CS-2001 Data Structures

Binary Trees

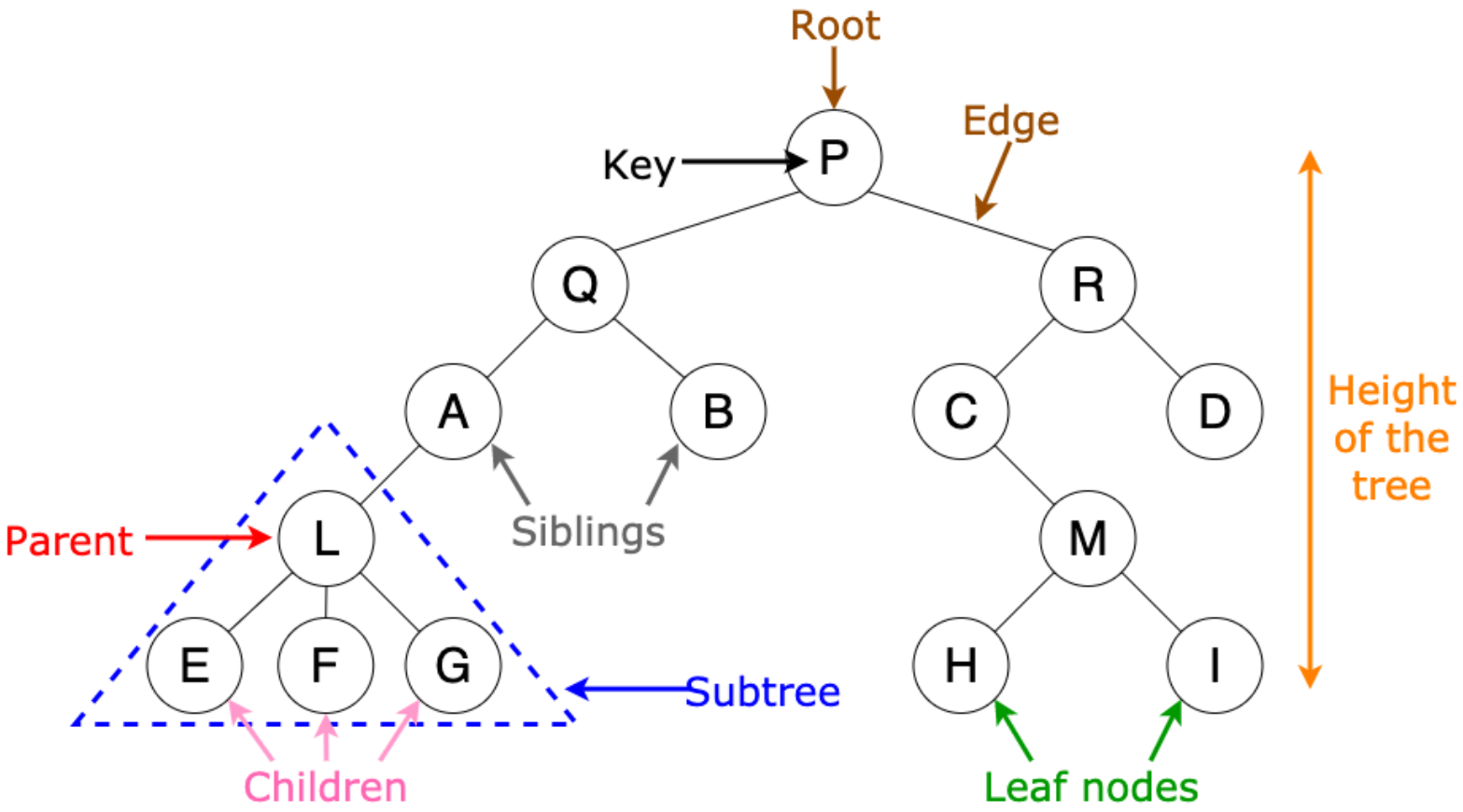
Tree

- A **Tree** is a data structure that is:
  - Non-linear
  - Represents hierarchy
  - Can be seen as a non-linear linked list

- A **Tree** consists of nodes and edges connecting these nodes

- A single node consists of data as well as pointers to its child nodes

Tree Terminologies: Example



Binary Tree

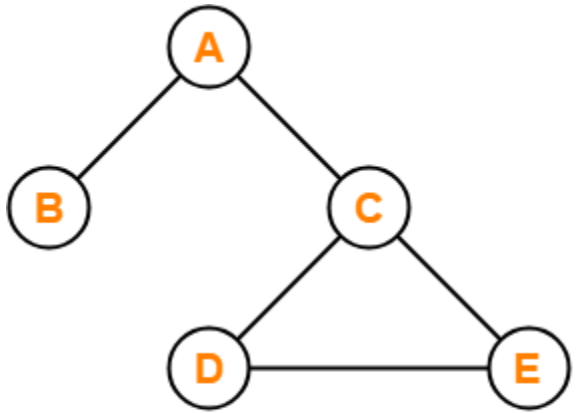
- A **Binary Tree** is a case of Tree data structure in which each node has either **0**, **1** **or** **2** children (i.e. each node can have **at most** 2 child nodes)

- A **Binary Tree** has many different applications including searching, partitioning and sorting algorithms

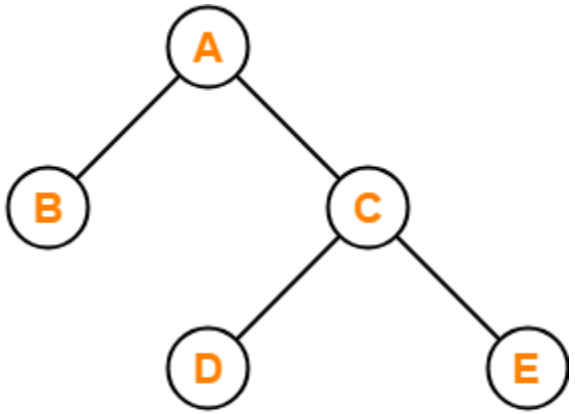
- A Tree that has an arbitrary no. of children is called an ***m*-ary Tree** (for ***m*** arbitrary nodes). If the value of ***m*** is **2** then it is simply a **Binary Tree**

Difference between Graph and Tree

- A **Tree** is a special case of **Graph** in which there are **no loops**

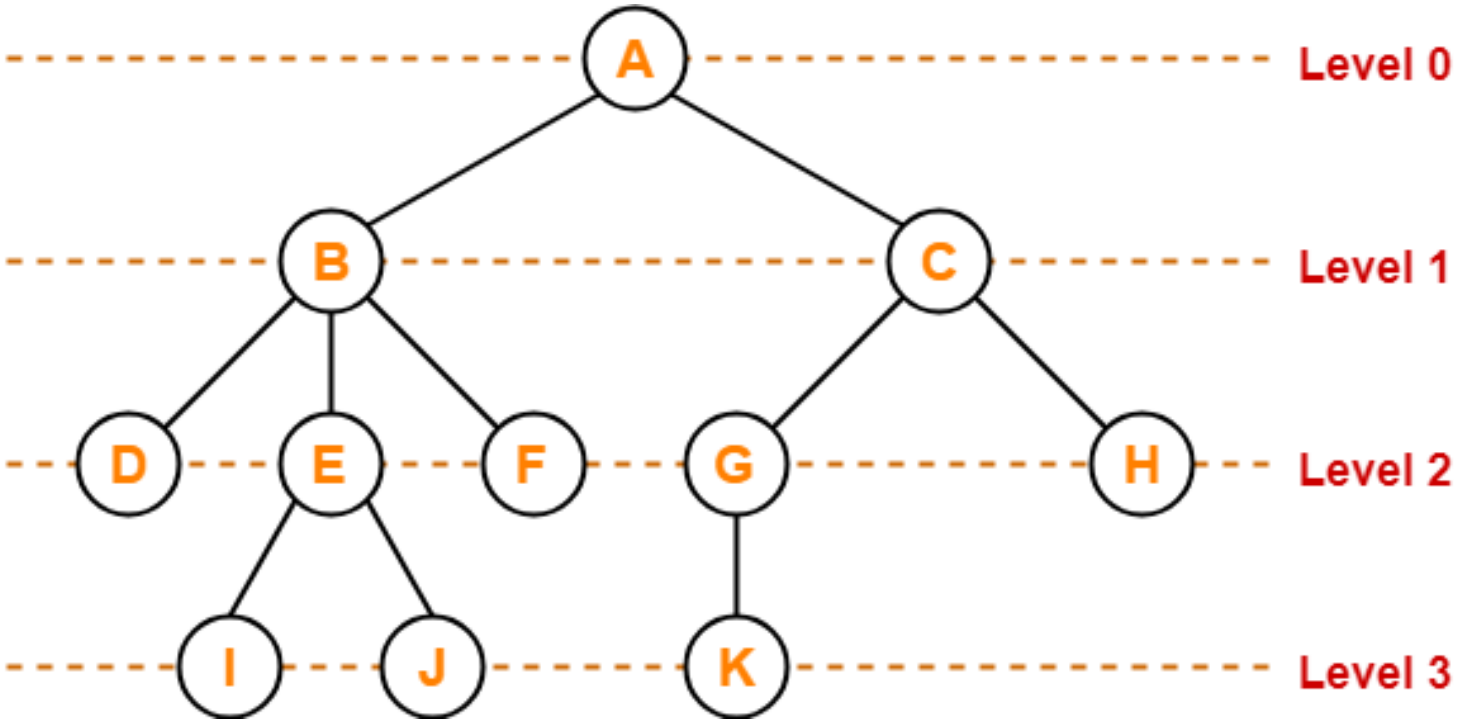


This graph is not a Tree



This graph is a Tree

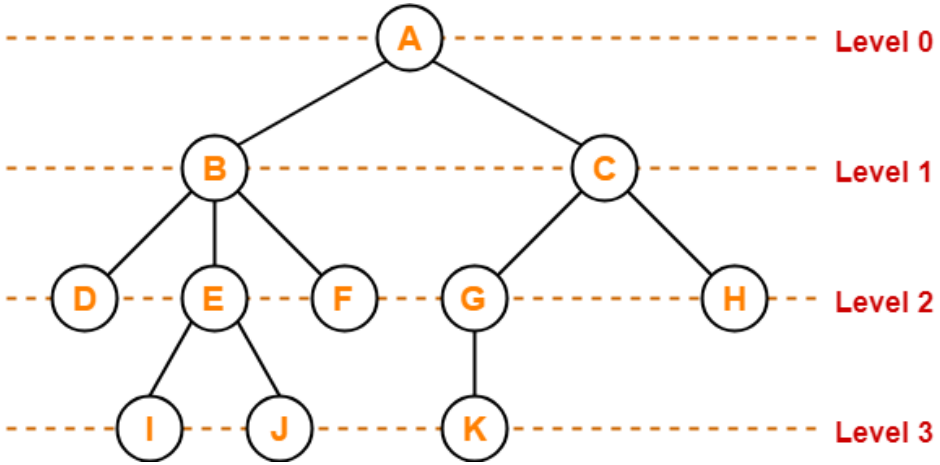
Levels in Binary Tree: Example



Height of a Binary Tree

- Height of a Binary Tree is no. of edges from its root to any leaf node at the lowest level in the tree

- For example, height of the following Binary Tree is **3**

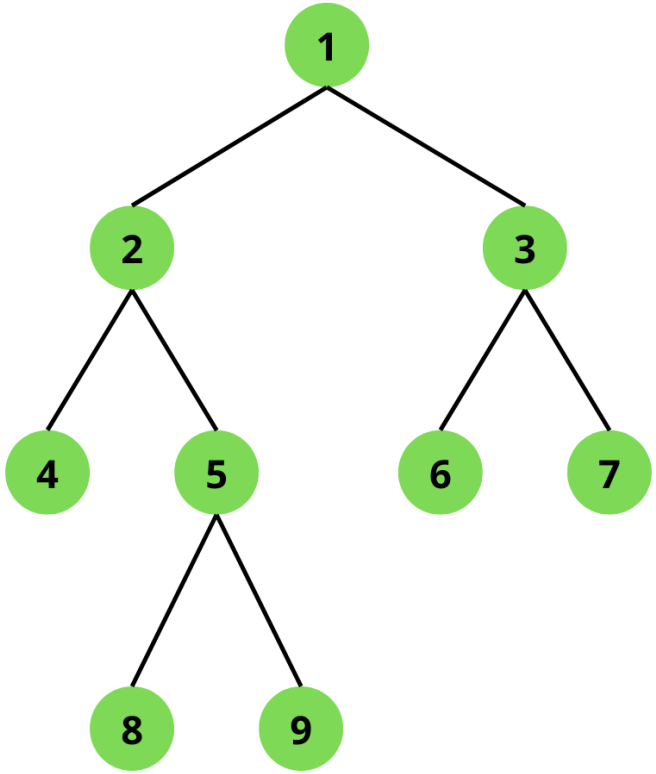


Types of Binary Tree

- Based on the physical structure of the Binary Tree, it can be classified into the following types:
  - **Strict Binary Tree**
  - **Full Binary Tree** *(also called Perfect Binary Tree)*
  - **Complete Binary Tree**
  - **Skewed Binary Tree**
  - **Degenerate Binary Tree**

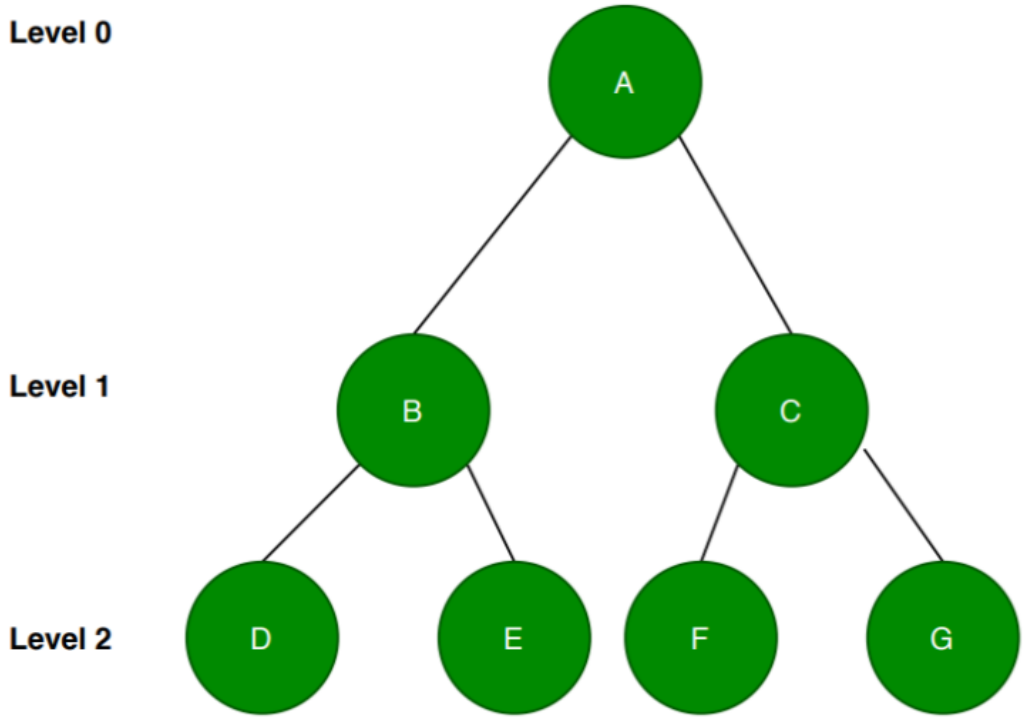
Strict Binary Tree

- A strict Binary Tree is one in which each node has **exactly 0 or 2 children**



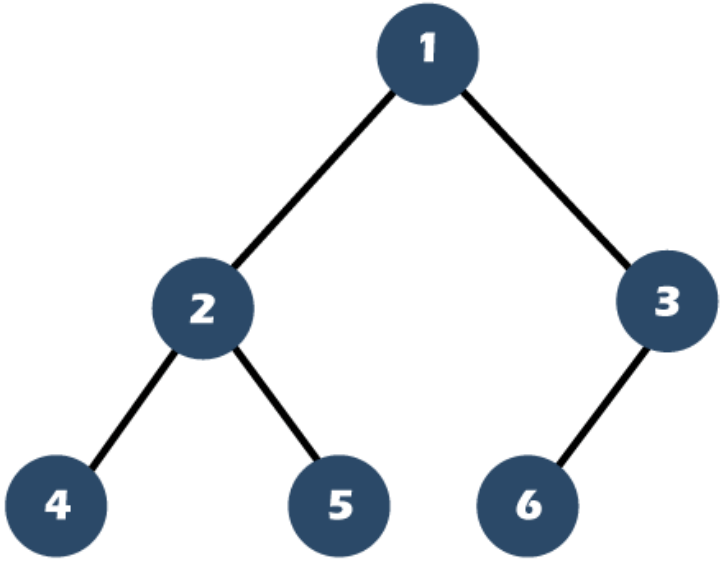
Full Binary Tree

- A full Binary Tree is one with the following properties:
  - It is a Strict Binary Tree
  - All leaf nodes are at the same level



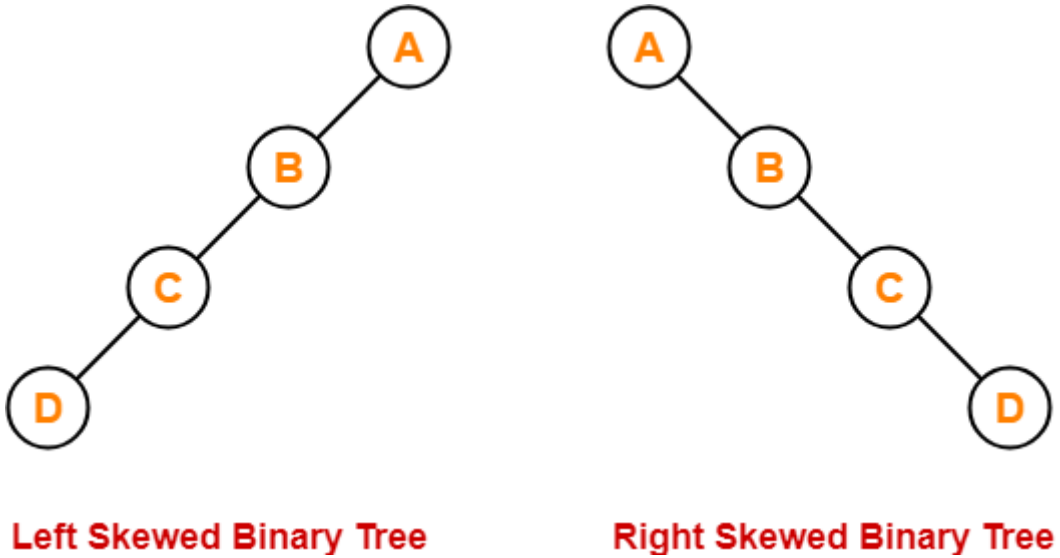
Complete Binary Tree

- A Complete Binary Tree is one with the following properties:
  - It is a Full Binary Tree up until second last level
  - At the last level the nodes are inserted from left to right
  - There are no missing links (holes) at the last level



Skewed Binary Tree

- A Skewed Binary Tree is one in which root has almost all of its nodes in one of the subtrees

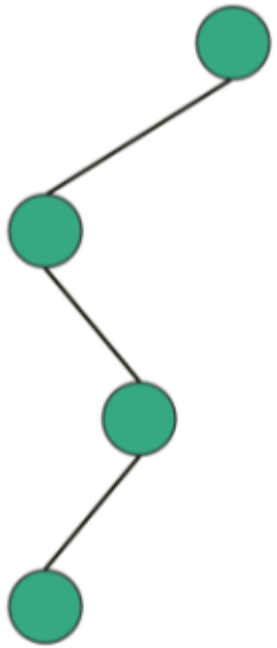


Left Skewed Binary Tree

Right Skewed Binary Tree

Degenerate Binary Tree

- A Degenerate Binary Tree is one which is left or right heavy but not perfectly skewed



Properties of Binary Tree

- **Min no. of nodes** — $H+1$
- **Max no. of nodes** — $2^{H+1} - 1$
- **Total no. of leaf nodes** — Total nodes with 2 children + 1
- **Max no. of nodes at a given level** — 2^{L}
- **Min height of a Binary Tree** — $\log_2 (N+1) - 1$

where N = no. of nodes, L = level, H = height