Non-Linear Data Structures

“Making room for real-life concepts”

Prerequisite: None

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Types of Data Structures in C++

Raw Data Structures	Abstract Data Types
Concrete representation of data	Conceptual model defined by its behavior from the point of view of a user

• Primitive Data Types
  • int
  • float, double
  • char
• Array
• Struct
• Class
	• Vector, Deque
	• Set, Map
	• Stack, Queue, Priority Queue
	• Single Linked List
	• Doubly Linked List
	• Tree
	• Graph

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Classification of ADT

Abstract Data Types

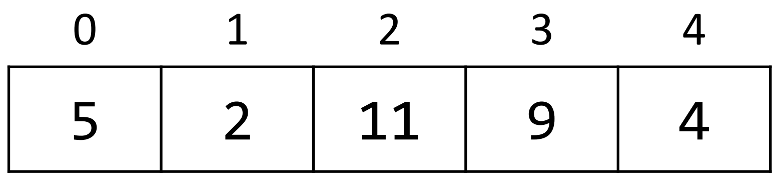
Linear

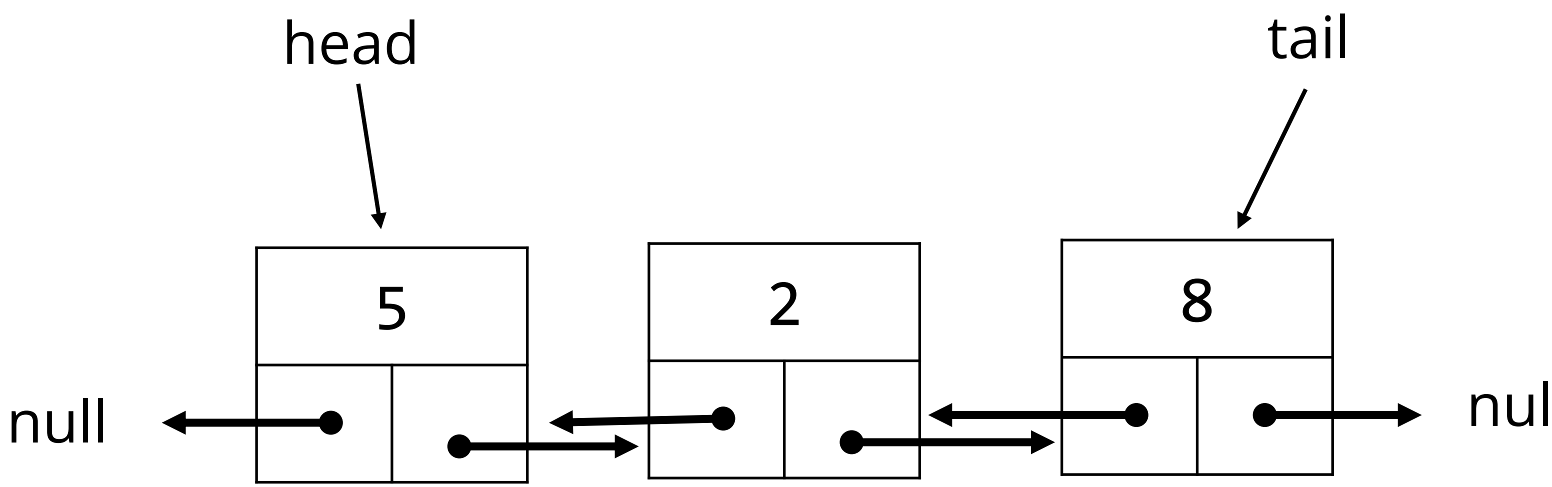
- Unique first element
- Unique last element
- Specific one next element
- Specific one previous element

Non-Linear

- First element may or may not be fixed
- No specific last element
- No specific next element
- Previous element may or may not be fixed

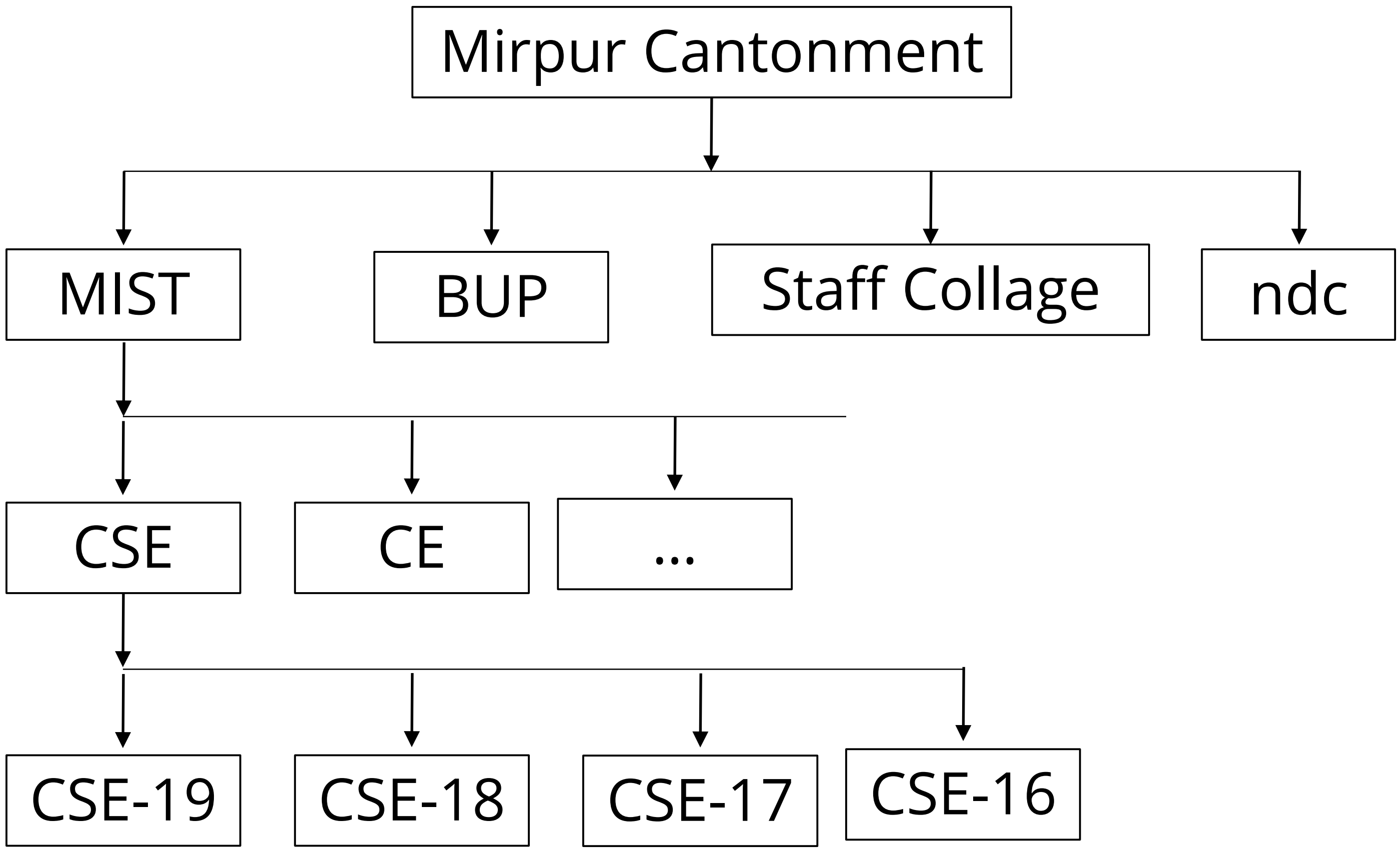
Linear Data Structures



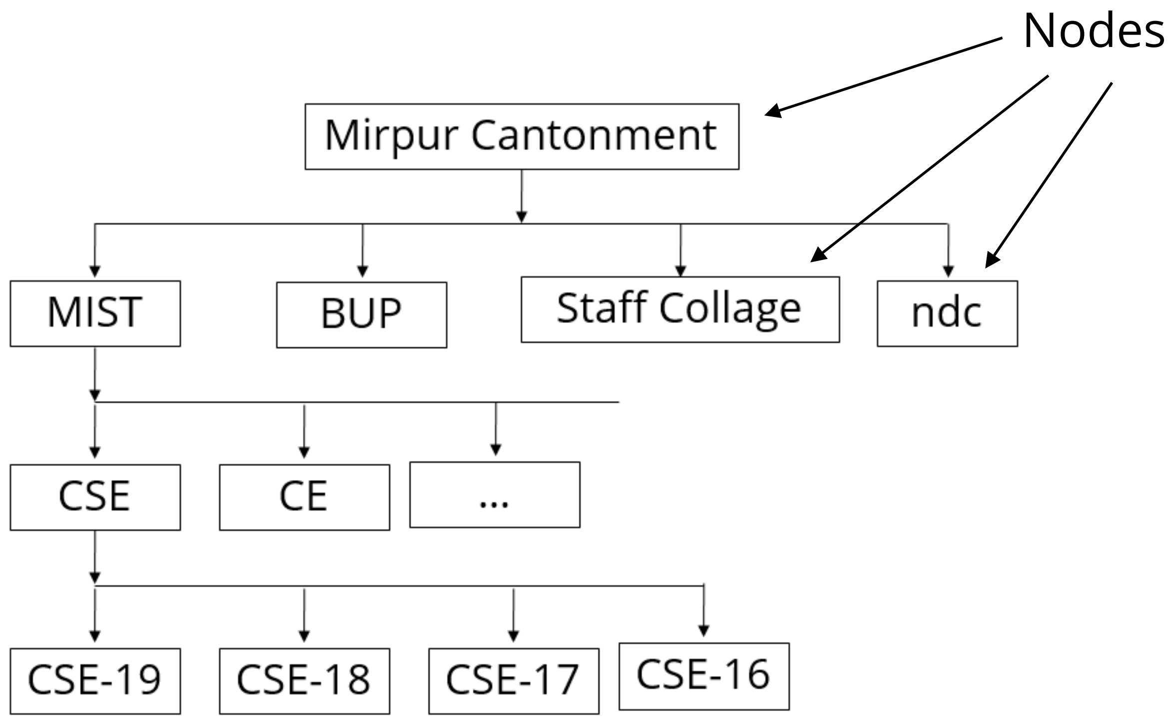


Limitation of Linear Data Structures

The following information cannot be adjusted into a linear data structure



Tree



- First element may or may not be fixed
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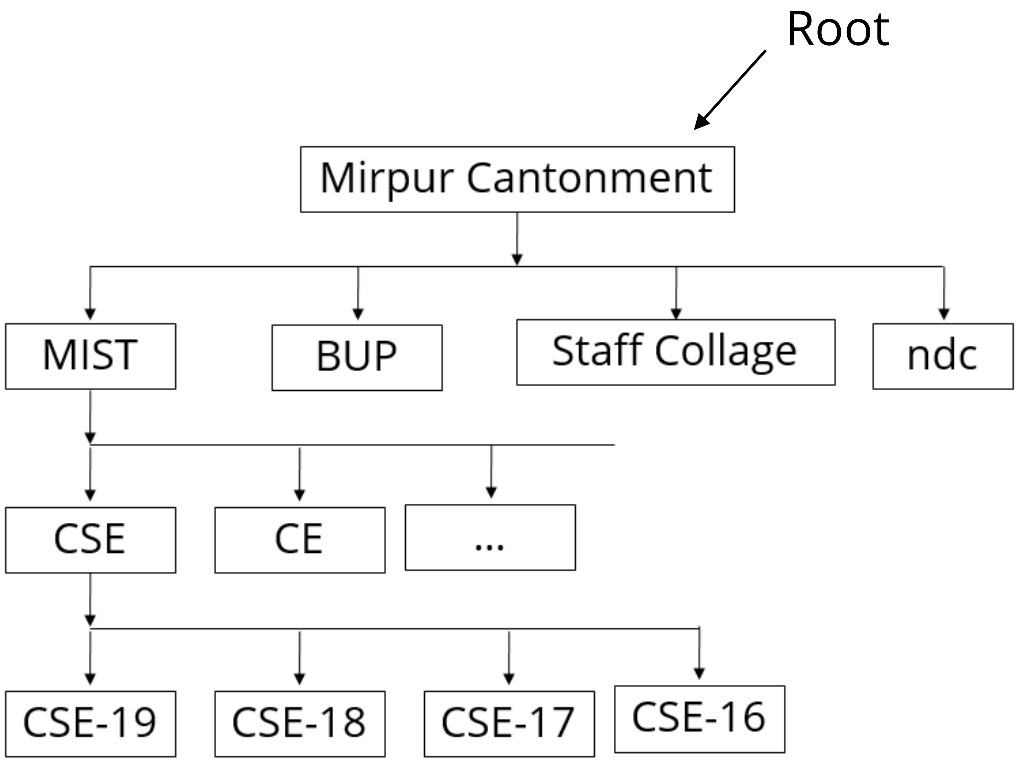
Tree



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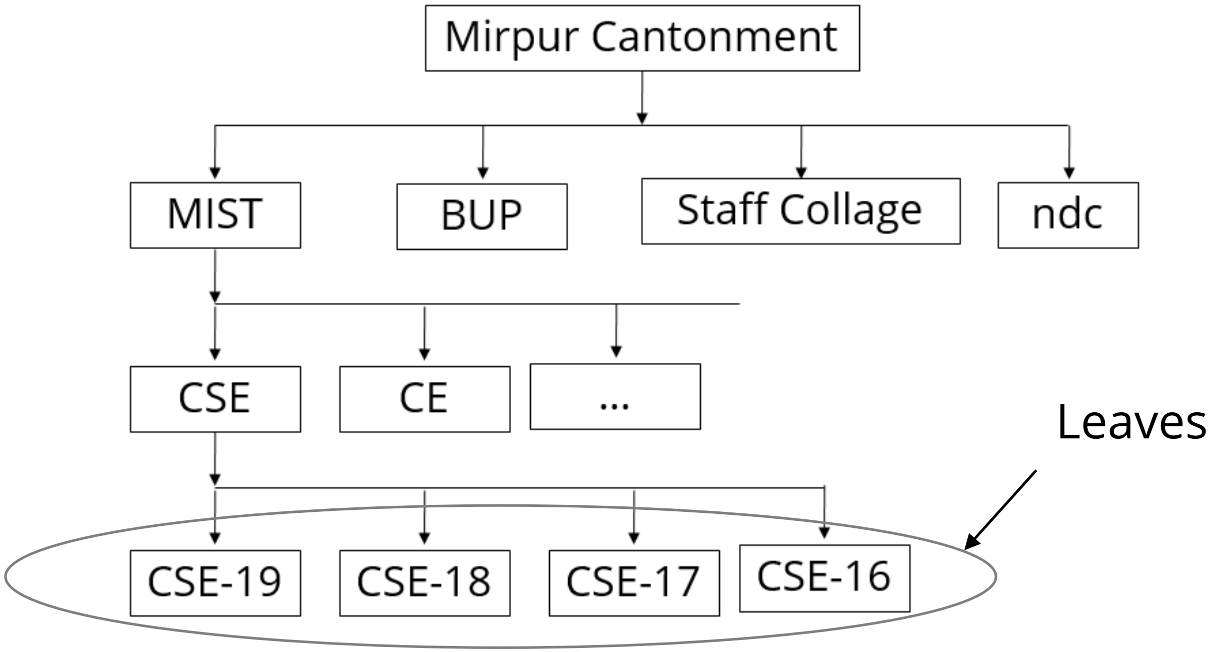

- First element fixed
- No specific last element
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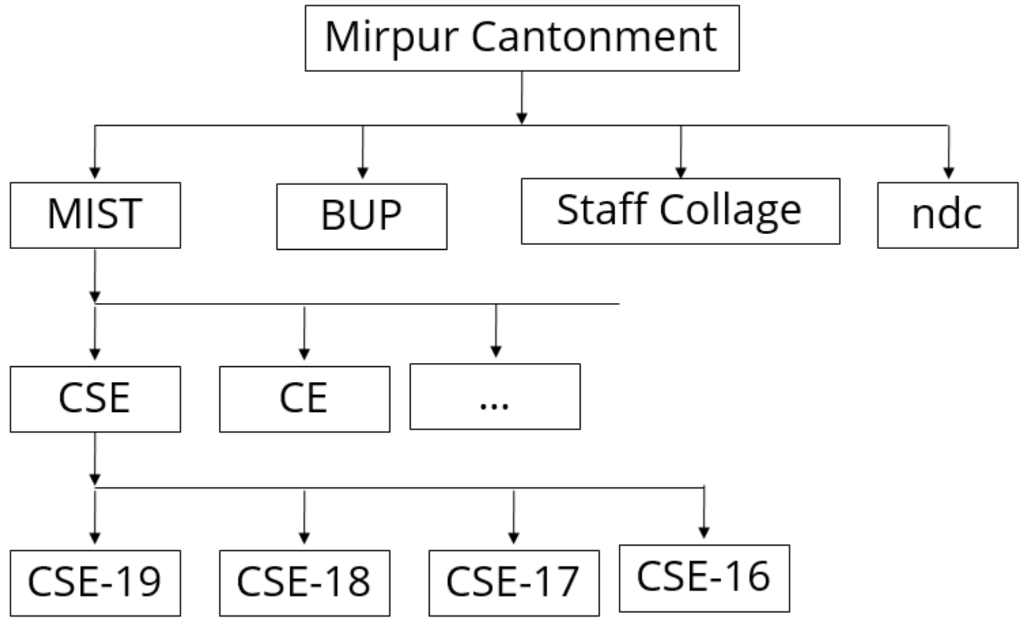
Tree



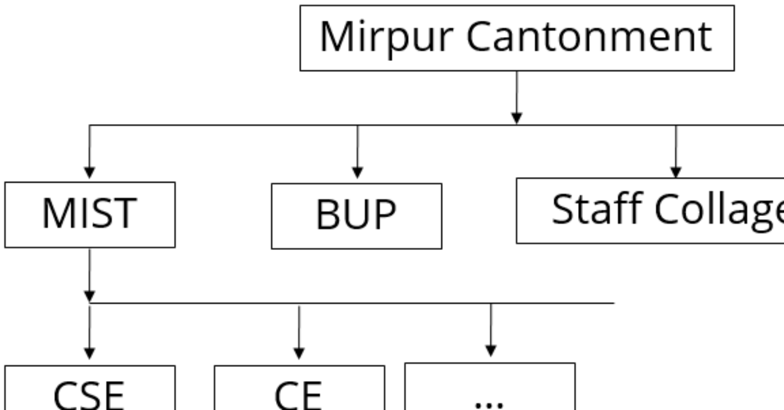
- First element fixed
- No specific last element
- No specific next element
- Previous element is unique, called parent

Tree

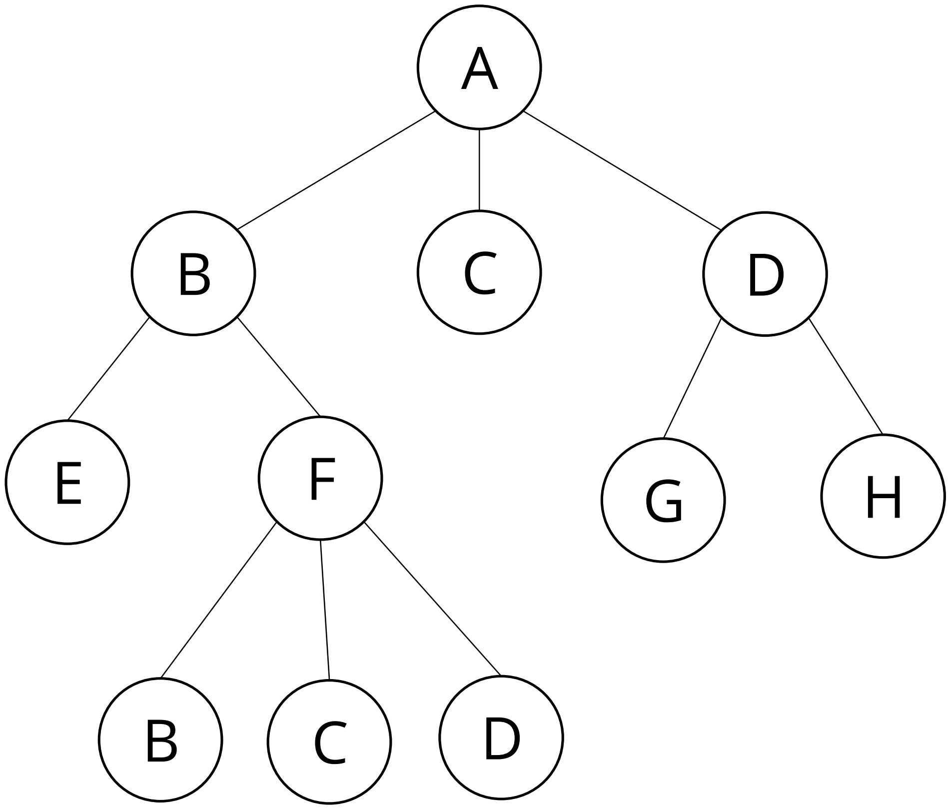
Formal Definition of a Tree T

T is a set of nodes with parent-child relationship where-

- T has a special node r (called root), with no parent node
- Each node v of T except r has a unique parent node u.
- v is called the child of u.

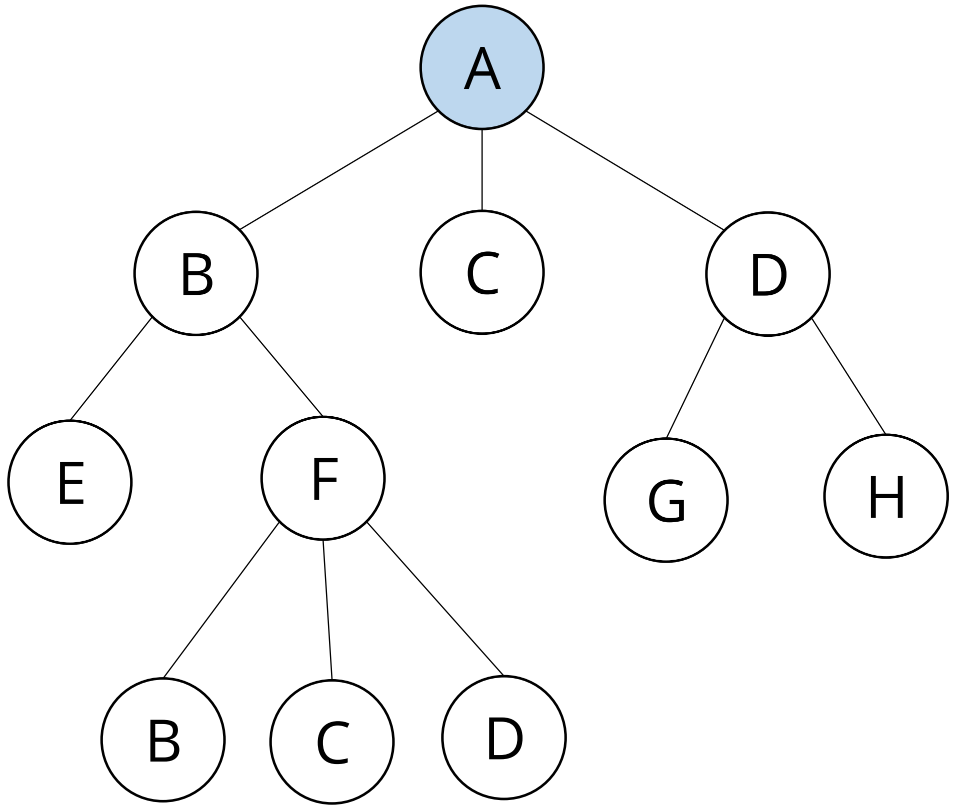


Tree Terminology



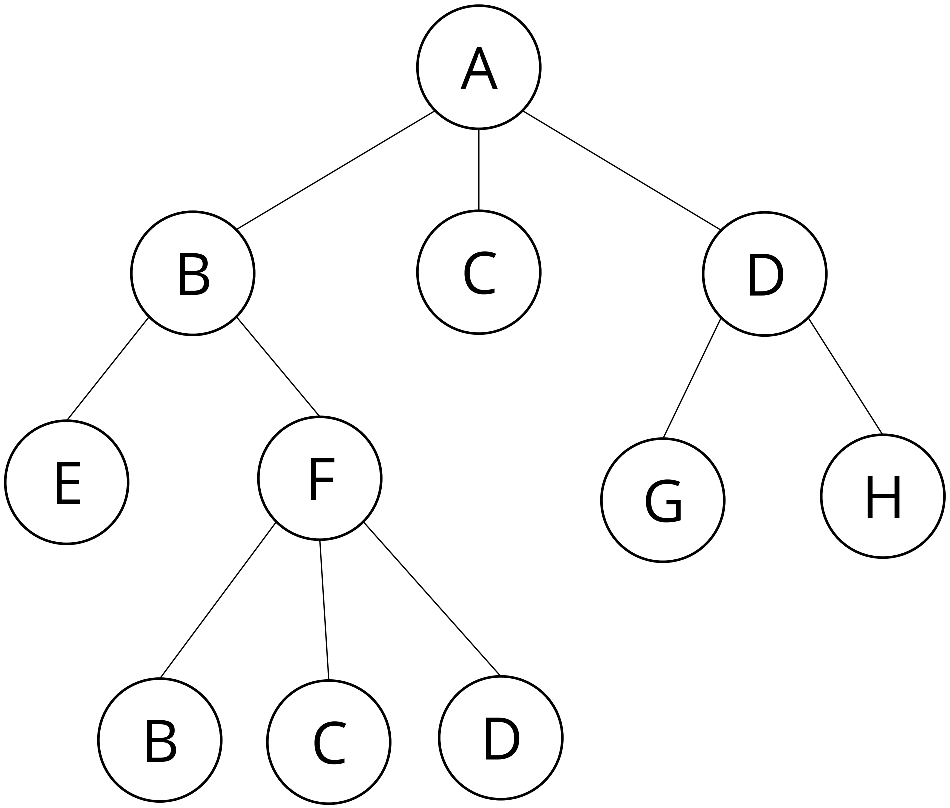
Root

Node without parent



Internal Node

Node with at least one child



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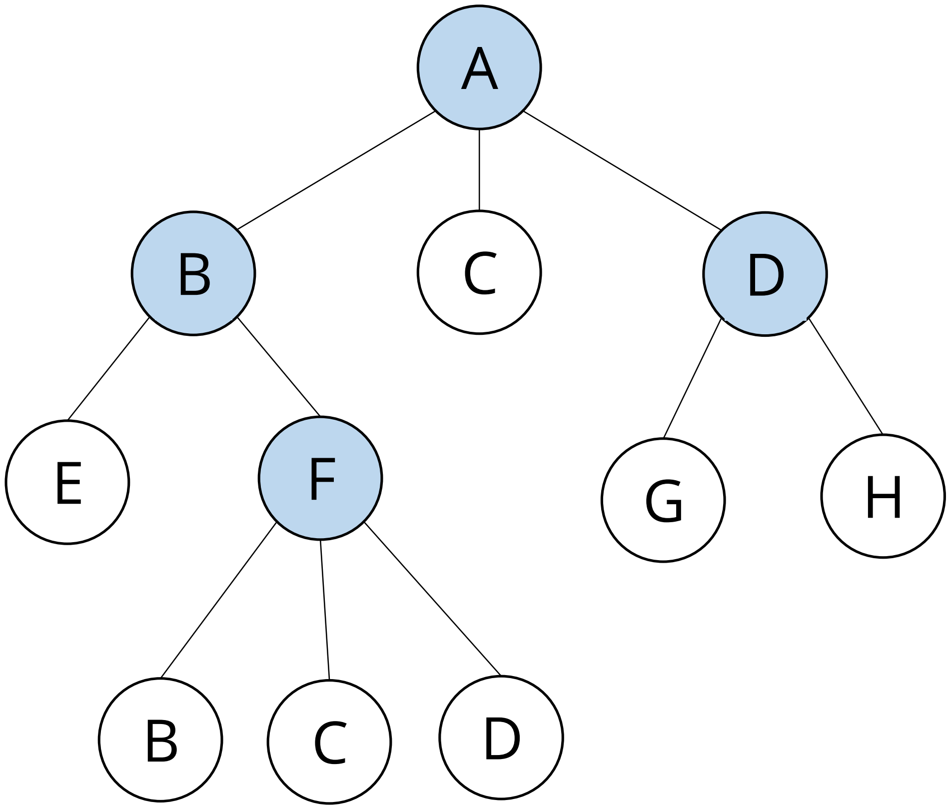
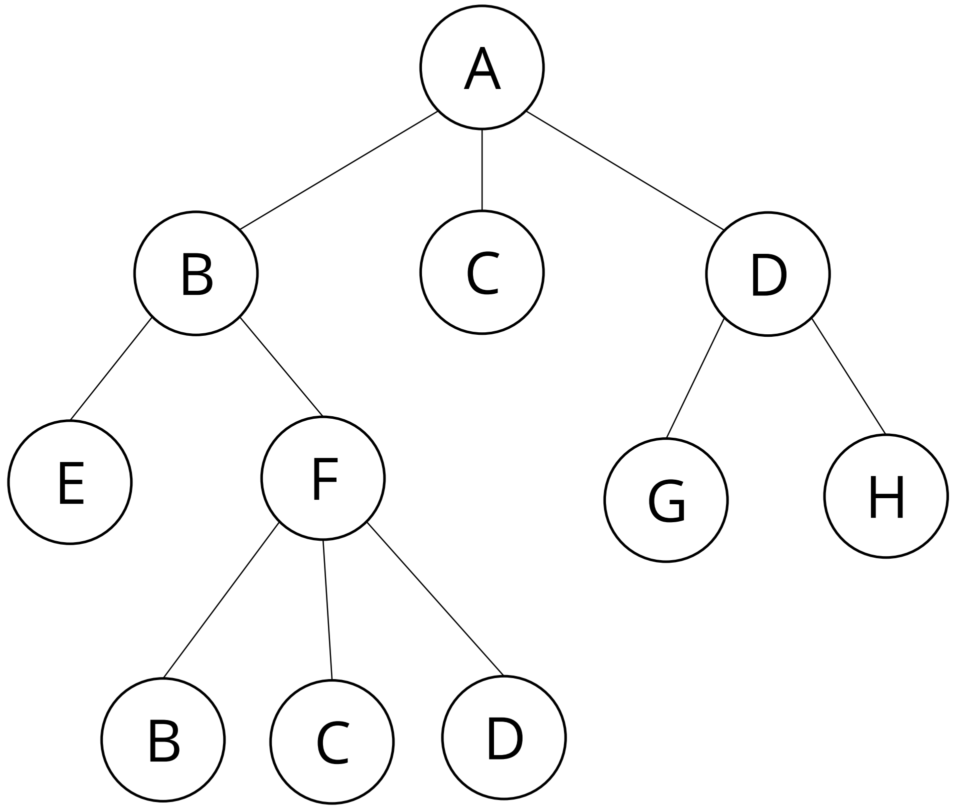


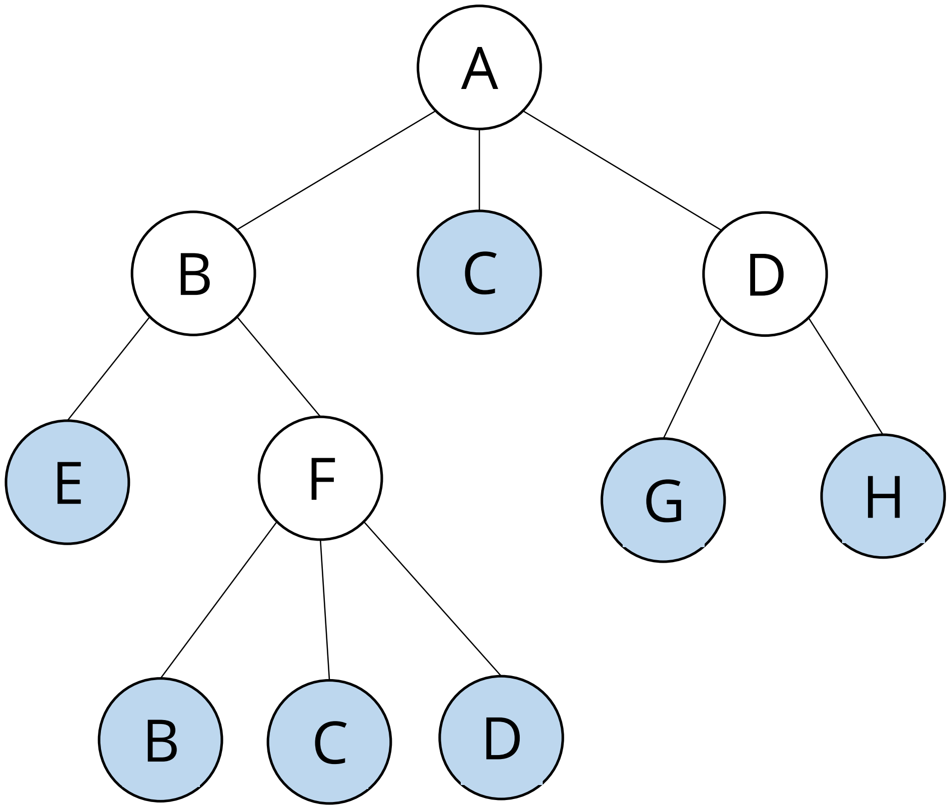
External Node (Leaf)

Node without children



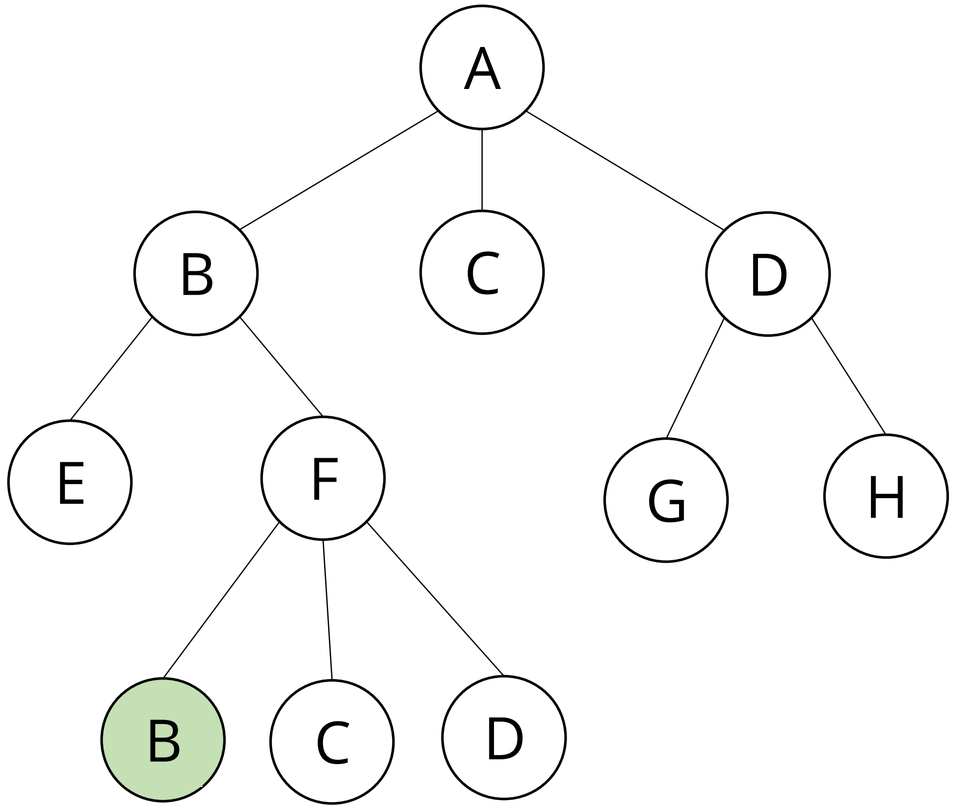
External Node (Leaf)

Node without children



Ancestor of a node

Parent, grand-parent, grand-grandparent etc



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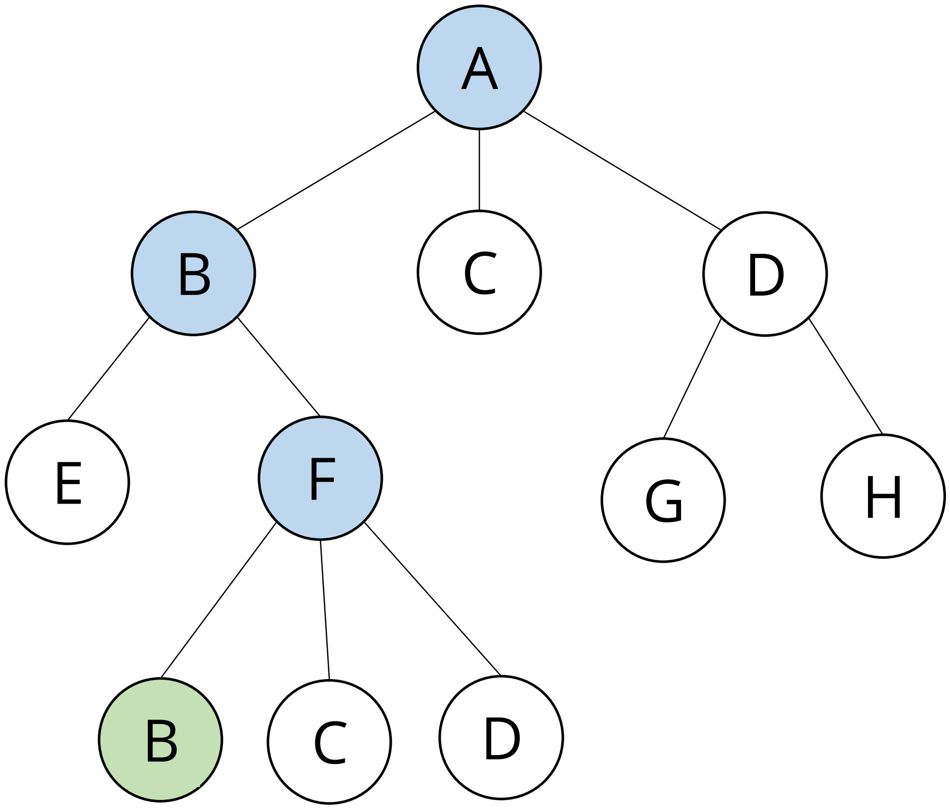
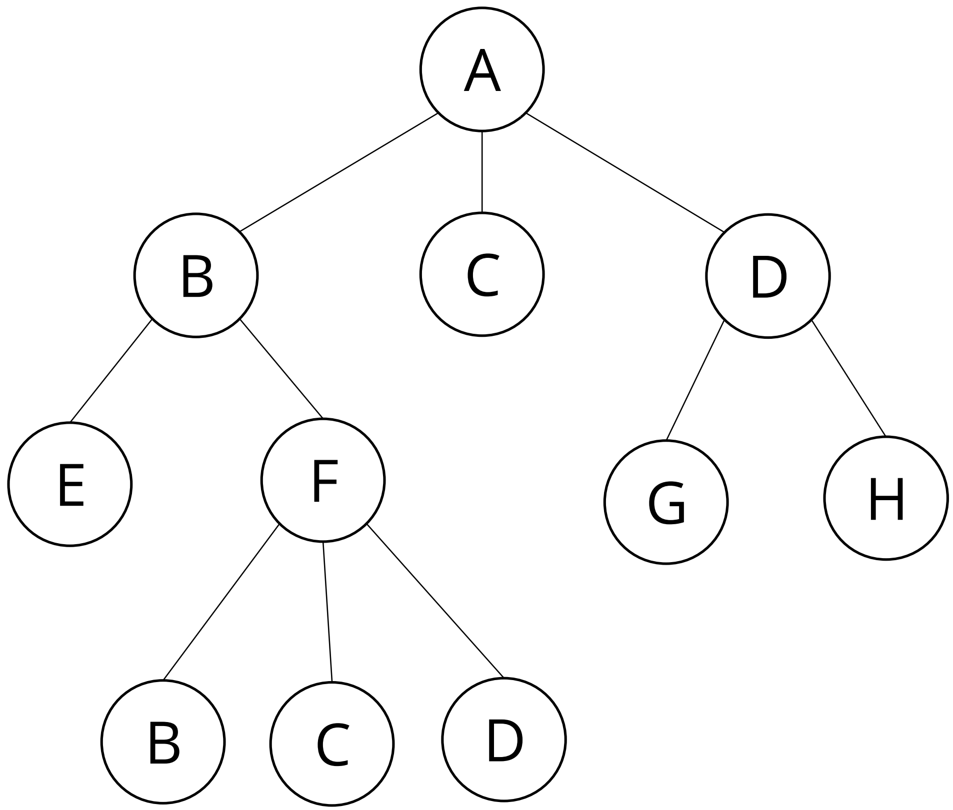


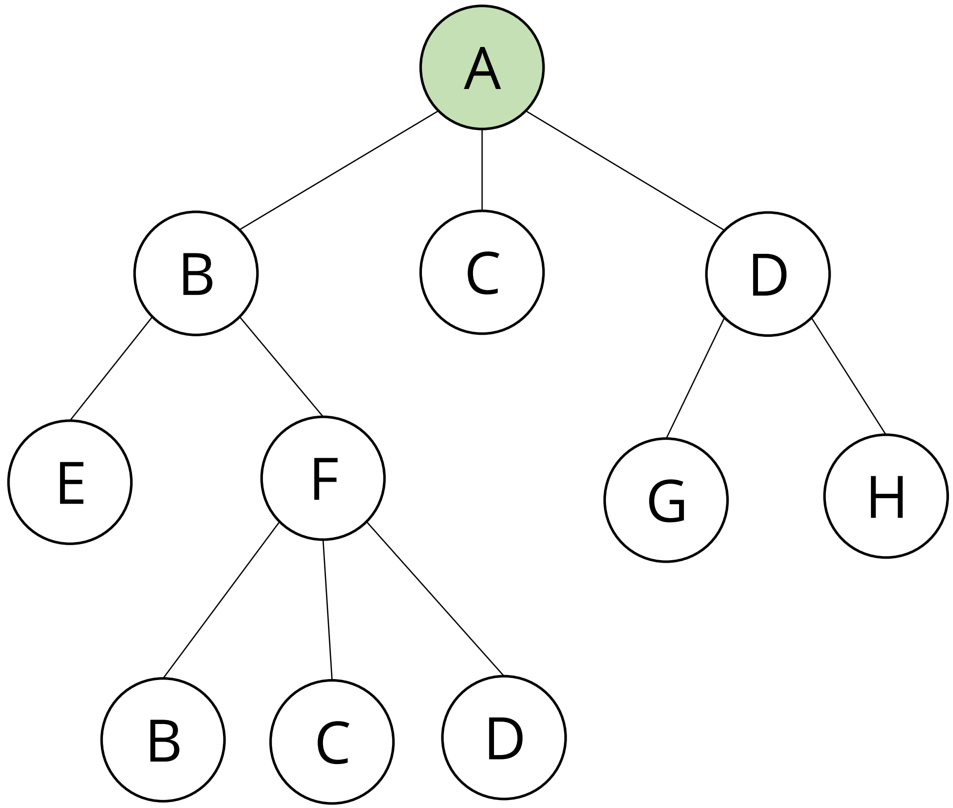
Descendant of a Node

Child, grandchild, grand-grandchild etc



Descendant of a Node

Child, grandchild, grand-grandchild etc



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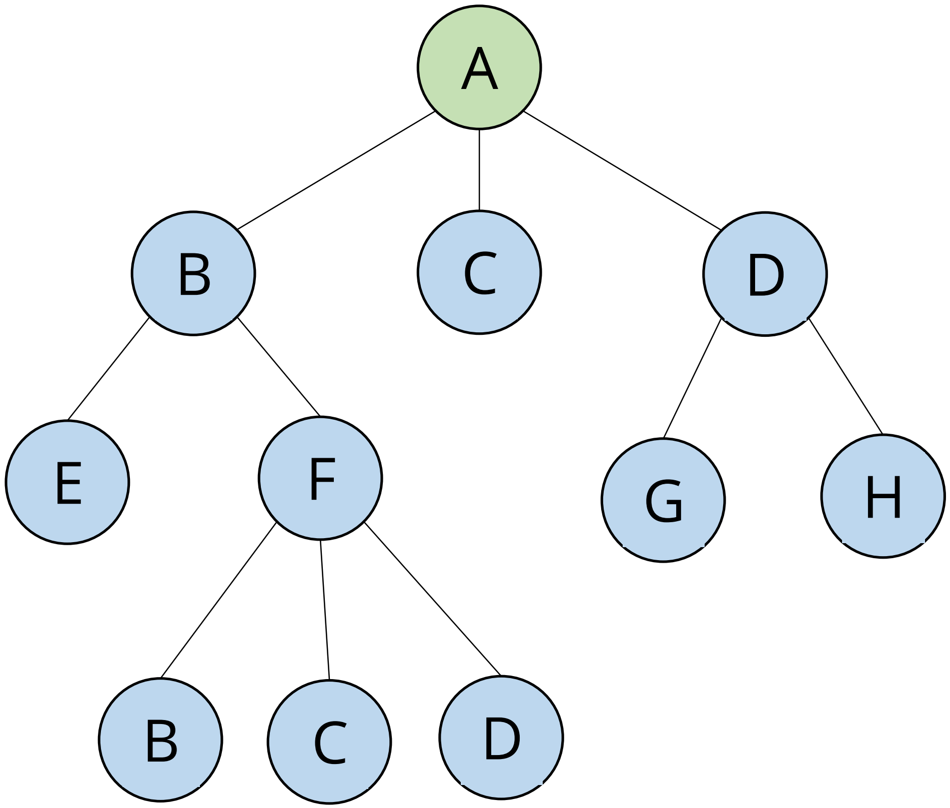
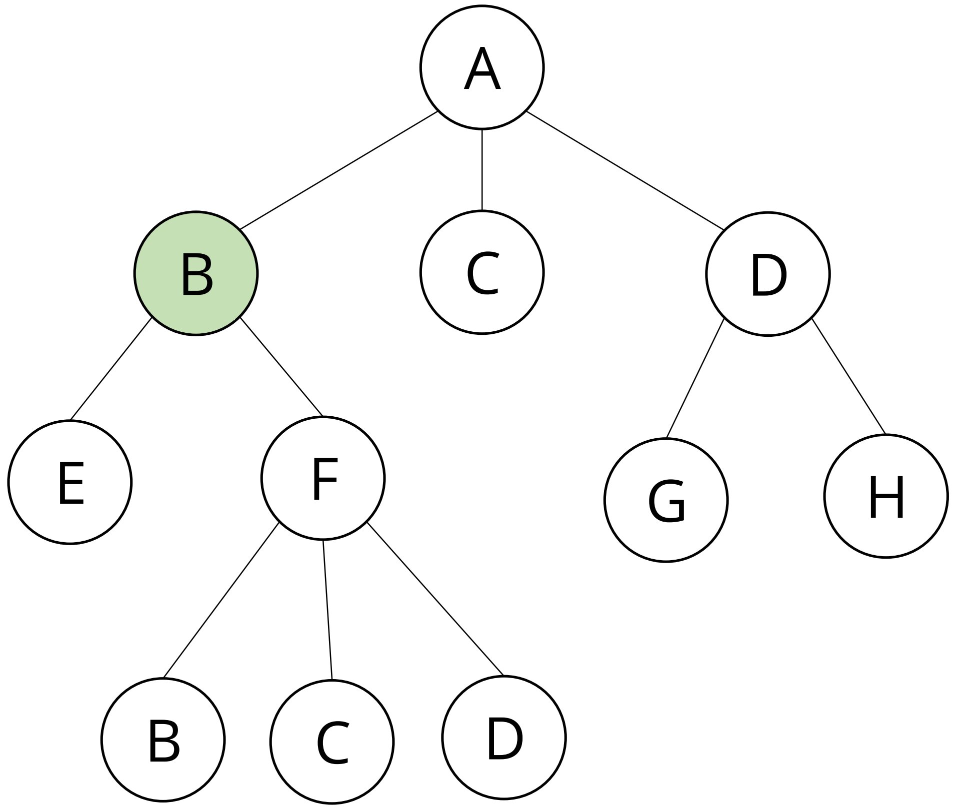


Descendant of a Node

Child, grandchild, grand-grandchild etc



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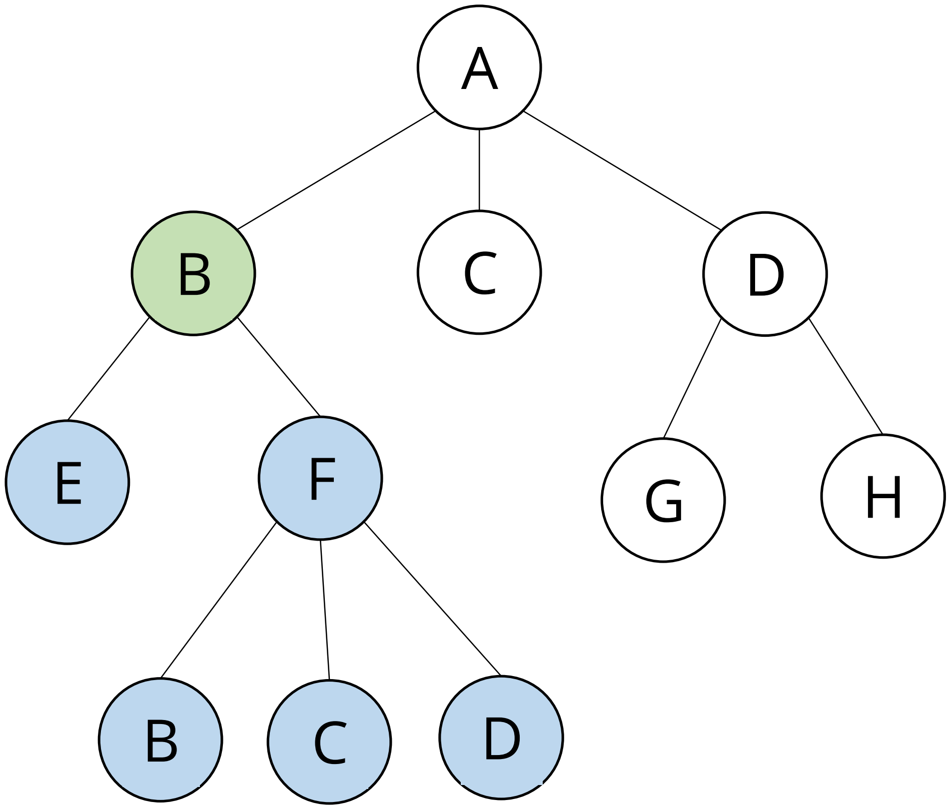

Descendant of a Node

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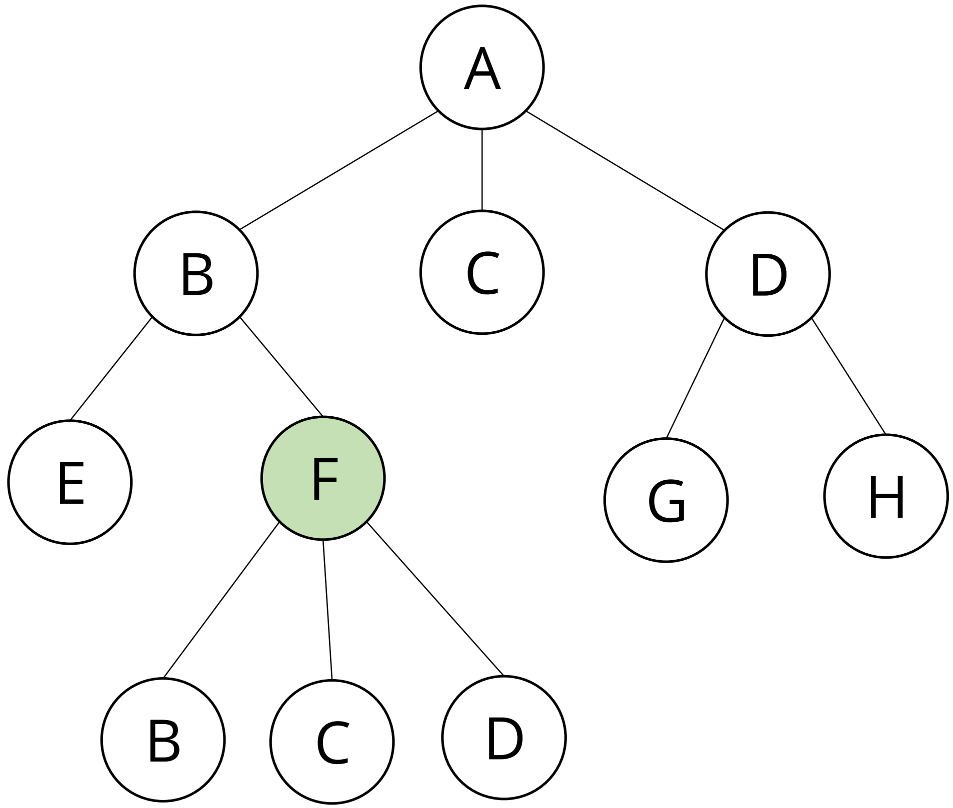

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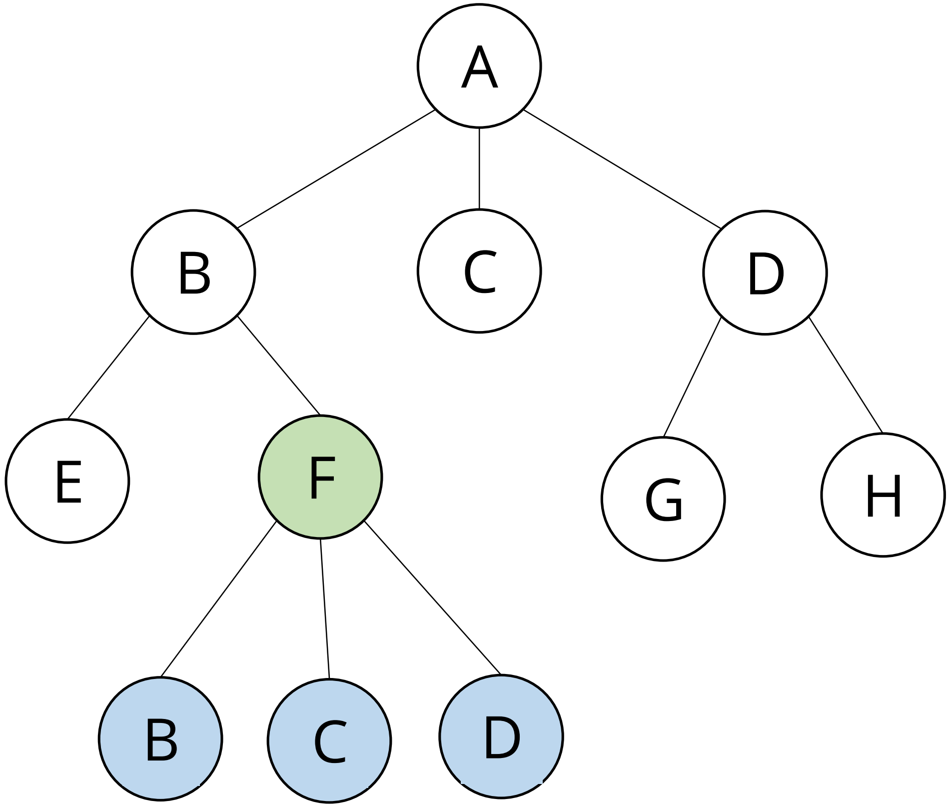
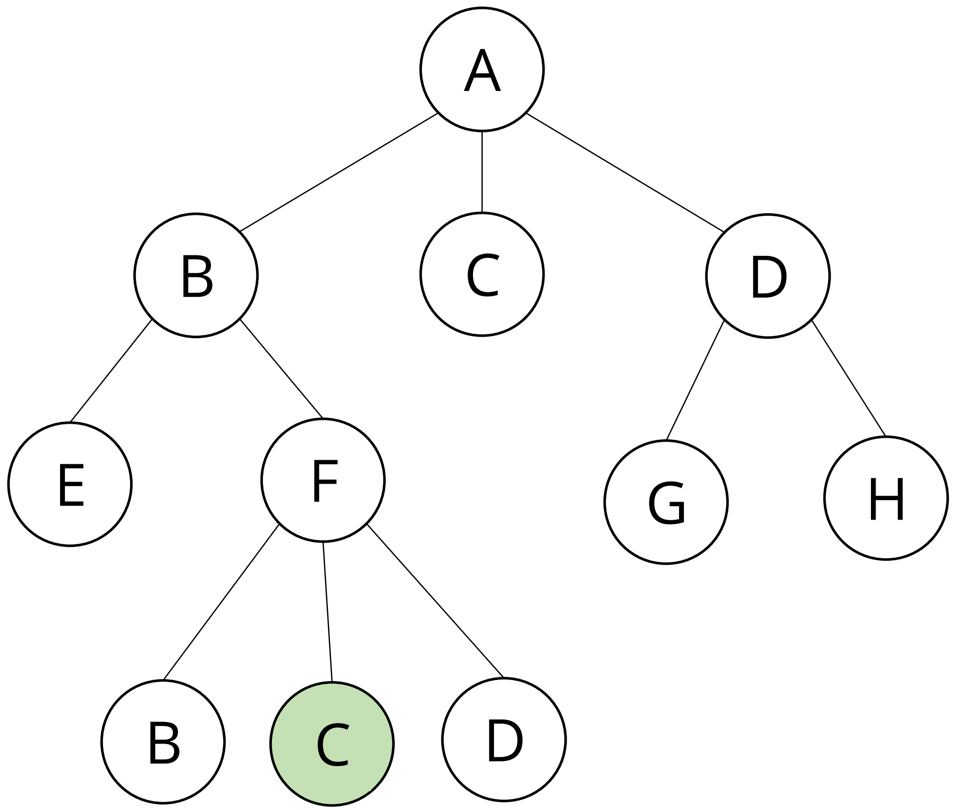


Depth of a node

Number of ancestors excluding the node itself



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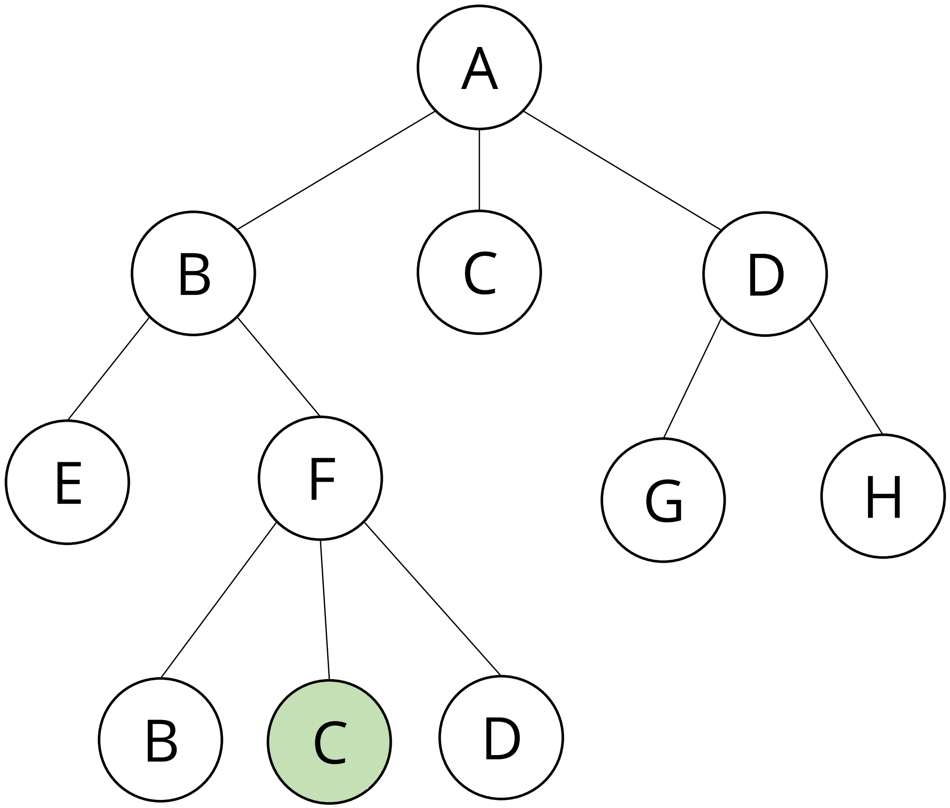
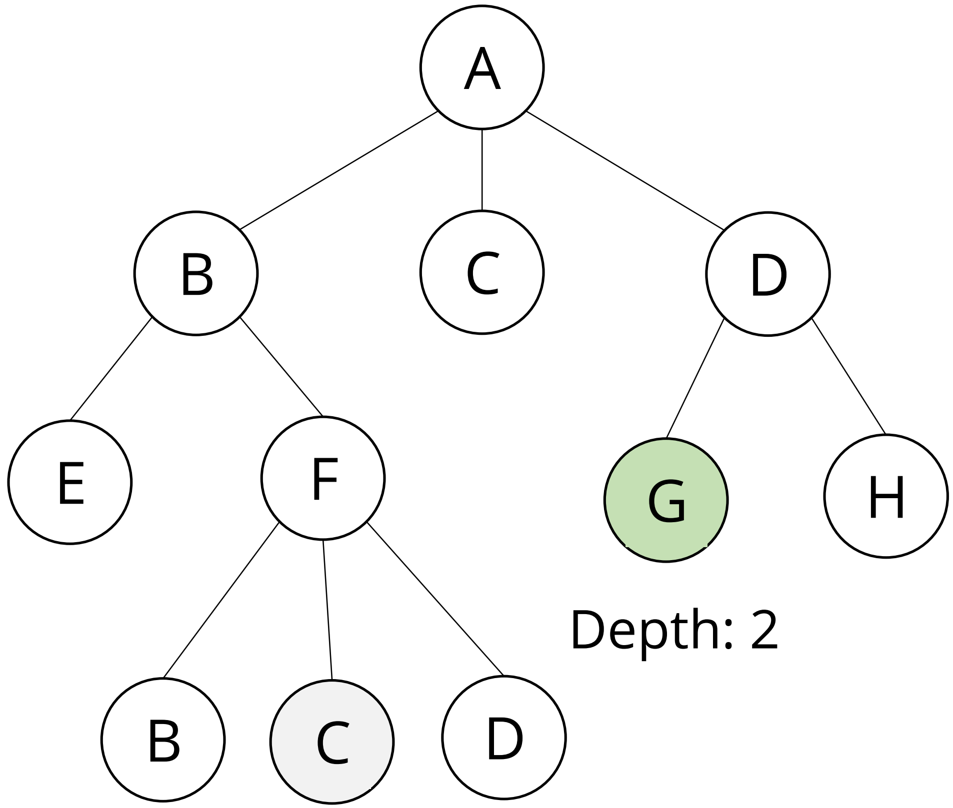


Depth: 3

Depth of a node

Number of ancestors excluding the node itself



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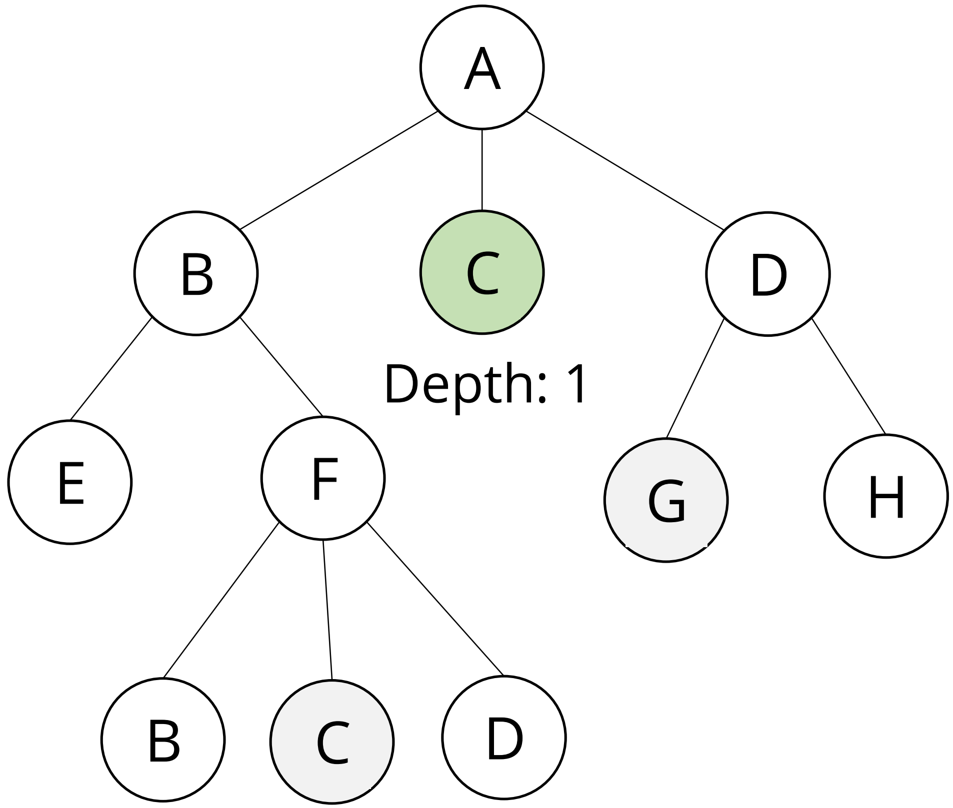
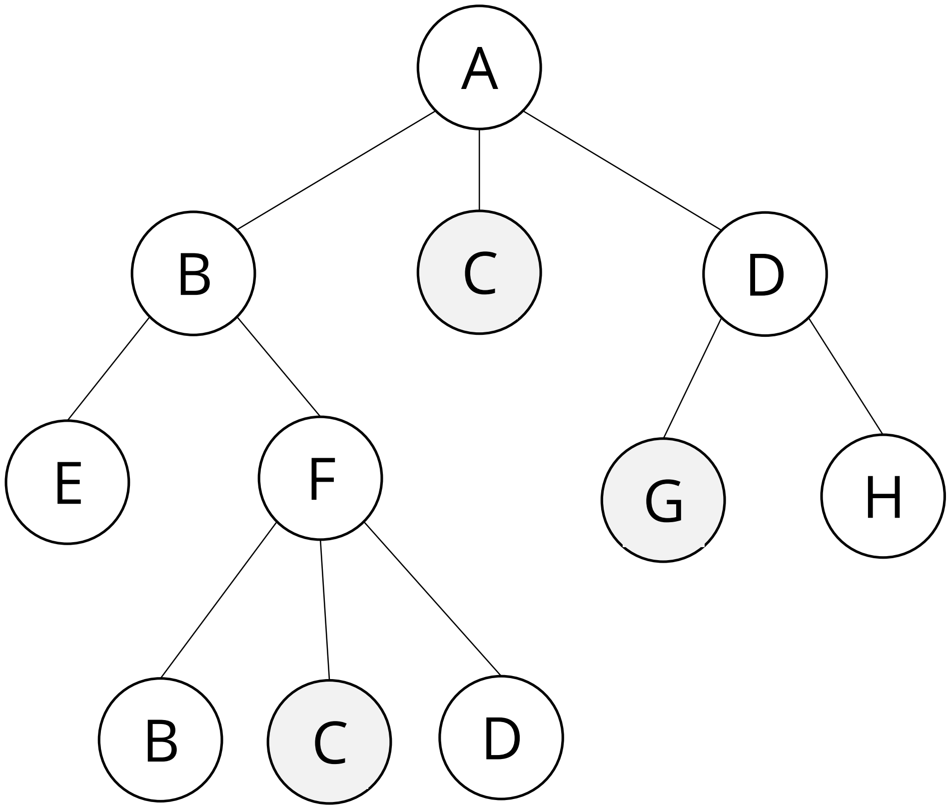


Height of a Tree

Max depth among all the nodes



Height of a Tree

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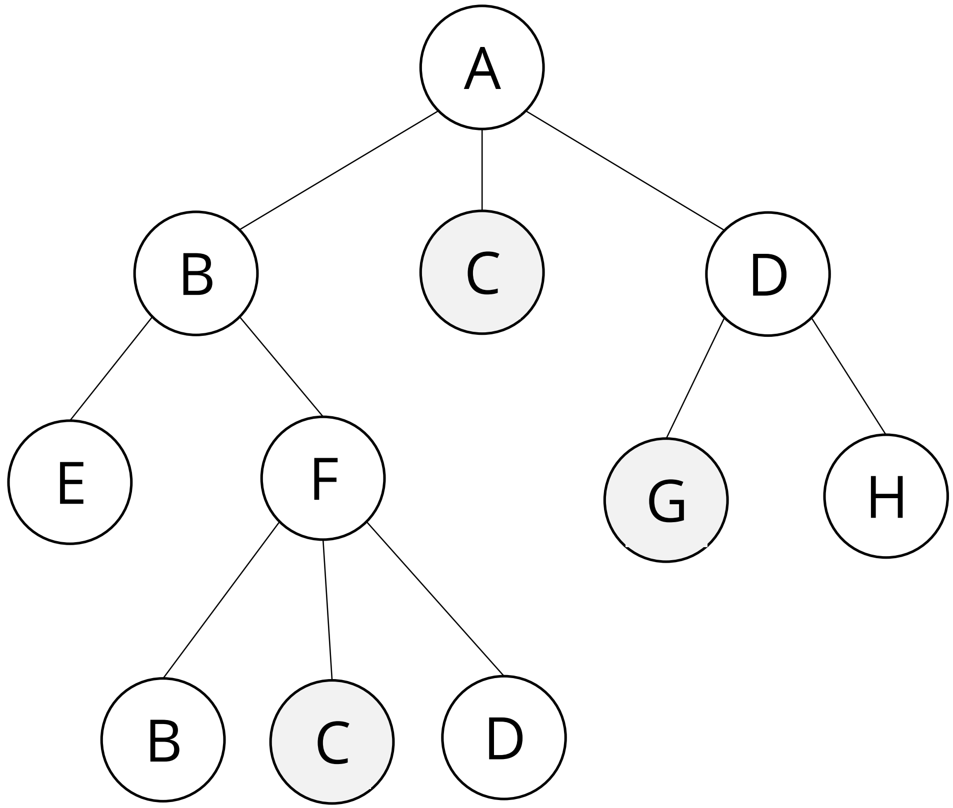
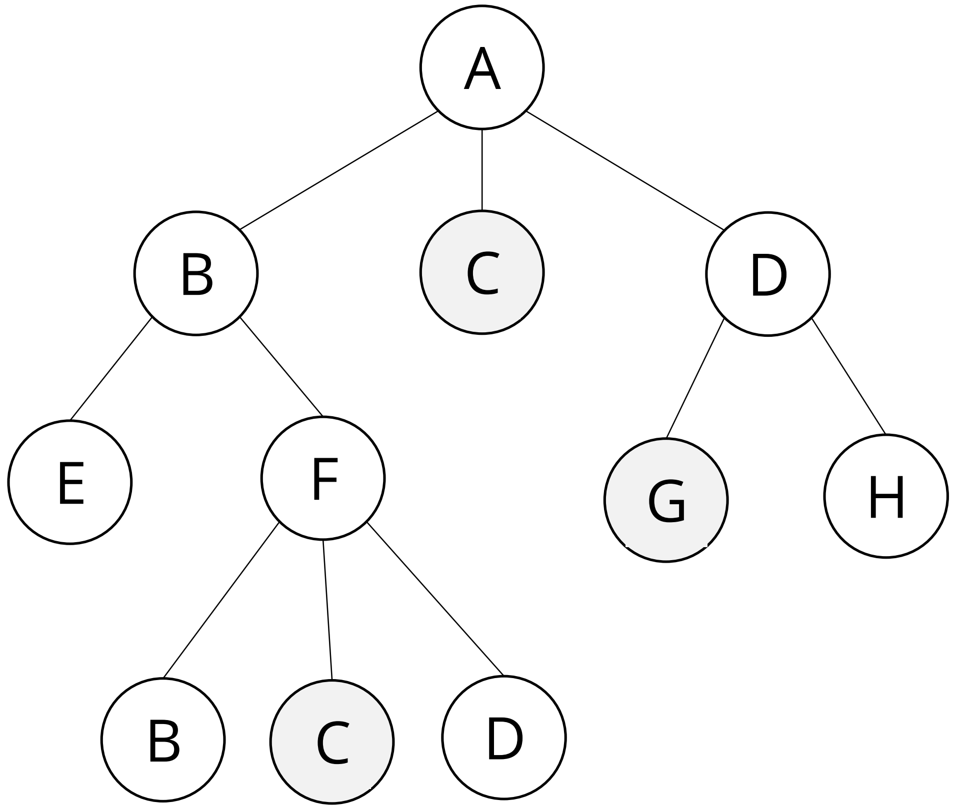


Height : 3

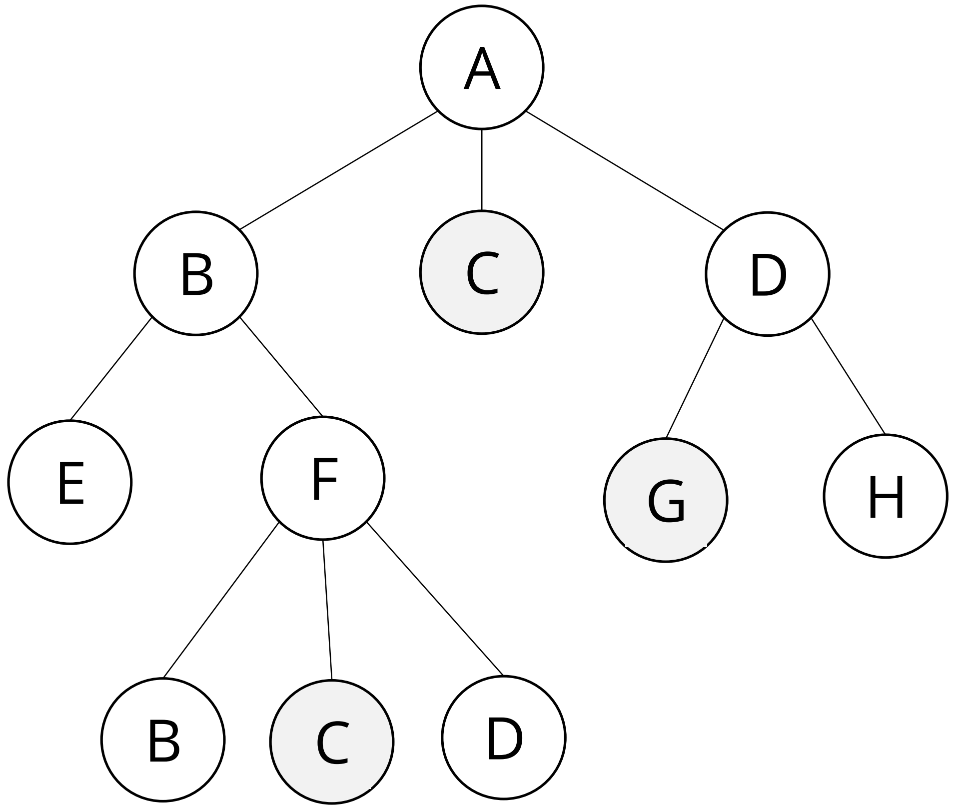
Siblings

Two nodes are siblings if their parents are same



Subtree

Tree consisting of a node and its descendants



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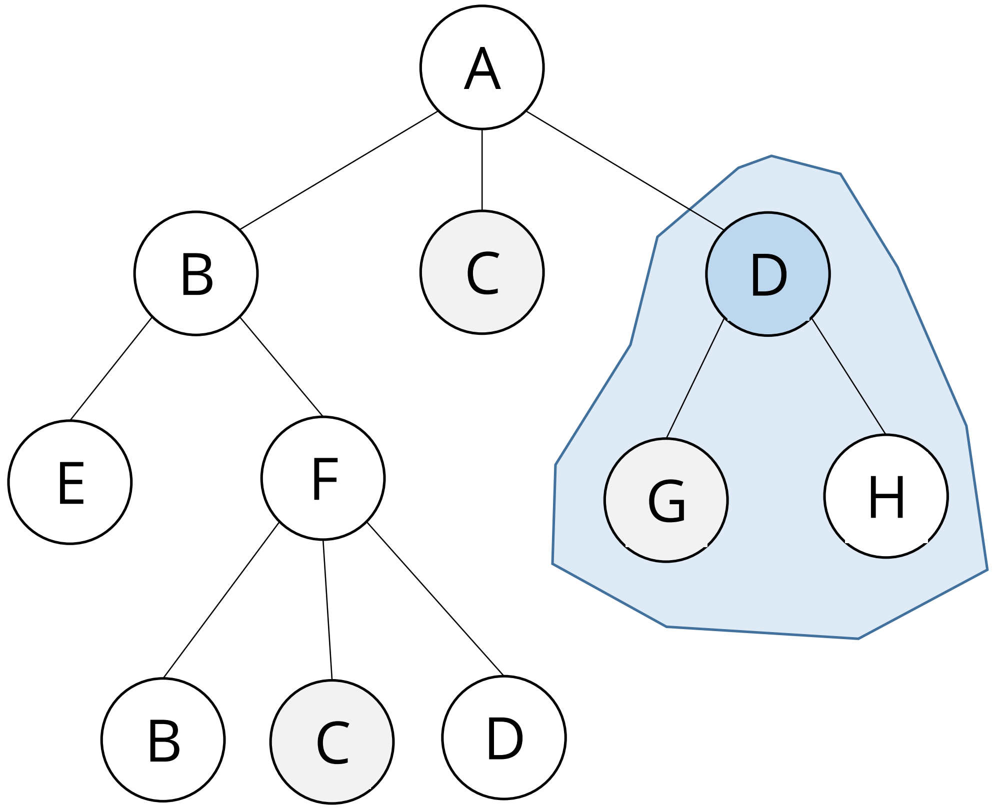

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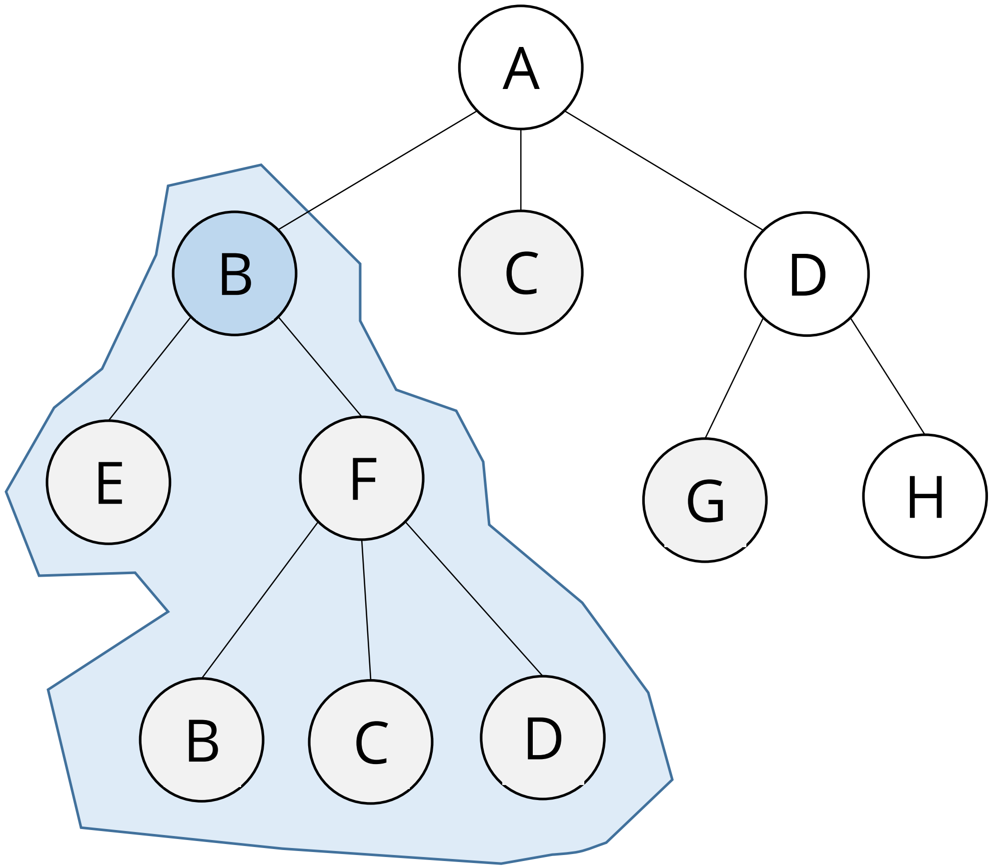
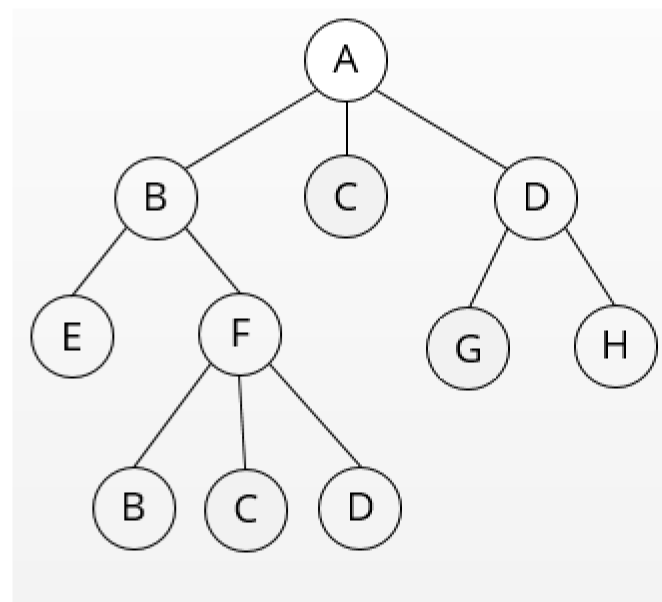


Depth calculation

Can be calculated recursively

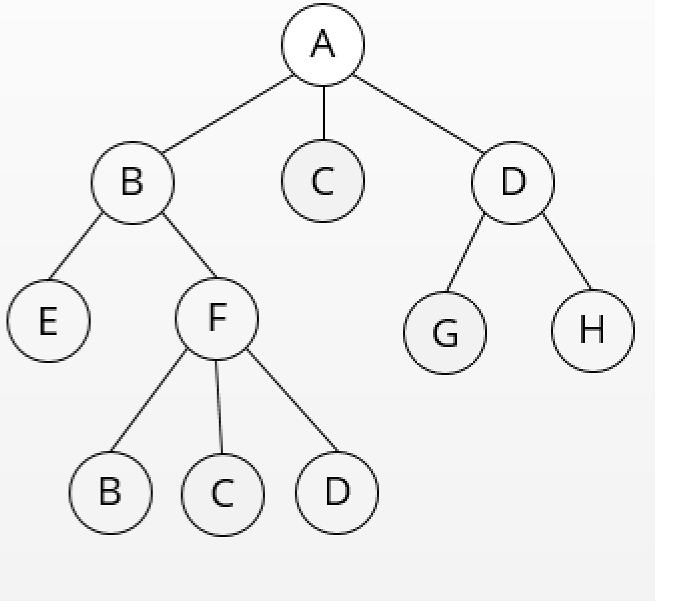
- If v is the root, then the depth is 0
- Otherwise, depth of v is 1 + depth(parent of v)

```
depth(v)
    if (isRoot(v)) then
            return 0
    else
            return 1 + depth(parent(v))
```



Height calculation

Can also be calculated recursively. How?

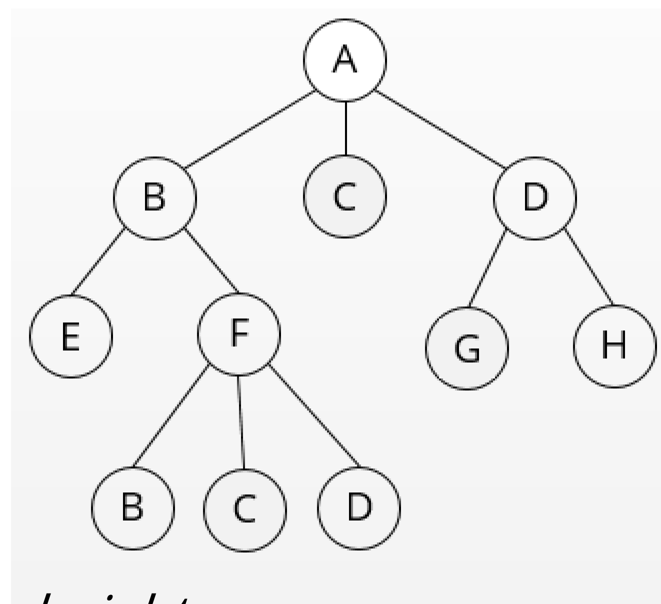


Height calculation

Can also be calculated recursively.

- If v is the leaf, then the height is 0
- Otherwise, depth of v is 1 + max(heights of children of v)

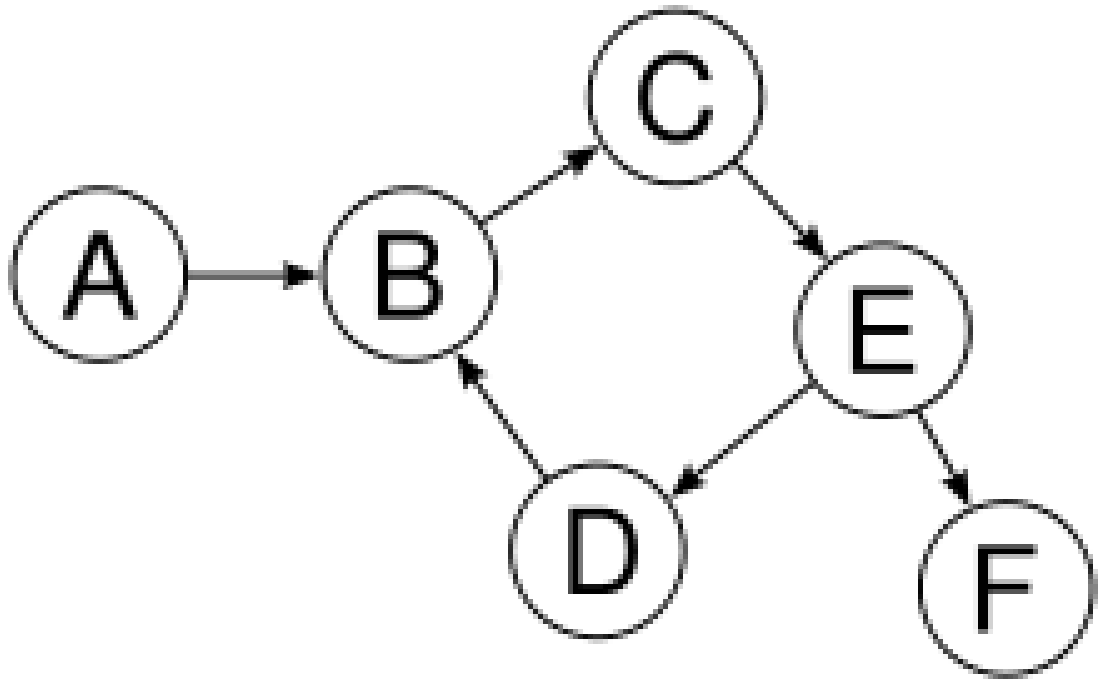
```
int height(int v)
    If (v is leaf node) return 0
    h = 0
    for each child of v as w:
        h = max(h, height(w))
    return 1 + h
```



Note: Max depth among all leaves is the height

Exercise

Is it a tree?



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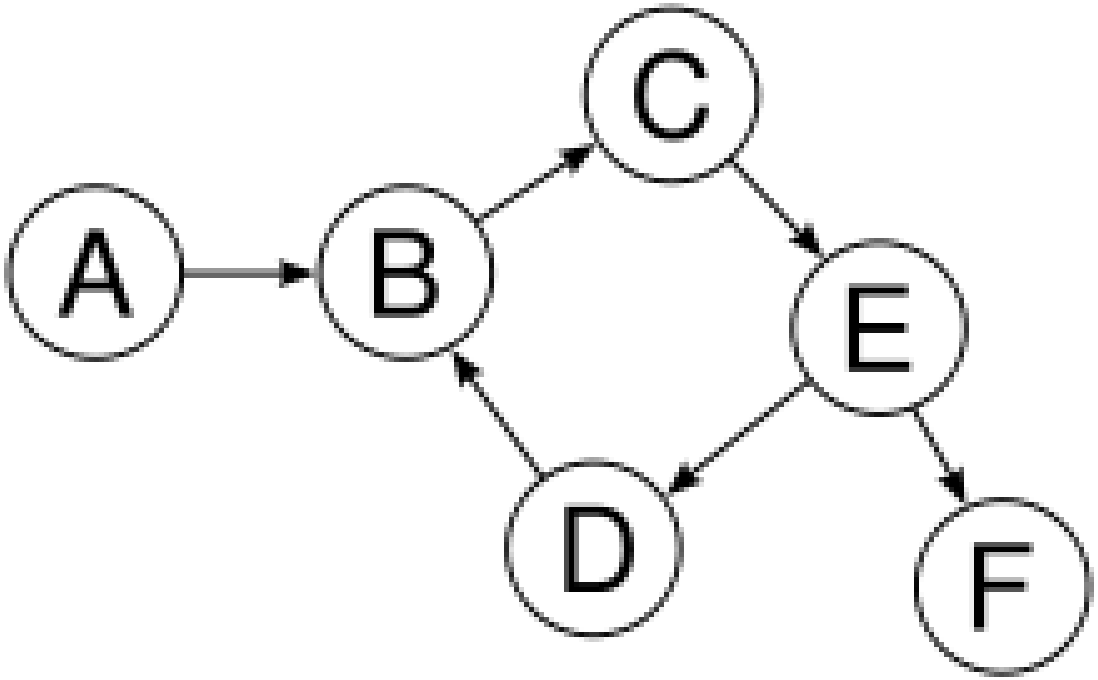

 No, because B has more than one parent

Exercise

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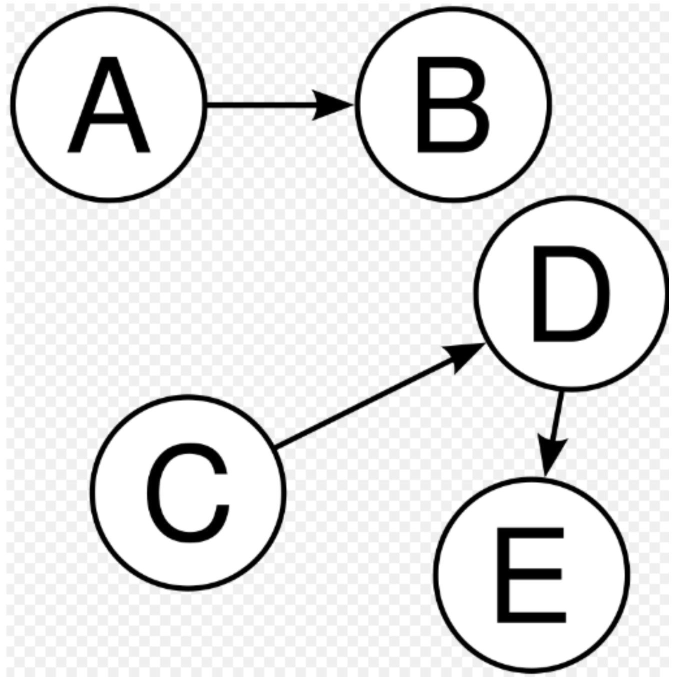

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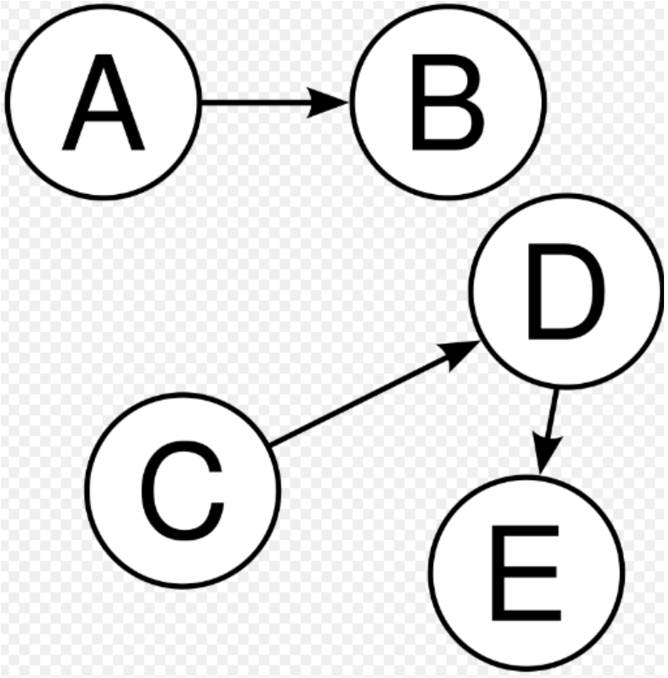

 No, because the tree has more than one root

Exercise

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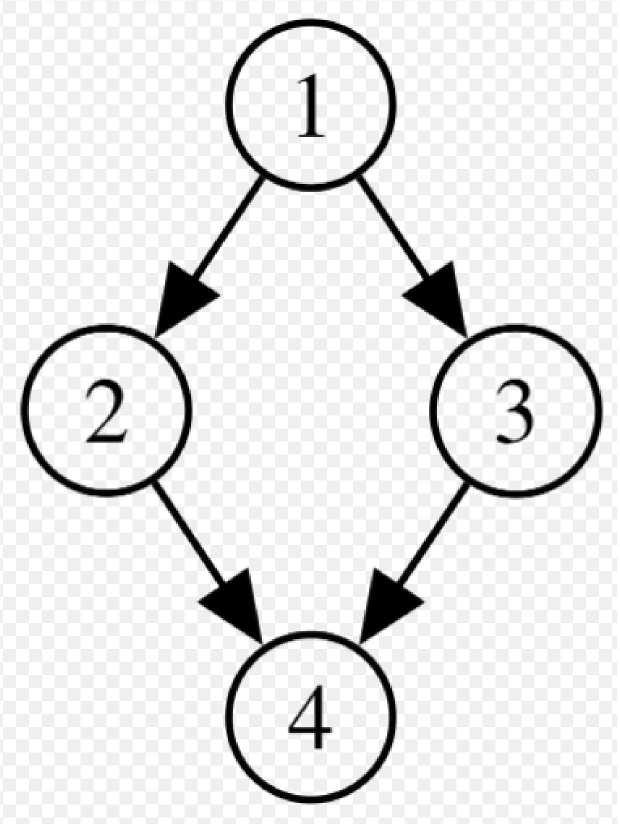

Exercise

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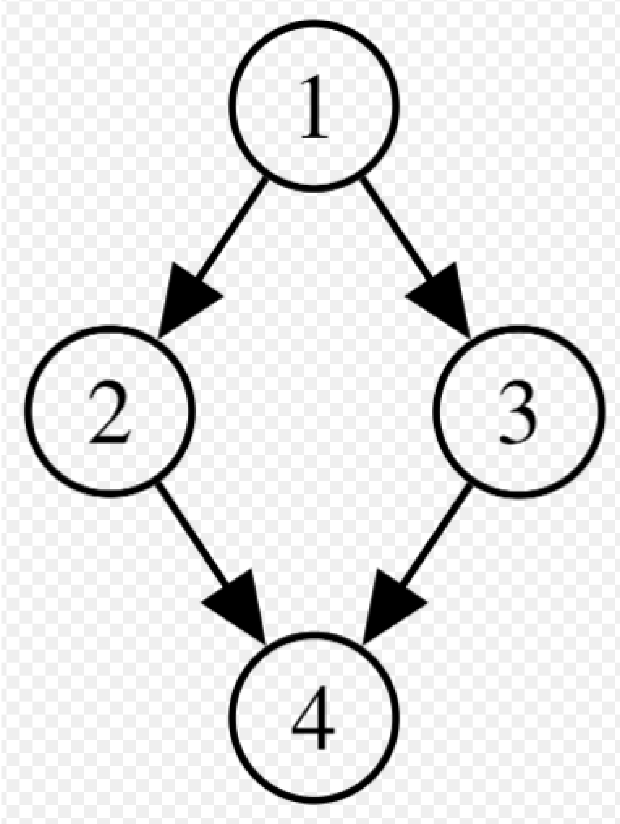
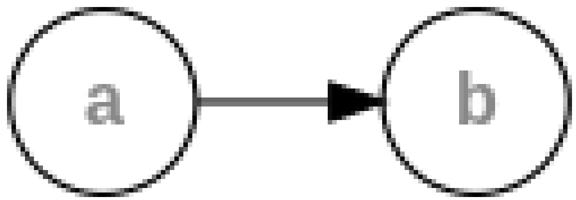


 No, because 4 has more than one parent

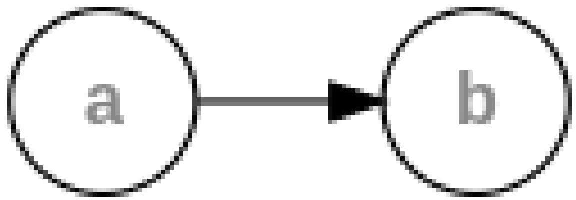
Exercise

Is it a tree?



Exercise

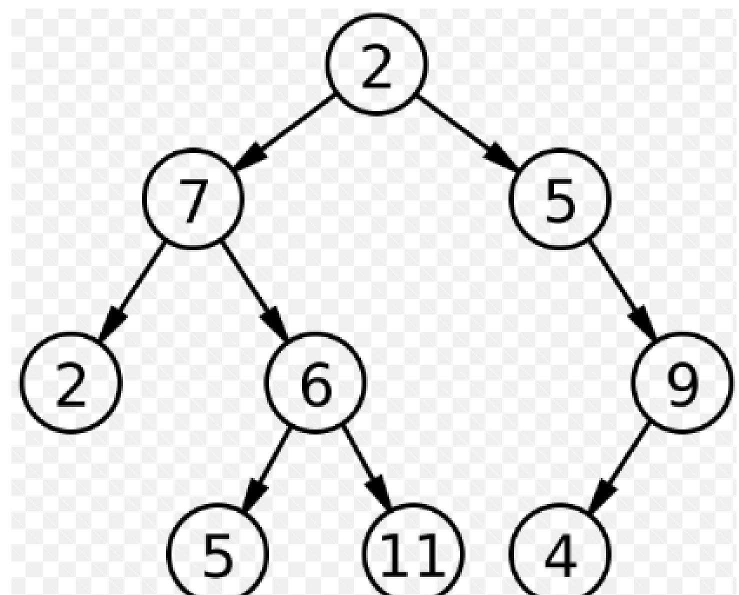
Is it a tree?



Yes. Linked List is trivially a tree

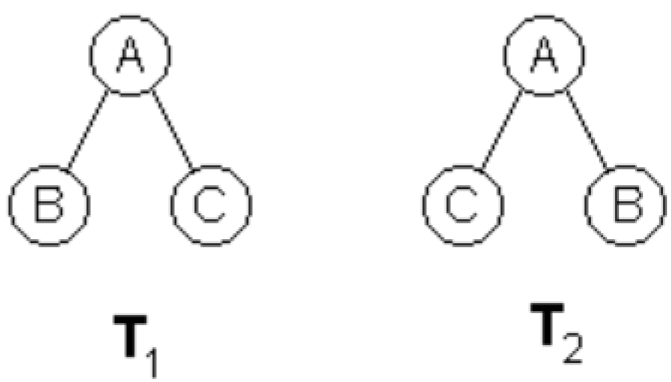
Binary Tree

- A binary tree is composed of zero or more nodes (At most 2)
- Each node contains:
  - A value (some sort of data item)
  - A reference or pointer to a left child (may be null), and
  - A reference or pointer to a right child (may be null)
- A binary tree may be empty (contain no nodes)
- If not empty, a binary tree has a root node
- Every node in the binary tree is reachable from the root node by a unique path
- A node with no left child and no right child is called a leaf
- In some binary trees, only the leaves contain a value



Ordered Tree

- A tree is ordered if there is a linear ordering defined for the children of the nodes
- A binary tree is an ordered tree in which every node has at most two children.
- If each node of a tree has either zero or two children, the tree is called a proper (strictly) binary tree.



If T_1 and T_2 are ordered trees then $T_1 \neq T_2$ else $T_1 = T_2$.

Ordered Tree

- A tree is ordered if there is a linear ordering defined for each child of each node.
- A binary tree is an ordered tree in which every node has at most two children.
- If each node of a tree has either zero or two children, the tree is called a proper (strictly) binary tree.

- The following two binary trees are different-