# Artificial Intelligence

## Lecture 26

# Problem Solving by Search

*Prepared by:*

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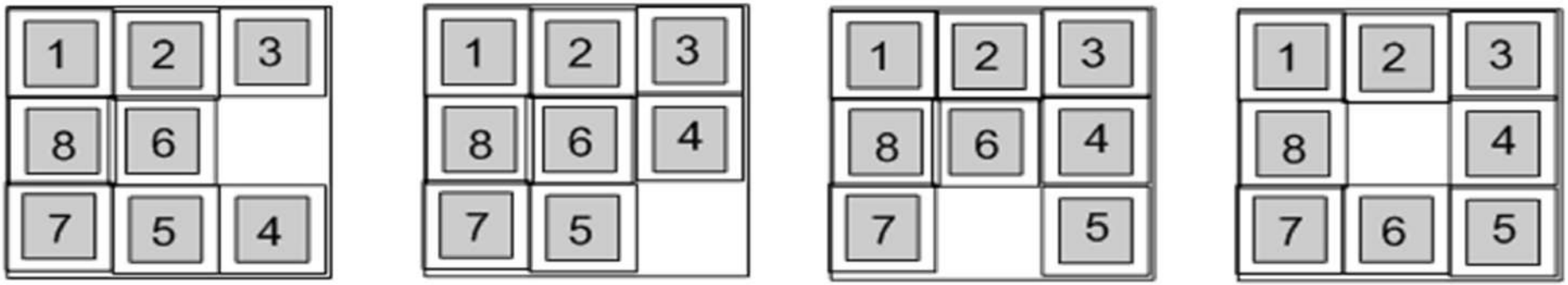
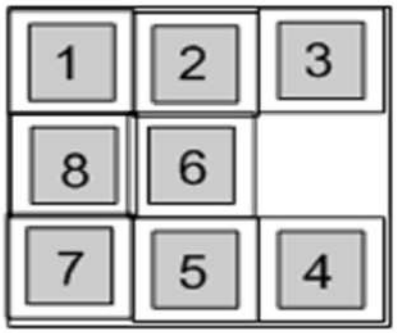
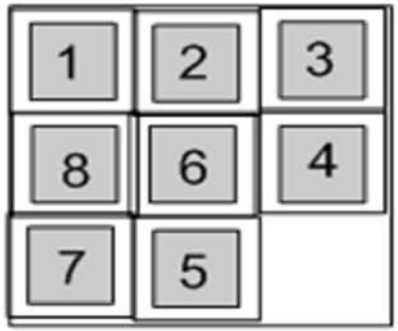
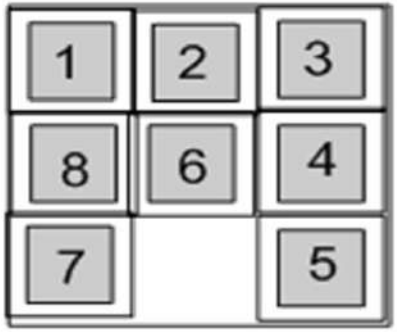


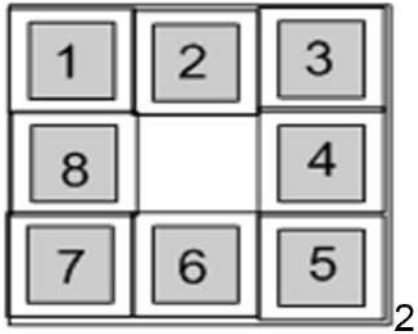
# Lecture Outlines

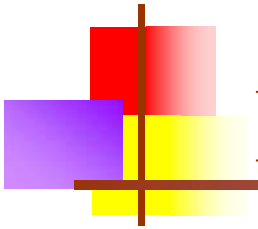
- Problem solving
- Search and examples of search problems
- Searching for solutions
- Tree searches and search strategies
- Search algorithms
- …



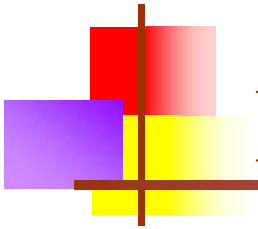





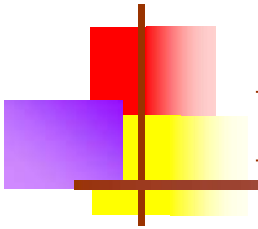
# Problem Solving

- An important aspect of intelligence is *goal-based* problem solving.
- The solution of many problems (e.g. noughts and crosses, timetabling, chess) can be described by finding a sequence of actions that lead to a desirable goal.
- Each action changes the *state* and the aim is to find the sequence of actions and states that lead from the initial (start) state to a final (goal) state.



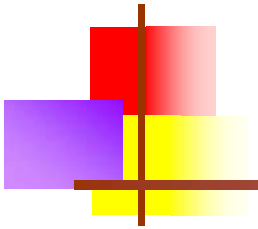
# Problem Solving

- Problem solving involves:
  - problem definition - detailed specifications of inputs and what constitutes an acceptable solution;
  - problem analysis;
  - knowledge representation;
  - problem solving - selection of best techniques.



# Problem Solving

- A well-defined problem can be described by:
  - **Initial state**
  - **Operator or successor function** - for any state x returns s(x), the set of states reachable from x with one action
  - **State space** - all states reachable from initial by any sequence of actions
  - **Path** - sequence through state space
  - **Path cost** - function that assigns a cost to a path. Cost of a path is the sum of costs of individual actions along the path
  - **Goal test** - test to determine if at goal state

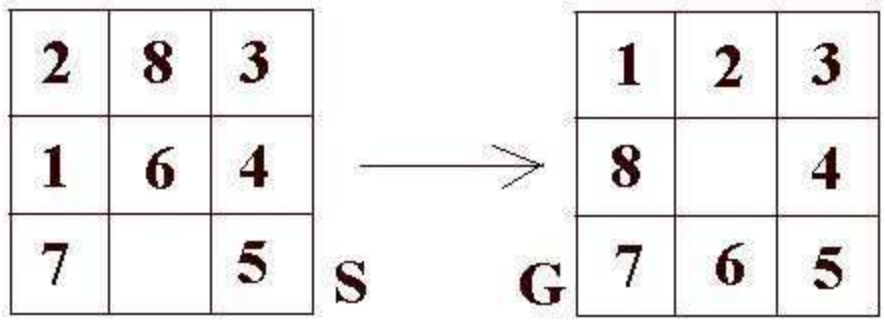


# Search

- Search is the systematic examination of states to find path from the start/root state to the goal state.
- The set of possible states, together with *operators* defining their connectivity constitute the *search space*.
- The output of a search algorithm is a solution, that is, a path from the initial state to a state that satisfies the goal test.
- Search techniques fall into three groups:
  - Methods which find *any* start - goal path,
  - Methods which find the *best* path, and finally
  - Search methods in the face of adversaries

# Example Problems

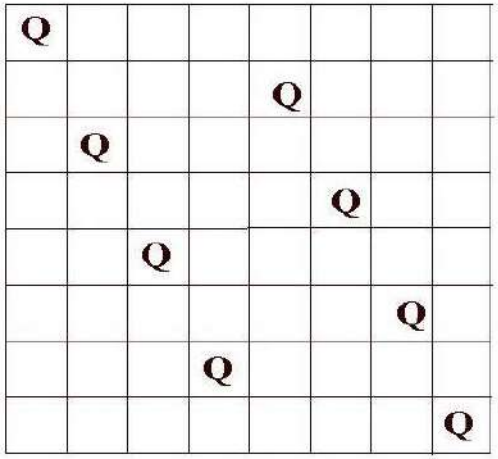
- The real art of problem solving is in deciding the description of the states and the operators.
- The 8-puzzle:



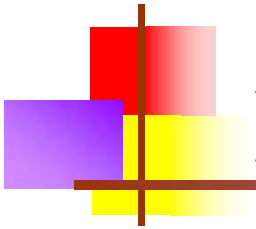

  - State: location of blank
  - Operator: blank moves left, right, up and down
  - Goal Test: match G
  - Path Cost: each step costs 1 so cost is length of path

# Example Problems

- The 8-queens problem:

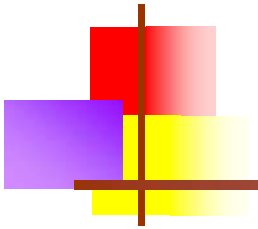



  - Aim of problem is to place 8 queens on chess board so none attacks another, diagram shows a solution.



# Example Problems

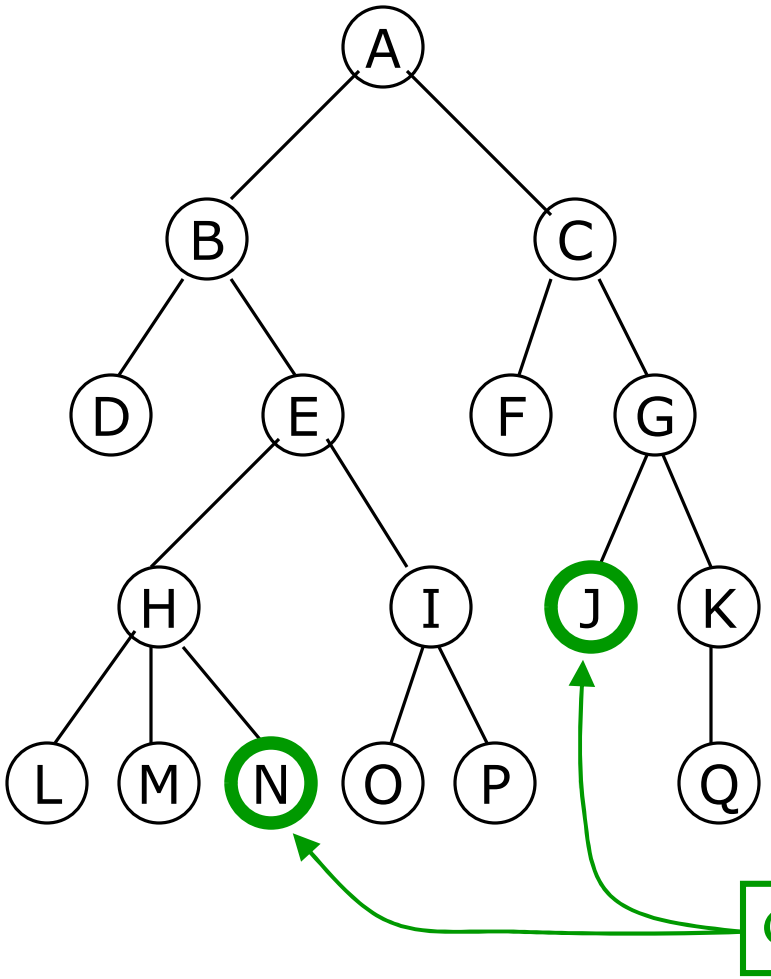
- **Real Problems**
  - Route finding
  - Travelling salesman
  - Scheduling and planning
  - Theorem proving
  - VLSI layout
  - Speech recognition
  - Model based vision
  - Robot navigation



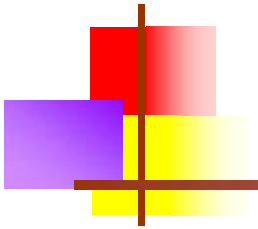
# Searching for solutions

- **Searching for solutions: Graphs or nets versus trees**
- The map of all paths within a state-space is a *graph* of *nodes* which are connected by *links*.
- Like graphs, trees have nodes, but they are linked by *branches*. The start node is called the *root* and nodes at the other ends are *leaves*.
- The aim of search is *not* to produce complete physical trees in memory, but rather explore as little of the virtual tree looking for root-goal paths.

# Tree searches

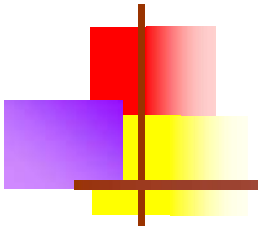



- A tree search starts at the root and explores nodes from there, looking for a goal node (a node that satisfies certain conditions, depending on the problem)
- For some problems, any goal node is acceptable (N or J); for other problems, you want a minimum-depth goal node, that is, a goal node nearest the root (only J)



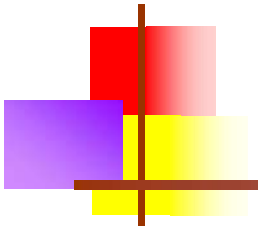
# Search Strategies…

- A search strategy simply determines which node in the fringe to expand next.
- **Measuring performance**
  - What are the ways we measure the performance of a search strategy or algorithm?
  - **Completeness:** will the algorithm find a solution if one exists?
  - **Optimality:** will the algorithm find the optimal solution? (lowest path cost among all solutions)
  - **Time complexity:** how long does it take to find a solution?
  - **Space complexity:** how much memory is needed to perform the search?



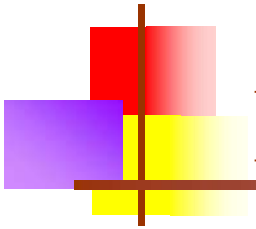
# Search Strategies…

- **Measuring performance**
- Some properties of the search space we will use to answer these questions are as follows:
- **Branching factor:** *b,* maximum number of successors of any node
- **Depth of solution:** *d,* is the minimum number of steps to get to the goal
- **Maximal path length in the space:** what is the longest path we could follow?



# Search Strategies

- **Types:**
- **Uninformed or Blind search** - can only move according to position in search.
- Uninformed search strategies use only the information available in the problem definition.
  - Depth-first search
  - Breadth-first
- **Informed or Heuristic search** - use *domain-specific* information to decide where to search next.
  - Hill climbing
  - Beam search
  - Best-first search



# Direction of search

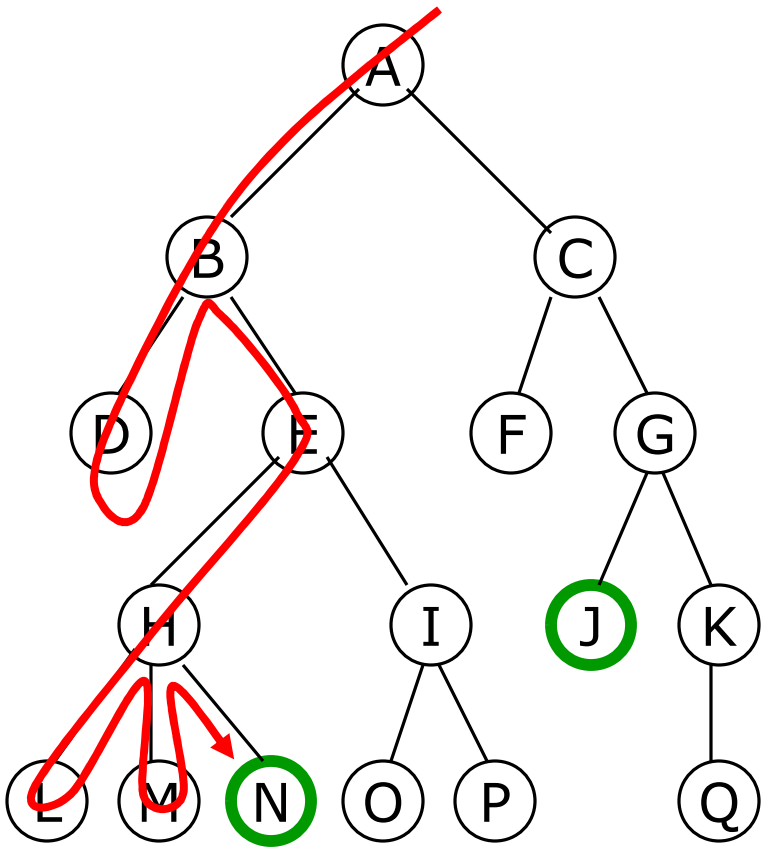
- Forward search: from start to goal
- Backward search: from goal to start
- Bidirectional search

- In expert systems:

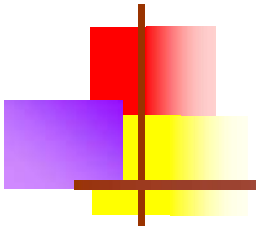
  Forward chaining

  Backward chaining

# Depth-first searching




- A depth-first search (DFS) explores a path all the way to a leaf before backtracking and exploring another path
- For example, after searching A, then B, then D, the search backtracks and tries another path from B
- Node are explored in the order A B D E H L M N I O P C F G J K Q
- N will be found before J



# Depth-first Algorithm

- The depth-first algorithm is:

Step-1: Form a one element queue Q consisting of the root node.

Step-2: Until the Q is empty or the goal has been reached,

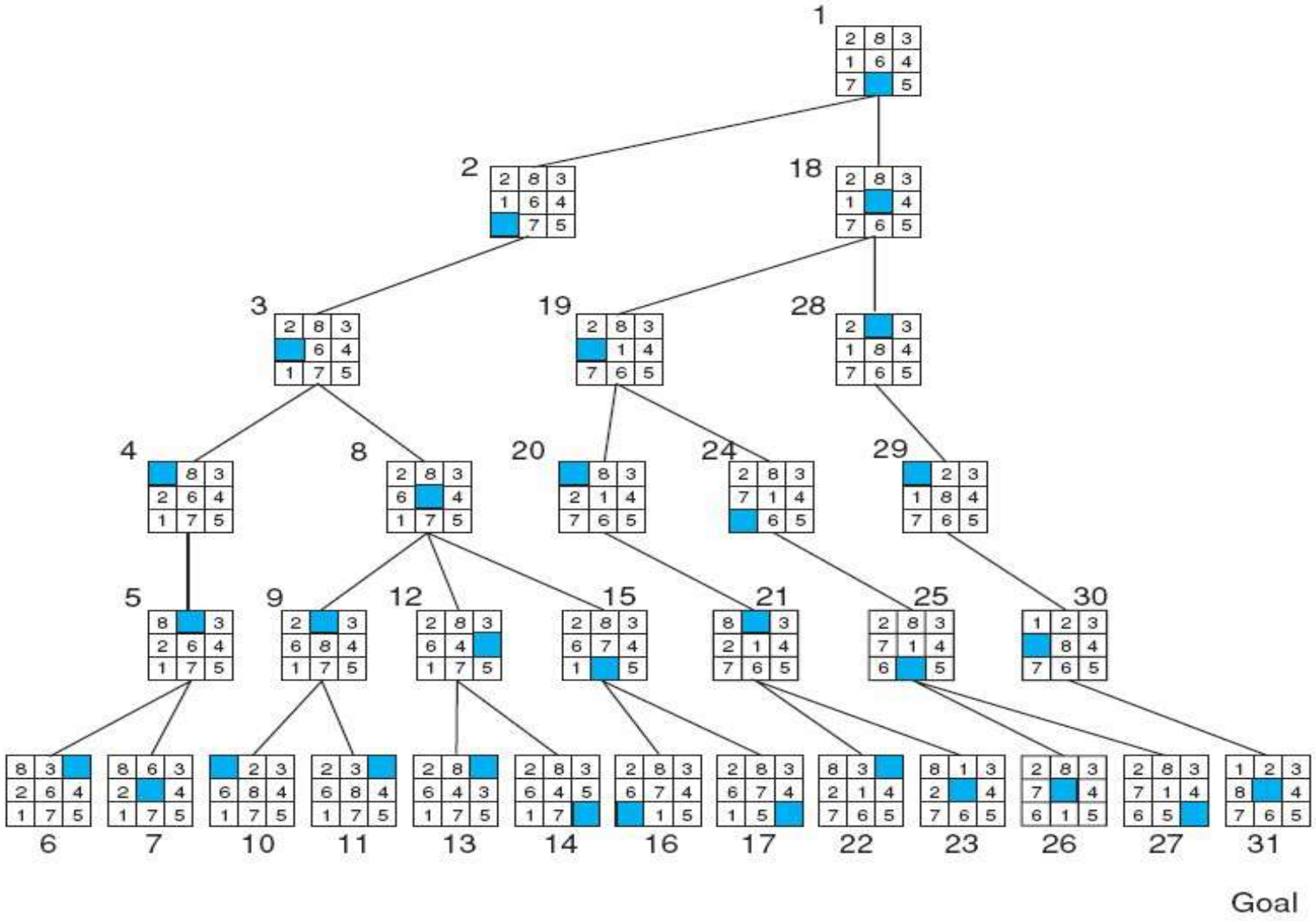
determine if the first element in the Q is the goal.

a) If it is, do nothing.

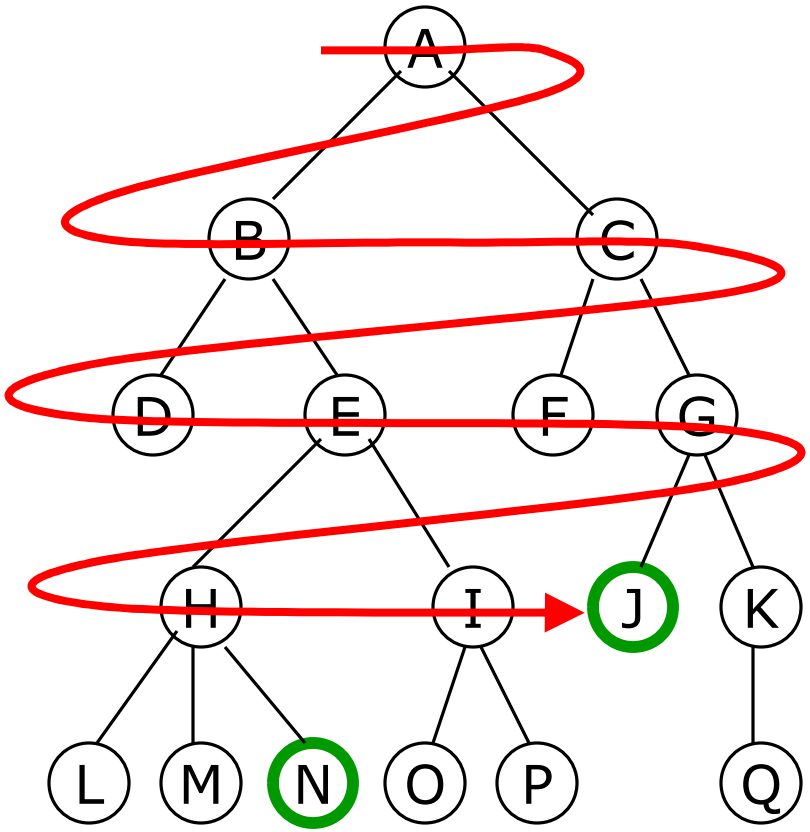
b) If is isn't, remove the first element from the Q and add the first element's children, if any, to the FRONT of the Q.

Step-3: If the goal is reached, success; else failure.

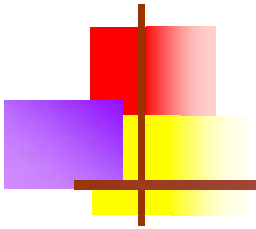
# DFS for Puzzle Problem



# Breadth-first searching




- A breadth-first search (BFS) explores nodes nearest the root before exploring nodes further away
- For example, after searching A, then B, then C, the search proceeds with D, E, F, G
- Node are explored in the order A B C D E F G H I J K L M N O P Q
- J will be found before N



# Breadth-first Algorithm

- The breadth-first algorithm is:

Step-1: Form a one element queue Q consisting of the root node.

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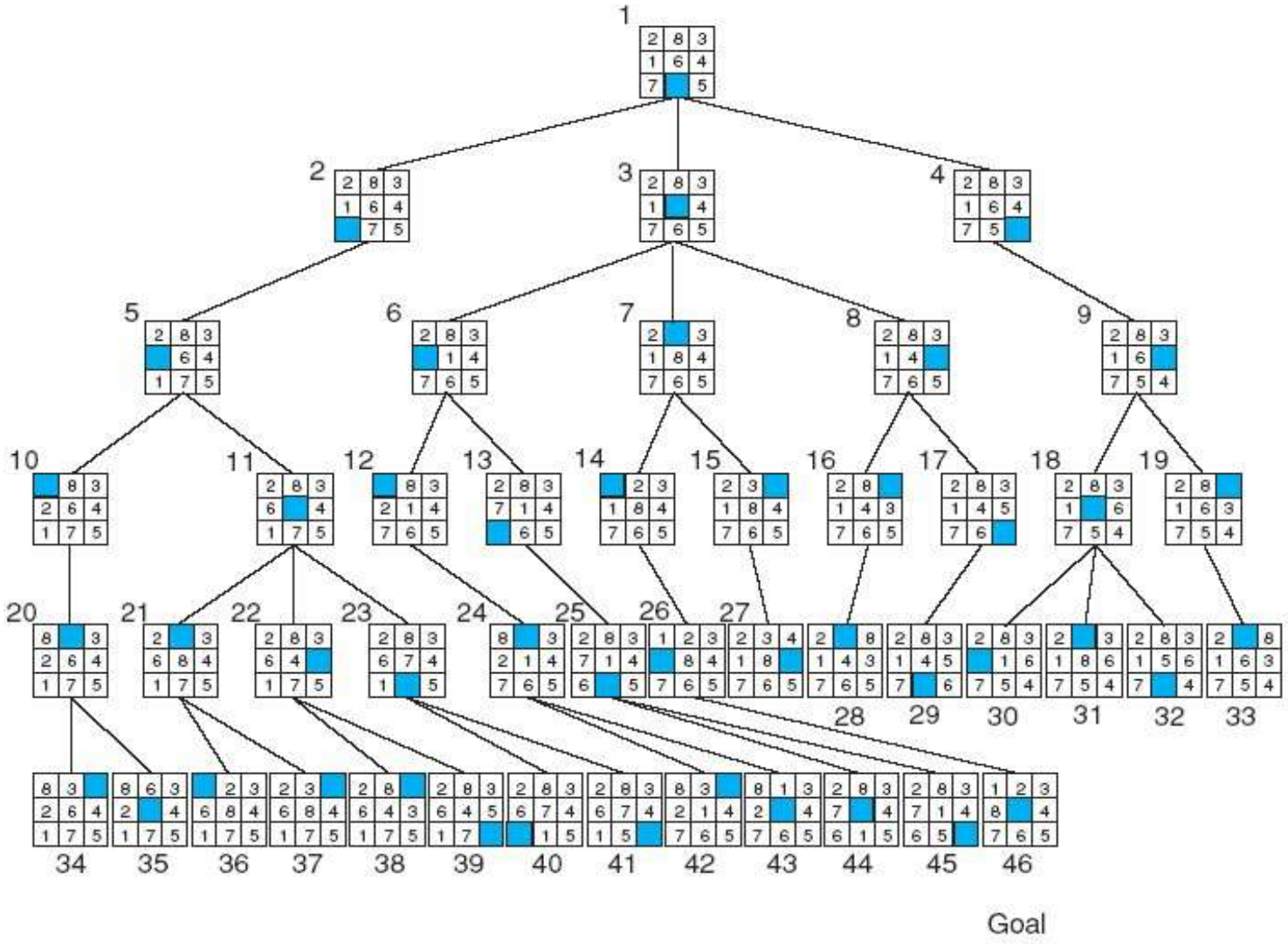
# BFS for Puzzle Problem



**Problem Solving by Search**

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**TO BE CONTINUED…**