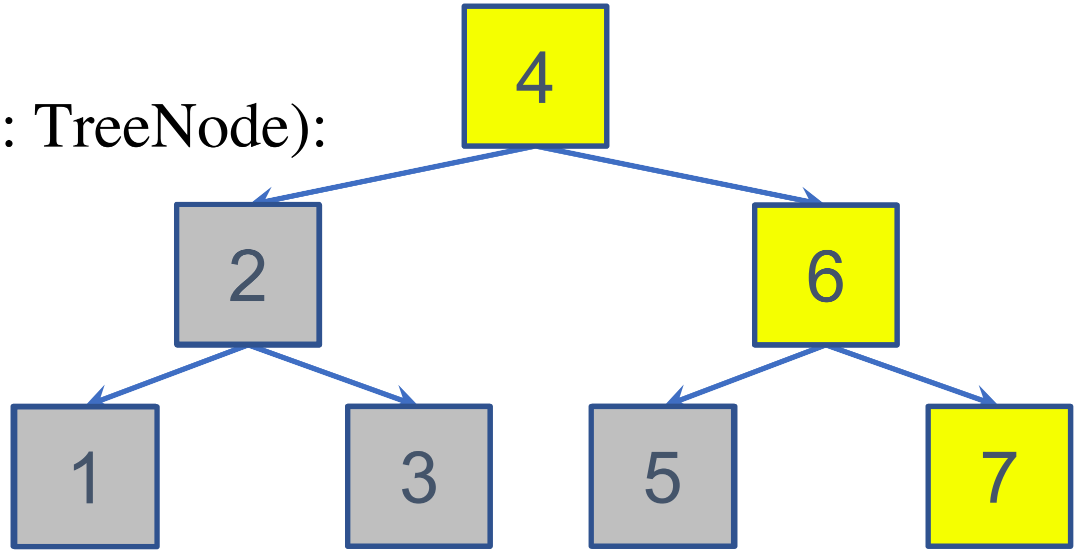
Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```



```
Out: 1 2 3 4 5 6
```

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
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        for i in range(len(curNode.child)):
            if i == 1:
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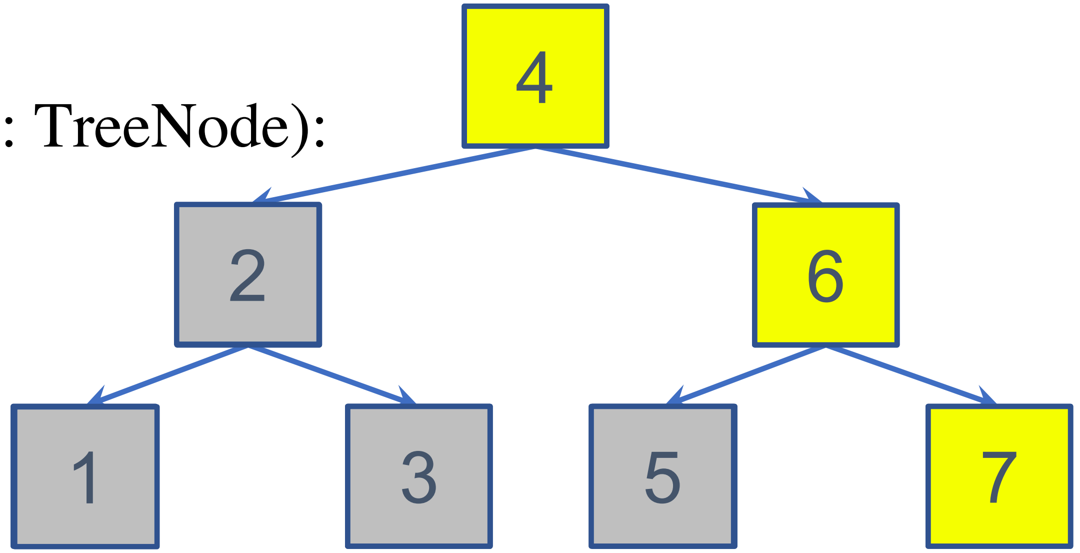
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```



Out: 1 2 3 4 5 6 7

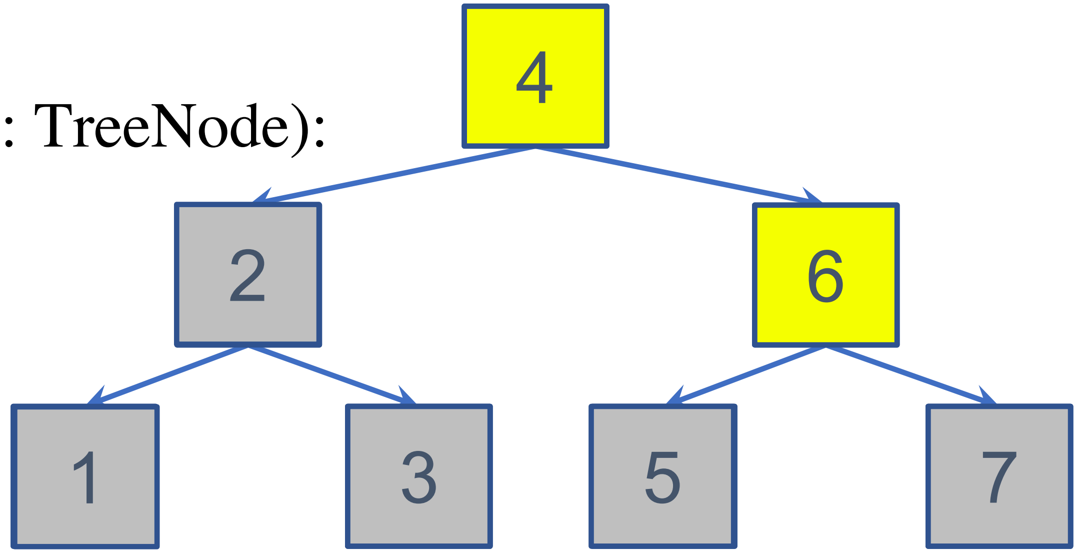
Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```



Out: 1 2 3 4 5 6 7

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
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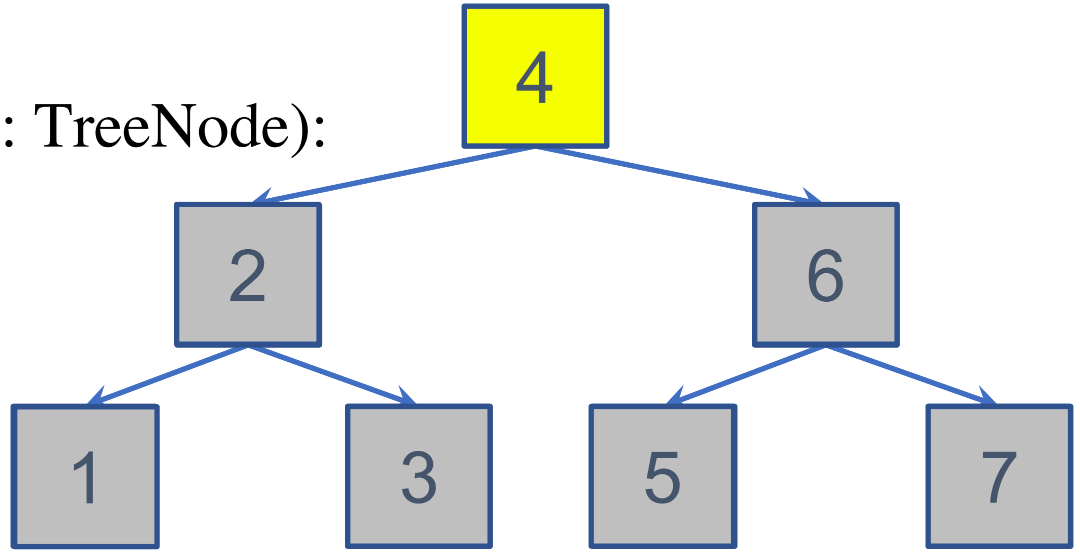
            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
        self.__DFT_inorderHelp(self.root)
```



Out: 1 2 3 4 5 6 7

Depth First Traversals – Inorder

- Traverse a node's children from left to right and visit the node **in the middle**

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_inorderHelp(self, curNode: TreeNode):
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            return
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            if i == 1:
                self.visit(curNode)
            self.__DFT_inorderHelp(curNode.child[i])

    def DFT_inorder(self):
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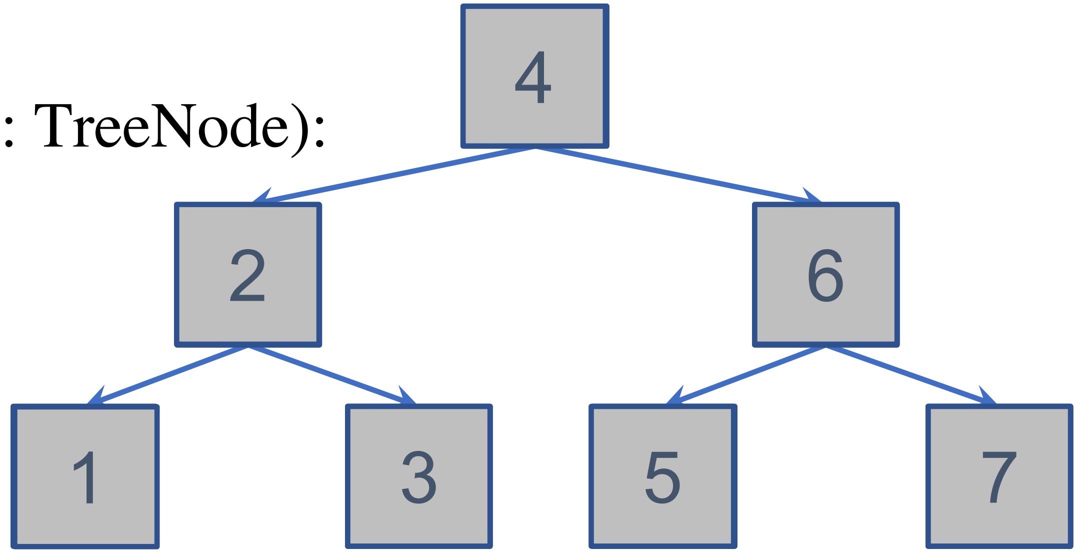
```



```
Out: 1 2 3 4 5 6 7
```

Depth First Traversals – Inorder

- **Application**: Covert a binary search tree to a sorted list (Flattening a BST)

Depth-First Traversal

- Depth-First Traversal
- Preorder
- Inorder
- **Postorder**

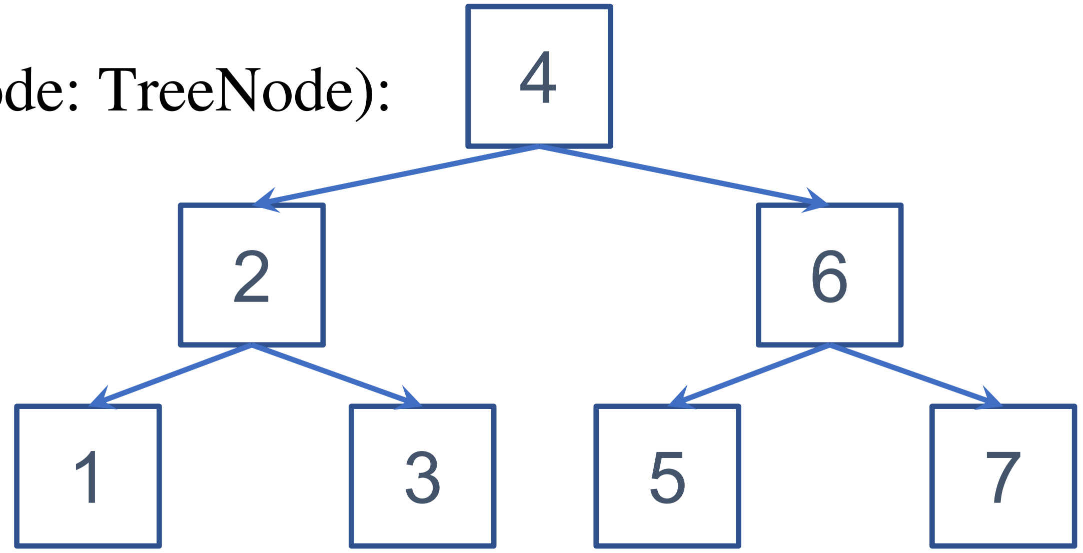
Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```



Out:

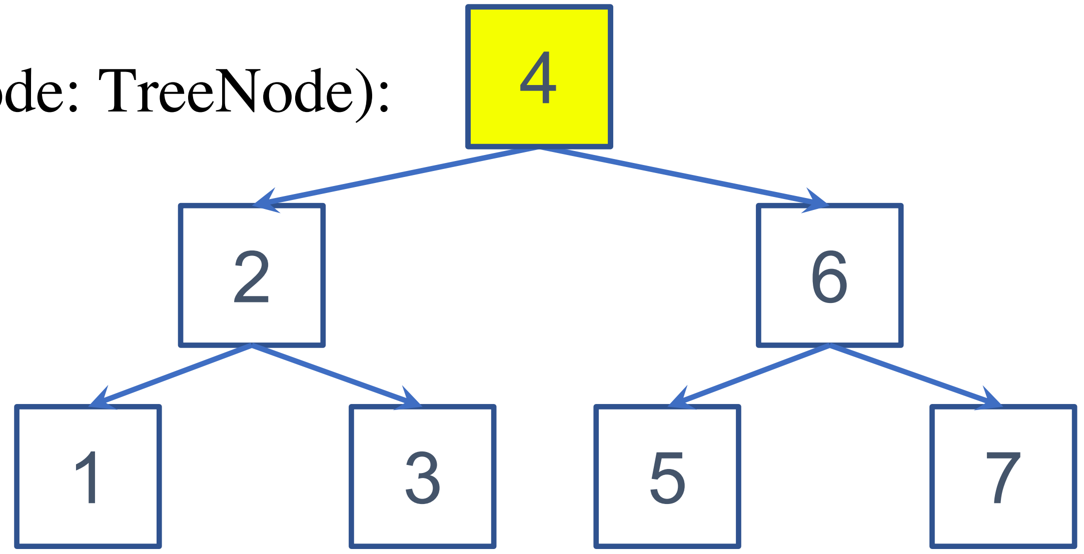
Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```



Out:

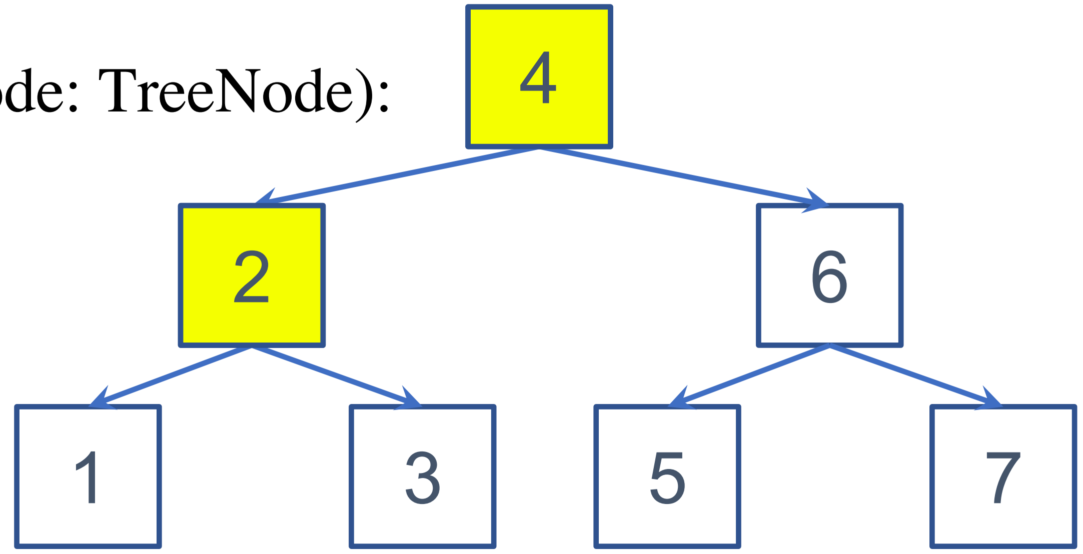
Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```



Out:

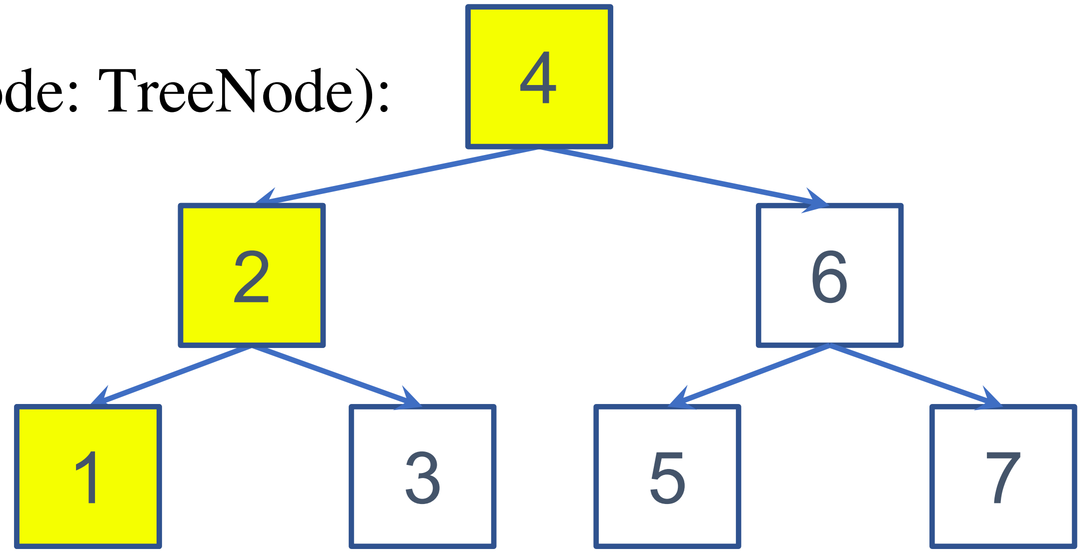
Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```



Out:

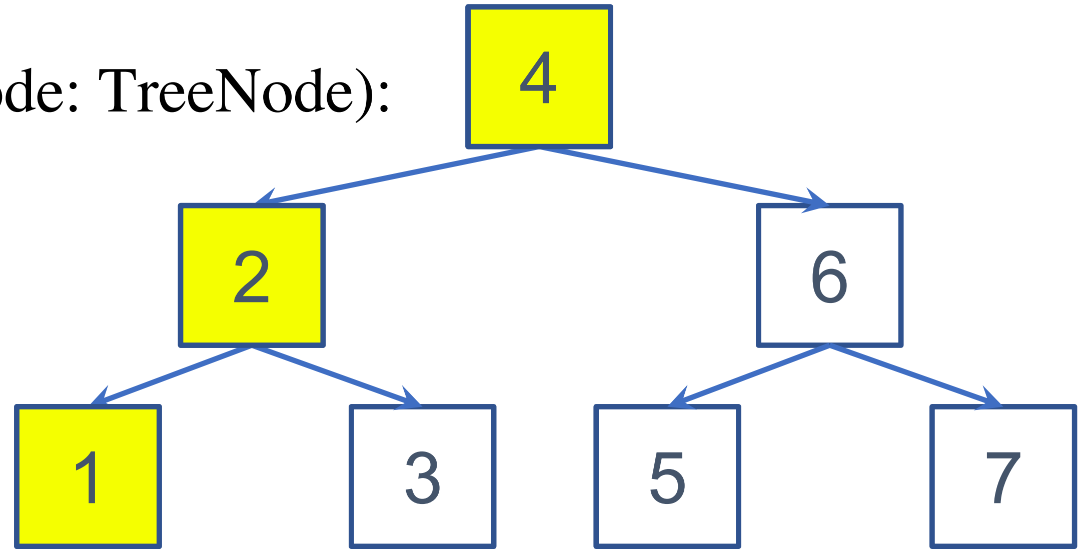
Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```



Out: 1

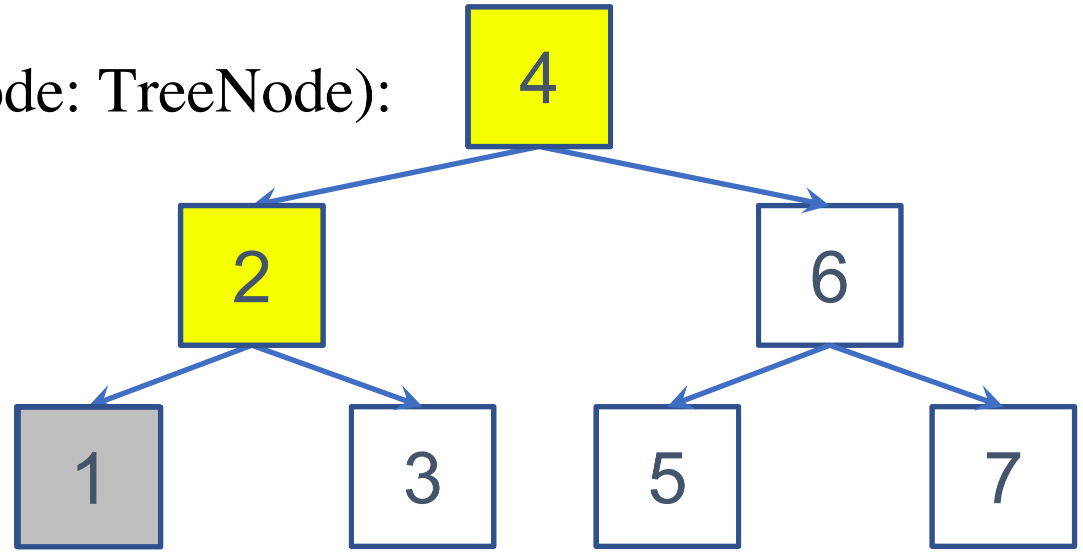
Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```



```
Out: 1
```

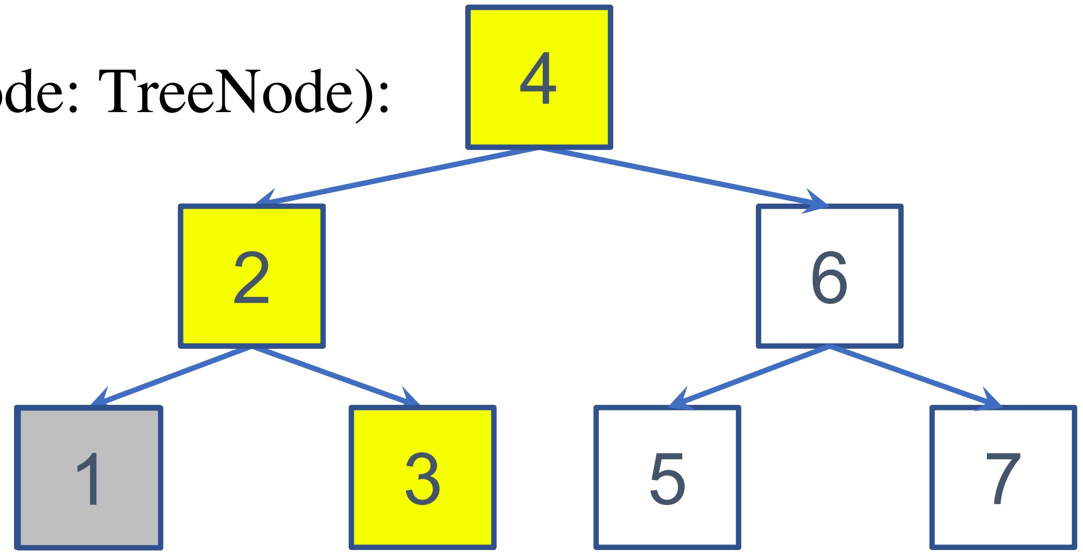
Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```



Out: 1

Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

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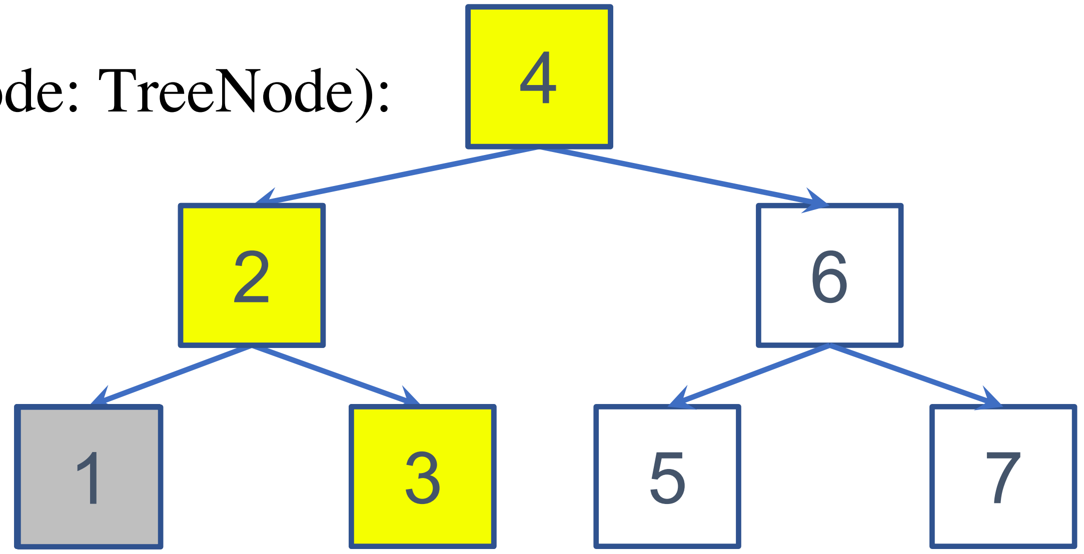
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```



Out: 1 3

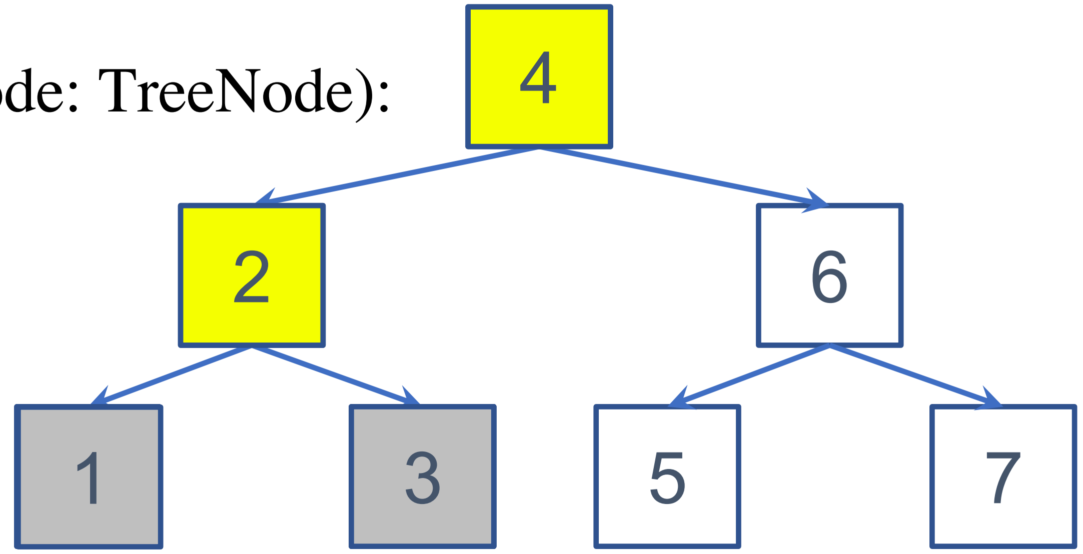
Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
        def visit(self, node: TreeNode):
            print(node.val)

        def __DFT_postorderHelp(self, curNode: TreeNode):
            if curNode == None:
                return
            for i in range(len(curNode.child)):
                self.__DFT_postorderHelp(curNode.child[i])
            self.visit(curNode)

        def DFT_postorder(self):
            self.__DFT_postorderHelp(self.root)
```



```
Out: 1 3
```

Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
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        if curNode == None:
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            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

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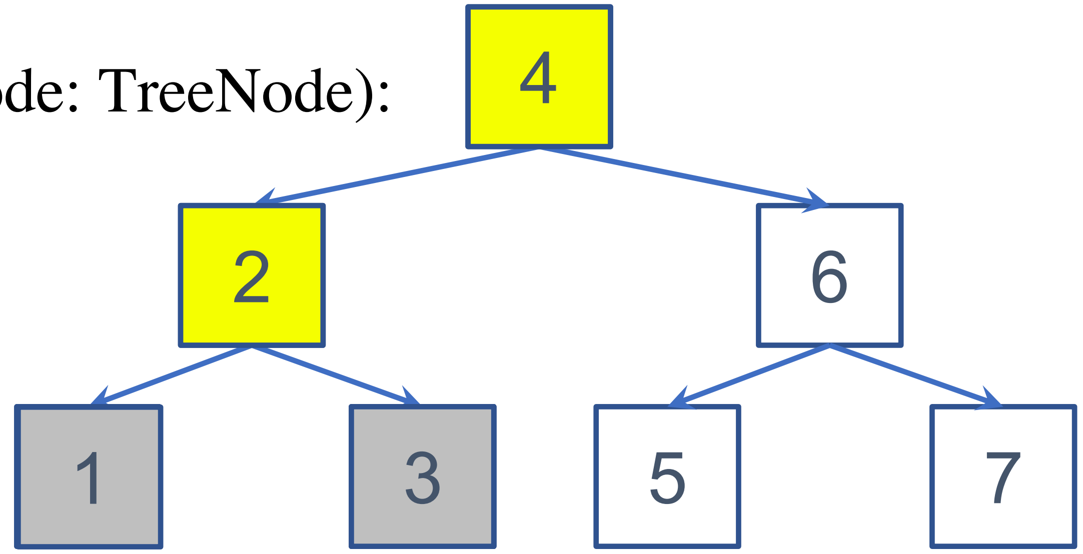
```



```
Out: 1 3 2
```

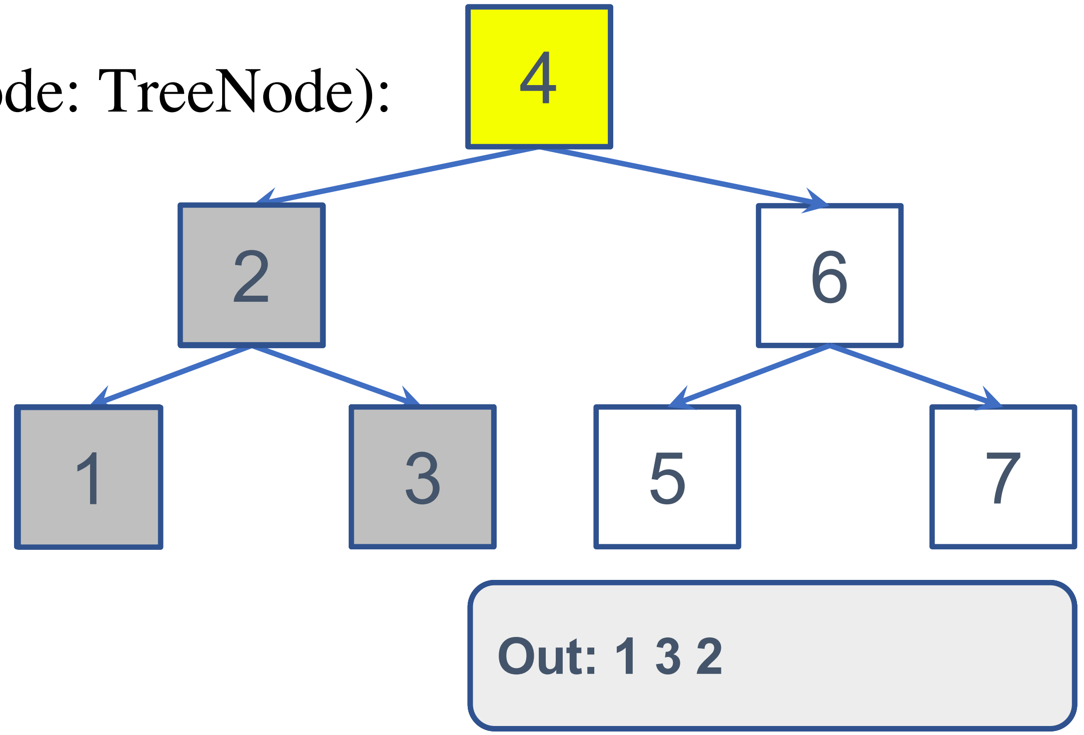
Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```



Depth First Traversals – Postorder

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class Tree():
    def visit(self, node: TreeNode):
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            self.__DFT_postorderHelp(curNode.child[i])
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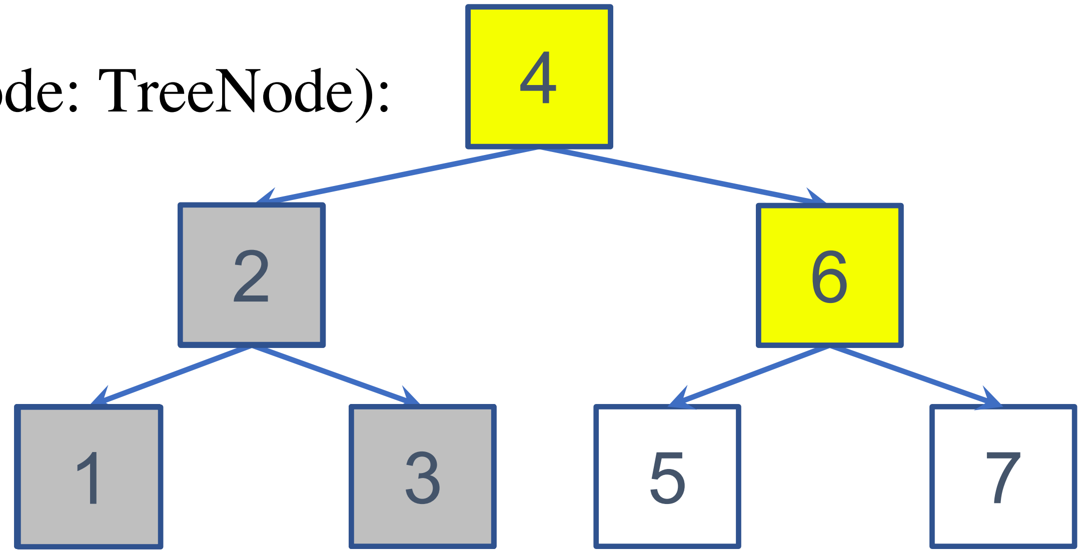

Out: 1 3 2

Depth First Traversals – Postorder

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    def visit(self, node: TreeNode):
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            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
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```

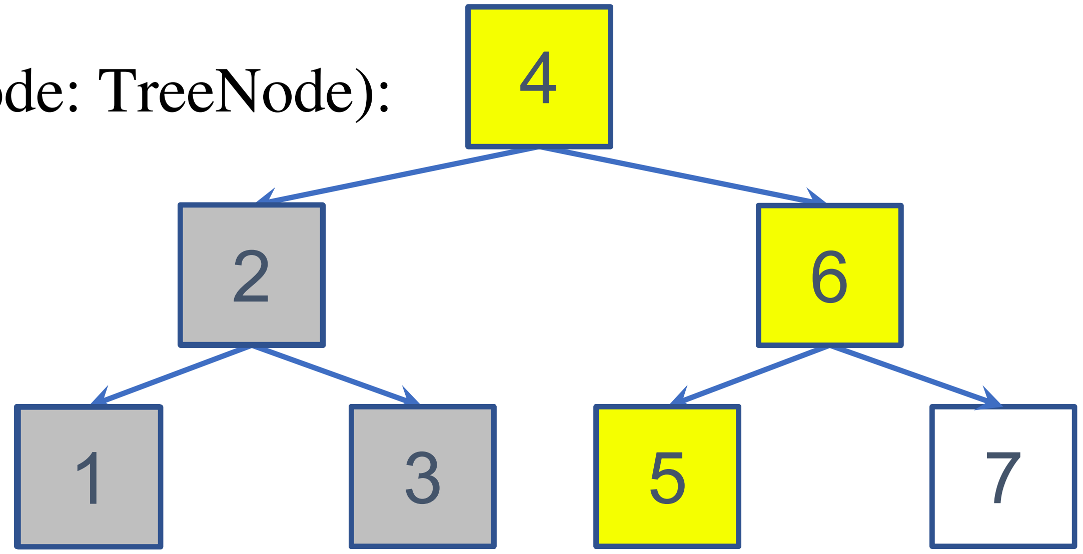

Out: 1 3 2

Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
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    def visit(self, node: TreeNode):
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        if curNode == None:
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        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

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        self.__DFT_postorderHelp(self.root)
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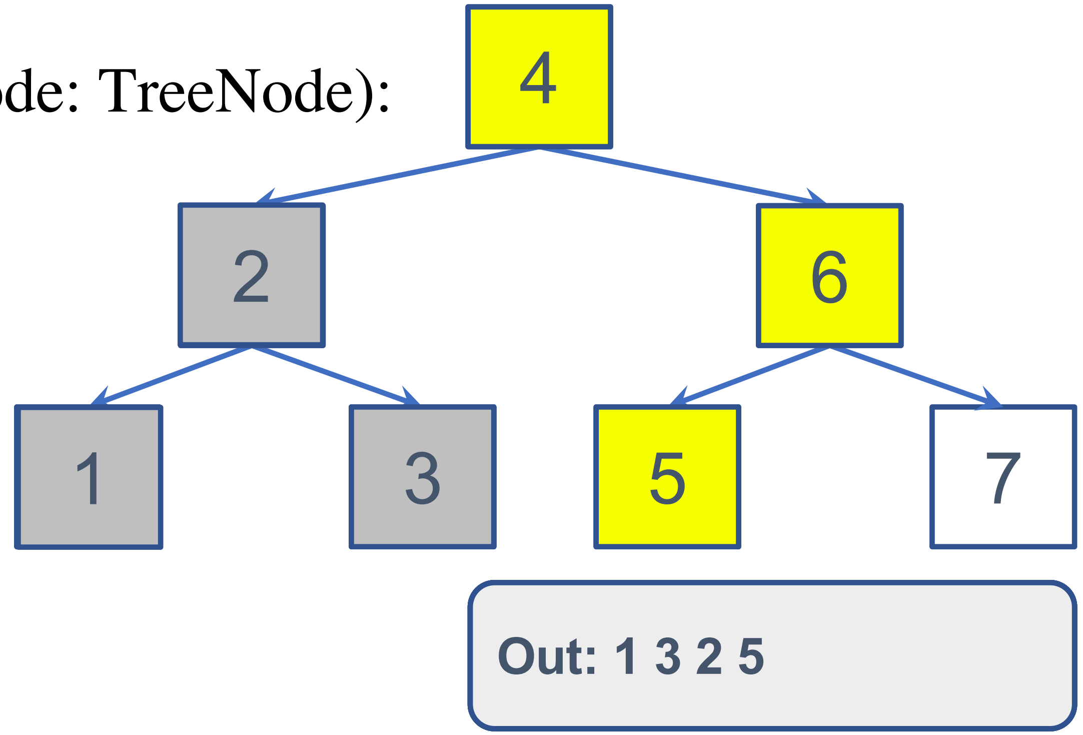

Depth First Traversals – Postorder

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```

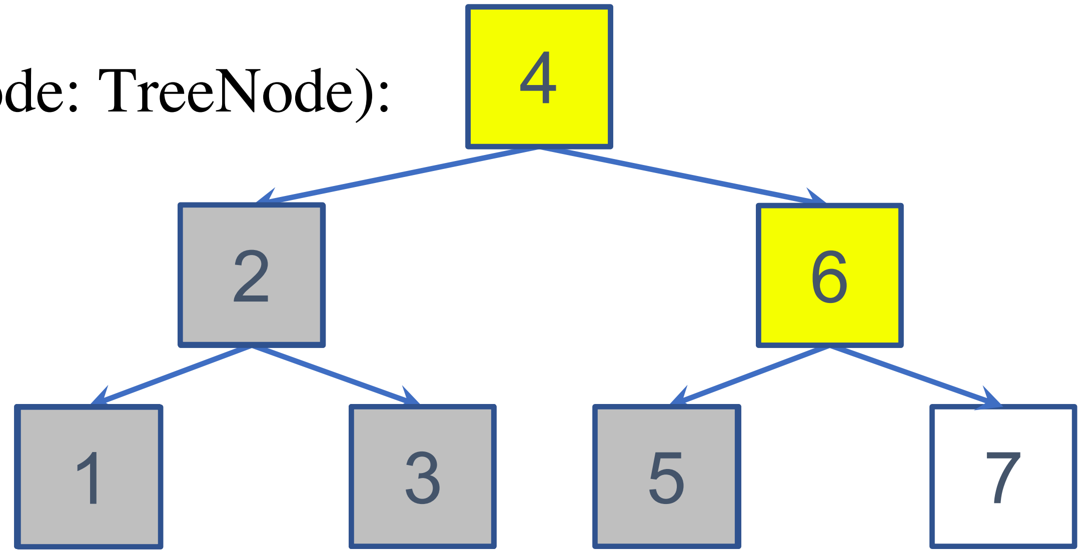

```
Out: 1 3 2 5
```

Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
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            self.__DFT_postorderHelp(curNode.child[i])
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        self.__DFT_postorderHelp(self.root)
```
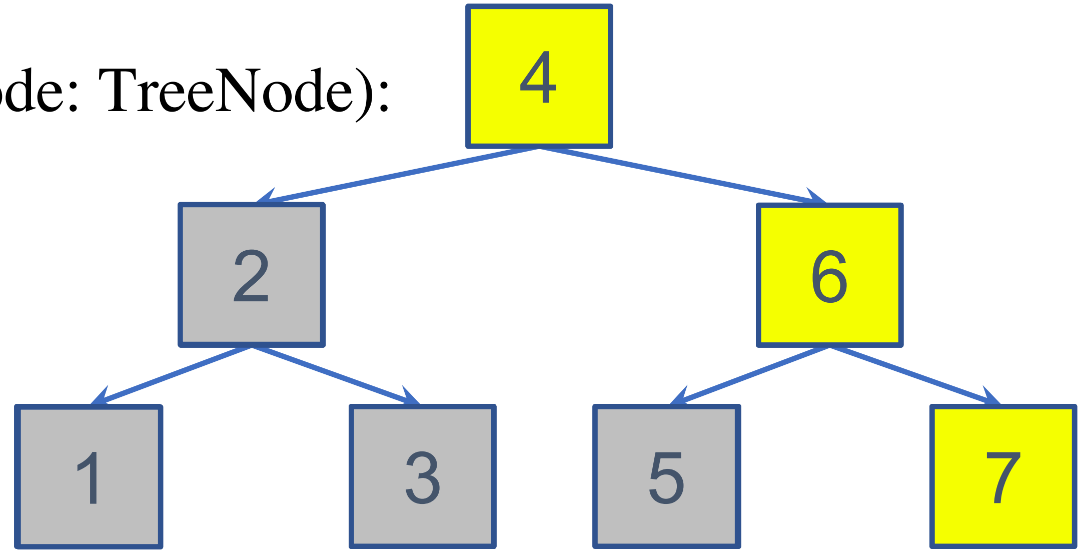
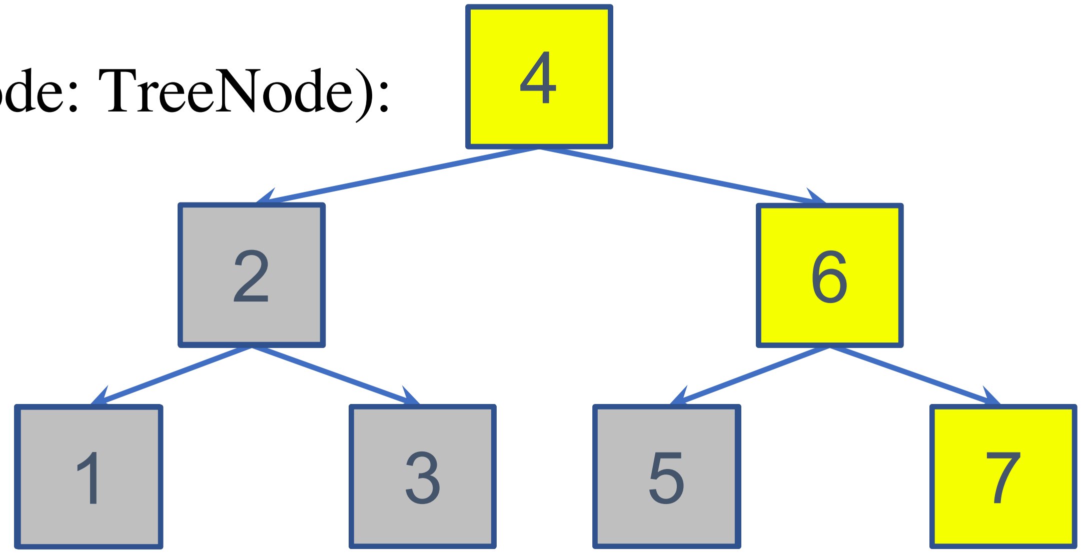



Out: 1 3 2 5

Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```

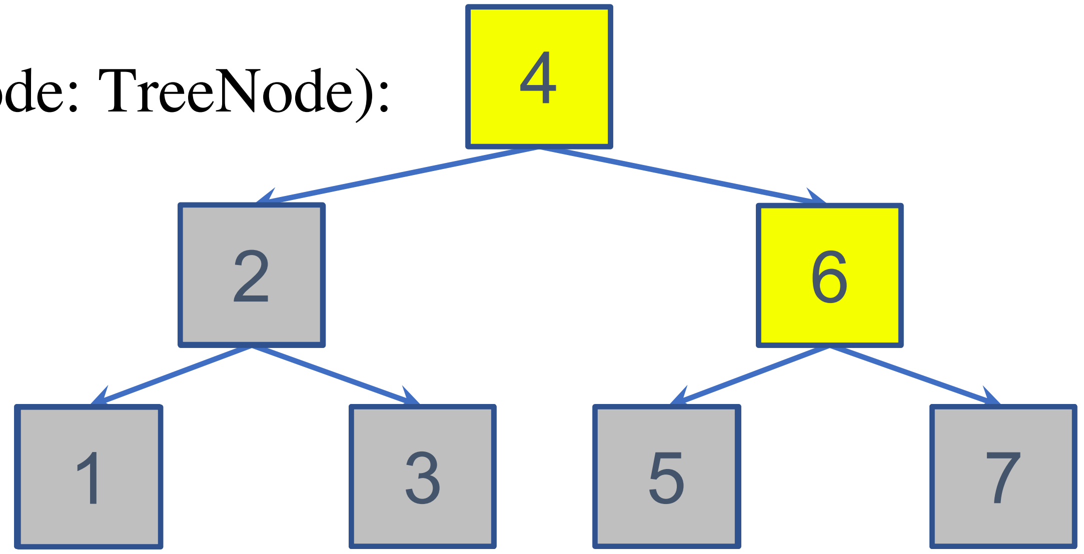


```
Out: 1 3 2 5 7
```

Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```

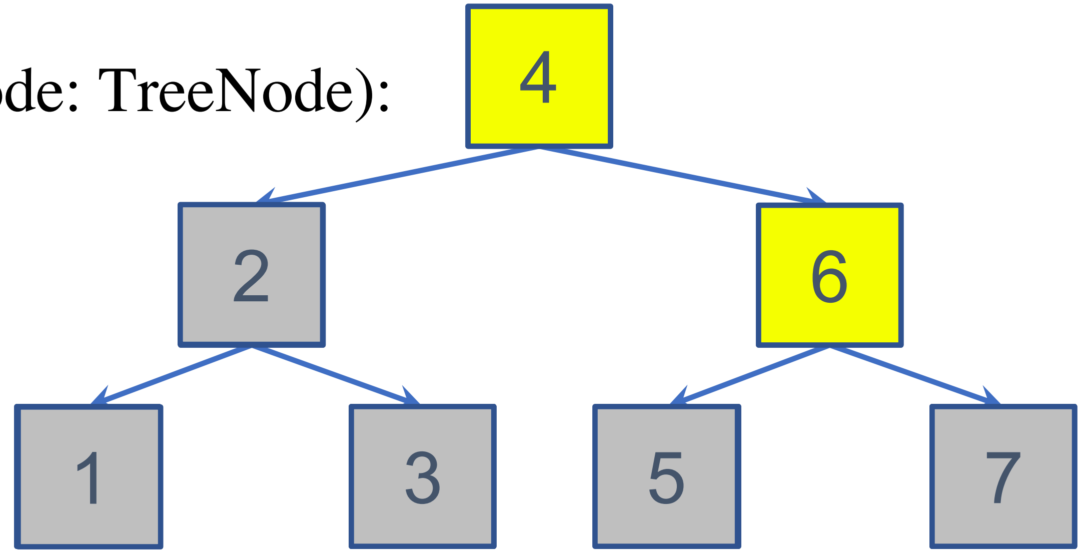


Out: 1 3 2 5 7

Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```

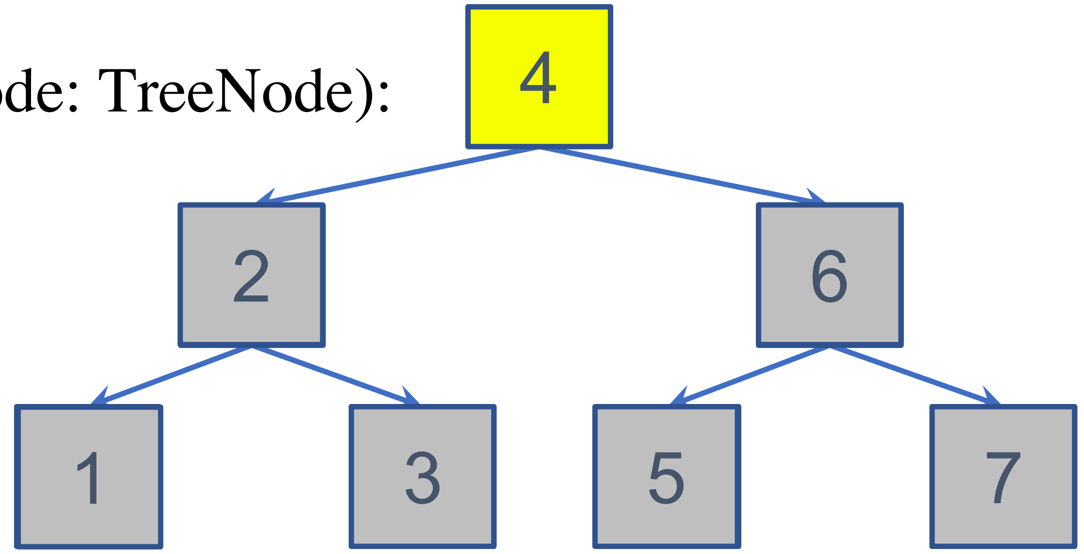


Out: 1 3 2 5 7 6

Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```

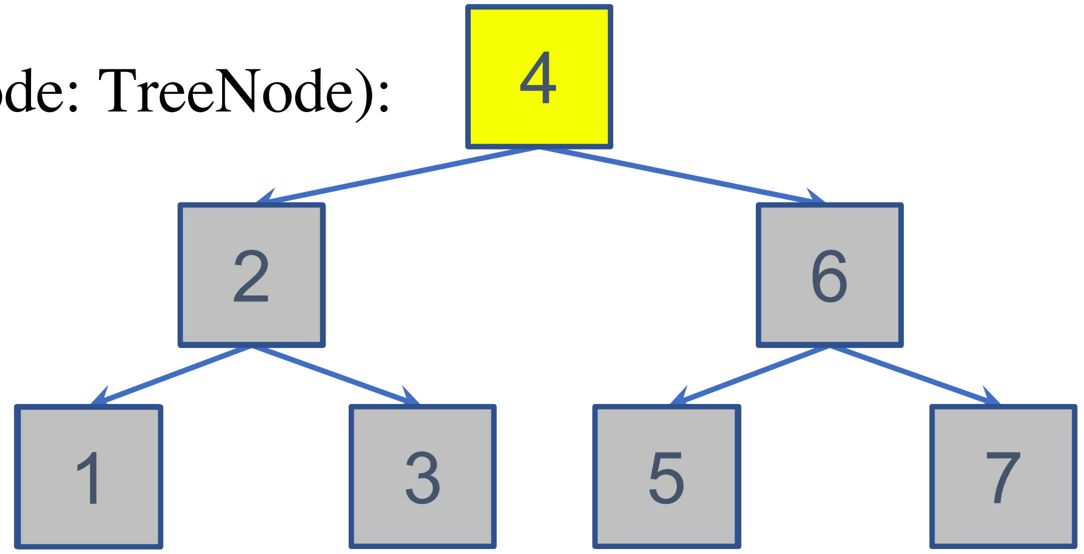


```
Out: 1 3 2 5 7 6
```

Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```

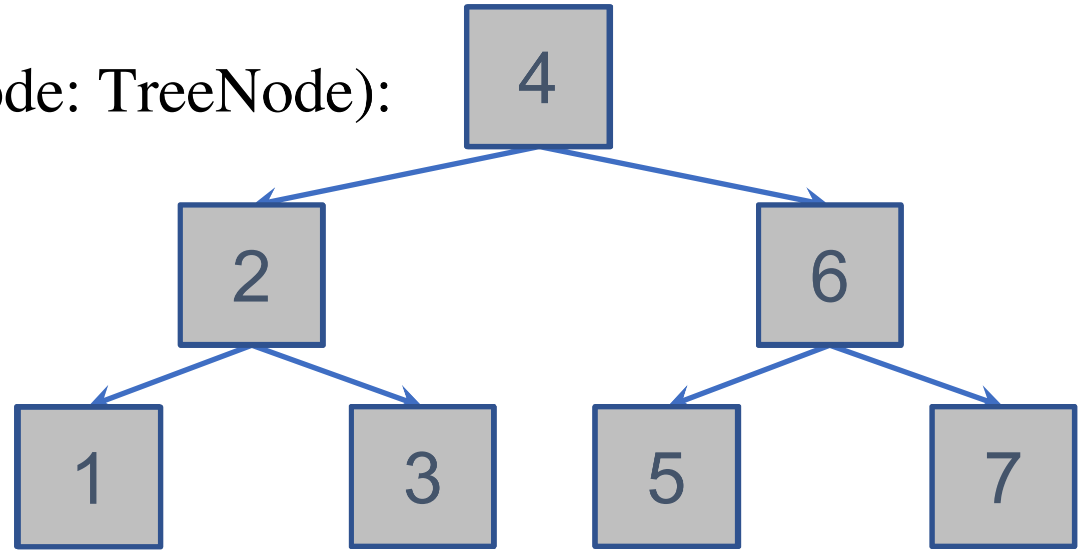


Out: 1 3 2 5 7 6 4

Depth First Traversals – Postorder

- Visit a node **after** traversing its children from left to right

```
class Tree():
    def visit(self, node: TreeNode):
        print(node.val)

    def __DFT_postorderHelp(self, curNode: TreeNode):
        if curNode == None:
            return
        for i in range(len(curNode.child)):
            self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode)

    def DFT_postorder(self):
        self.__DFT_postorderHelp(self.root)
```

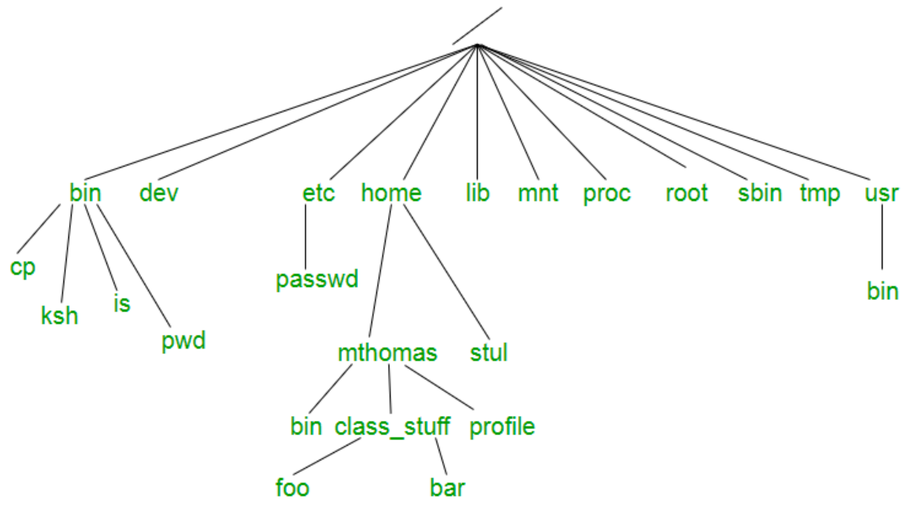


Out: 1 3 2 5 7 6 4

Depth First Traversals – Postorder

- **Application**: File size calculation

```
class Tree():
    def visit(self, node: TreeNode, size: float) -> None:
        node.val += size

    def __DFT_postorderHelp(curNode: TreeNode) -> float:
        if not curNode:
            return 0
        subSize = 0
        for i in range(len(curNode.child)):
            subSize += self.__DFT_postorderHelp(curNode.child[i])
        self.visit(curNode, subSize)
        return curNode.val

    def DFT_postorder(self) -> float:
        return self.__DFT_postorderHelp(self.root)
```



Summary

Summary

- Breadth-first traversal
  - Implementation using FIFO queue (deque in Python)

- Depth-first traversal
  - Implementation using recursion (or LIFO stack – also using deque in Python)
  - Three types for different purposes
    - Preorder
    - Inorder
    - Postorder

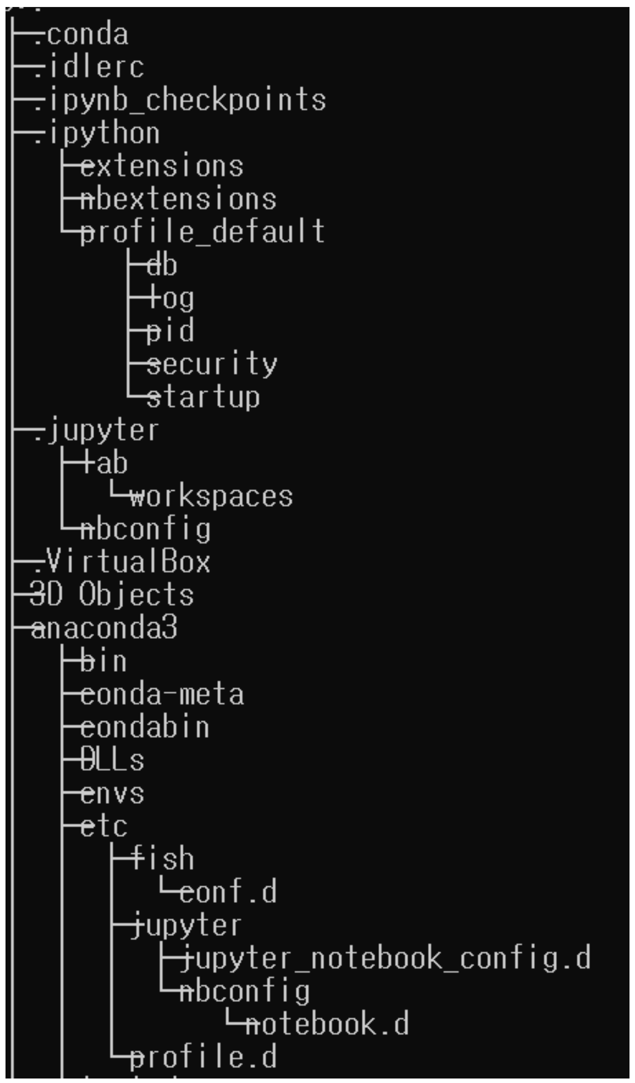
Practice 9

Trees

Practice Problem

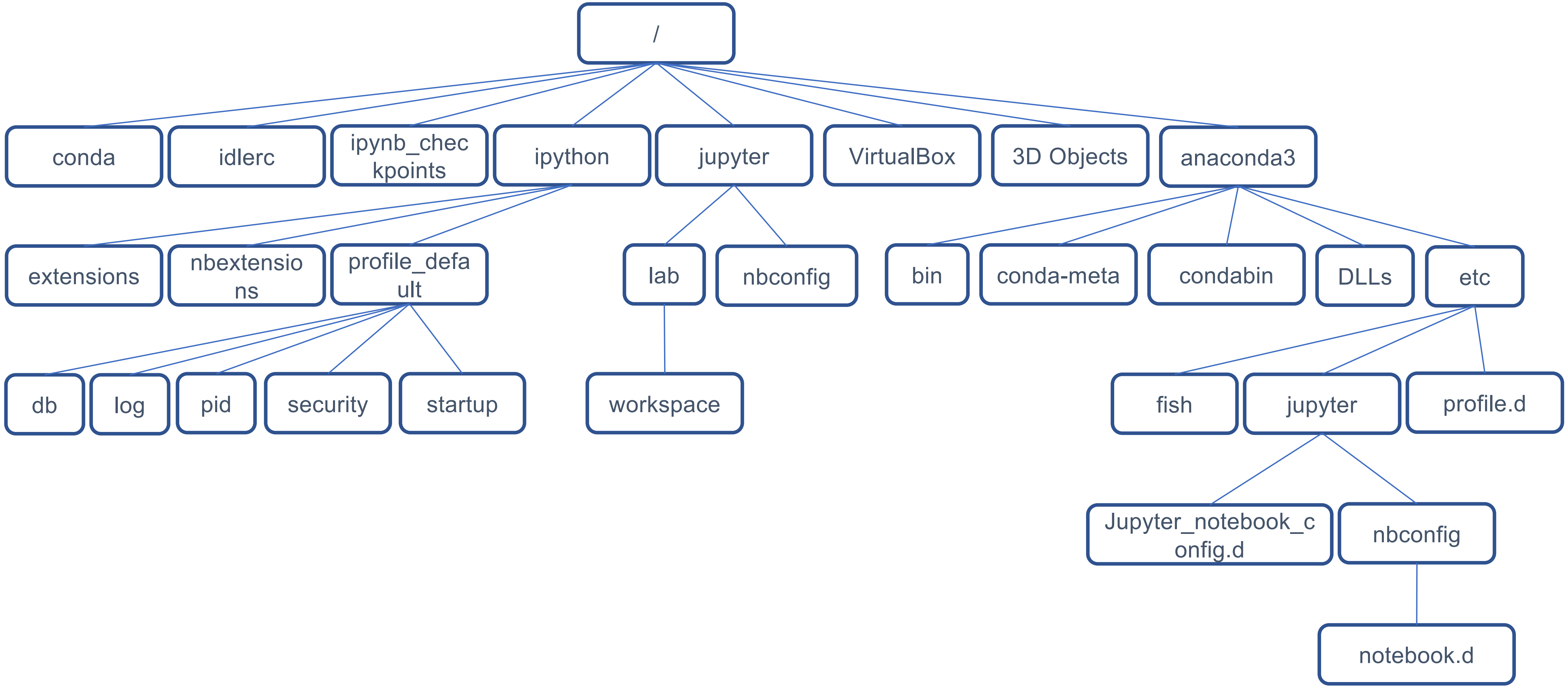
- Implement a preorder traversal for directory listing

- Each directory name is stored in a TreeNode below
  - class TreeNode():
  - def __init__(self, s: str, k: int):
  - self.name = s
  - self.ary = k
  - self.child = [None]*k



```
├─.conda
├─.idlerc
├─.ipynb_checkpoints
├─.ipython
│  ├─extensions
│  ├─nbextensions
│  └─profile_default
│      ├─db
│      ├─log
│      ├─pid
│      ├─security
│      └─startup
├─.jupyter
│  ├─lab
│  │  └─workspaces
│  └─nbconfig
├─.VirtualBox
├─3D Objects
├─anaconda3
│  ├─bin
│  ├─conda-meta
│  ├─condabin
│  ├─DLLs
│  ├─envs
│  ├─etc
│  │  ├─fish
│  │  │  └─conf.d
│  │  ├─jupyter
│  │  │  ├─jupyter_notebook_config.d
│  │  │  └─nbconfig
│  │  │      └─notebook.d
│  │  └─profile.d
```

Practice Problem – The Tree You Have



Practice Problem – The Ouput You Should See

```
 /
-- conda
-- idlerc
-- ipynb_checkpoints
-- ipython
---- extensions
---- nbextensions
---- profile_default
------ db
------ log
------ pid
------ security
------ startup
-- jupyter
---- lab
------ workspace
---- nbconfig
-- VirtualBox
-- 3D Objects
-- anaconda3
---- bin
---- conda-meta
---- condabin
---- DLLs
---- etc
------ fish
-------- conf.d
------ jupyter
-------- jupyter_notebook_config.d
-------- nbconfig
---------- notebook.d
------ profile.d
```

Q&A

Any questions?

Thanks!