Imperial College London

Uninformed Search
(Blind Search)

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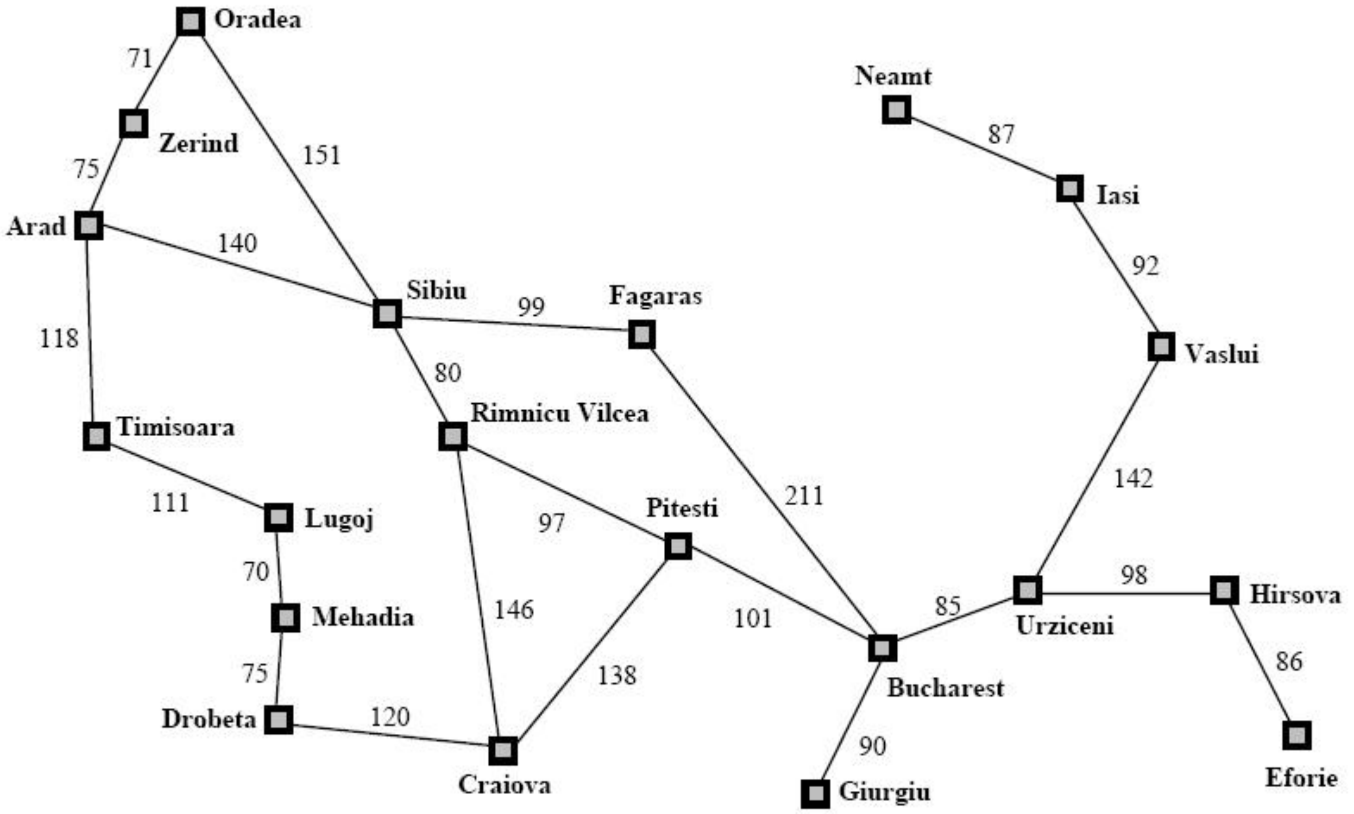
Overview

- Depth-first search
- Breadth-first search
- Iterative deepening
- Uniform cost search

An Example Search Problem

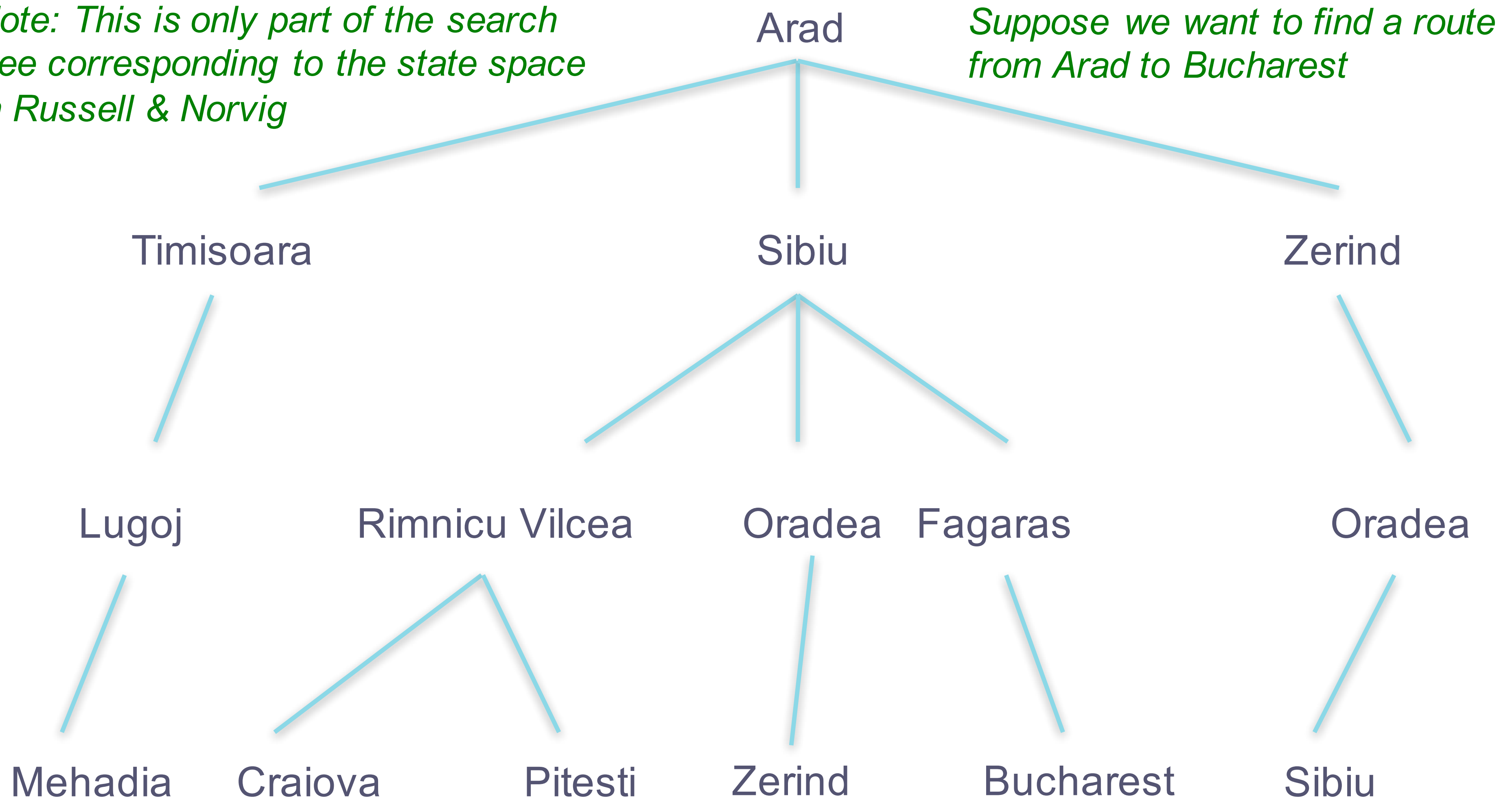
- Here is a *state-space* diagram of railway connections in Romania (taken from Russell & Norvig)
- Suppose we want to find a route from one city (the *initial state*) to another (the *goal state*)



Example Search Tree

Note: This is only part of the search tree corresponding to the state space in Russell & Norvig

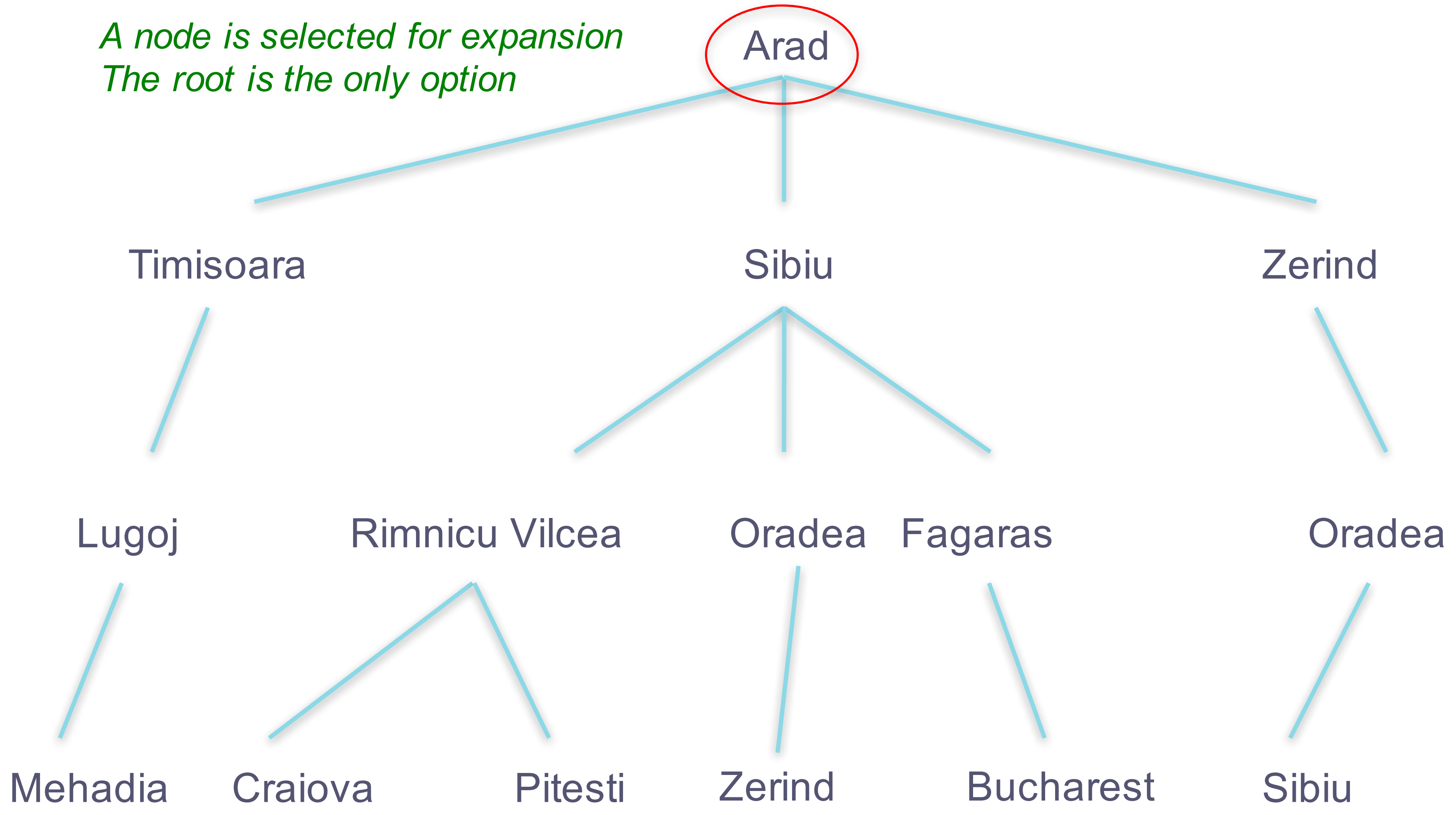
Suppose we want to find a route from Arad to Bucharest



Depth-first Search

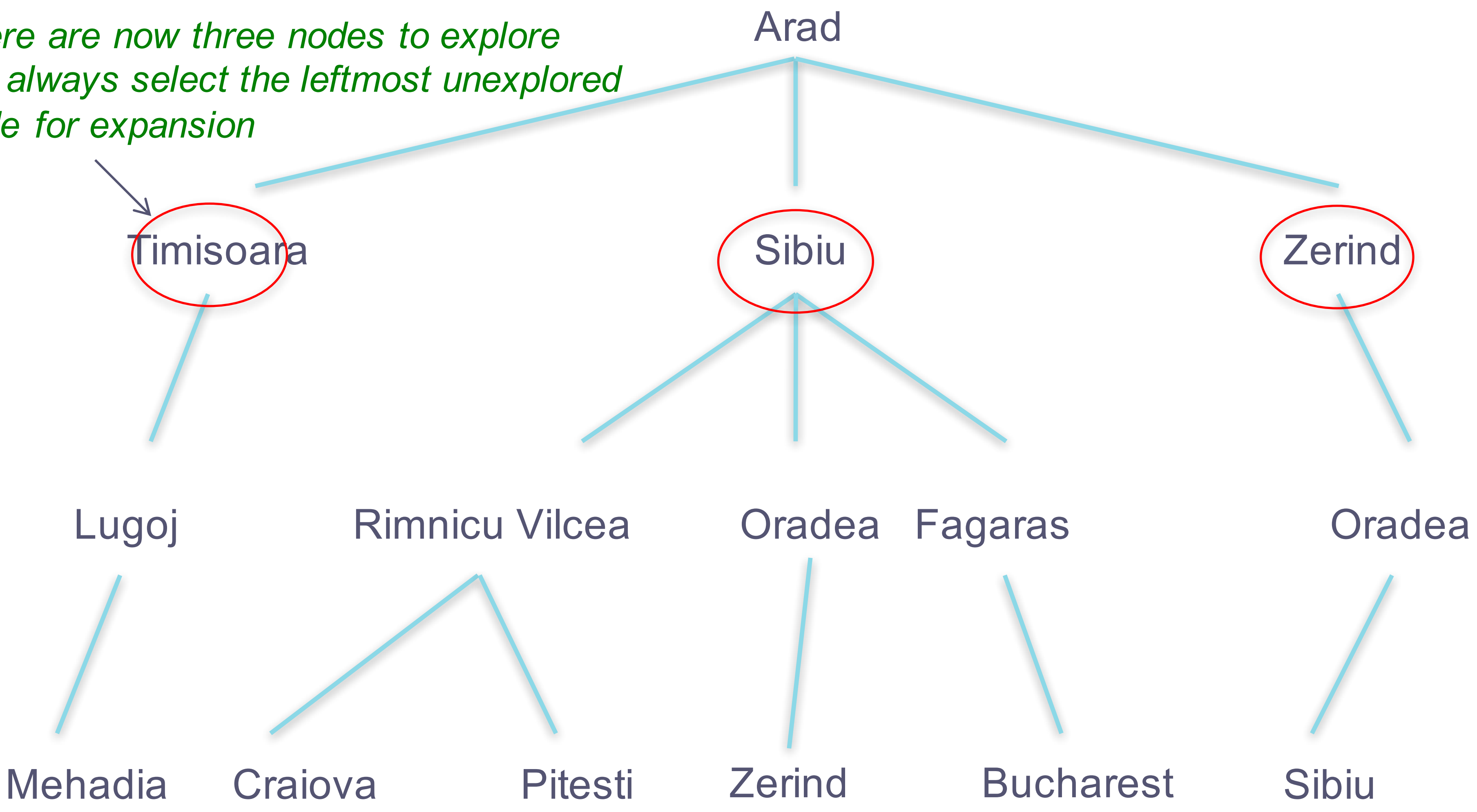
Depth-first Search 1

A node is selected for expansion
The root is the only option

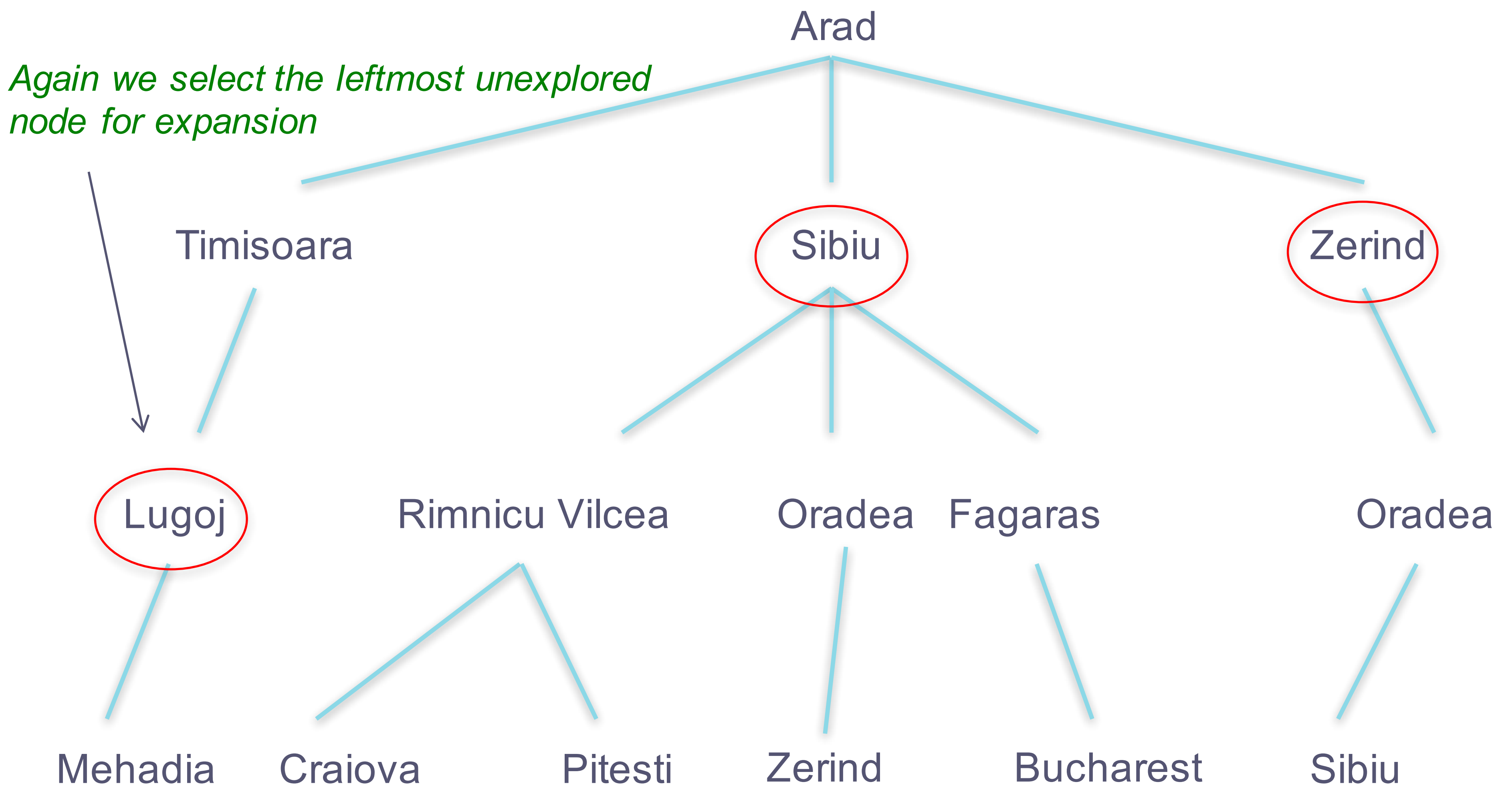


Depth-first Search 2

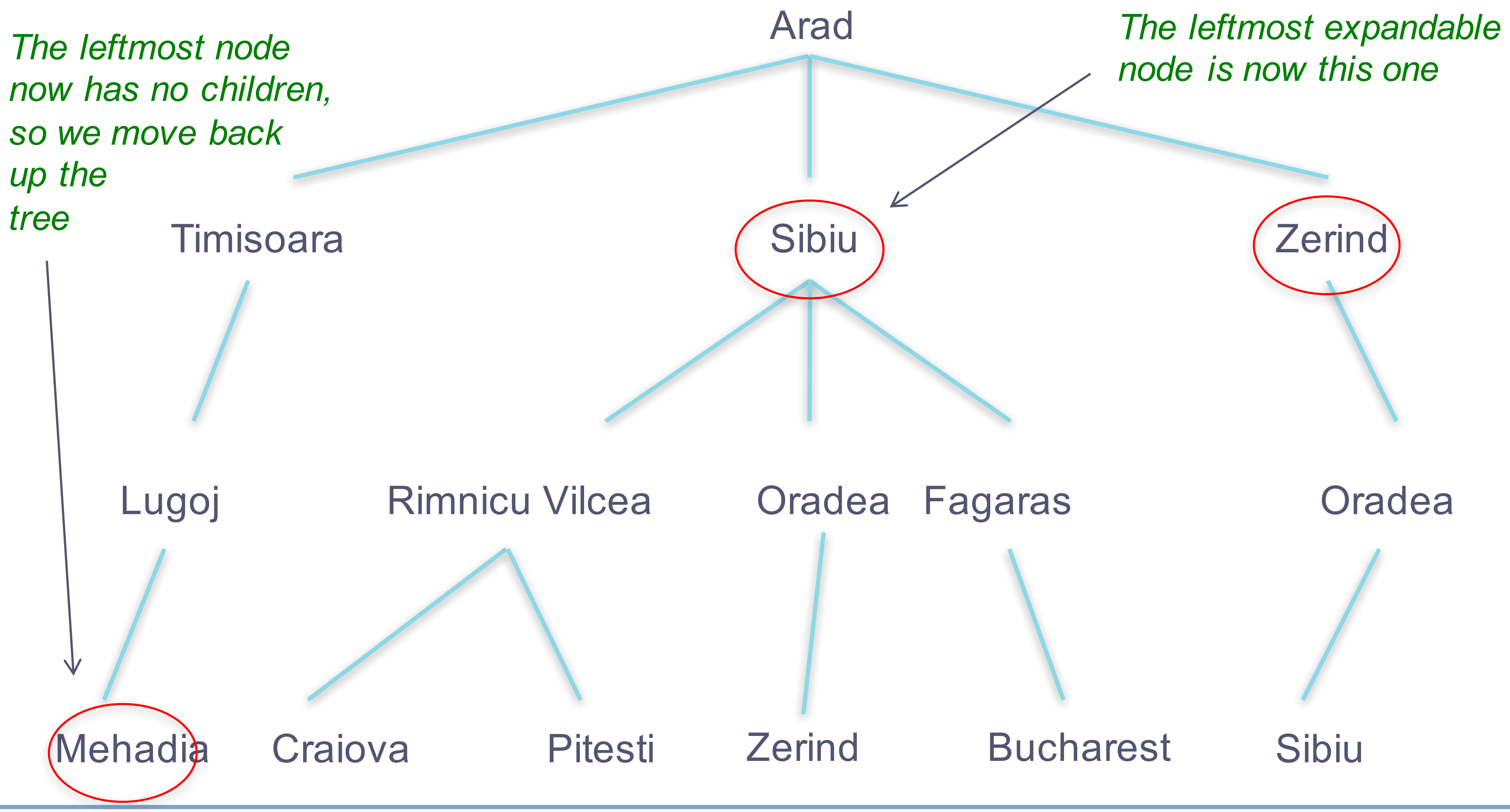
There are now three nodes to explore
We always select the leftmost unexplored node for expansion



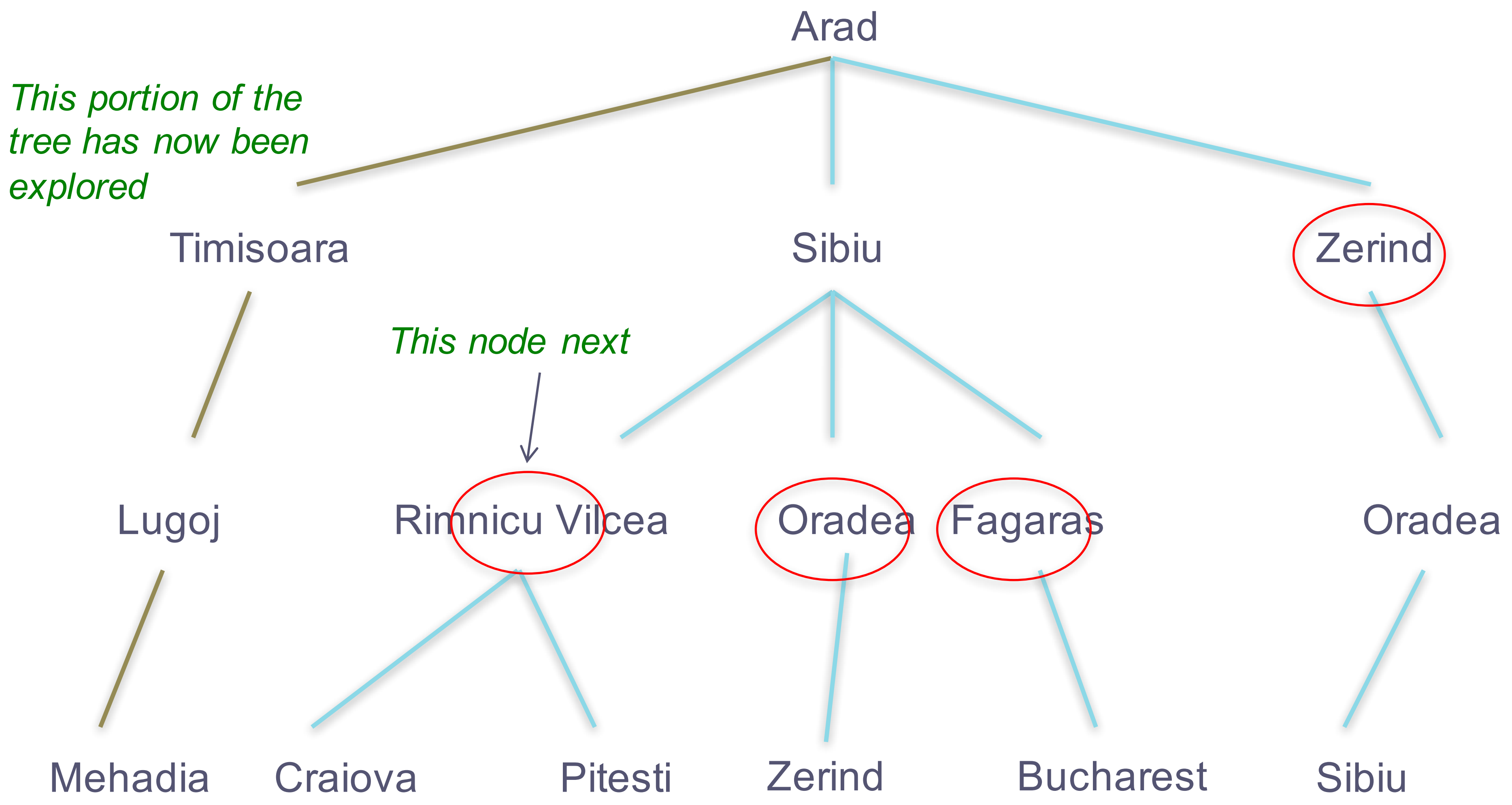
Depth-first Search 3



Depth-first Search 4


The leftmost node now has no children, so we move back up the tree
The leftmost expandable node is now this one
Arad
Timisoara
Sibiu
Zerind
Lugoj
Rimnicu Vilcea
Oradea
Fagaras
Oradea
Mehadia
Craiova
Pitesti
Zerind
Bucharest
Sibiu

Depth-first Search 5



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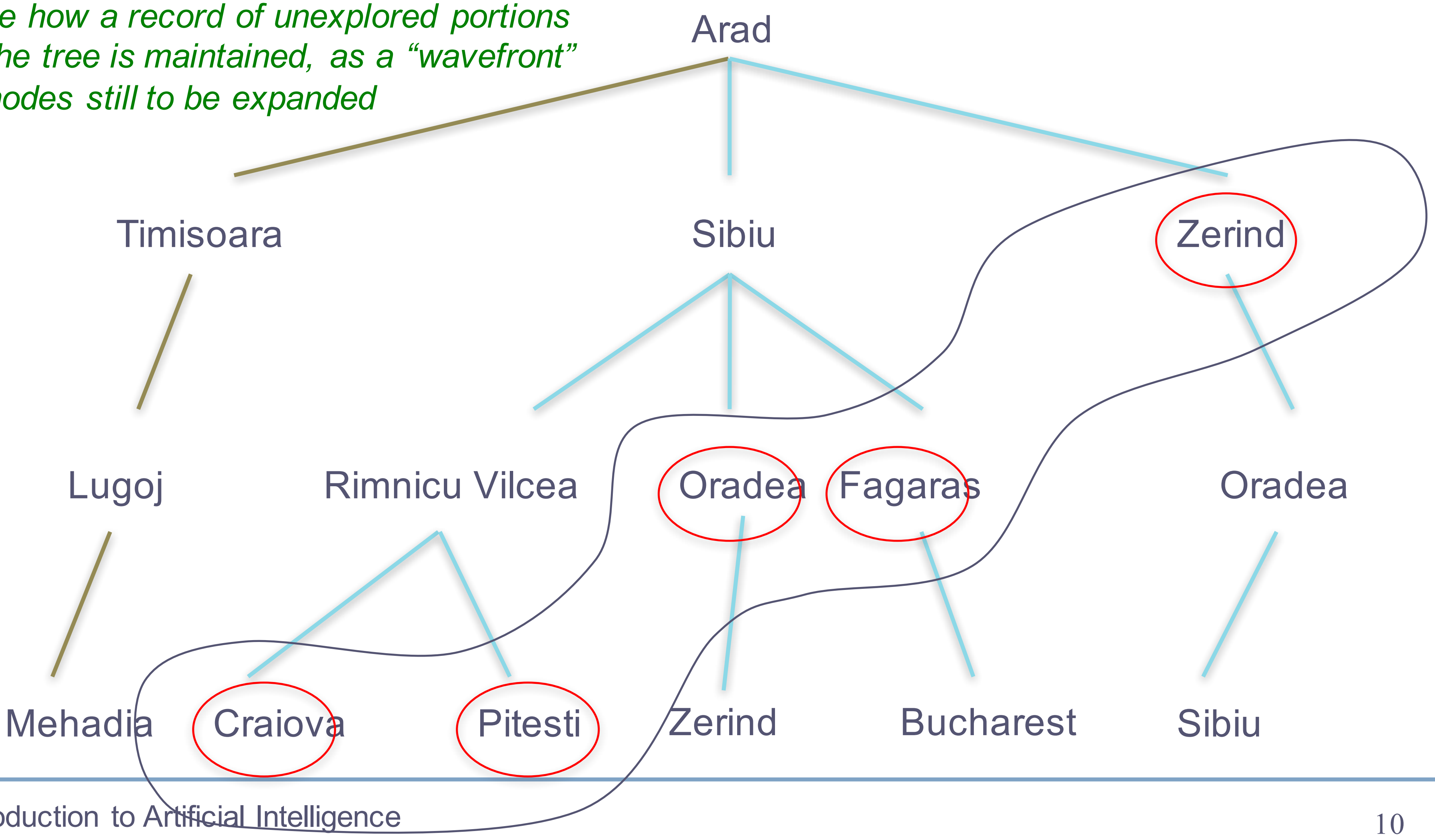
Depth-first Search 6

Note how a record of unexplored portions of the tree is maintained, as a "wavefront" of nodes still to be expanded



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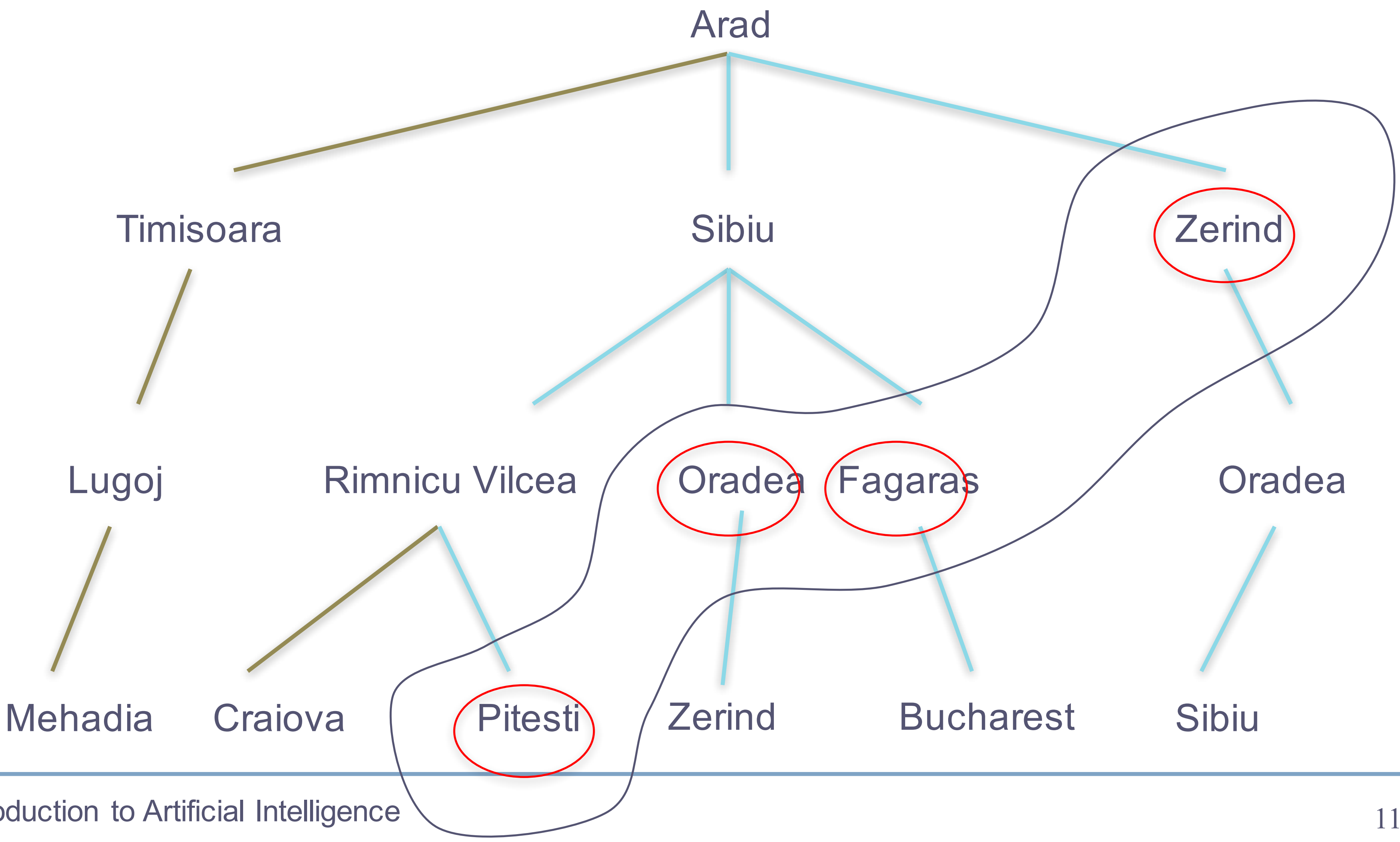
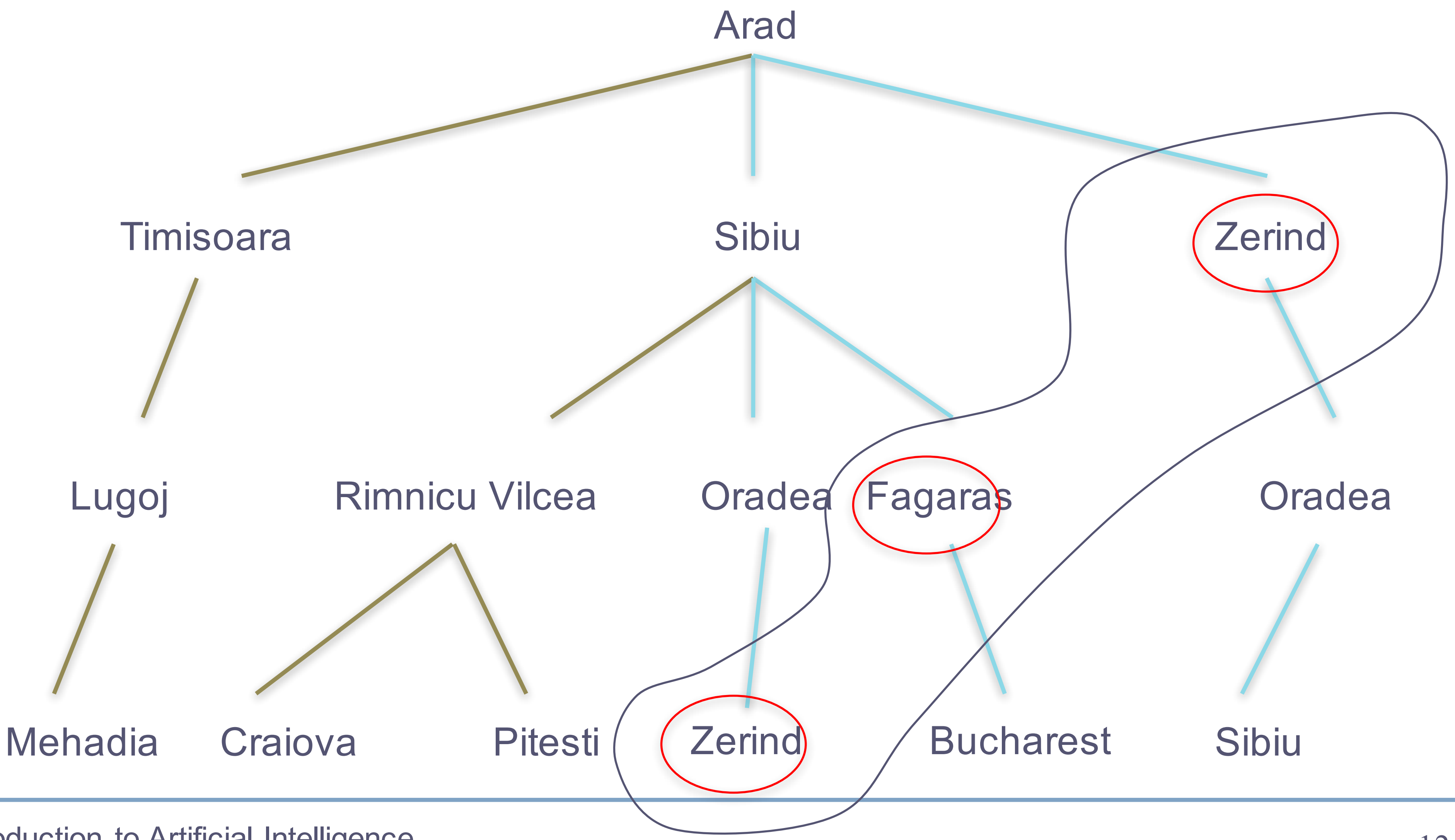
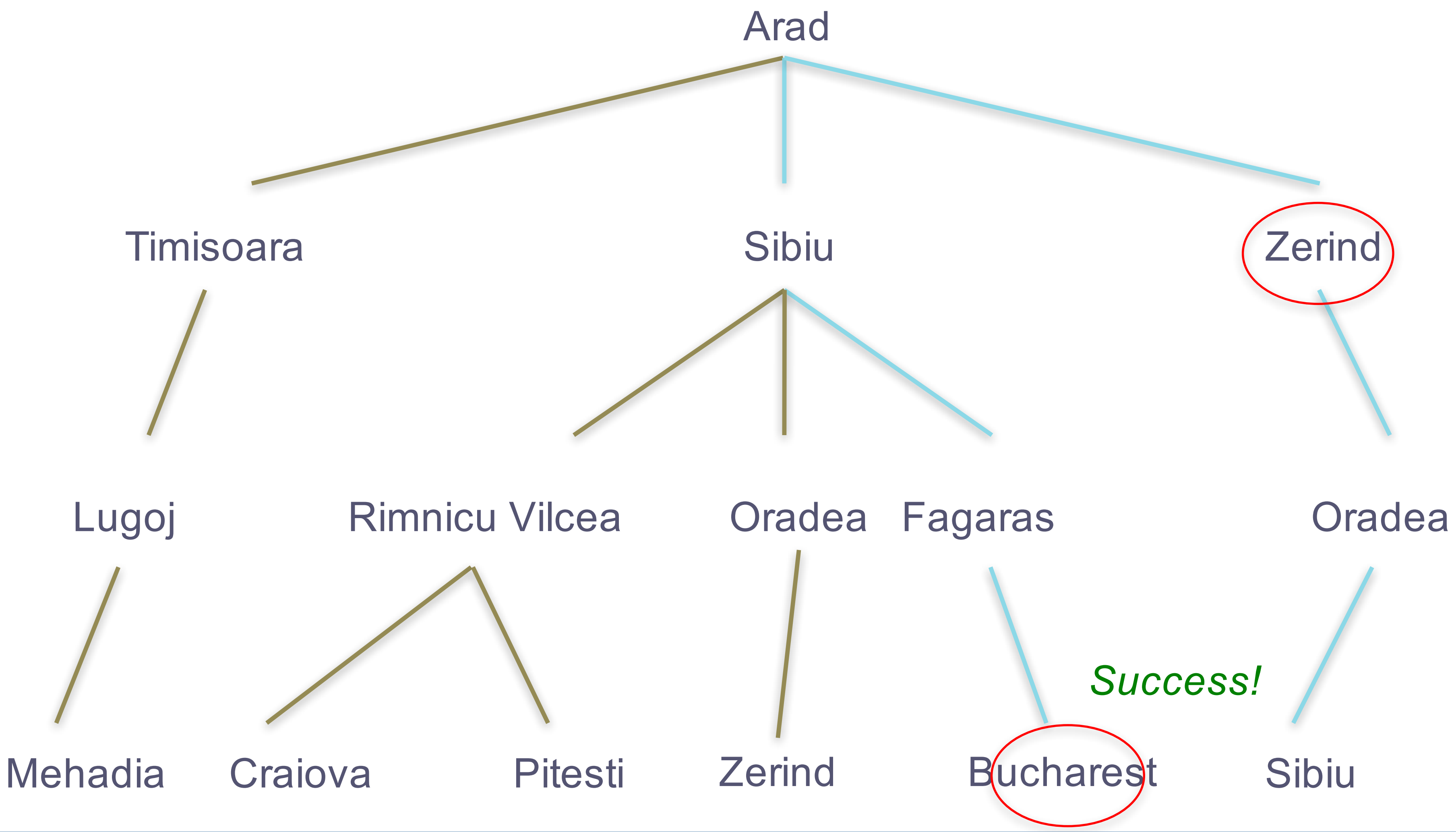
Depth-first Search 7



Depth-first Search 8



Depth-first Search 8



Properties of Depth-first

- Not guaranteed to find a solution (not complete), because it can get lost in infinite branches of the tree
- Not guaranteed to find the shortest path to a solution
- Efficient use of memory

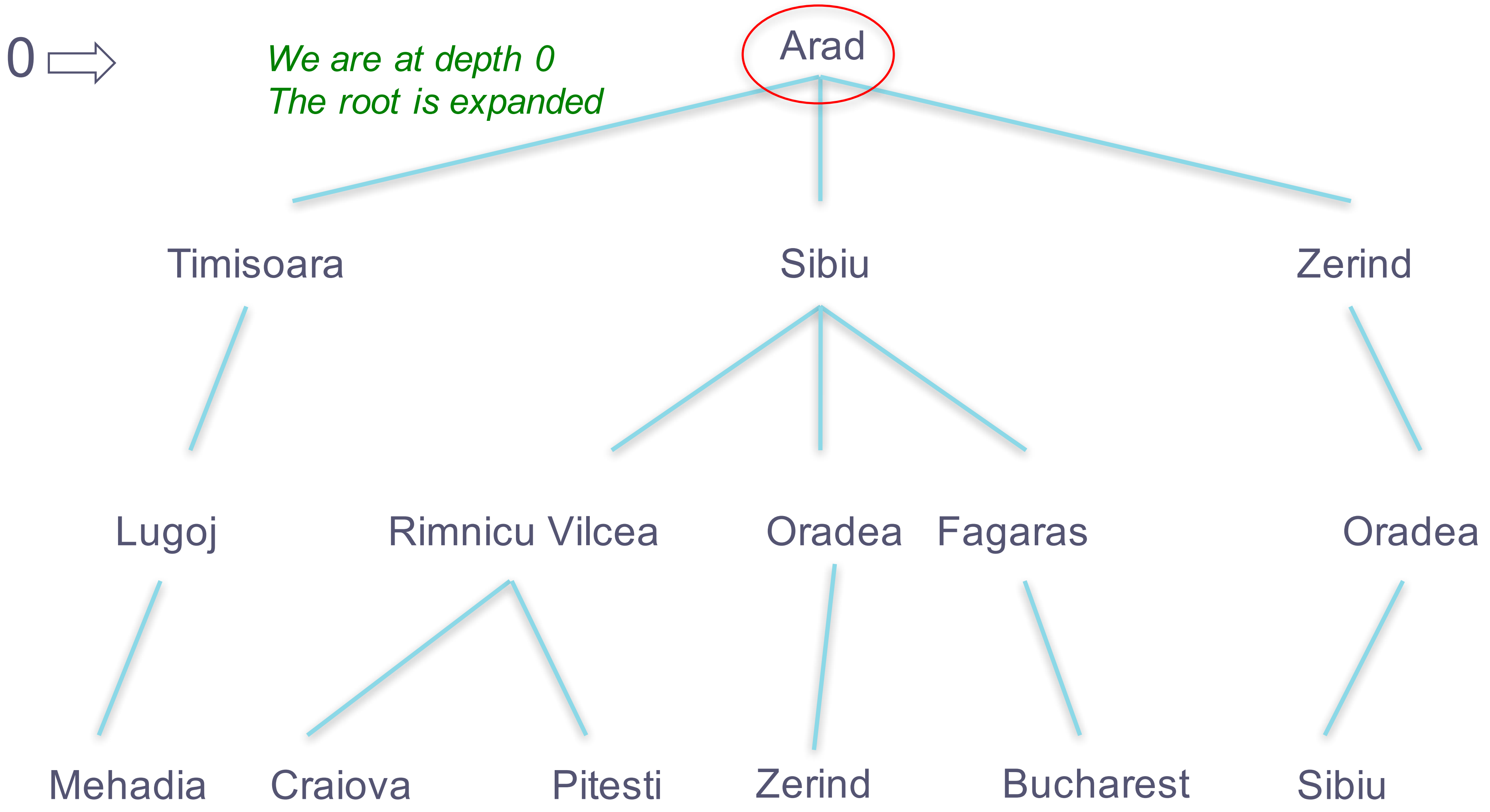
Prolog Code

```
search(Paths,X):-
        choose([Node|Path],Paths,_),
        goal(Node),
        reverse([Node|Path],X).

search(Paths,Path):-
        choose(P,Paths,RestofPaths),
        findall([S|P],S expands P,Exps),
        combine(Exps,RestofPaths,NewPaths),
        search(NewPaths,Path).

NewState expands [State|_]:-
        arc(State,NewState).
```

- Call `search([[s0]],X)` where `s0` is the initial state
- `Paths` is a list of lists of nodes
- Each list of nodes in `Paths` represents a partial branch of the tree
- The head of each list of nodes in `Paths` is the next node in that branch to be expanded

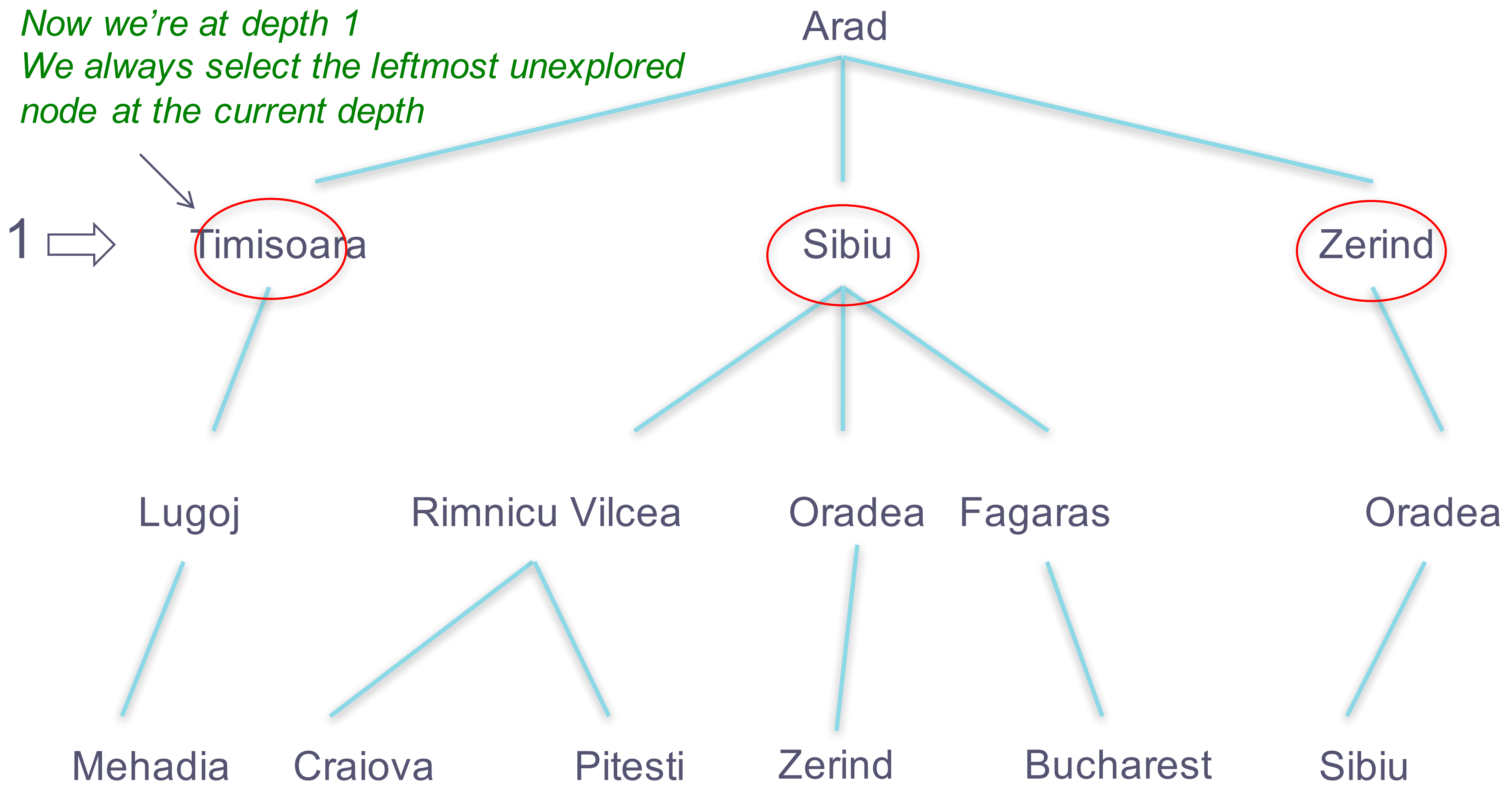
Breadth-first Search

Breadth-first Search 1



Breadth-first Search 2

Now we're at depth 1
We always select the leftmost unexplored node at the current depth



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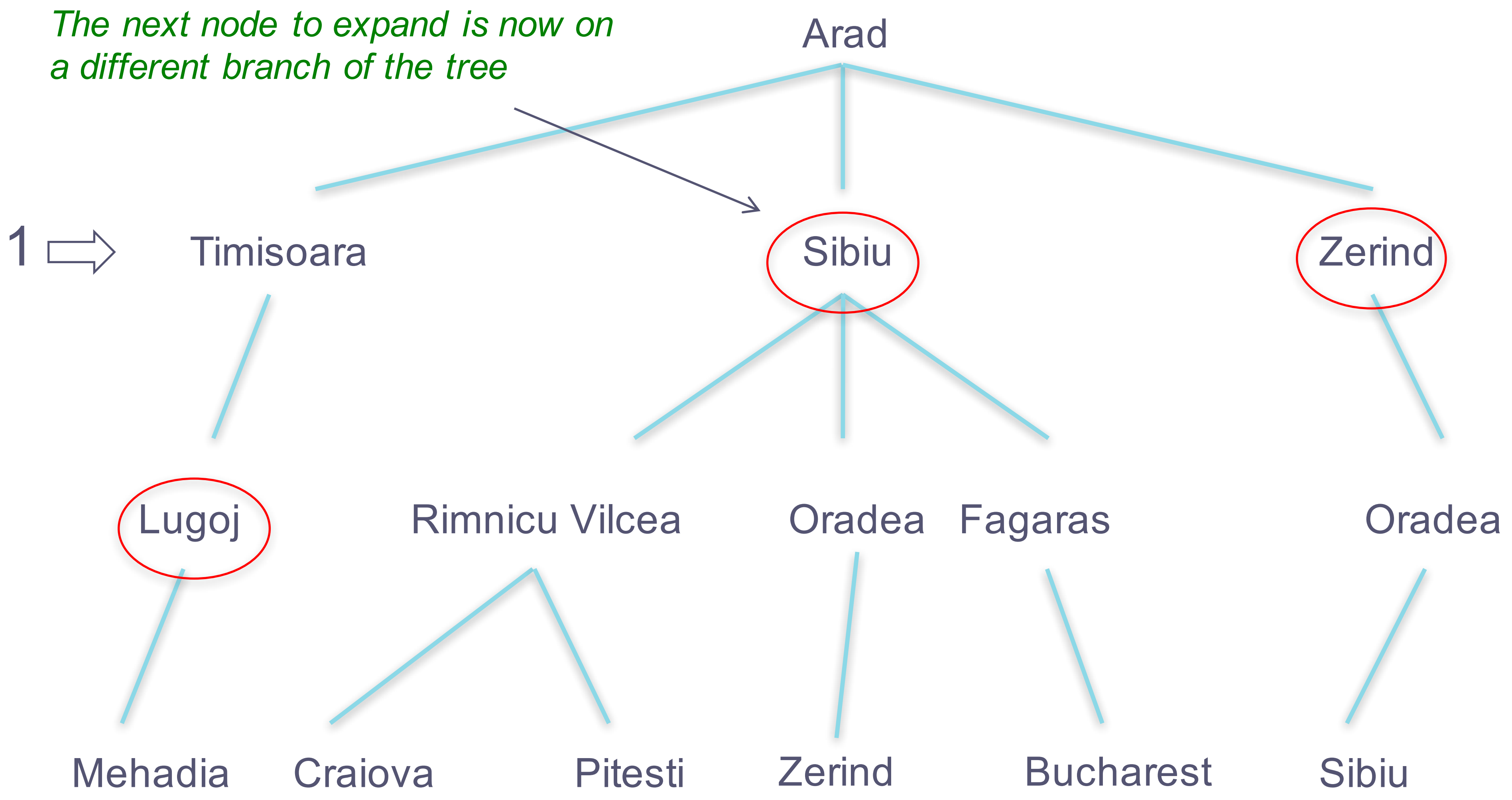
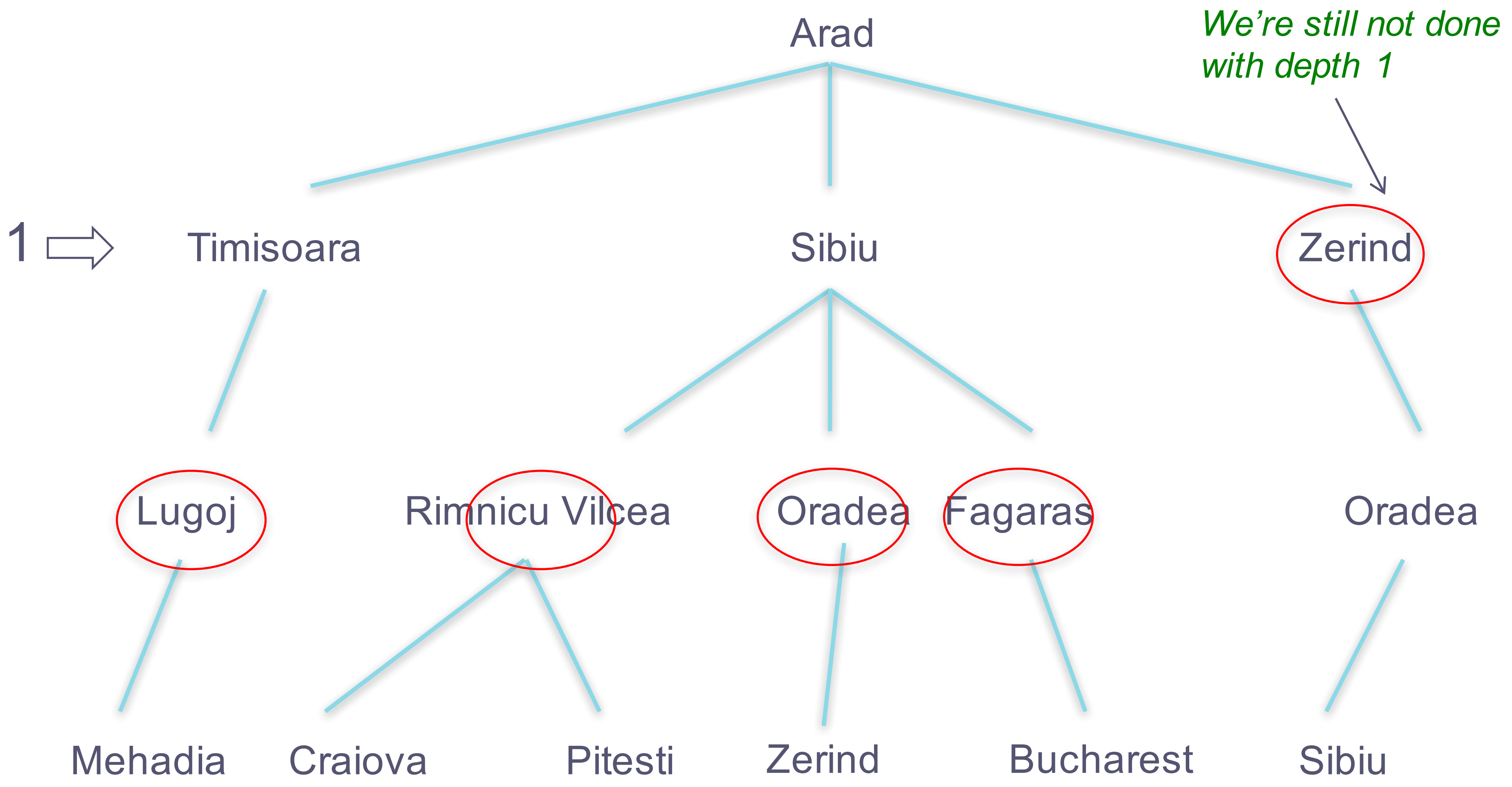
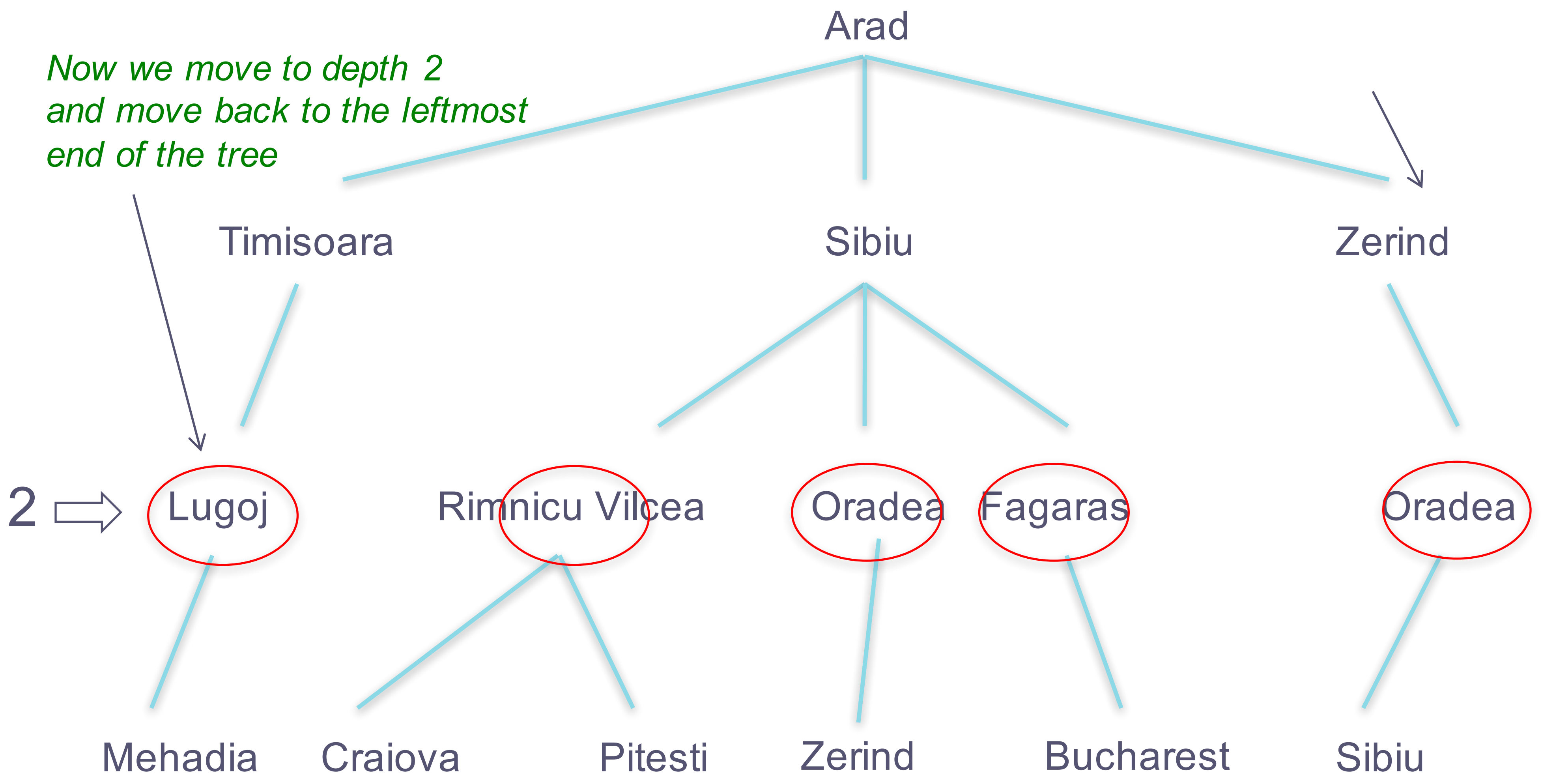
Breadth-first Search 3



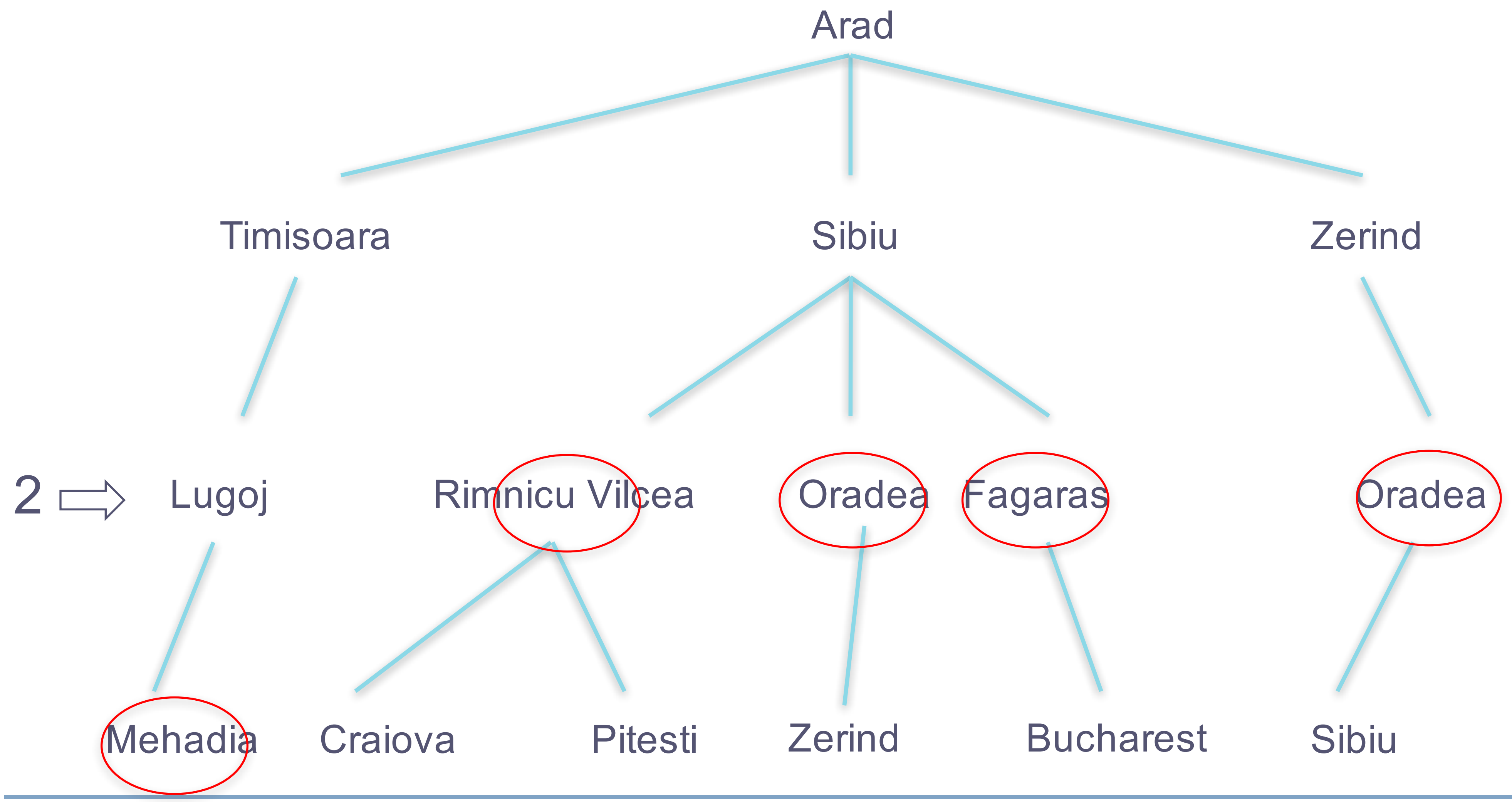
Breadth-first Search 4



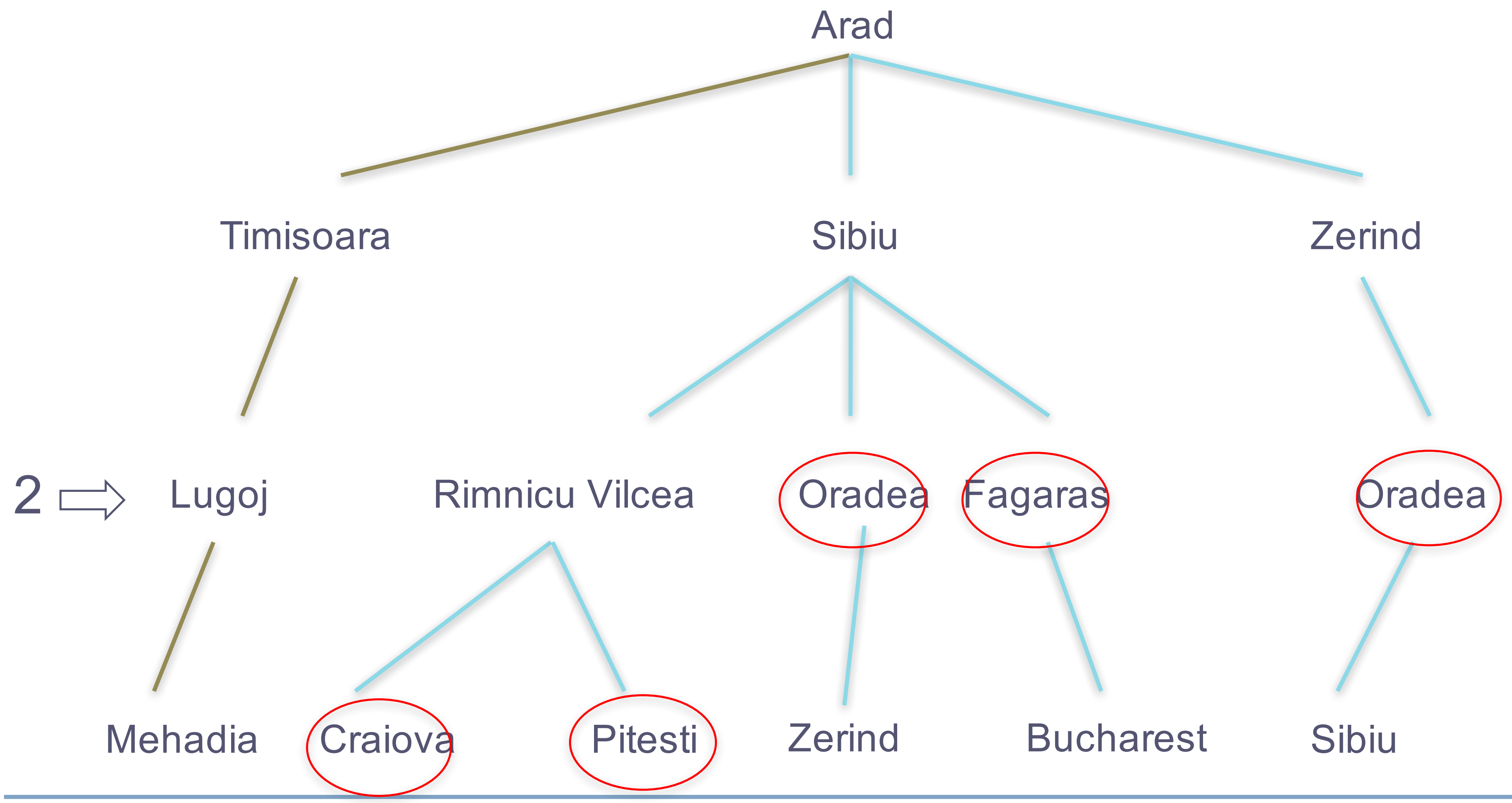
Breadth-first Search 5



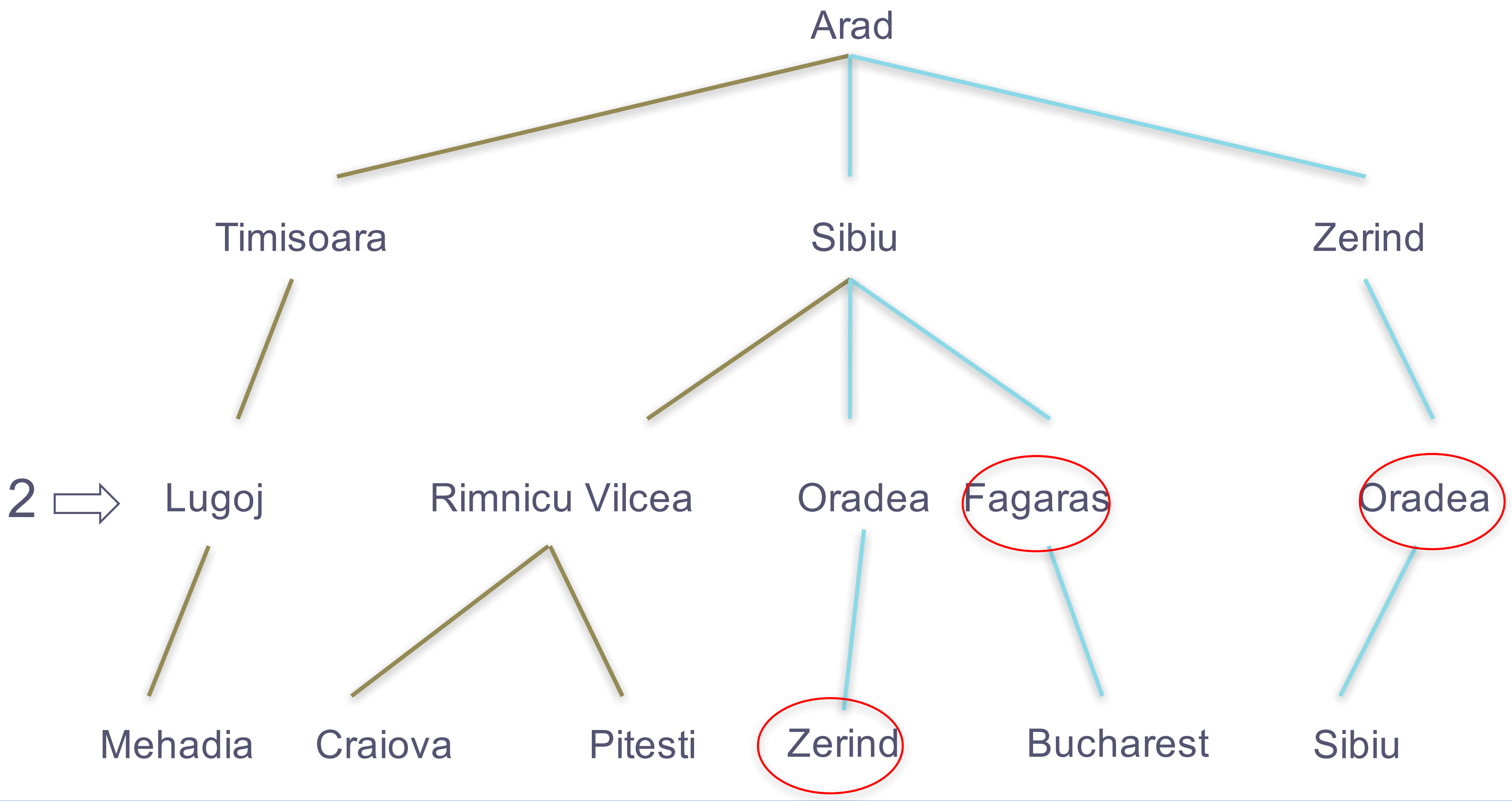
Breadth-first Search 6



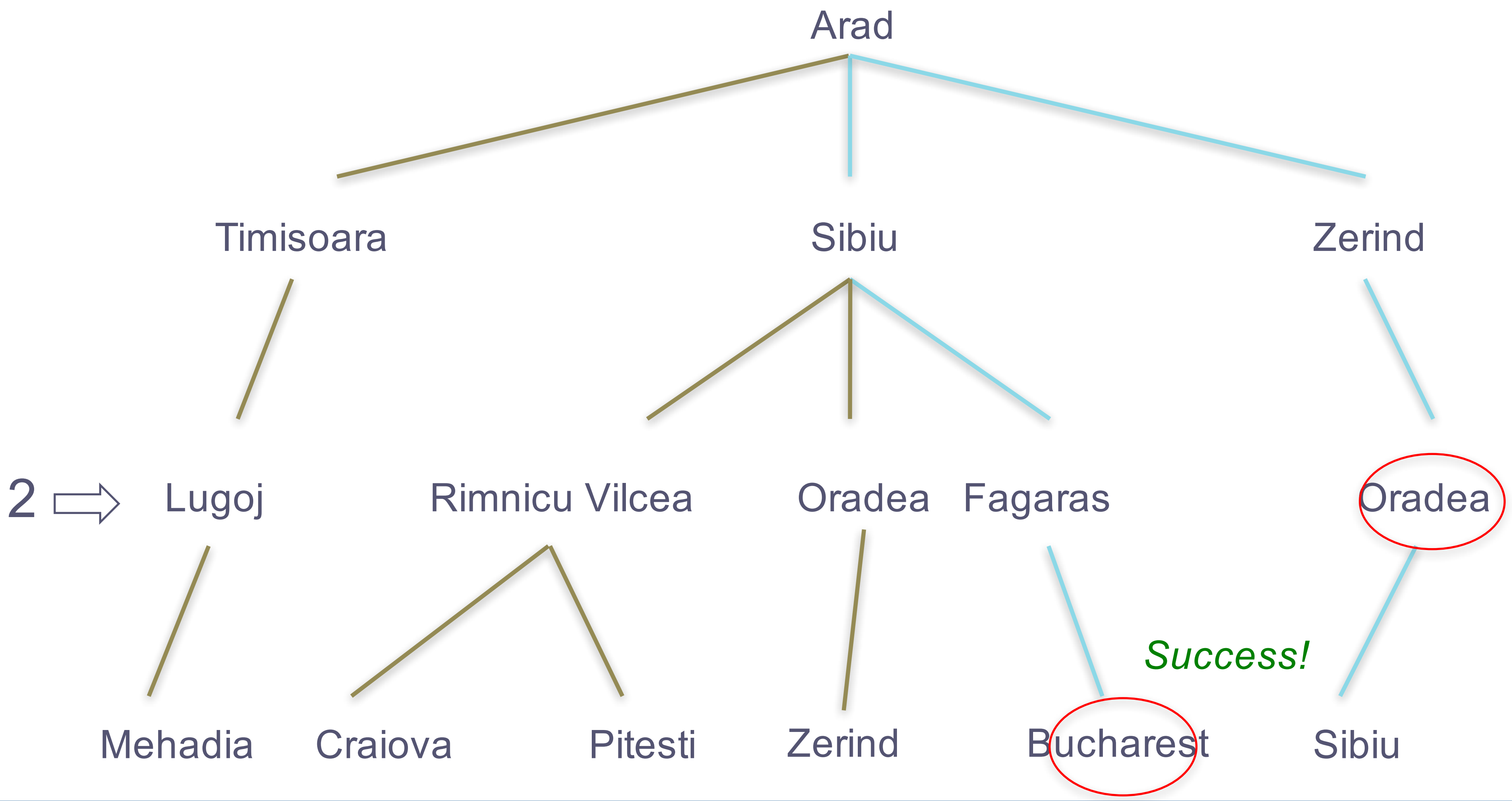
Breadth-first Search 7



Breadth-first Search 8



Breadth-first Search 9



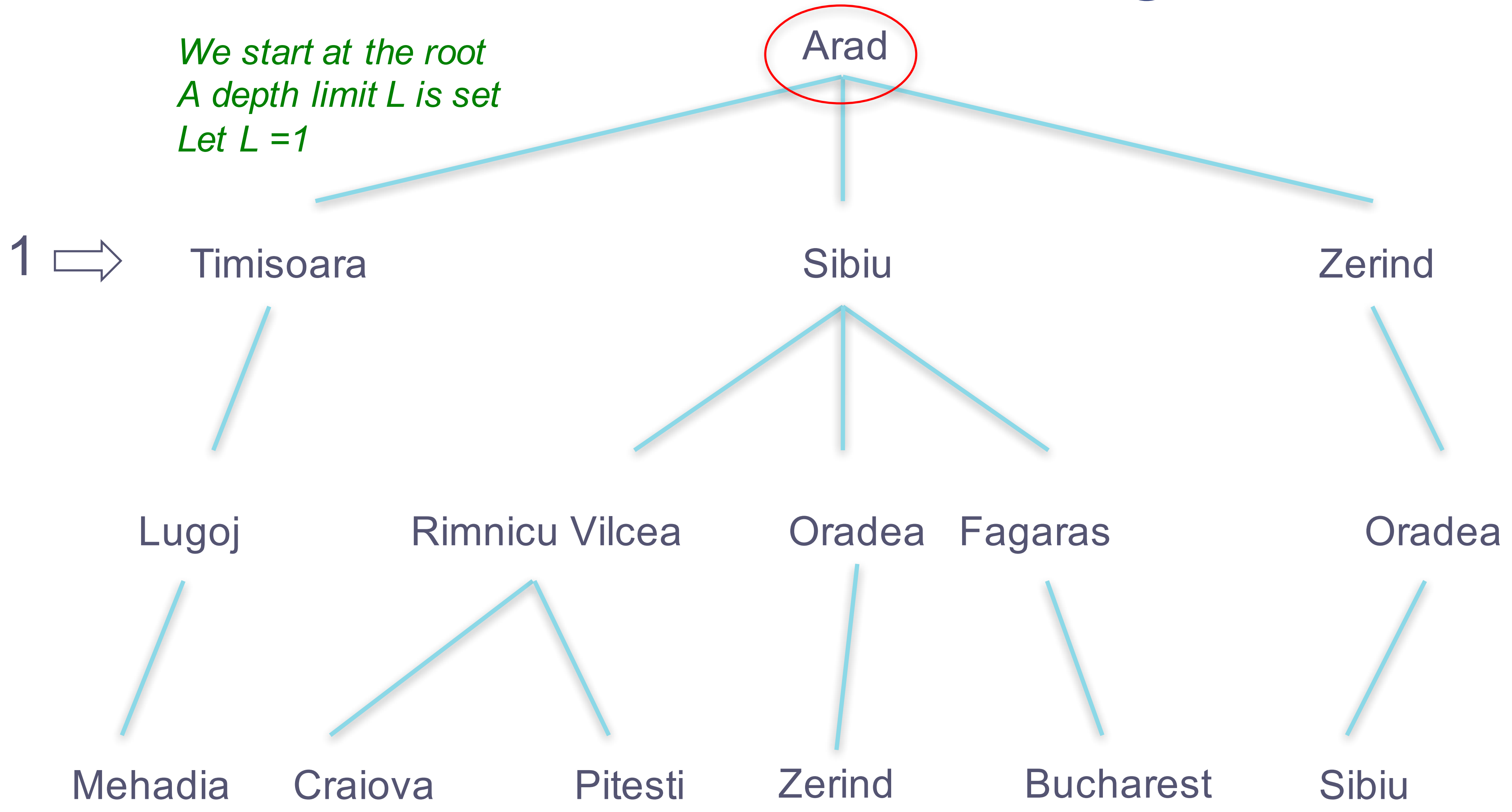
Properties of Breadth-first

- Guaranteed to find a solution if one exists, because every node in the tree is visited eventually
- Guaranteed to find the shortest path to a solution
- Very poor use of memory: exponential in mean branching factor

Iterative Deepening

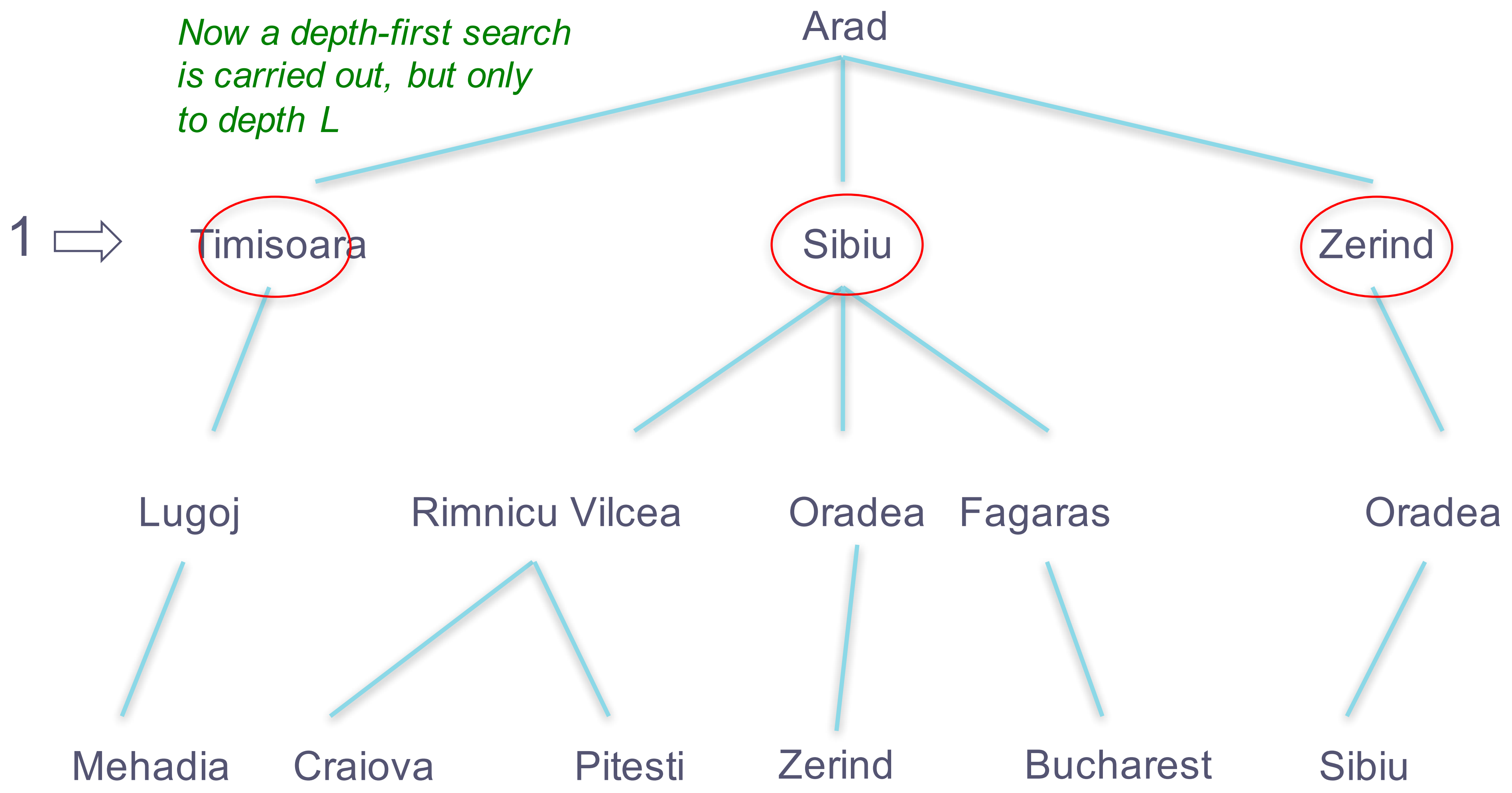
Iterative Deepening 1

We start at the root
A depth limit L is set
Let L =1



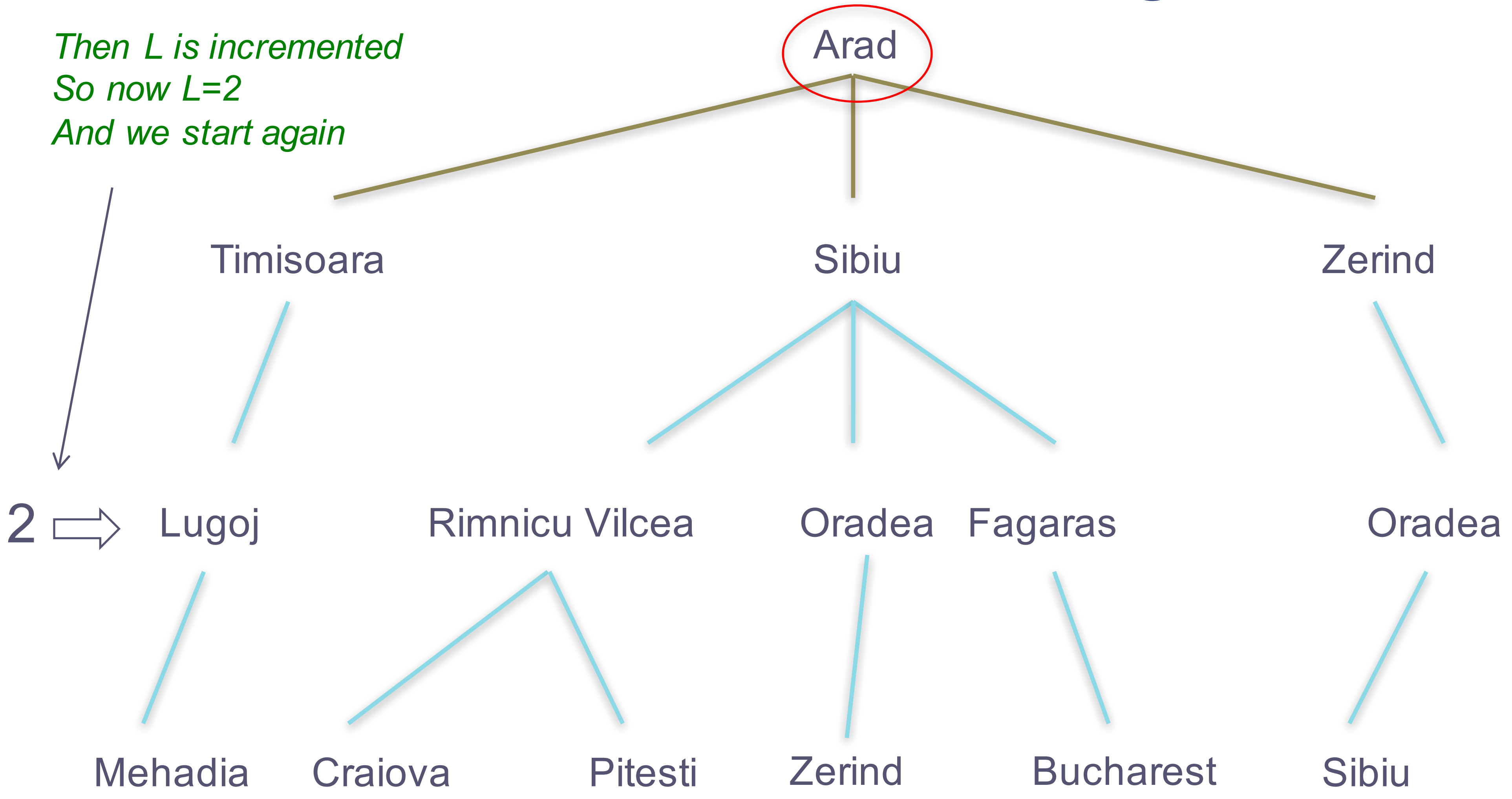
Iterative Deepening 2

Now a depth-first search
is carried out, but only
to depth L

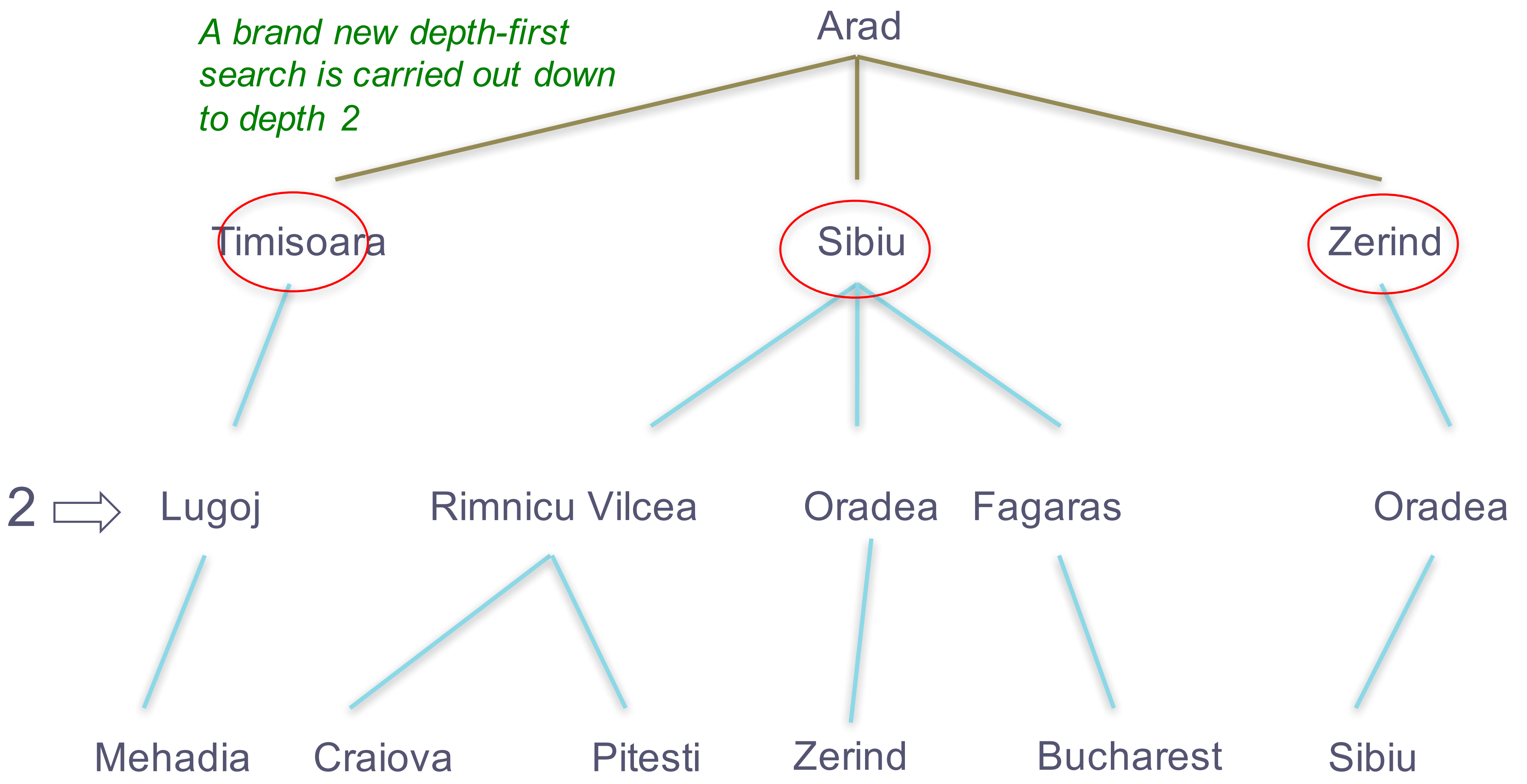


Iterative Deepening 3

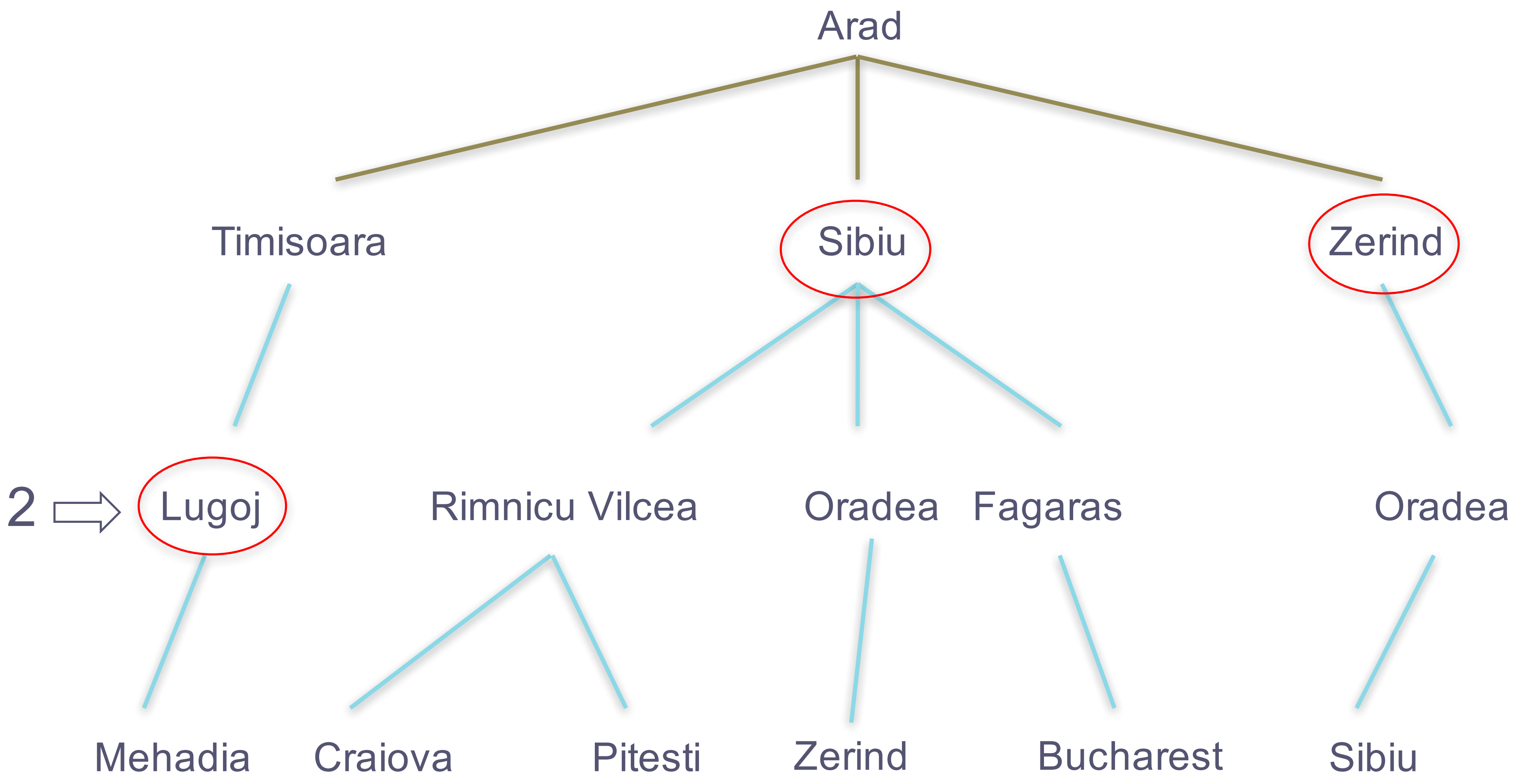
Then L is incremented
So now L=2
And we start again



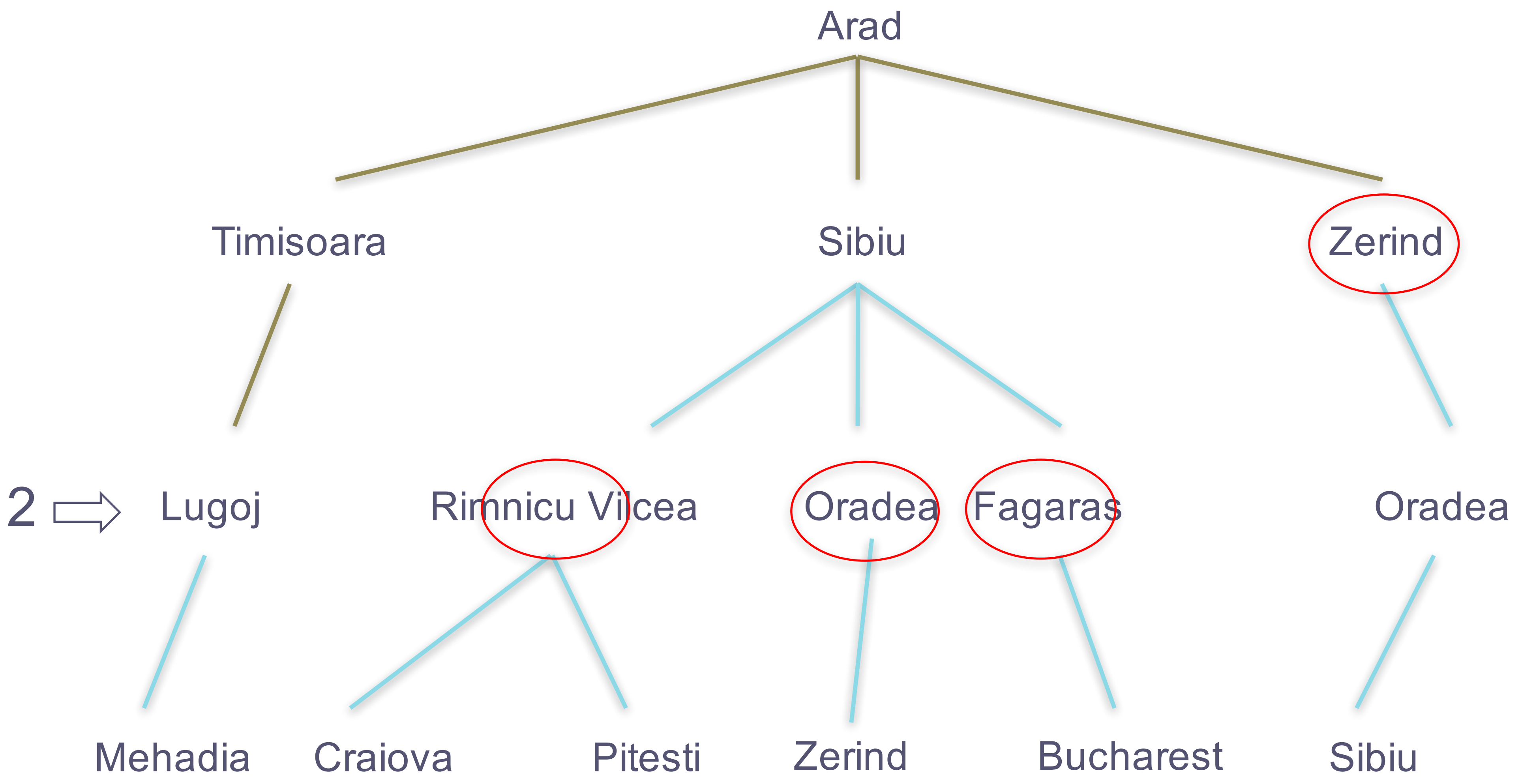
Iterative Deepening 4



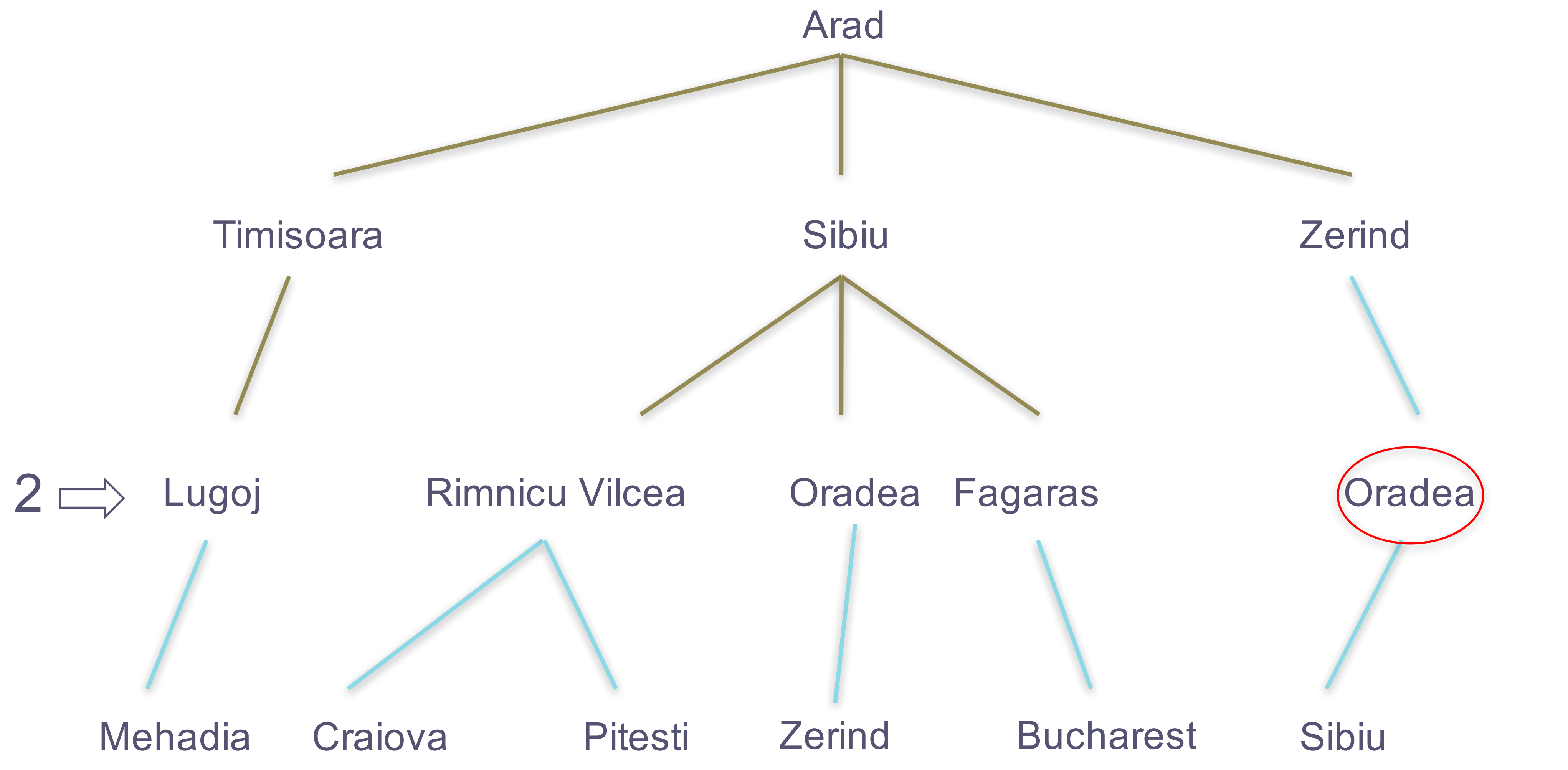
Iterative Deepening 5



Iterative Deepening 6

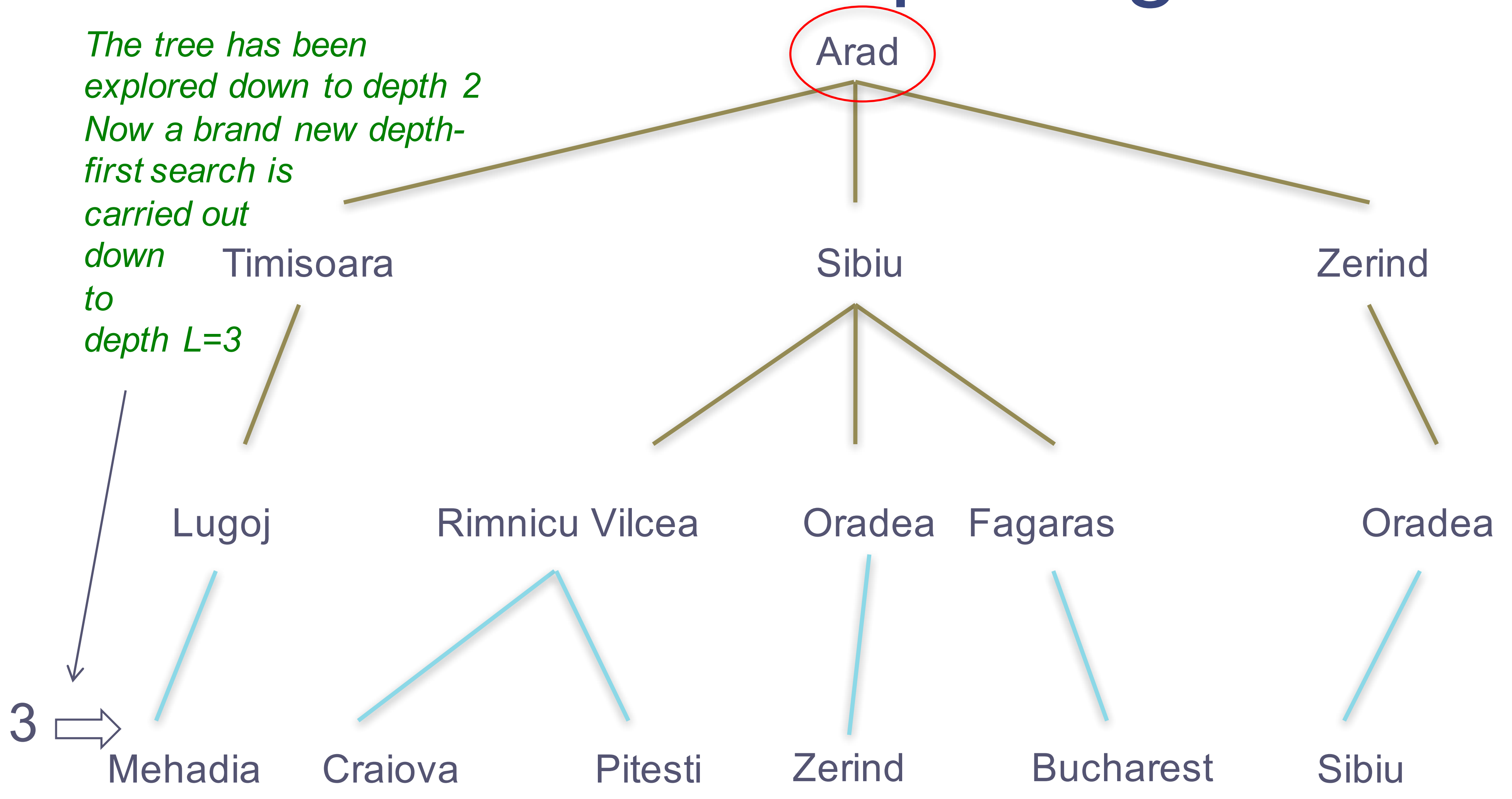


Iterative Deepening 7



Iterative Deepening 8

The tree has been explored down to depth 2 Now a brand new depth-first search is carried out down to depth L=3



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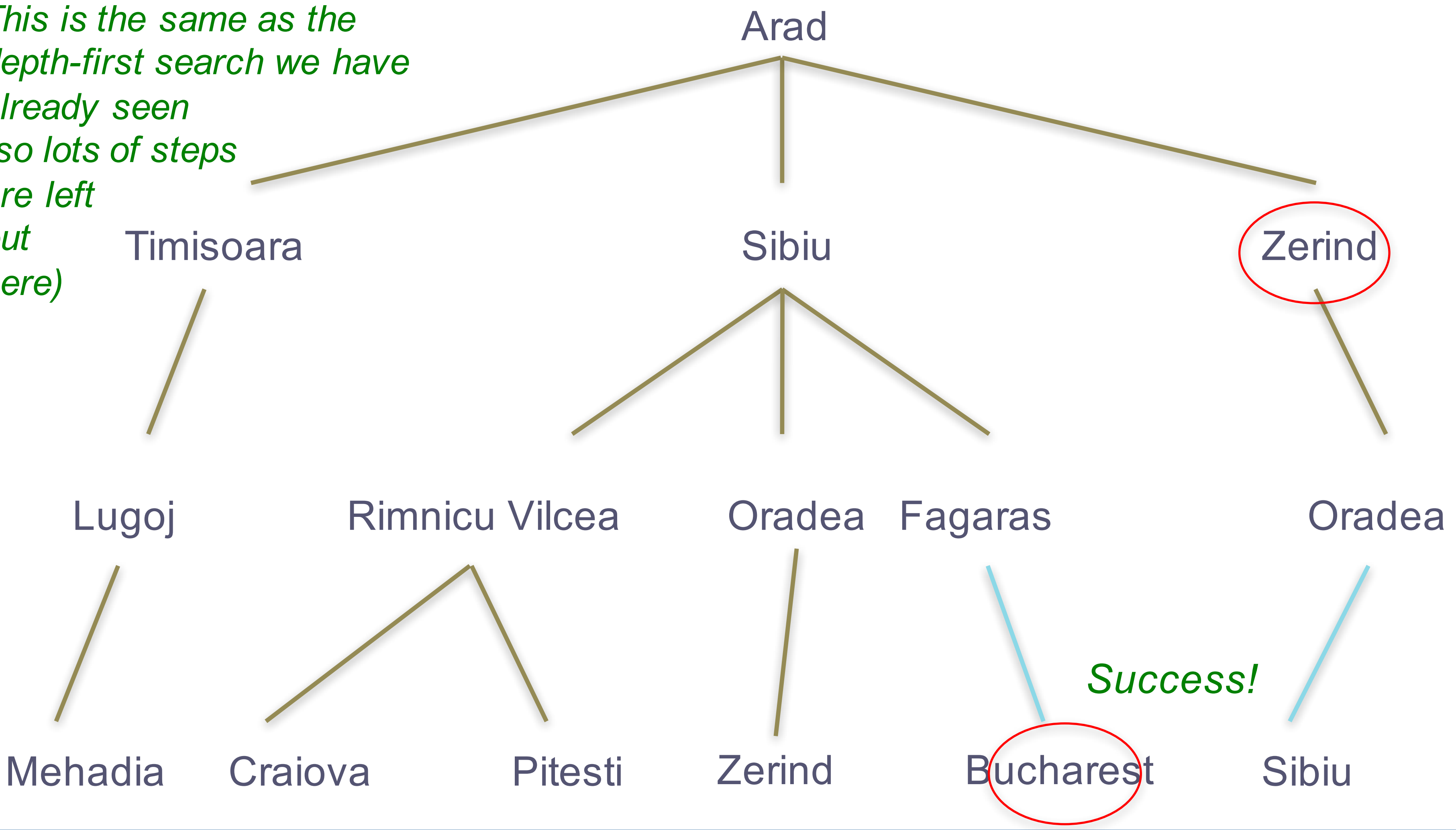
Iterative Deepening 9

This is the same as the depth-first search we have already seen (so lots of steps are left out here)

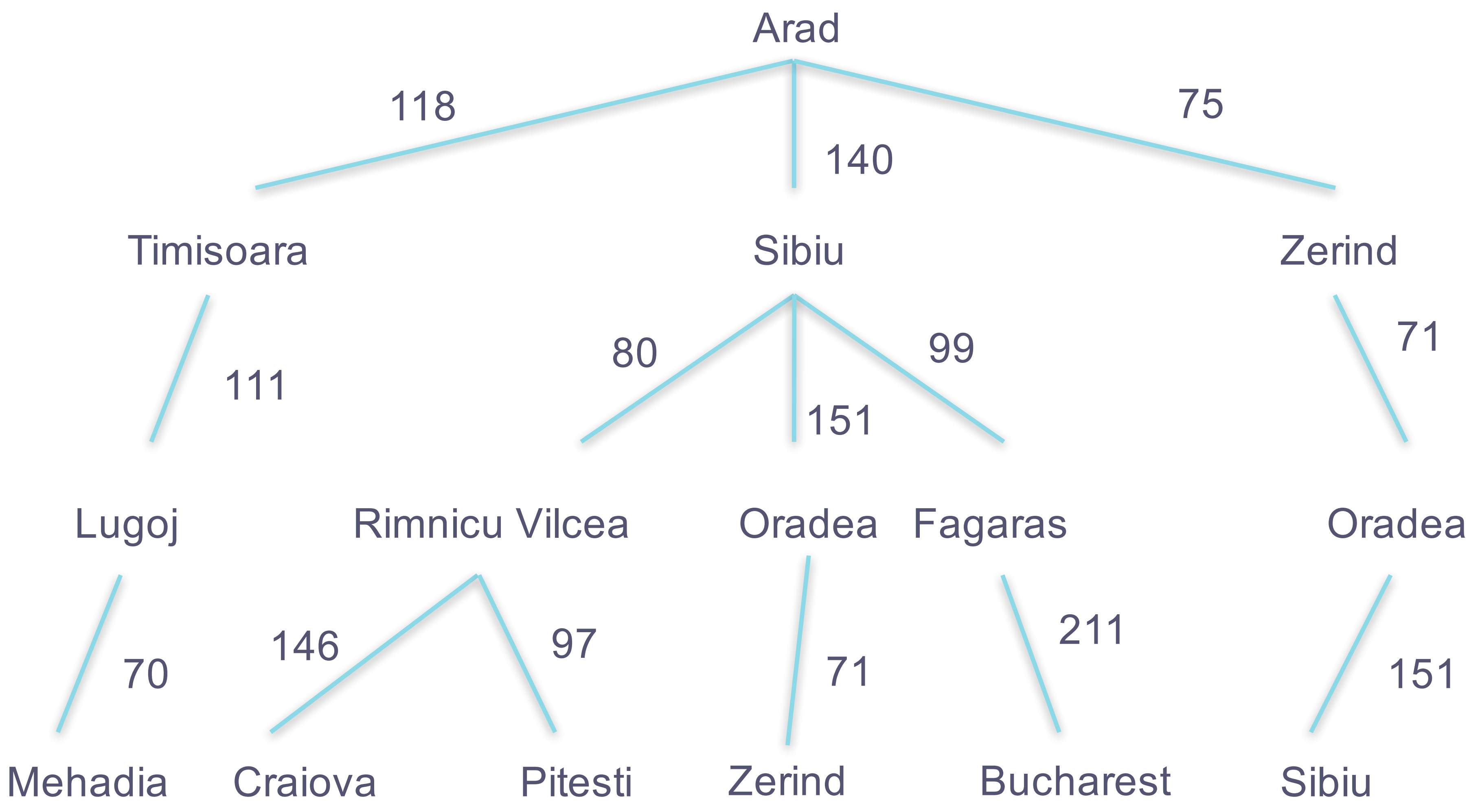


Properties of Iterative Deepening

- Combines completeness of breadth-first search with memory efficiency of depth-first search
- Guaranteed to find a solution if one exists
- Slower than both breadth-first and depth-first
- Efficient use of memory
- Guaranteed to find the shortest path to a solution

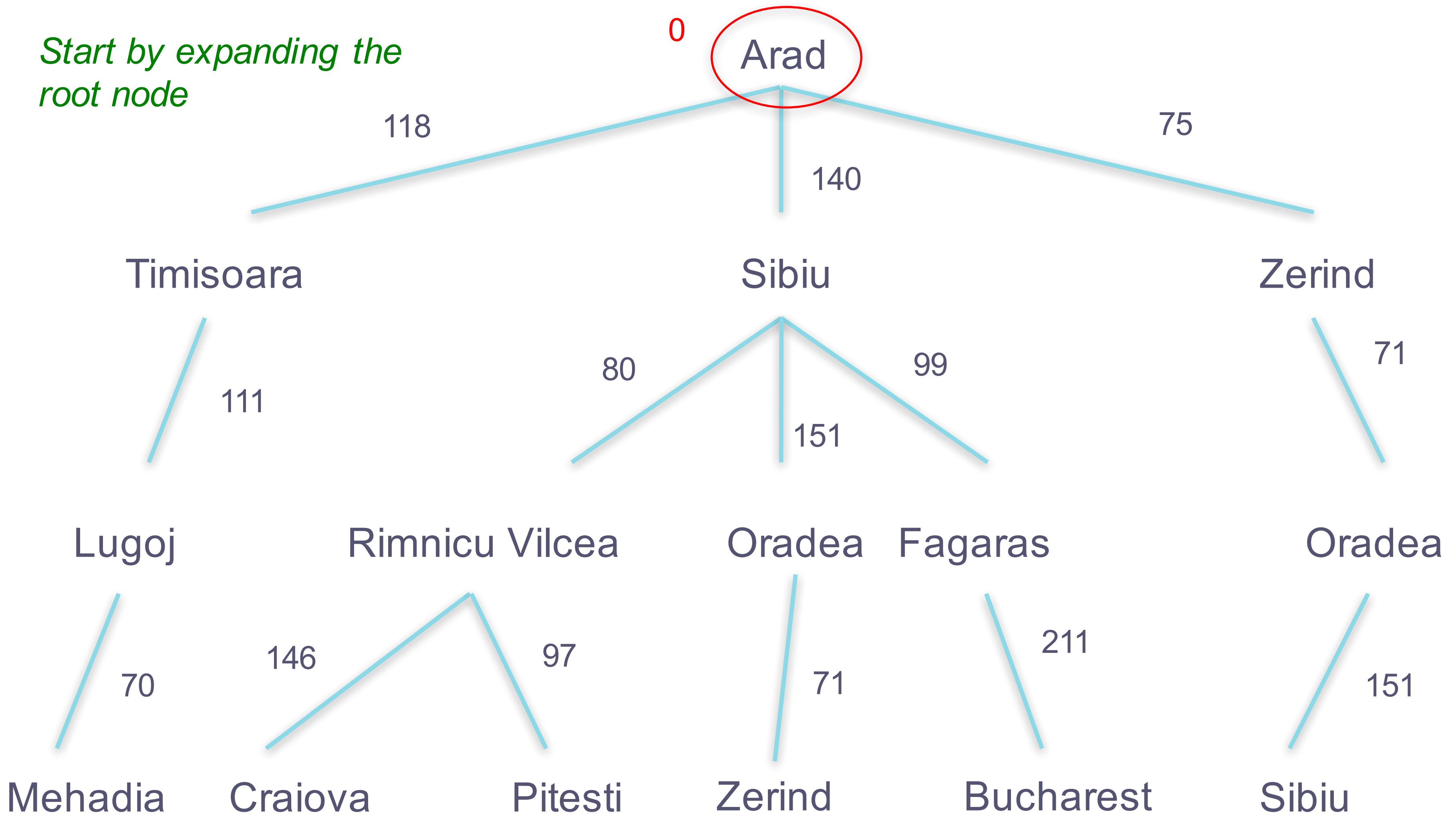
Uniform Cost Search

Search Tree with Costs

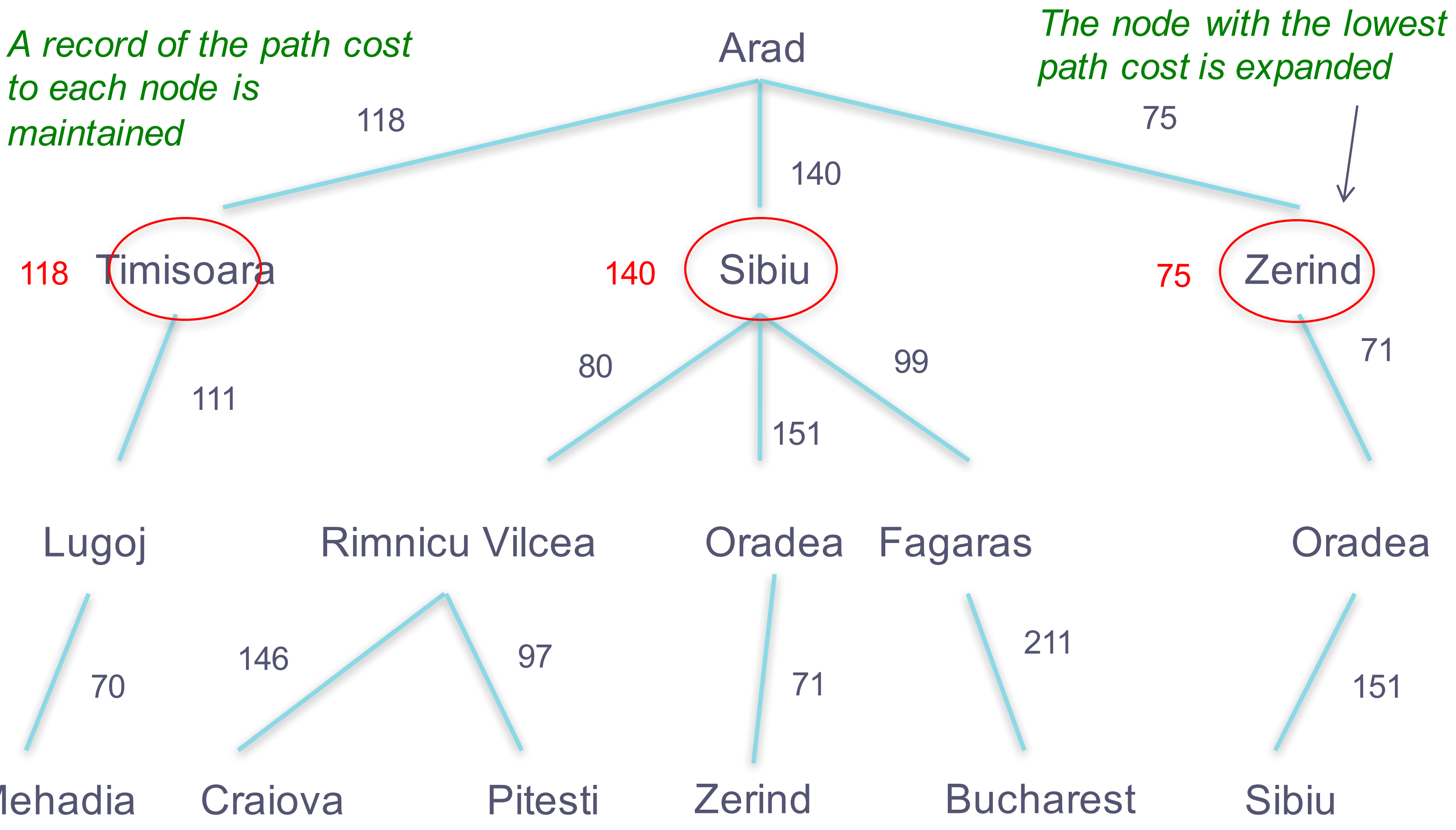


Uniform Cost Search 1

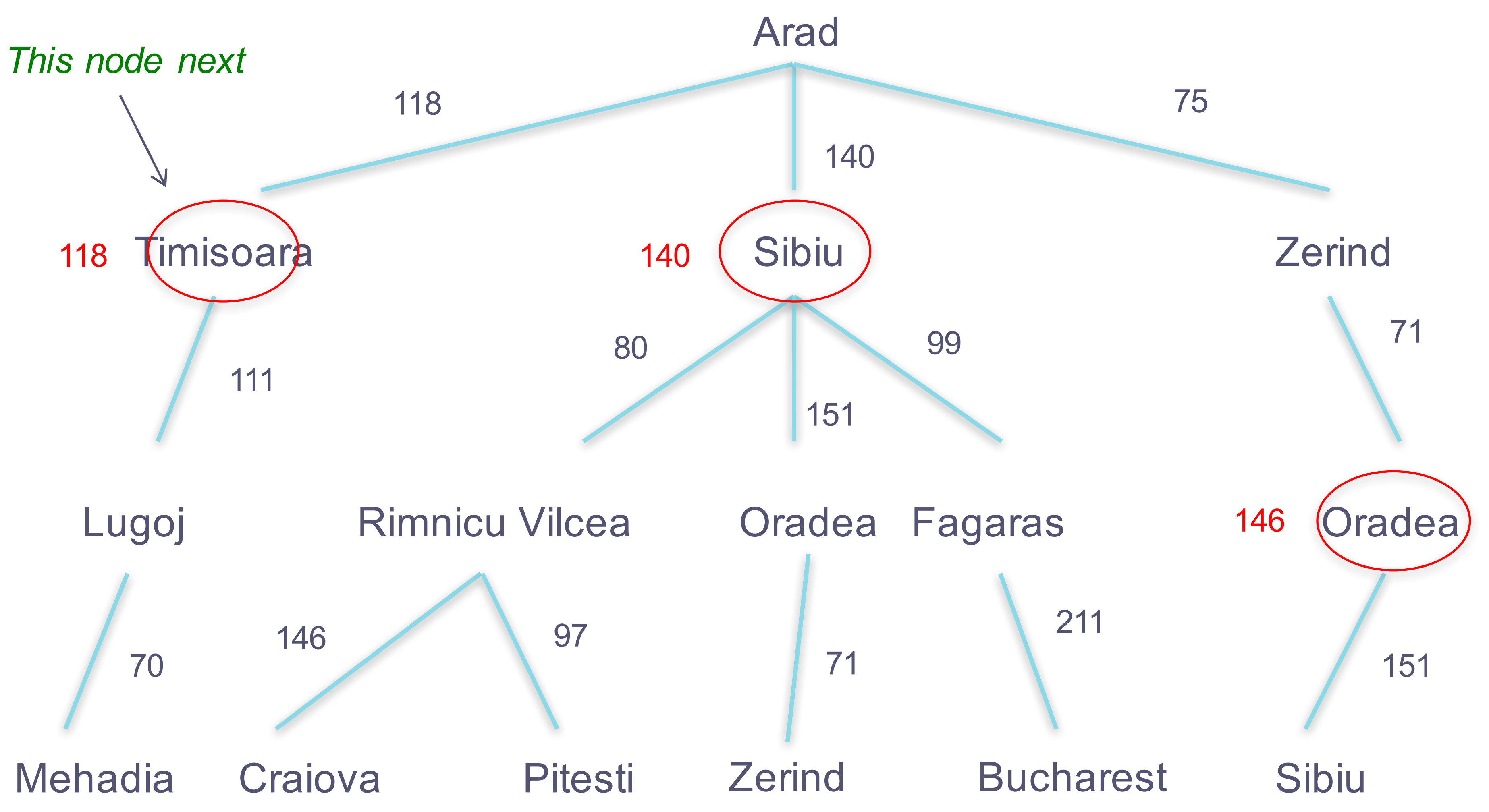
Start by expanding the root node



Uniform Cost Search 2



Uniform Cost Search 3



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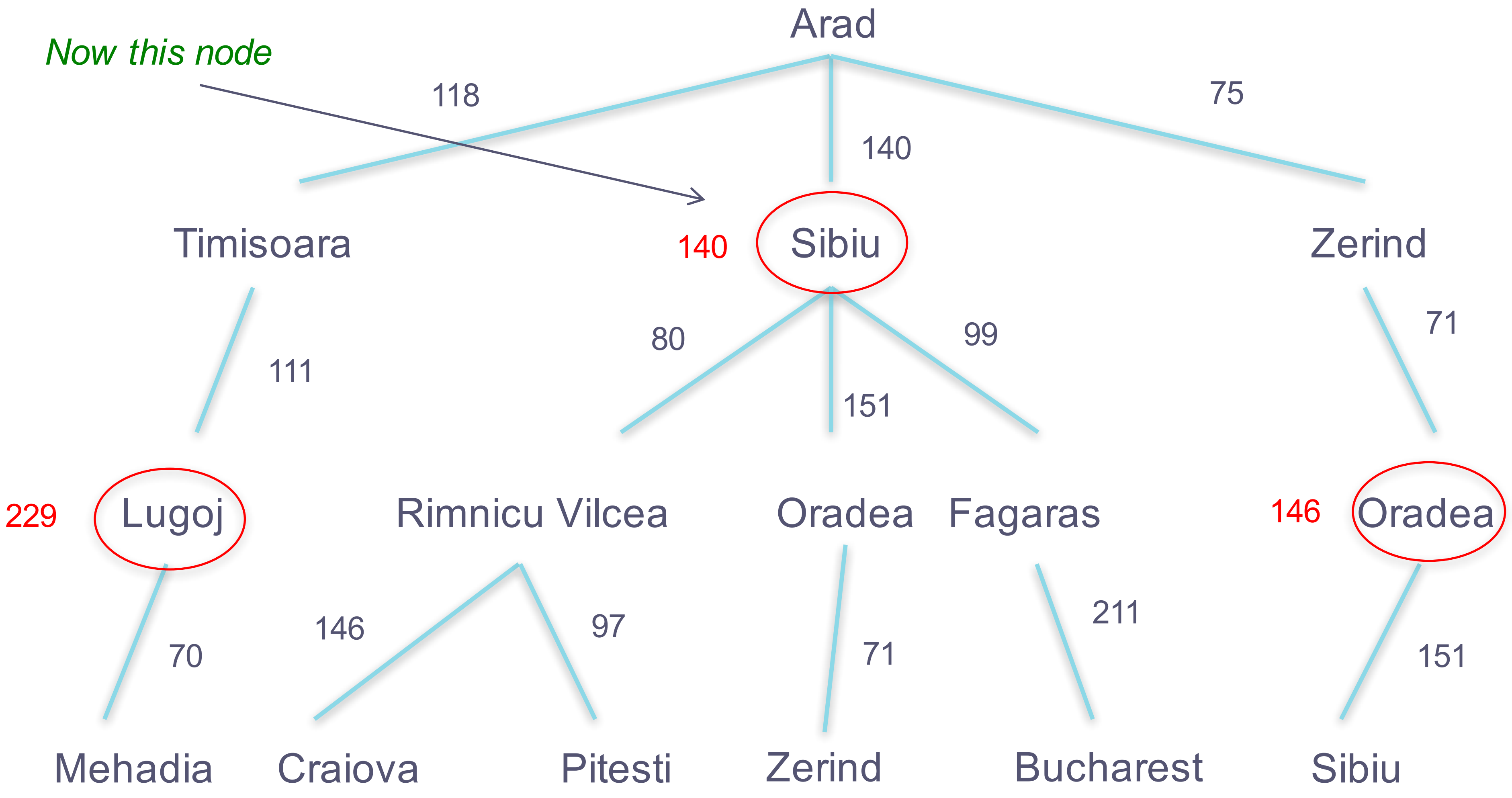
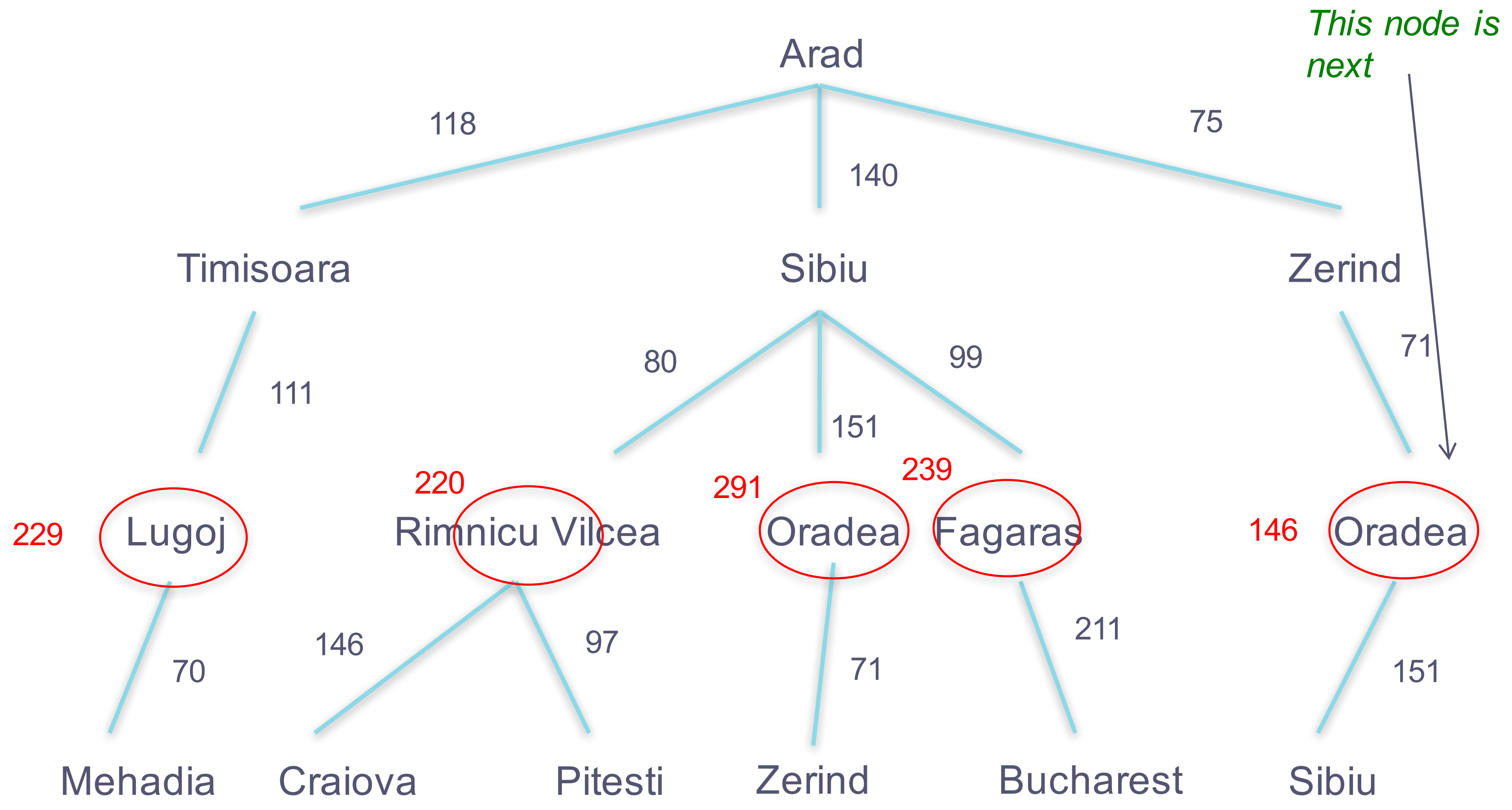
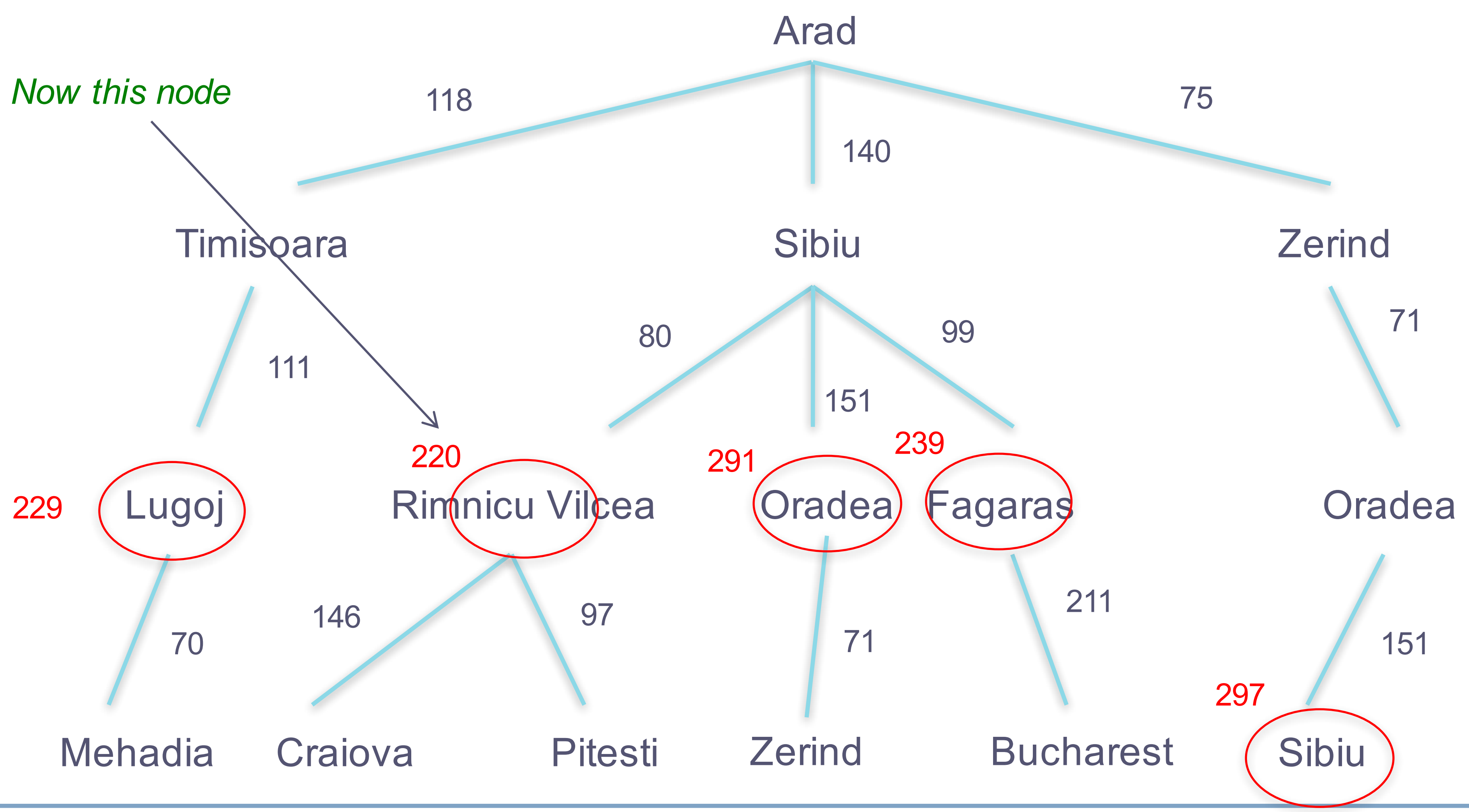
Uniform Cost Search 4



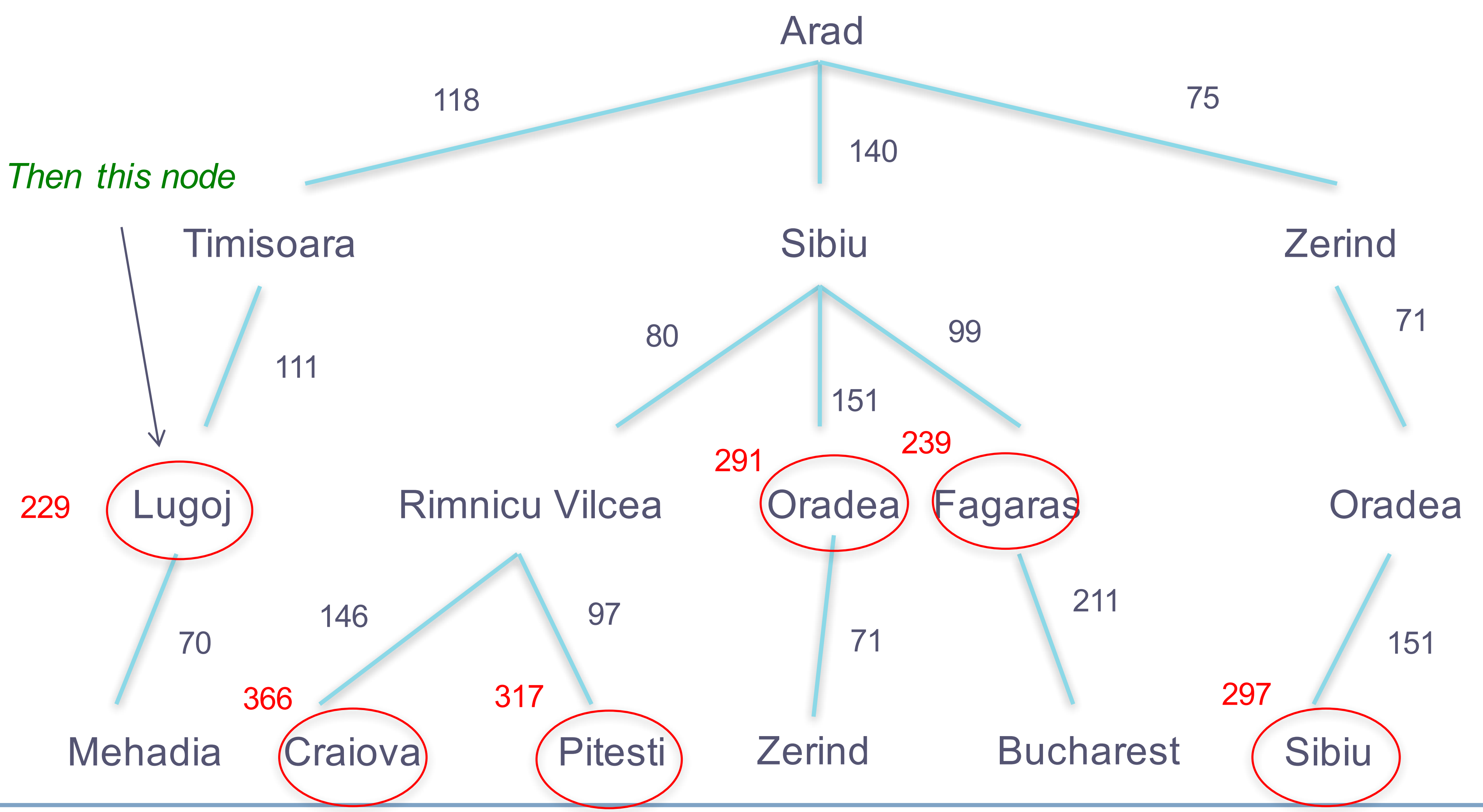
Uniform Cost Search 5



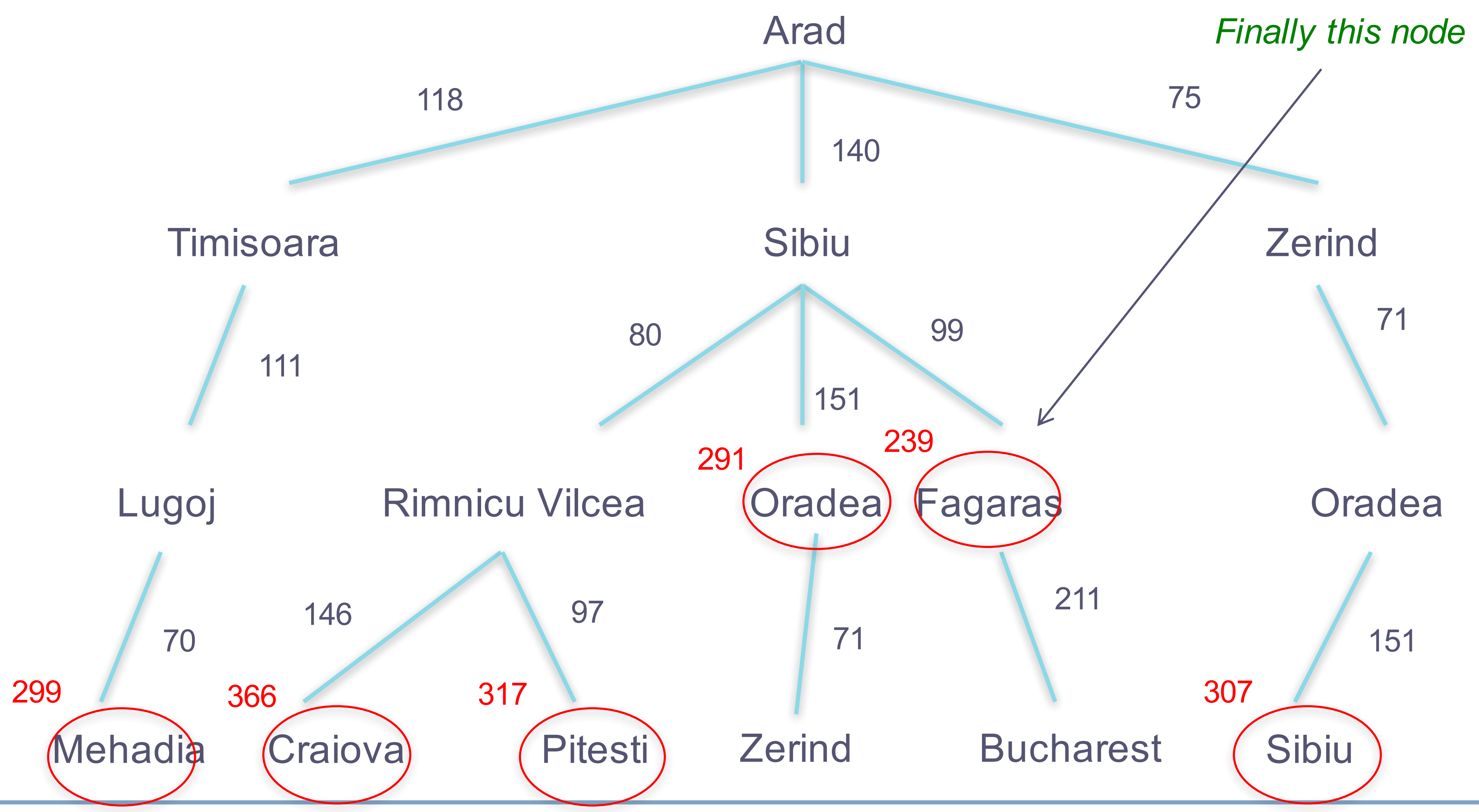
Uniform Cost Search 6



Uniform Cost Search 7

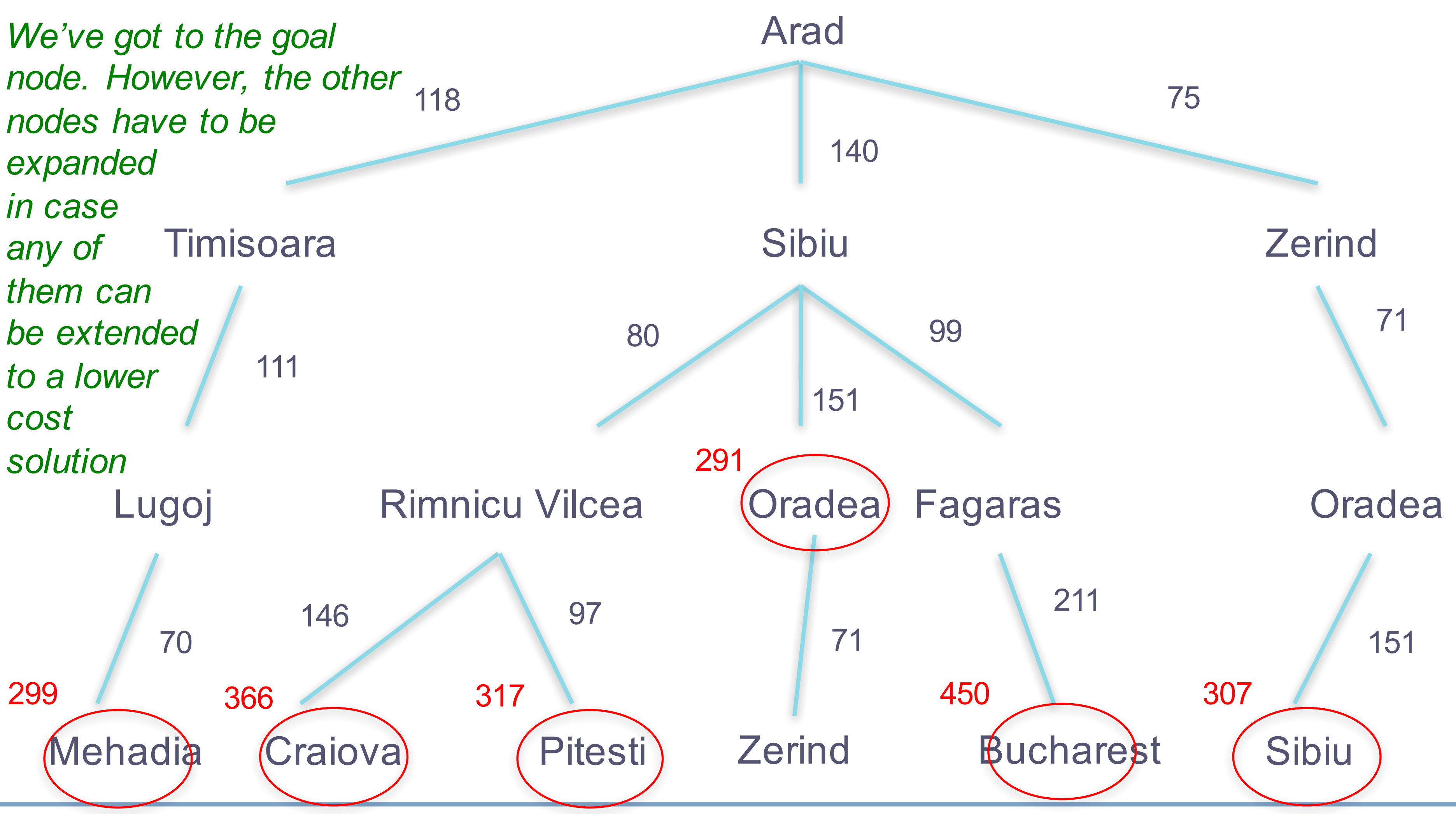


Uniform Cost Search 8



Uniform Cost Search 9

We've got to the goal node. However, the other nodes have to be expanded in case any of them can be extended to a lower cost solution



Properties of Uniform Cost Search

- Guaranteed to find a solution if one exists, as long as costs are all above some ε where $\varepsilon > 0$ (to avoid getting stuck in infinite branches)
  - Note: it's not enough for all costs to be above zero
  - Consider an infinite branch with successive costs $\frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \ldots$
- Time and memory use proportional to number of nodes with cost less than that of optimal solution
- Guaranteed to find optimal solution