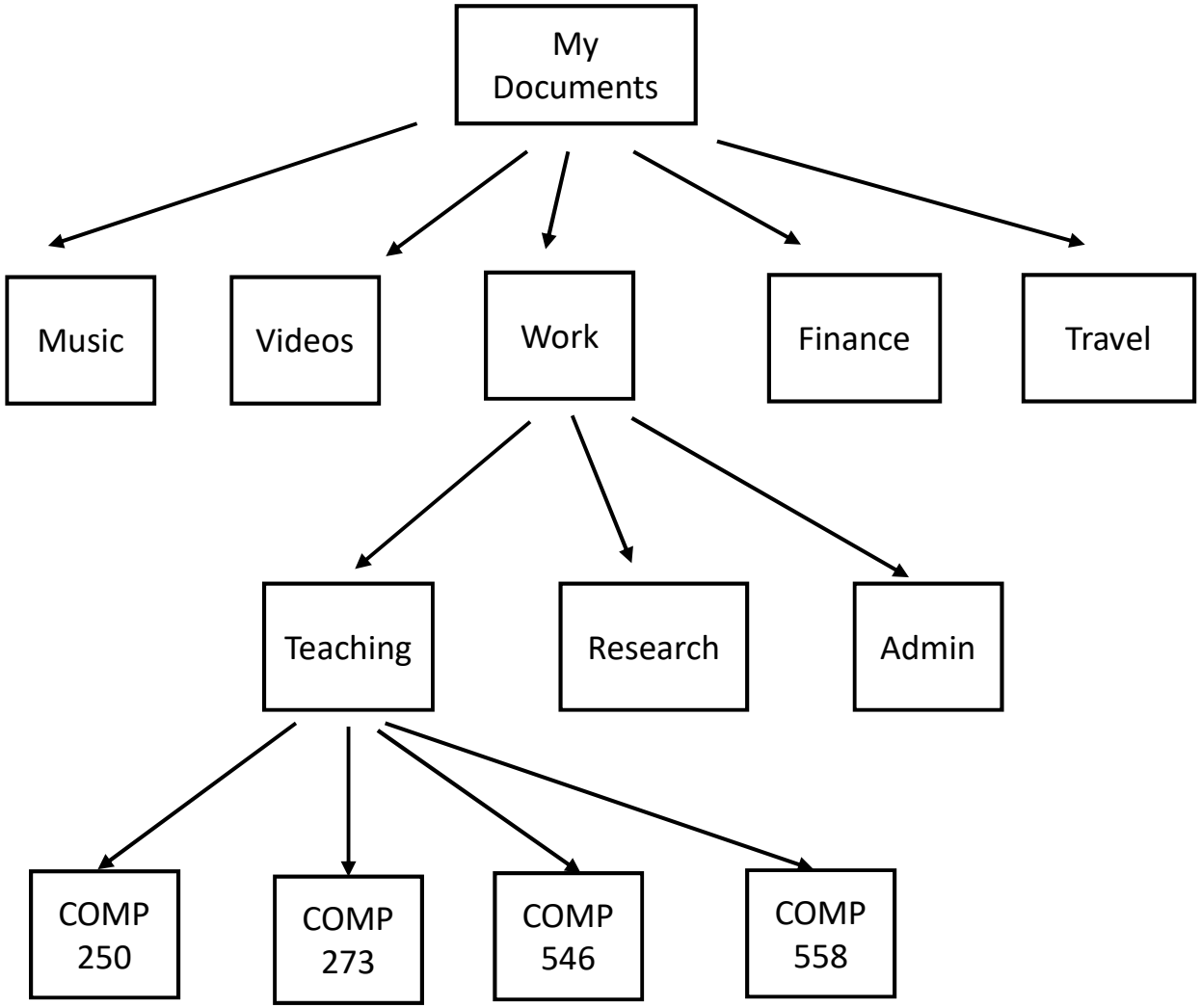
COMP 250

Lecture 24

tree traversal

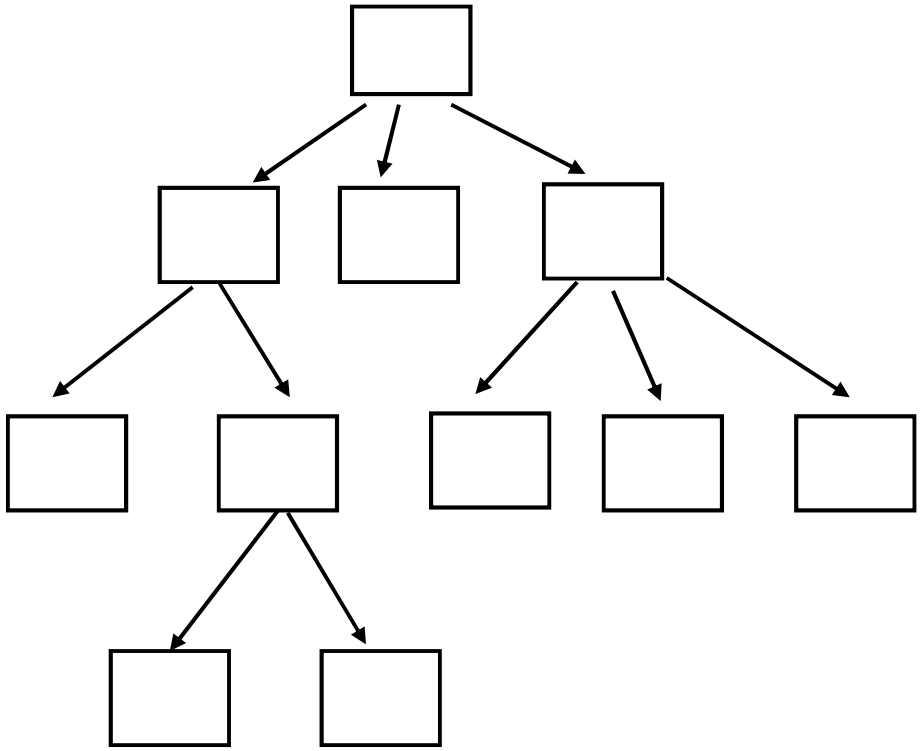
March 9, 2022

Tree: Example



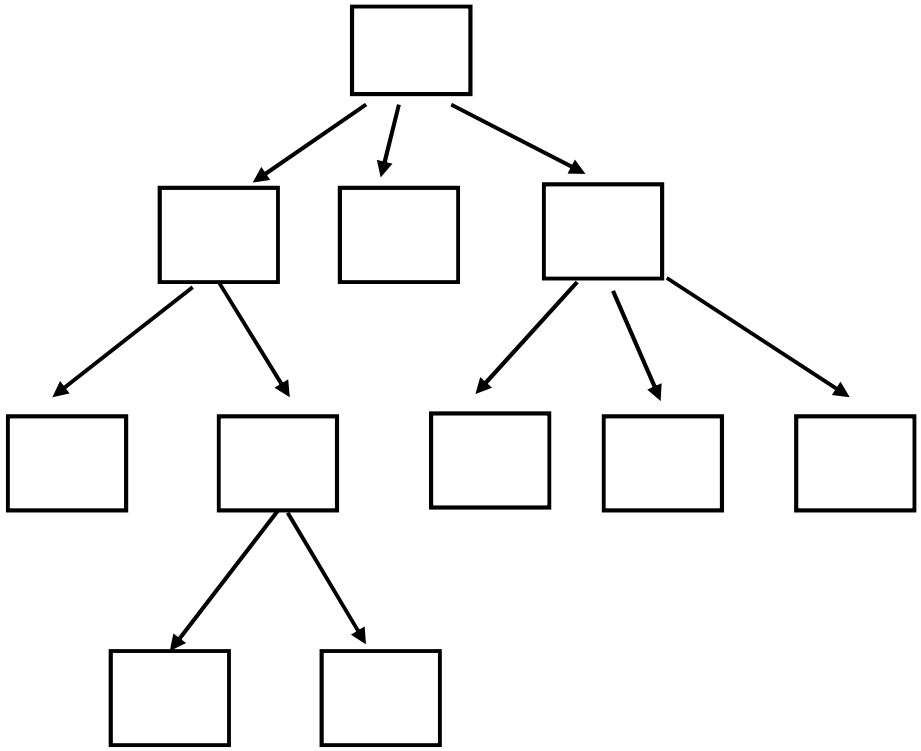
Tree Traversal

How to “visit” / “traverse” / “iterate through” the nodes in a tree ?



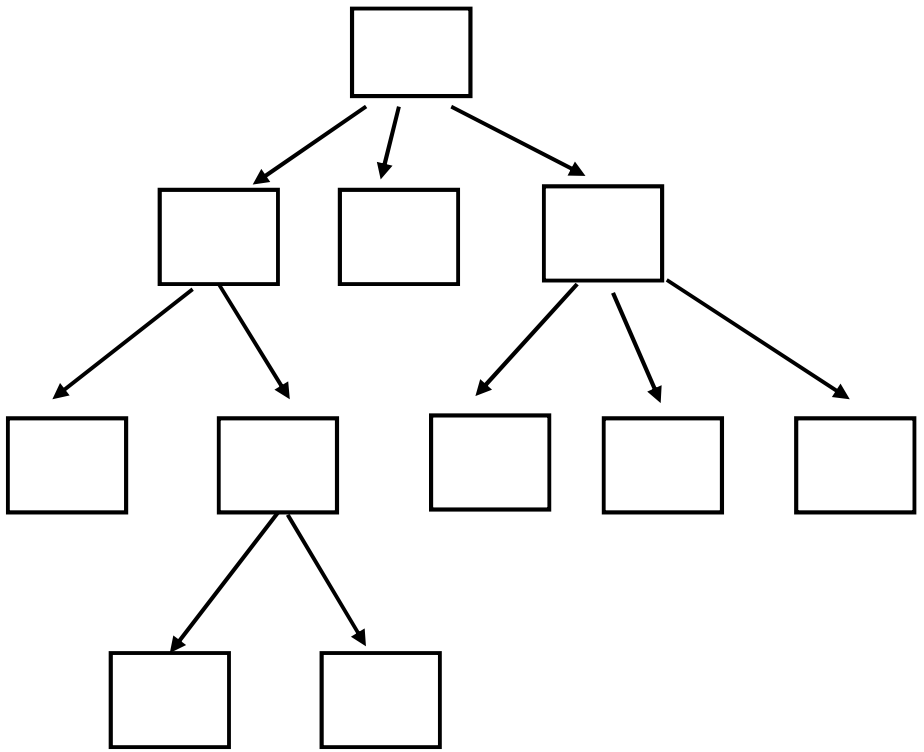
Tree Traversal

How to “visit” / “traverse” / “iterate through” the nodes in a tree ?



Recall – depth of a node

The depth or level of a node is the length of the path *from the root to the node*.



Tree Traversal

- Depth first traversal (also called depth first *search*)

  Start from root and follow paths to the leaves, backtracking only when a leaf is found

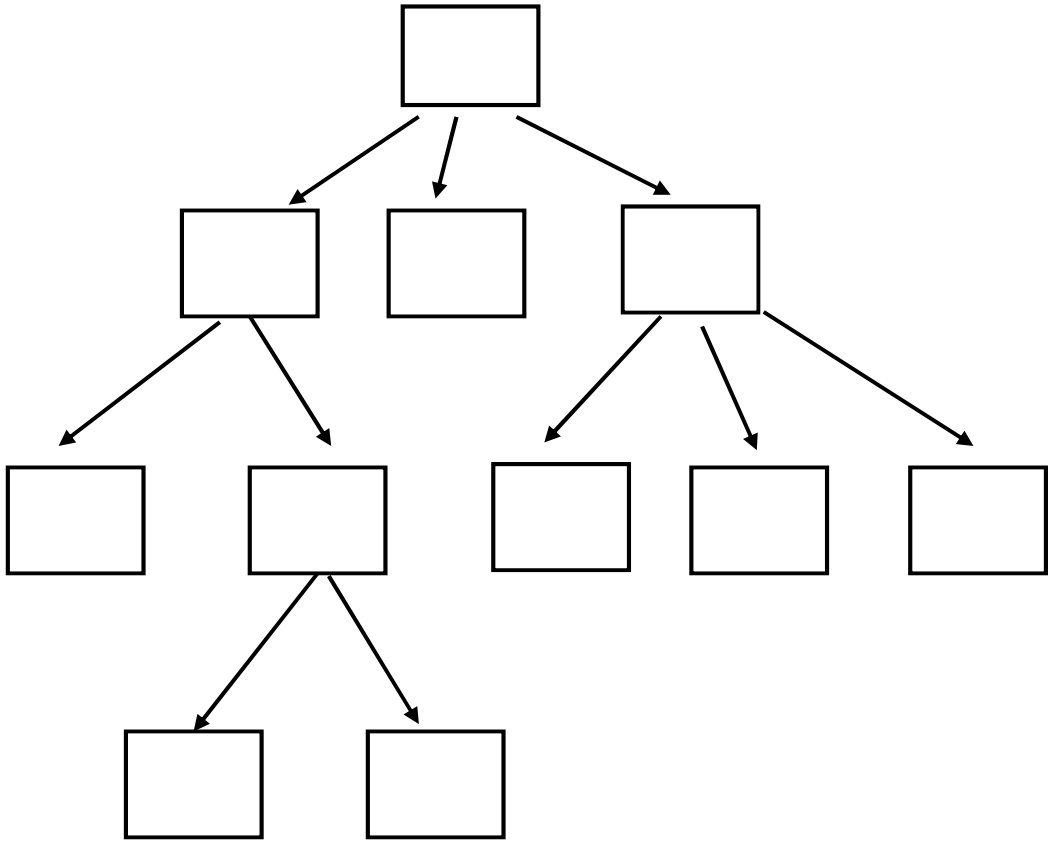
- Breadth first traversal (also called breadth first *search*)

  Start from root and visit all nodes at depth k before any nodes at depth k+1.

"Visit" a node implies that you do something at that node.

We will see some examples later.

```
depthfirst (root){
    visit root
    for each child of root
        depthfirst( child )
}
```



```
depthfirst (root){
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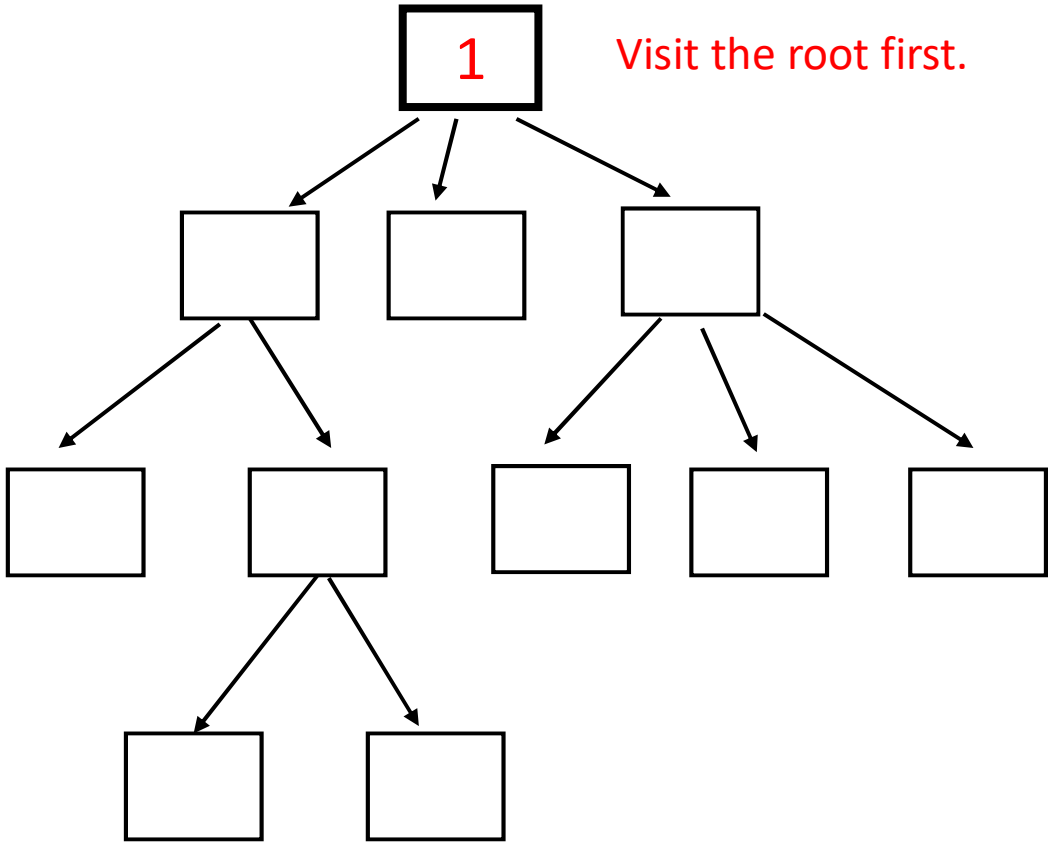
}
```

"preorder" traversal: visit the root before the children



```
depthfirst (root){
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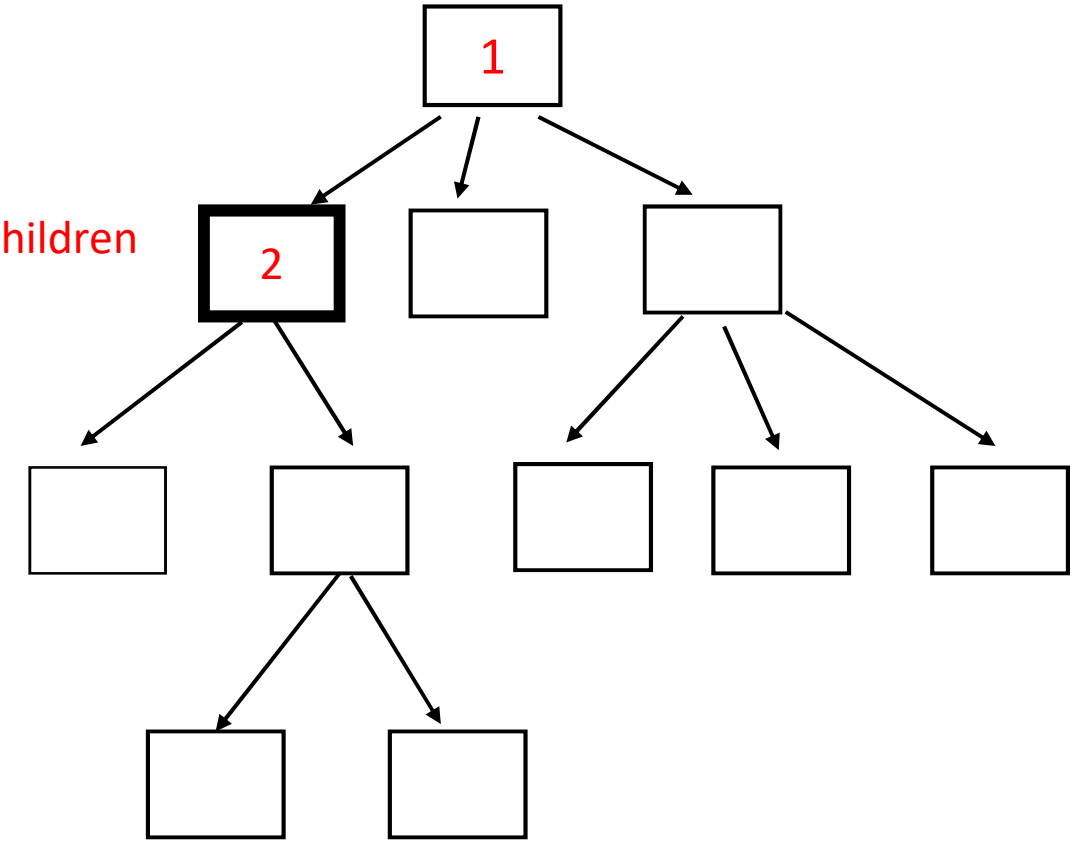
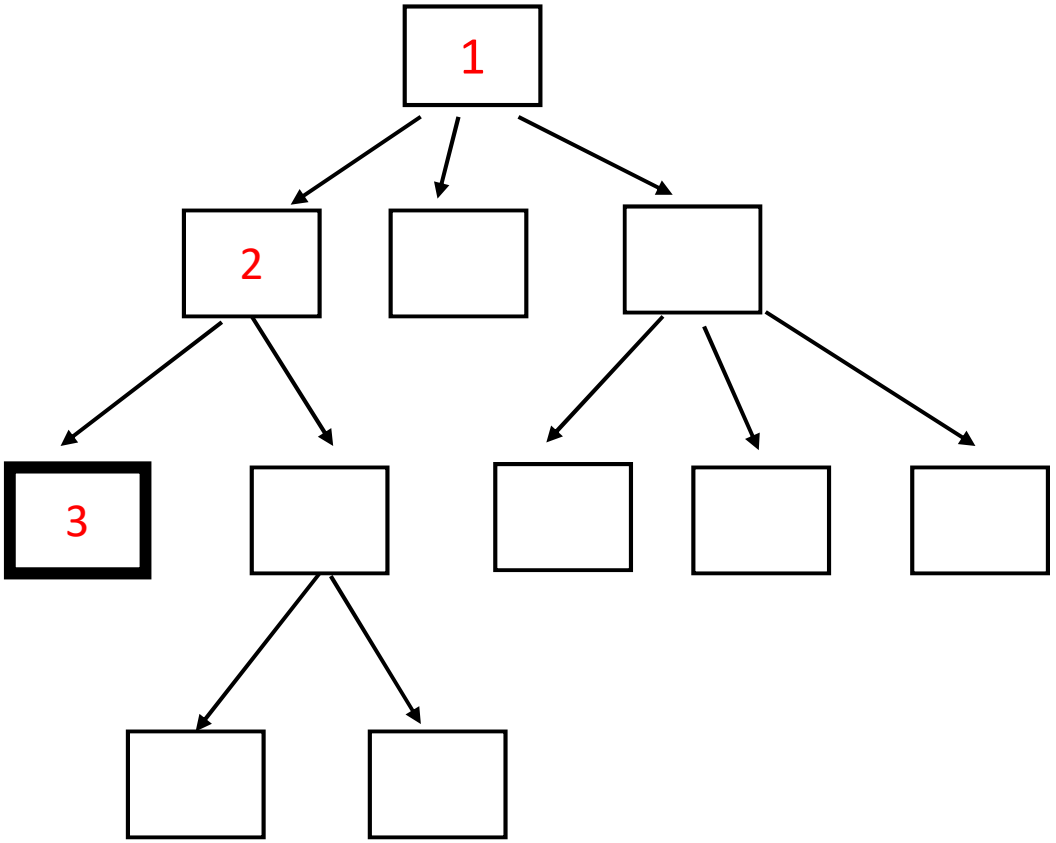
        depthfirst( child )
}
```

Assume we visit children from left to right.



```
depthfirst (root){
    visit root
    for each child of root
        depthfirst( child )
}
```

This node has no children.



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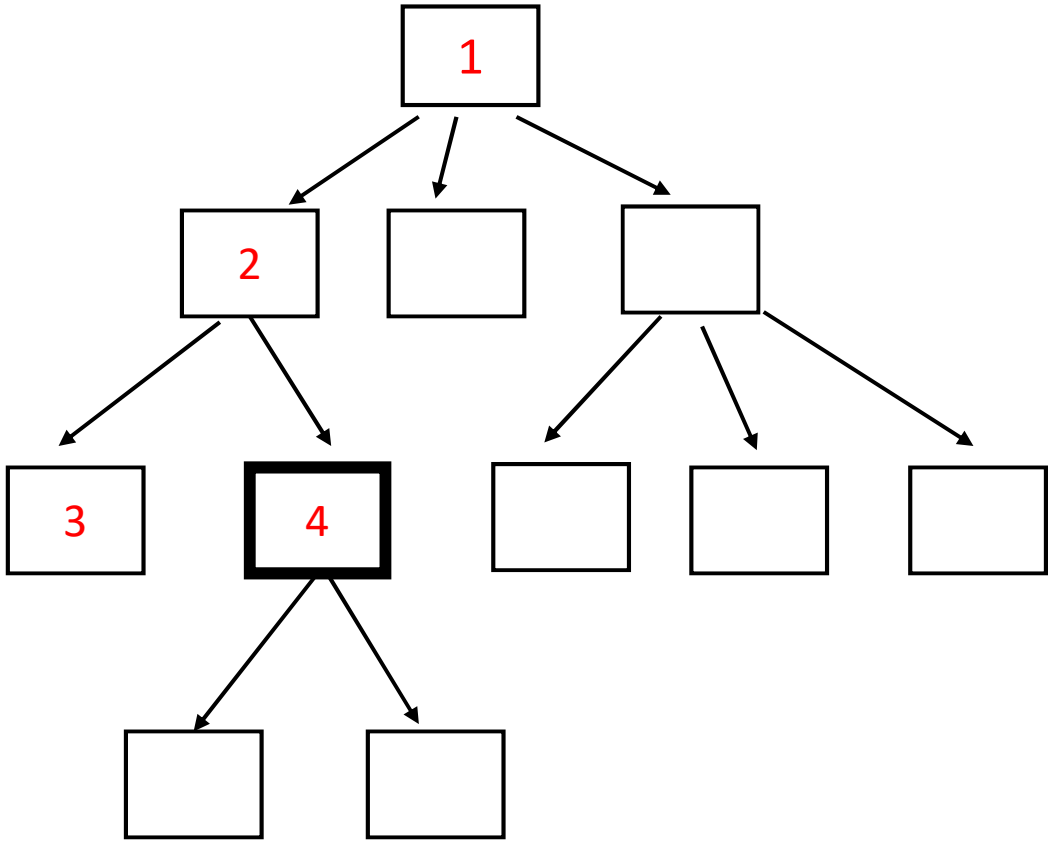

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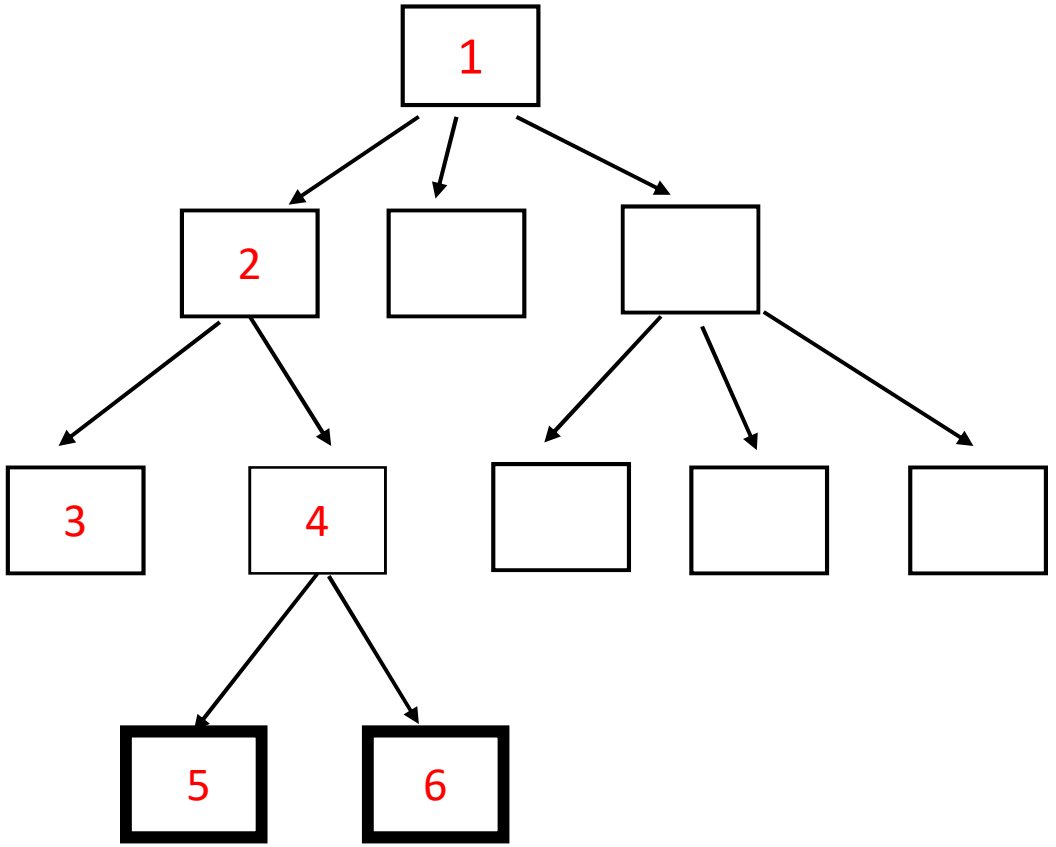

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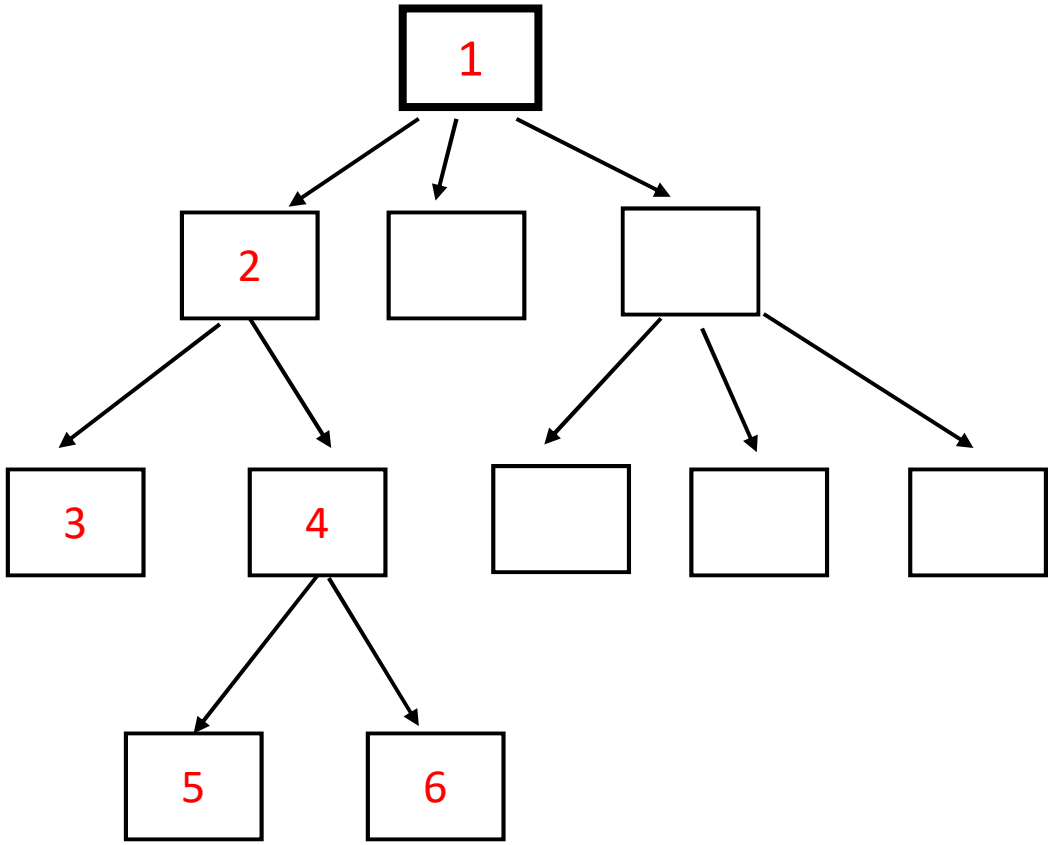

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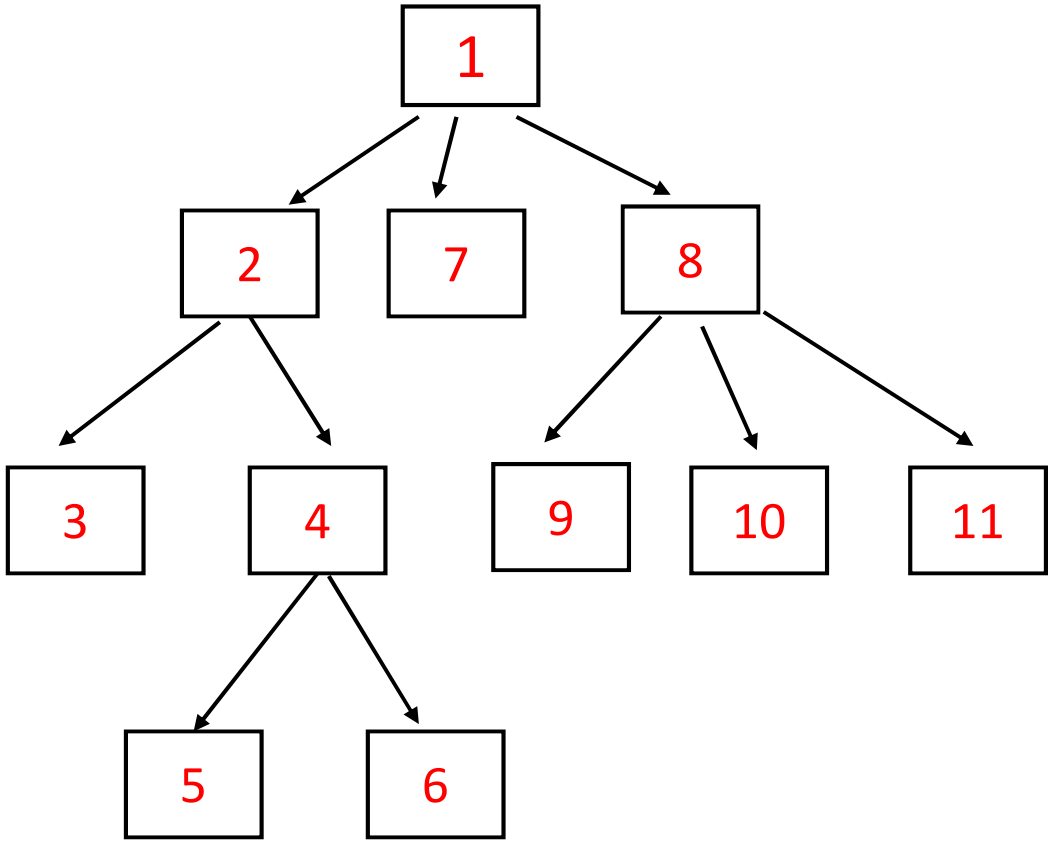
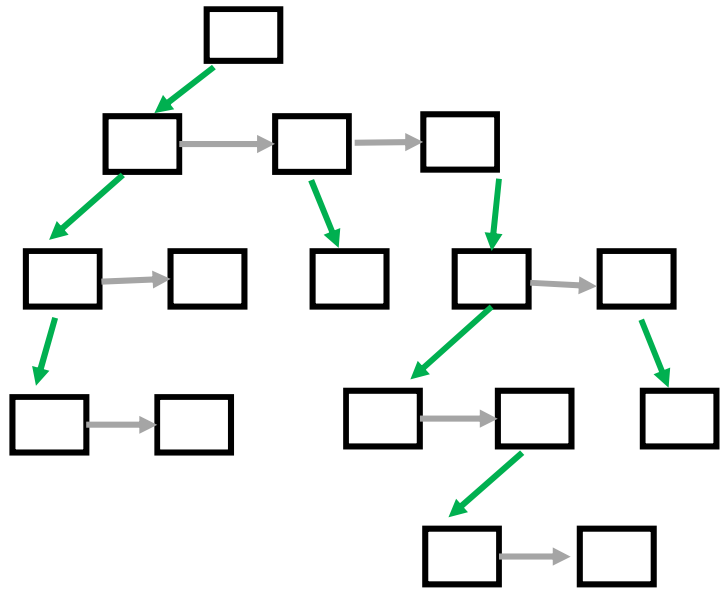


Implementation details

Recall the "first child, next sibling" implementation

Then when we write

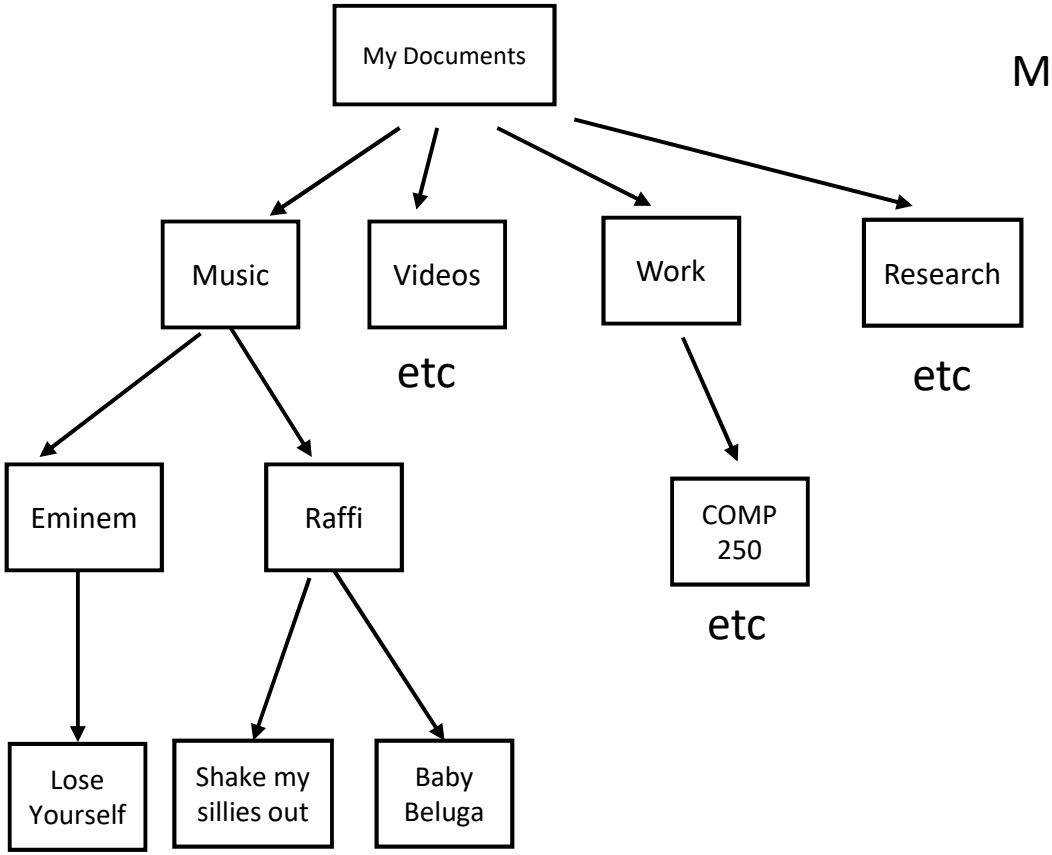
```
for each child of root {
        :
}
```



we would mean:

```
child = root.firstChild
while  (child !=null) {
        :
        child = child.nextSibling
}
```

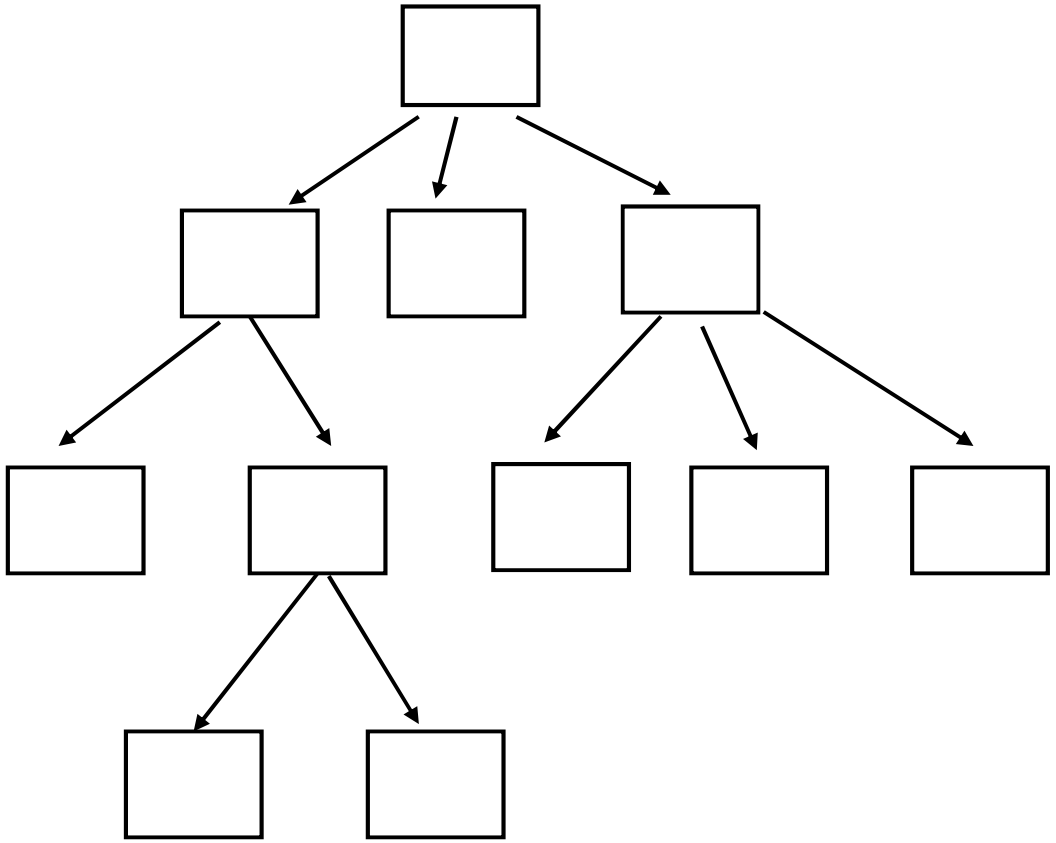
Example of Preorder Traversal:
printing a hierarchical file system
(visit = print directory or file name)



My Documents (directory)
- Music (directory)
  - Eminem (directory)
    - Lose Yourself (file)
  - Raffi (directory)
    - Shake My Sillies Out (file)
    - Baby Beluga (file)
- Videos (directory)
  - : (file)
- Work (directory)
  - COMP250 (directory)
  - :
- Research (directory)
  - :

```
depthfirst (root){
    for each child of root
        depthfirst( child )
    visit root
}
```

"postorder" traversal: visit the root *after* the children



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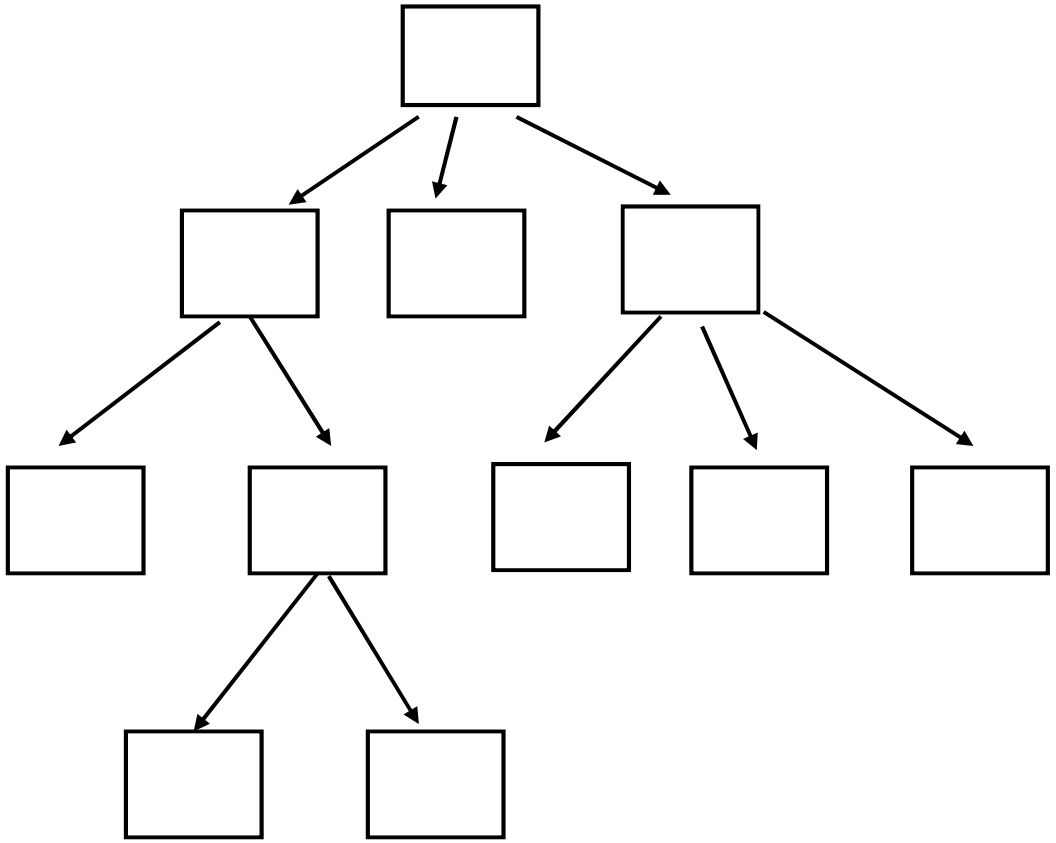
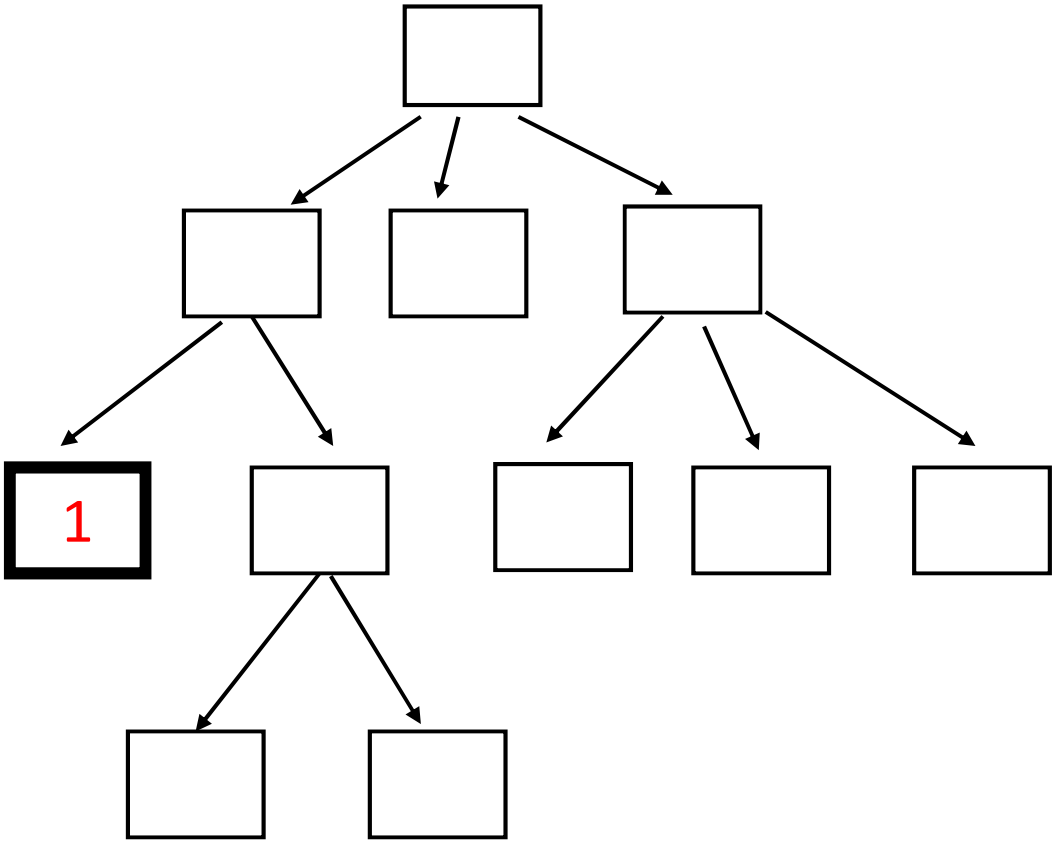


Q: Which node is visited first?

```
depthfirst (root){
    for each child of root
        depthfirst( child )
    visit root
}
```

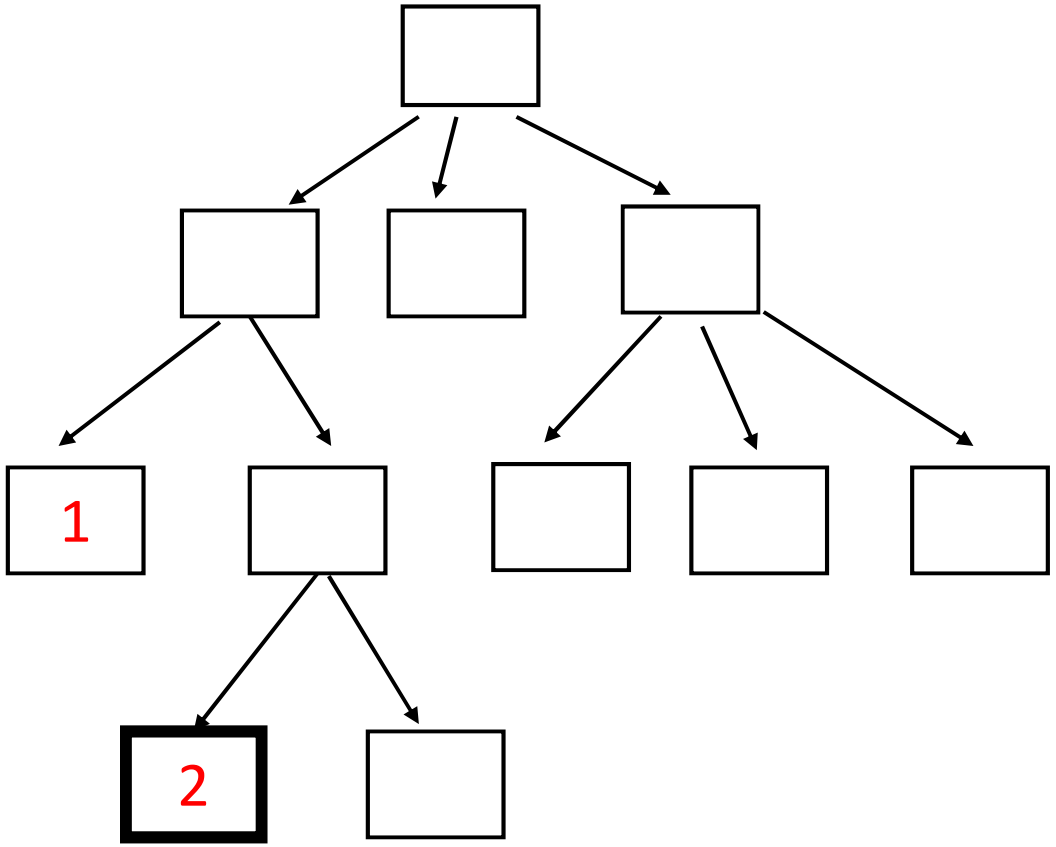
"postorder" traversal: visit the root after the children



Q: Which node is visited second?

```
depthfirst (root){
    for each child of root
        depthfirst( child )
    visit root
}
```

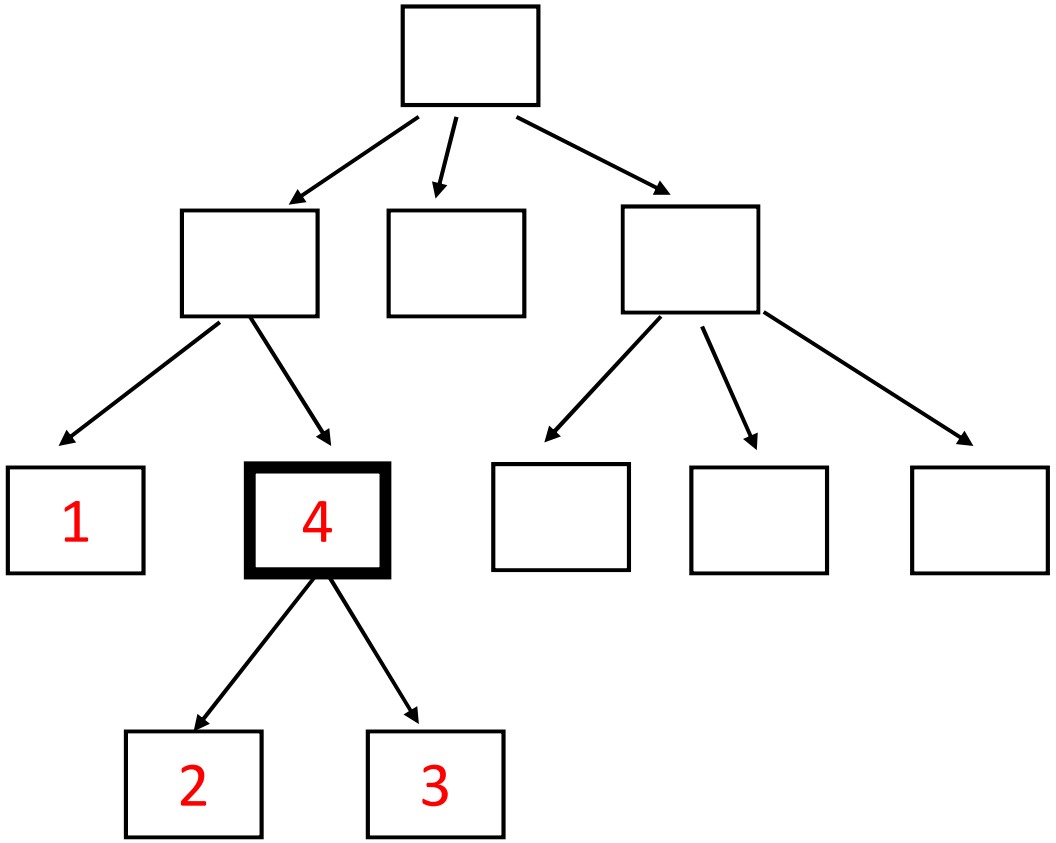
"postorder" traversal: visit the root after the children



Q: Which node is visited 3rd and 4th ?

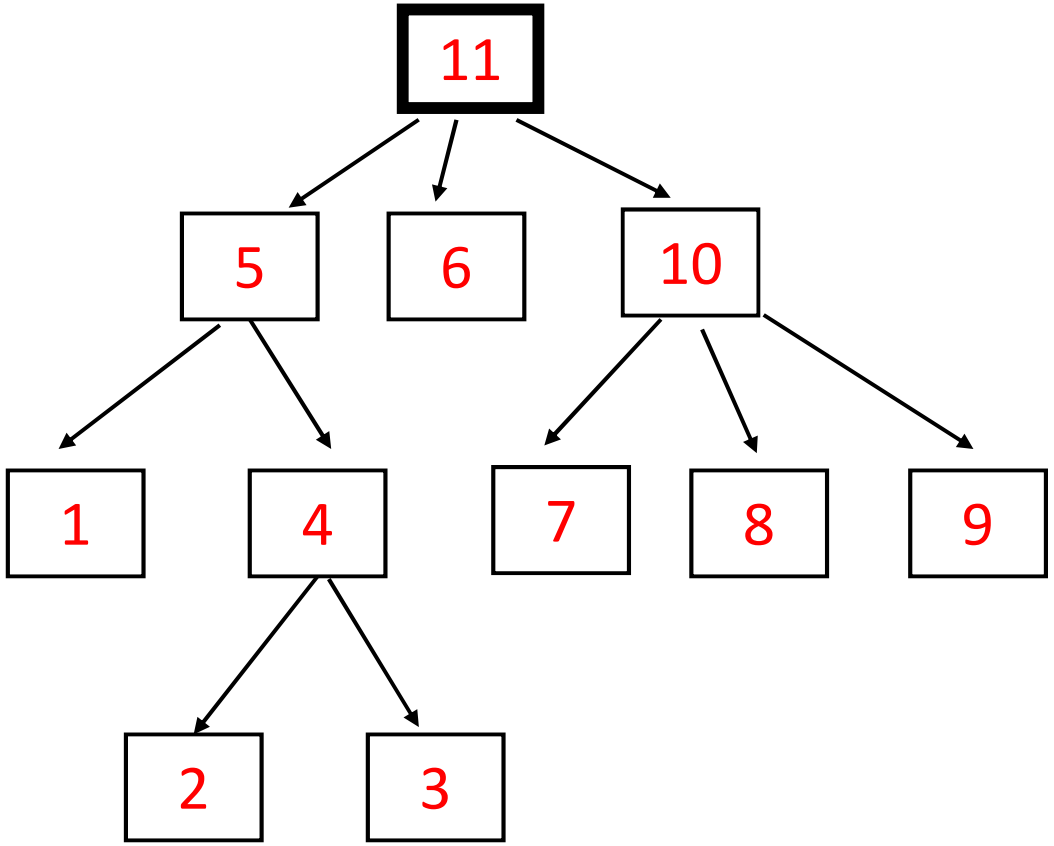
```
depthfirst (root){
    if (root is not empty){
        for each child of root
            depthfirst( child )
        visit root
    }
}
```

"postorder" traversal: visit the root after the children

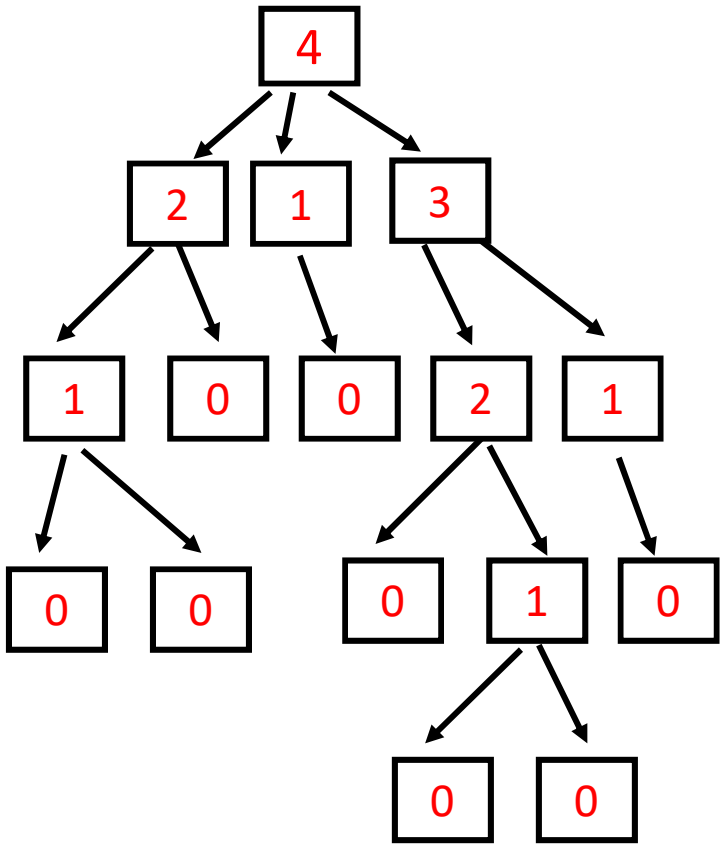


```
depthfirst (root){
    for each child of root
        depthfirst( child )
    visit root
}
```

"postorder" traversal: visit the root after the children



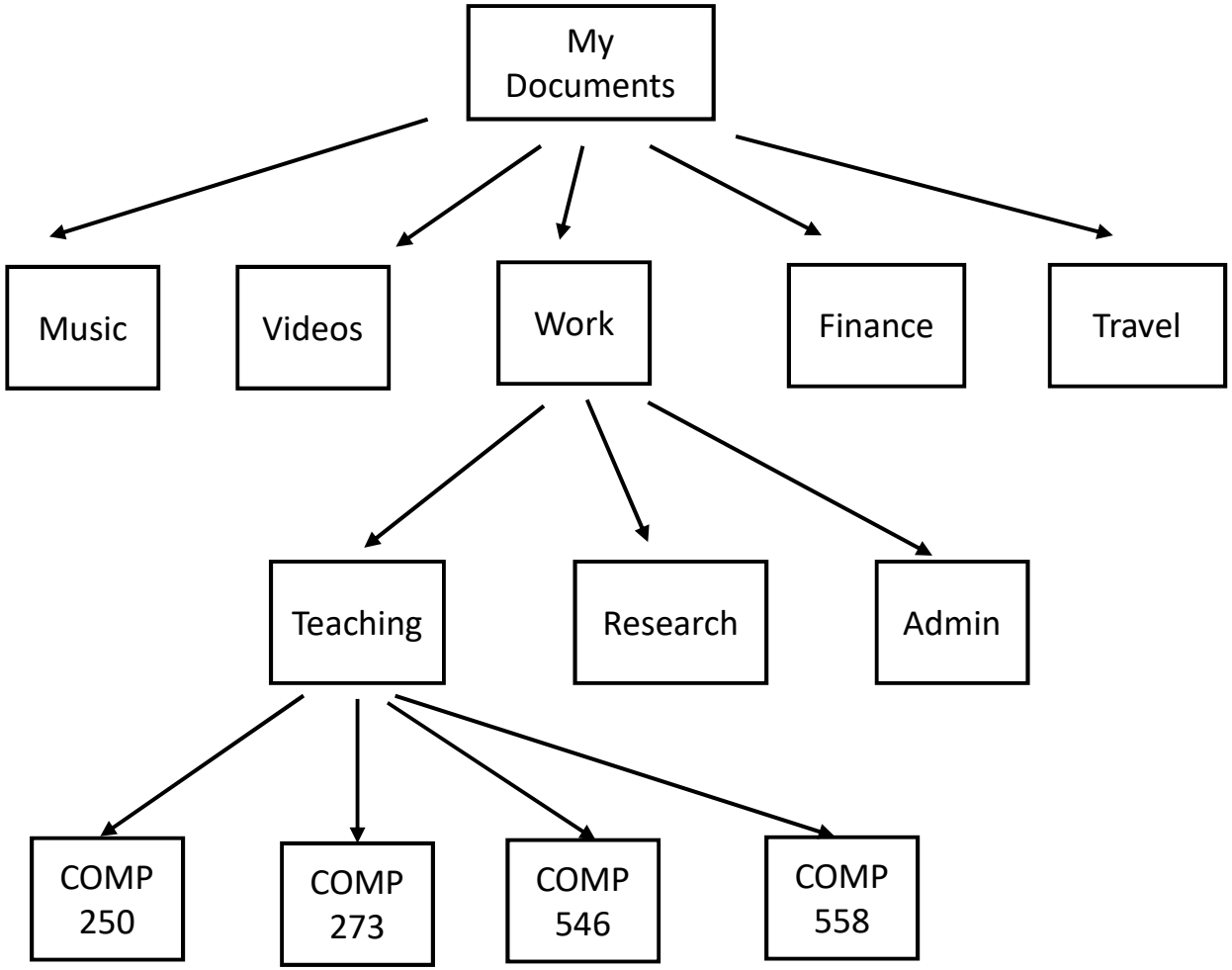
Example 1 postorder: height




```
height(v){
    if (v has no children)
        return 0
    else{
        h = 0
        for each child w of v
            h = max(h, height(w))
        return 1 + h
    }
}
```

`visit' a node here means `determine height of' the node

Example 2 Postorder:
total number of bytes (in a file or in some directory including subdirectories)



```
numBytes(root){
    if root has no children
        return number of bytes at root   //  0, if root is directory
    else {
        
    }
}
```


'visit' here means determine the number of bytes in subtree that is rooted at that node.

“preorder” traversal

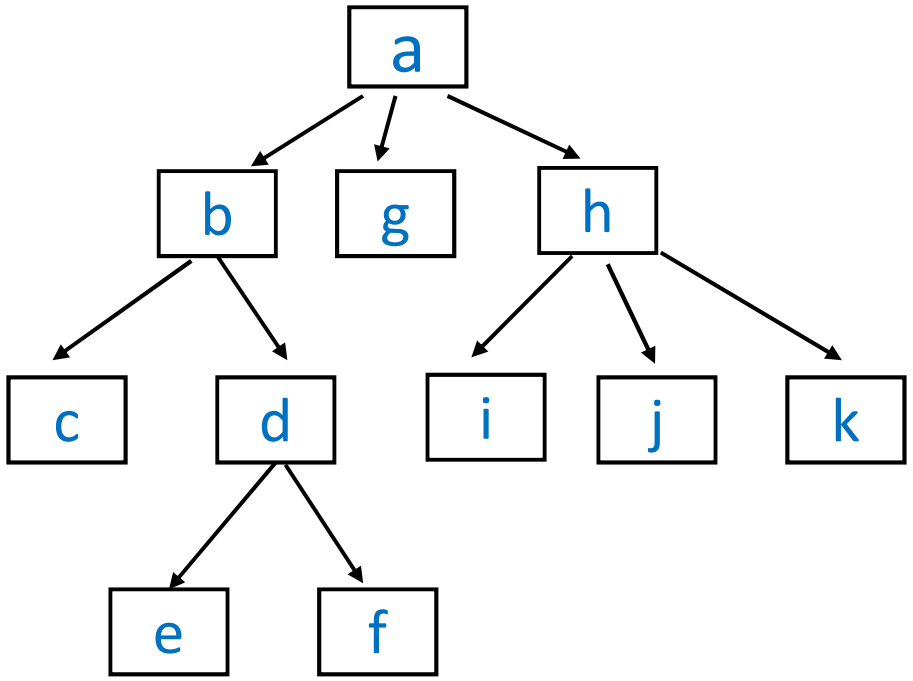
```
depthfirst (root){
    visit root
    for each child of root
        depthfirst( child )
}
```

“postorder” traversal

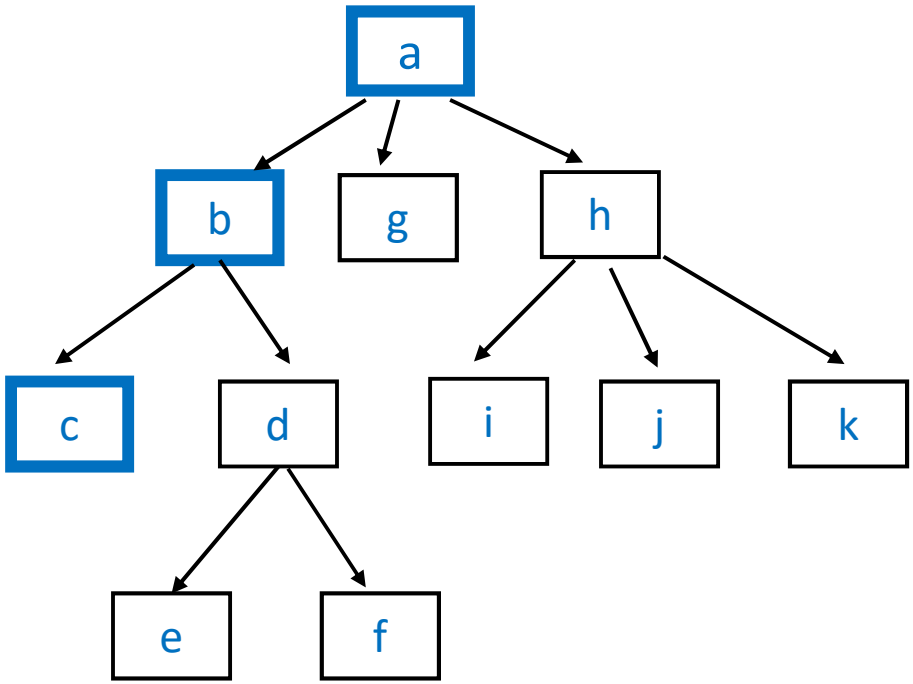
```
depthfirst (root){
    for each child of root
        depthfirst( child )
    visit root
}
```

The same depthfirst(root) *call sequence* occurs for preorder and postorder. Only the visiting order changes.

In example below, the letter order corresponds to the depthfirst(root) *call order*. Let's next examine the call stack.

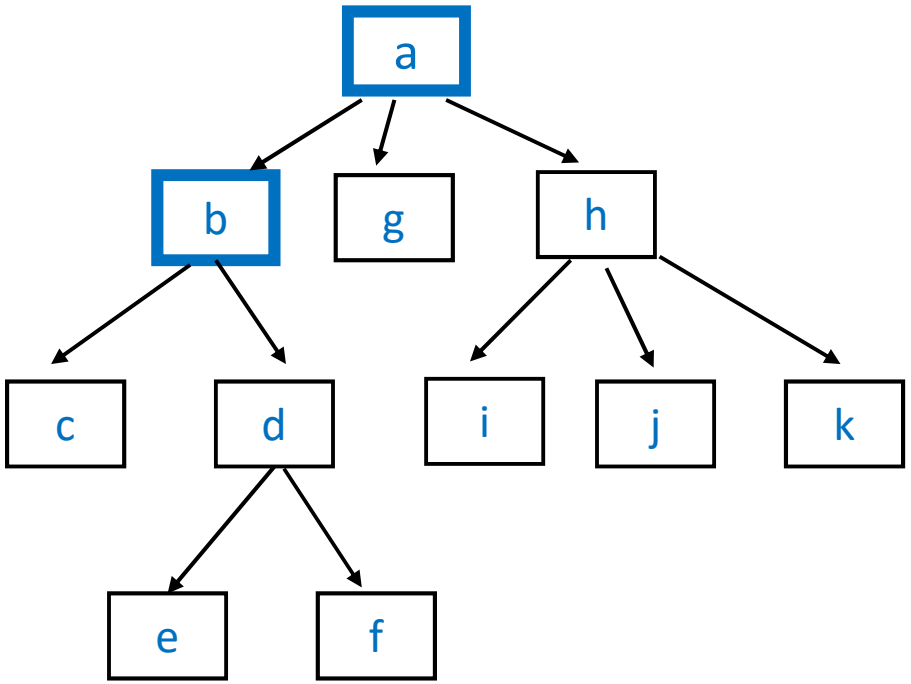


Call stack for depthfirst(root)



The “call stack” figure below only shows the root parameter.

Call stack for depthfirst(root)



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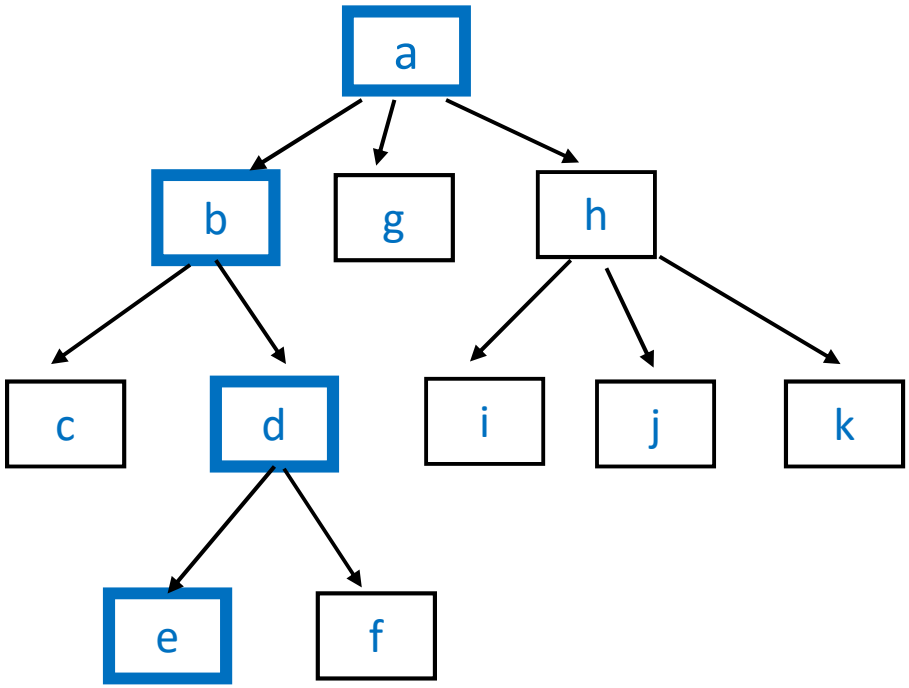
Call stack for depthfirst(root)



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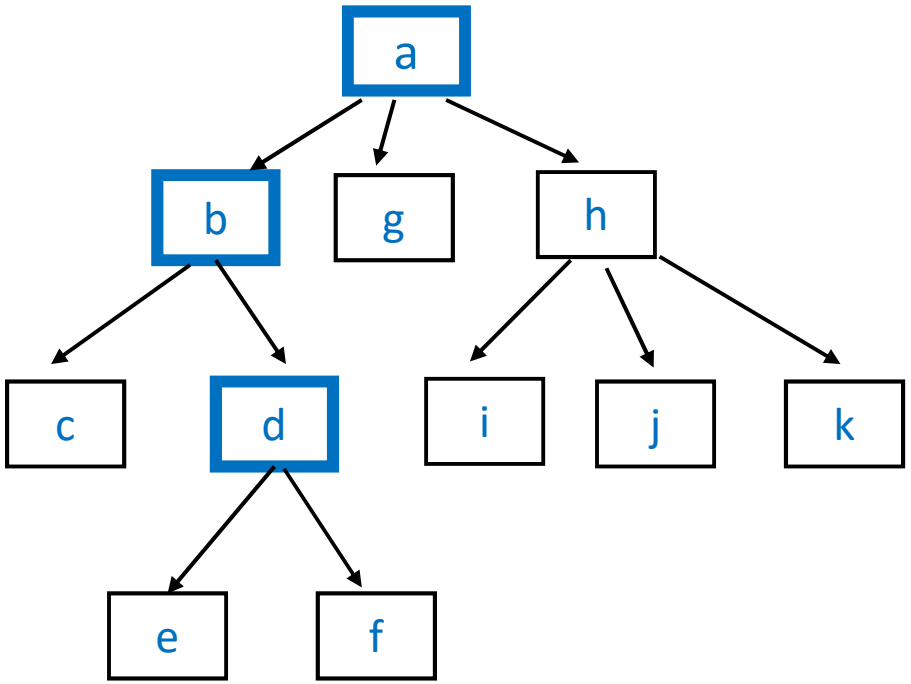
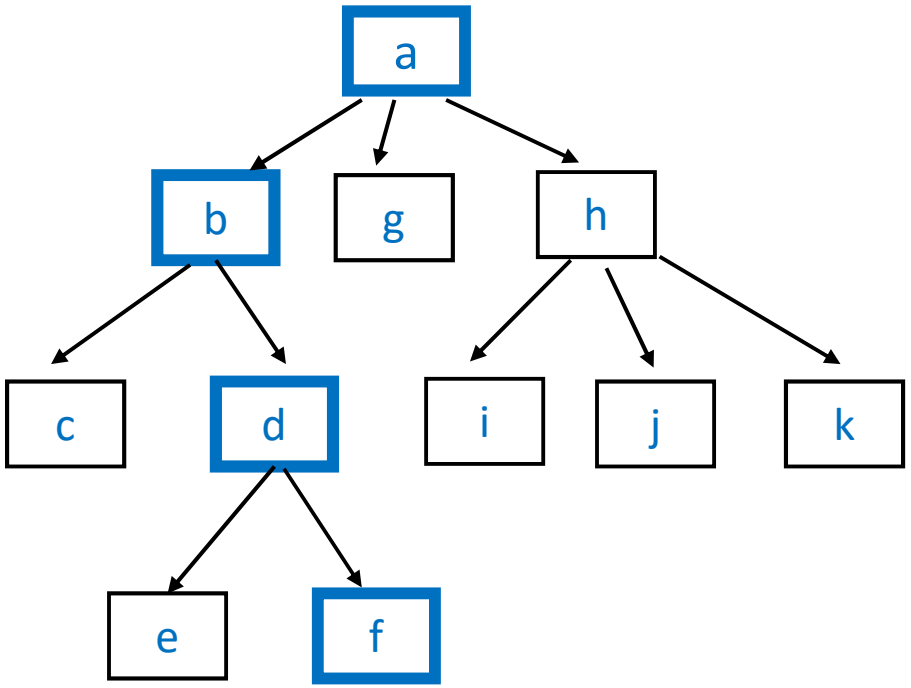
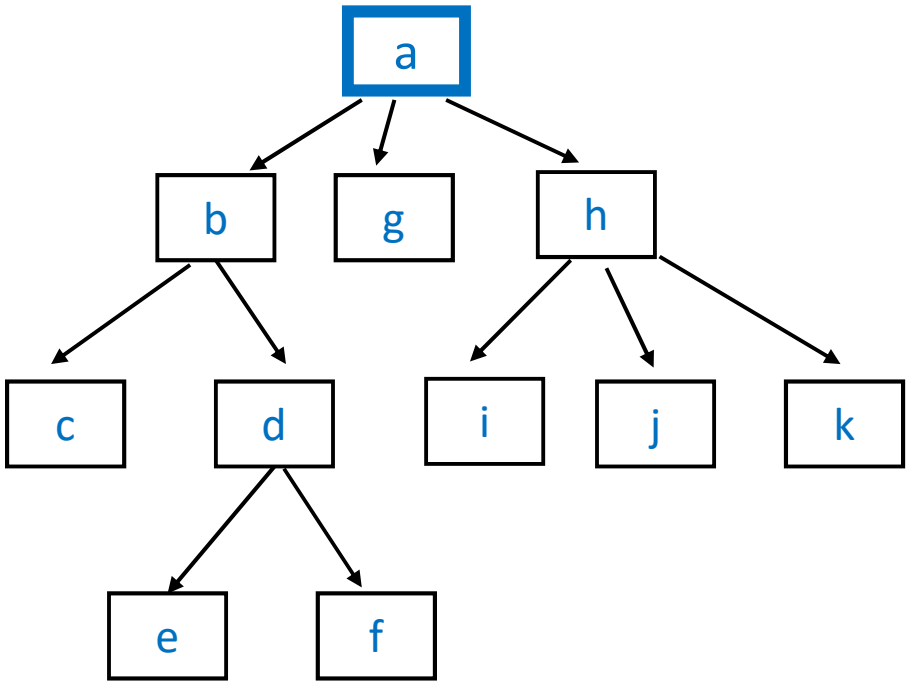
Call stack for depthfirst(root)

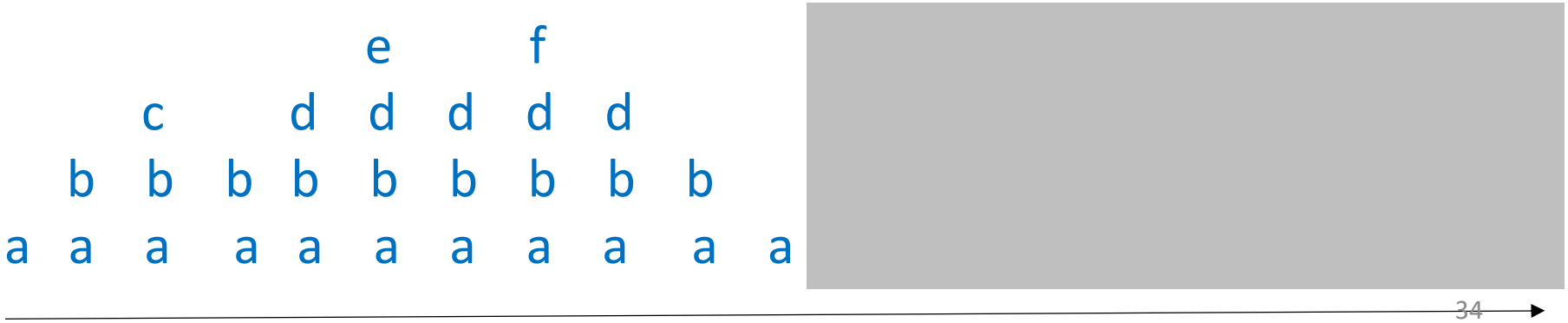


Call stack for depthfirst(root)

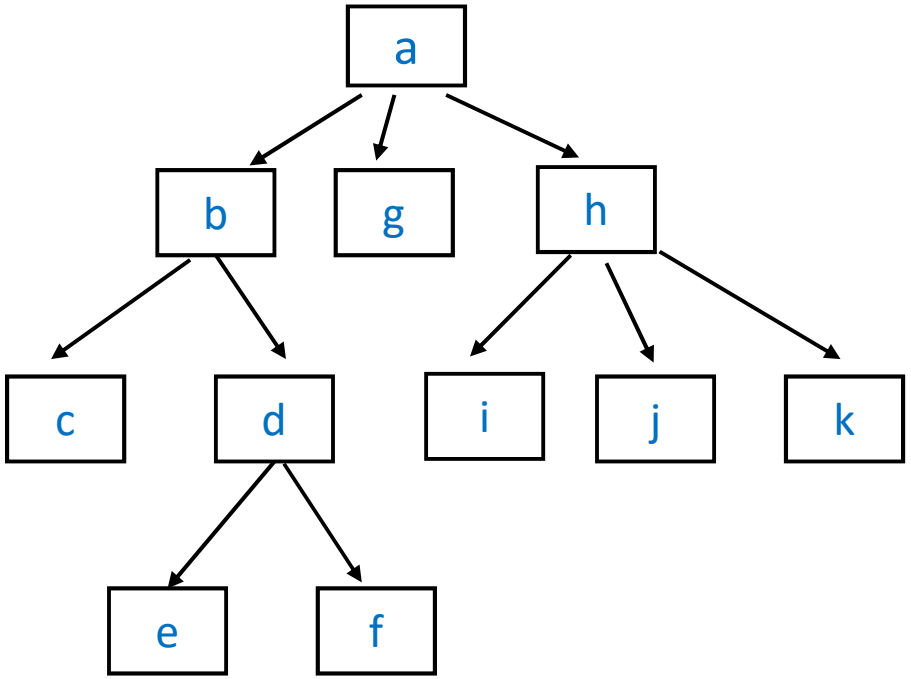


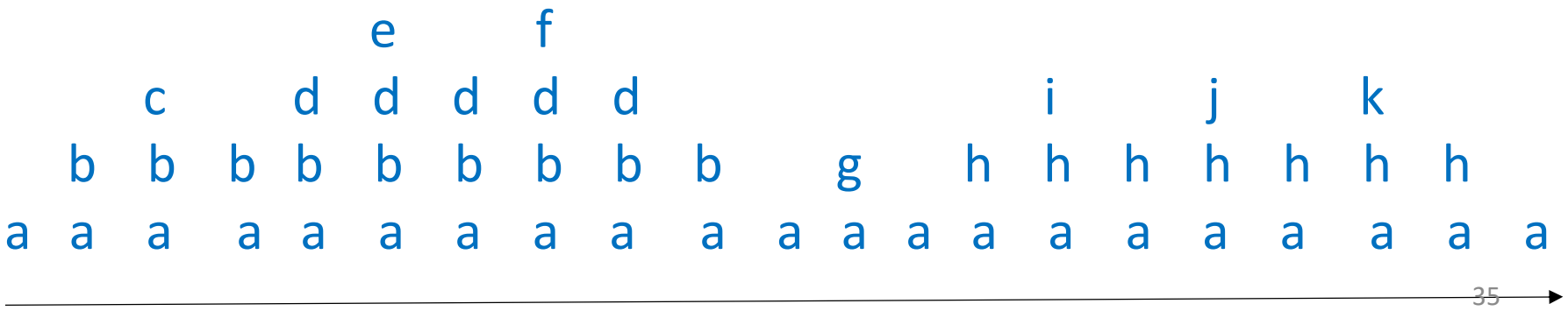
Call stack for depthfirst(root)





Call stack for depthfirst(root)





Tree traversal

Recursive

- depth first (pre- versus post-order)

Non-Recursive

- using a stack
- using a queue

```
treeTraversalUsingStack(root){
    initialize empty stack s
    s.push(root)
    
}
```

```
treeTraversalUsingStack(root){
    initialize empty stack s
    s.push(root)
    while s is not empty {
        cur = s.pop()
        visit cur
        
    }
}
```

```
treeTraversalUsingStack(root){
    initialize empty stack s
    s.push(root)
    while s is not empty {
        cur = s.pop()
        visit cur
        for each child of cur
            s.push(child)
    }
}
```

What is the order of nodes visited by treeTraversalUsingStack() ?

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treeTraversalUsingStack(root){
    initialize empty stack s
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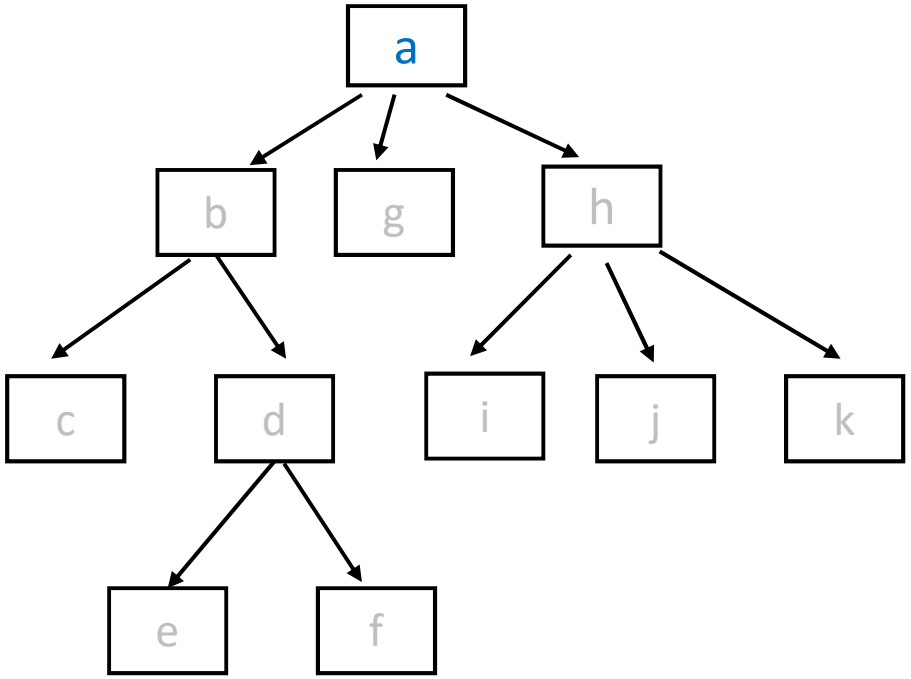

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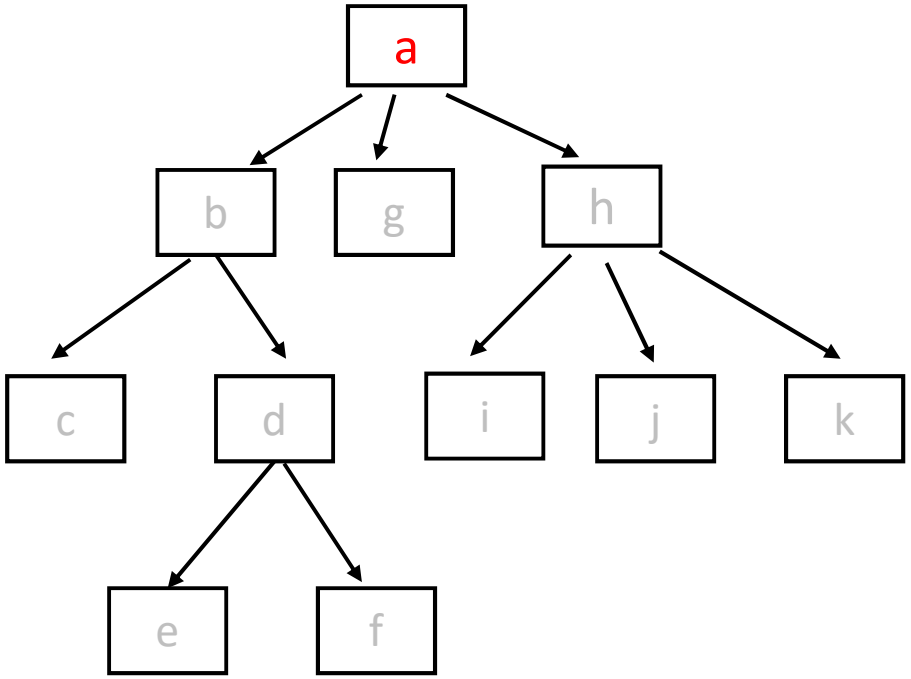

a _

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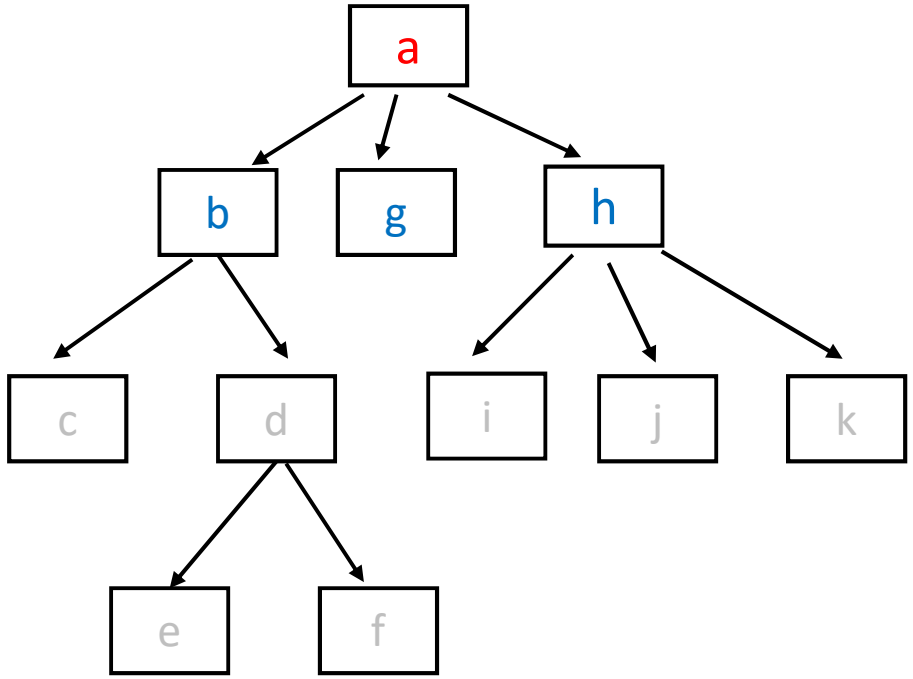

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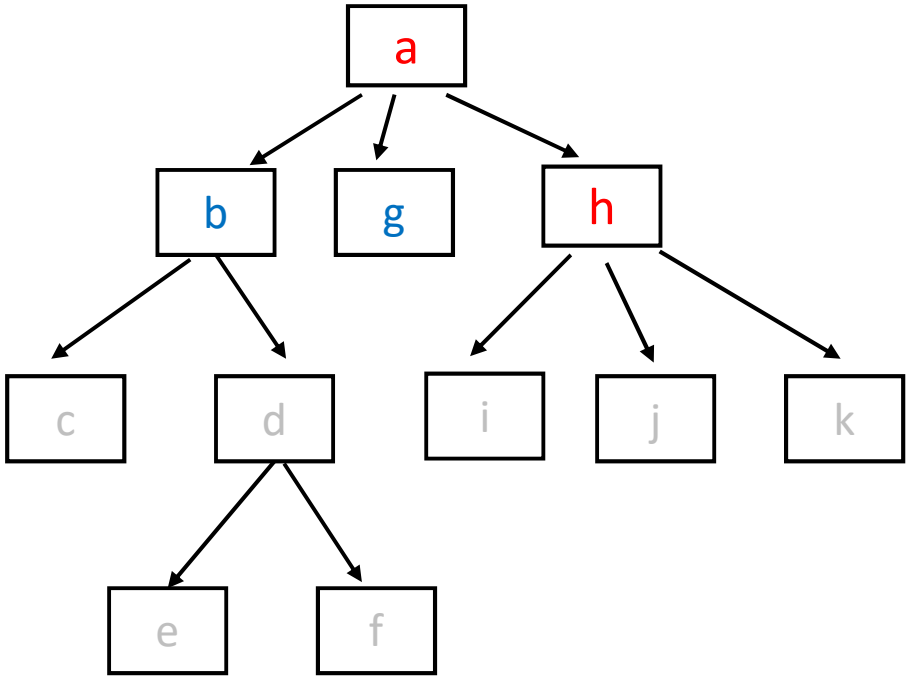

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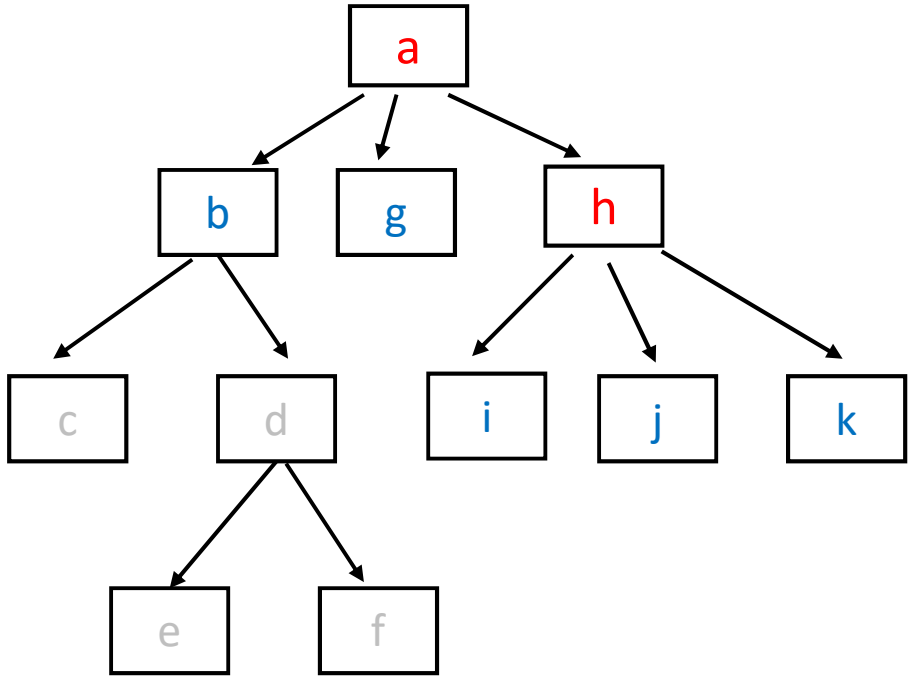

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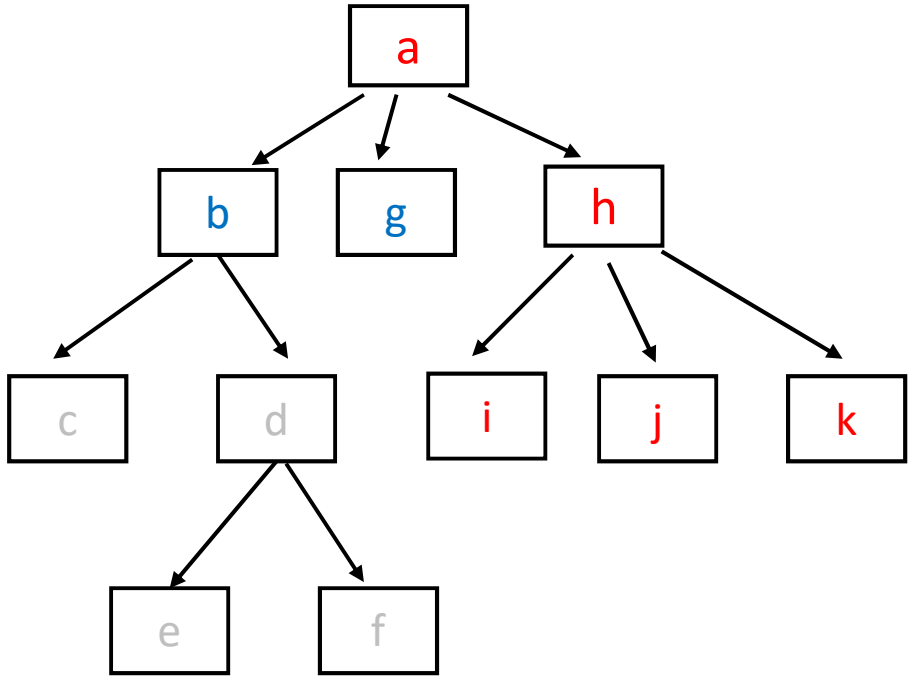

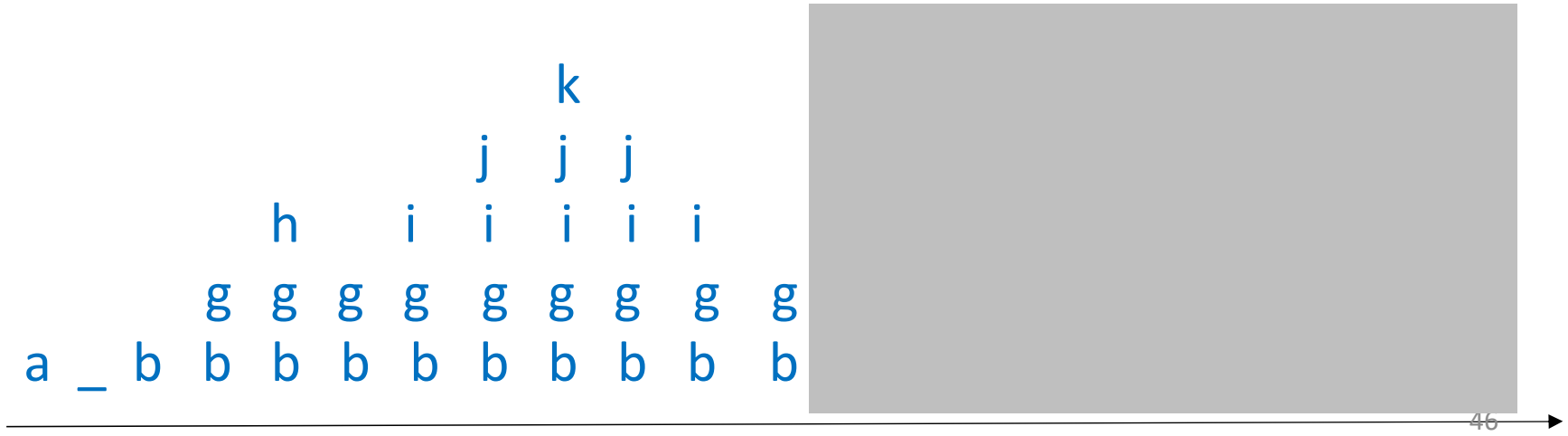

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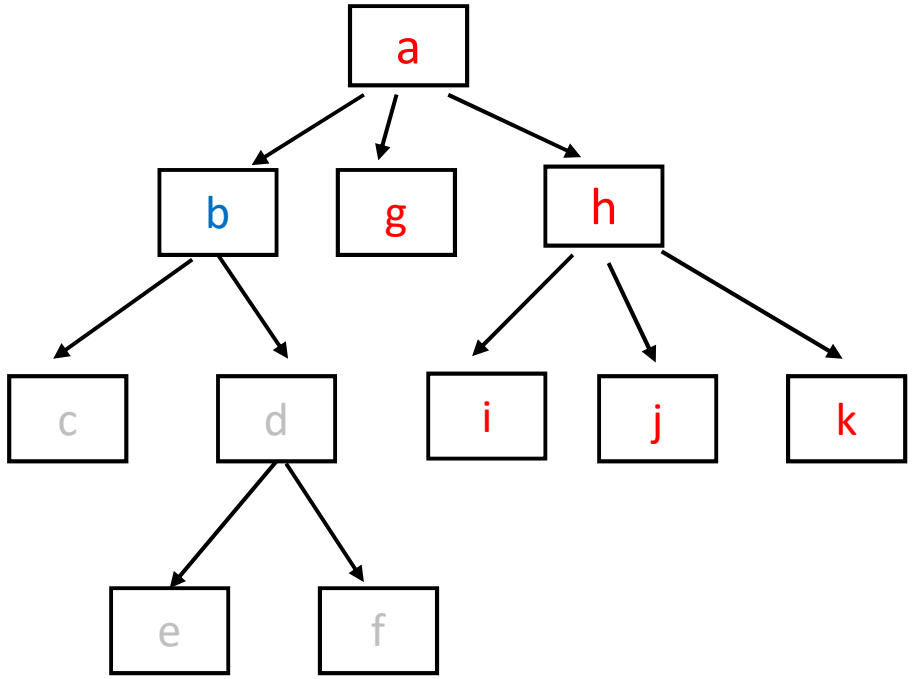

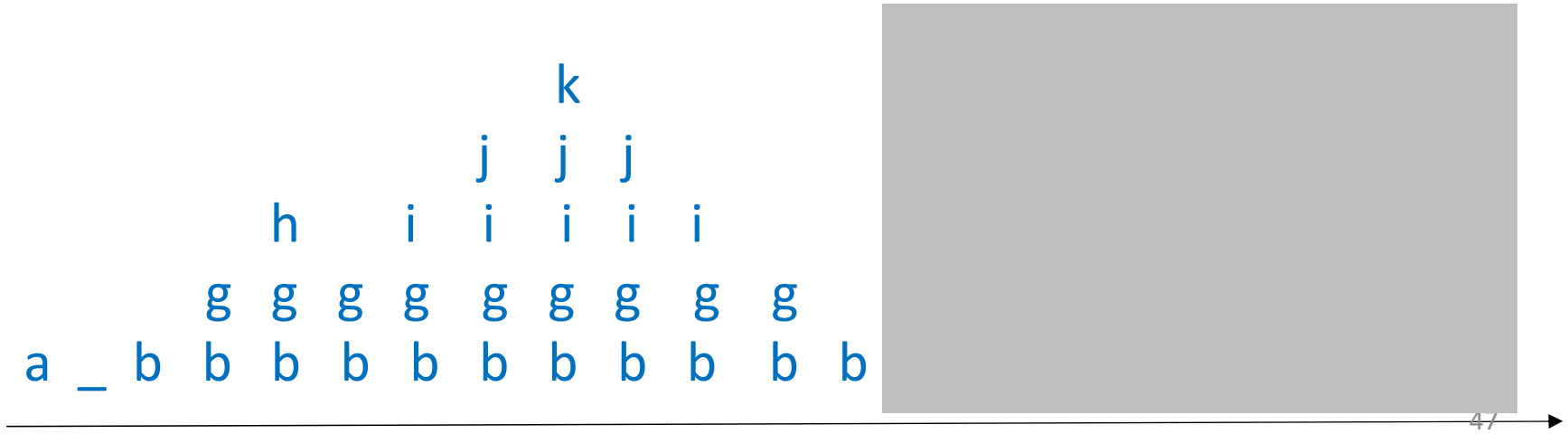

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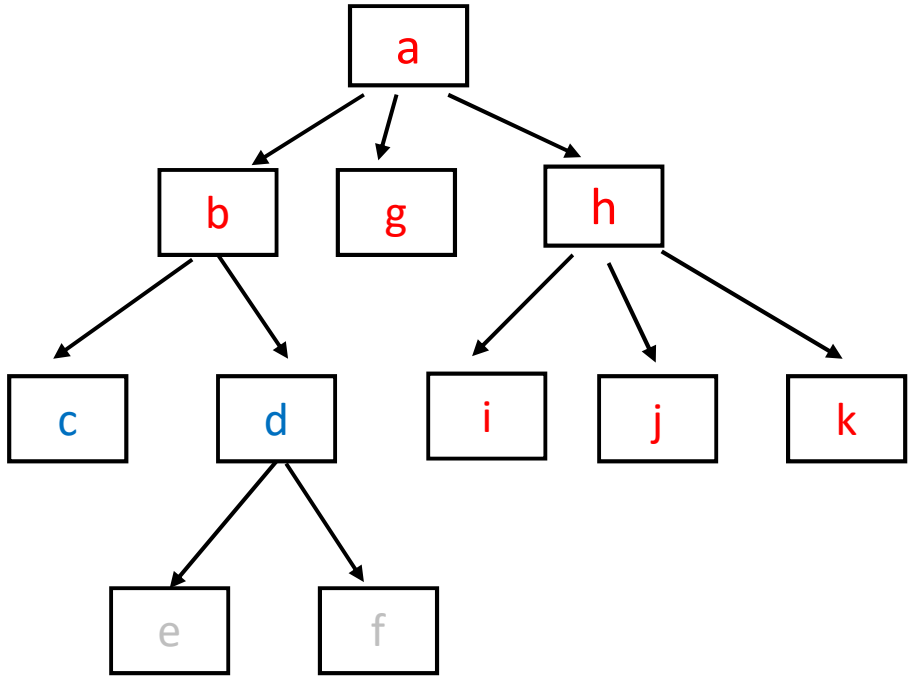

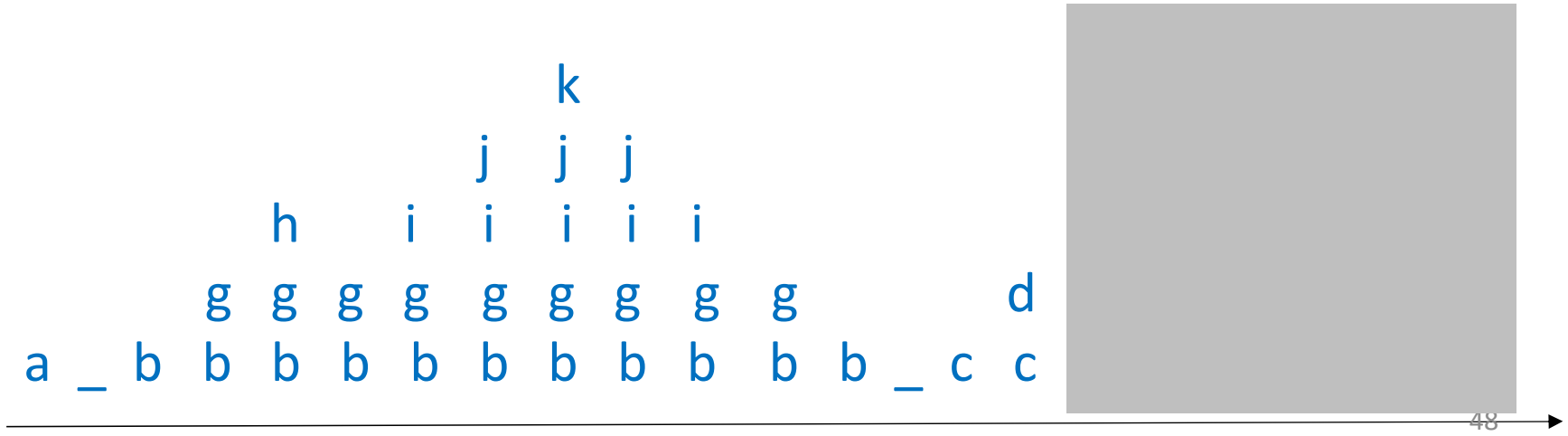

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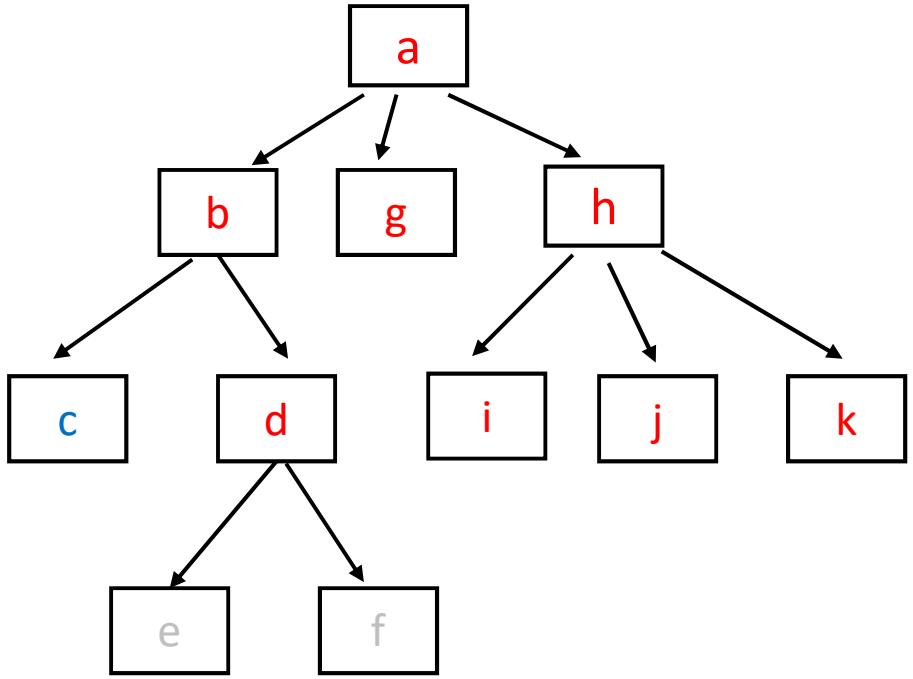
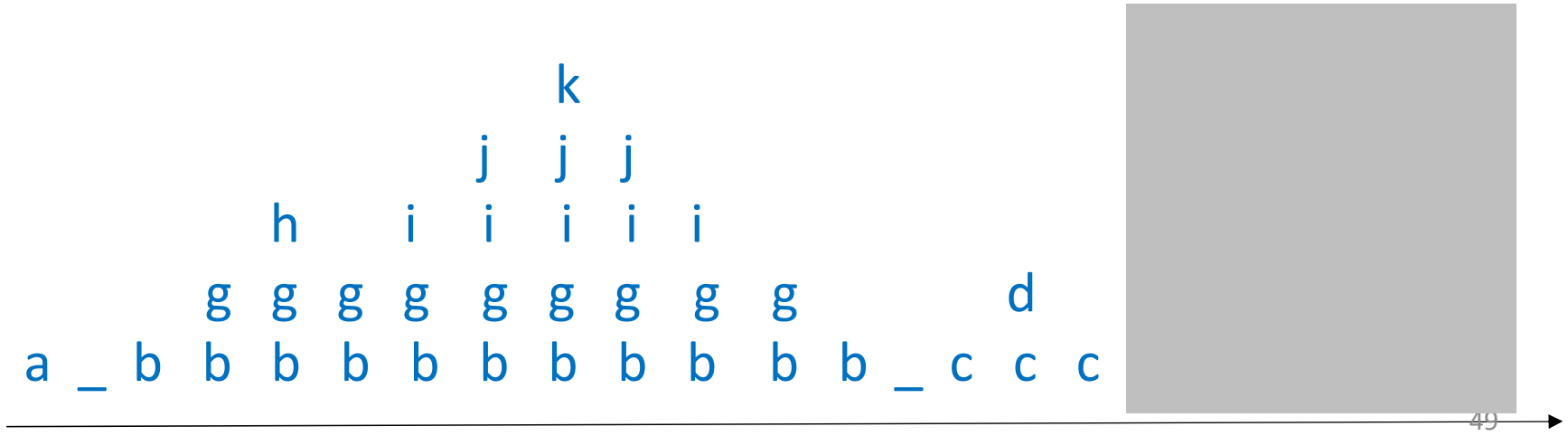
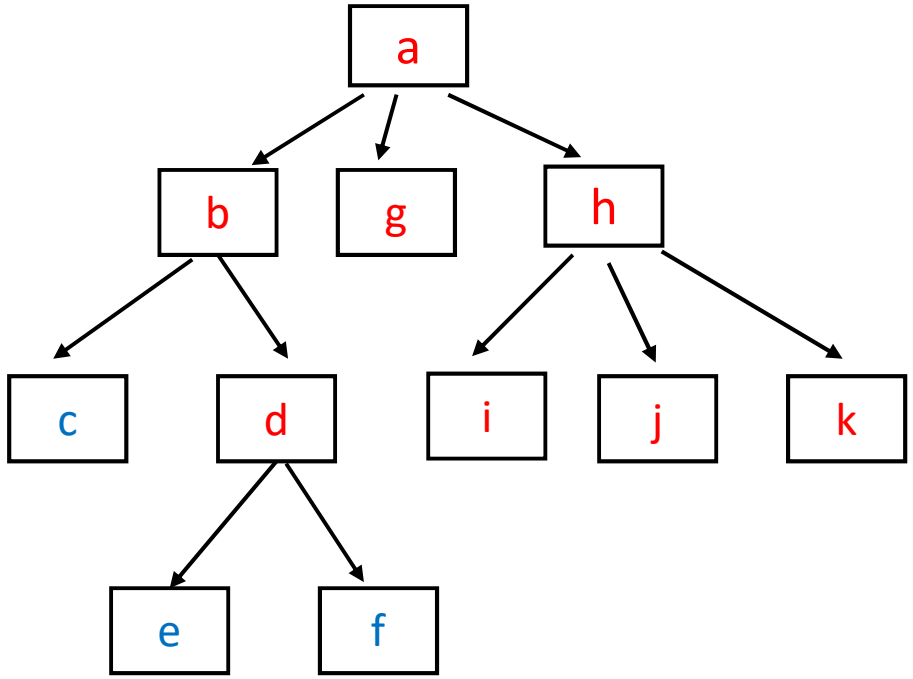
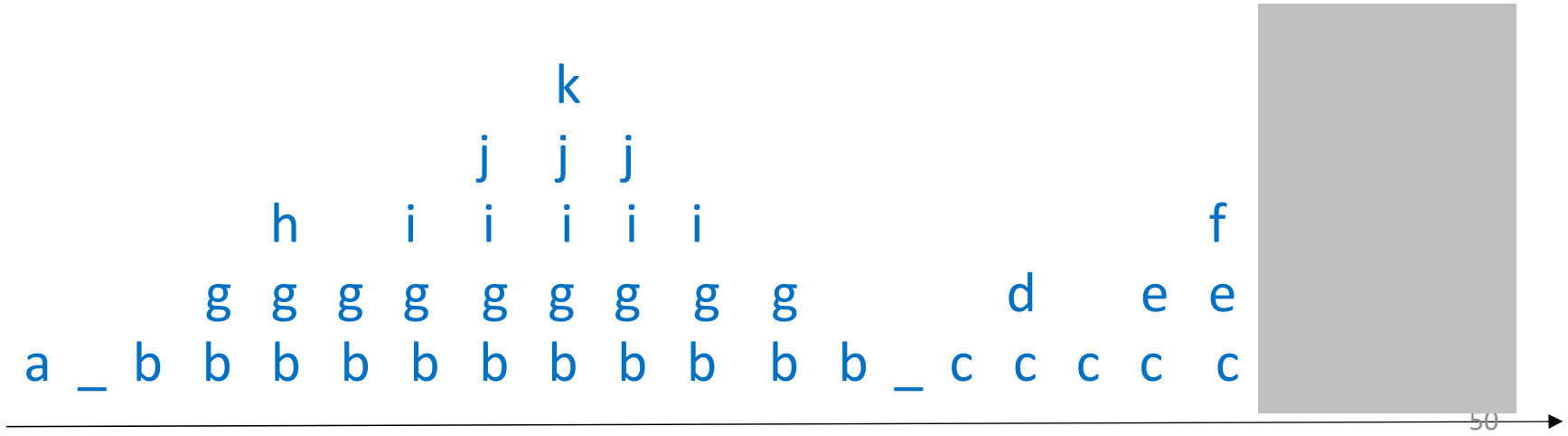
}
```



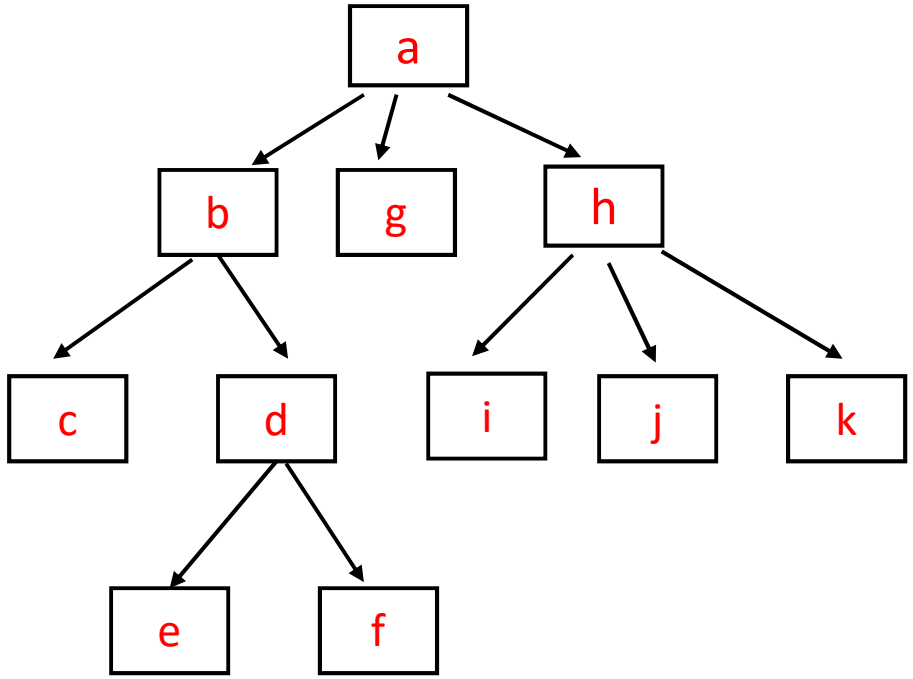


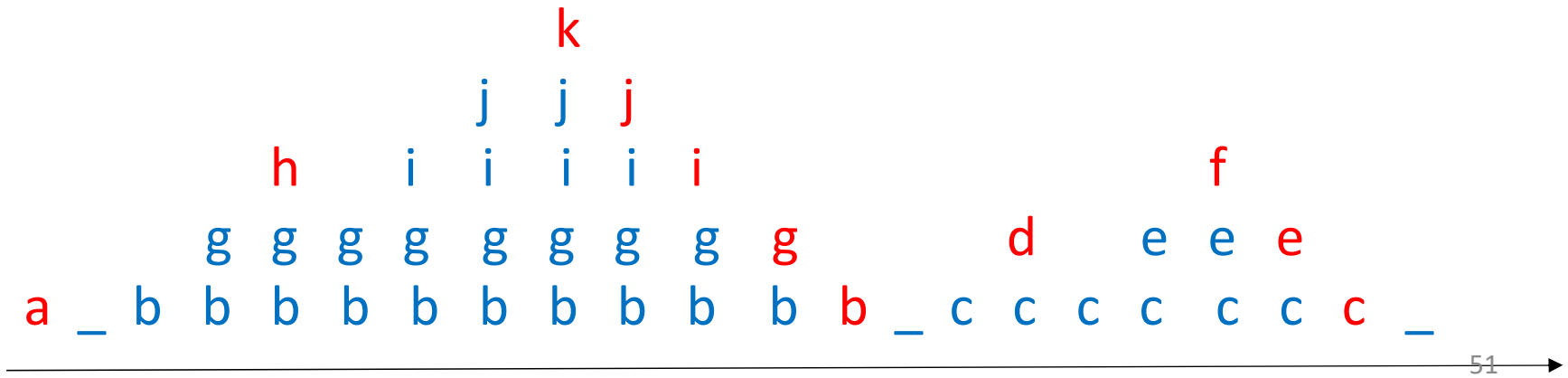
```
treeTraversalUsingStack(root){
    initialize empty stack s
    s.push(root)
    while s is not empty {
        cur = s.pop()
        visit cur
        for each child of cur
            s.push(child)
    }
}
```



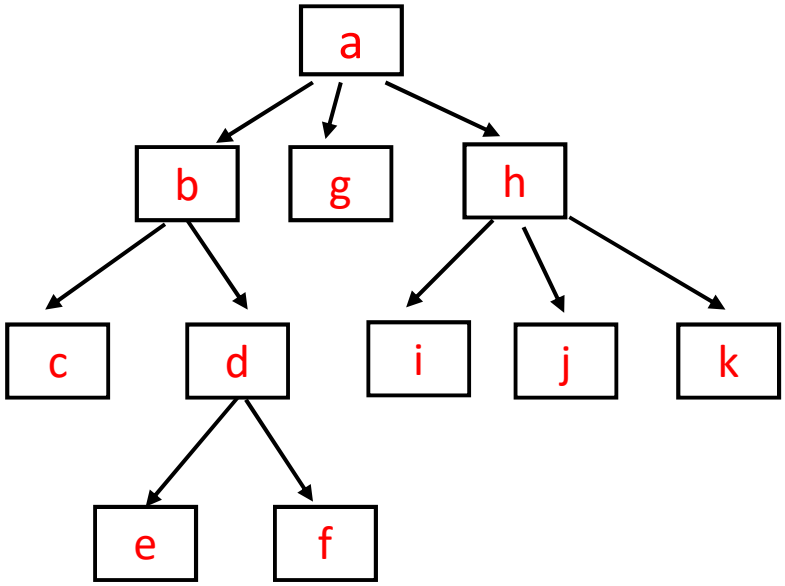


```
treeTraversalUsingStack(root){
    initialize empty stack s
    s.push(root)
    while s is not empty {
        cur = s.pop()
        visit cur
        for each child of cur
            s.push(child)
    }
}
```





The stack based method is also depth first, but we are visiting children from right to left



recursive preorder : abcdefghijk

recursive postorder : cefdbgijkha

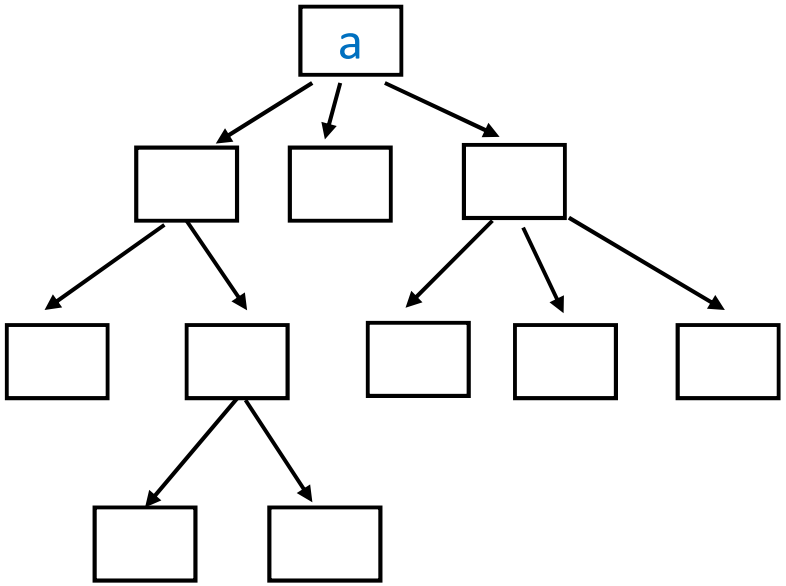
non-recursive (stack) : ahkjigbdfec

What if we use a queue instead?

```
treeTraversalUsingStack(root){
    initialize empty stack s
    s.push(root)
    while s is not empty {
        cur = s.pop()
        visit cur
        for each child of cur
            s.push(child)
    }
}
```

```
treeTraversalUsingQueue(root){
    initialize empty queue  q
    q.enqueue(root)
    while q is not empty {
        cur = q.dequeue()
        visit cur
        for each child of cur
            q.enqueue(child)
    }
}
```

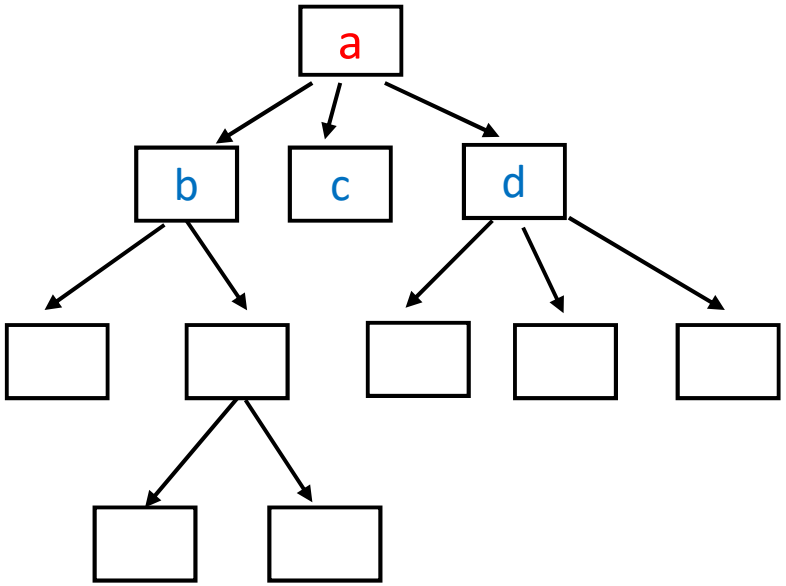
```
treeTraversalUsingQueue(root){
    initialize empty queue  q
    q.enqueue(root)
    while q is not empty {
        cur = q.dequeue()
        visit cur
        for each child of cur
            q.enqueue(child)
    }
}
```



Queue state at start of the while loop

a

```
treeTraversalUsingQueue(root){
    initialize empty queue  q
    q.enqueue(root)
●   while q is not empty {
        cur = q.dequeue()
        visit cur
        for each child of cur
            q.enqueue(child)
    }
}
```

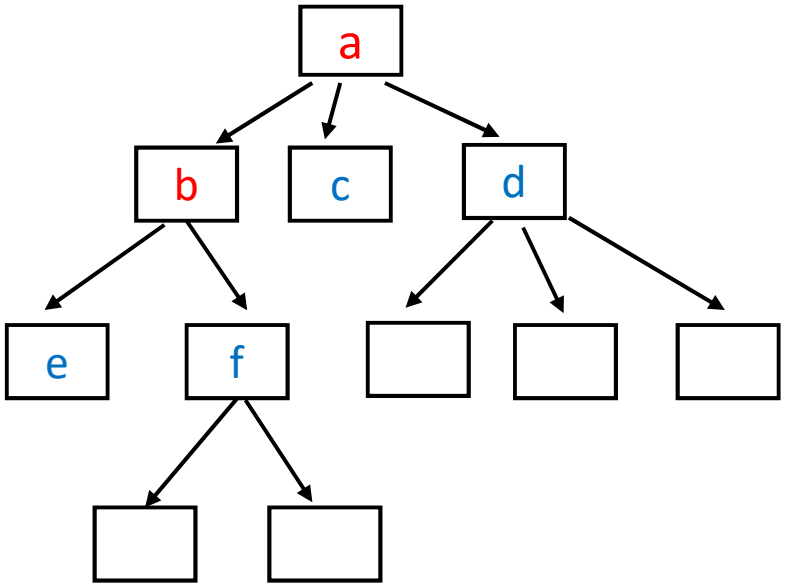


Queue state at start of the while loop

a

b c d

```
treeTraversalUsingQueue(root){
    initialize empty queue  q
    q.enqueue(root)
    while q is not empty {
        cur = q.dequeue()
        visit cur
        for each child of cur
            q.enqueue(child)
    }
}
```



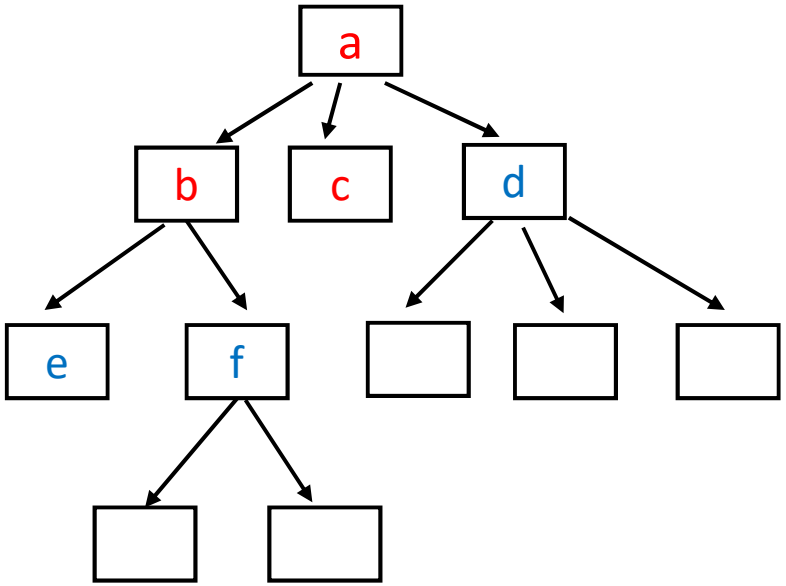
Queue state at start of the while loop

a

b c d

c d e f

```
treeTraversalUsingQueue(root){
    initialize empty queue  q
    q.enqueue(root)
    while q is not empty {
        cur = q.dequeue()
        visit cur
        for each child of cur
            q.enqueue(child)
    }
}
```



Queue state at start of the while loop

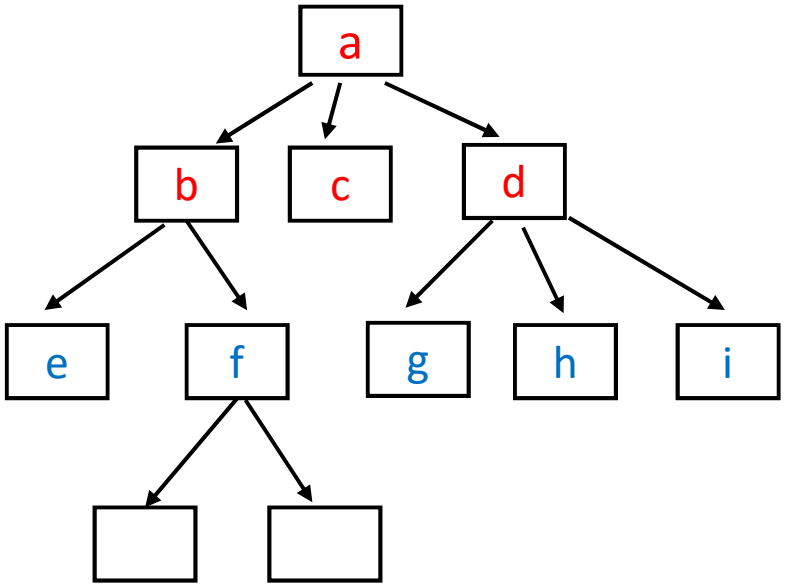
a

b c d

c d e f

d e f

```
treeTraversalUsingQueue(root){
    initialize empty queue  q
    q.enqueue(root)
●   while q is not empty {
        cur = q.dequeue()
        visit cur
        for each child of cur
            q.enqueue(child)
    }
}
```



Queue state at start of the while loop

a

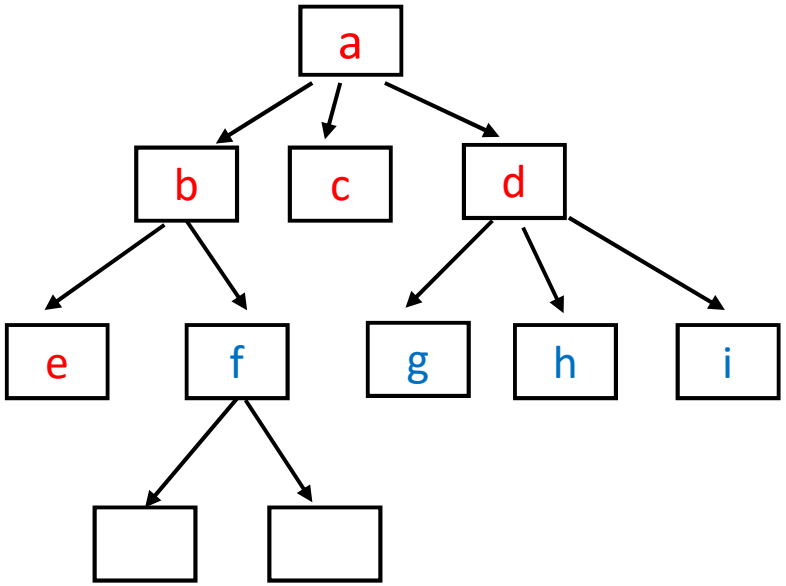
b c d

c d e f

d e f

e f g h i

```
treeTraversalUsingQueue(root){
    initialize empty queue  q
    q.enqueue(root)
    while q is not empty {
        cur = q.dequeue()
        visit cur
        for each child of cur
            q.enqueue(child)
    }
}
```



Queue state at start of the while loop

a

b c d

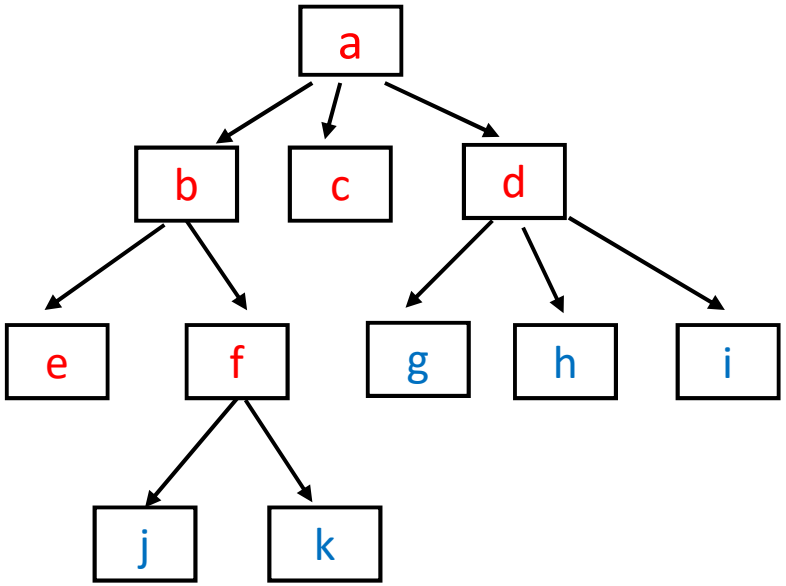
c d e f

d e f

e f g h i

f g h i

```
treeTraversalUsingQueue(root){
    initialize empty queue  q
    q.enqueue(root)
    while q is not empty {
        cur = q.dequeue()
        visit cur
        for each child of cur
            q.enqueue(child)
    }
}
```



Queue state at start of the while loop

a

b c d

c d e f

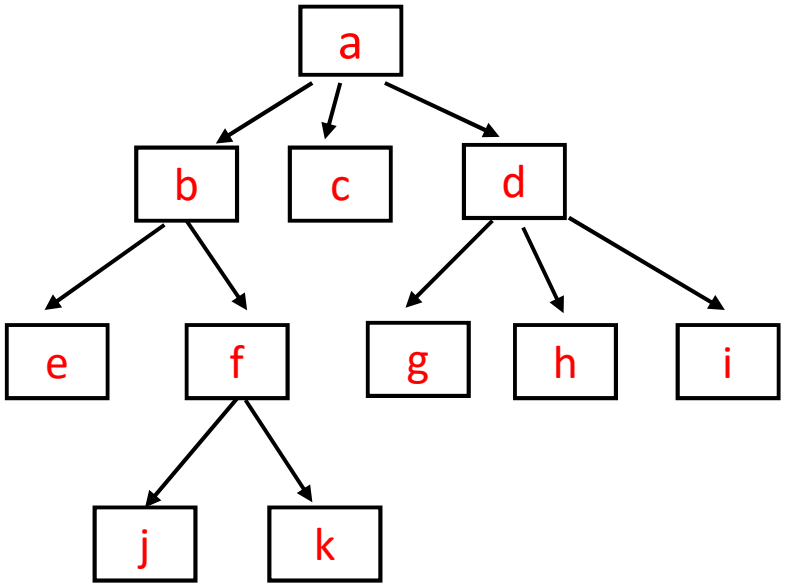
d e f

e f g h i

f g h i

g h i j k

```
treeTraversalUsingQueue(root){
    initialize empty queue  q
    q.enqueue(root)
    while q is not empty {
        cur = q.dequeue()
        visit cur
        for each child of cur
            q.enqueue(child)
    }
}
```



Queue state at start of the while loop

a

b c d

c d e f

d e f

e f g h i

f g h i

g h i j k

h i j k

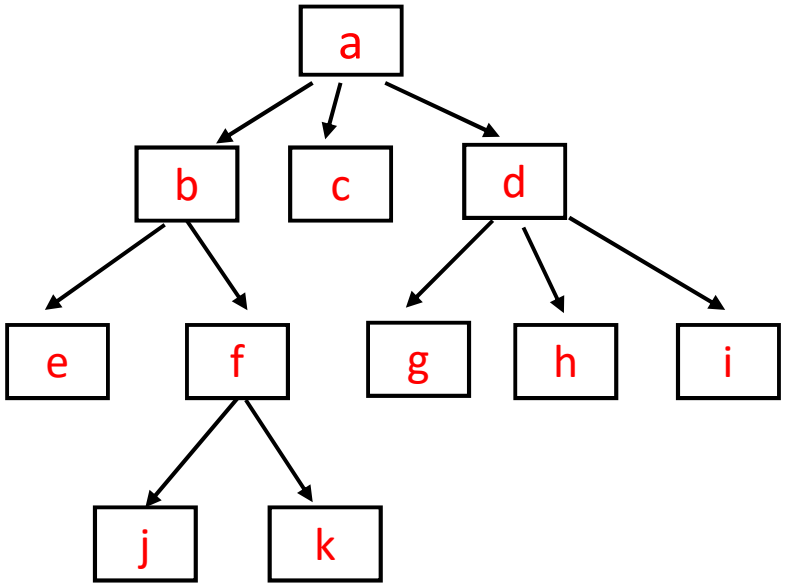
i j k

j k

k

breadth first traversal

for each level i
    visit all nodes at level i



order visited: abcdefghijk

Coming up...

Lectures

Fri. March 11 (lecture 25)
Expression Trees

Mon. March 14
Binary Search Trees

Wed & Fri. March 16 & 18
Heaps

Tutorial + Assessments

Tutorial for Assignment 3
today at 6 pm

Assignment 3
due Wed. March 16

Quiz 4 (lectures 20-25)
Fri. March 18