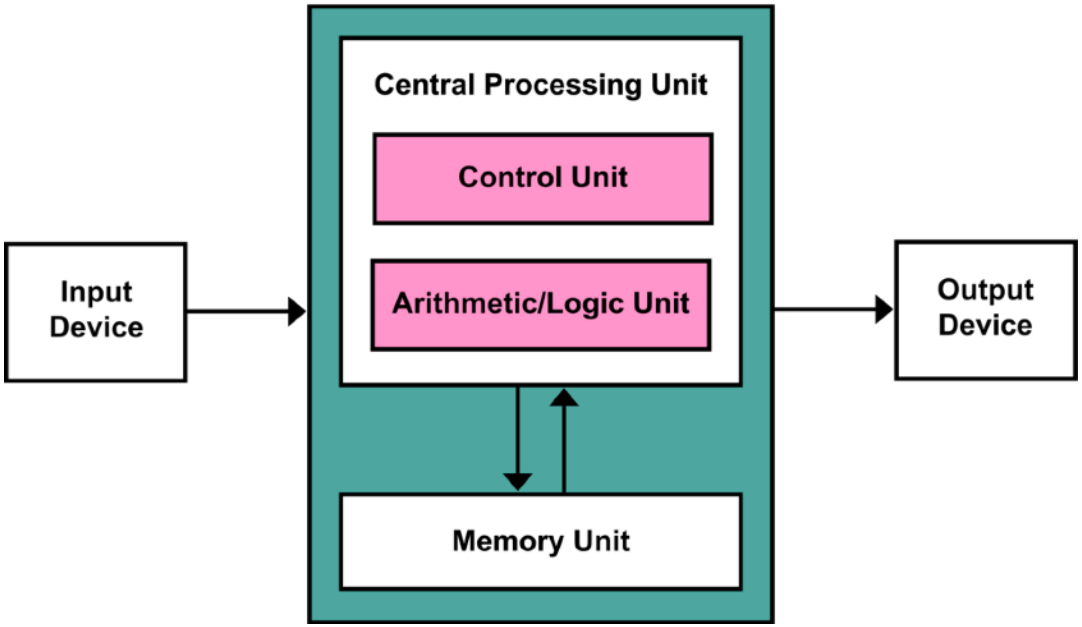
Graphs

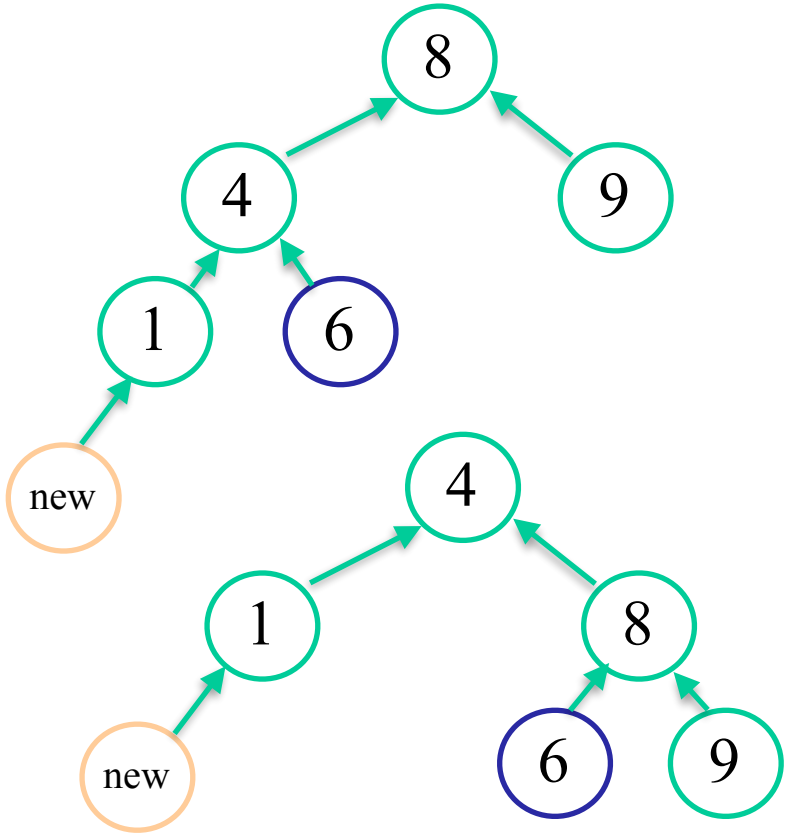
John Von Neumann

1903-1957



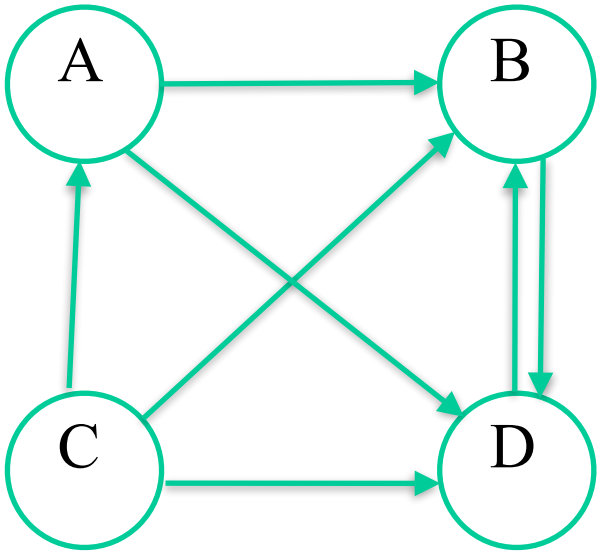
AVL Rotation Issues

- The wayward node problem
- Deletions
  - may require up to lg(n) rotations



Graphs

- Consist of nodes and edges
  - edges may be
    - weighted or unweighted
    - Directed or undirected
- No distinguished starting location
- Loops allowed



A graph with 4 nodes and unweighted, directed edges

Representing Graphs

- Edge List
  - store edges in an arrayList
- Adjacency Matrix
  - store nodes in a 2D array
- Adjacency List
  - store edges from node in a list with node

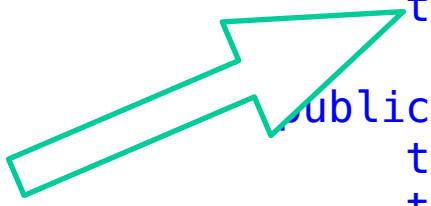
Nodes and Edges

- Represent using internal classes
- Some graph representations will not need both

```
private class Node<H> {
    public H payload;
    public Node(H payl) {
        this.payload = payl;
    }
}

private class Edge<J> {
   Node<J> from;
   Node<J> too;
   double wei;
   public Edge(Node<J> fr, Node<J> t2)
        this(fr, t2, 1.0);

   public Edge(Node<J> fr, Node<J> t2,
        this.from = fr;
        this.too = t2;
        this.wei = w;
    }
}
```



Edge Lists

- Just store every edge in graph
- often inconvenient
  - for instance, "where can I go from A"

```
public class EdgeList<G> {

    ArrayList<Edge<G>> egLi;
    HashMap<G, Node<G>> nodeHash;

     private Node<G> getNode(G g) {
         Node<G> ret = nodeHash.get(g);
         if (ret == null) {
             ret = new Node<>(g);
             nodeHash.put(g, ret);
         }
         return ret;
     }

    public void addEdge(G fr, G t2) {
     egLi.add(new Edge<G>(getNode(fr),
                          getNode(t2)));
    }
```

Edge Lists

```
public static void main(String[] args) {
    EdgeList<String> edl = new EdgeList<>("A");
    edl.addEdge("A", "B");
    edl.addEdge("A", "D");
    edl.addEdge("B", "D");
    edl.addEdge("C", "D");
    edl.addEdge("C", "B");
    edl.addEdge("C", "A");
    edl.addEdge("D", "B");
    System.out.println(edl);
}
```

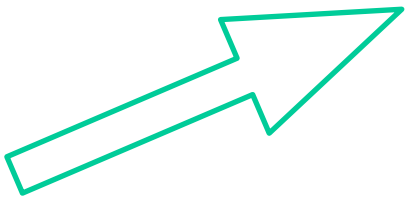
Adjacency Matrix

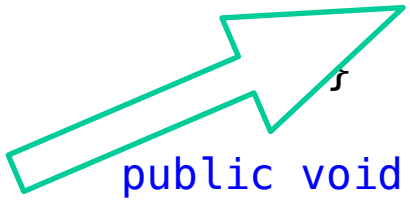
- Edge lists are awkward.
- Instead, store edges implicitly in 2D array
  - rows are from
  - columns are to
- So, "where can I get to from A" is just read across row.
- Unweighted edges,
  - store T/F in matrix
- Weighted edges
  - store weights.
    - The "no edge problem"

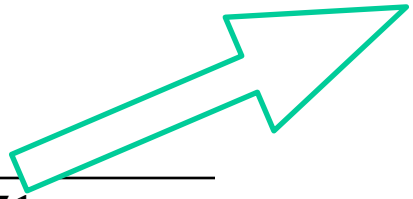
Adjacency Matrix

```
public class AdjMatrix<M> {
    //The adjacency matrix
    double[][] aMatrix;
    ArrayList<M> nodes;
    public AdjMatrix(ArrayList<M> nds) {
        nodes = new ArrayList<>();
        for (M nm : nds) {
            nodes.add(nm);
        }
        aMatrix = new double[nodes.size()][nodes.size()];
        for (int i=0; i<nodes.size(); i++)
            for (int j = 0; j < nodes.size(); j++) {
                aMatrix[i][j] = -99;
            }

    public void addEdge(M fr, M t2, double w) {
        int fri = nodes.indexOf(fr);
        int t2i = nodes.indexOf(t2);
        if (fri < 0 || t2i < 0)
            return;
        aMatrix[fri][t2i] = w;
    }
```







Adjacency Lists

- Each node holds list of edges leaving the node
  - Add an ArrayList of edges to the node definition
- Edge need only store destination
- How do you store bi-directional links?

```
private class Node<H> {
    // Node content
    public H payload;
    // hold the list
    public ArrayList<Edge<G>> edges;

    public Node(H payl) {
        this.payload = payl;
        this.edges = new ArrayList<Edge
    }

    public void addEdge(Node<G> n, doub
        edges.add(new Edge<G>(n, w));
    }
```

Adjacency Lists

- Only store in outer class is the nodes
- Get to from X is just the list in X

```
public class AdjList<G> {
    private HashMap<G, Node<G>> nodeHash;

    public void addNode(G g) {
        nodeHash.put(g, new Node<G>(g));
    }

    public void addEdge(G fr, G t2, double w) {
        Node<G> frn = nodeHash.get(fr);
        Node<G> t2n = nodeHash.get(t2);
        if (frn == null || t2n == null)
            return;
        frn.addEdge(t2n, w);
    }
```