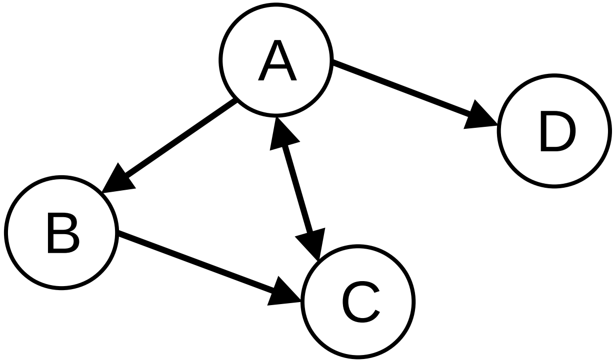
C03 Graph Traversal

Graphs and Trees
Traversal

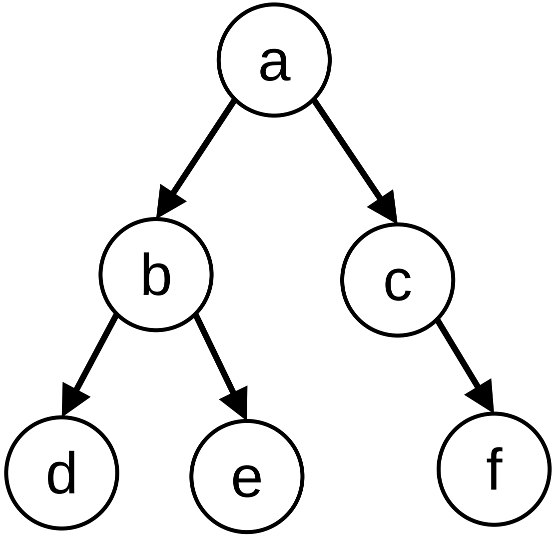
ANU – School of Computing – Structured Programming 1110 / 1140 / 6710

Graphs and Trees

- A powerful abstraction in computing.



Directed **Graph**



Directed Rooted **Tree**

(*connected directed* acyclic graph)

With ordering of children: *Ordered* Tree

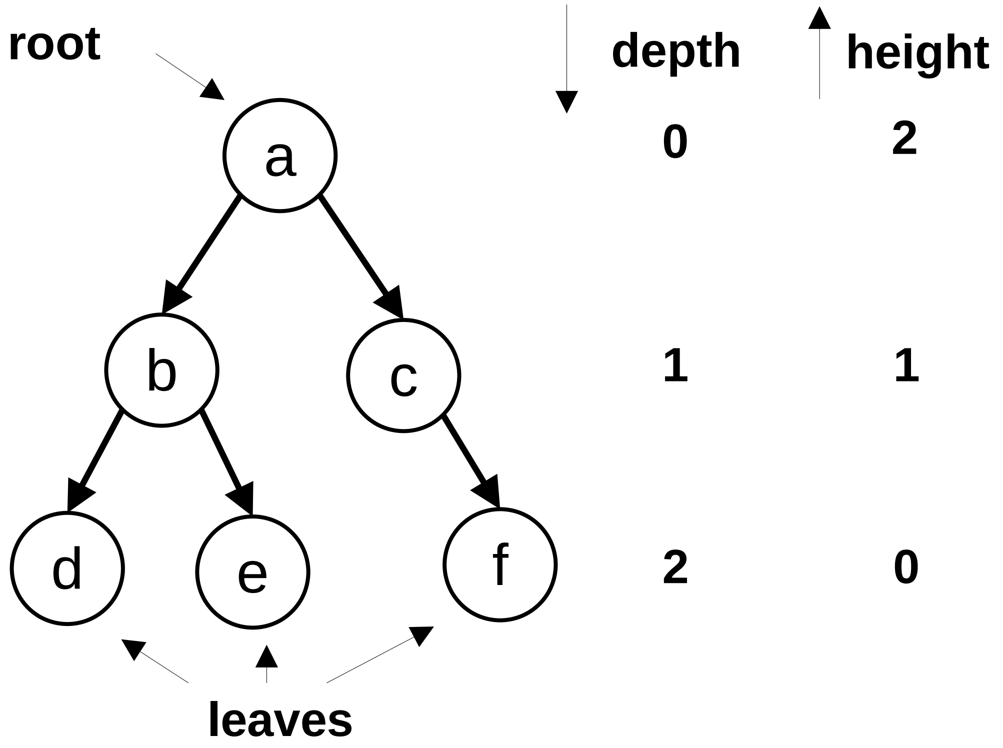
Nodes: A B C D
Edges: (A, B) (B, C) (A, C) (C, A) (A, D)

Tree Features

b is the **parent** of d and e

d is a **child** of b

b has a **branching factor** (outdegree) of 2 (the number of children)



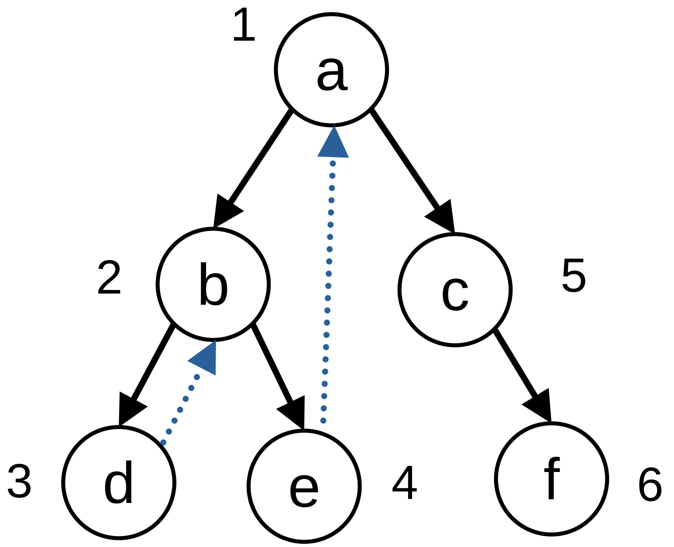
Traversal

- Visiting the elements in a data structure:
  - searching
  - modifying
  - reachability
  - path finding
- Lists / arrays are a form of “linear data structure” that has a natural sequence for traversal.
- Trees and Graphs can be traversed in many ways.

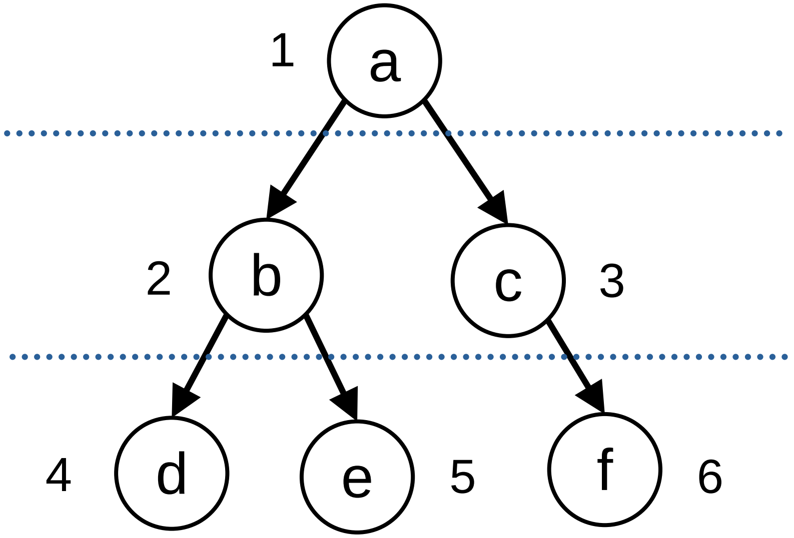
Tree Traversal

- Special case of graph traversal.
- Two common forms:
  - **Depth-First Search (DFS)**
    - Explore as deep as possible along a branch until a leaf is reached.
    - *Backtrack* to another branch (e.g., *sibling* of leaf, or sibling of parent, or …).
  - **Breadth-First Search (BFS)**
    - Starting at root, visit all nodes at given depth before going deeper.

DFS and BFS



Pre-order DFS traversal
a b d e c f



BFS traversal
a b c d e f

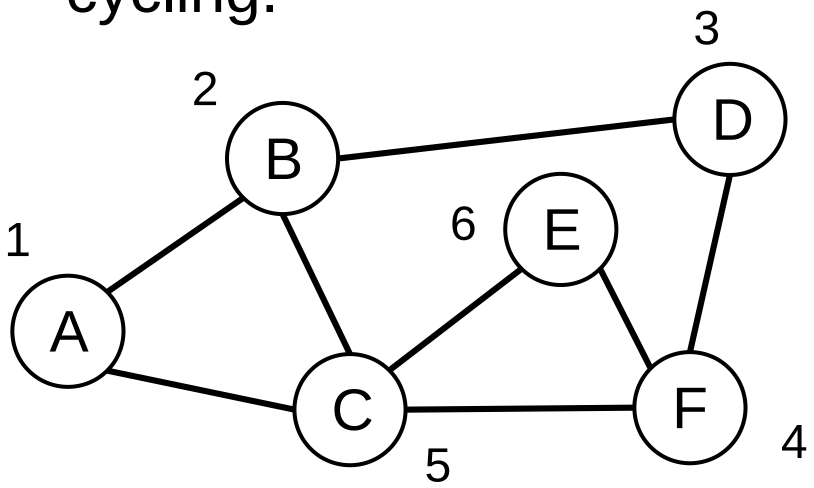
Implementing Tree Traversal

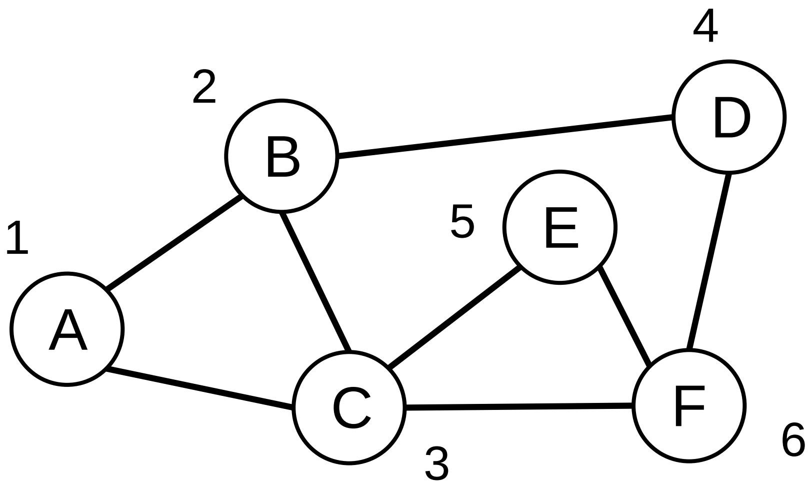
- **Depth-First Search (DFS)**
  - Iteratively using a **Stack**: Last-In First-Out (LIFO) data structure
  - Recursively by implicitly using the *call stack*
  - Variations on ordering: post-order, pre-order, in-order
- **Breadth-First Search (BFS)**
  - Iteratively using a **Queue**: First-In First-Out (FIFO) data structure
  - *Corecursively** by passing all sub-trees of same level
  - Only one ordering

* Building (generating) data from a simple “base case”, rather than breaking down (reducing) data until base case reached.

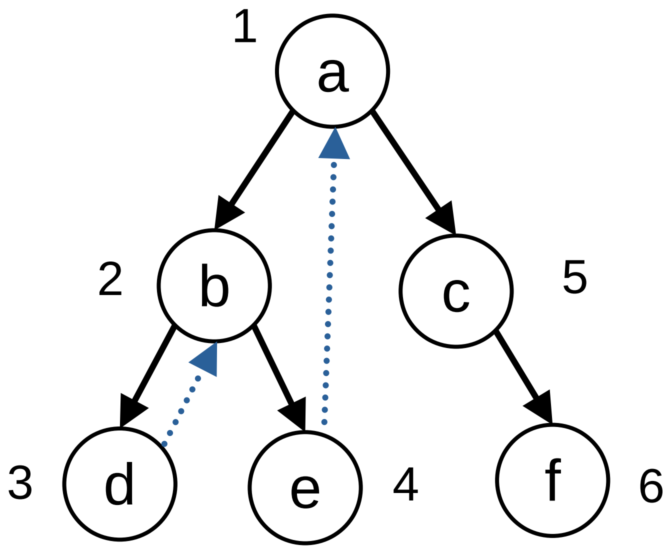
Graph Traversal

- DFS and BFS generalise from tree traversal.
- Starting node selected based on problem.
- Additionally need to **keep track of "visited"** nodes to avoid cycling.





Implementation DFS: Stack



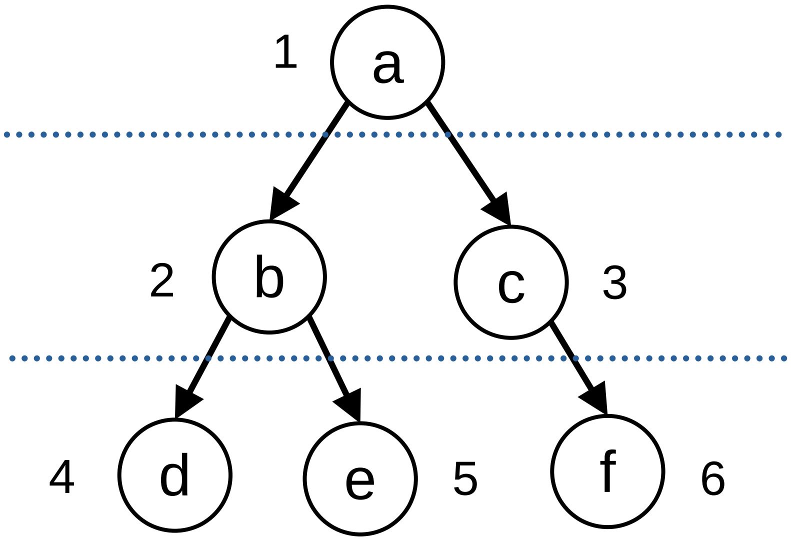
Pre-order DFS traversal
a b d e c f

Stack [ ]: ***push*** onto end, ***pop*** off end

DFS: pop node, push it's children, repeat.

```
0 push a:   [a]
1 pop:      []       a
  push c:   [c]
  push b:   [c b]
2 pop:      [c]      b
  push e:   [c e]
  push d:   [c e d]
3 pop:      [c e]    d
4 pop:      [c]      e
5 pop:      []       c
  push f:   [f]
6 pop:      []       f
```

Implementation BFS: Queue



BFS traversal
a b c d e f

Queue { }: *enqueue* onto back, *dequeue* off front

BFS: dequeue node, enqueue it's children, repeat.

```
0 enq a:    {a}
1 deq:      {}       a
  enq b:    {b}
  enq c:    {b c}
2 deq:      {c}      b
  enq d:    {c d}
  enq e:    {c d e}
3 deq:      {d e}    c
  enq f:    {d e f}
4 deq:      {e f}    d
5 deq:      {f}      e
6 deq:      {}       f
```

Example: Distance Between Nodes

- The *distance* between A and E is the number of edges on a *shortest path* between the two nodes.
- **BFS** can naturally track the distance.
- **DFS** might visit E via a non-shortest *path* – need to revisit nodes