كلية الحاسبات والذكاء الاصطناعي

FACULTY OF COMPUTERS & ARTIFICIAL INTELLIGENCE

# ARTIFICIAL INTELLIGENCE
# LAB 03 – SEARCHING PROBLEMS (1)

AI Course Team

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# GUIDELINES

You don't need to memorize what will be mentioned. Instead, try to understand

Each PowerPoint Presentation will be available as PDF file on Google Drive Folder of the Course

# REMEMBER !

In our course, we are targeting

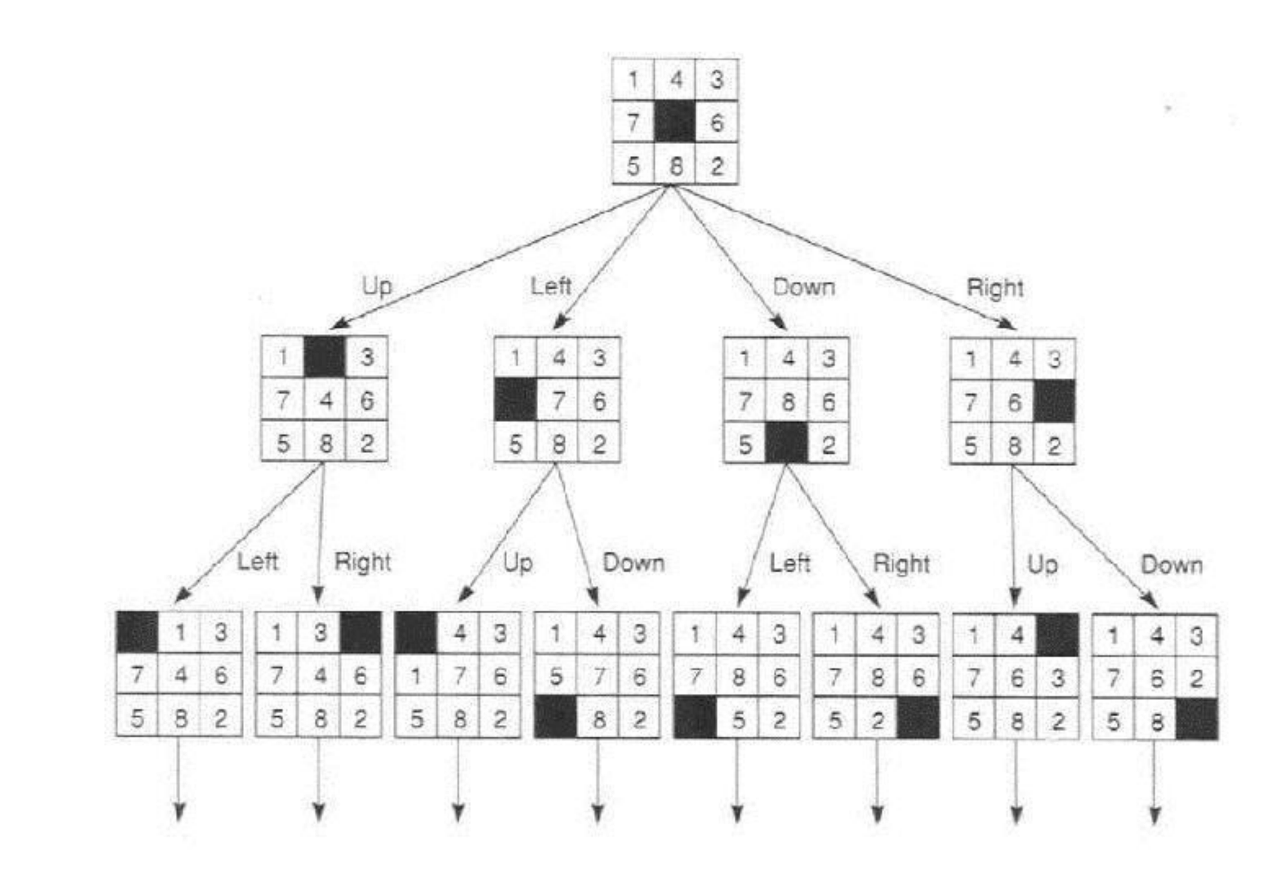
Goal-based agent in fully observable, deterministic and discrete environments

Which means, all of our problems will be in the form of states that shows all possible forms of the environment

# STATE SEARCH SPACE

# STATE SEARCH SPACE

**state search space** is the collection of all possible states a system can be in while searching for a solution to a given problem.

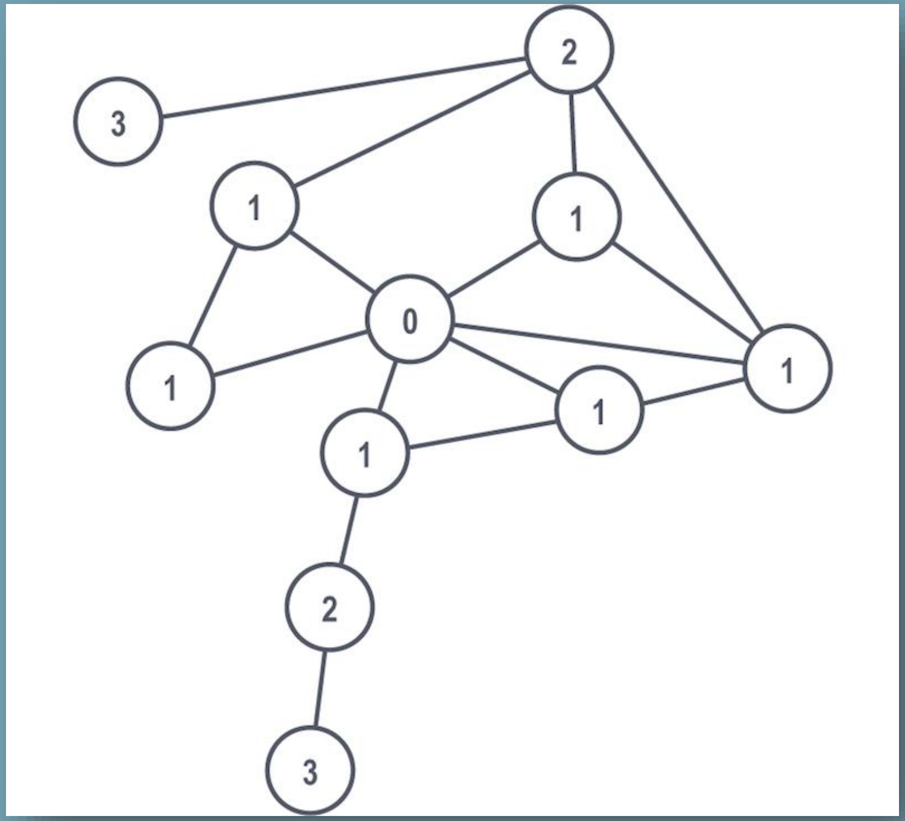


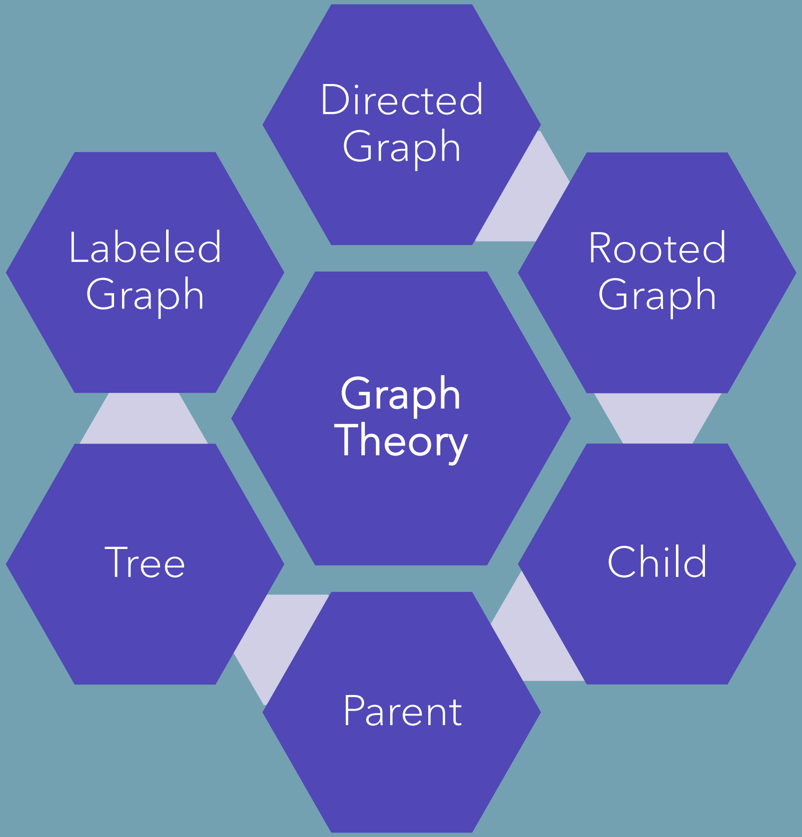
# KEY ASPECTS OF "STATE SEARCH SPACE"

- States
- Initial State
- Goal State
- Operators
- Space Graph
- Search Path
- Optimal Solution
- Strategy

# (1) SPACE GRAPH

- A representation of all possible states and transitions between them.



## (1) SEARCH GRAPH

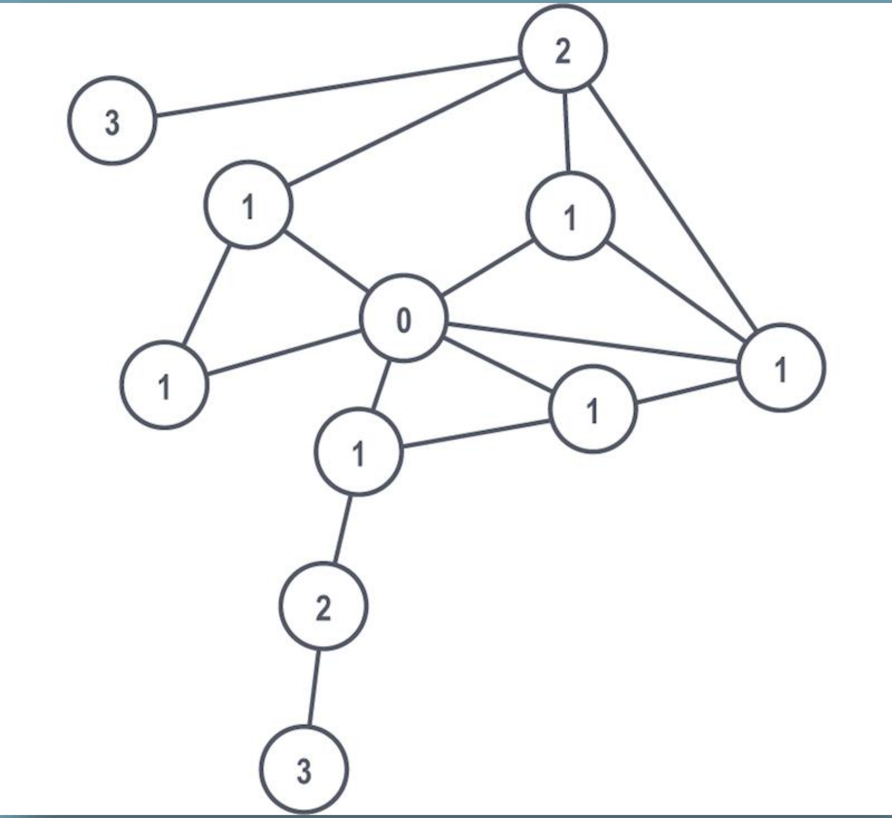
# What is "Graph" ?

- A **graph** is a data structure used to represent relationships between objects. It consists of:
  1. Nodes (Vertices, V) → Represent objects or states.
  2. Edges (E) → Represent connections or relationships between nodes.

| | | | | |
|---|---|---|---|---|
| Directed Graph | Undirected Graph | Weighted Graph | Unweighted Graph | Cyclic Graph |
| | Acyclic Graph | Connected Graph | Disconnected Graph | |

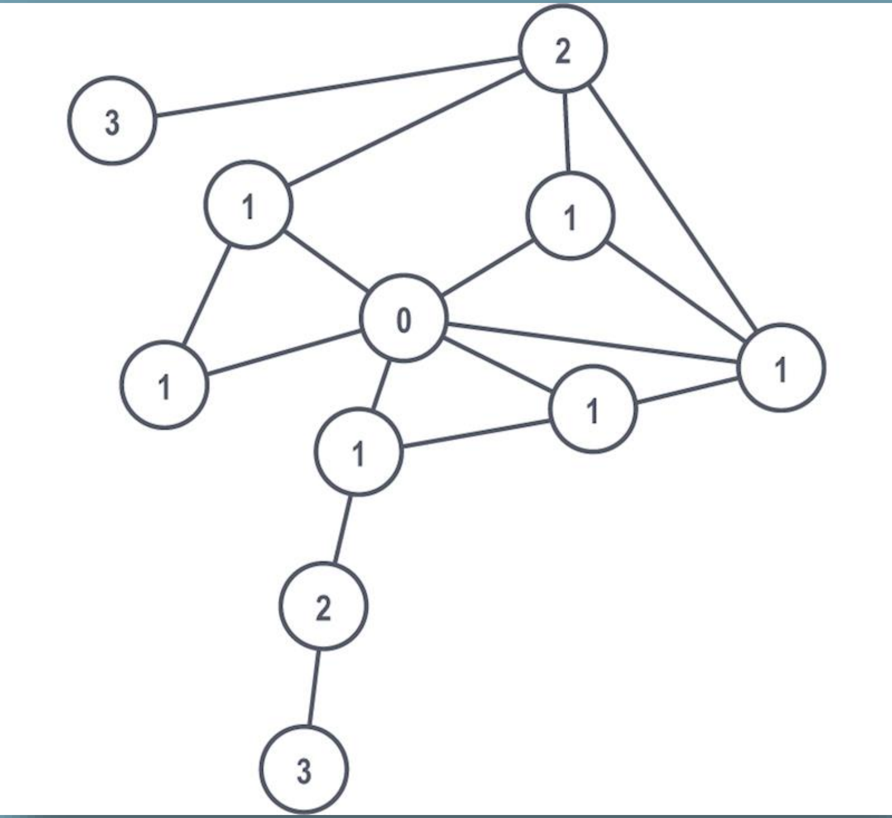
# (2) STATES

- Each unique configuration of the system is called a state.



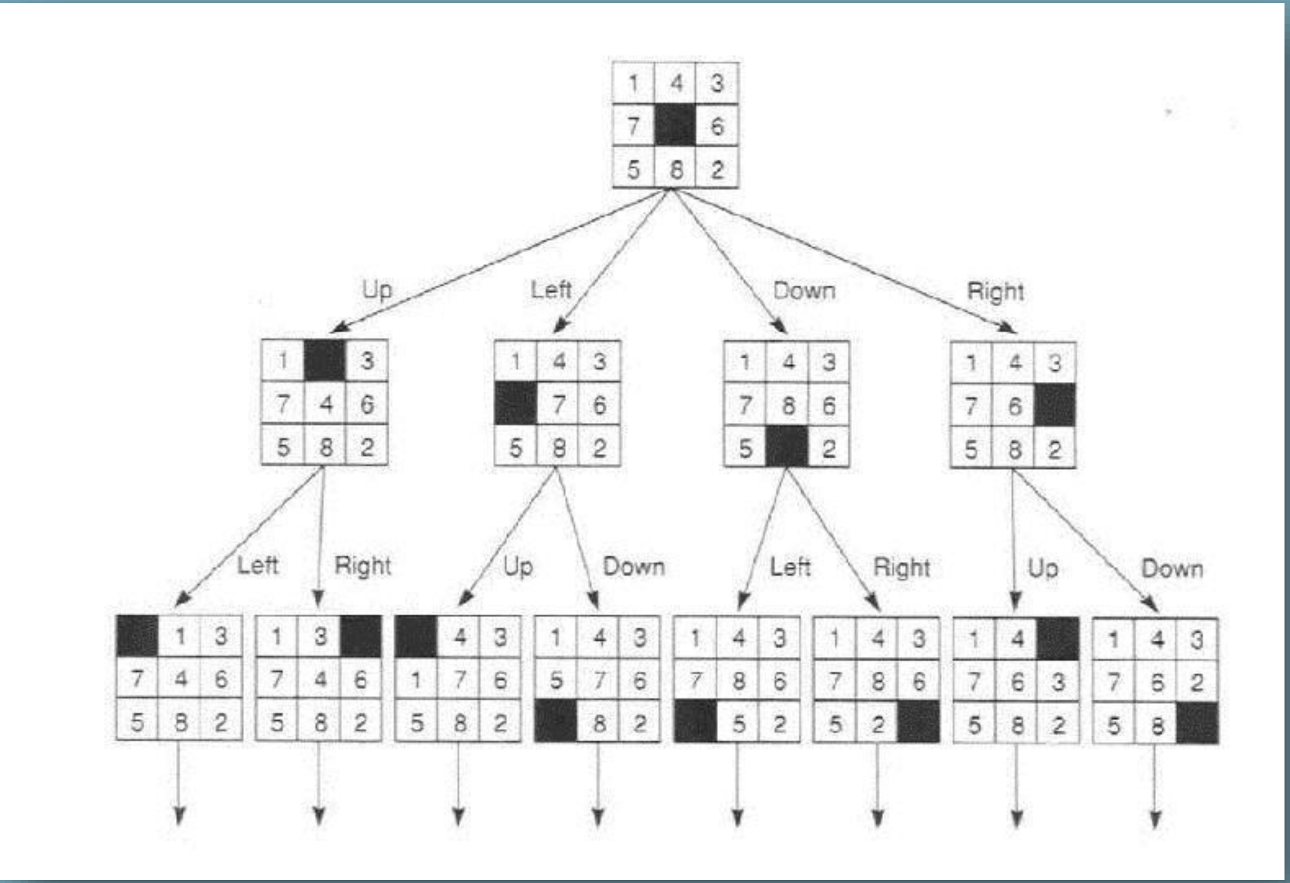
# (3) INITIAL STATE

- The starting point in the search process.



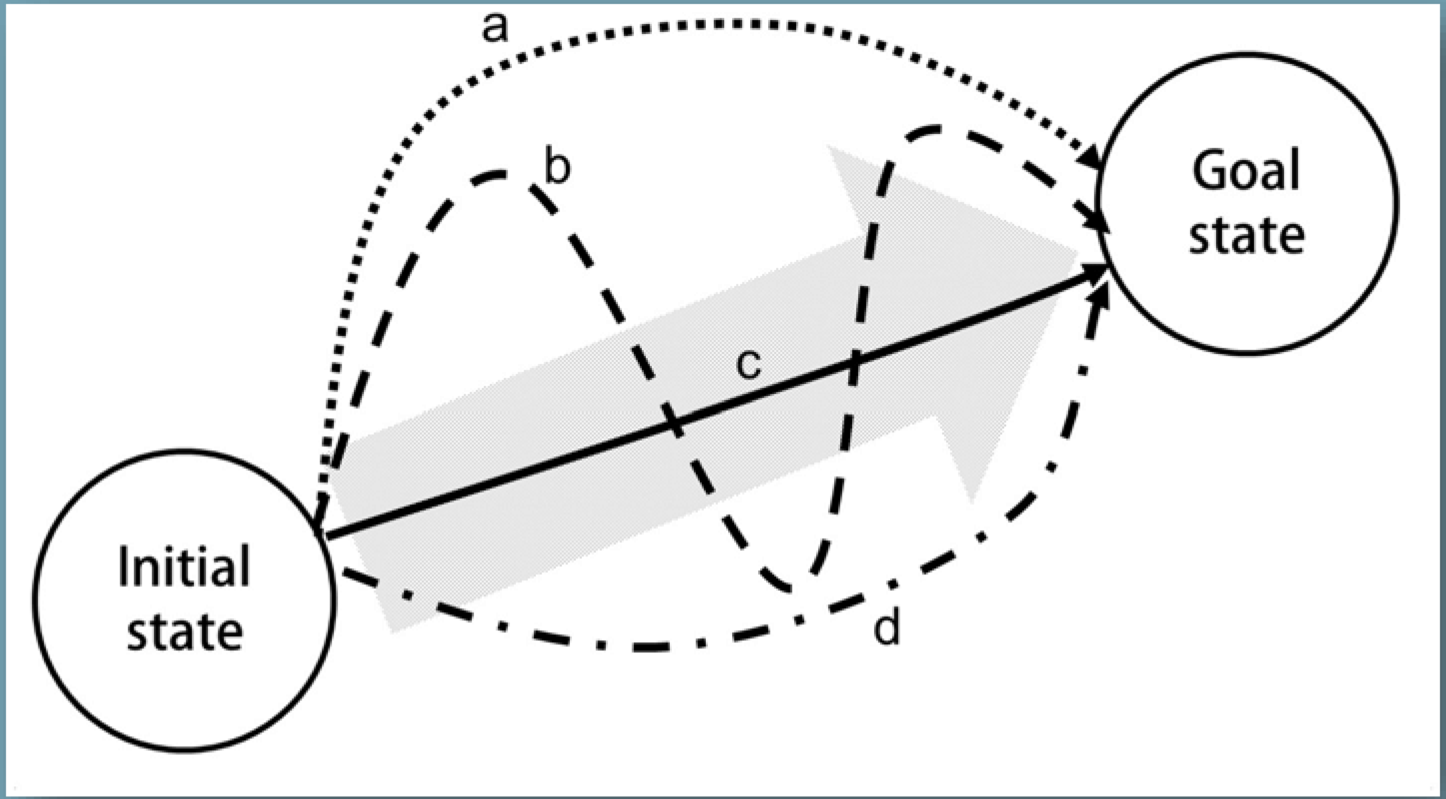
# (4) OPERATORS (STATE TRANSITIONS)

- Actions that move from one state to another.



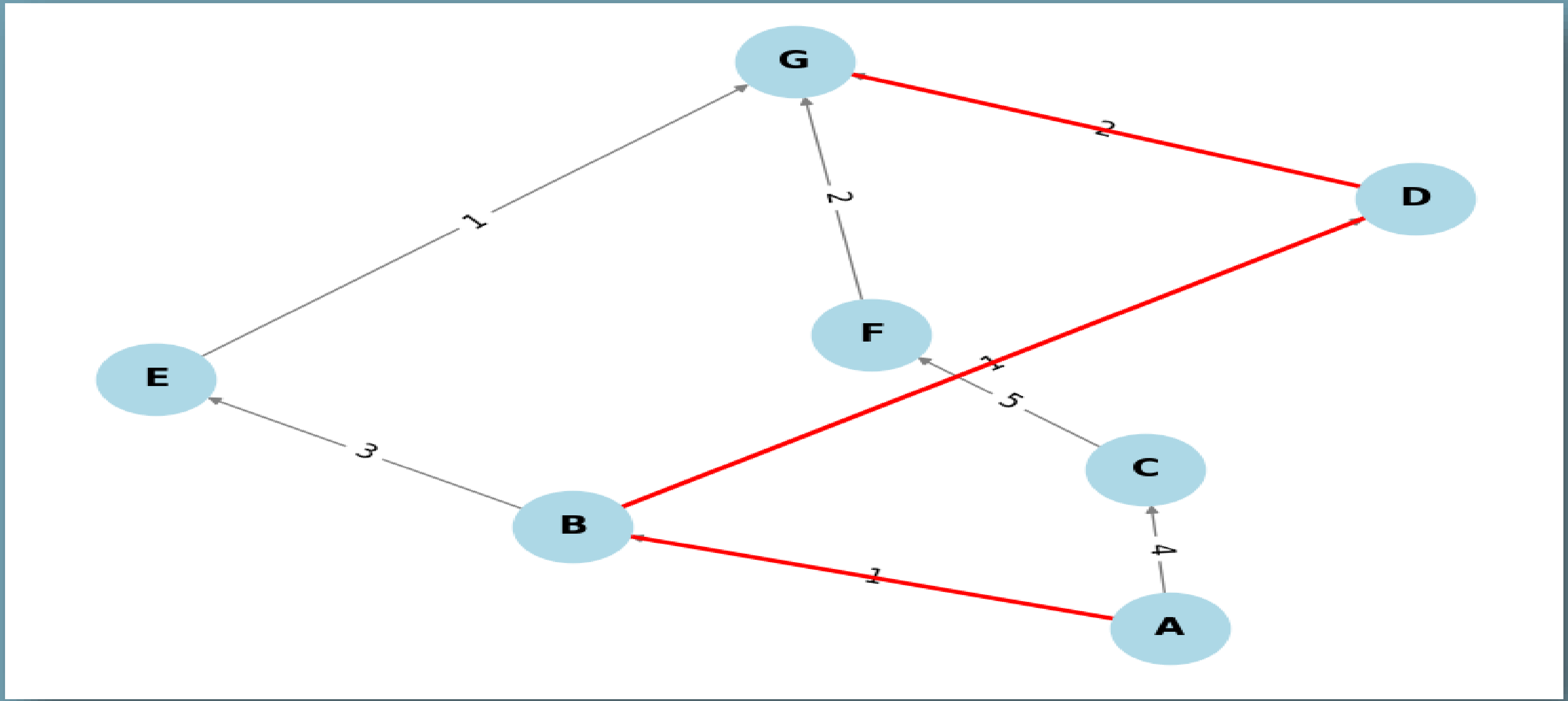
# (5) GOAL STATE

- The state that meets the problem's success conditions.



# (6) SEARCH PATH

- The sequence of states from the initial state to the goal state.



# (7) SEARCH STRATEGY

- Depth First Search
- Breadth First Search
- A* Search
- Uniform cost search
- Greedy search
- Bidirectional search
- Iterative deepening search

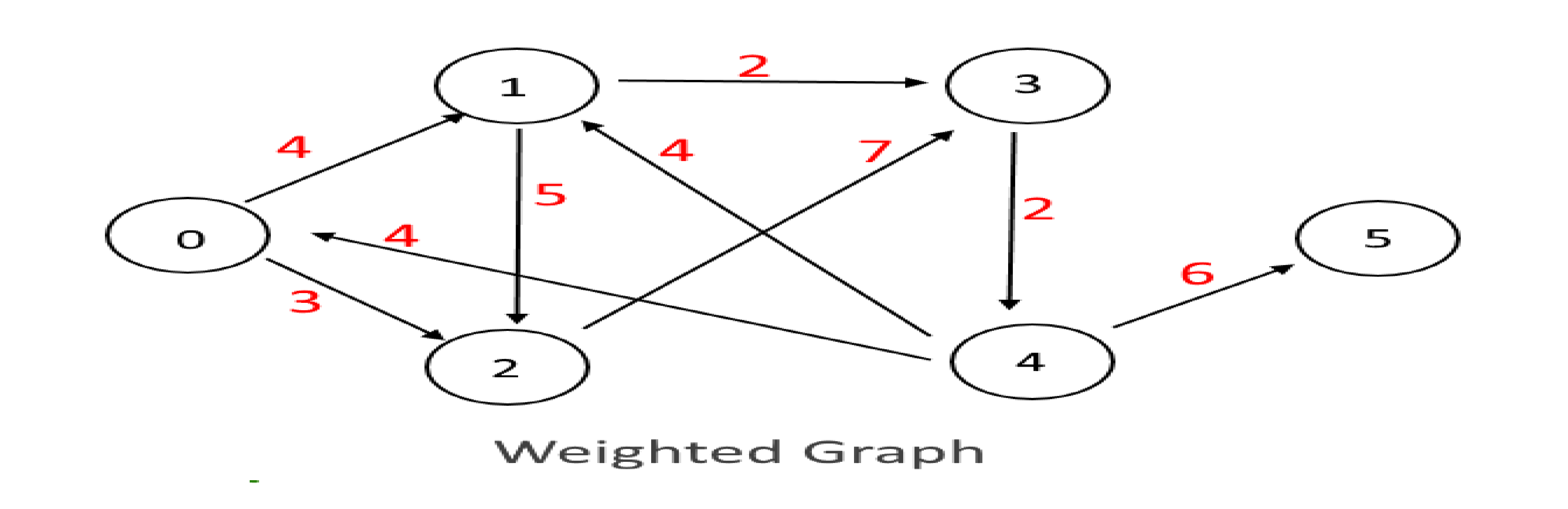
# (8) OPTIMAL SOLUTION PATH

- The best sequence of actions that leads to the goal state efficiently.


How to measure the performance **"Optimality"** ?
1- Reaching the goal
2- How **"expensive"** that path to the goal is

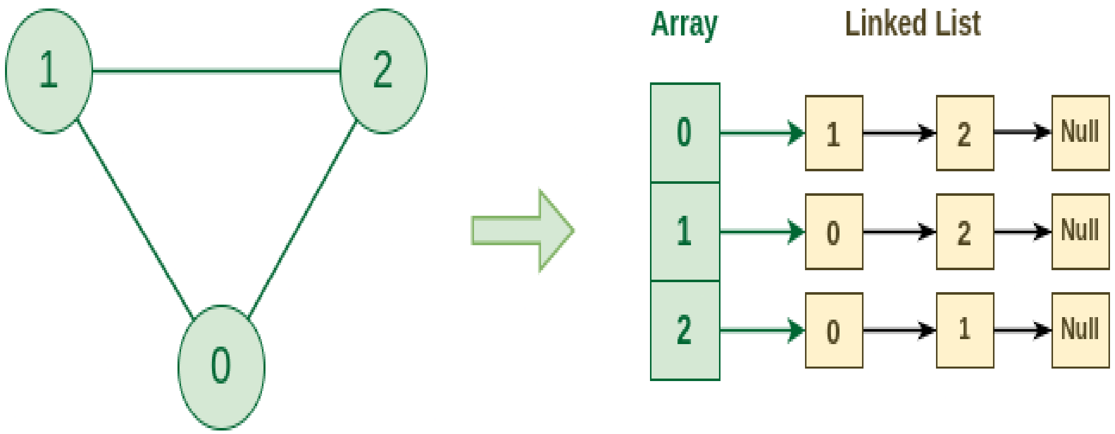
# (9) ADDITIONAL: PATH COST

- **Path Cost** refers to the total weight or cost of a path between two nodes in a graph.
- **For the solution path**, the total cost is the **sum of edge weights** along a specific path.



# GRAPH REPRESENTATIONS

# UNDIRECTED GRAPH



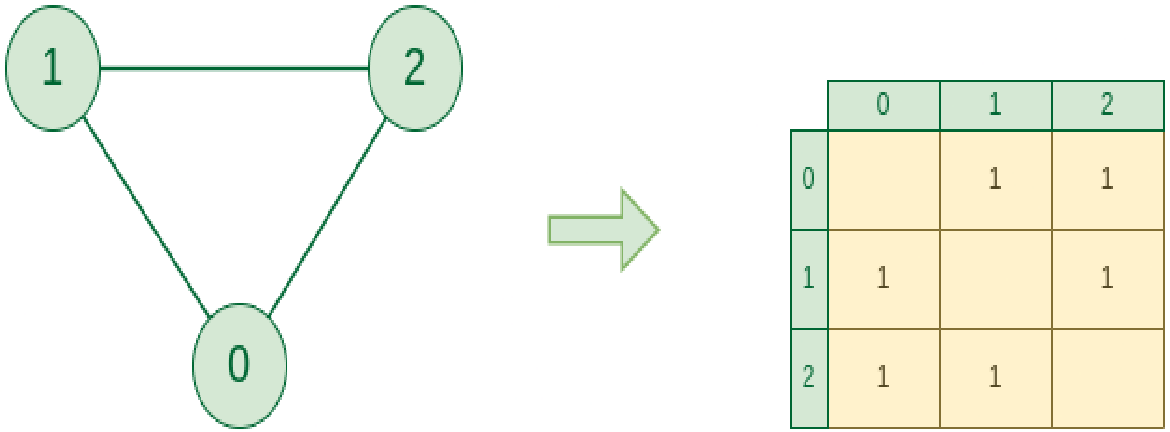

Undirected Graph

Adjacency List

## Adjacency List Method

Graph Representation of Undirected graph to Adjacency List

## Adjacency Matrix Method

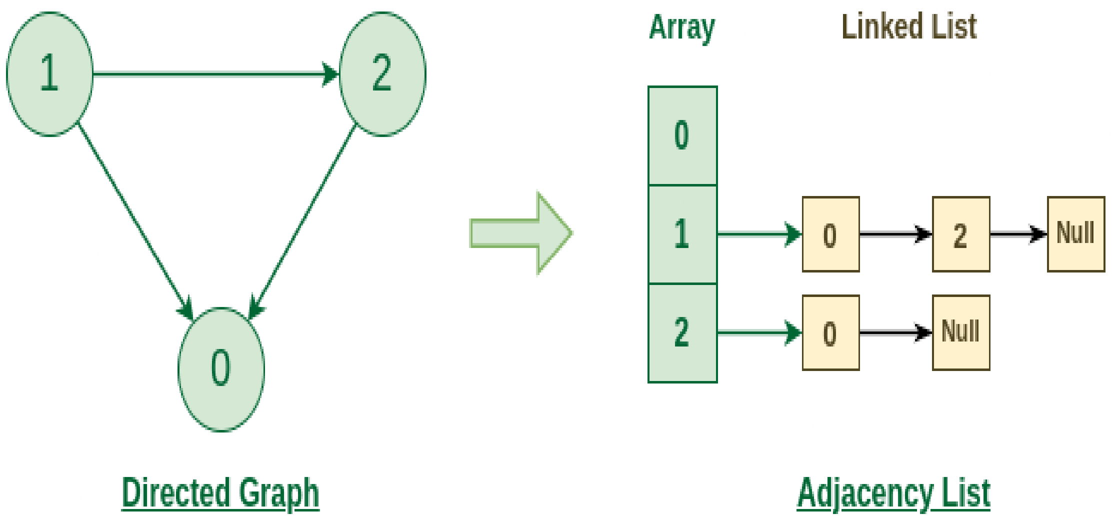


Undirected Graph

Adjacency Matrix

Graph Representation of Undirected graph to Adjacency Matrix

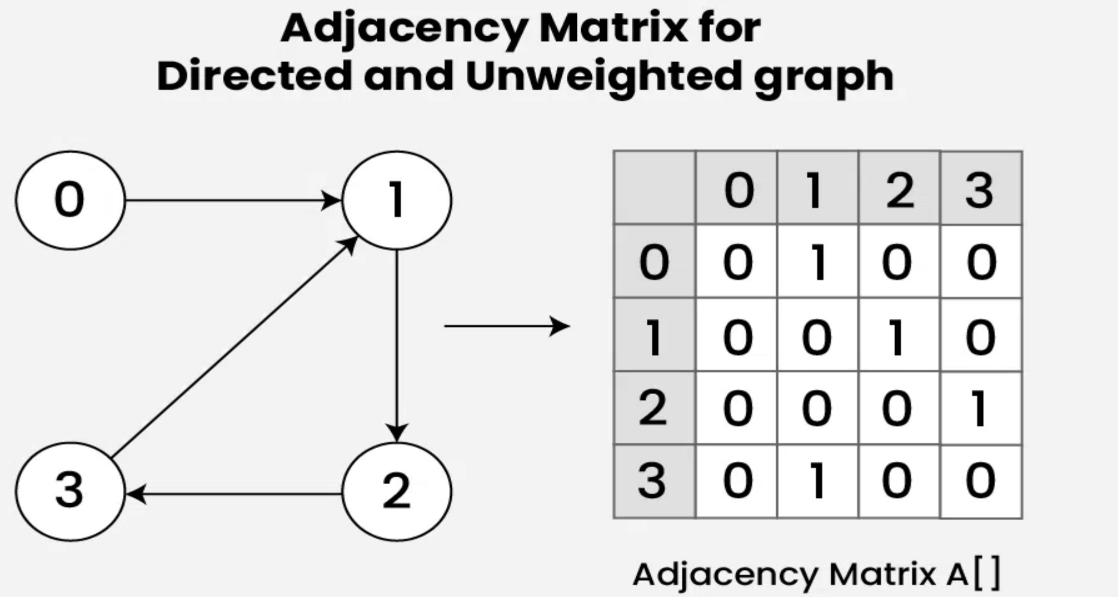
# DIRECTED GRAPH



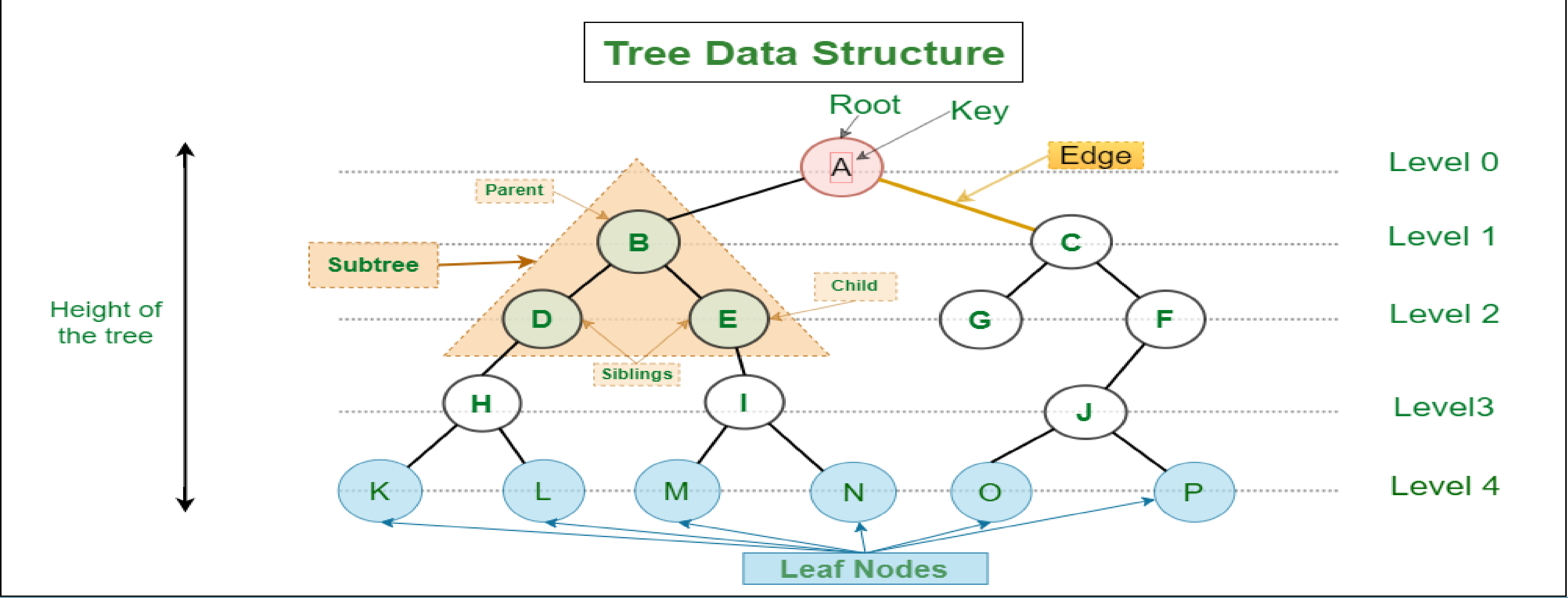

## Adjacency List Method

Graph Representation of Directed graph to Adjacency List

## Adjacency Matrix Method



# TREES




TREES

Special Type of graphs !

# TREE TRAVERSING

- **Tree traversal** refers to the process of visiting each node in a tree **systematically**. It is essential for searching, sorting, and processing data in tree-based structures.

| Pre-order | In-order | Post-order |
|---|---|---|
| Root-L-R | L-Root-R | L-R-Root |

# TREE TRAVERSING

- **Tree traversal** refers to the process of visiting each node in a tree **systematically**. It is essential for searching, sorting, and processing data in tree-based structures.

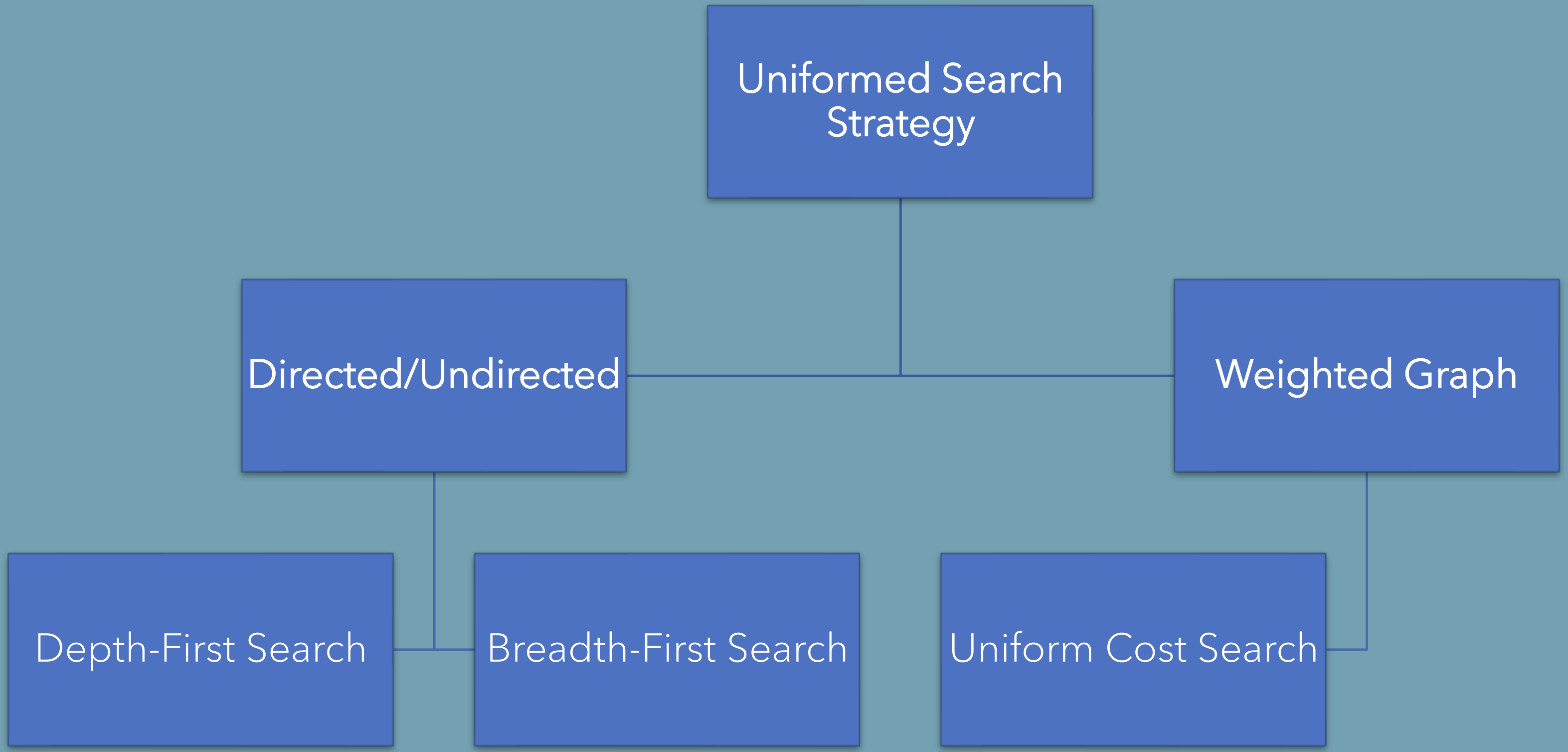
| Pre-order | In-order | Post-order |
| --- | --- | --- |
| Root-L-R | L-Root-R | L-R-Root |

Our Focus

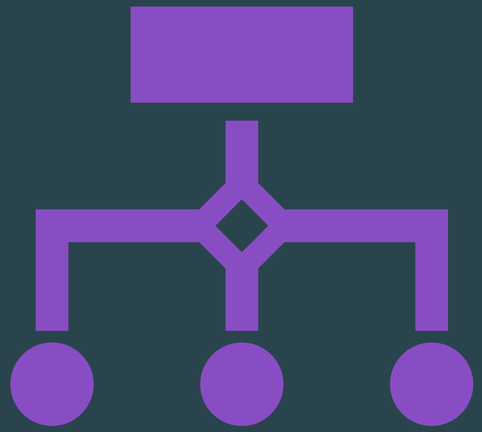
# HOW TO SEARCH ?
# (SEARCH STRATEGY)

# UNIFORMED SEARCH

- **Uniformed Search (Blind Search):** a type of search algorithm used in artificial intelligence to explore a problem space without any additional information about the state to reach it.



# BASIC SEARCH



1. Initialize an **empty list** and put the **initial state** in it
2. Take the first state in the **list as the current if <u>it is not visited yet</u> otherwise skip it**, and remove it from the list
3. **Check if the current is the goal state**, if it is, then terminate the search and **return the solution path**
4. Otherwise, expand the current of its successors, **and add them into the list using a queuing function**
5. Repeat from (2) to (4)
6. If the current becomes empty, then there is no solution and **return "fail"**

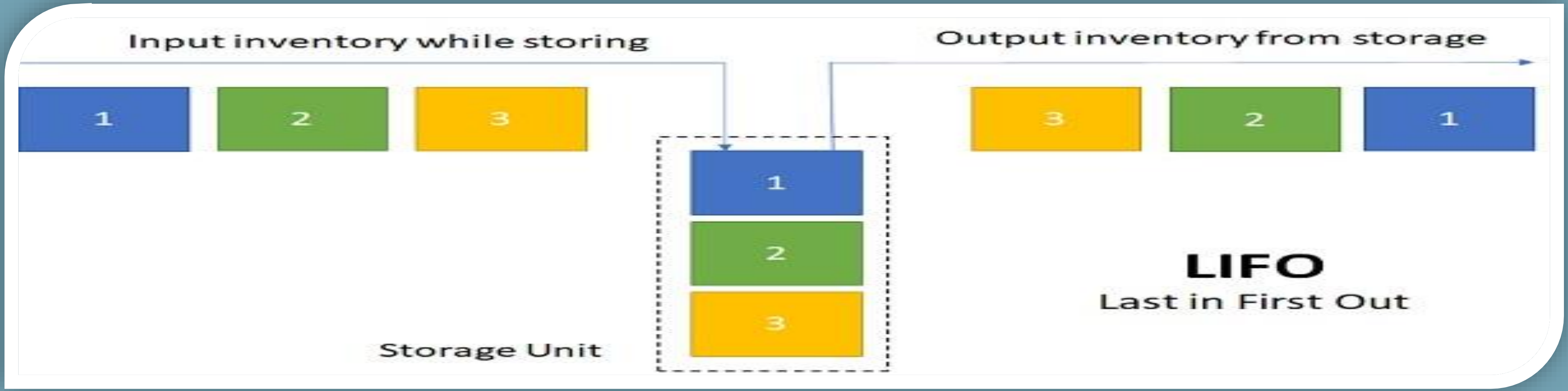
Don't Worry !

The only difference between all strategies is the <u>queuing function</u>

# DEPTH-FIRST SEARCH (العمق أولاً)

# LIFO Function

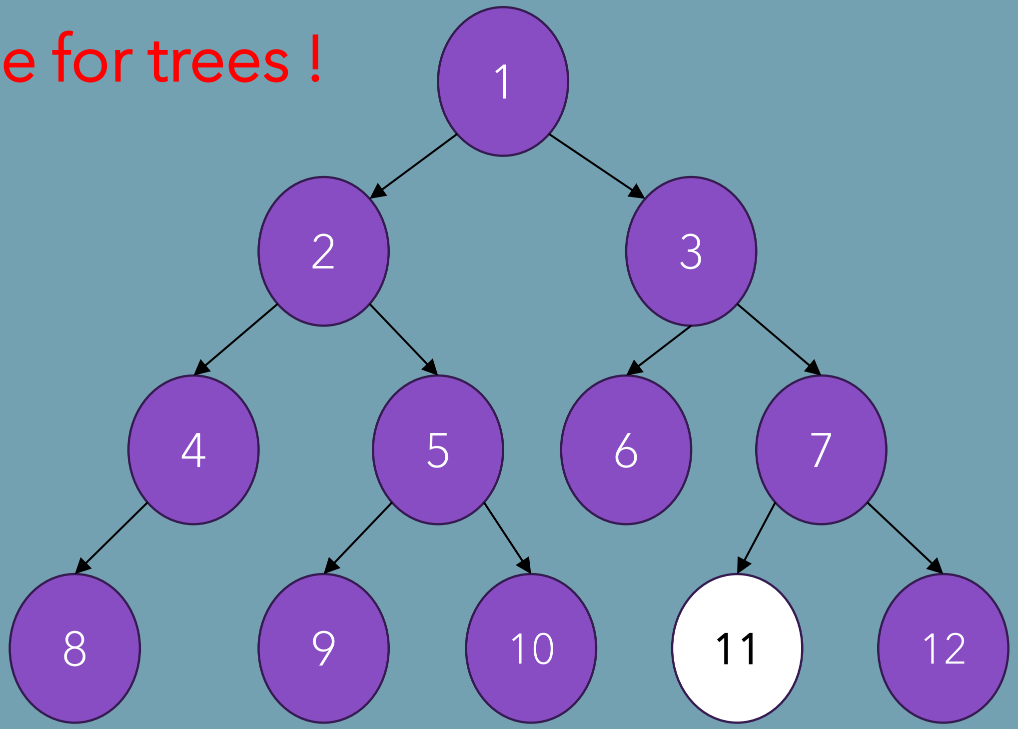
LIFO (Last In, First Out) is a data access principle where the last element added is the first one to be removed.



# DEPTH-FIRST SEARCH

Goal: 11

Remember:
Only Pre-order traverse for trees !

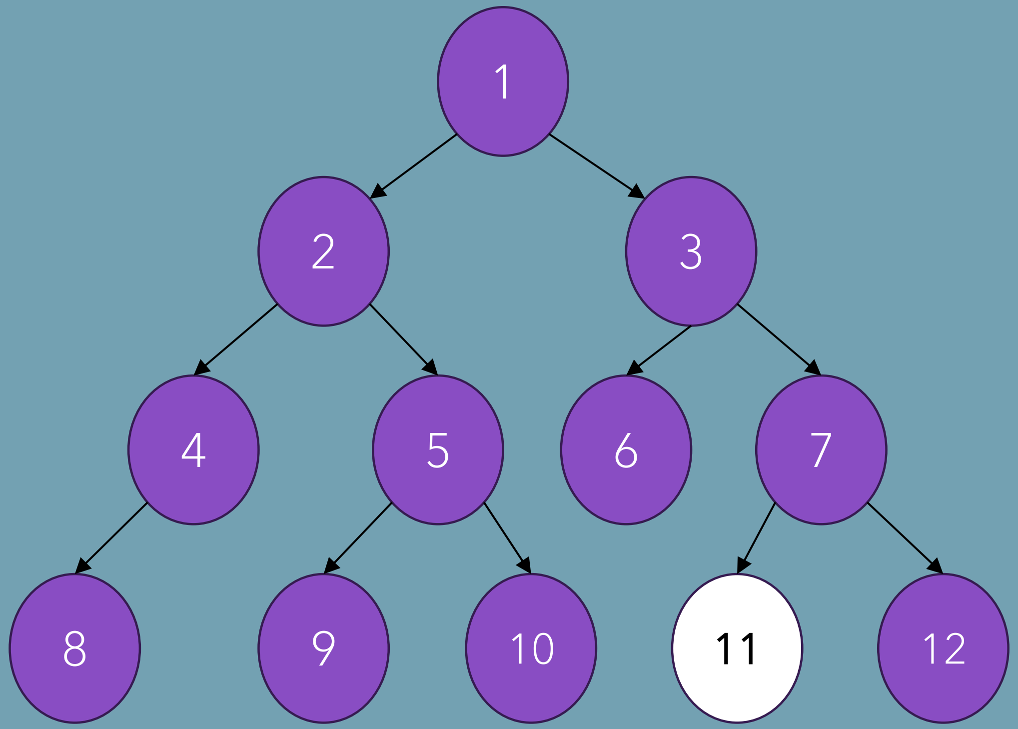



List

Direction of insert/remove

# DEPTH-FIRST SEARCH

Goal: 11



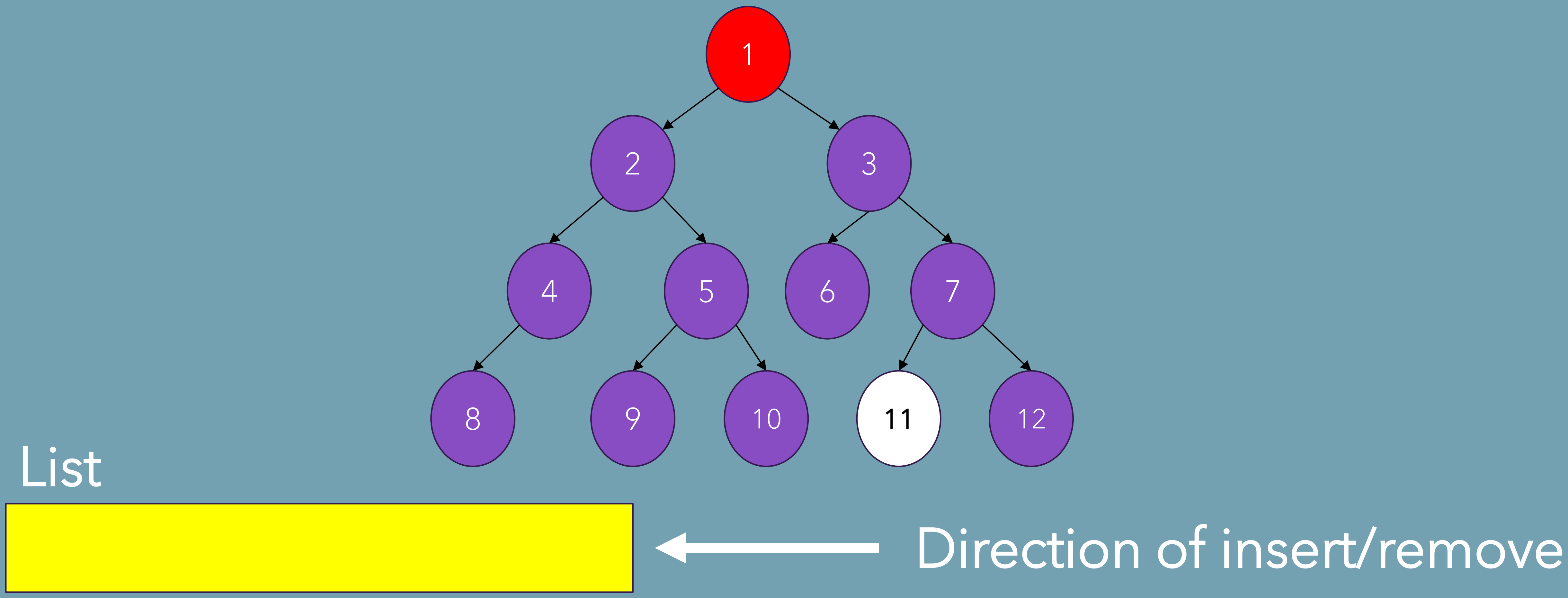

List

1

Direction of insert/remove

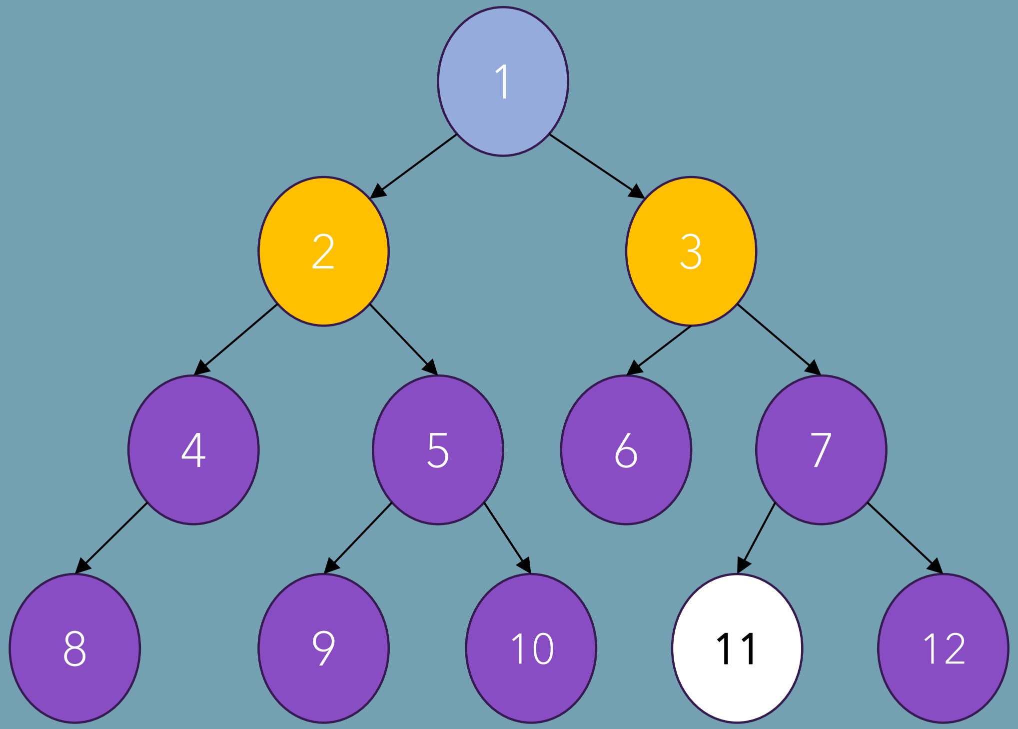
# DEPTH-FIRST SEARCH

Goal: 11



# DEPTH-FIRST SEARCH

Goal: 11



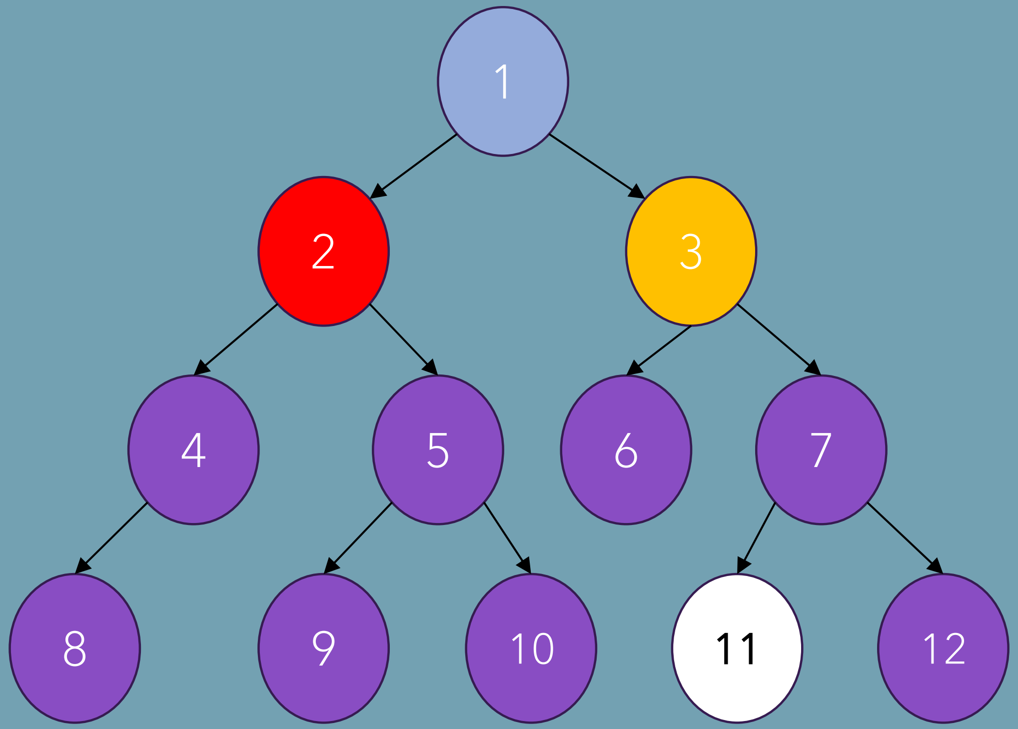

List

3,2

Direction of insert/remove

# DEPTH-FIRST SEARCH

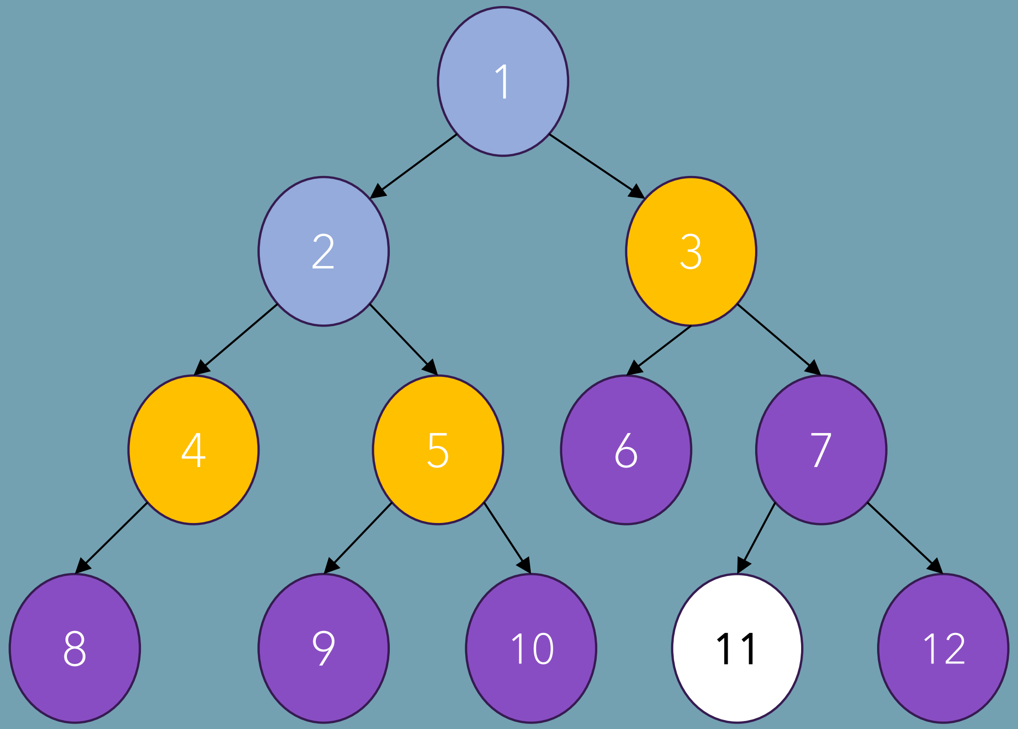
Goal: 11




List

# DEPTH-FIRST SEARCH

## Goal: 11



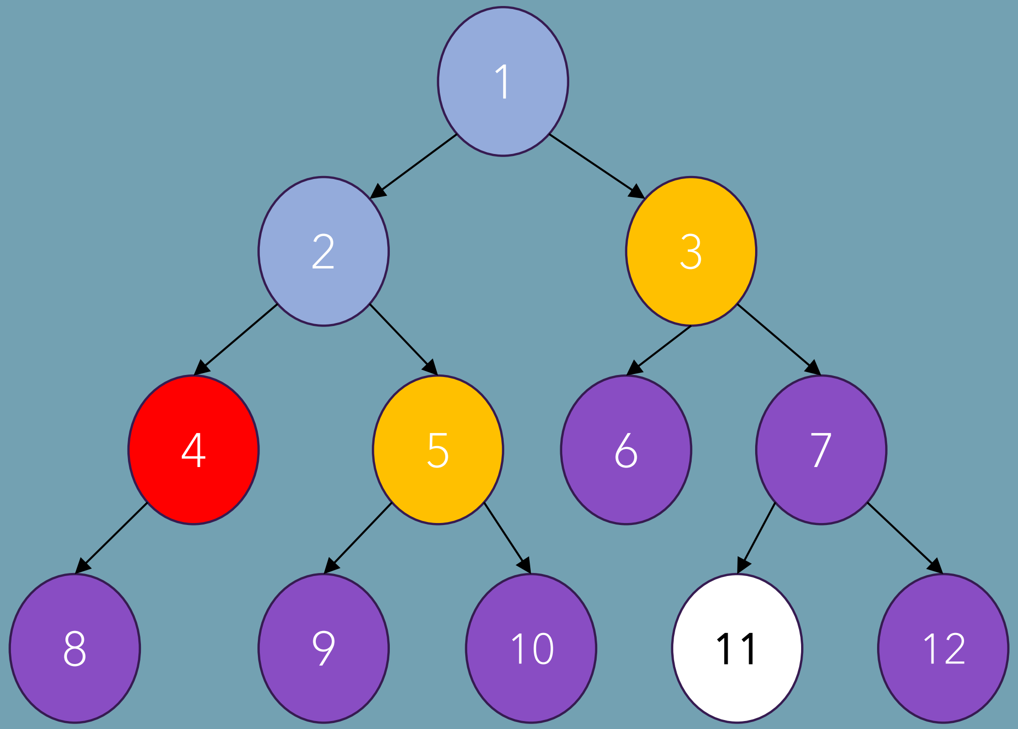

List

| |
|---|
| 3,5,4 |

← Direction of insert/remove

# DEPTH-FIRST SEARCH

Goal: 11



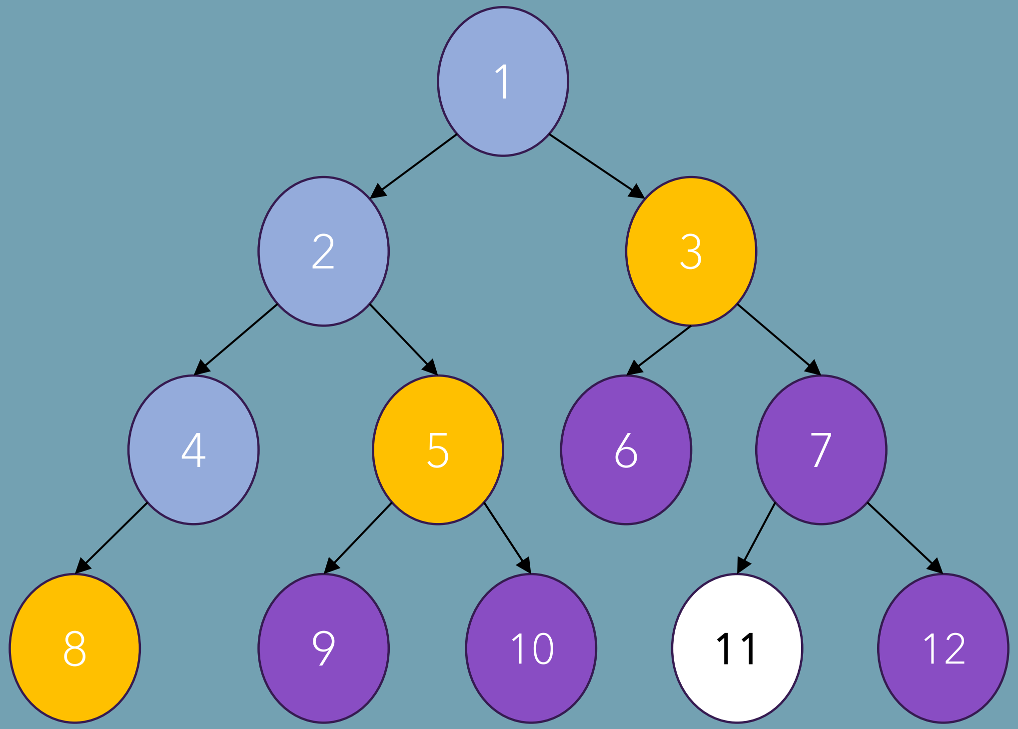

List

3,5

Direction of insert/remove

# DEPTH-FIRST SEARCH

# Goal: 11



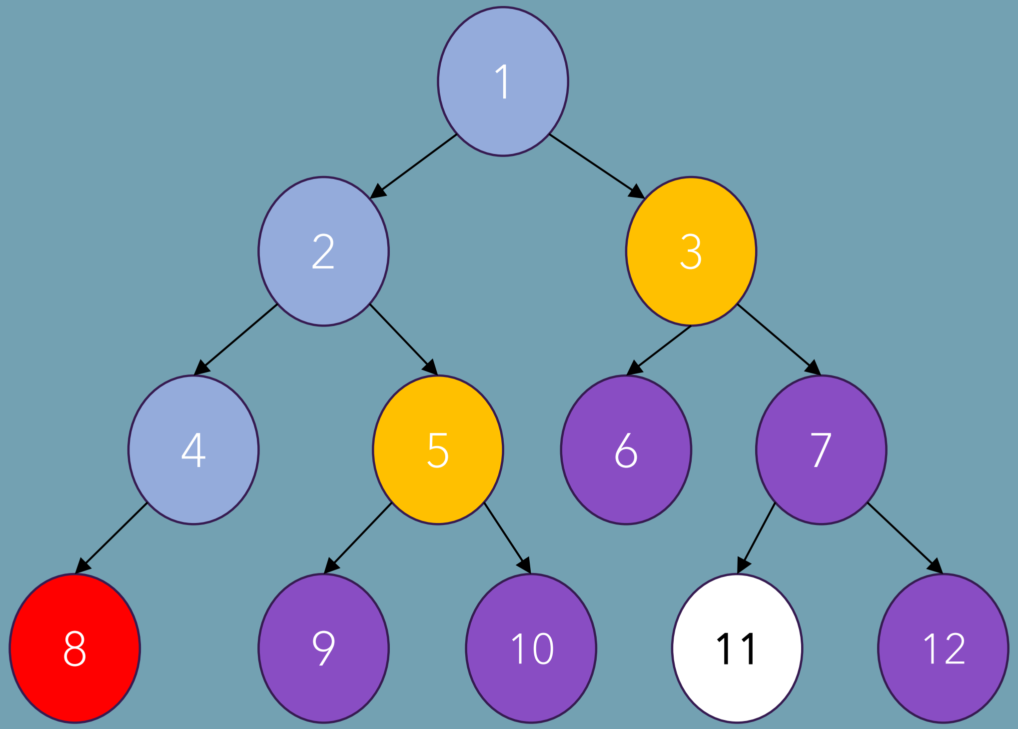

List

3,5,8

Direction of insert/remove

# DEPTH-FIRST SEARCH

# Goal: 11



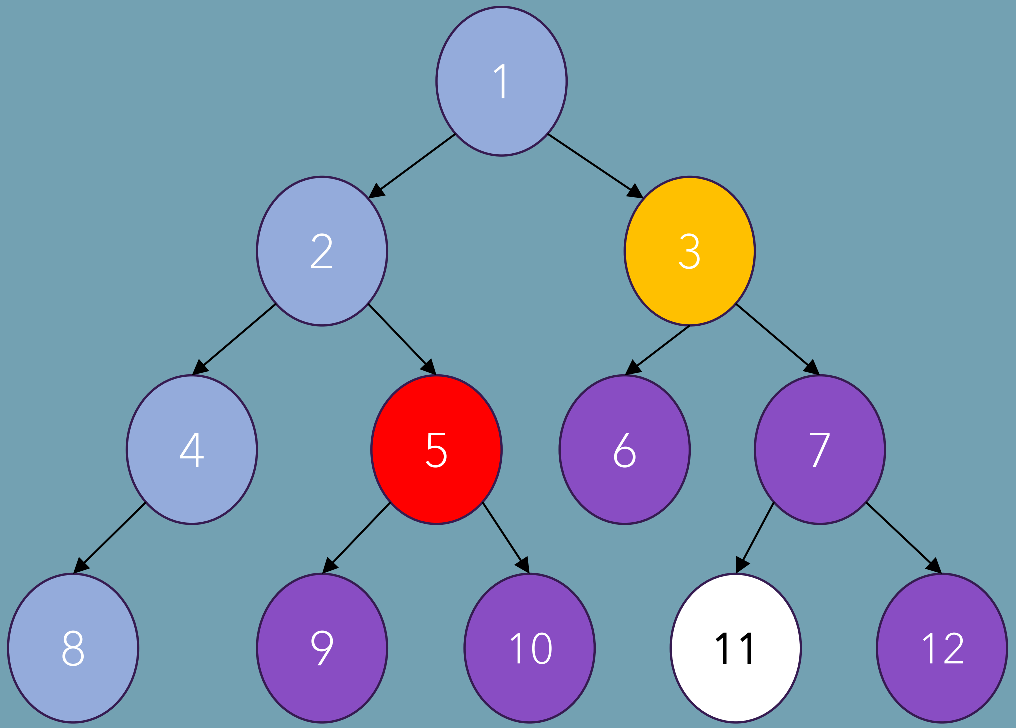

List

3,5

Direction of insert/remove

# DEPTH-FIRST SEARCH

Goal: 11



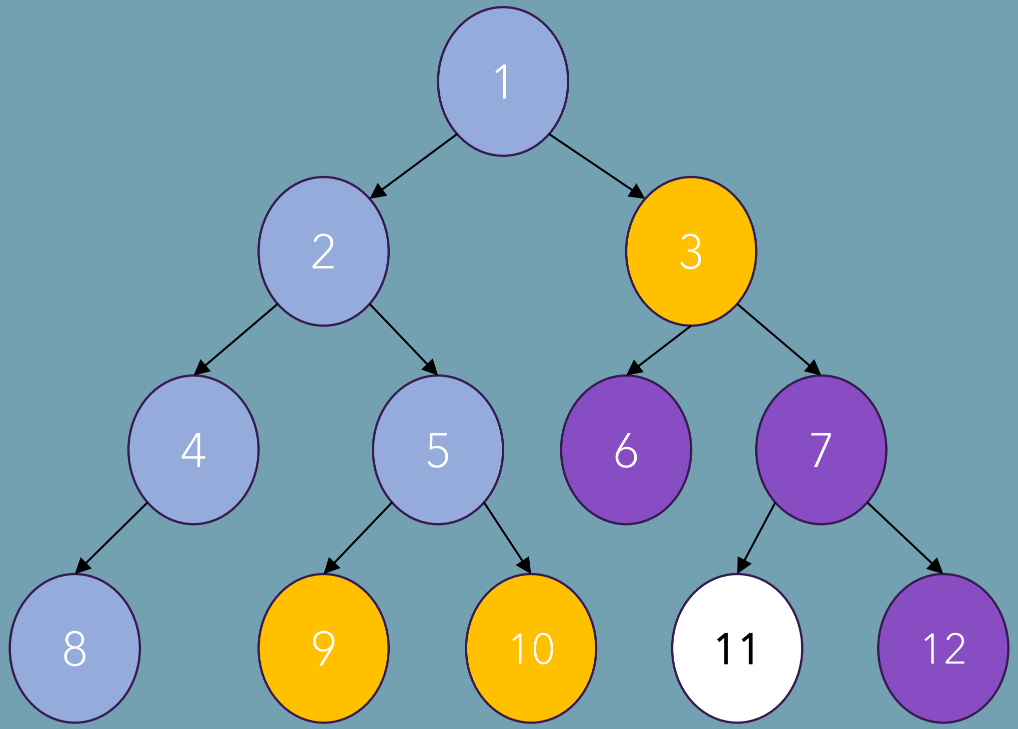

List

| |
|---|
| 3 |

Direction of insert/remove

# DEPTH-FIRST SEARCH

# Goal: 11



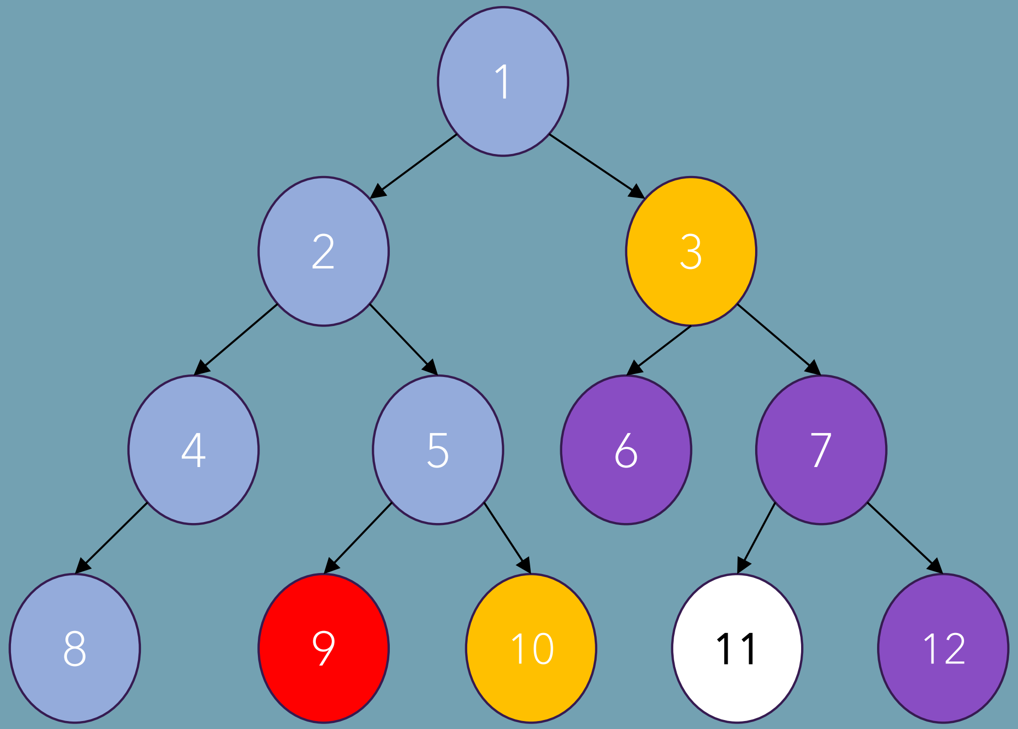

List

3,10,9

Direction of insert/remove

# DEPTH-FIRST SEARCH

# Goal: 11



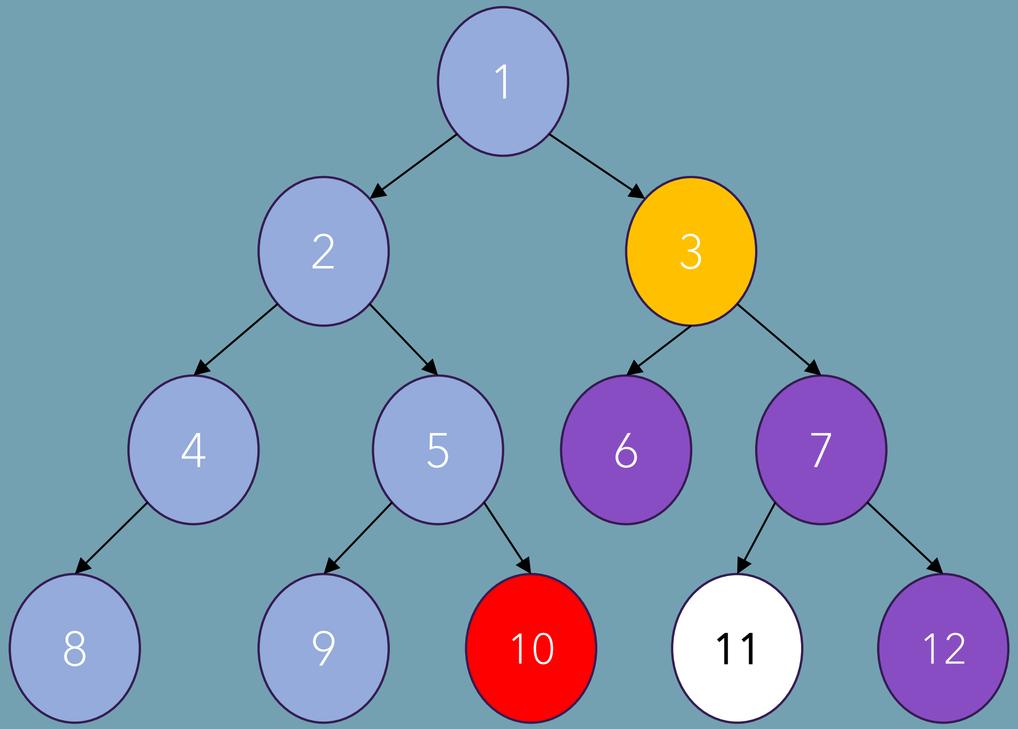

List

3,10

Direction of insert/remove

# DEPTH-FIRST SEARCH

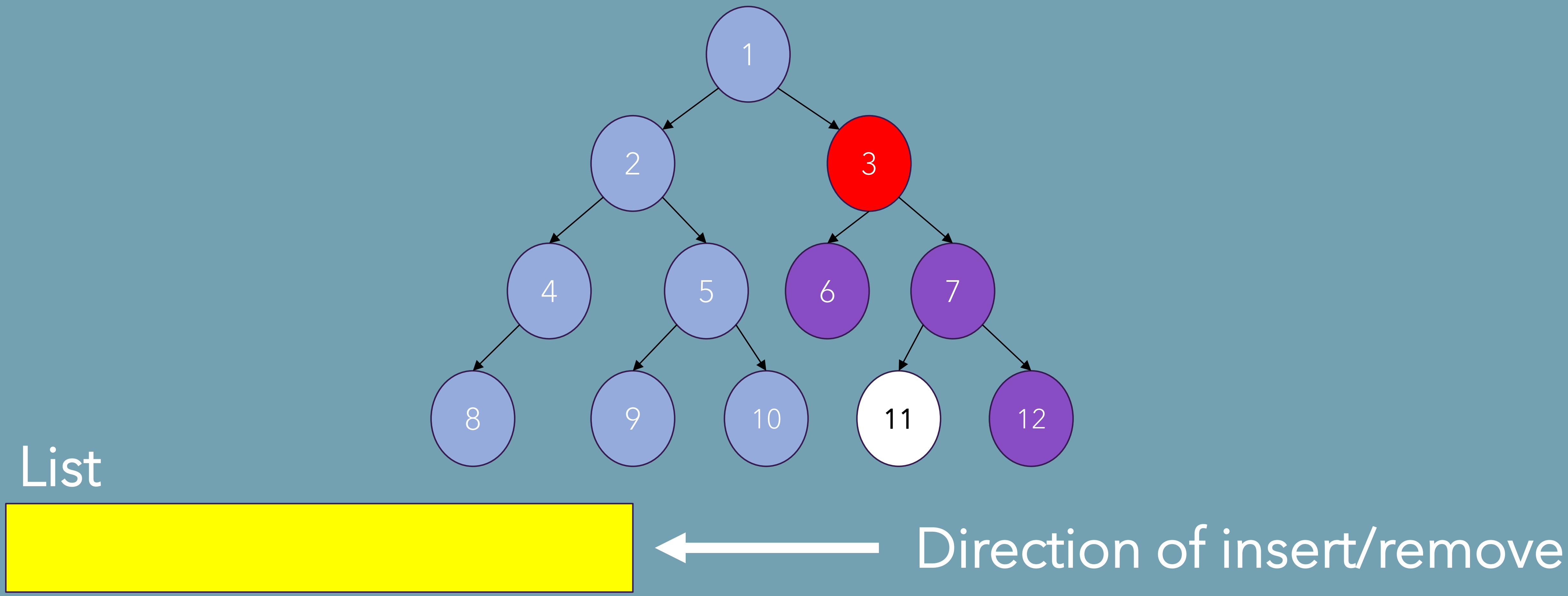
Goal: 11




List

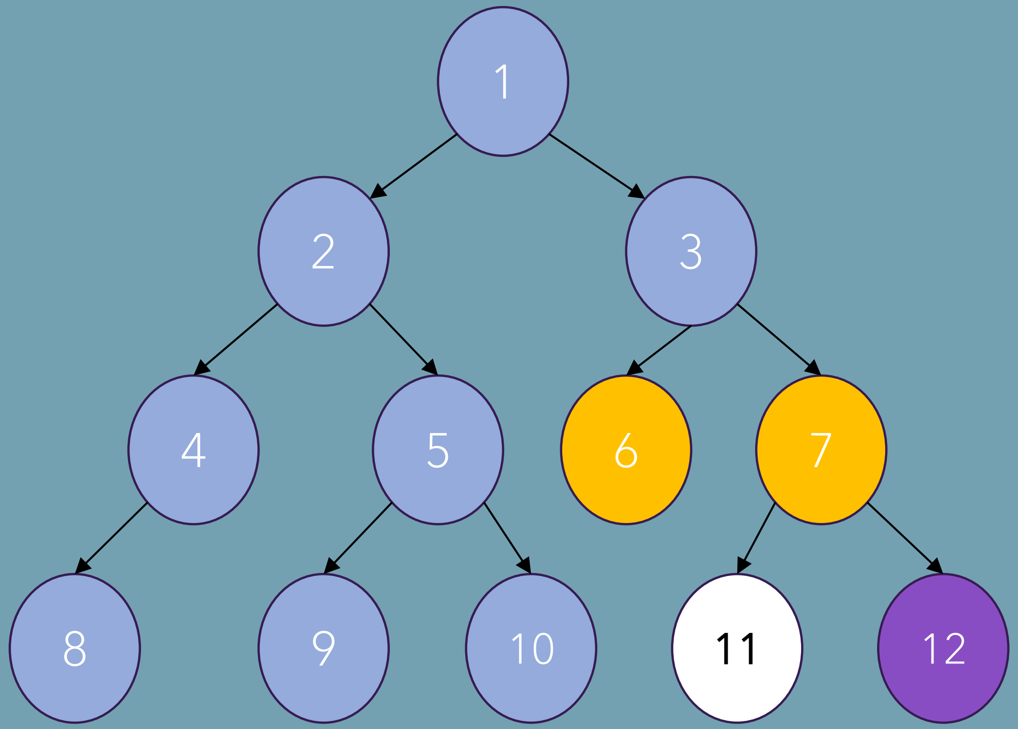
# DEPTH-FIRST SEARCH

## Goal: 11



# DEPTH-FIRST SEARCH

Goal: 11



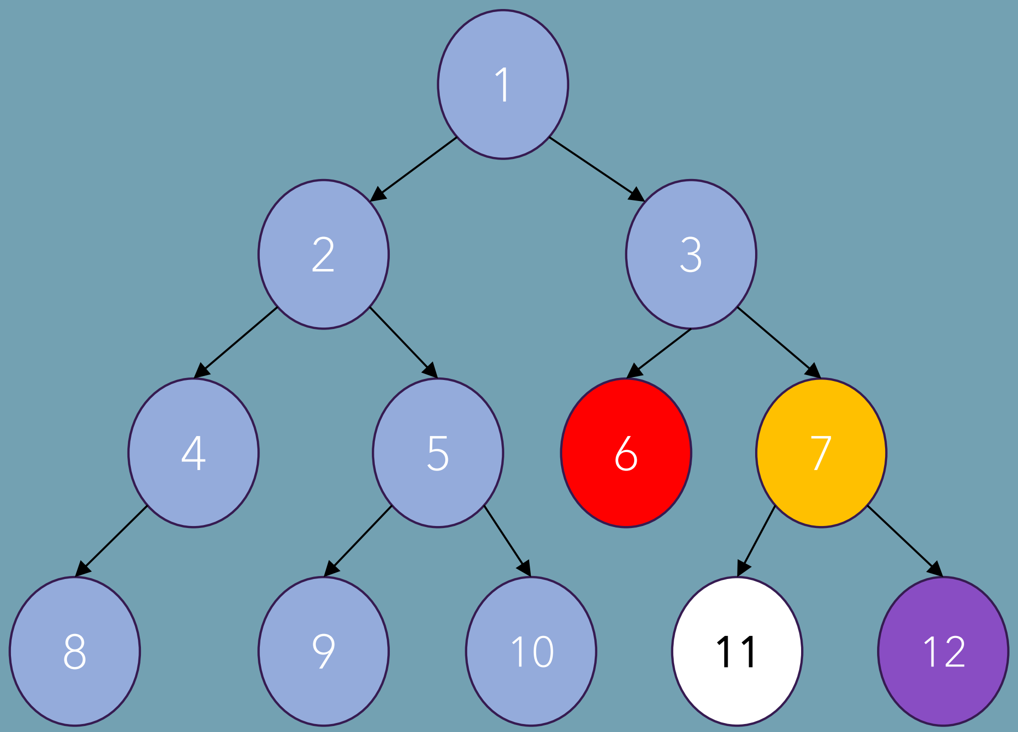

List

7,6

Direction of insert/remove

# DEPTH-FIRST SEARCH

# Goal: 11



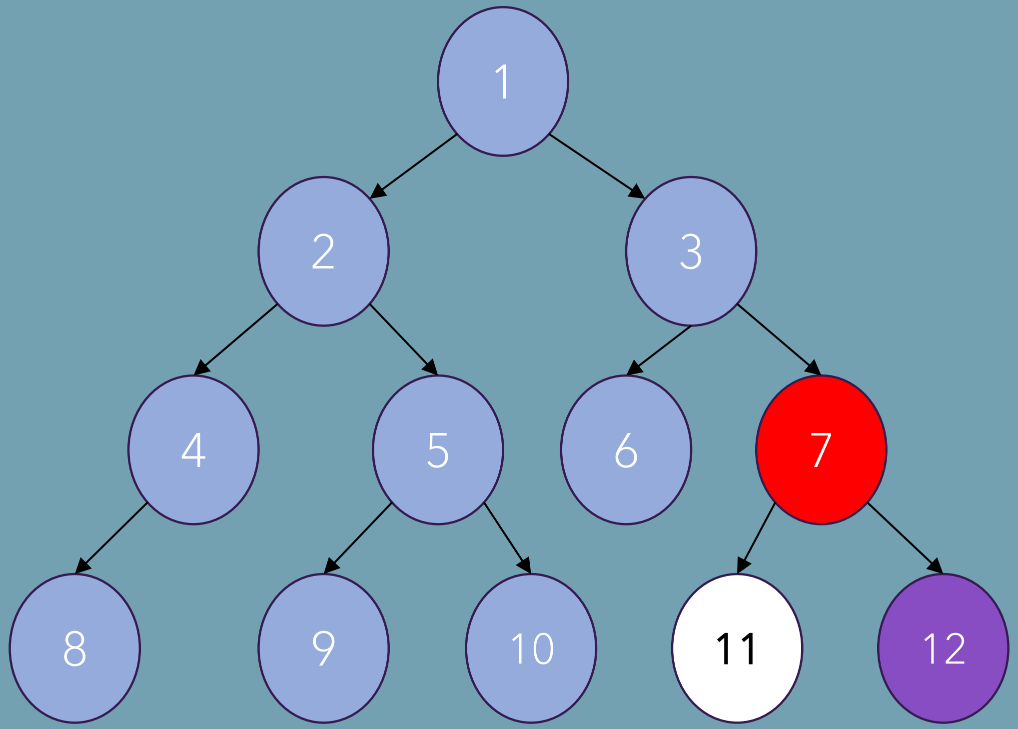

List

| |
|---|
| 7 |

Direction of insert/remove

# DEPTH-FIRST SEARCH

## Goal: 11

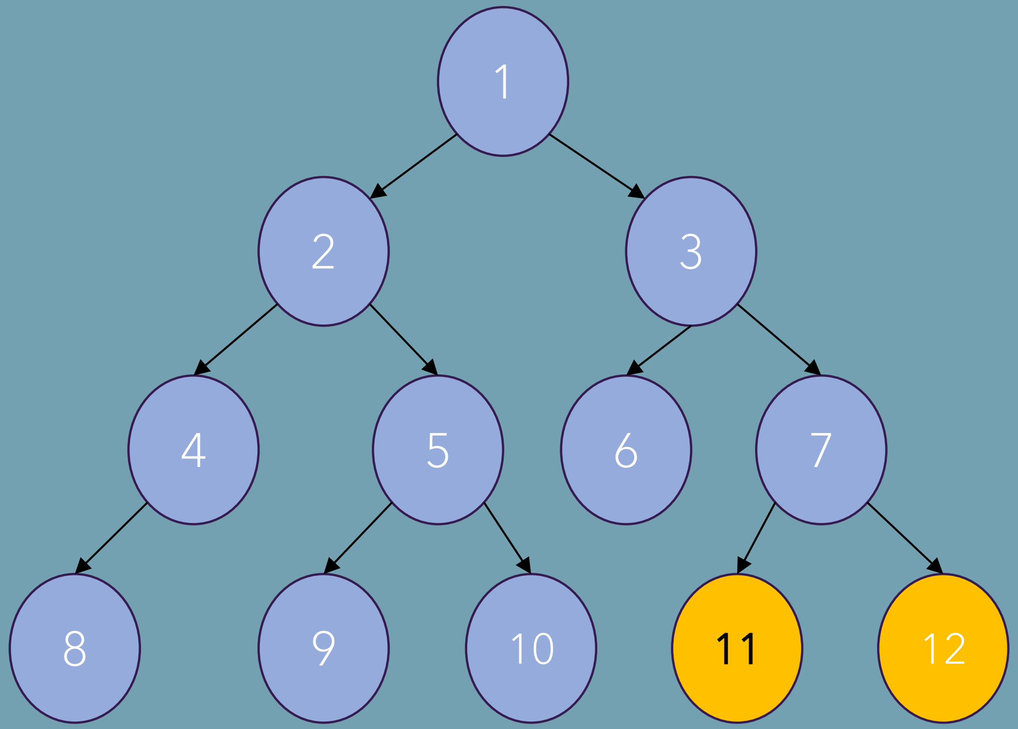



List

Direction of insert/remove

# DEPTH-FIRST SEARCH

# Goal: 11



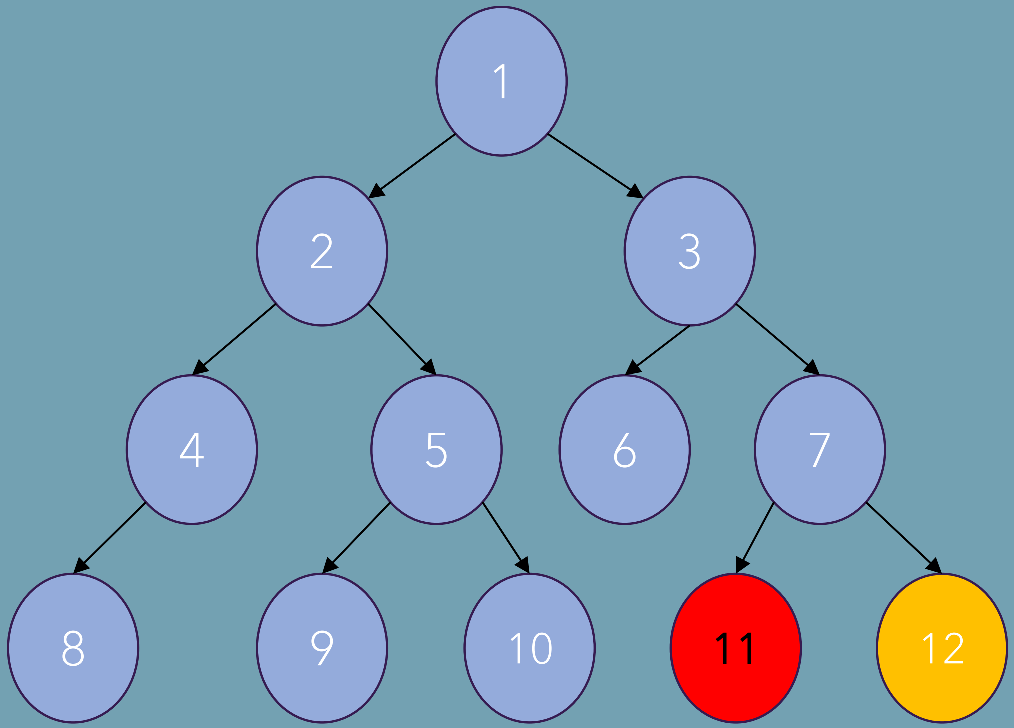

List

12,11

Direction of insert/remove

# DEPTH-FIRST SEARCH

## Goal: 11

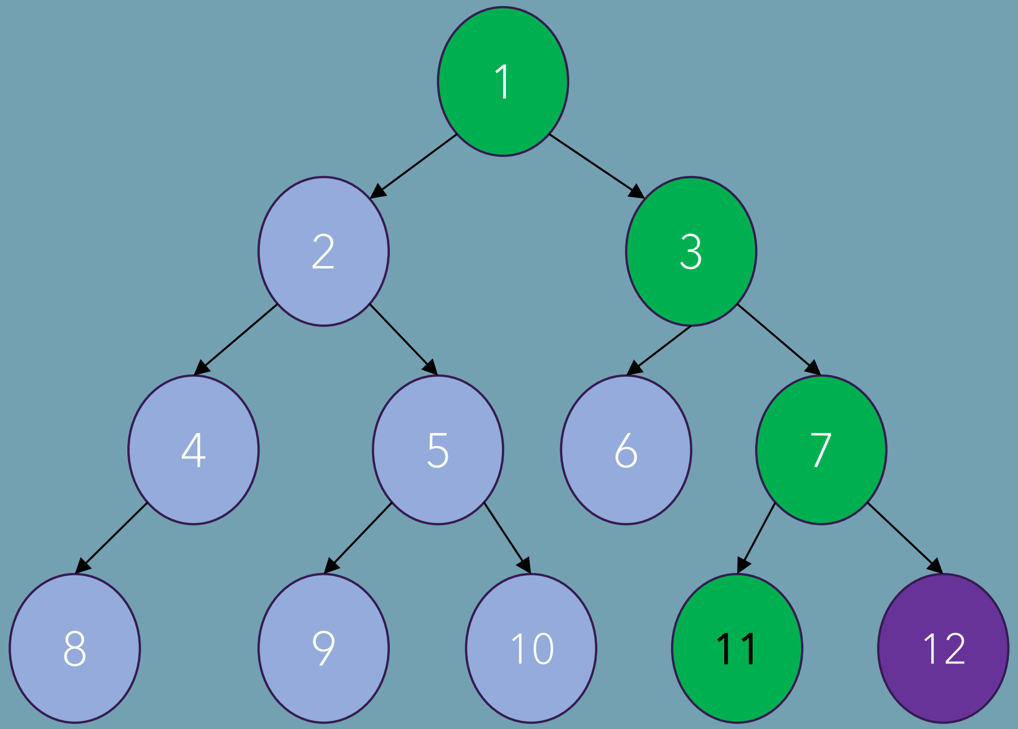



List

| |
|---|
| 12 |

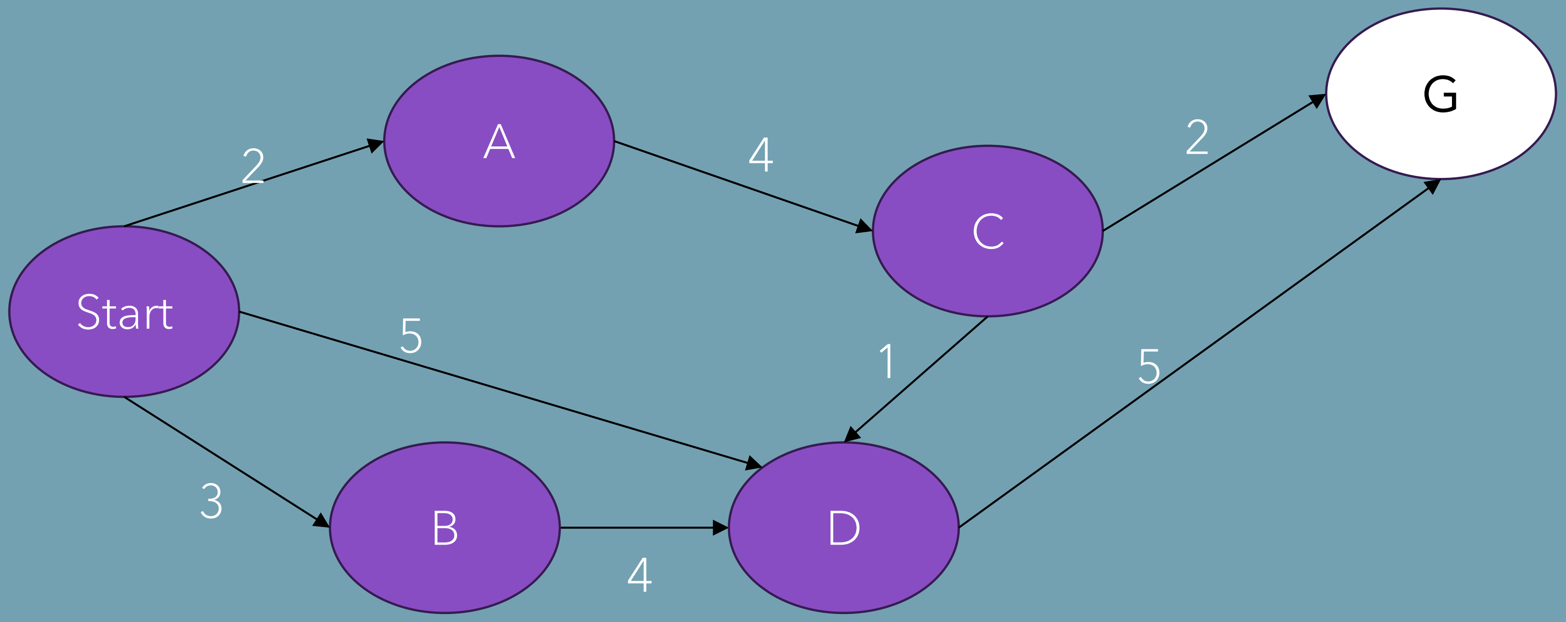
Direction of insert/remove

# DEPTH-FIRST SEARCH




Solution: [1, 3, 7, 11] – Visited: [1,2,4,8,5,9,10,3,6,7,11]

# DEPTH-FIRST SEARCH (GRAPH)




| Current | LIFO<br>- - - > TOP |
|---|---|
| | [S] |
| [S] | [S, A] , [S , B] , [S, D] |
| [S, D] | [S, A], [S , B] , [S, D, G] |
| [S, D, G] | [S, A] , [S , B] |

In graphs, Sort alphabetically each expansion only for unified answer for all students !

BREADTH-FIRST SEARCH (الاتساع بالعرض أولاً)

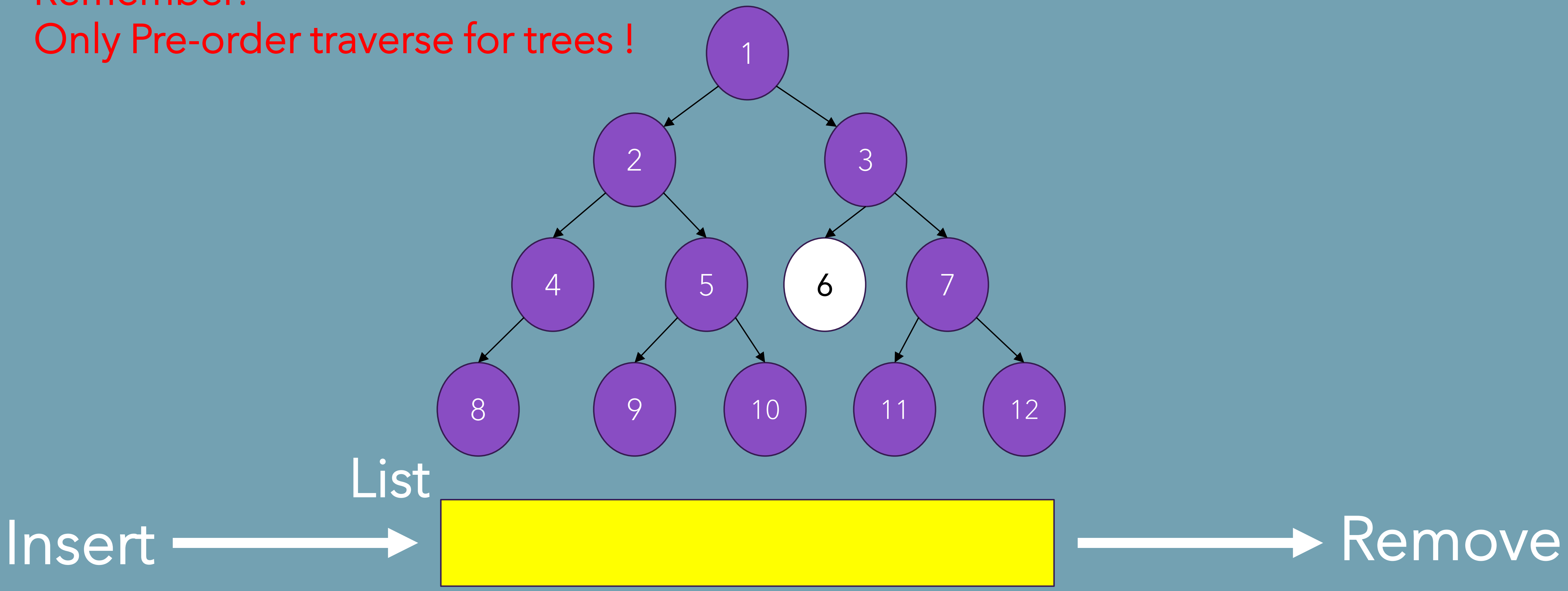
# FIFO Function

FIFO (First In, First Out) is a data access principle where the first element added is the first one to be removed.

# BREADTH-FIRST SEARCH

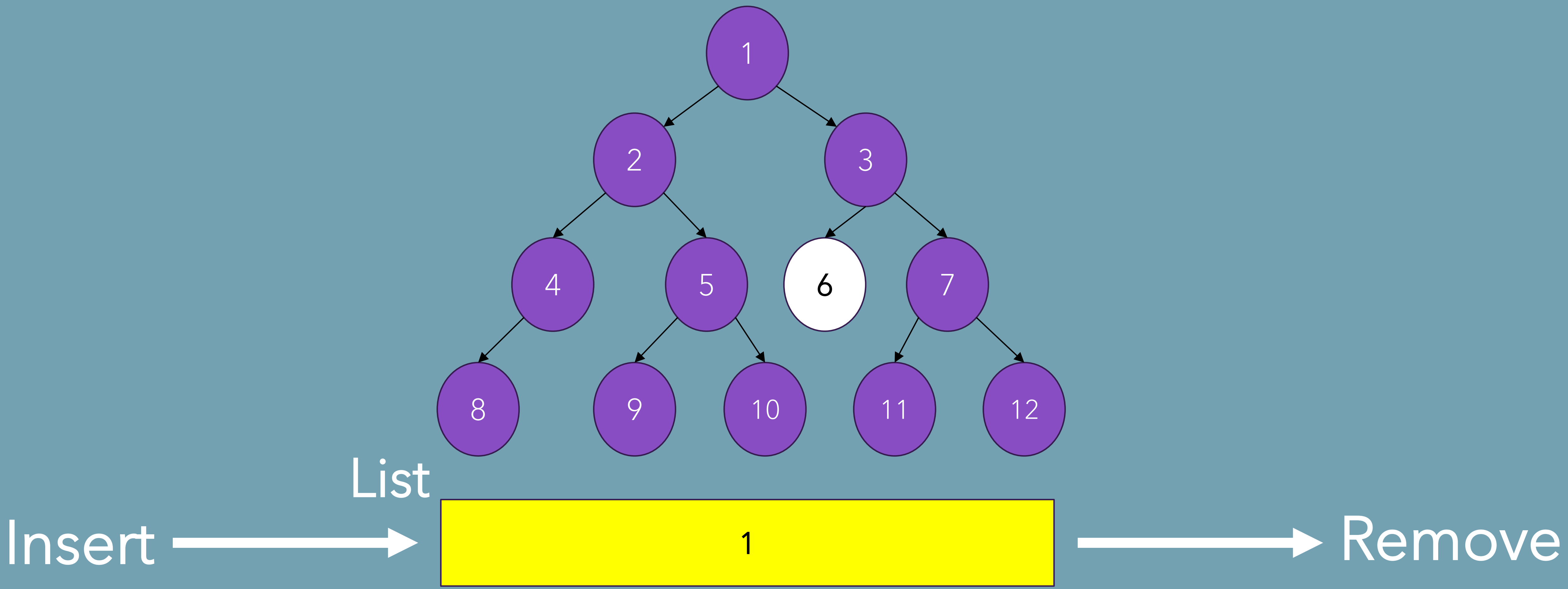
Goal: 6

Remember:
Only Pre-order traverse for trees !



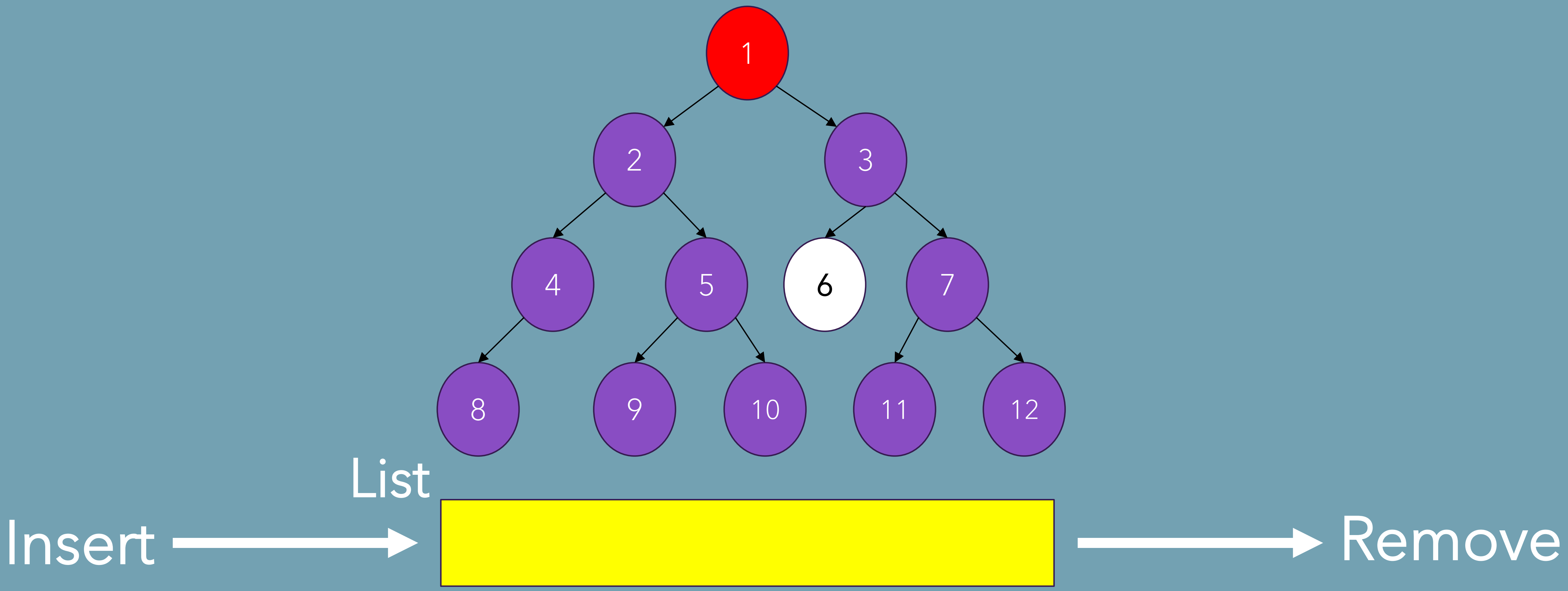
# BREADTH-FIRST SEARCH

Goal: 6



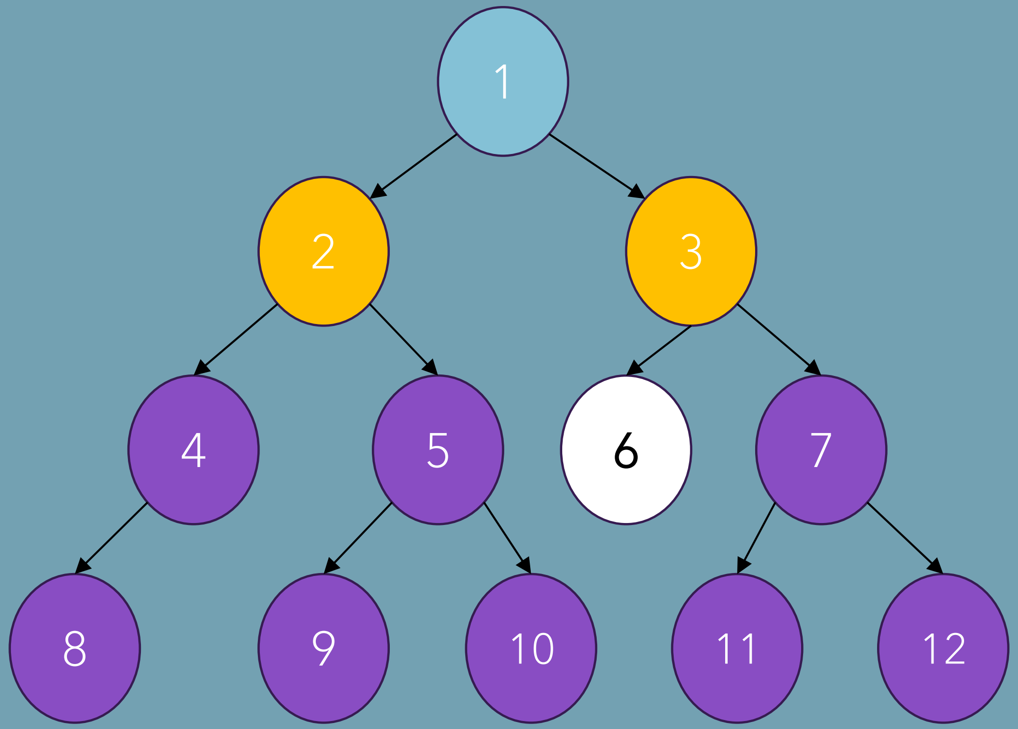
# BREADTH-FIRST SEARCH

Goal: 6



# BREADTH-FIRST SEARCH

# Goal: 6

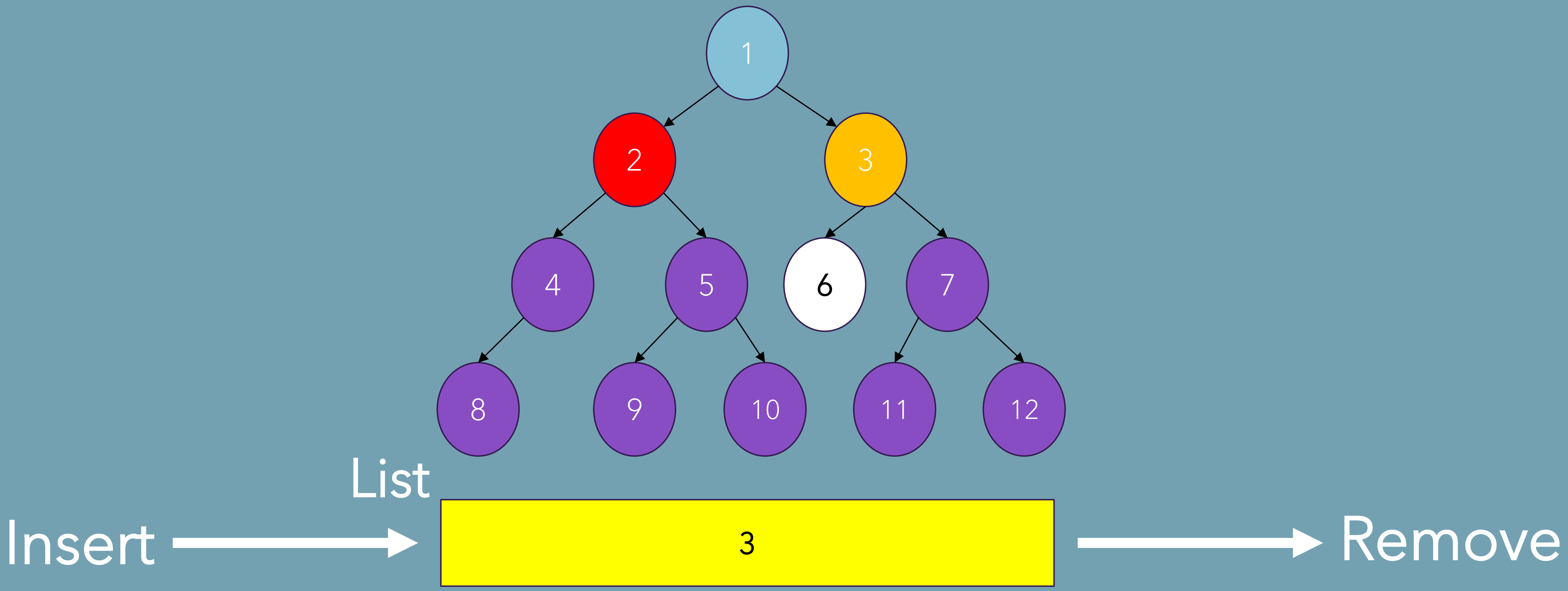



List

Insert → 3,2 → Remove

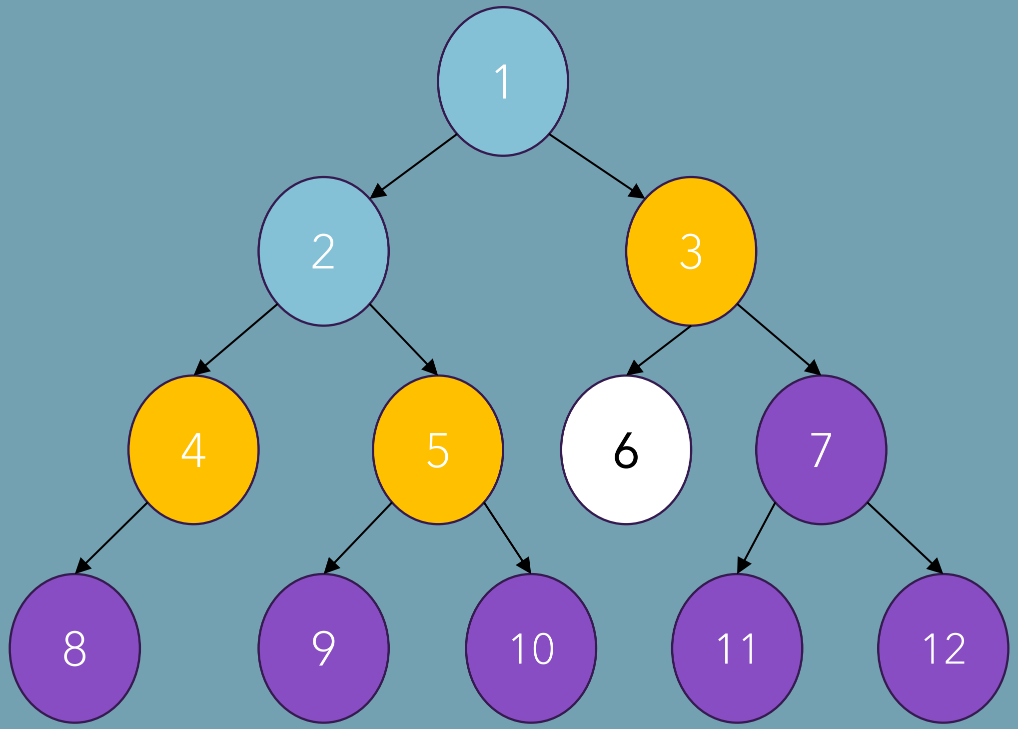
# BREADTH-FIRST SEARCH

Goal: 6



# BREADTH-FIRST SEARCH

Goal: 6

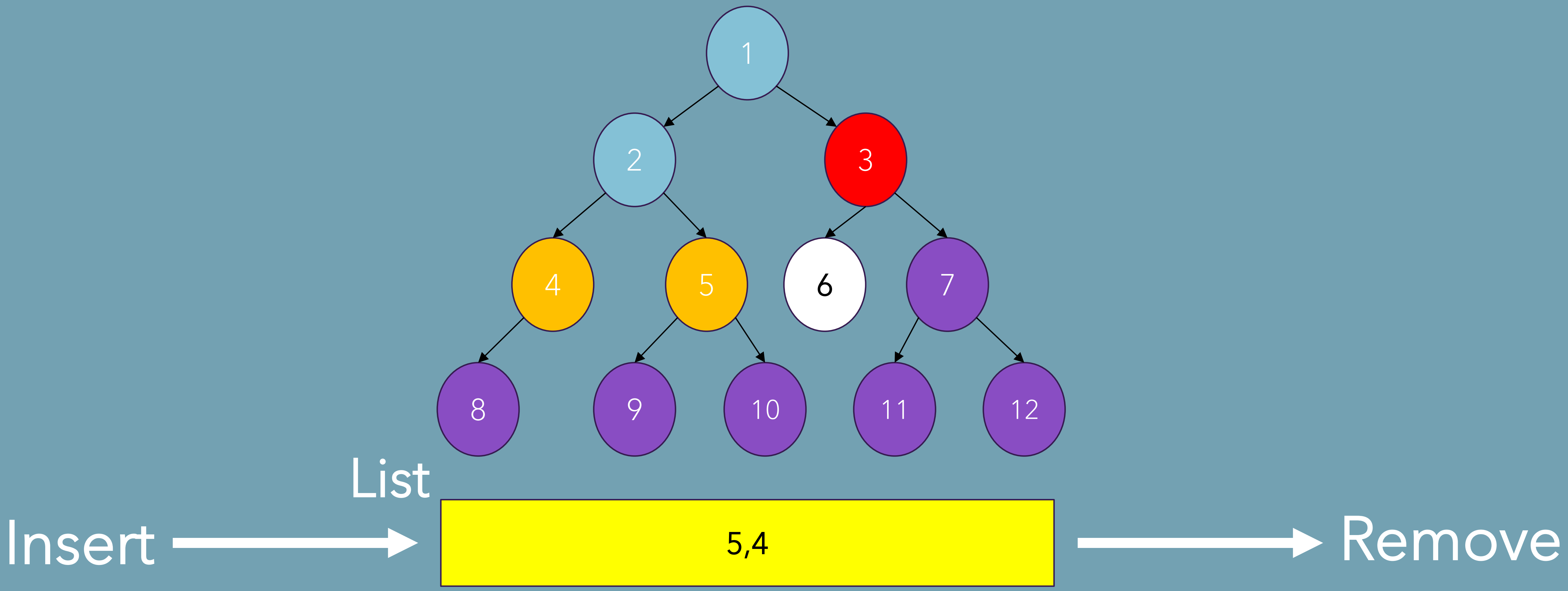



List

Insert → 5,4,3 → Remove

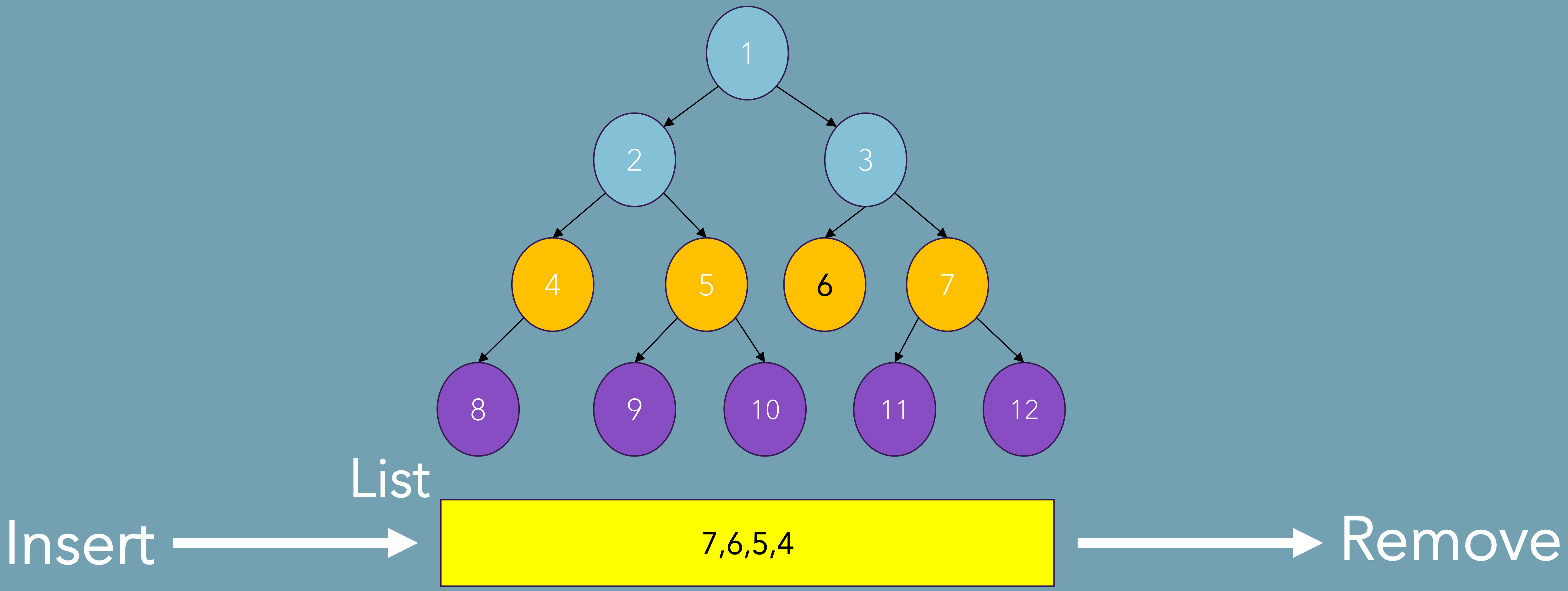
# BREADTH-FIRST SEARCH

Goal: 6



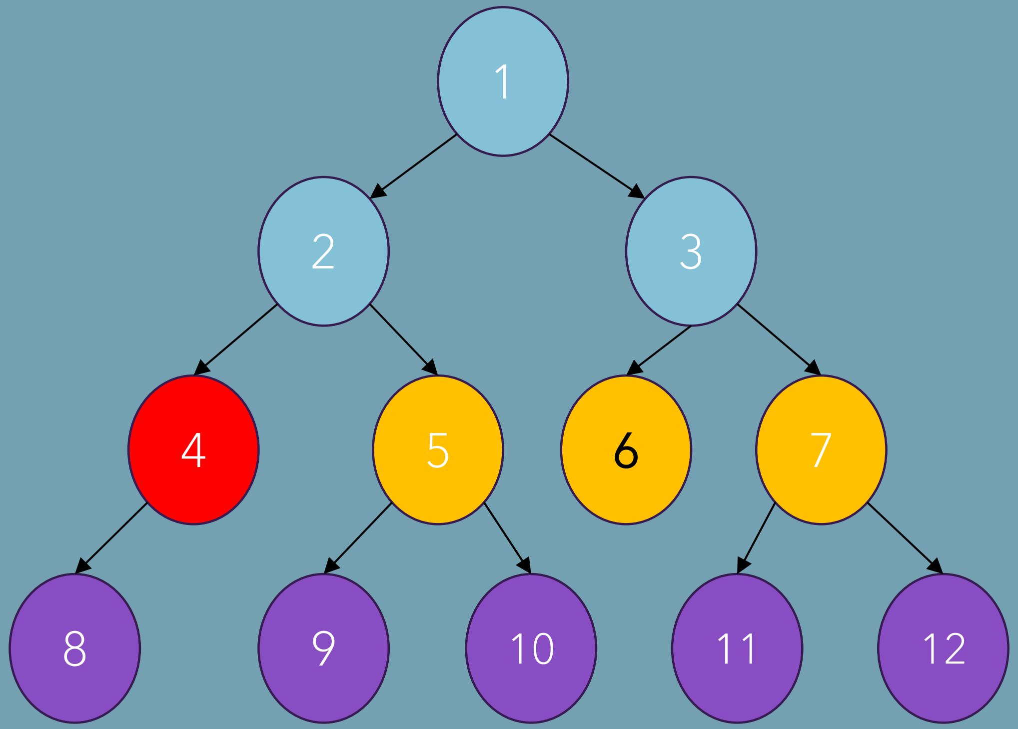
# BREADTH-FIRST SEARCH

Goal: 6



# BREADTH-FIRST SEARCH

Goal: 6

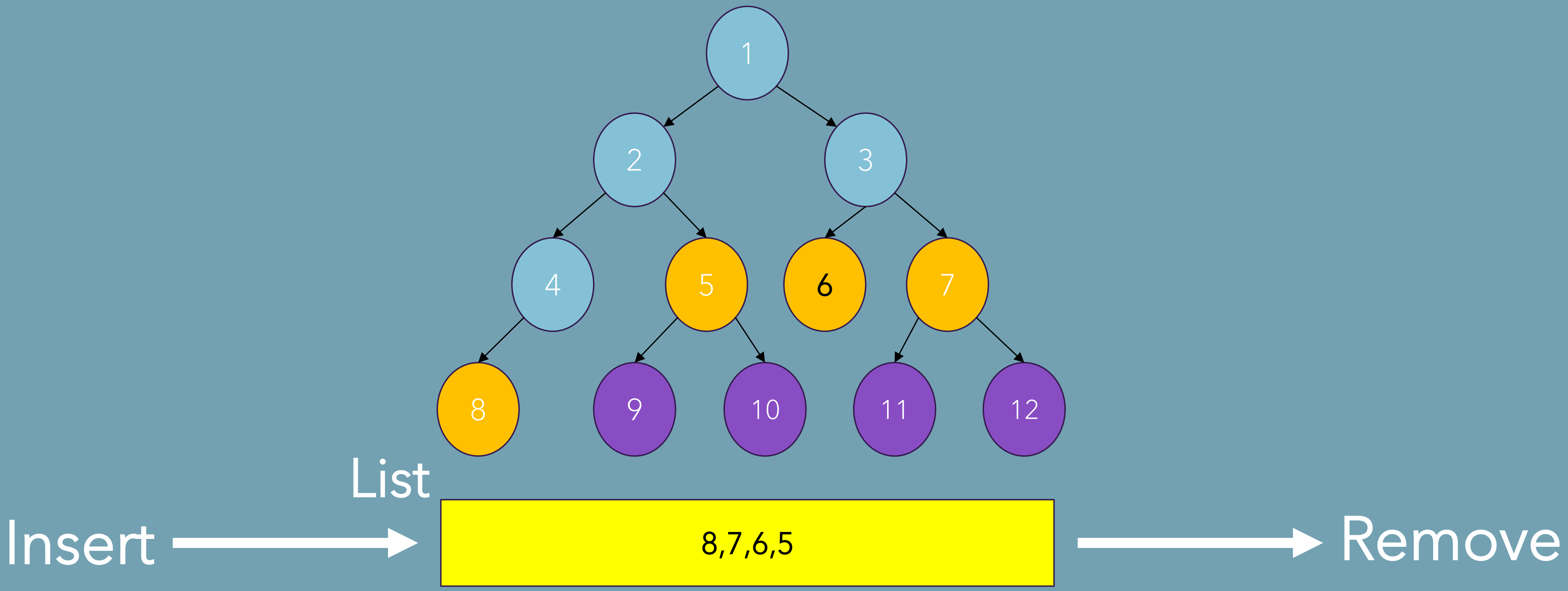



List

Insert → 7,6,5 → Remove

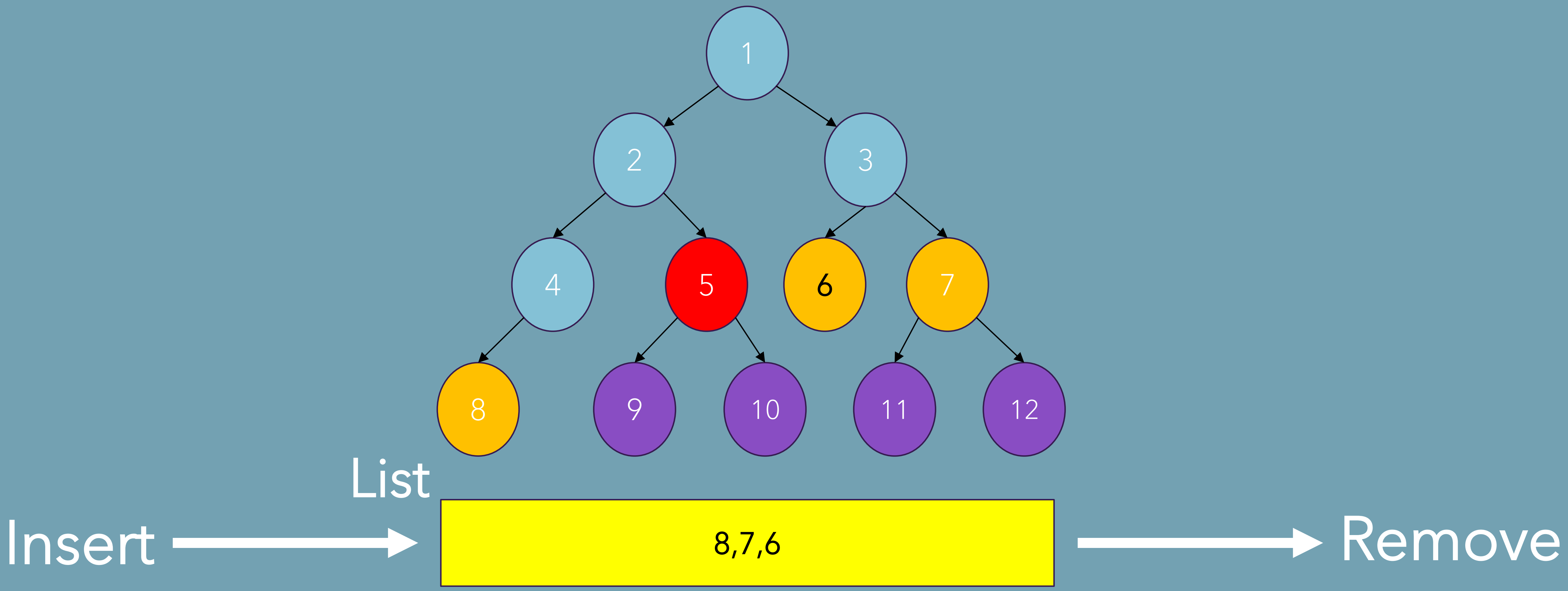
# BREADTH-FIRST SEARCH

Goal: 6



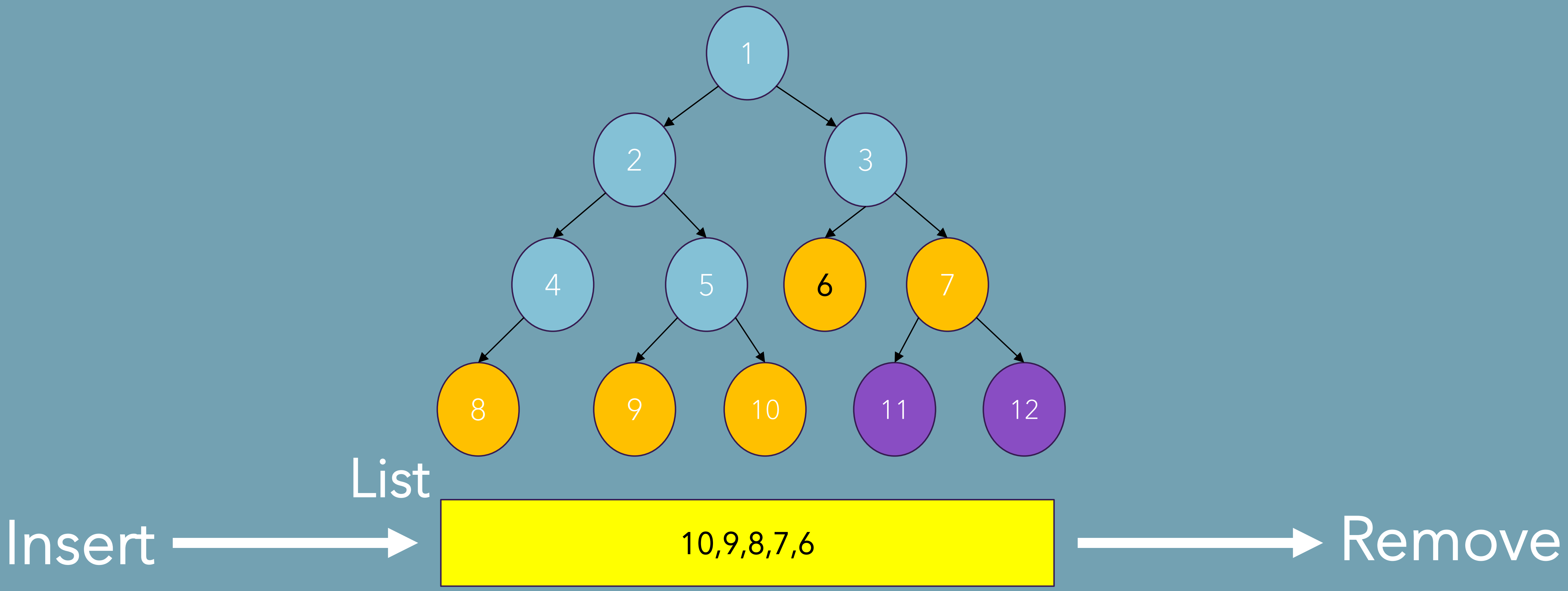
# BREADTH-FIRST SEARCH

Goal: 6



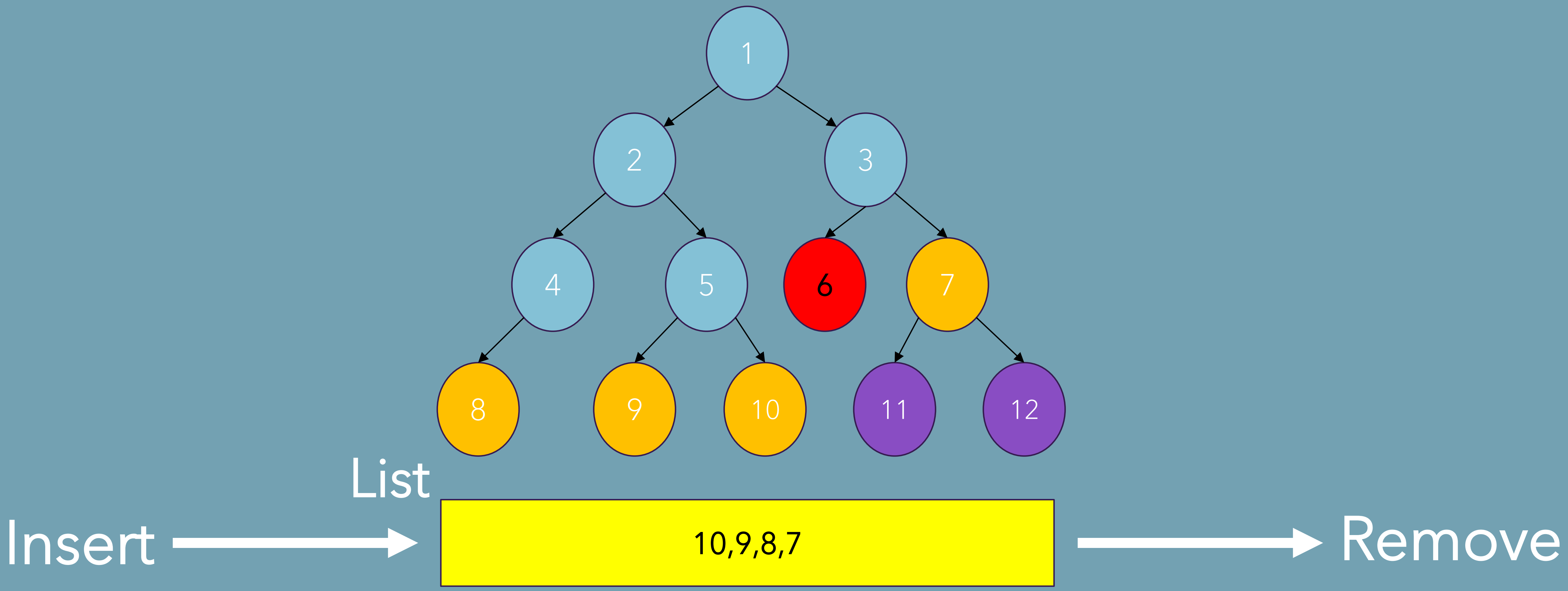
# BREADTH-FIRST SEARCH

Goal: 6



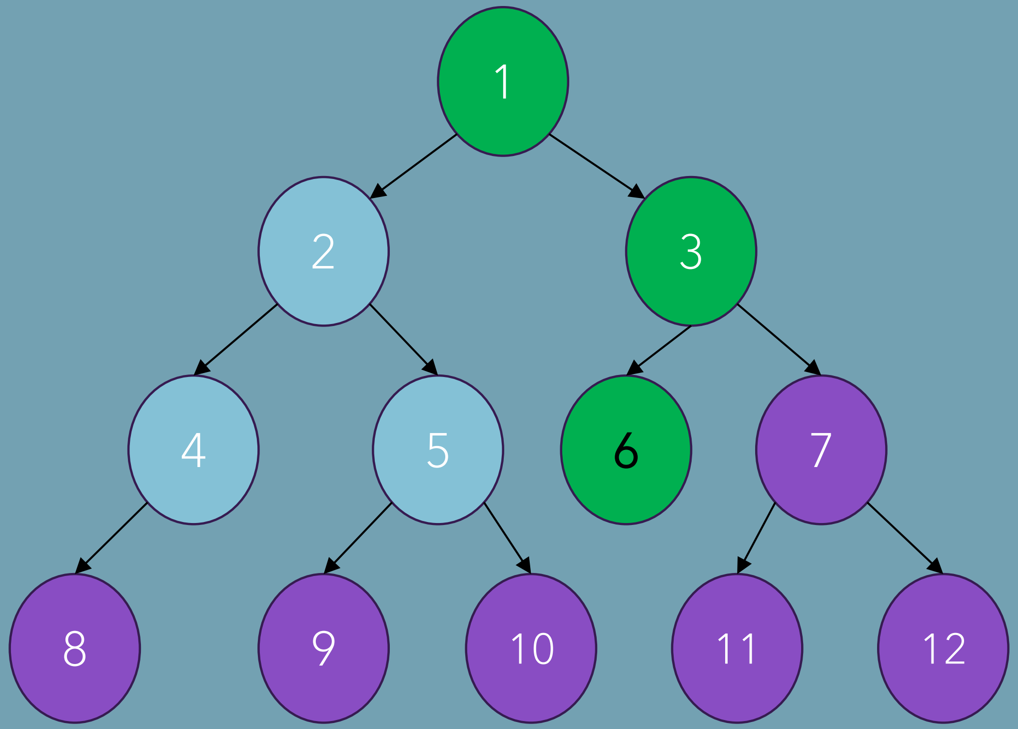
# BREADTH-FIRST SEARCH

Goal: 6



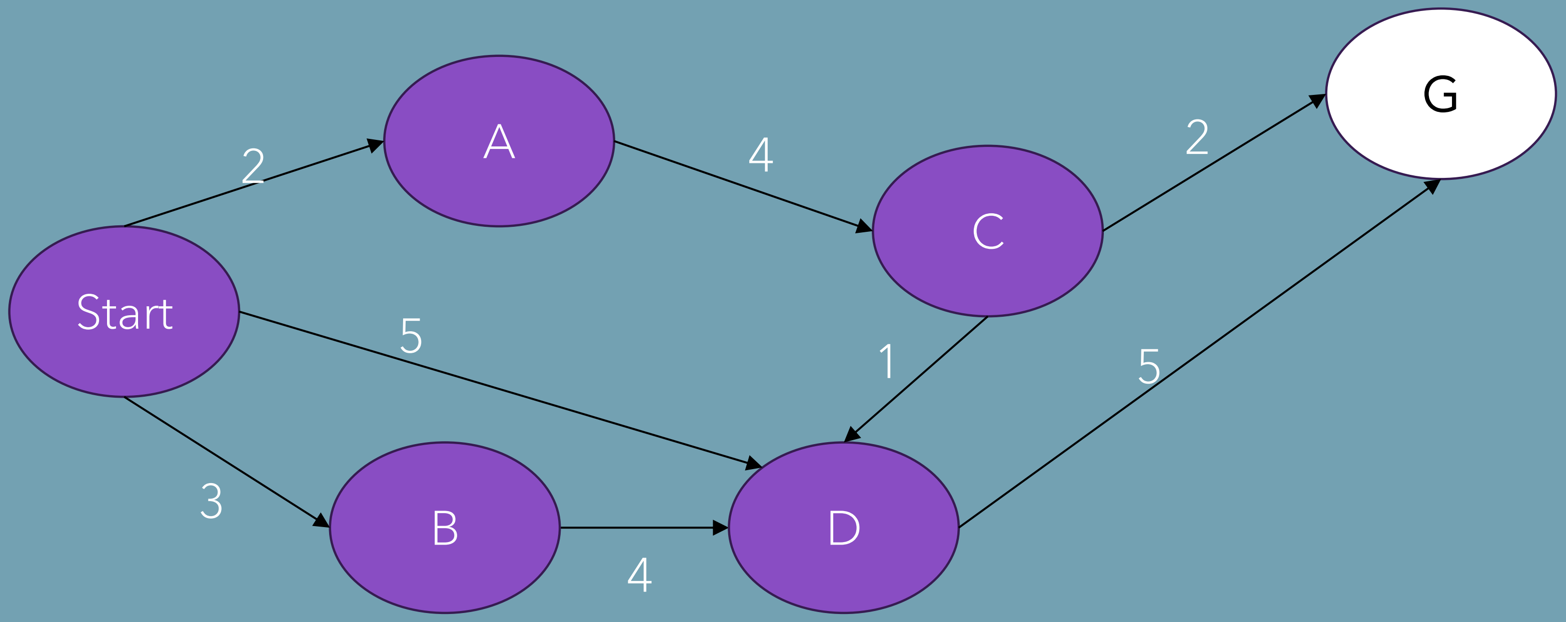
# BREADTH-FIRST SEARCH

Goal: 6




Solution: [1, 3, 6] – Visited [1, 2, 3, 4, 5, 6]

# BREADTH-FIRST SEARCH (GRAPH)




| Current | FIFO<br>FRONT < - - - - - - - > REAR |
|---|---|
| | [S] |
| [S] | [S,A] , [S,B] , [S,D] |
| [S, A] | [S,B] , [S,D], [S,A,C] |
| [S, B] | [S,D], [S,A,C], [S,B,D] |
| [S,D] | [S,A,C], [S,B,D], [S,D,G] |
| [S,A,C] | [S,B,D], [S,D,G], [S,A,C,D], [S,A,C,G] |
| [S,D,G] | |

In graphs, Sort alphabetically each expansion only for unified answer for all students !

# DFS VS. BFS

## DFS

| Current | LIFO<br>- - - > TOP |
|---|---|
| | [S] |
| [S] | [S,A] , [S,B] , [S,D] |
| [S, D] | [S,A] , [S,B] , [S,D, G] |
| [S, D, G] | Actual Cost: 10<br>Sol. Steps: 3 |

## BFS

| Current | FIFO<br>FRONT < - - - - - - - > REAR |
|---|---|
| | [S] |
| [S] | [S,A] , [S,B] , [S,D] |
| [S, A] | [S,B] , [S,D], [S,A,C] |
| [S, B] | [S,D], [S,A,C], [S,B,D] |
| [S,D] | [S,A,C], [S,B,D], [S,D,G] |
| [S,A,C] | [S,B,D], [S,D,G], [S,A,C,D], [S,A,C,G] |
| [S,D,G] | Actual Cost: 10<br>Sol. Steps: 6 |

# IMPLEMENTATION

# GRAPH CLASS (ADJACENCY LIST REP.)

```
# Make a Graph class
class Graph:
    def __init__(self, root=None, weighted=None, directed=None):
        # Adjacency list representation
        if root:
            self.__graph = {root:[]}
        else:
            self.__graph = {"root":[]}

        self.__weighted = weighted
        if weighted == True:
            self.__weighted = weighted
        elif self.__weighted != None:
            raise Exception("weighted parameter should be True or None")

        self.__directed = False
        if directed == True:
            self.__directed = directed
        elif self.__directed == None:
            raise Exception("directed parameter should be True or None")

        print(f"Graph is created with root name: {list(self.__graph.keys())[0]}")
```

# GRAPH CLASS (ADD VERTICES METHOD)

```
def add_vertex(self, vertex):
    if vertex not in self.__graph.keys():
        self.__graph[vertex] = []
        print("Vertex is added successfully !")
    else:
        print("This vertex does exist in the graph already !")
```

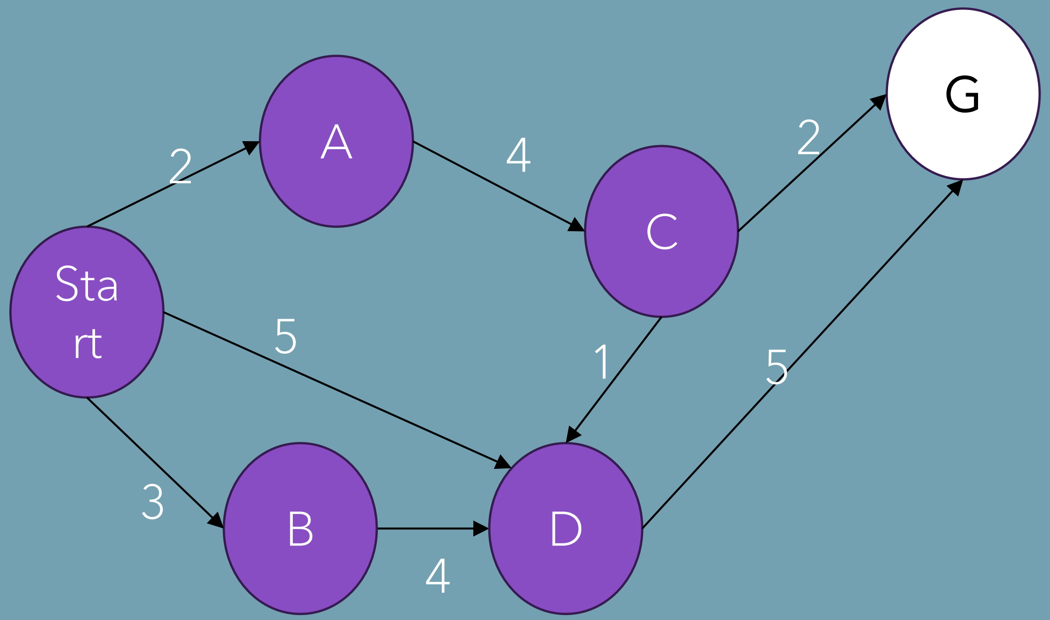
# GRAPH CLASS (ADD EDGES METHOD)

```
def add_edge(self, vertex_1, vertex_2, weight=None):
    if vertex_1 in self.__graph.keys() and vertex_2 in self.__graph.keys():
        if not self.__directed:
            if not self.__weighted:
                self.__graph[vertex_1].append(vertex_2)
                self.__graph[vertex_2].append(vertex_1)
            else:
                if weight != None:
                    self.__graph[vertex_1].append((vertex_2, weight))
                    self.__graph[vertex_2].append((vertex_1, weight))
                else:
                    raise Exception("It should be a weight for the edge")
        else:
            if not self.__weighted:
                self.__graph[vertex_1].append(vertex_2)
            else:
                if weight != None:
                    self.__graph[vertex_1].append((vertex_2, weight))
                else:
                    raise Exception("It should be a weight for the edge")
    else:
        raise Exception("It should be both vertices exist in the graph !")

    print(f"Edge added between {vertex_1} and {vertex_2}")
```

# GRAPH CLASS (GET GRAPH METHOD)

```
def get_graph(self):
    return self.__graph
```

# FORMULATE THE PROBLEM



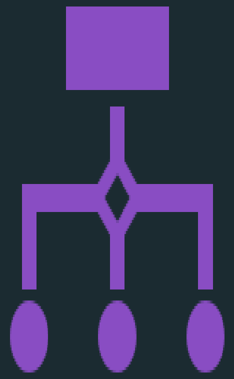

```python
my_graph = Graph("S", directed=True, weighted=True)
my_graph.add_vertex("A")
my_graph.add_vertex("B")
my_graph.add_vertex("C")
my_graph.add_vertex("D")
my_graph.add_vertex("G")
my_graph.add_edge("S","B", 3)
my_graph.add_edge("S","A", 2)
my_graph.add_edge("S","D", 5)
my_graph.add_edge("A","C", 4)
my_graph.add_edge("C","G", 2)
my_graph.add_edge("C","D", 1)
my_graph.add_edge("B","D", 4)
my_graph.add_edge("D","G", 5)
print(my_graph.get_graph())
```

```
Graph is created with root name: S
Vertex is added successfully !
Vertex is added successfully !
Vertex is added successfully !
Vertex is added successfully !
Vertex is added successfully !
Edge added between S and B
Edge added between S and A
Edge added between S and D
Edge added between A and C
Edge added between C and G
Edge added between C and D
Edge added between B and D
Edge added between D and G
{'S': [('B', 3), ('A', 2), ('D', 5)], 'A': [('C', 4)], 'B': [('D', 4)], 'C': [('G', 2), ('D', 1)], 'D': [('G', 5)], 'G': []}
```

# GRAPH CLASS (DFS METHOD)

```python
def DFS(self, goal, start=None):
    if start != None:
        lst = [[start]]
    else:
        lst = [["root"]]

    visited = []
    while lst:
        # basic search
        current_path = lst.pop() # LIFO
        current_node = current_path[-1]

        if current_node in visited:
            continue
        visited.append(current_node)

        if current_node == goal:
            return current_path, visited
        else:
            # Sort all elements alphabetically to get a unified answer !
            # Sorting in ascending order to follow "LIFO" principle !
            adjacent_nodes = self.__graph[current_node]
            adjacent_nodes.sort()
            if self.__weighted:
                for node, _ in adjacent_nodes:
                    new_path = current_path.copy()
                    new_path.append(node)
                    lst.append(new_path)
            else:
                for node in adjacent_nodes:
                    new_path = current_path.copy()
                    new_path.append(node)
                    lst.append(new_path)

    raise Exception("Search Failed !")
```

## BASIC SEARCH

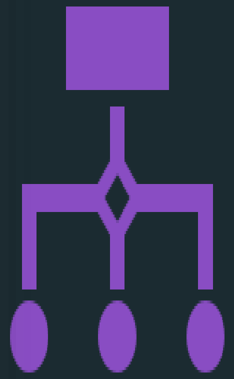


1. Initialize an **empty list** and put the **initial state** in it
2. Take the first state in the **list as the current if it is not visited yet otherwise skip it**, and remove it from the list
3. **Check if the current is the goal state**, if it is, then terminate the search and **return the solution path**
4. Otherwise, expand the current of its successors, **and add them into the list using a queuing function**
5. Repeat from (2) to (4)
6. If the current becomes empty, then there is no solution and **return "fail"**

# GRAPH CLASS (BFS METHOD)

```python
def BFS(self, goal, start=None):
    if start != None:
        lst = [[start]]
    else:
        lst = [["root"]]

    visited = []
    while lst:
        # basic search
        current_path = lst.pop(0) # FIFO
        current_node = current_path[-1]

        if current_node in visited:
            continue
        visited.append(current_node)

        if current_node == goal:
            return current_path, visited
        else:
            # Sort all elements alphabetically to get a unified answer !
            # Sorting in ascending order to follow "FIFO" principle !
            adjacent_nodes = self.__graph[current_node]
            adjacent_nodes.sort()
            if self.__weighted:
                for node, _ in adjacent_nodes:
                    new_path = current_path.copy()
                    new_path.append(node)
                    lst.append(new_path)
            else:
                for node in adjacent_nodes:
                    new_path = current_path.copy()
                    new_path.append(node)
                    lst.append(new_path)

    raise Exception("Search Failed !")
```

## BASIC SEARCH



1. Initialize an **empty list** and put the **initial state** in it
2. Take the first state in the **list as the current if <u>it is not visited yet</u> otherwise skip it**, and remove it from the list
3. **Check if the current is the goal state**, if it is, then terminate the search and **return the solution path**
4. Otherwise, expand the current of its successors, **and add them into the list using a queuing function**
5. Repeat from (2) to (4)
6. If the current becomes empty, then there is no solution and **return "fail"**

# TESTING

```
[3]: print(my_graph.DFS('G', start='S'))
     print(my_graph.BFS('G', start='S'))

     (['S', 'D', 'G'], ['S', 'D', 'G'])
     (['S', 'D', 'G'], ['S', 'A', 'B', 'D', 'C', 'G'])
```

**DFS**

| Current | LIFO ---> TOP |
|---|---|
| | [S] |
| [S] | [S,A] , [S,B] , [S,D] |
| [S, D] | [S,A] , [S,B] , [S,D, G] |
| [S, D, G] | Actual Cost: 10<br>Sol. Steps: 3 |

**BFS**

| Current | FIFO FRONT <------> REAR |
|---|---|
| | [S] |
| [S] | [S,A] , [S,B] , [S,D] |
| [S, A] | [S,B] , [S,D], [S,A,C] |
| [S, B] | [S,D], [S,A,C], [S,B,D] |
| [S,D] | [S,A,C], [S,B,D], [S,D,G] |
| [S,A,C] | [S,B,D], [S,D,G], [S,A,C,D], [S,A,C,G] |
| [S,D,G] | Actual Cost: 10<br>Sol. Steps: 6 |

# NEXT LAB: SEARCHING PROBLEMS (2)

Thank you