COMP20003
Algorithms and Data Structures
Traversing Trees and Graphs

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Traversal

- Traverse: to pass or move over, along, or through.
- Tree traversal: the process of visiting (examining or updating) each node exactly once, in a systematic way.
- Graph traversal: the process of visiting all the nodes in a graph.
- Tree traversal is a special case of graph traversal.

Traversal

Graph traversal *vs.* Tree traversal

- Graph traversal: complications due to:
  - Possible cycles.
  - Not necessarily connected.

Starting with trees: bst dfs traversal depth-first search

- Depth-first tree search can be done as:
  - In-order
  - Pre-order
  - Post-order

Recursive in-order search: binary tree

```
void
inorder(node_t   *t)
{
    if(t==NULL) return();
    inorder(t->left);
    visit(t);   /* e.g. print value */
    inorder(t->right);
}
```

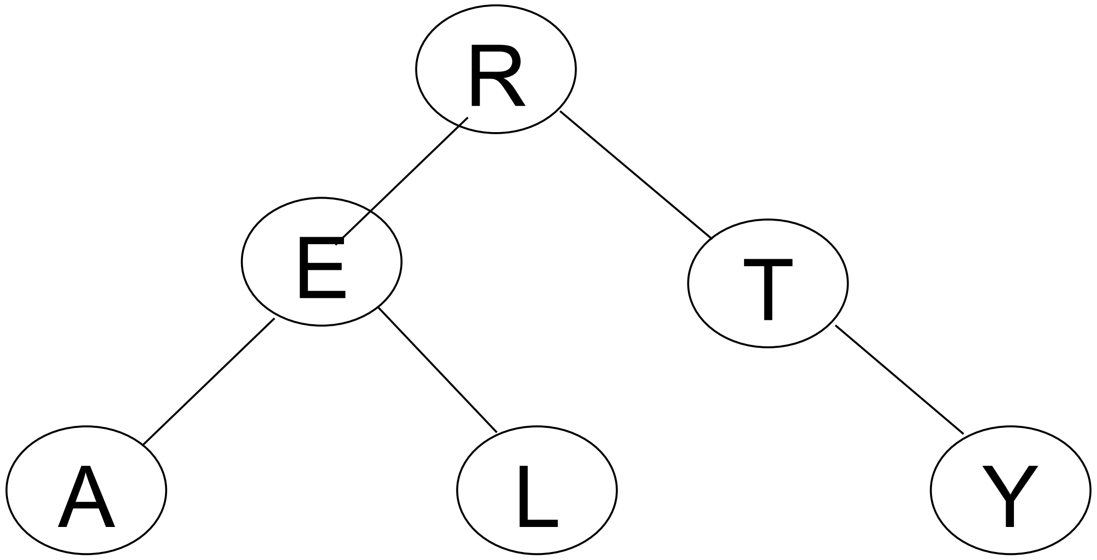
Recursive pre-order search: binary tree

```
void
preorder(node_t   *t)
{
    if(t==NULL) return();
    visit(t);   /* visit first */
    preorder(t->left);
    preorder(t->right);
}
```

Non-recursive pre-order search: DFS - explicit stack

```
void
preorder(stack_t  *st,node_t   *t)
{
    push(st,t);
    while(!stackempty(st))
    {
      t= pop(st); visit(t);
      if(t->r != NULL) push(st,t->r);
      if(t->l != NULL) push(st,t->l);
    }
}
/* note: stack contains pointers into the tree */
```

Depth-first search *vs.* breadth-first search



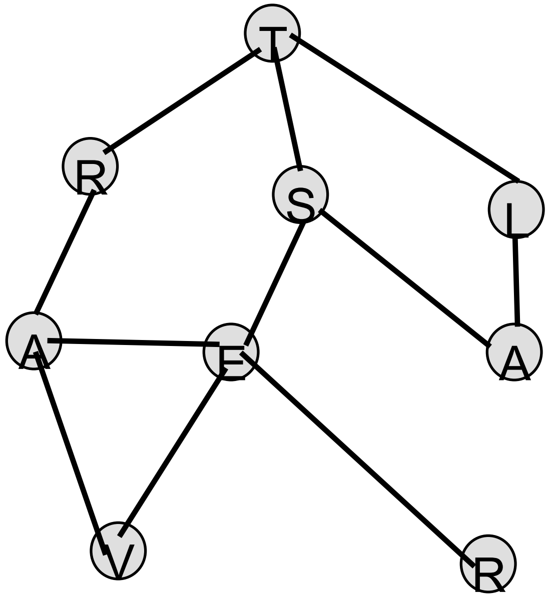
Breadth-first tree search: use a queue

```
void
preorder(queue *Q,node_t   *t)
{
    enQ(Q,t);
    while(!emptyQ(Q))
    {
      t = deQ(Q); visit(t);
      if(t->l != NULL) enQ(Q,t->l);
      if(t->r != NULL) enQ(Q,t->r);
    }
}
/* note: queue contains pointers into the tree */
```

Tree traversal: assumptions

- Assumes every node is reachable from the root.
- Assumes every node has only one parent, can only be visited once.
- Graph traversal needs to make sure that:
  - Every node is reached.
  - Every node is visited only once.

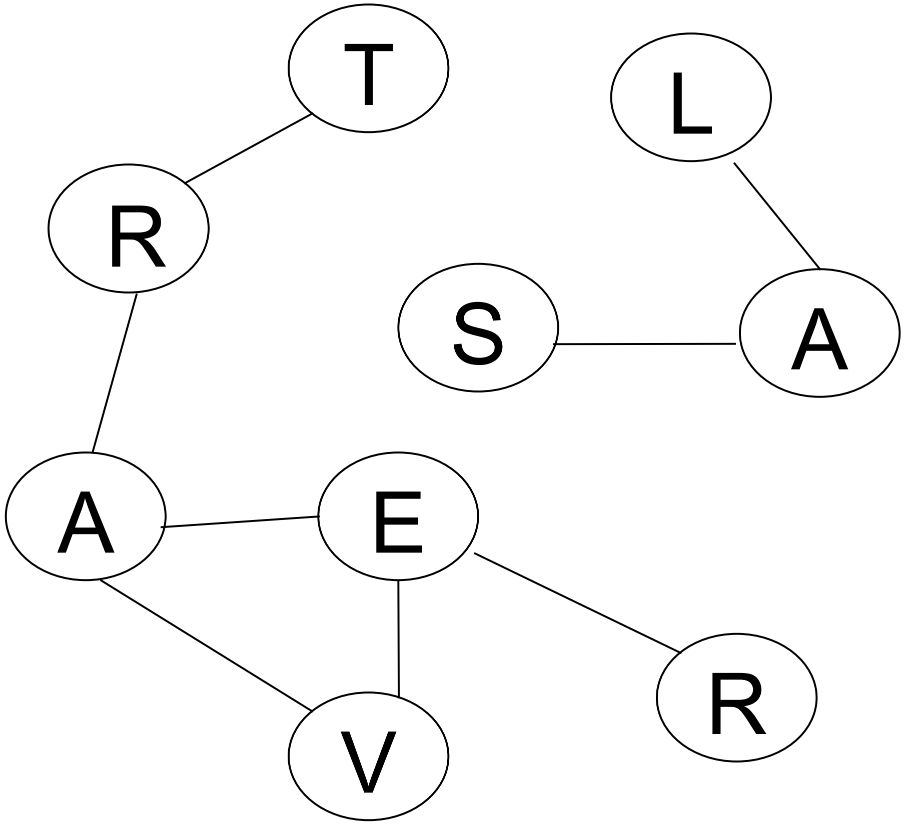
Traversing a connected graph (depth first)



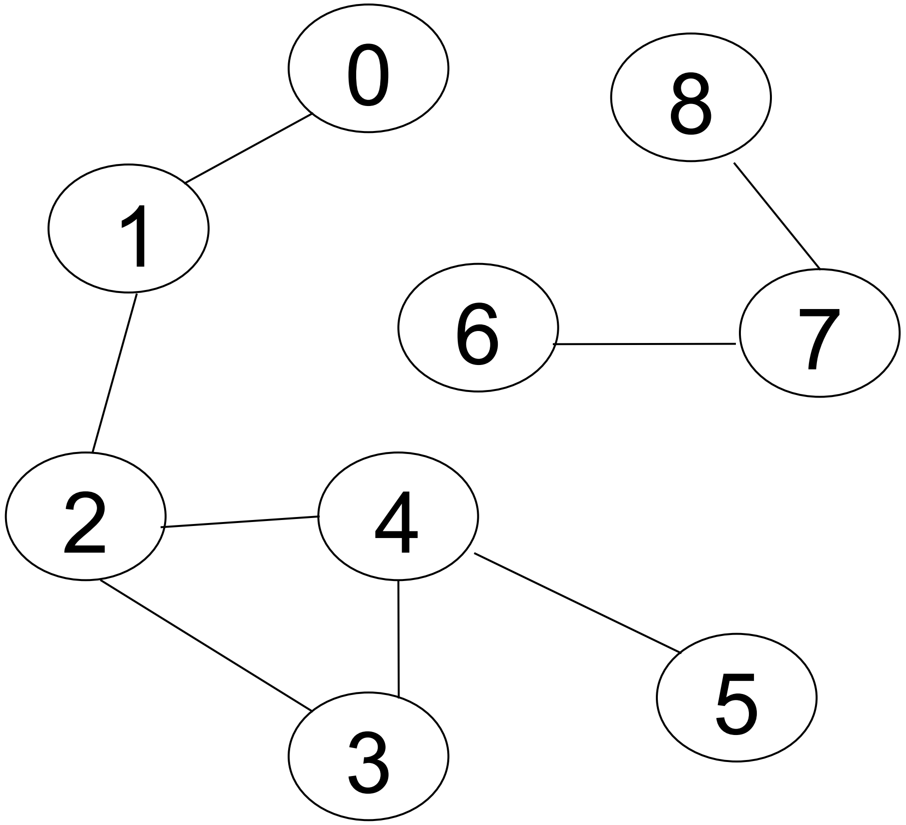
- Need to mark nodes as visited.

Traversing an unconnected graph (depth first)

- Need to traverse each connected component.
- Still need to mark nodes as visited.

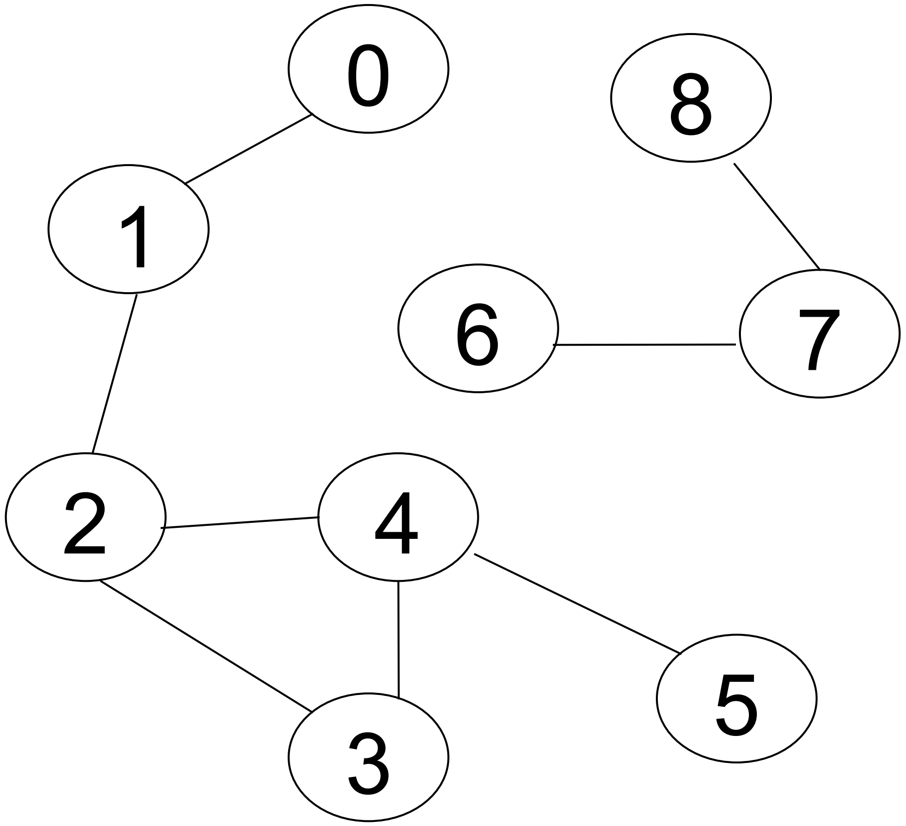


Traversing an unconnected graph (depth first)



Traversing an unconnected graph (depth first)

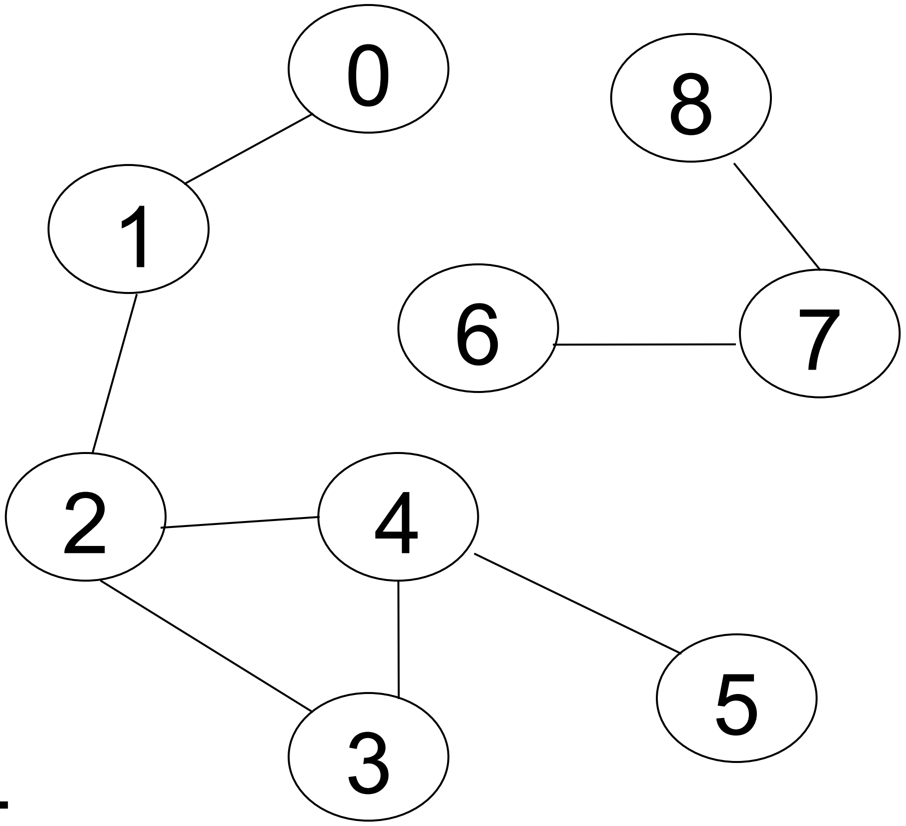
```
int  order=0;
```



Traversing an unconnected graph (depth first)

Matrix

	0	1	2	3	4	5	6	7	8
0		T							
1	T		T						
2		T		T	T				
3			T		T				
4			T	T		T			
5					T				
6								T	
7							T		T
8								T	



Traversing an unconnected graph (depth first)

Adjacency List

0 → 1

1→2

2→3→4→1

3→2→4

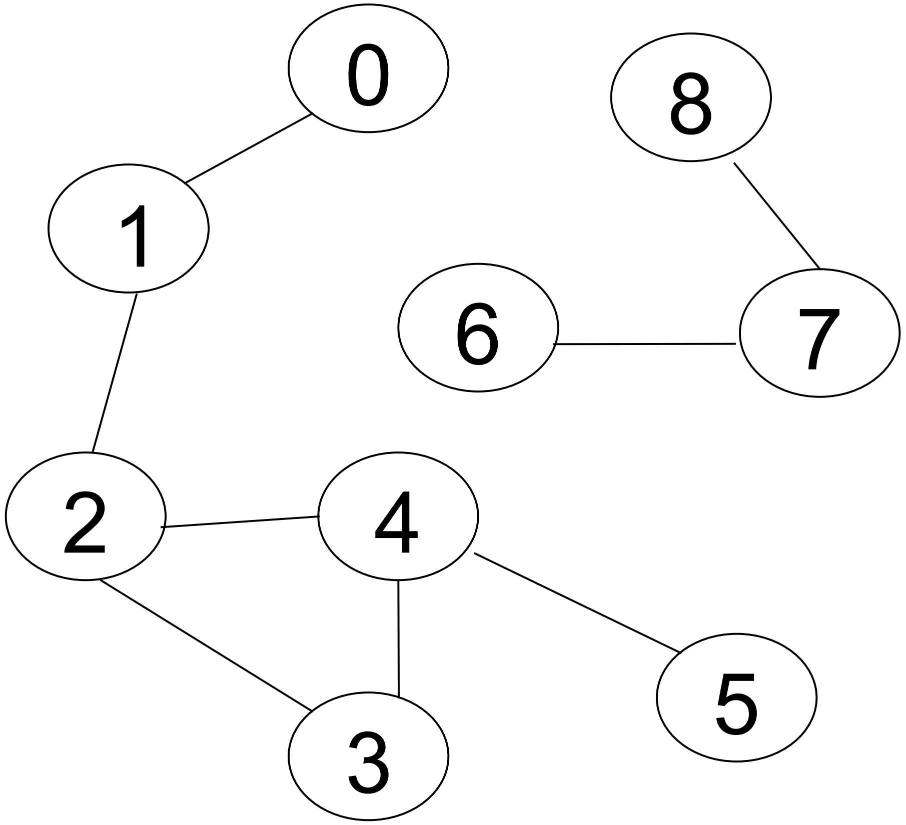
4→3→2→5

5→4

6→7

7→8→6

8→7



`visited[]` array: keeping track of what’s been done

```
/* invoke an array to track whether or not a
node has already been visited */
int  visited[V];
listdfs()
{
    int k;
    /* initialize - no nodes yet visited */
    for(k=0;k<V;k++) visited[k]= 0;
}
```

Adjacency list node

```
/* adjacency list is an array of pointers to
nodes; node is struct with value (nodeID)
and next ptr*/
struct node{
    int  value;
    struct node *next;
};
struct node   *adj[V];
```

Visiting nodes; updating the `visited[]` array

```
int  visited[V];
int  order=0;   /*keeps track of the order in
                which nodes are visited */
visit(int k)
{
     visited[k] = ++order;
     for(t=adj[k];t!=NULL;t=t->next)
       if(!visited[t→v]) visit(t->v);
}
```

Example dfs graph traversal

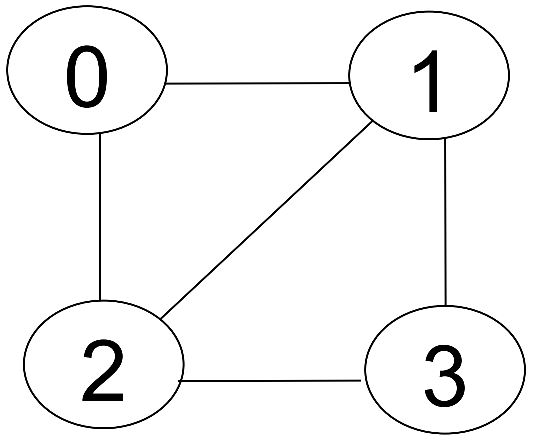
Adjacency List

0→1→2

1→0→2→3

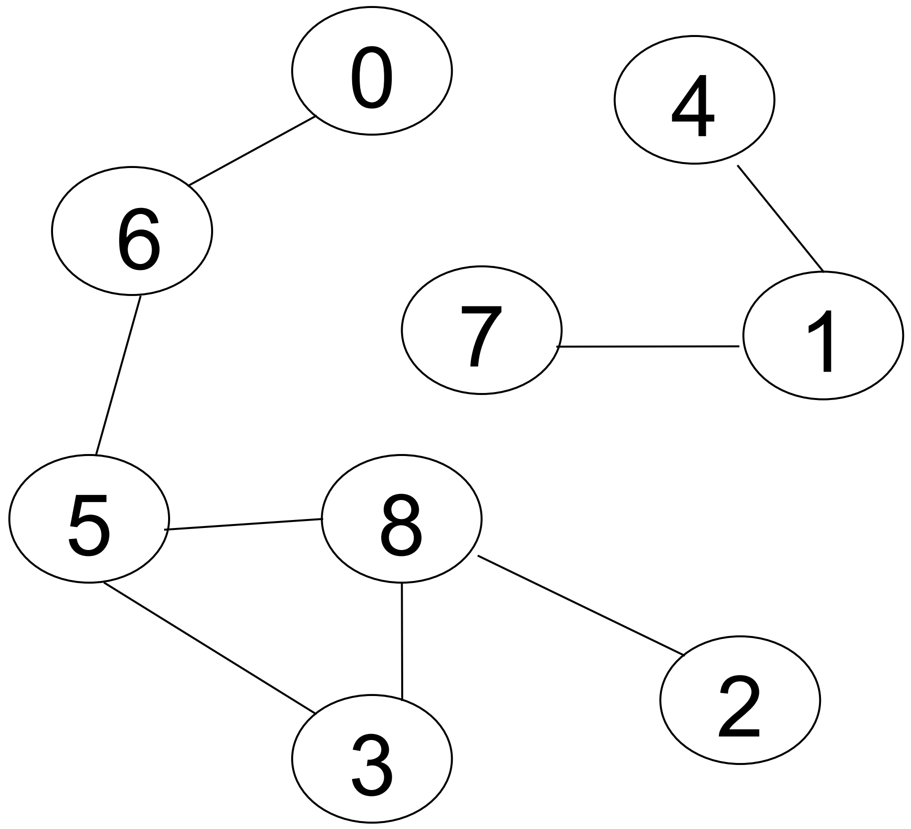
2→0→1→3

3→1→2



Example dfs graph traversal

Adjacency List
0→6
1→4→7
2→8
3→5→8
4→1
5→3→6→8
6→0→5
7→1
8→2→3→5



Graph dfs: Analysis

- Fill in the visited[] array:
- Examine (at most) each edge twice:

Graph dfs: Analysis

- Fill in the `visited[]` array:
    - |V|
- Examine (at most) each edge twice:
    - |E|
- Overall: |V|+|E|

Graph *breadth*-first search

- Again, modify the tree bfs, to make sure that:
    -
    -

Graph *breadth*-first search

- Again, modify the analogous tree search, to make sure that:
  - Every node is visited, even if the graph is not connected, and
  - Every node is visited only once

bfs visit()

```
int visited[V]; int order=0;
visit(int k){
   struct node *t;
   enQ(Q,k);
   while(!Qempty(Q)){
       k = deQ(Q);
       if(!visited[k]){
            visited[k]=++order;
            for(t=adj[k];t!=NULL; t=t→next)
              if(!visited[t→num]) enQ(Q,t->num);
         }
   }
}
```

Breadth-first graph search

}

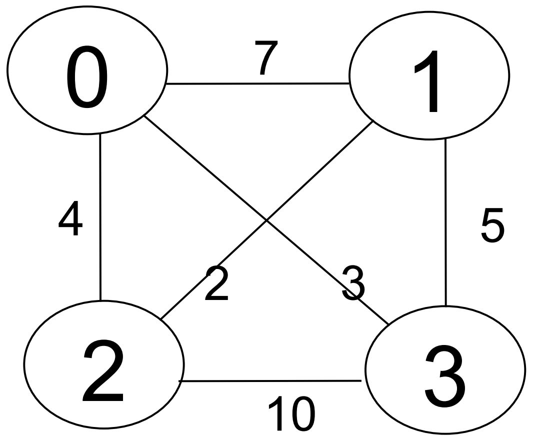
```
int  visited[V];
listbfs()
{
    int k;
    for(k=0;k<V;k++) visited[k]= 0;
    for(k=0;k<V;k++)
        if(!visited[k]) visit(k);
}
```

Weighted graphs

- So far, we have used somewhat arbitrary ordering of the nodes (determined by position in adjacency list or matrix).
- For weighted graphs, it might be nice to get the nodes out in order of distance.

Example weighted graph bfs

Adjacency List
0→1→2
1→0→2→3
2→0→1→3
3→1→2



Previous visit order from node 0:
But if these are restaurants and nightclubs, and we want to go to a nearby nightclub from restaurant 0…

Priority Queues

- We can still use a queue, but we make that a priority queue (PQ).

- Chapter 5, Skiena book