BREADTH FIRST SEARCH

bfs

Breadth-first search

- What is it good for?
- We have a graph and we want to visit every node → we can do it with BFS
- We visit every vertex exactly once
- We visit the neighbours then the neighbours of these new vertices and so on
- Running time complexity: **O(V+E)**
- Memory complexity is not good: we have to store lots of references
- Thats why DFS is usually preferred
- BUT it constructs a shortest path: Dijkstra algorithm does a BFS if all the edge weights are equal to 1

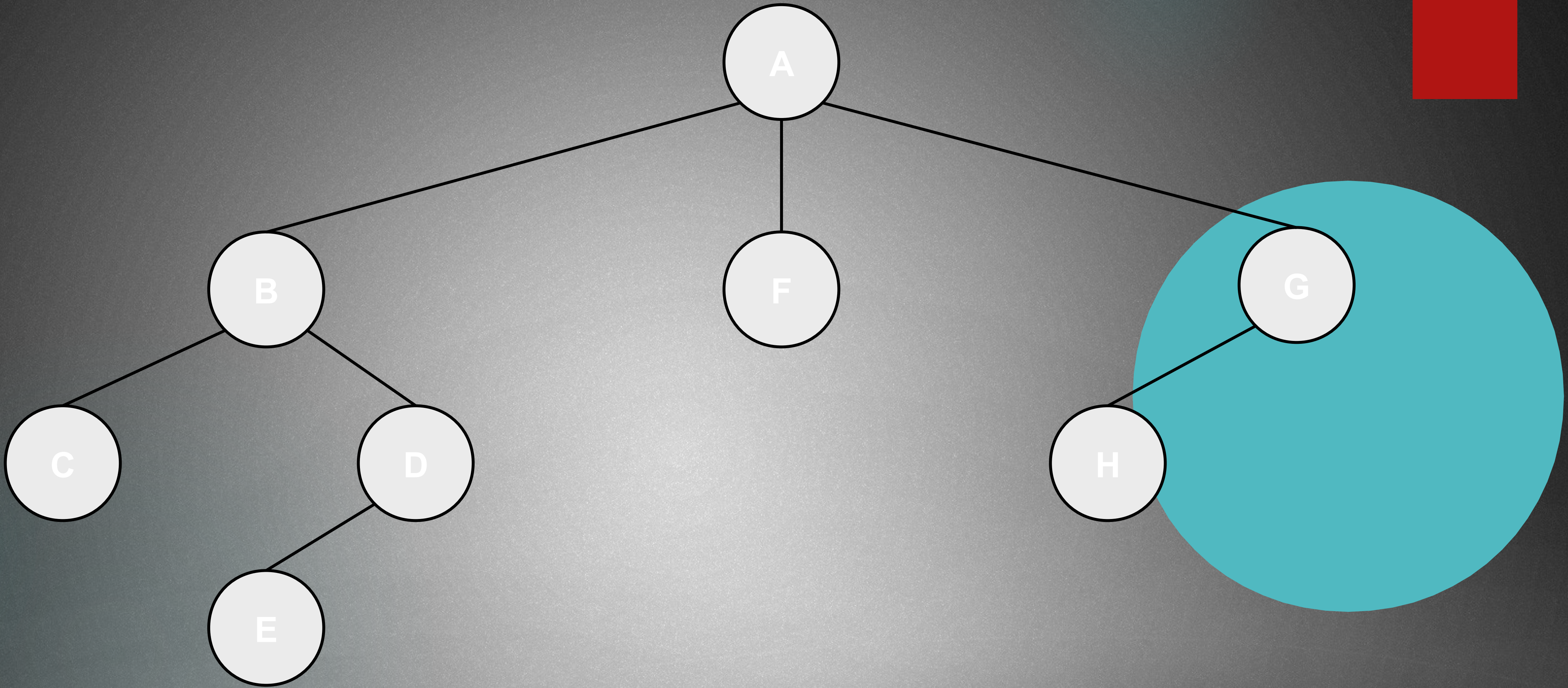
Breadth-first search

```
bfs(vertex)

    Queue queue
    vertex set visited true
     queue.enqueue(vertex)

    while queue not empty
        actual = queue.dequeue()

        for v in actual neighbours
            if v is not visited
                v set visited true
                queue.enqueue(v)
```

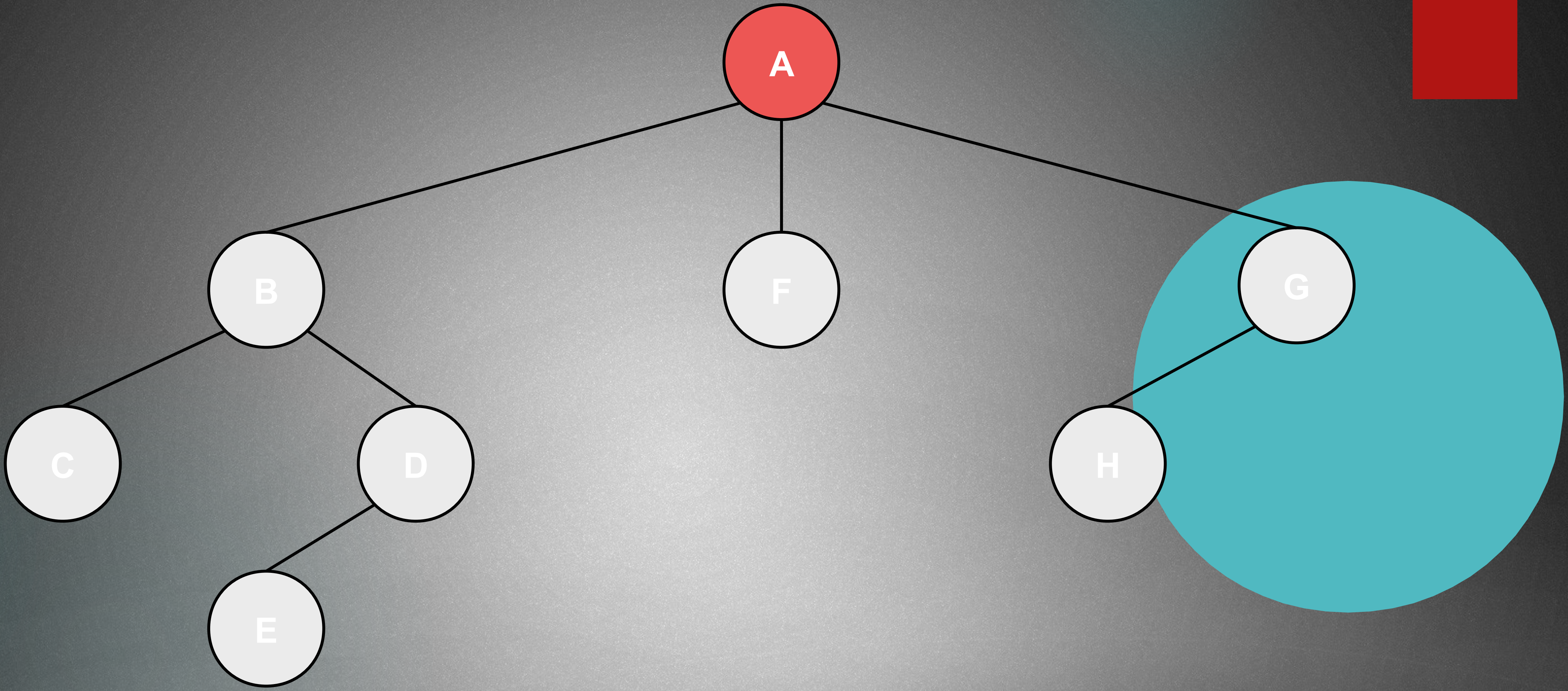
ITERATION

We have an empty queue at the beginning and we keep checking whether we have visited the given node or not

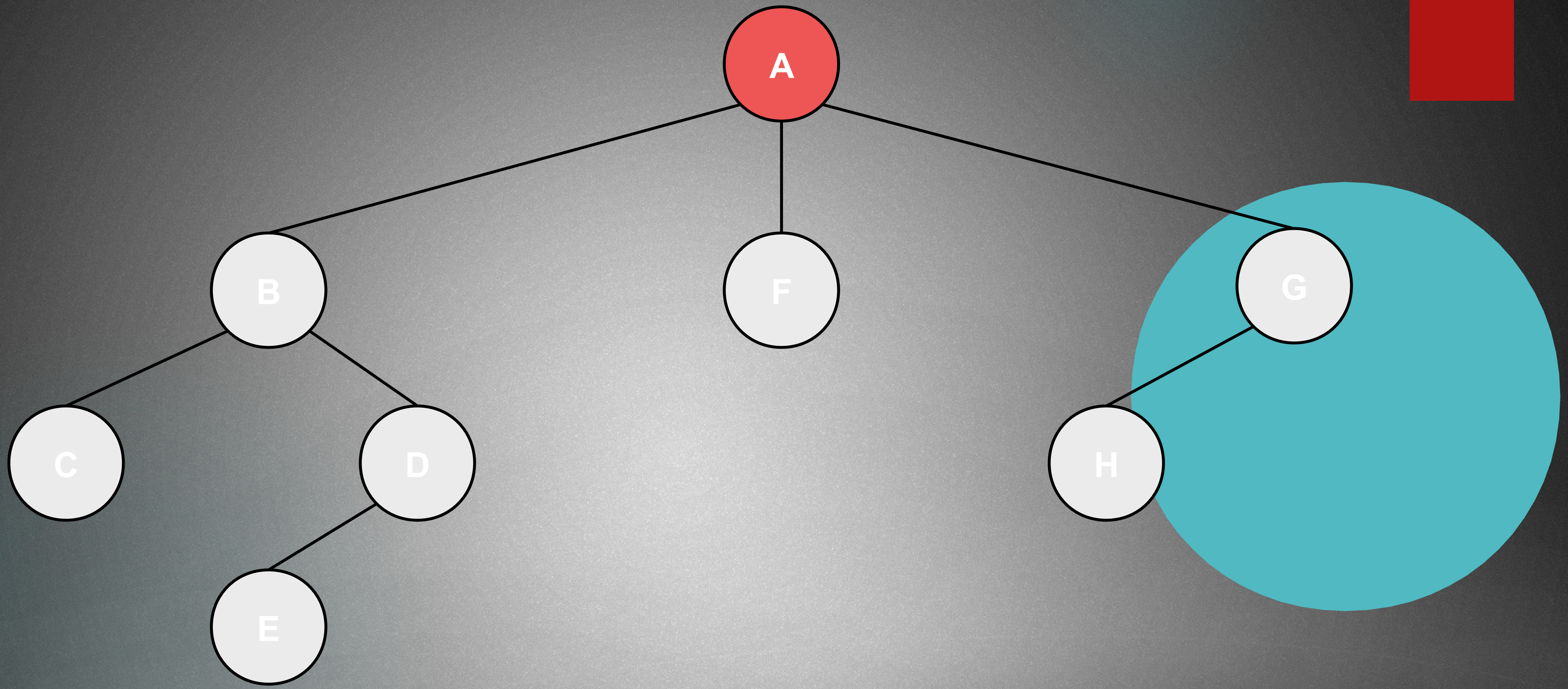
~ keep iterating until queue is not empty



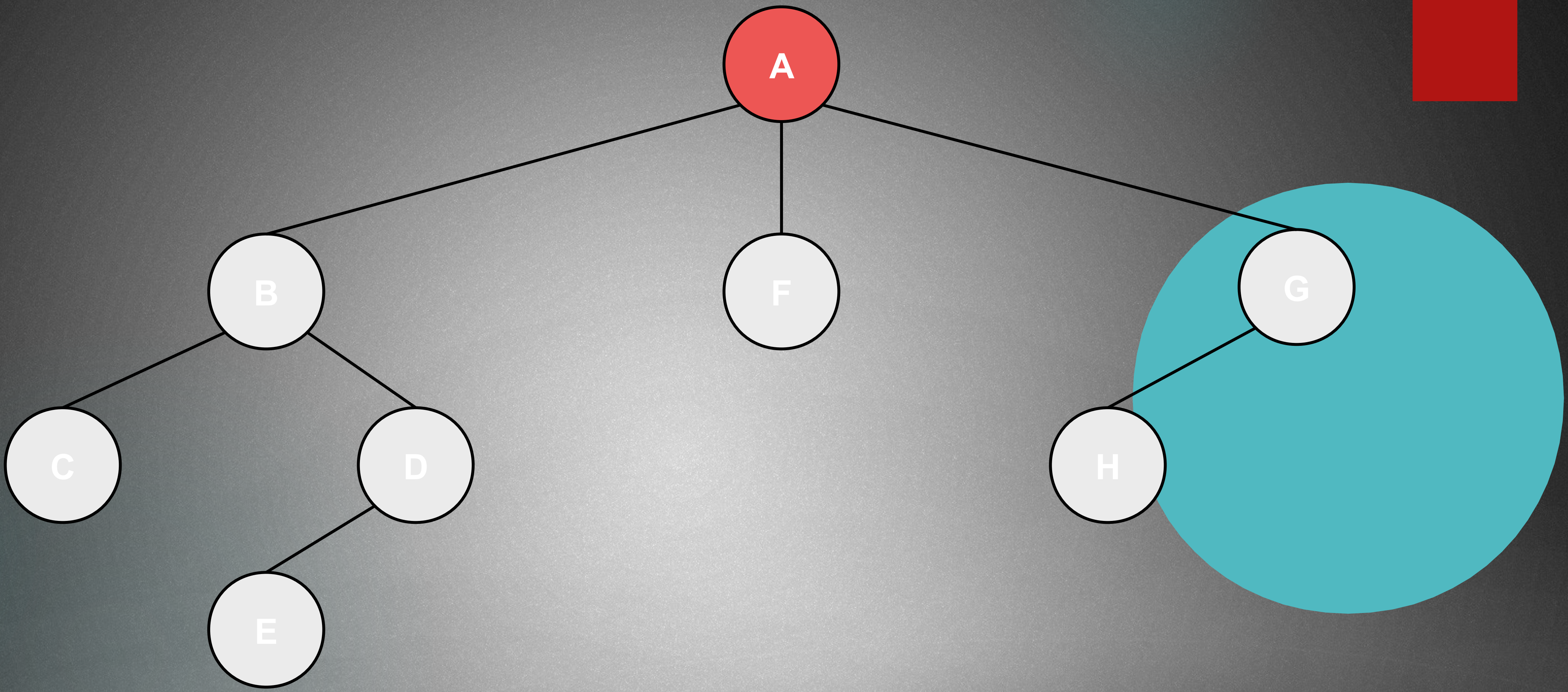
Queue: { }



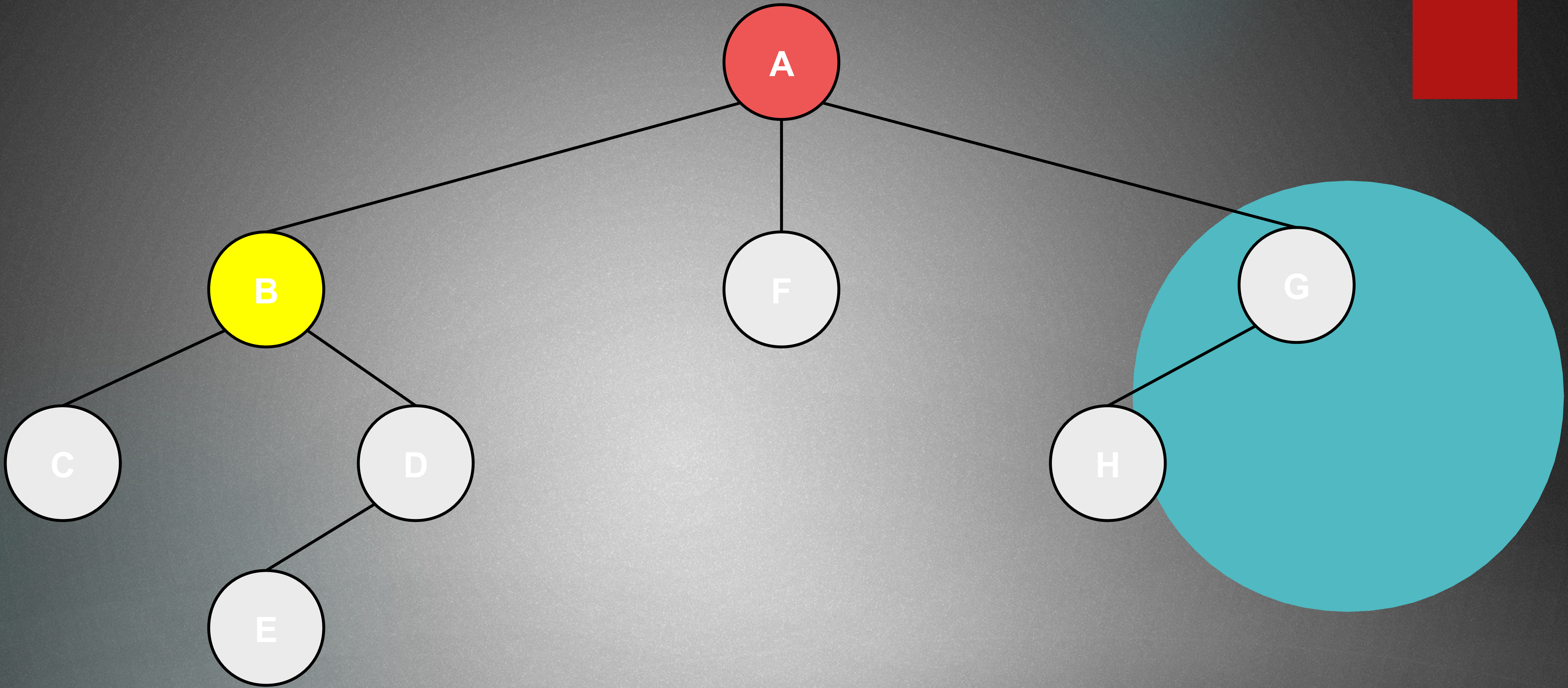
Queue: { A }



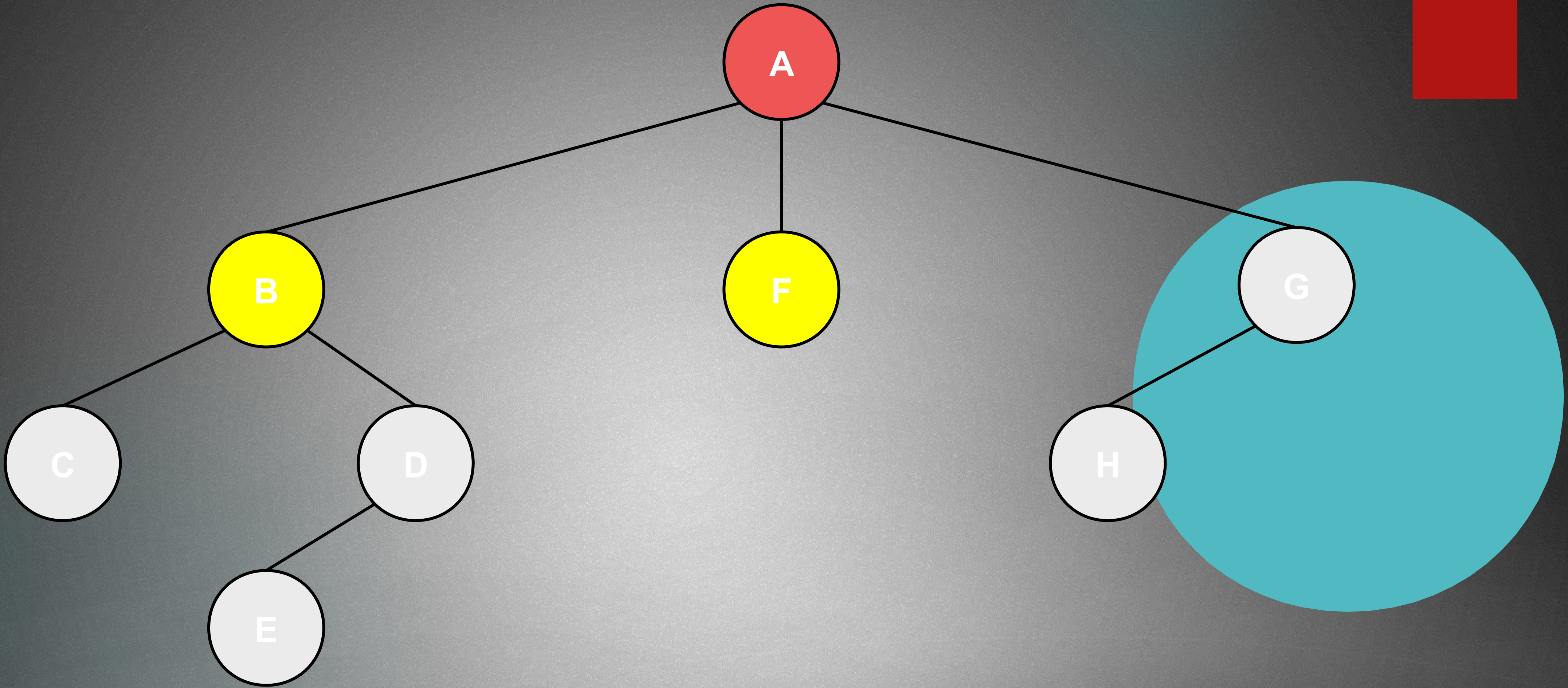
Queue: { **A** }   dequeue node A to be able to process its



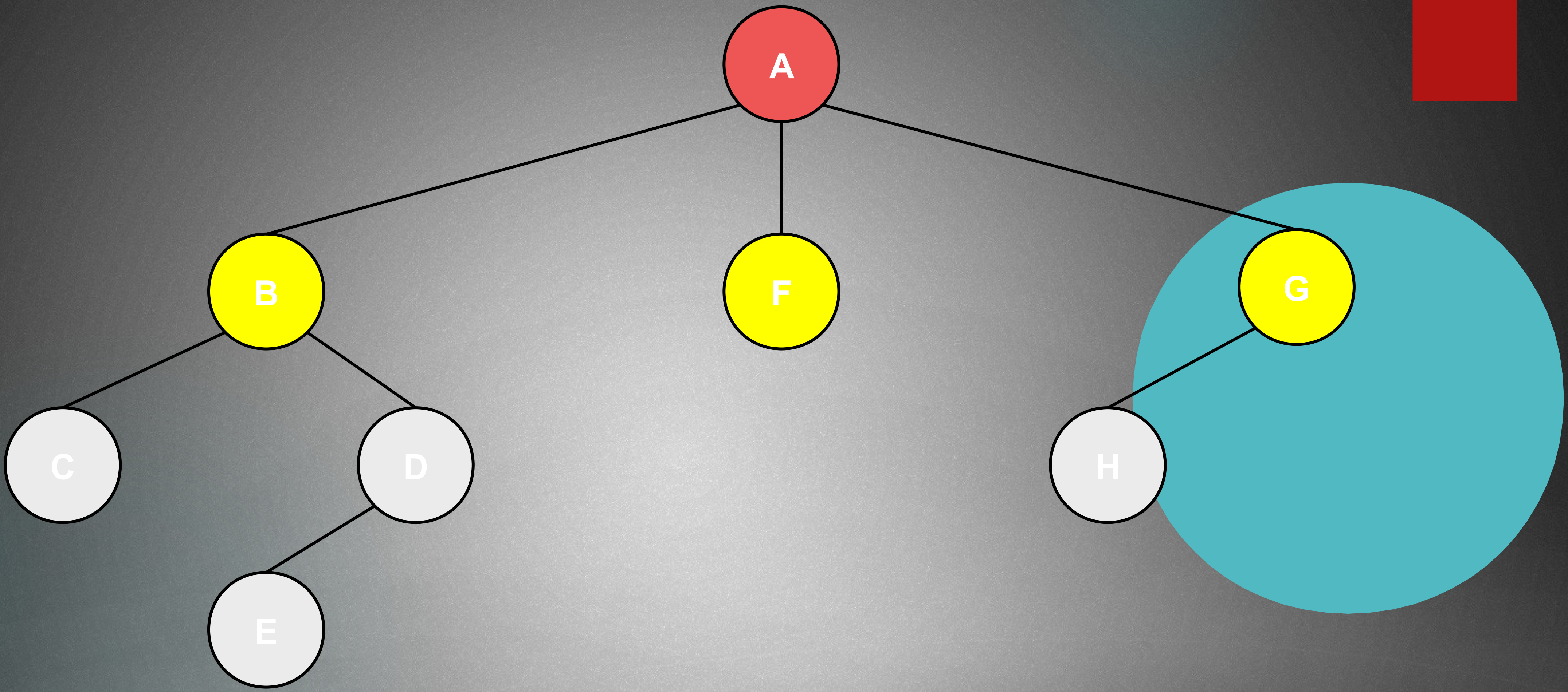
Queue: { } dequeue node A to be able to process its neighbours → visit all the children, if a node is unvisited then enqueue it !!!



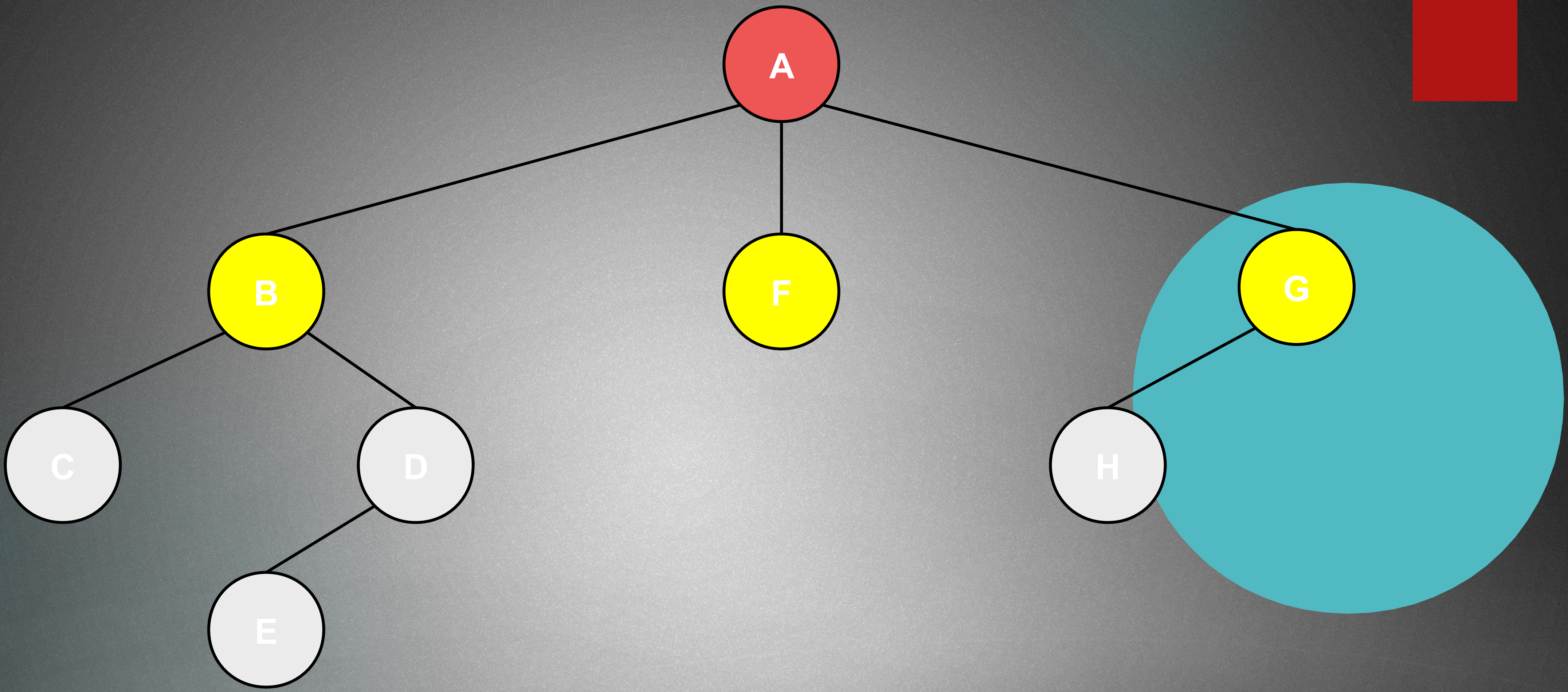
Queue: { B }   node B is not visited → put it to the queue



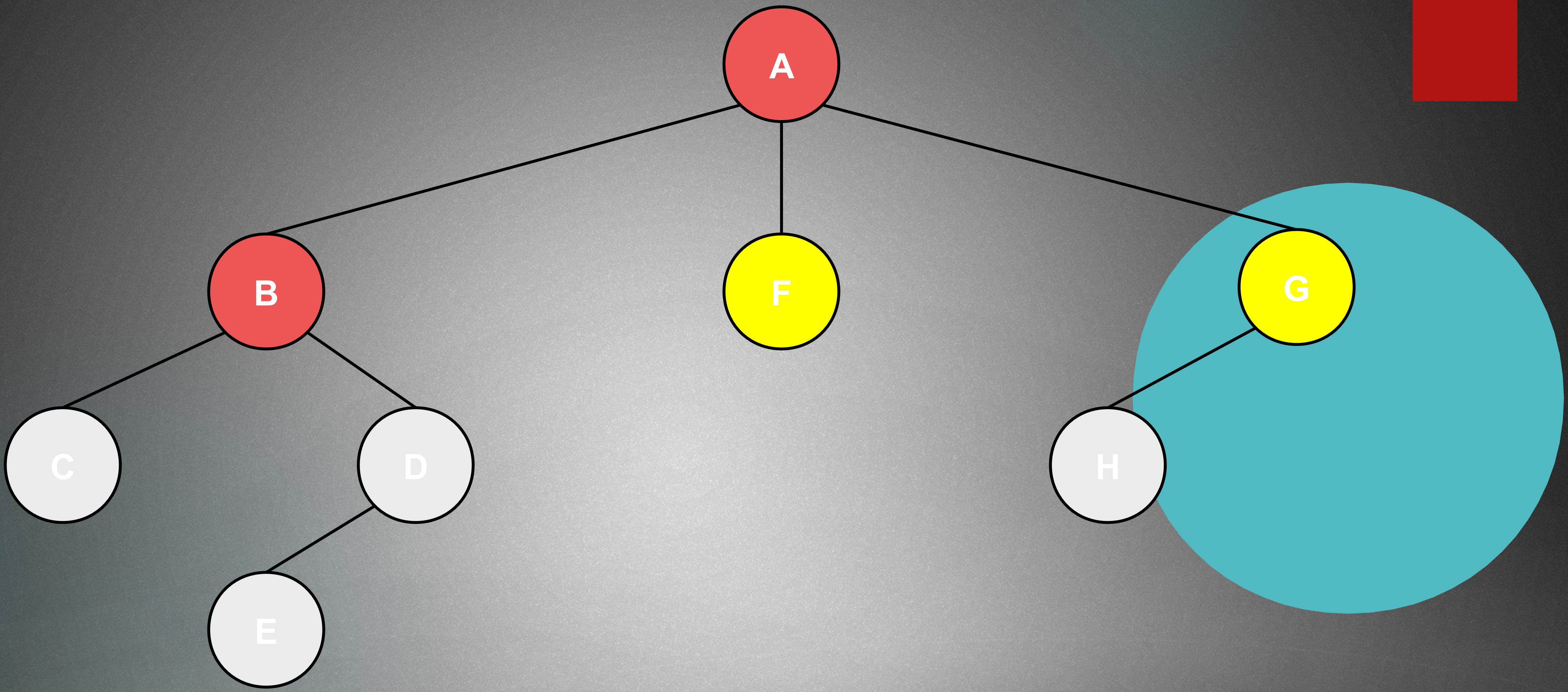
Queue: { F B }   node F is not visited → put it to the queue



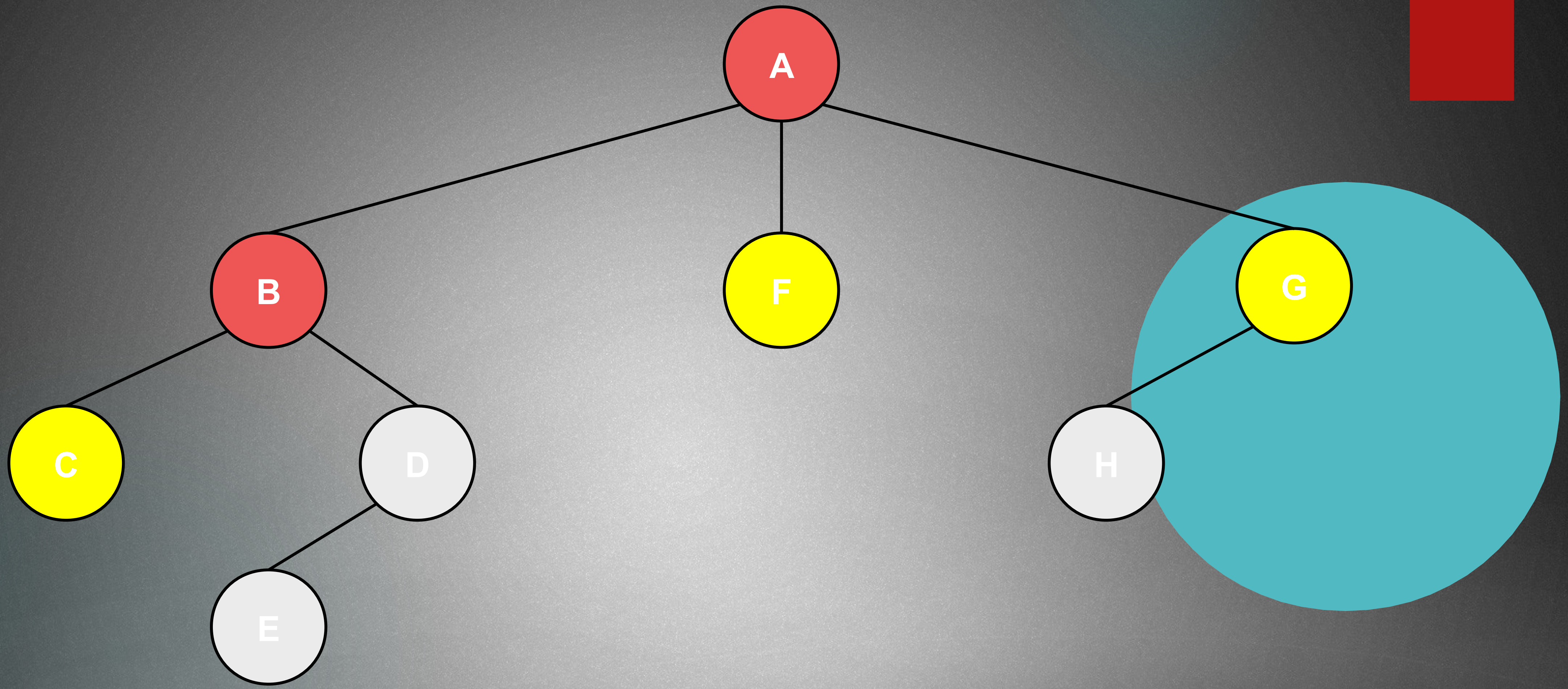
Queue: { G F B }   node G is not visited → put it to the queue



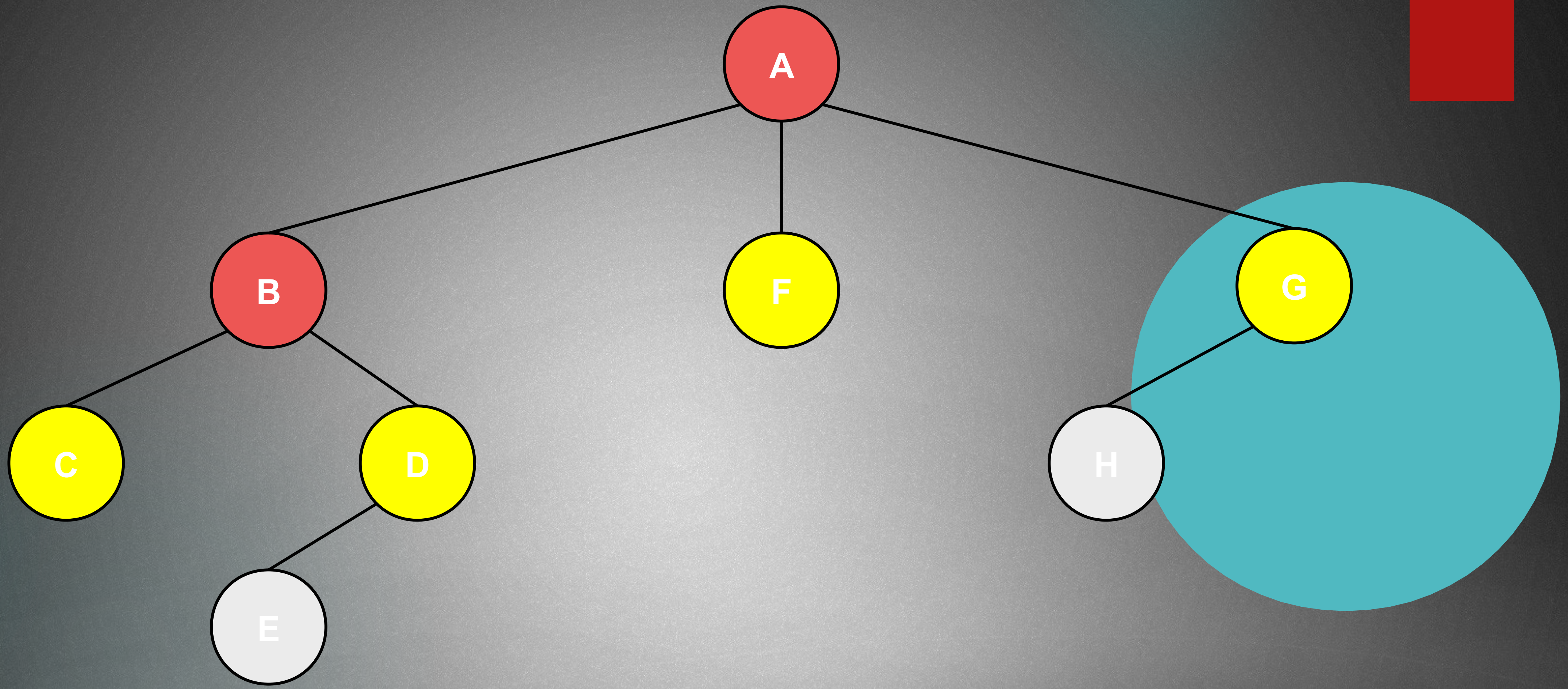
Queue: { G F **B** } dequeue the next node → it is B and visit its children + put them into the queue if necessary



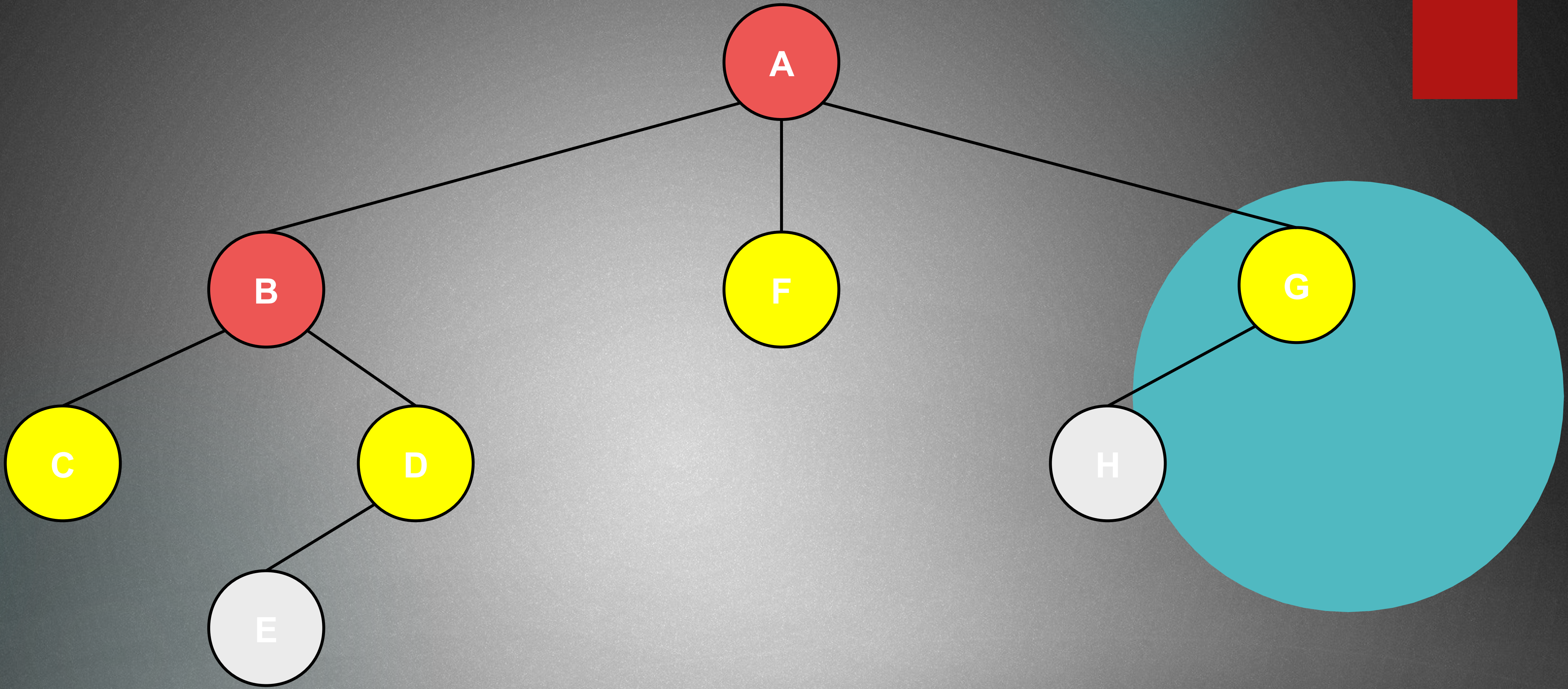
Queue: { G F }	dequeue the next node → it is G and visit its children + put them into the queue if necessary



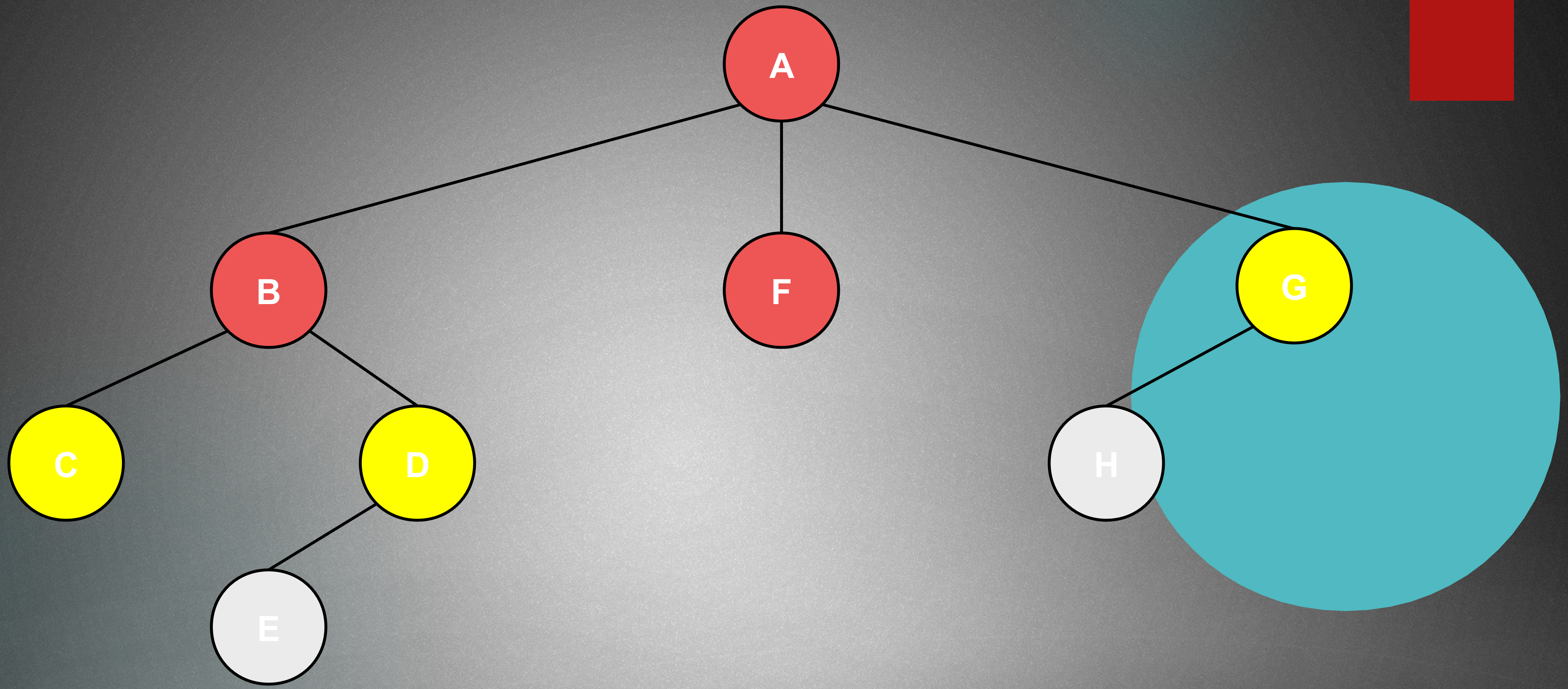
Queue: { C G F } dequeue the next node → it is G and visit its children + put them into the queue if necessary



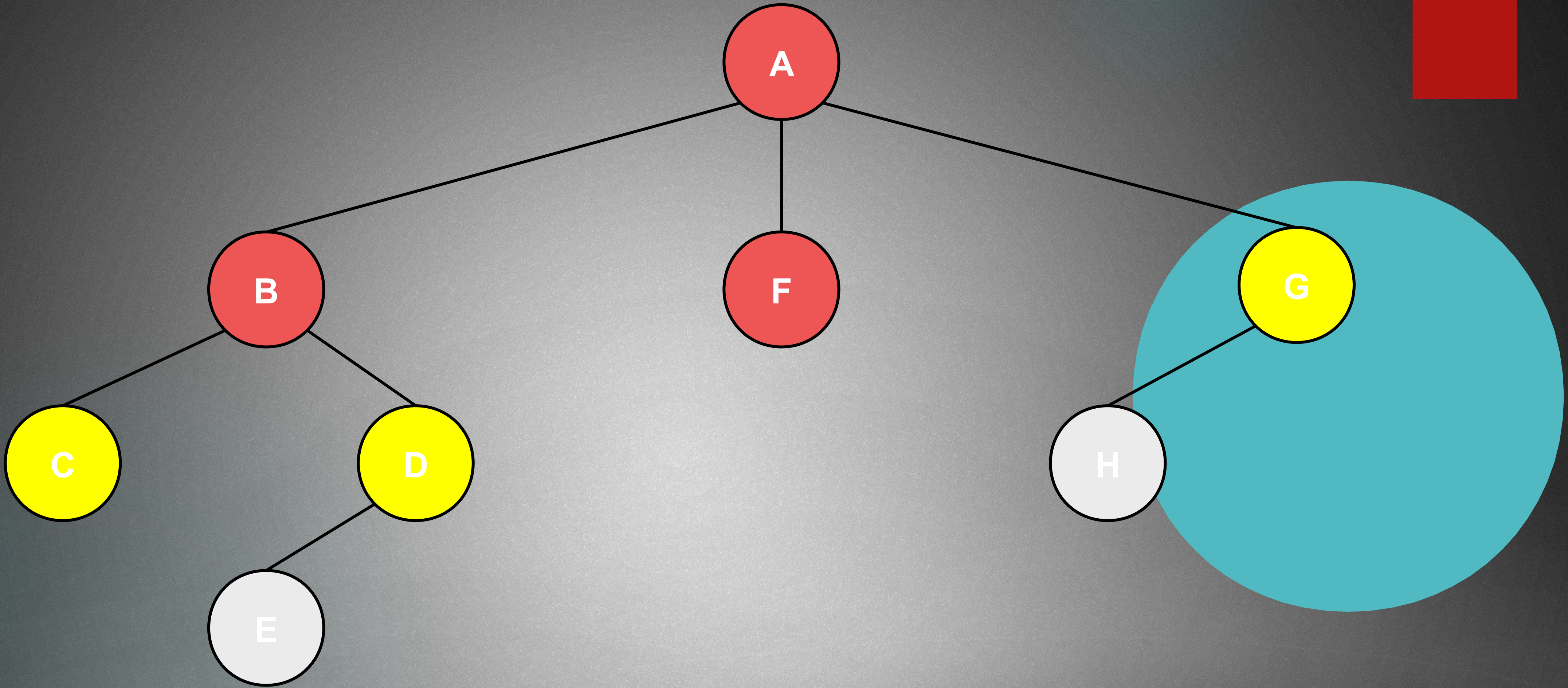
Queue: { D C G F }   dequeue the next node → it is G and visit its children + put them into the queue if necessary



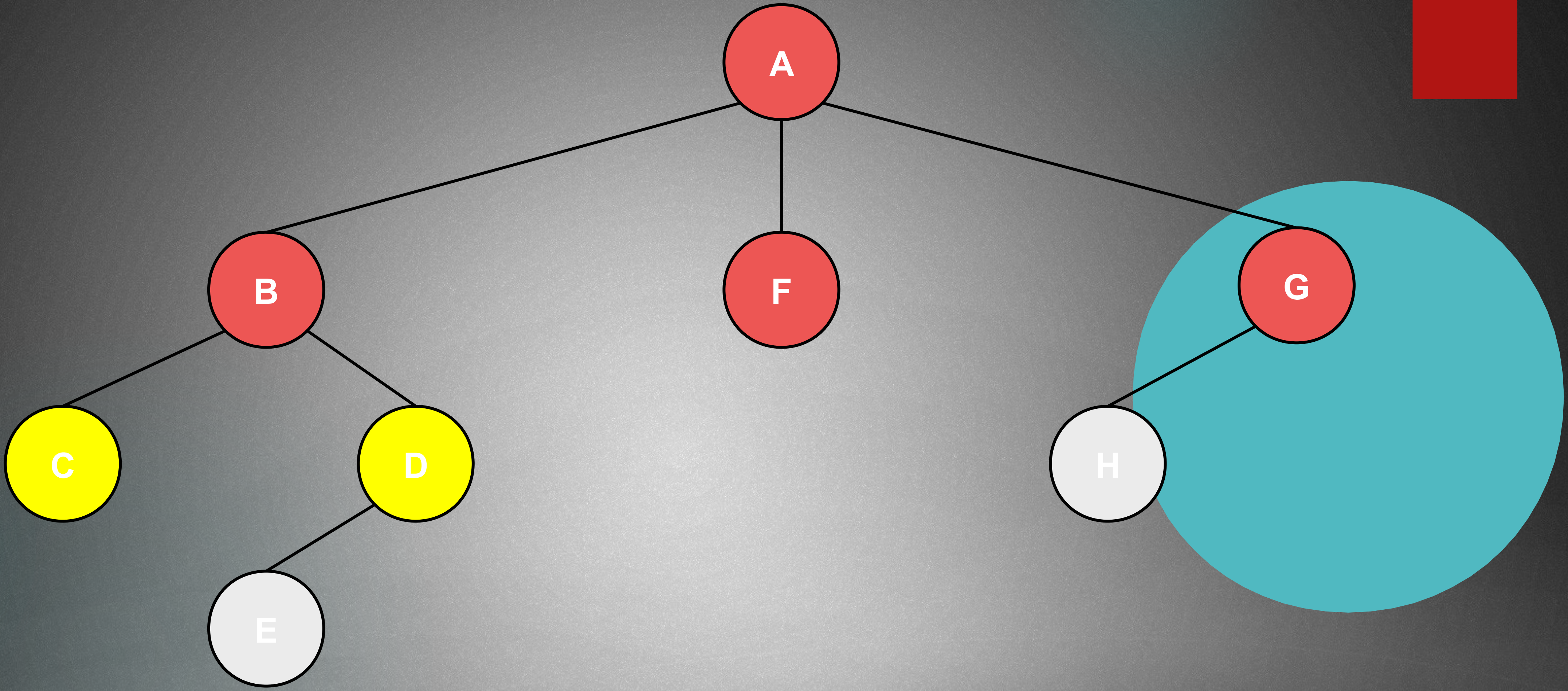
Queue: { D C G **F** }



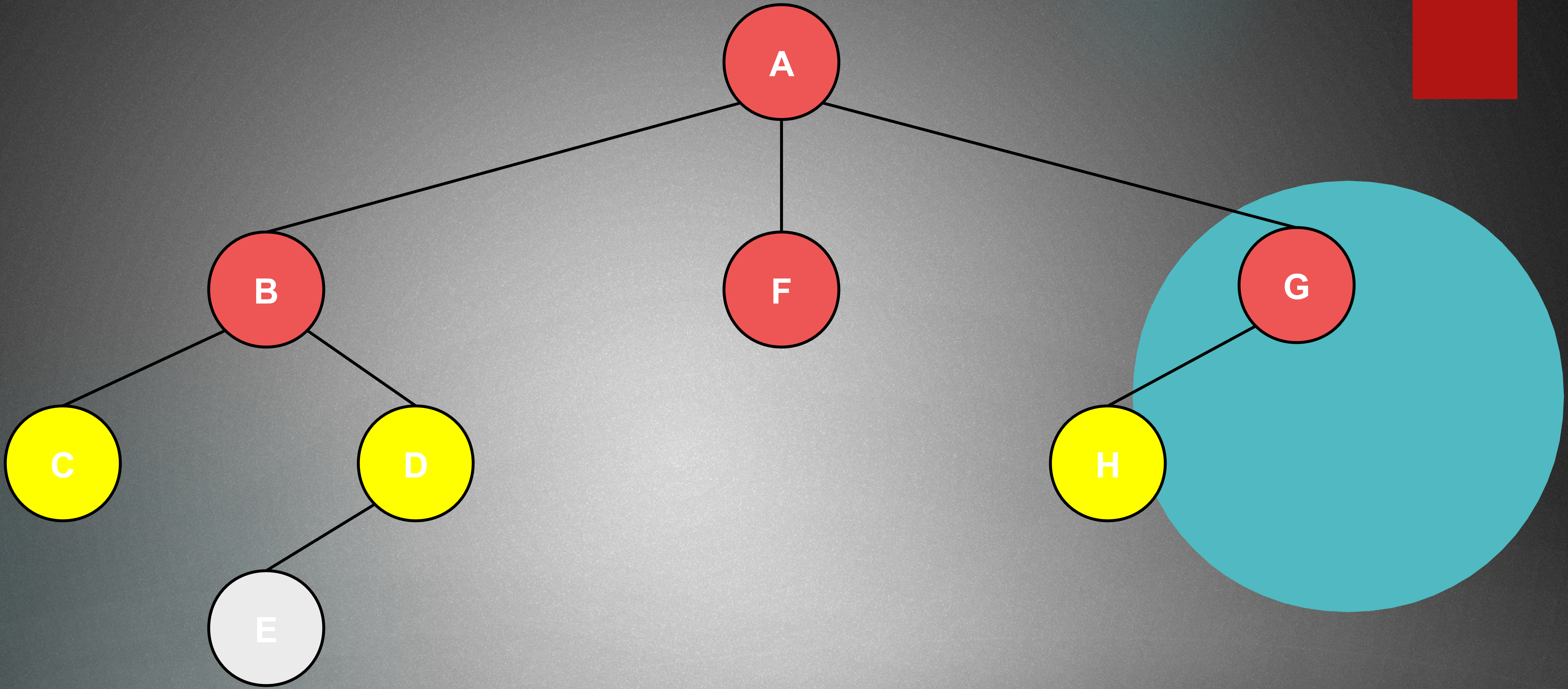
Queue: { D C G }



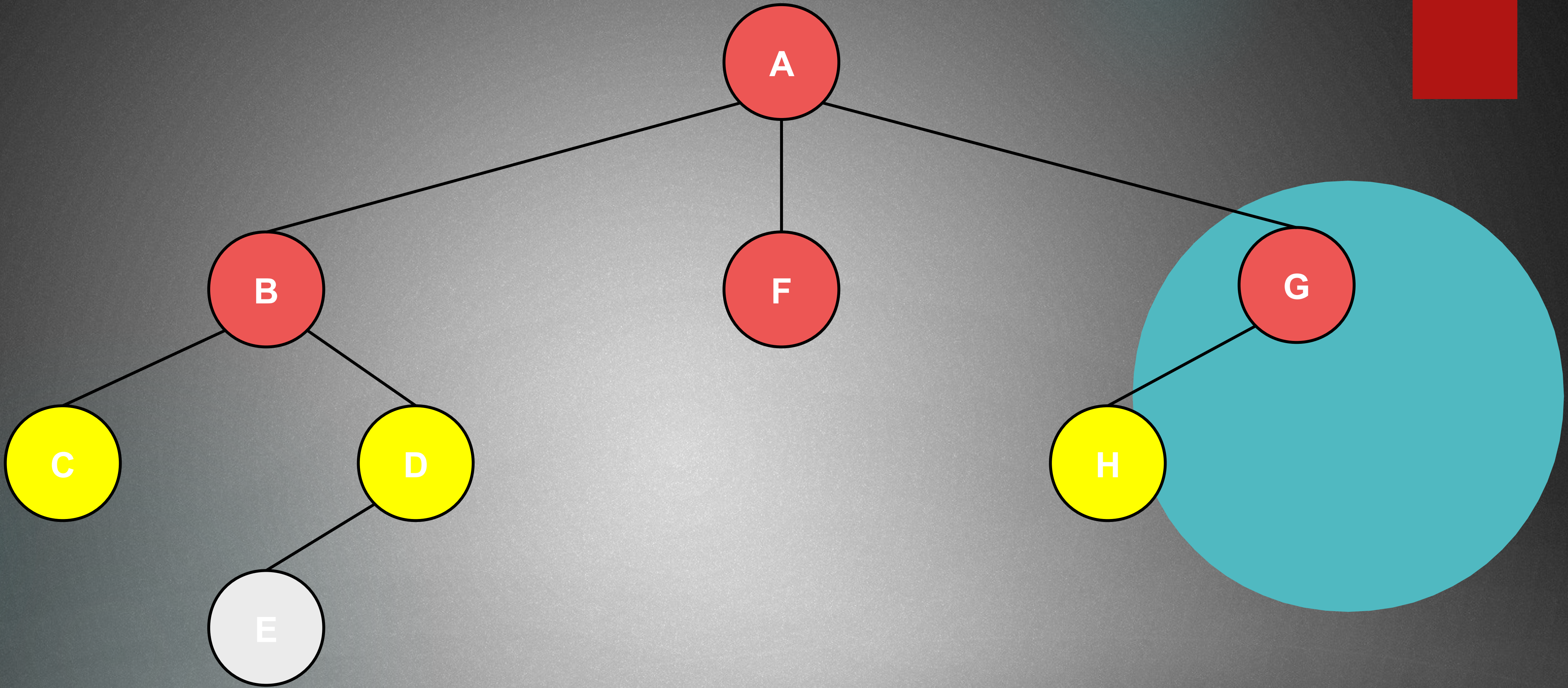
Queue: { D C **G** }



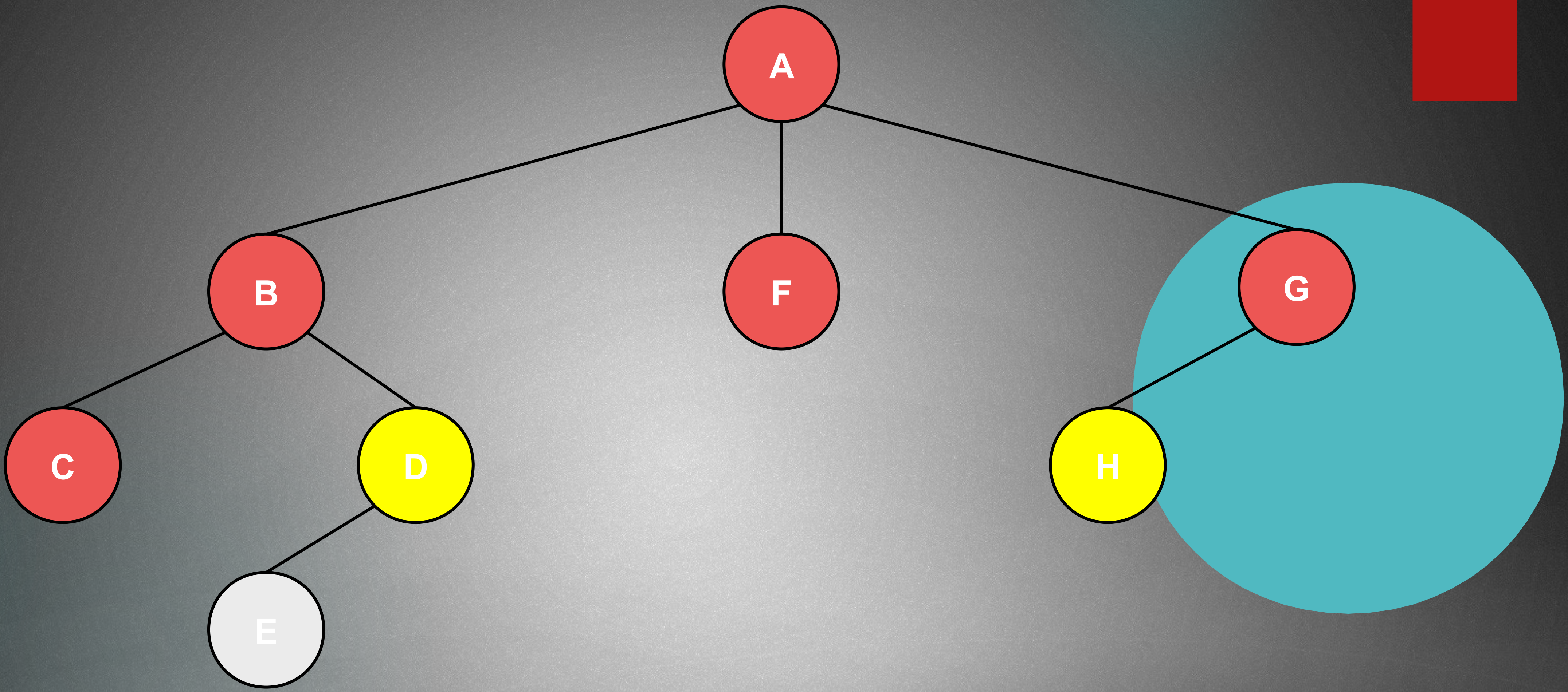
Queue: { D C }



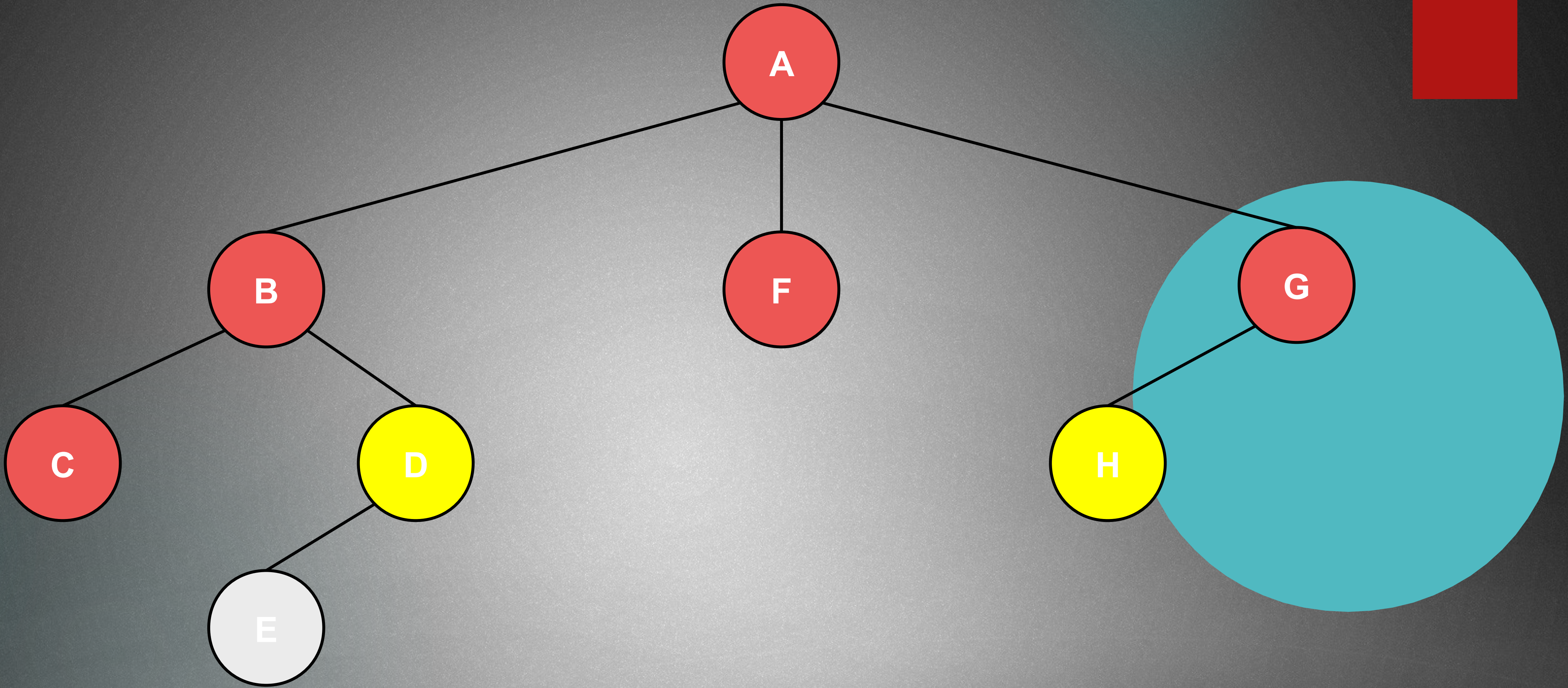
Queue: { H D C }



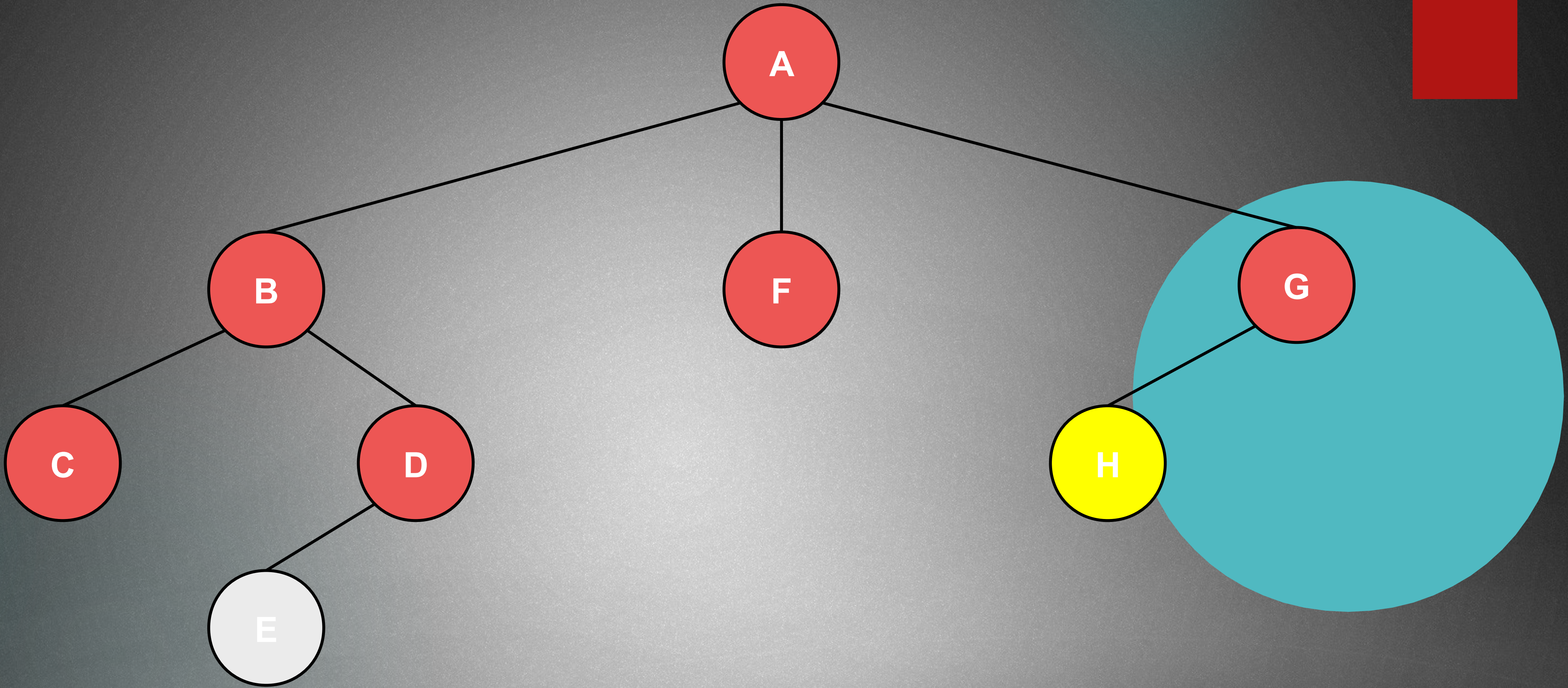
Queue: { H D **C** }



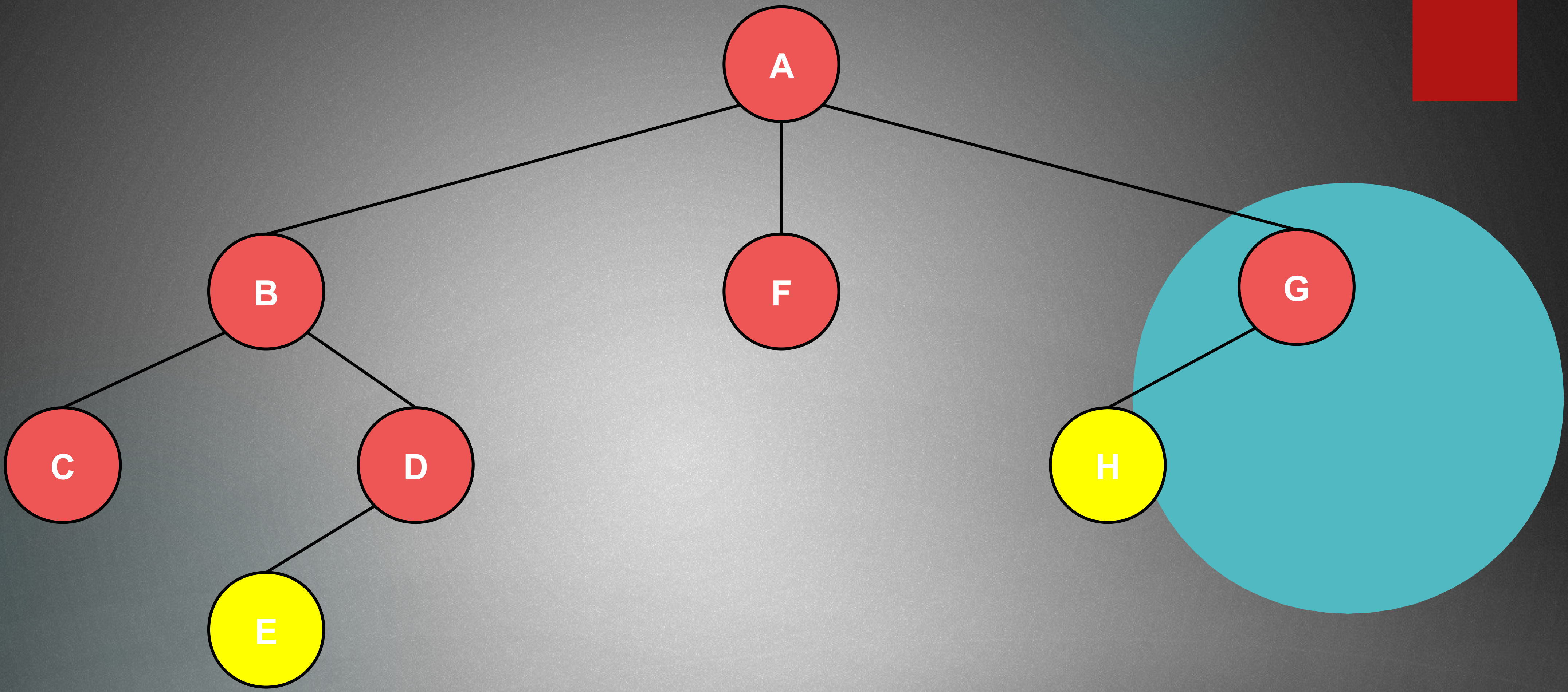
Queue: { H D }



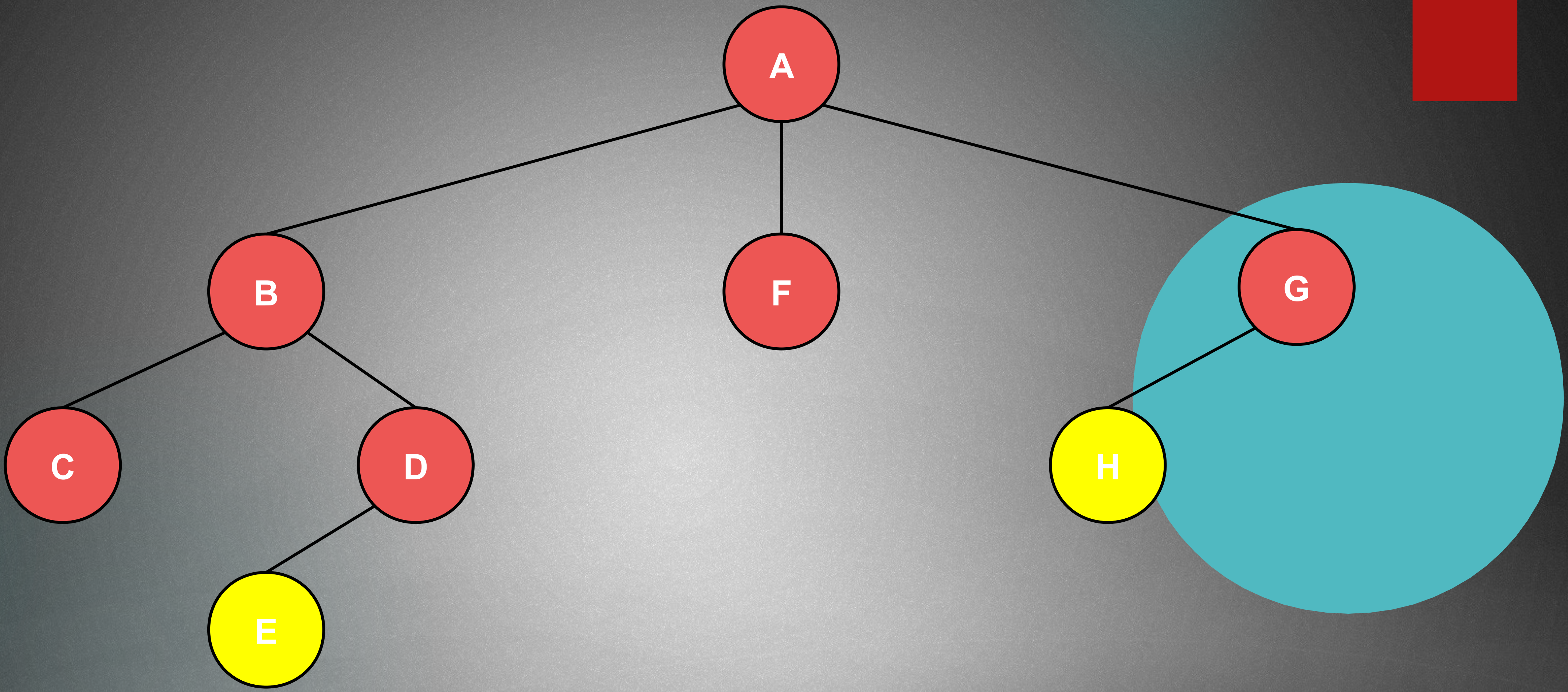
Queue: { H **D** }



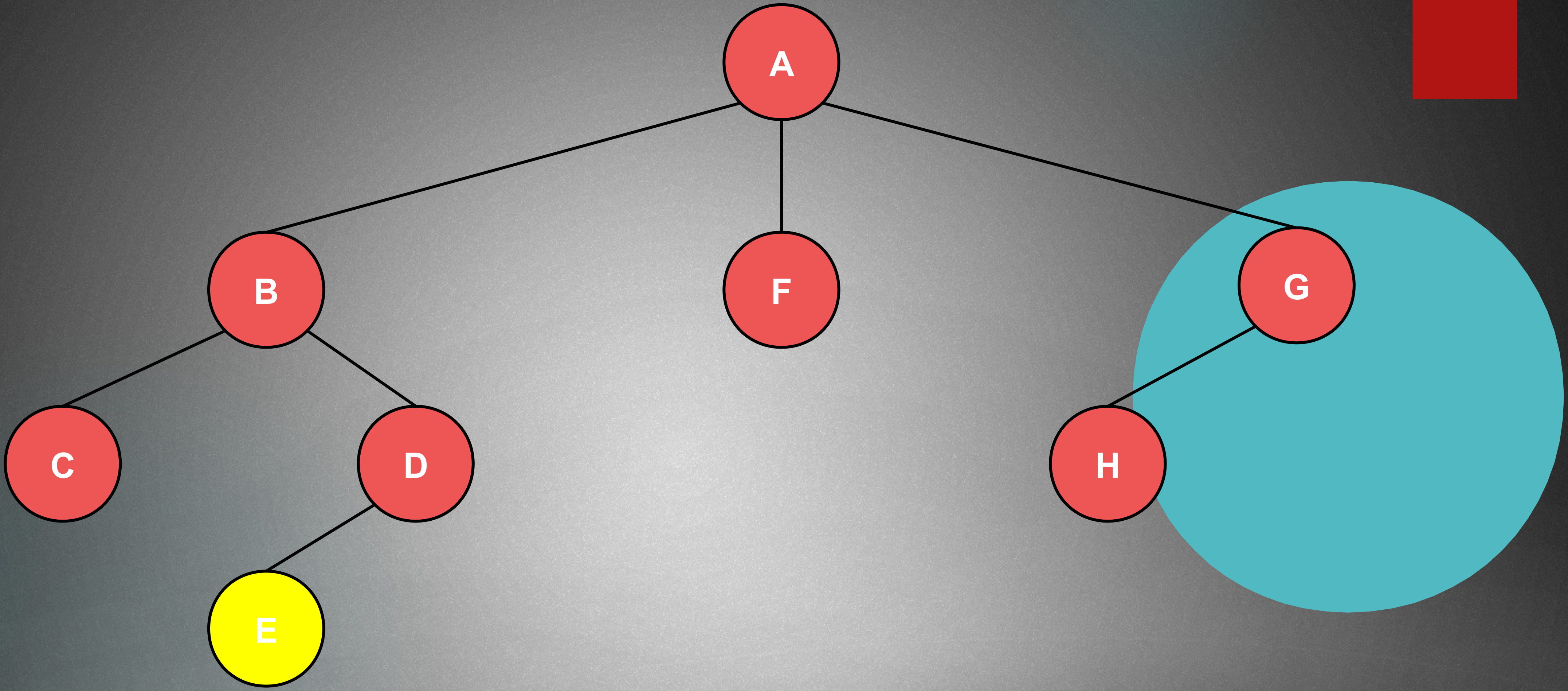
Queue: { H }



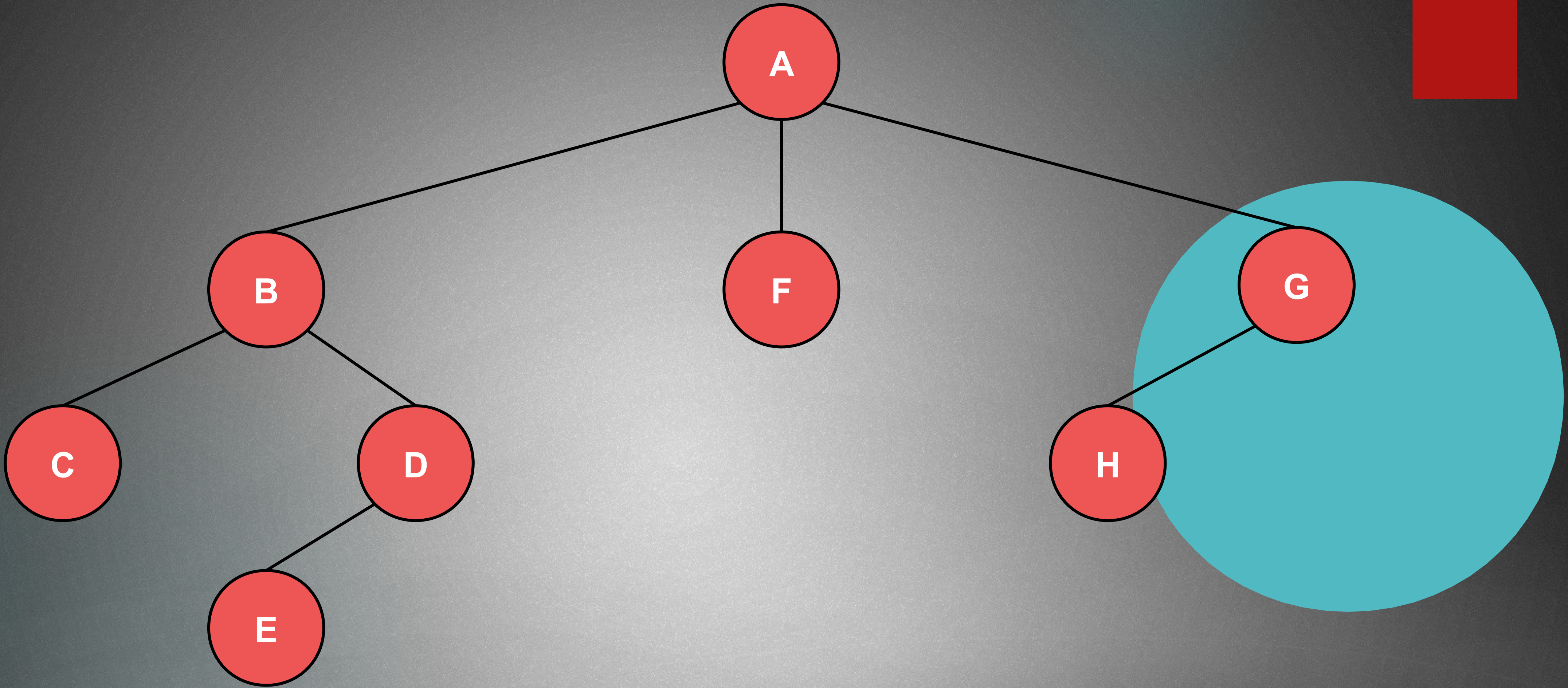
Queue: { E H }



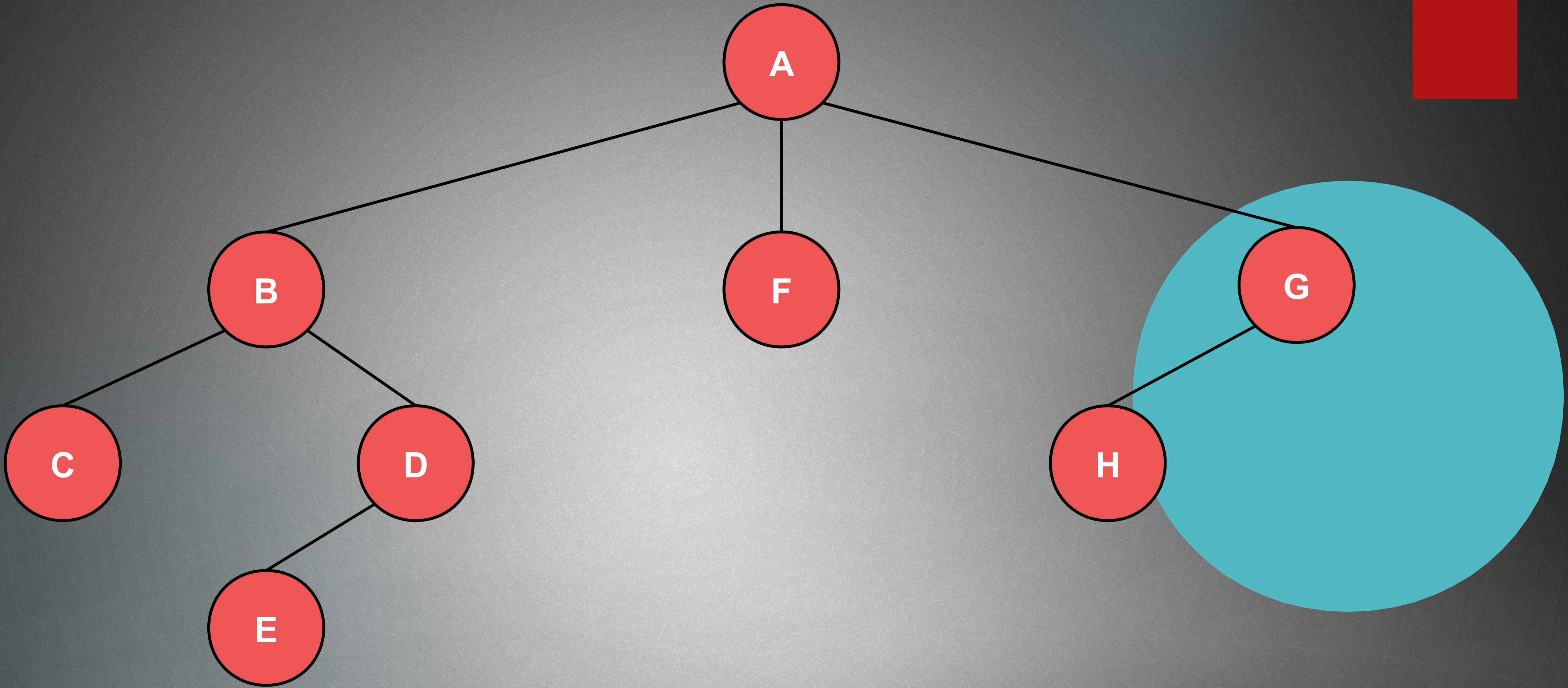
Queue: { E **H** }



Queue: { E }

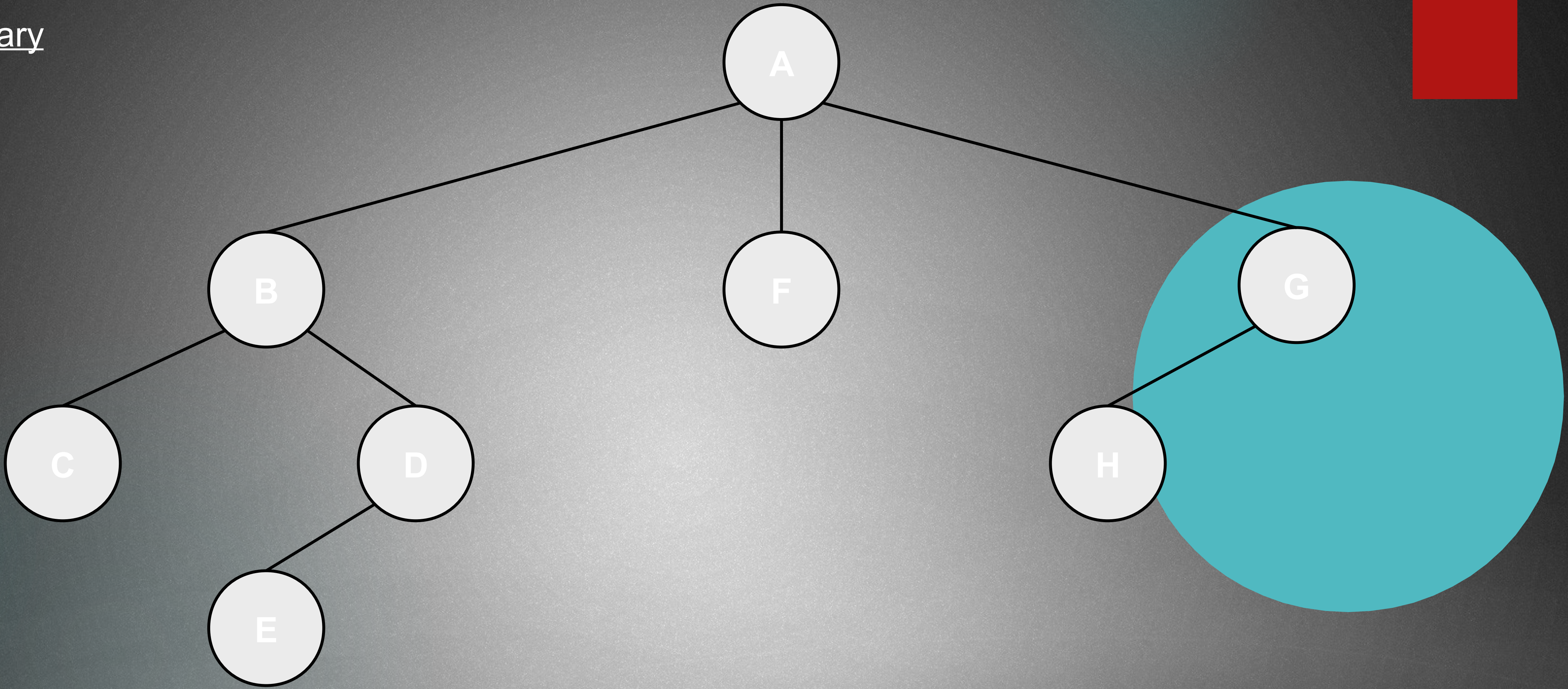


Queue: { **E** }

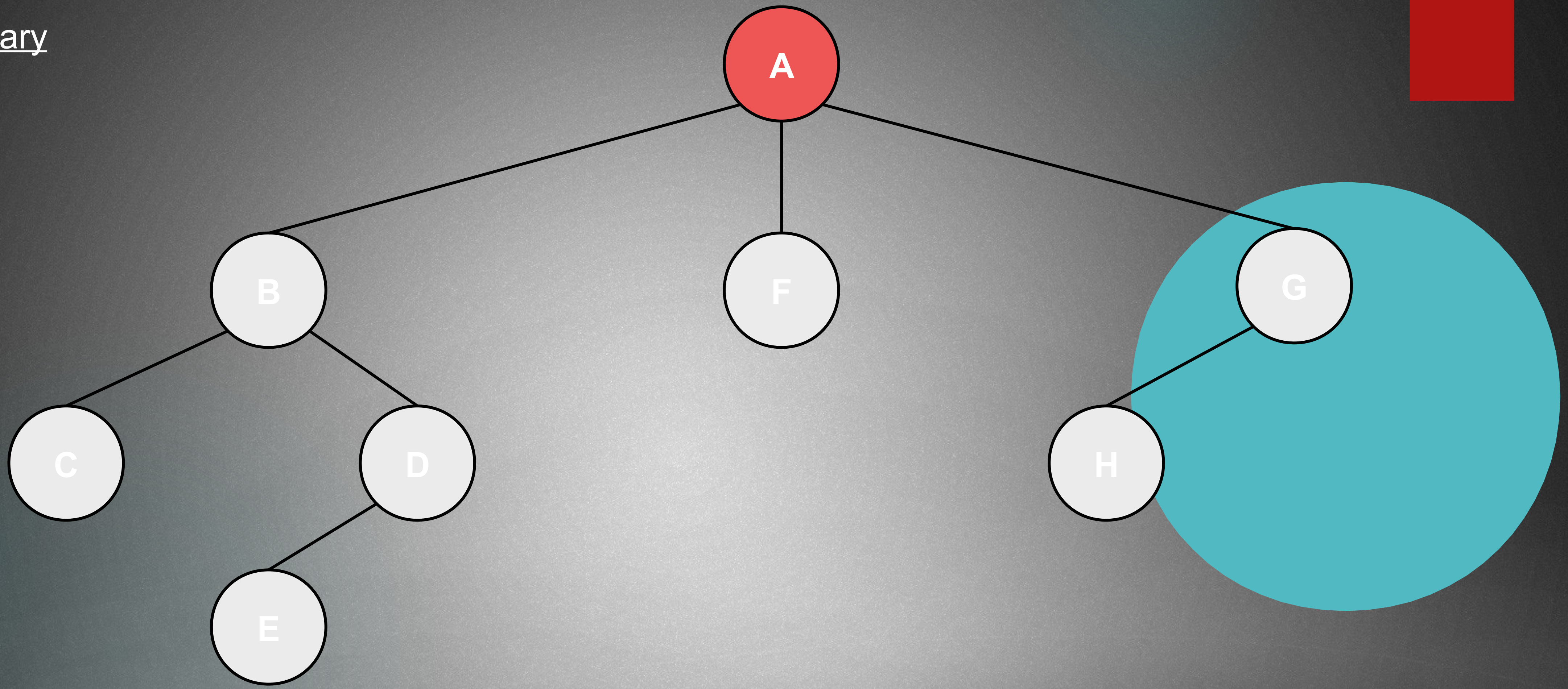


Queue: { } the queue is empty → **FINISHED** !!!

Summary



Summary



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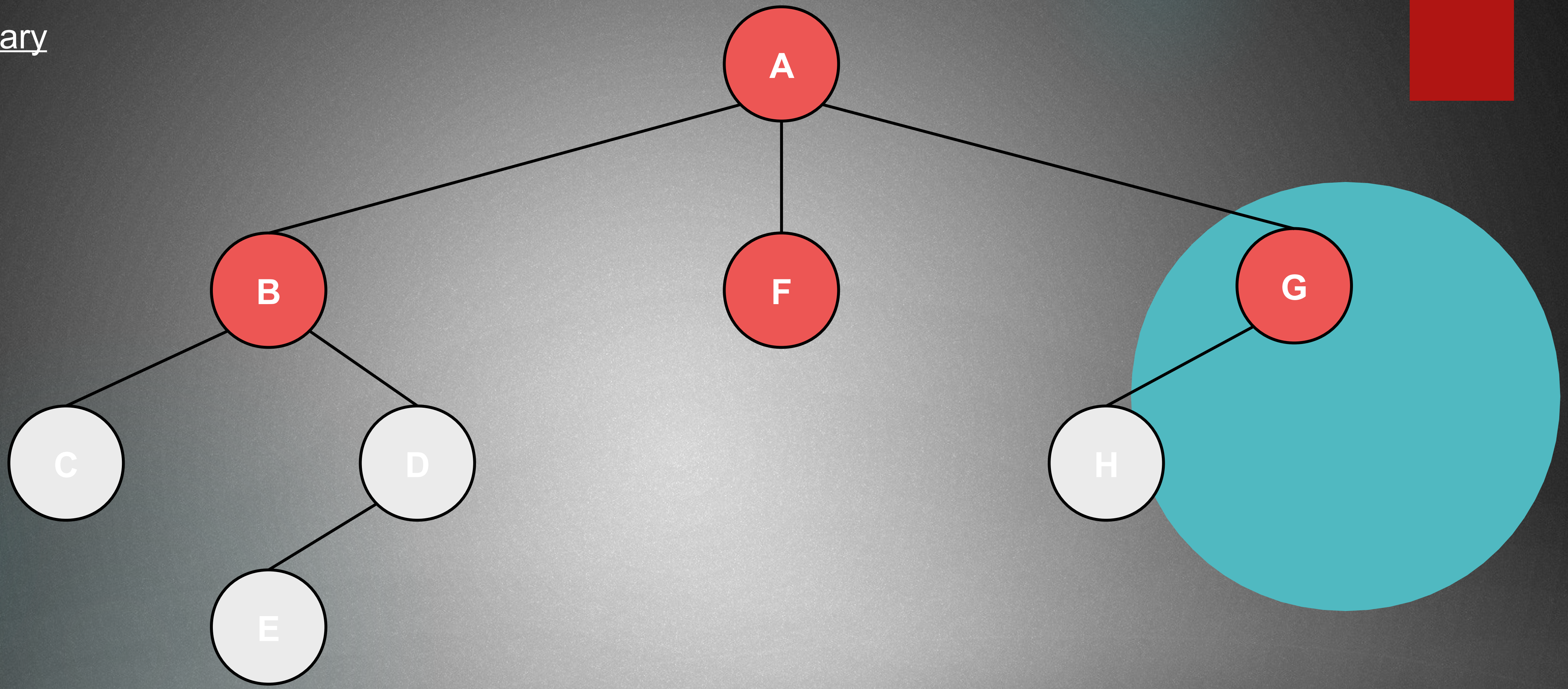

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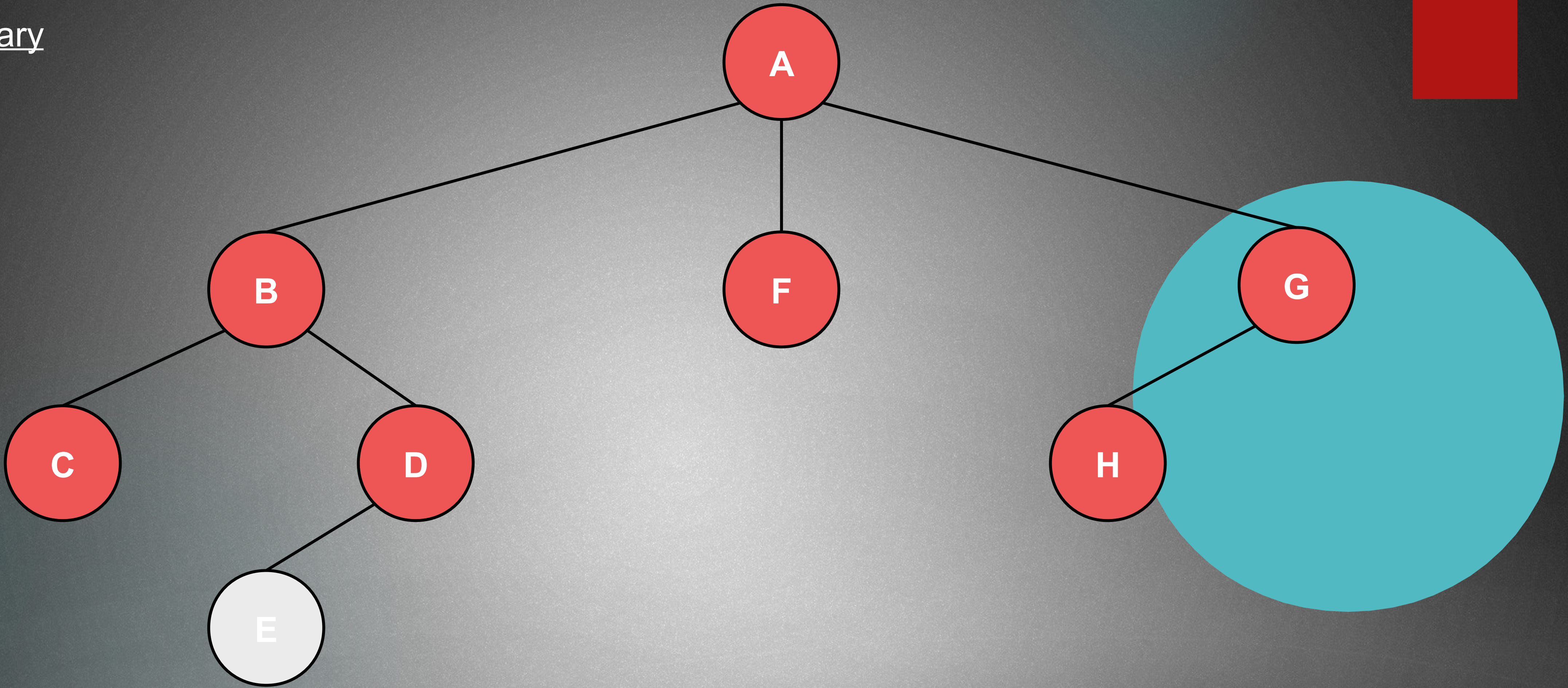

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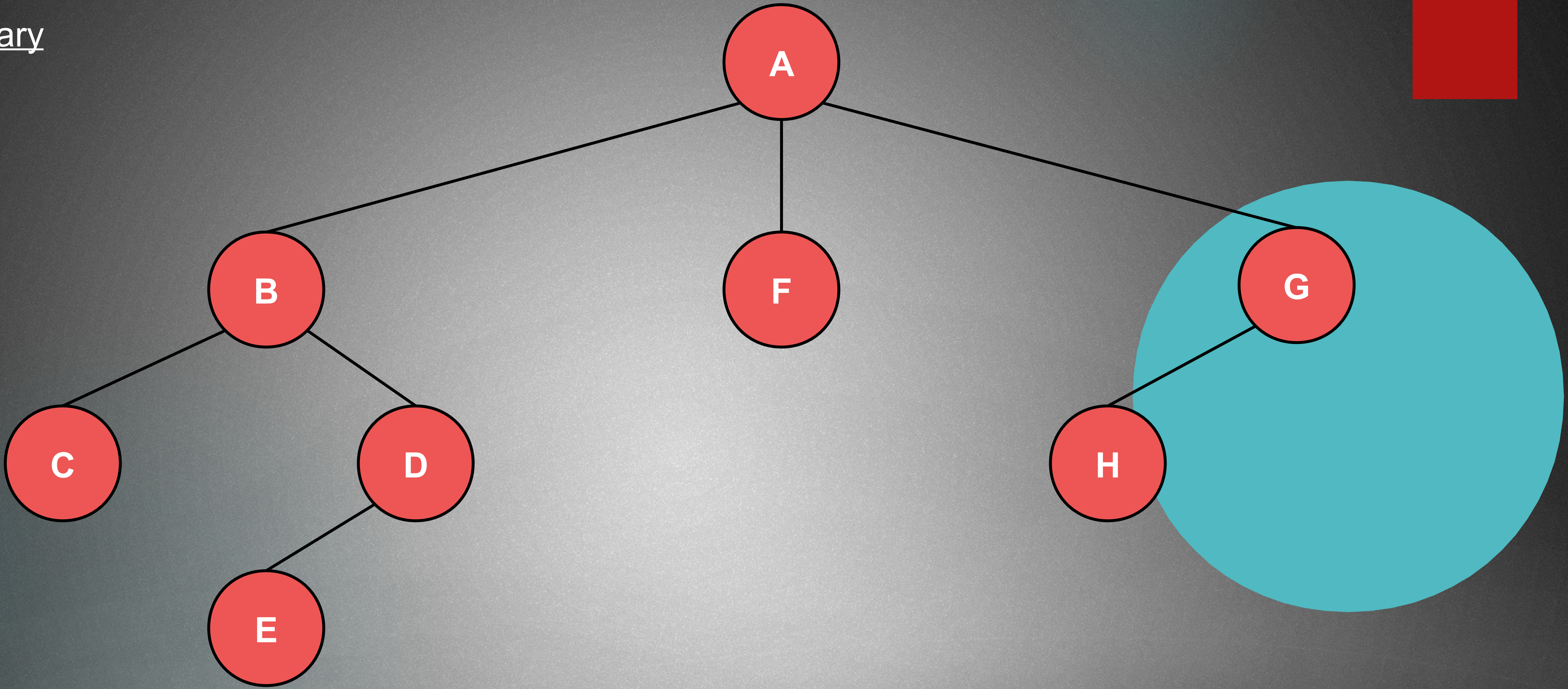


Applications

- In artificial intelligence / machine learning it can prove to be very important: robots can discover the surrounding more easily with BFS than DFS
- It is also very important in maximum flow: Edmonds-Karp algorithm uses BFS for finding augmenting paths
- Cheyen's algorithm in garbage collection → it help to maintain active references on the heap memory
- It uses BFS to detect all the references on the heap
- Serialization / deserialization of a tree like structure (for example when order does matter) → it allows the tree to be reconstructed in an efficient manner !!!

DEPTH FIRST SEARCH

dfs

Depth-first search

- Depth-first search is a widely used graph traversal algorithm besides breadth-first search
- It was investigated as strategy for solving mazes by Trémaux in the 19th century
- It explores as far as possible along each branch before backtracking // BFS was a layer-by-layer algorithm
- Time complexity of traversing a graph with DFS: **O(V+E)**
- Memory complexity: a bit better than that of BFS !!!

Depth-first search

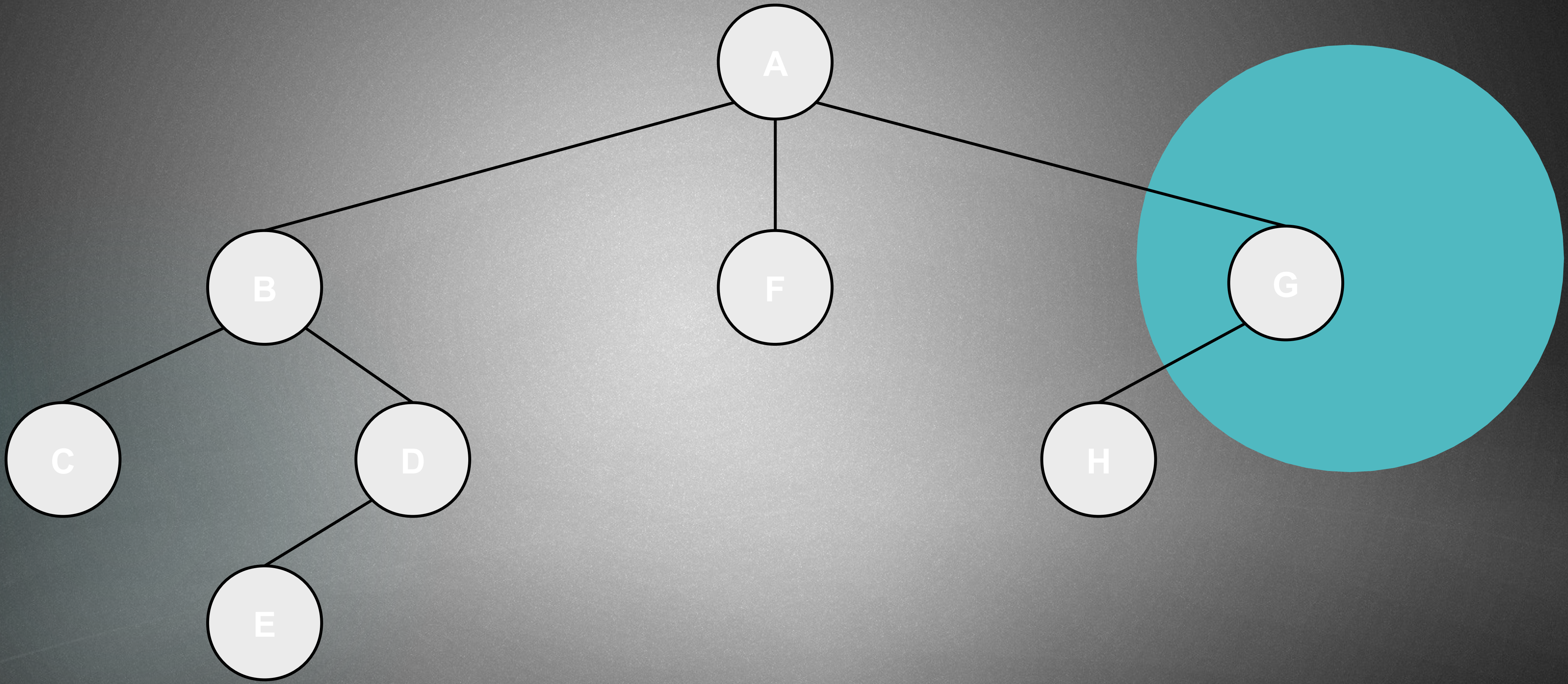
```
dfs(vertex)

    vertex set visited true
    print vertex

    for v in vertex neighbours
        if v is not visited
            dfs(v)
```

RECURSION

```
dfs(vertex)

    Stack stack
    vertex set visited true
    stack.push(vertex)

    while stack not empty
        actual = stack.pop()

        for v in actual neighbours
            if v is not visited
                v set visited true
                stack.push(v)
```

ITERATION

Recursively check every unmarked vertices!



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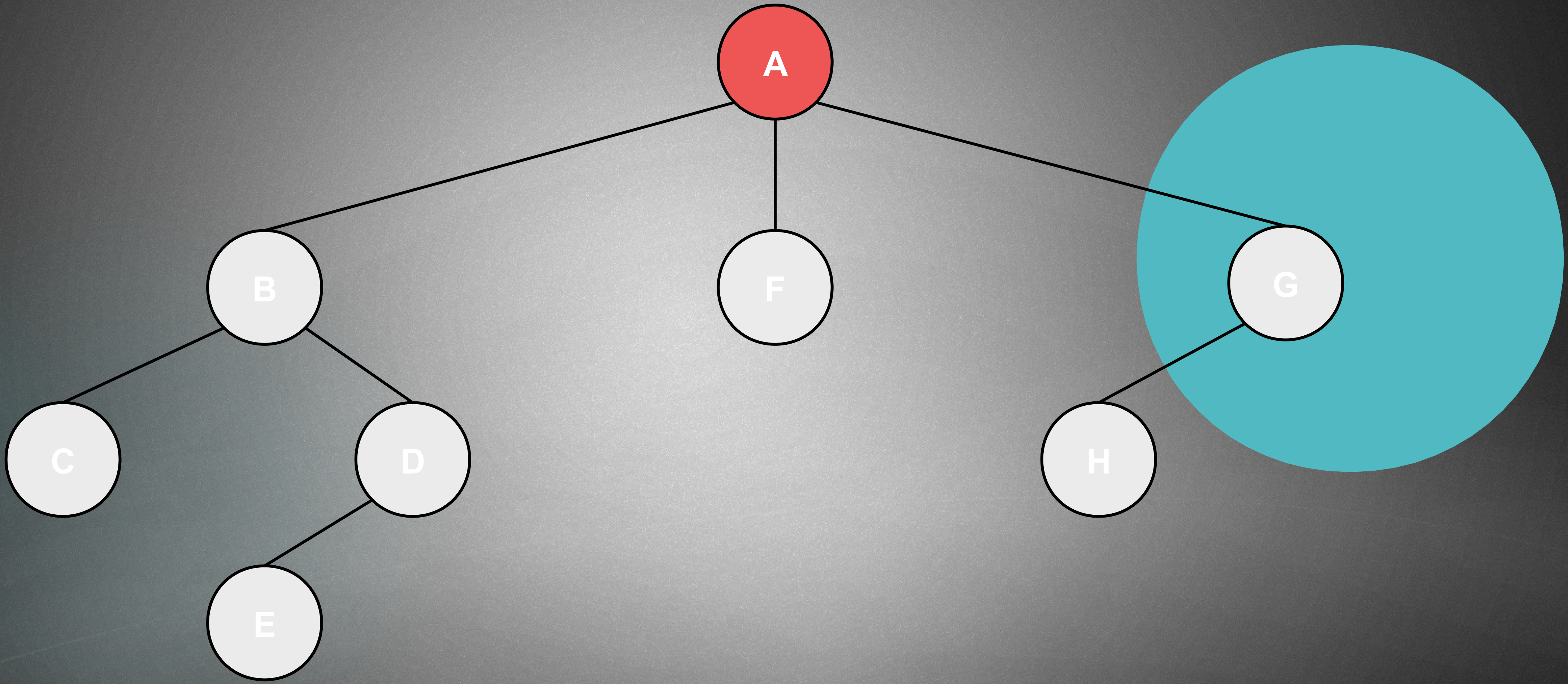

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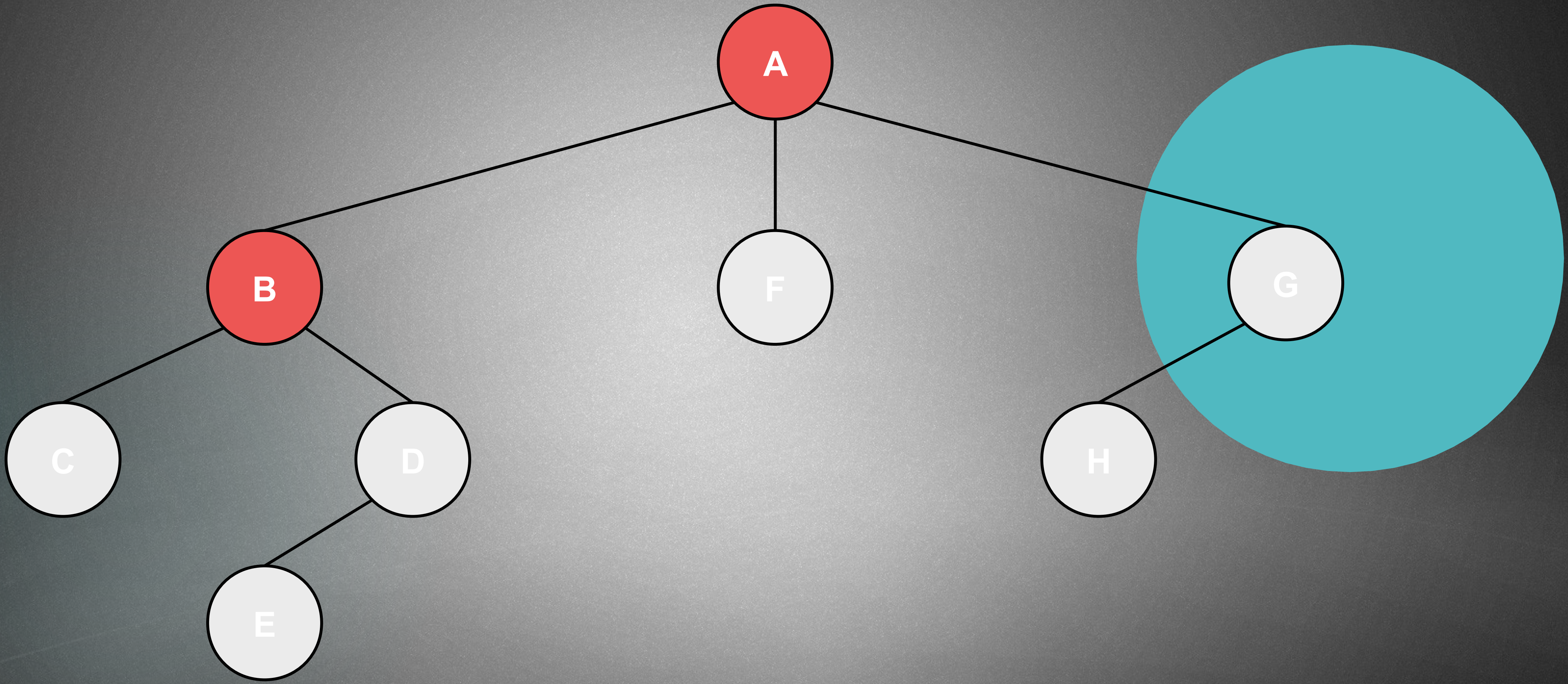

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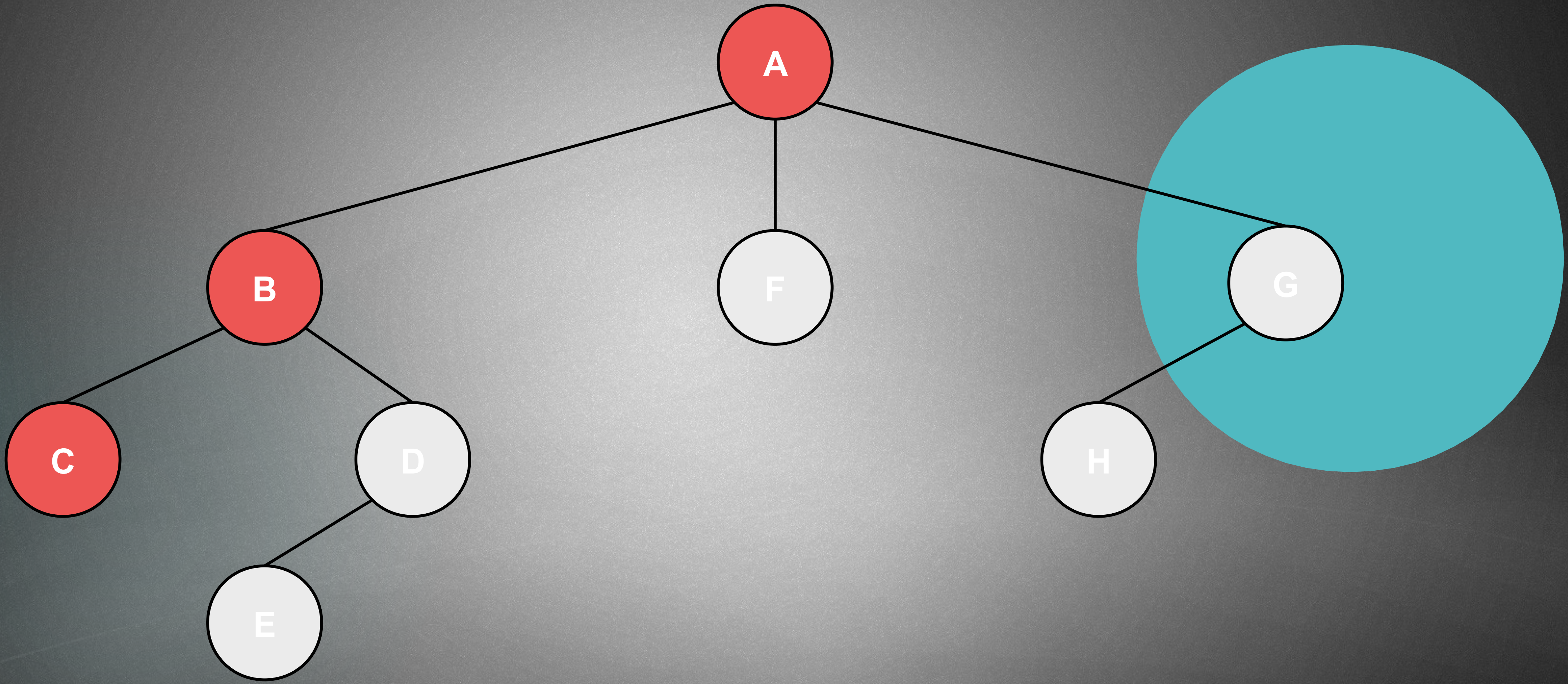

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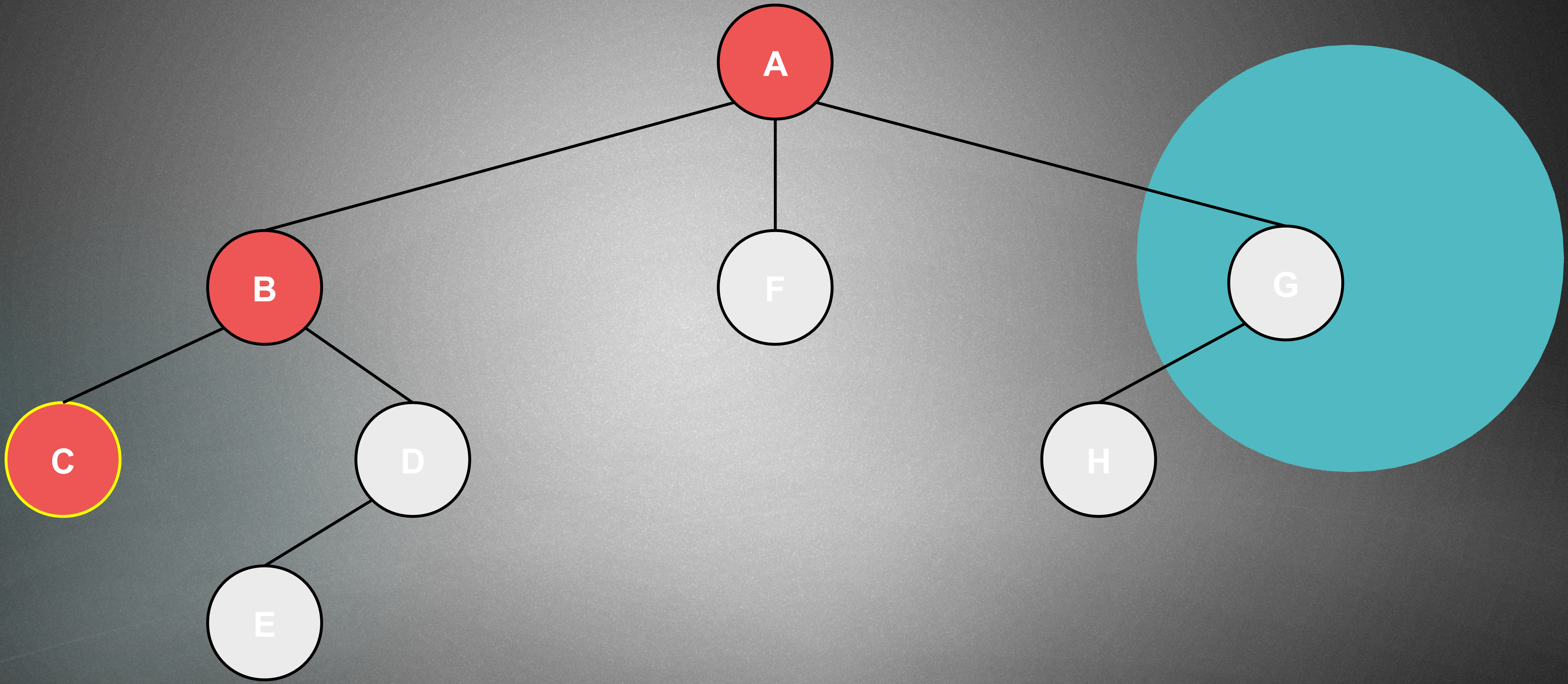

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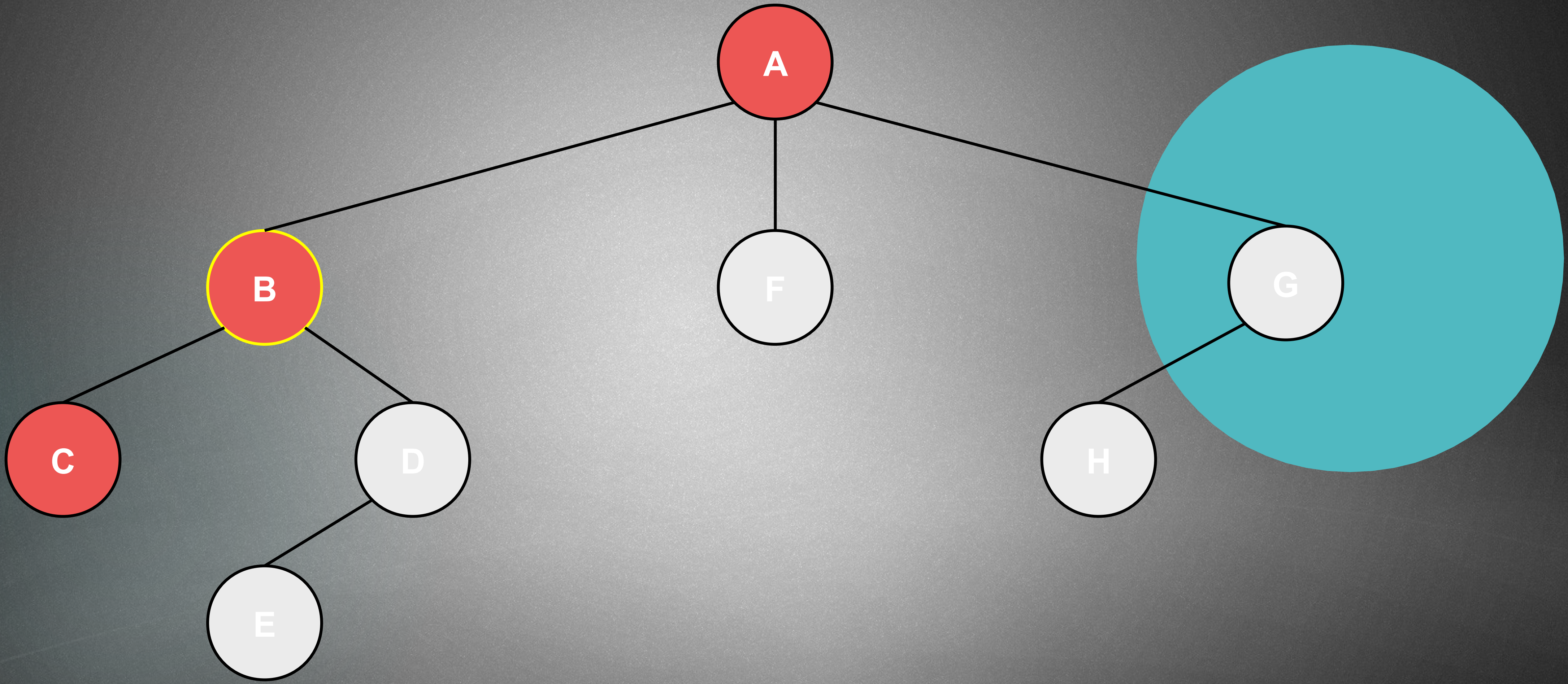

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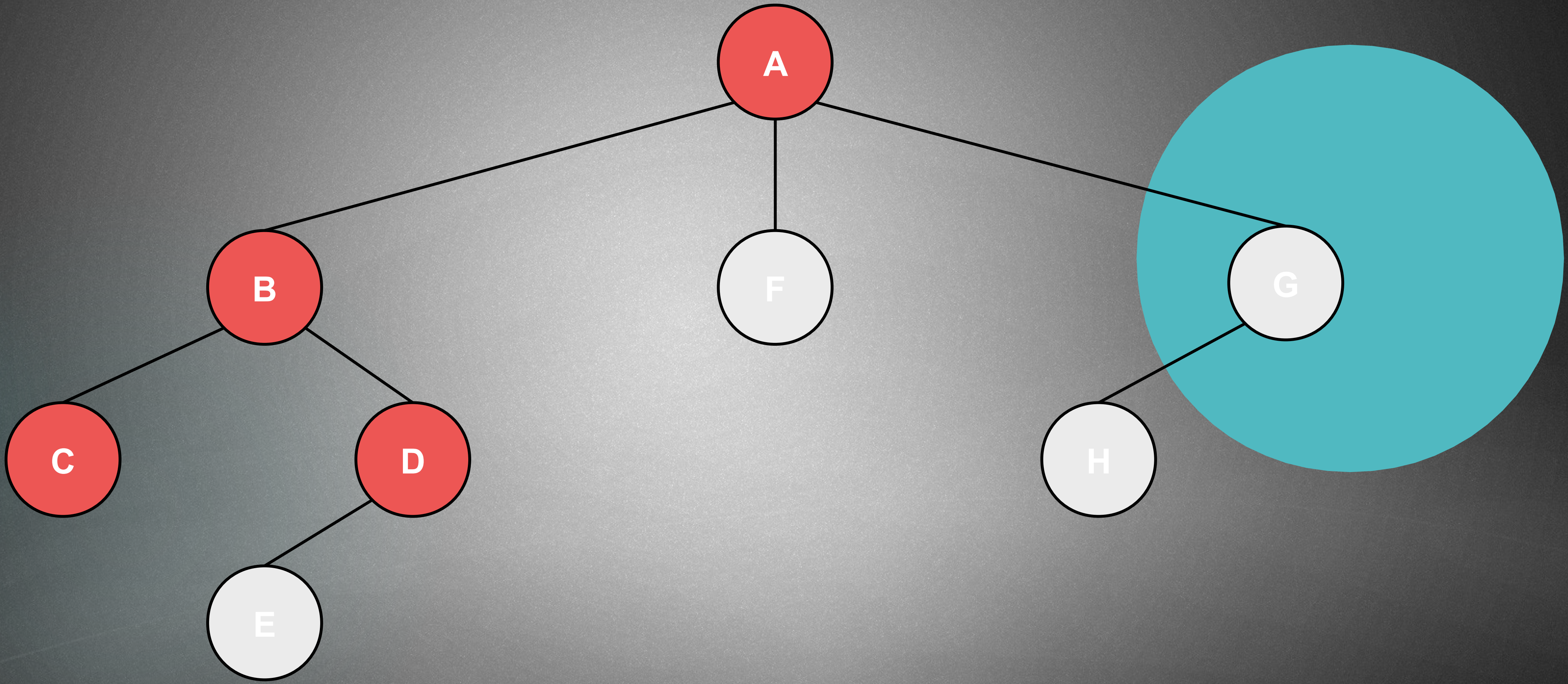

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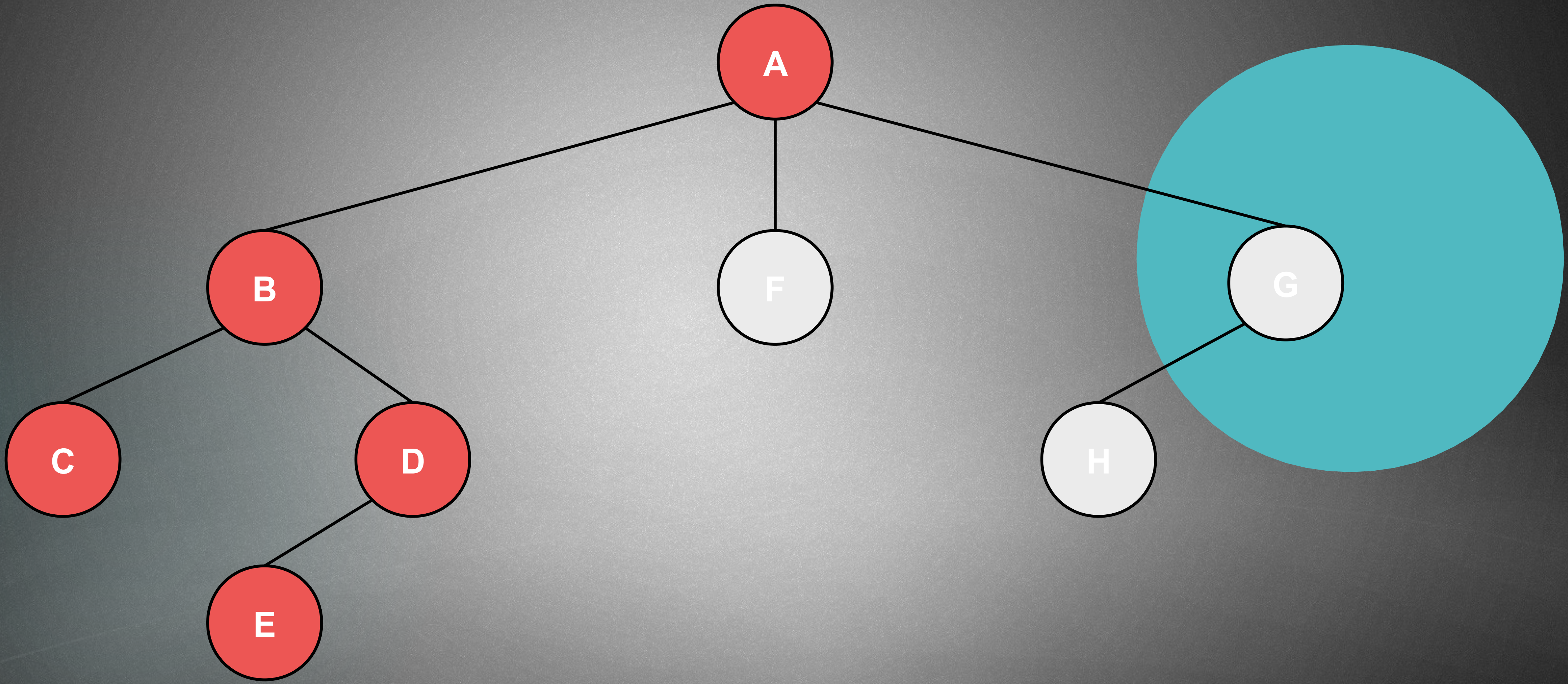

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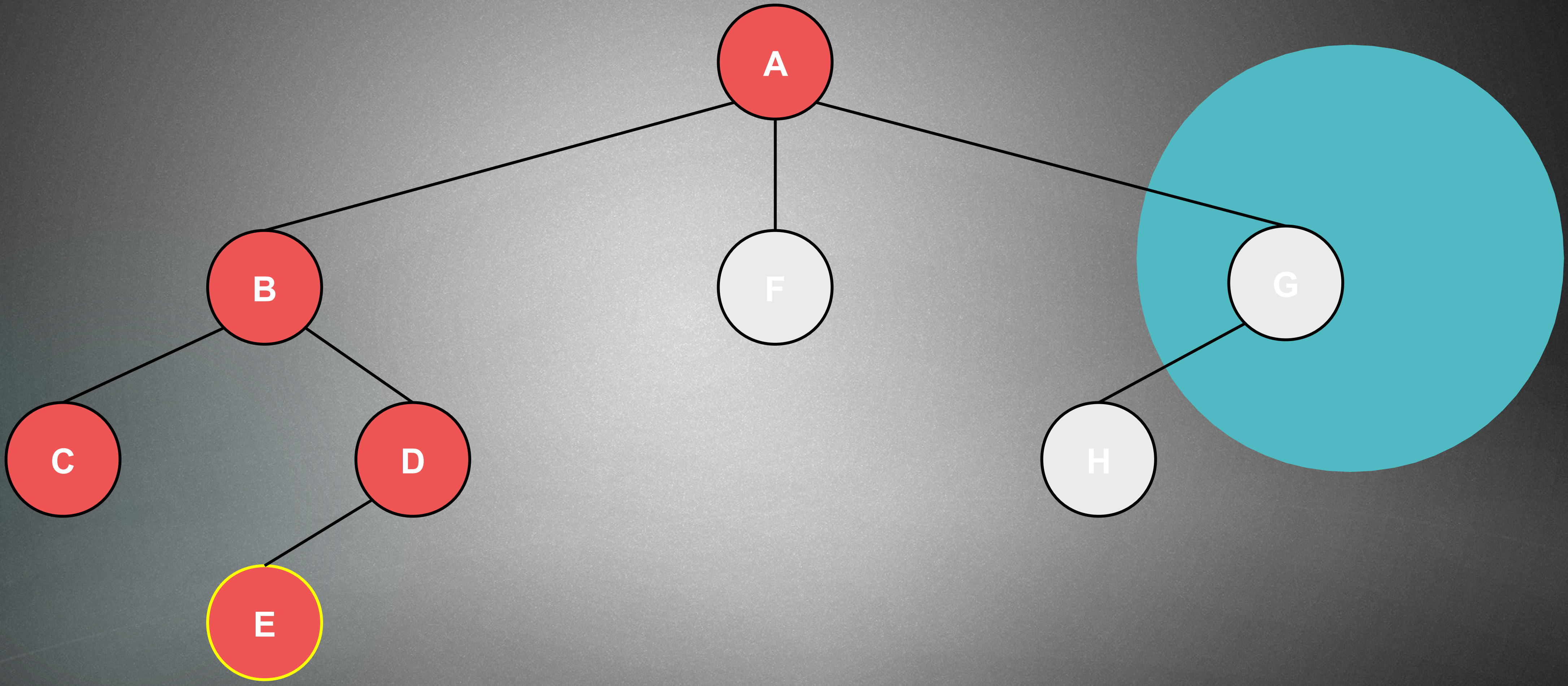

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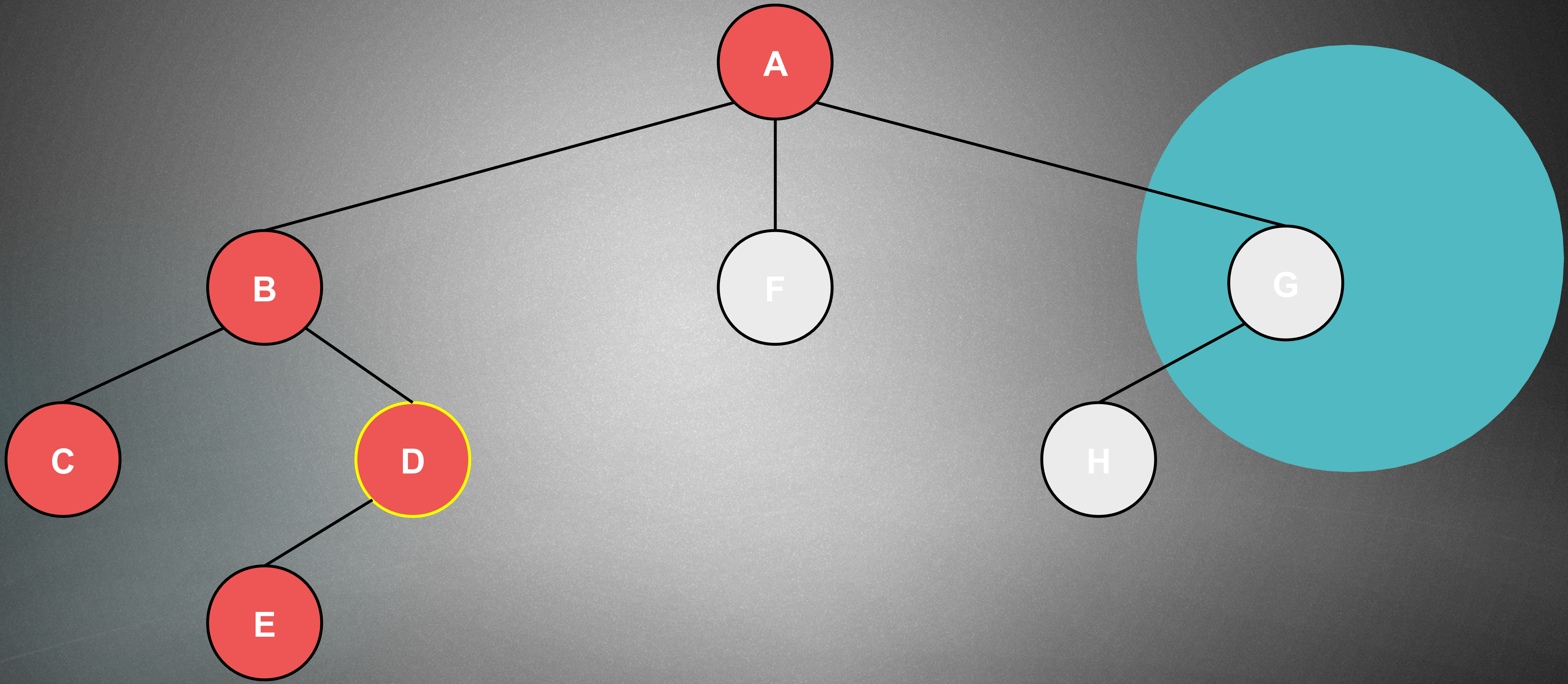

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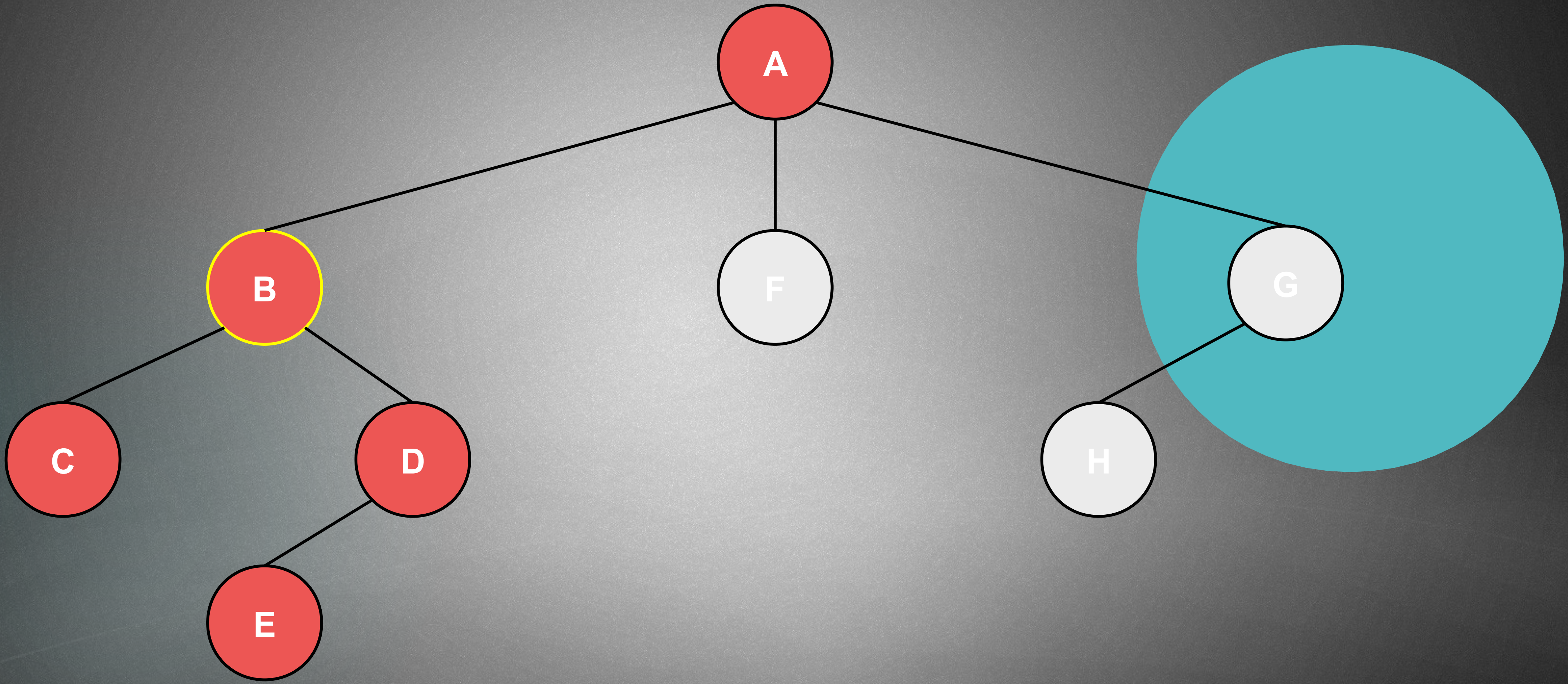

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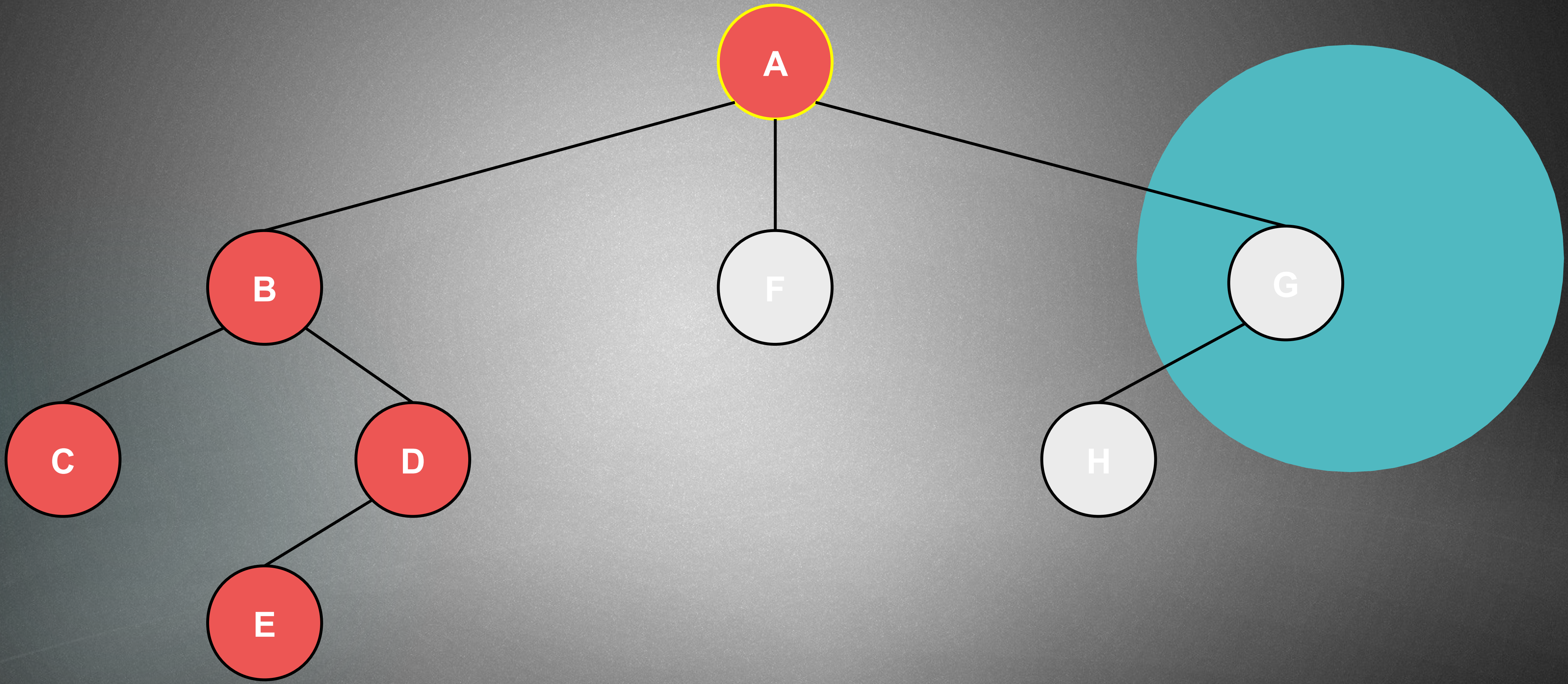

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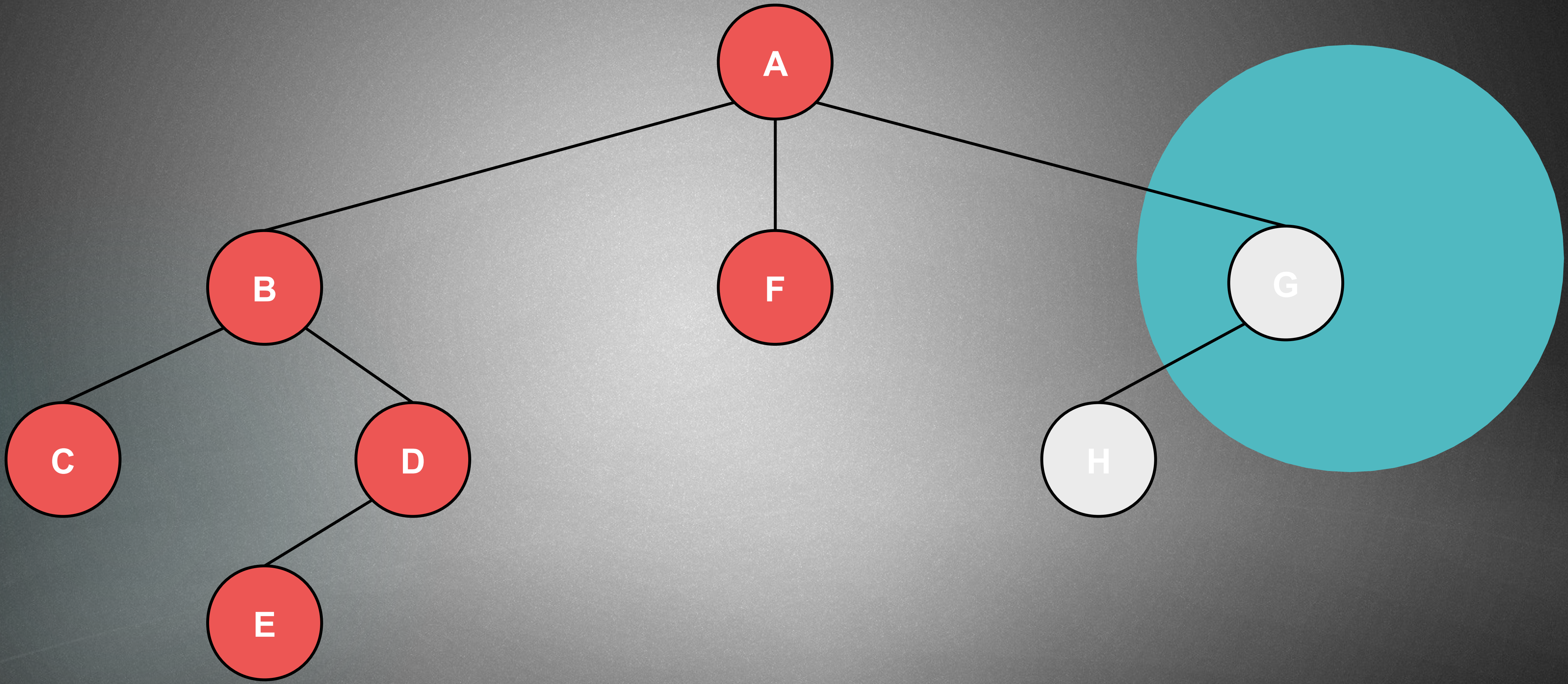

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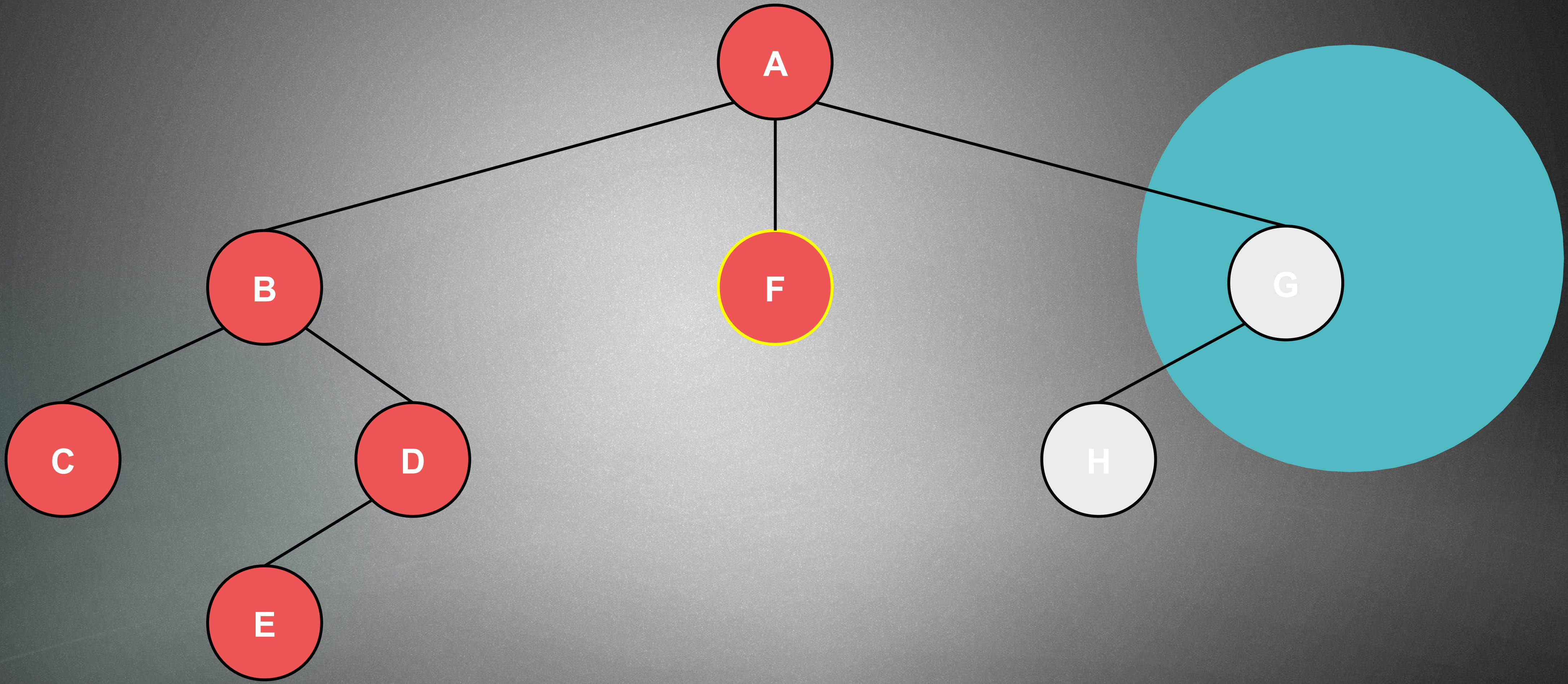

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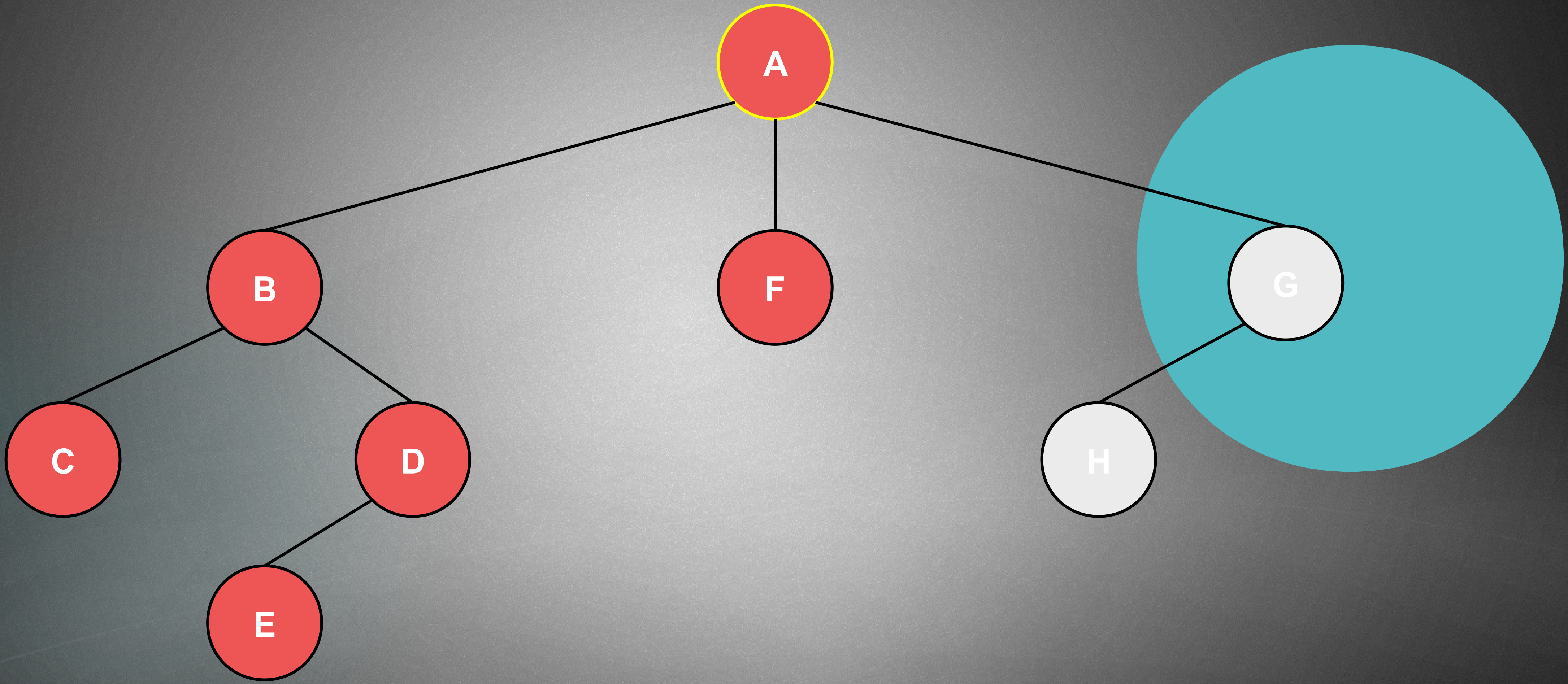

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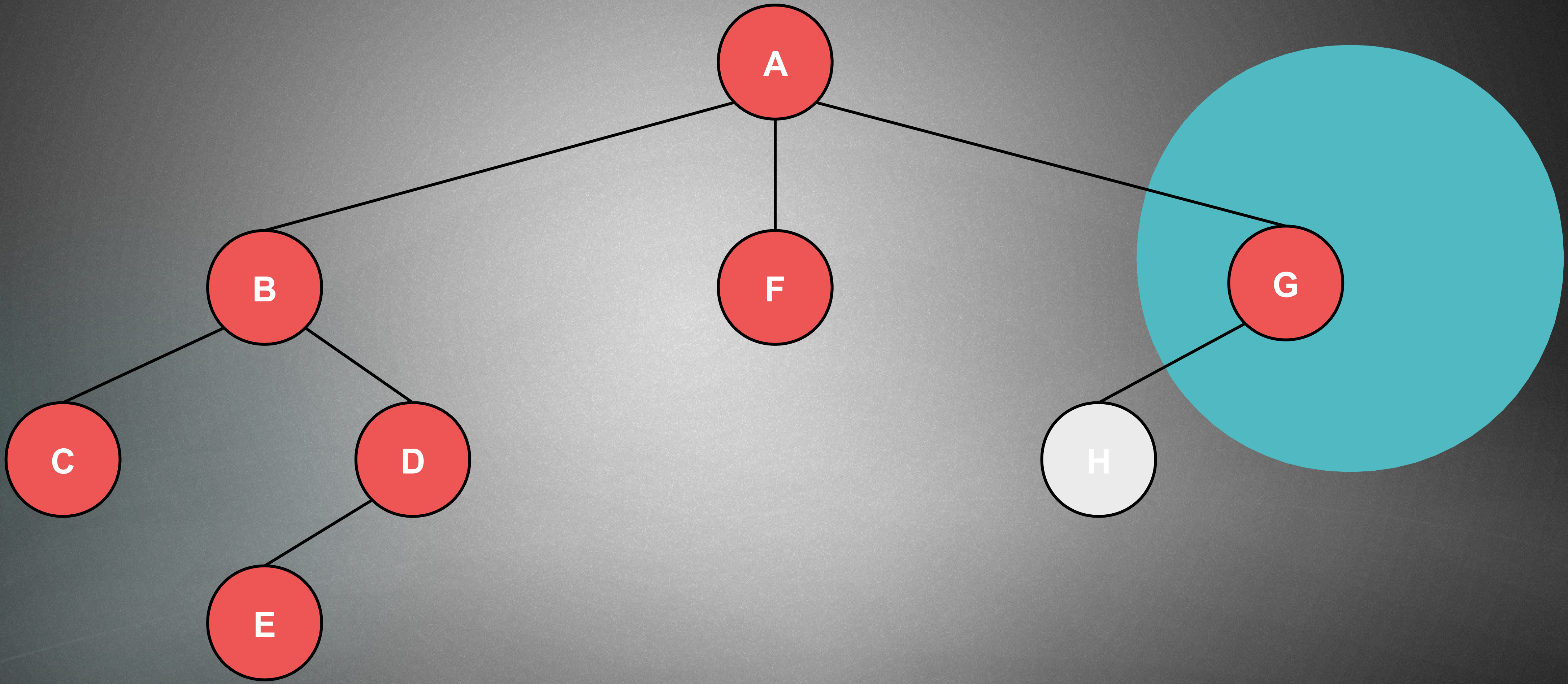

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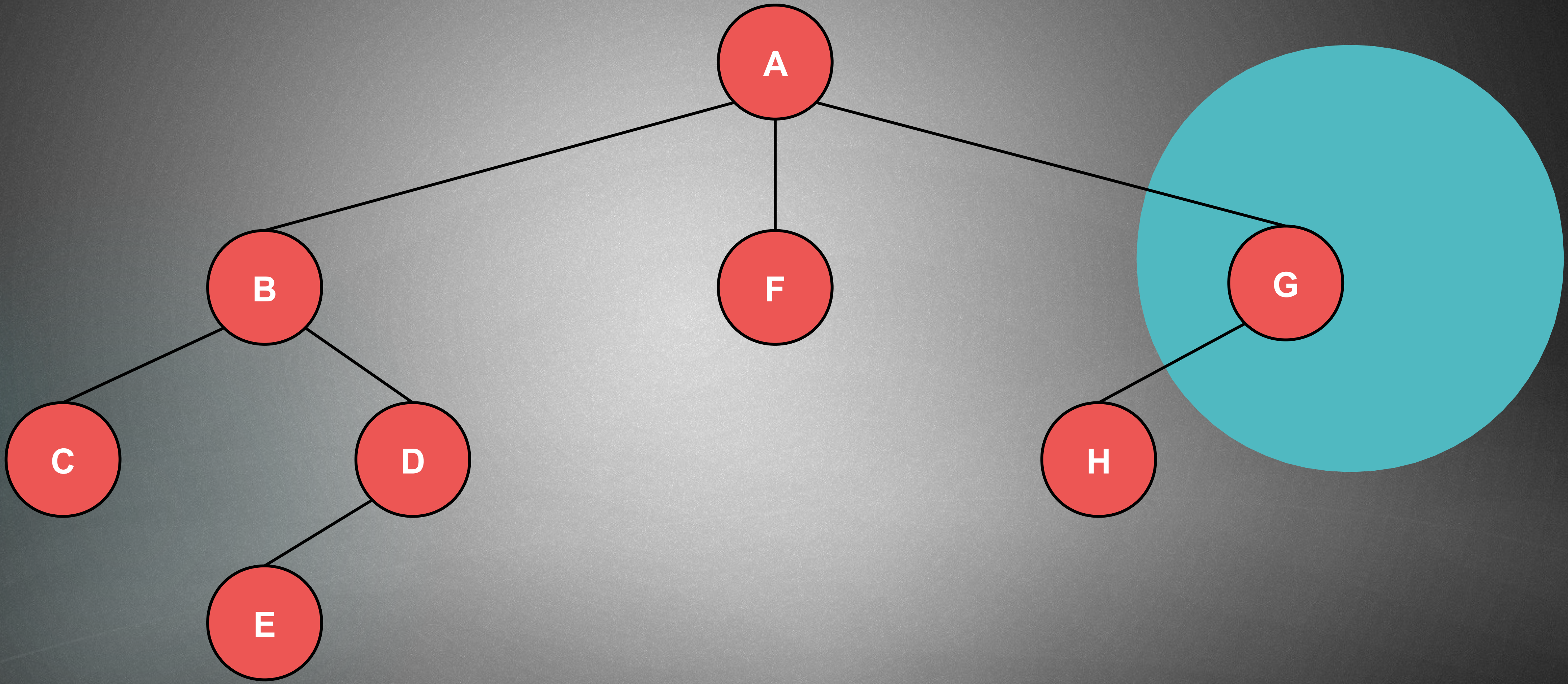

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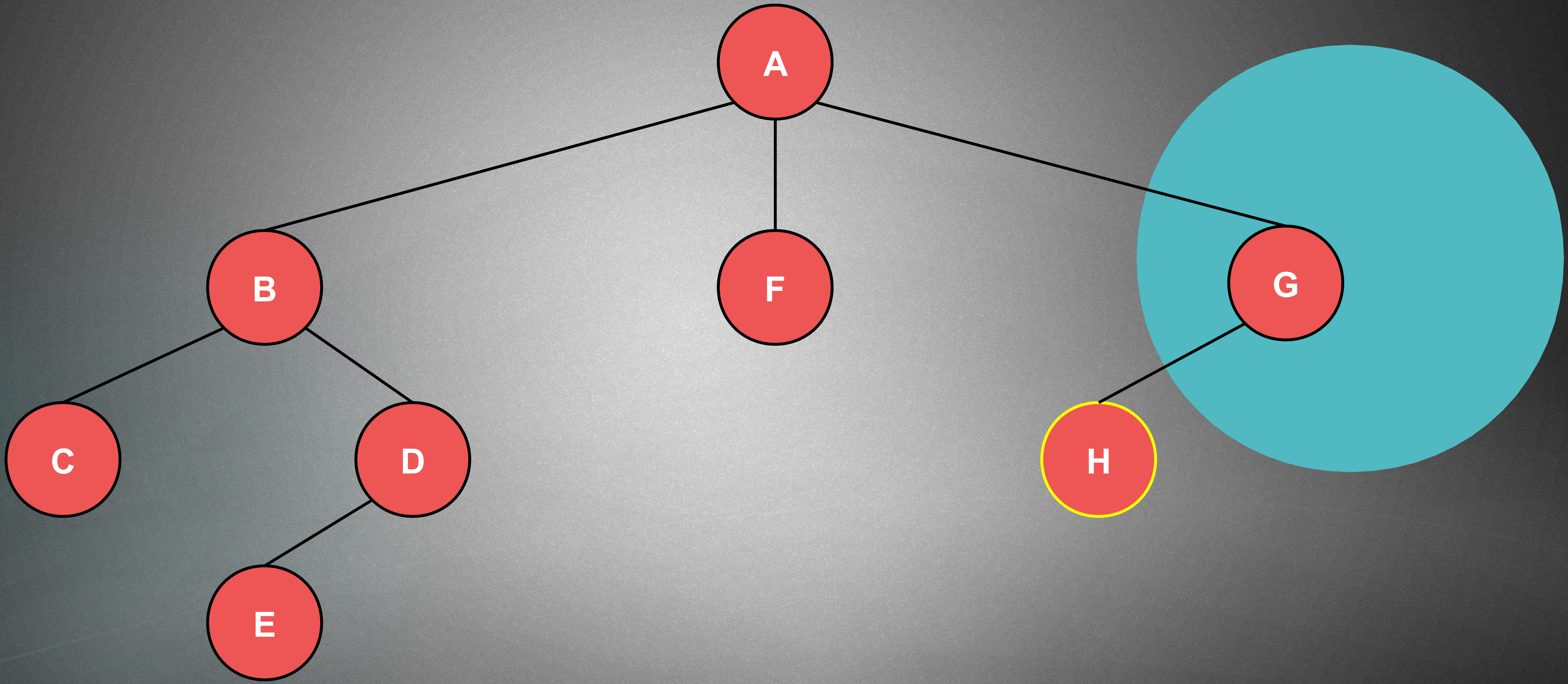

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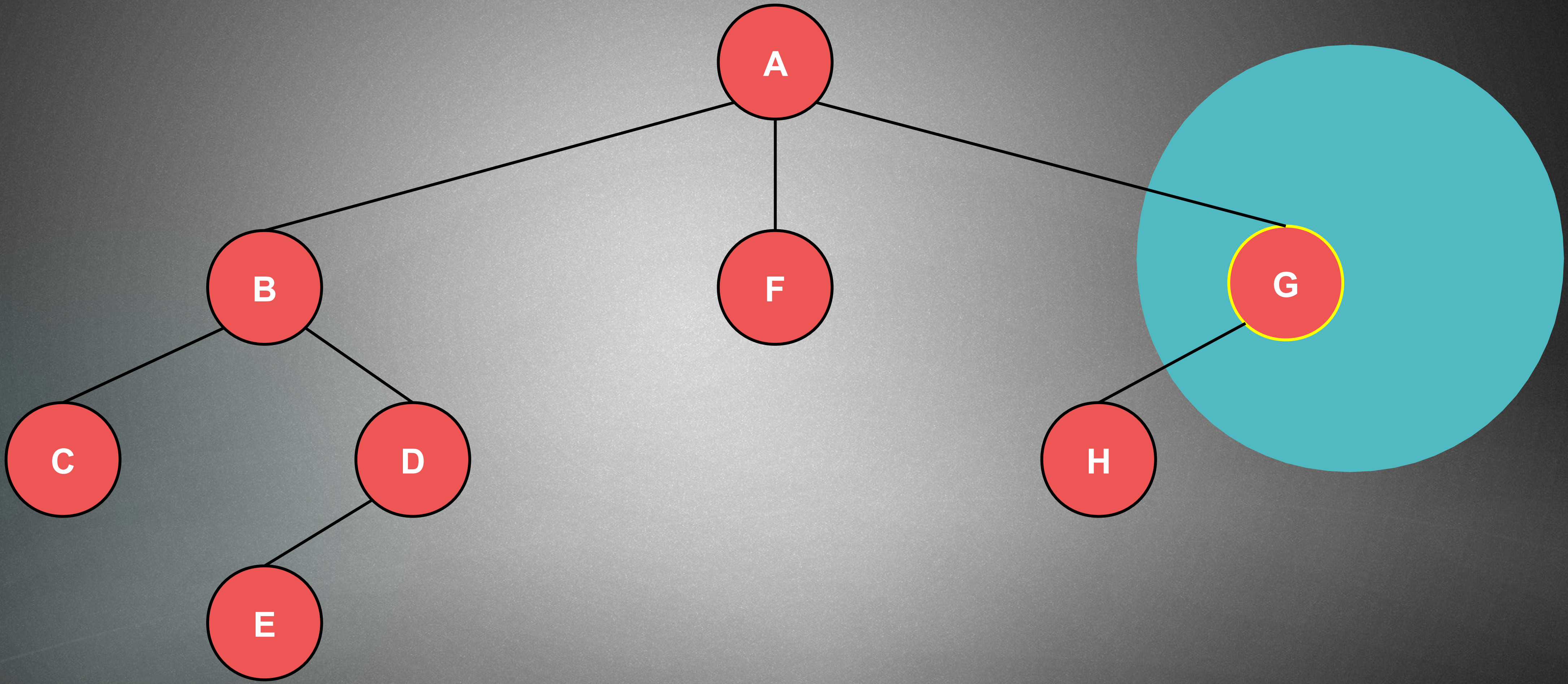

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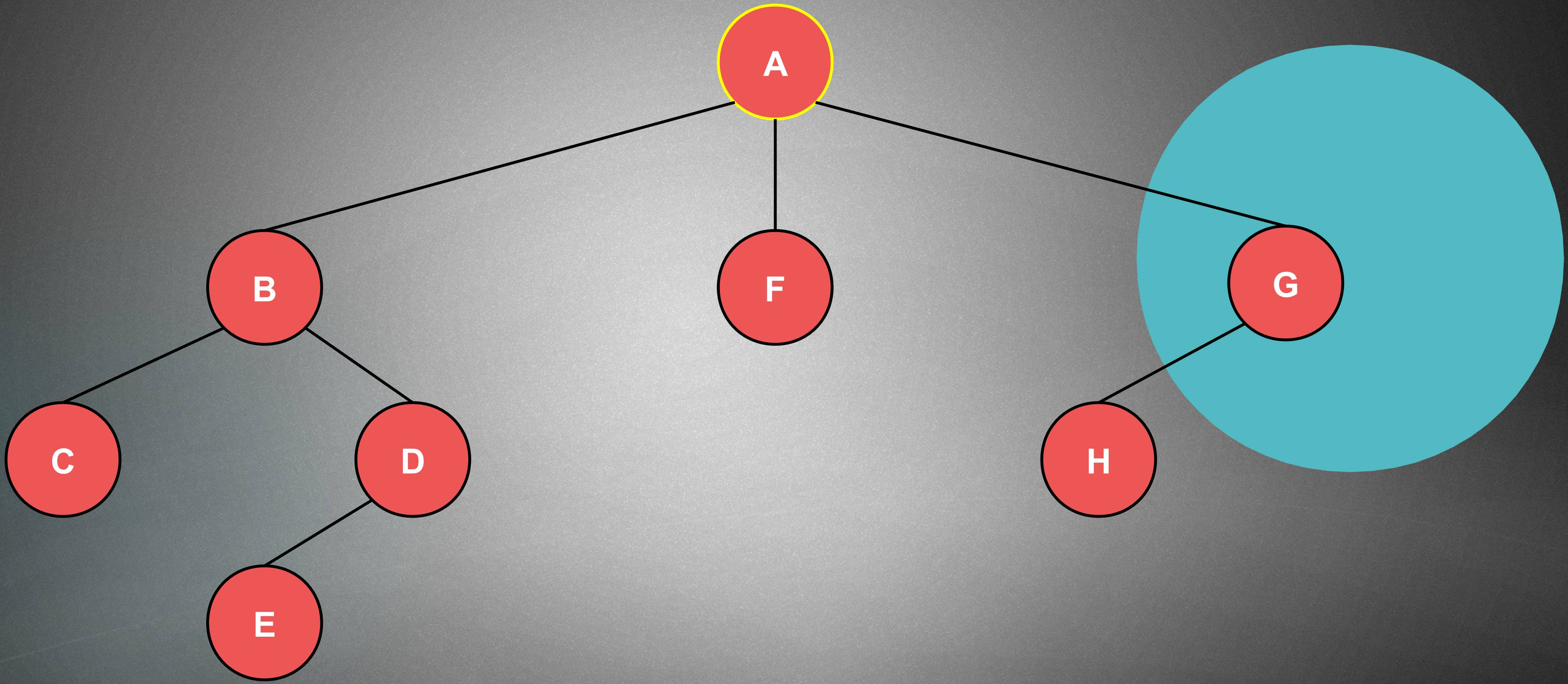
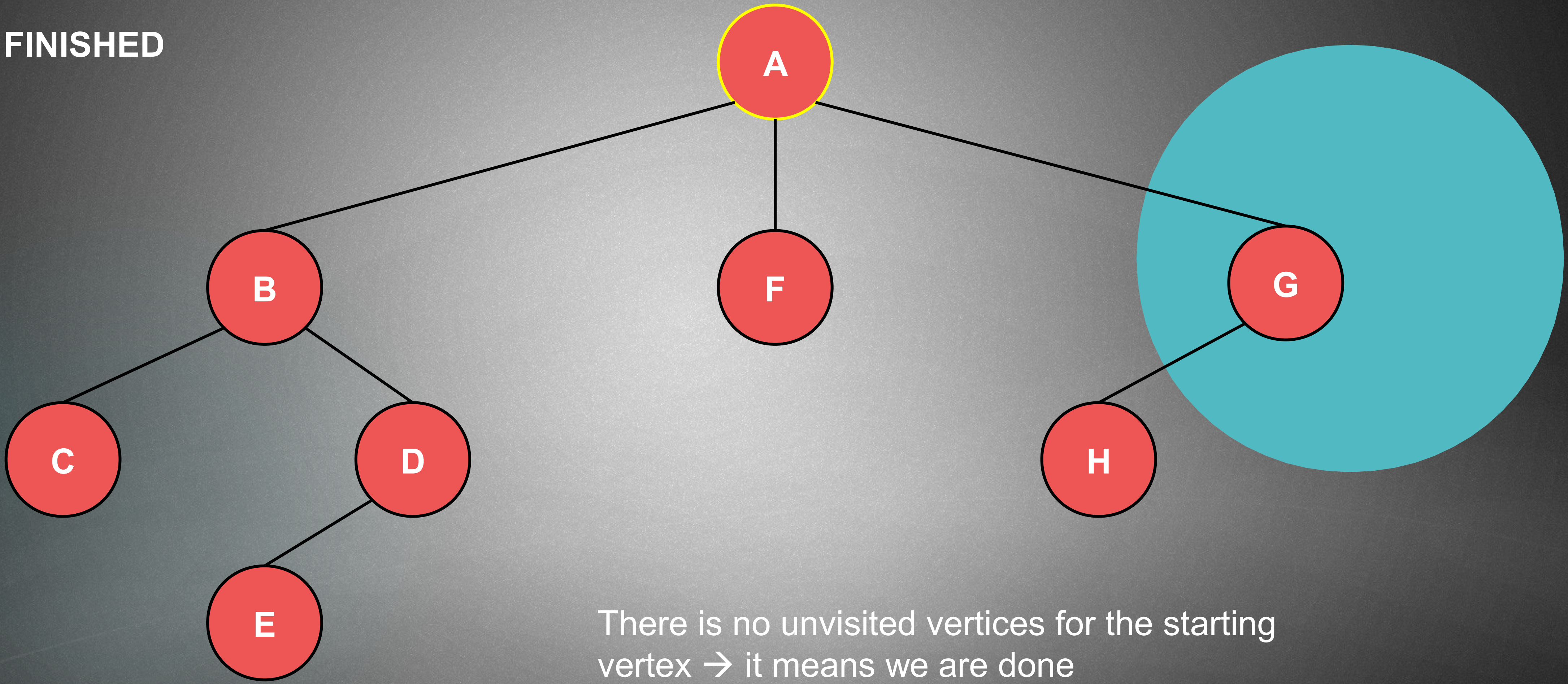


Recursively check every
unmarked vertices!

FINISHED

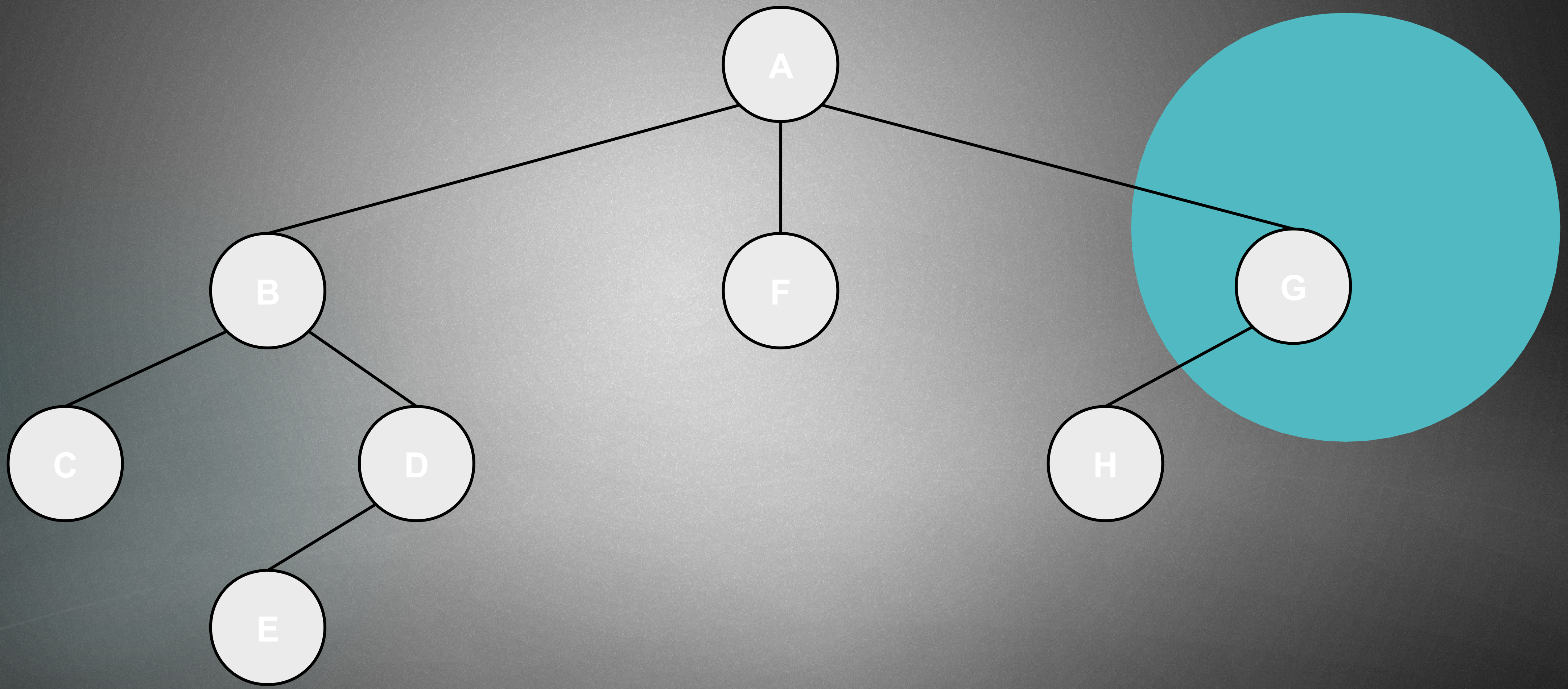


There is no unvisited vertices for the starting
vertex → it means we are done

Applications

- Topological ordering
- Kosaraju algorithm for finding strongly connected components in a graph which can be proved to be very important in recommendation systems (youtube)
- Detecting cycles (checking whether a graph is a DAG or not)
- Generating mazes OR finding way out of a maze

Revisiting breadth-first search



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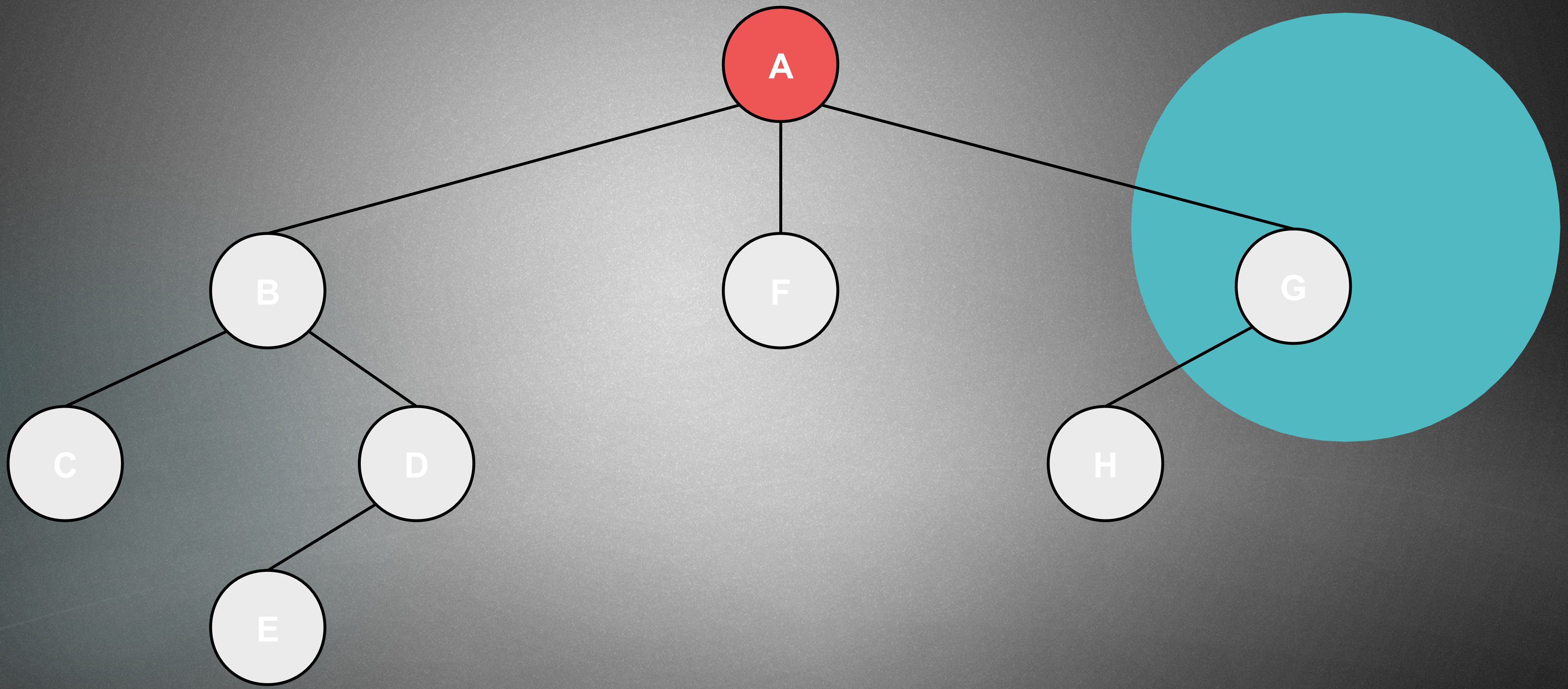

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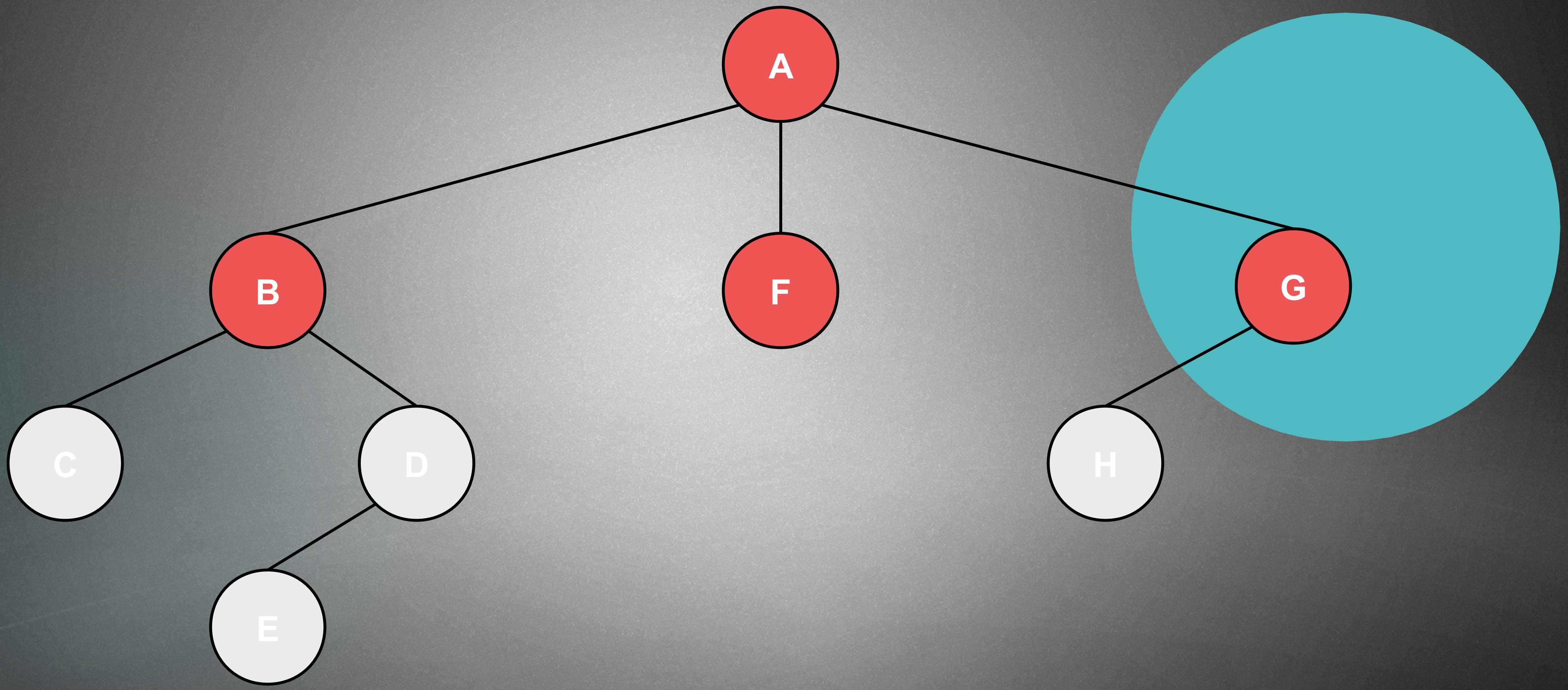

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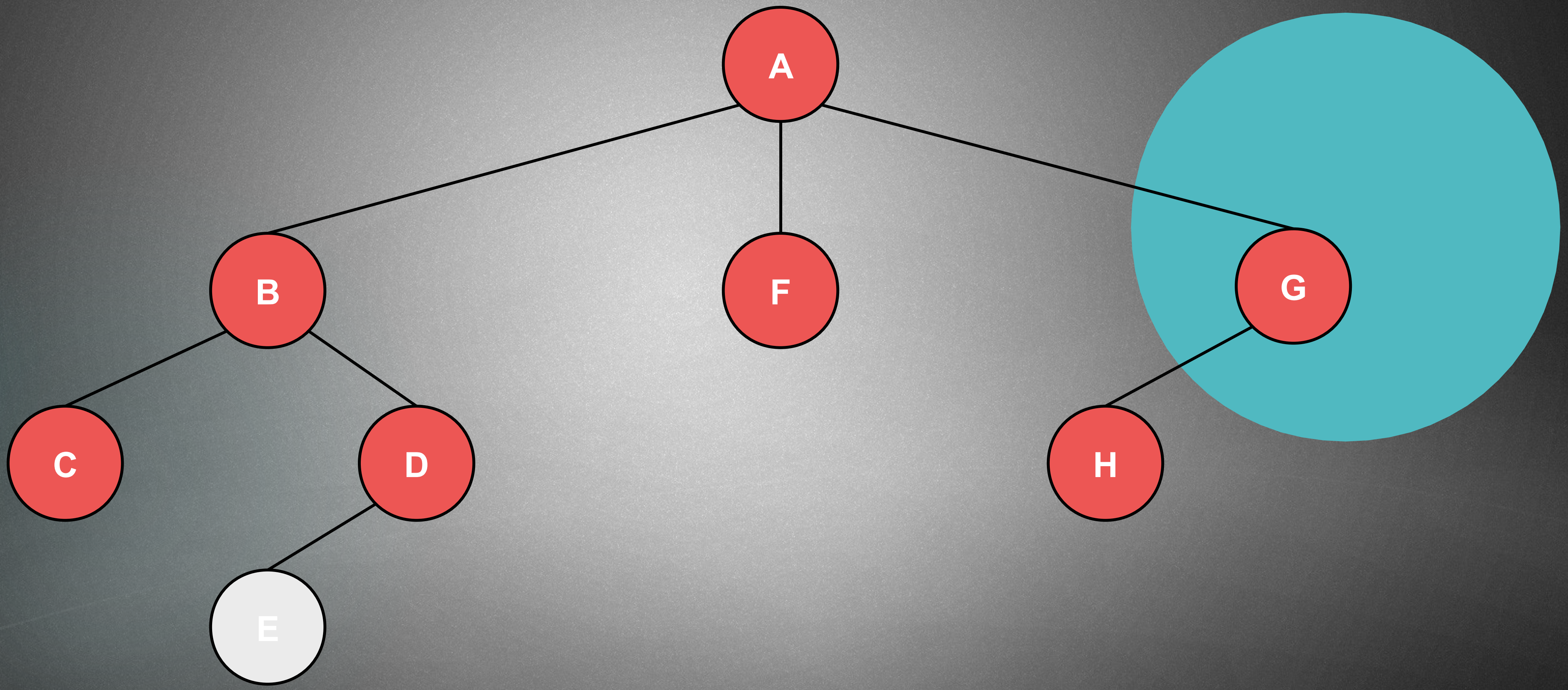

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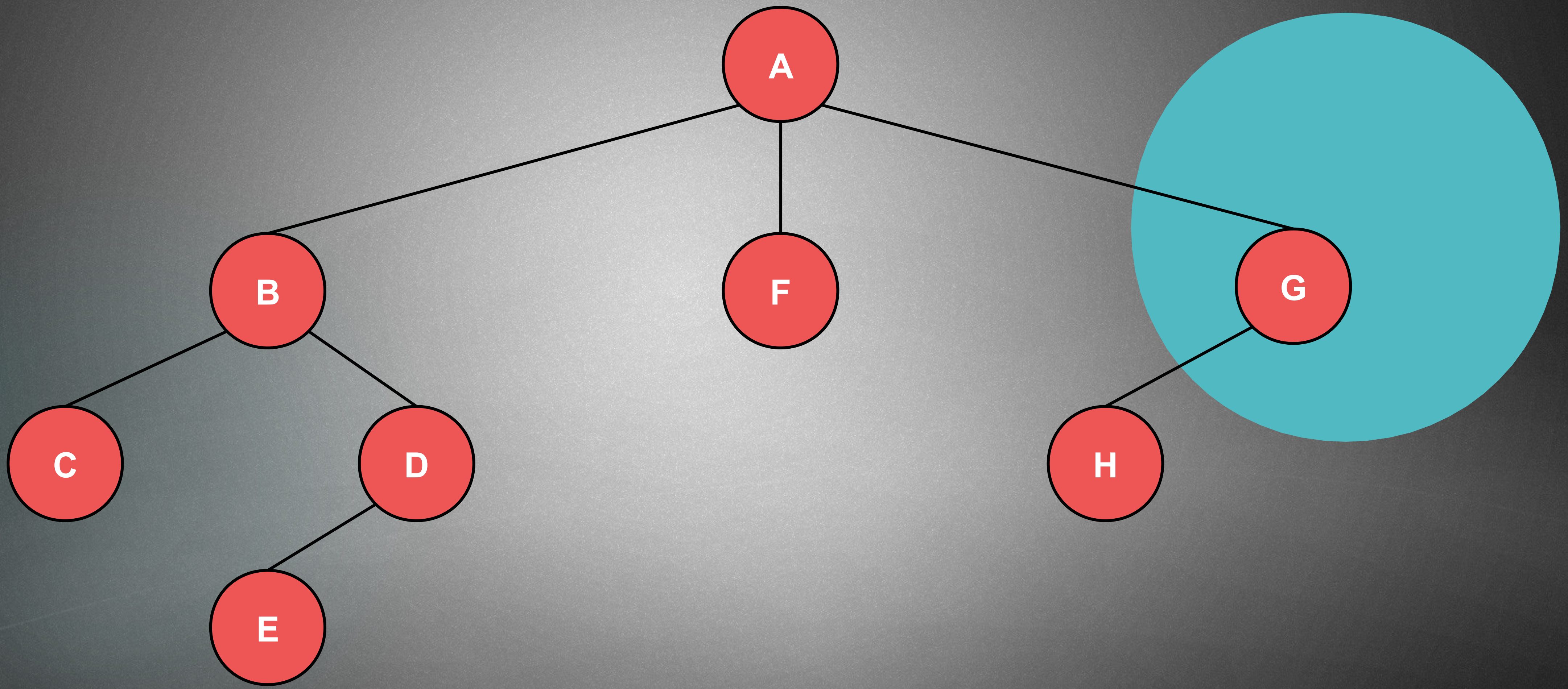
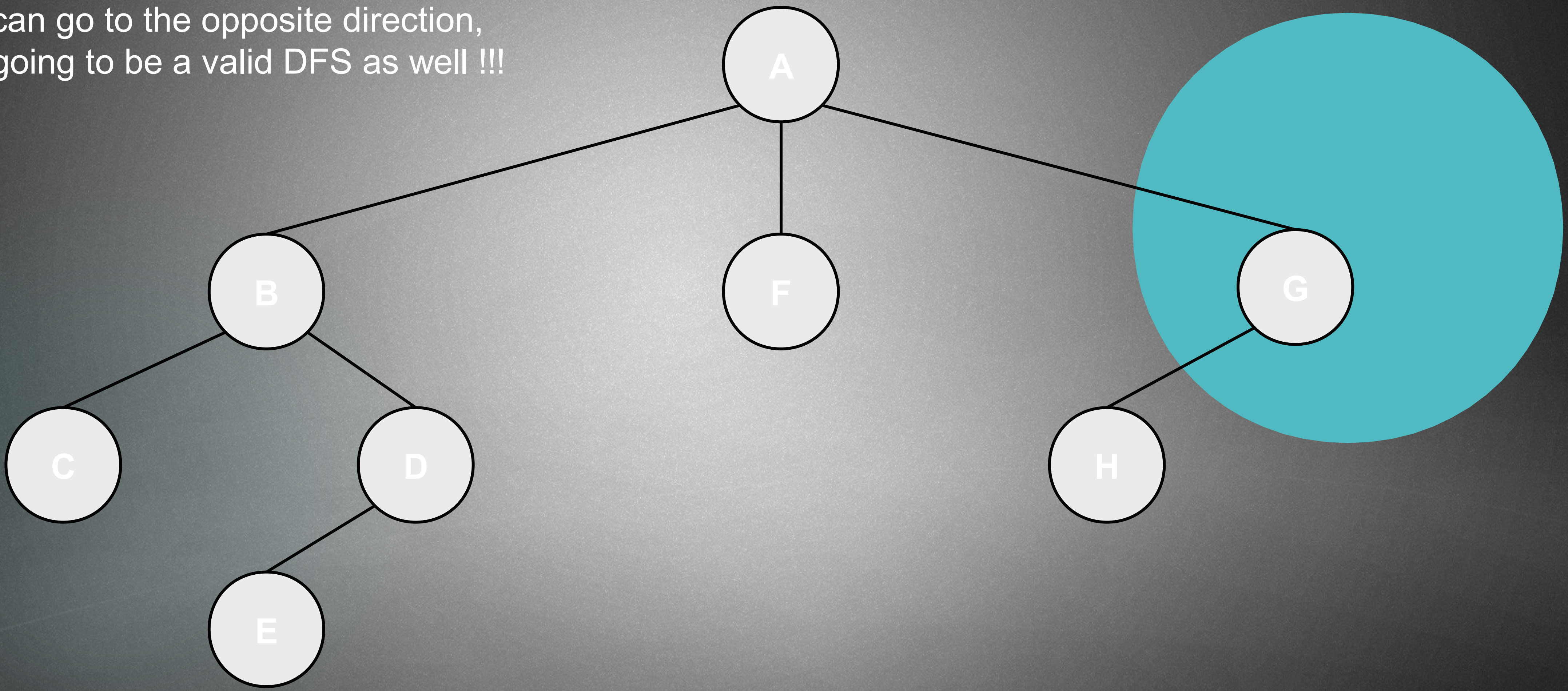


Symmetry in DFS

We can go to the opposite direction,
it is going to be a valid DFS as well !!!



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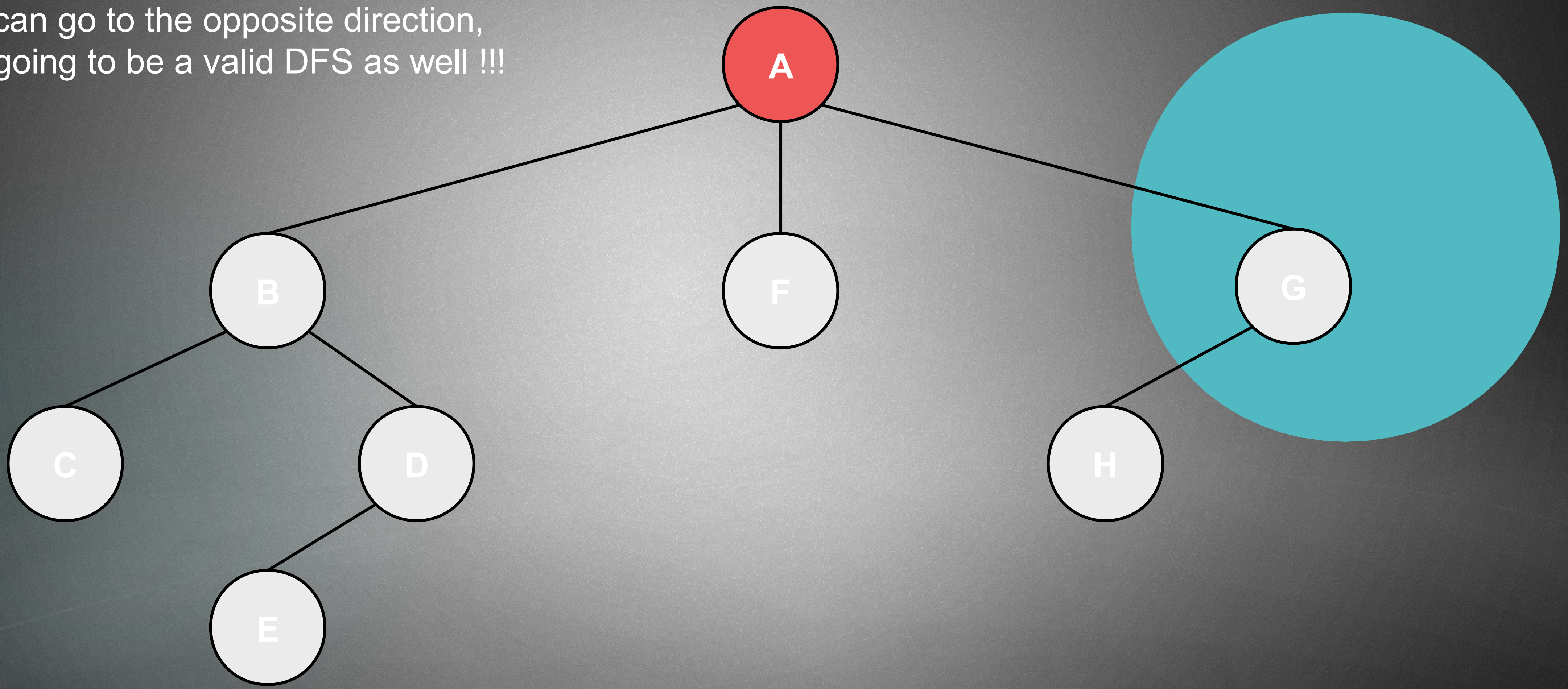

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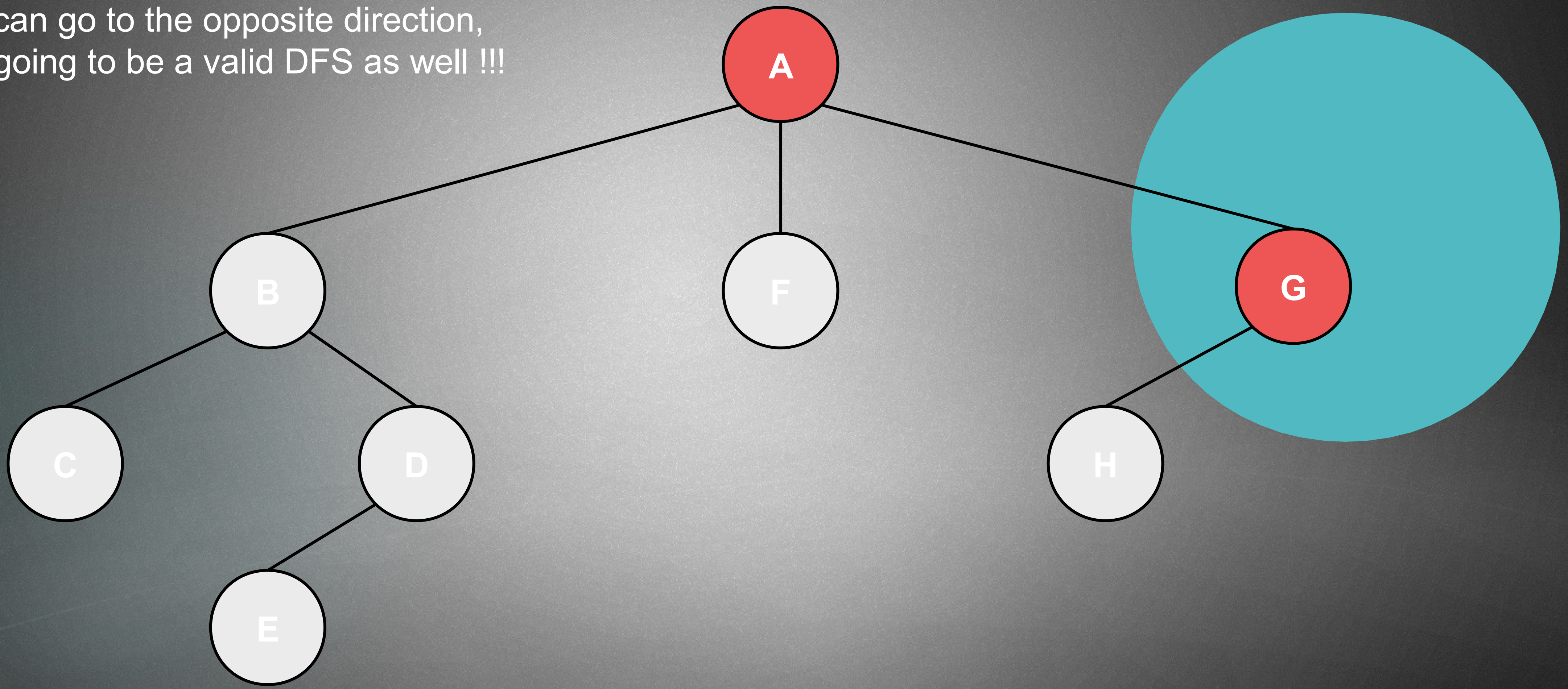

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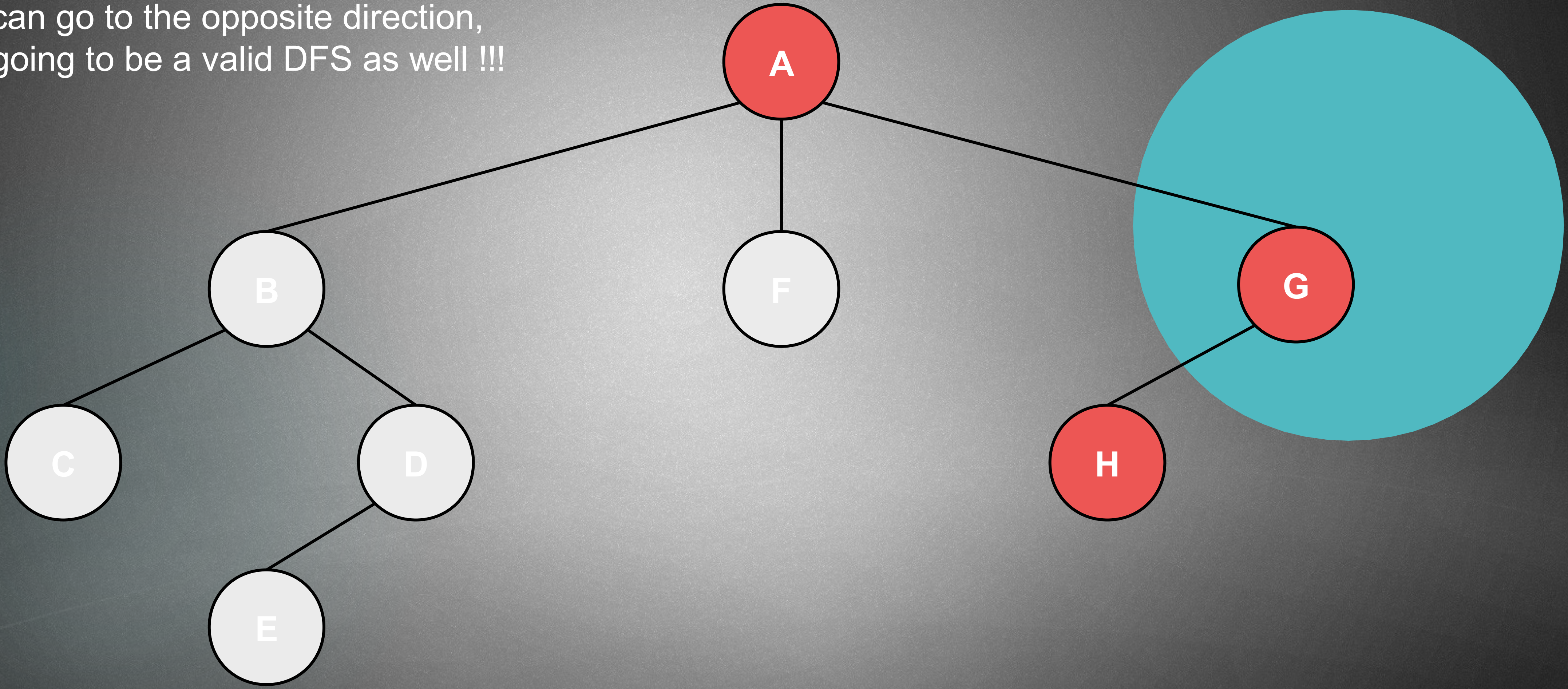

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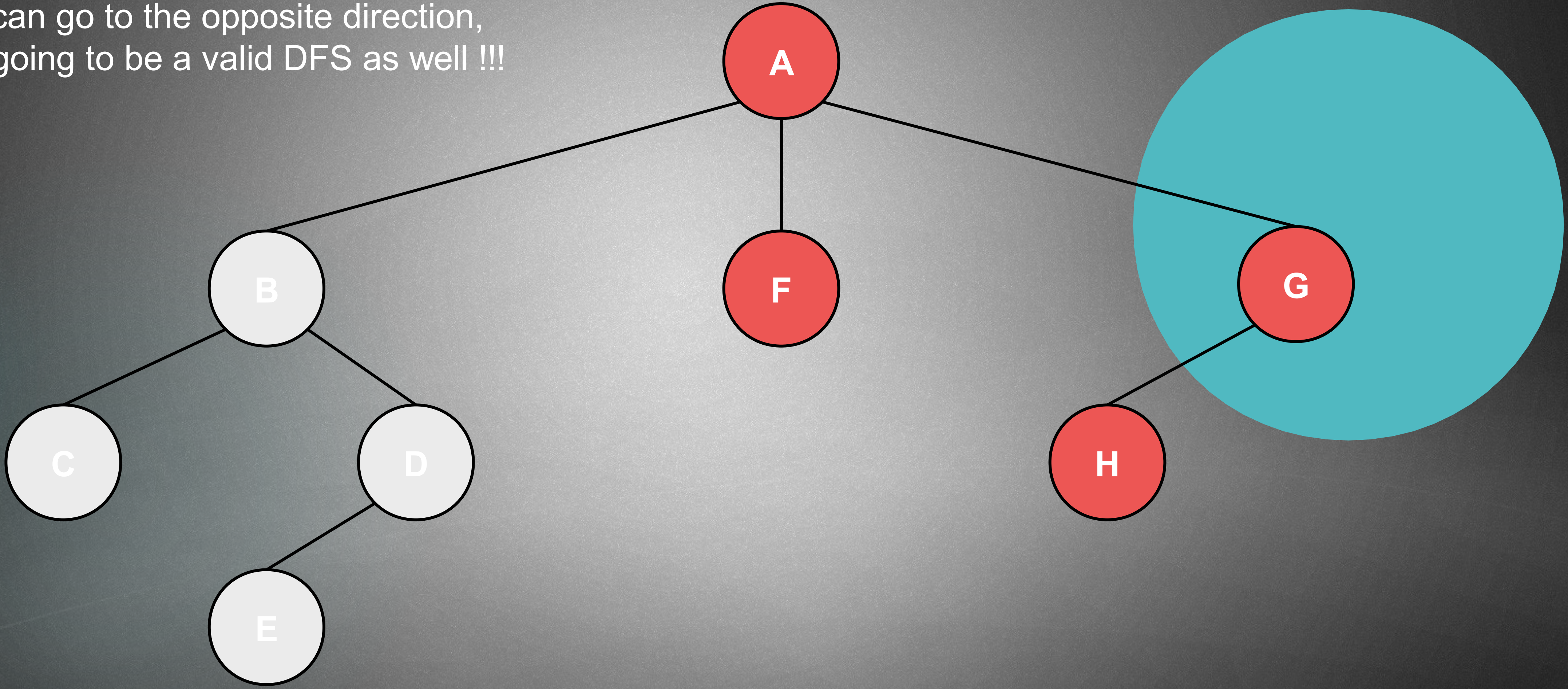

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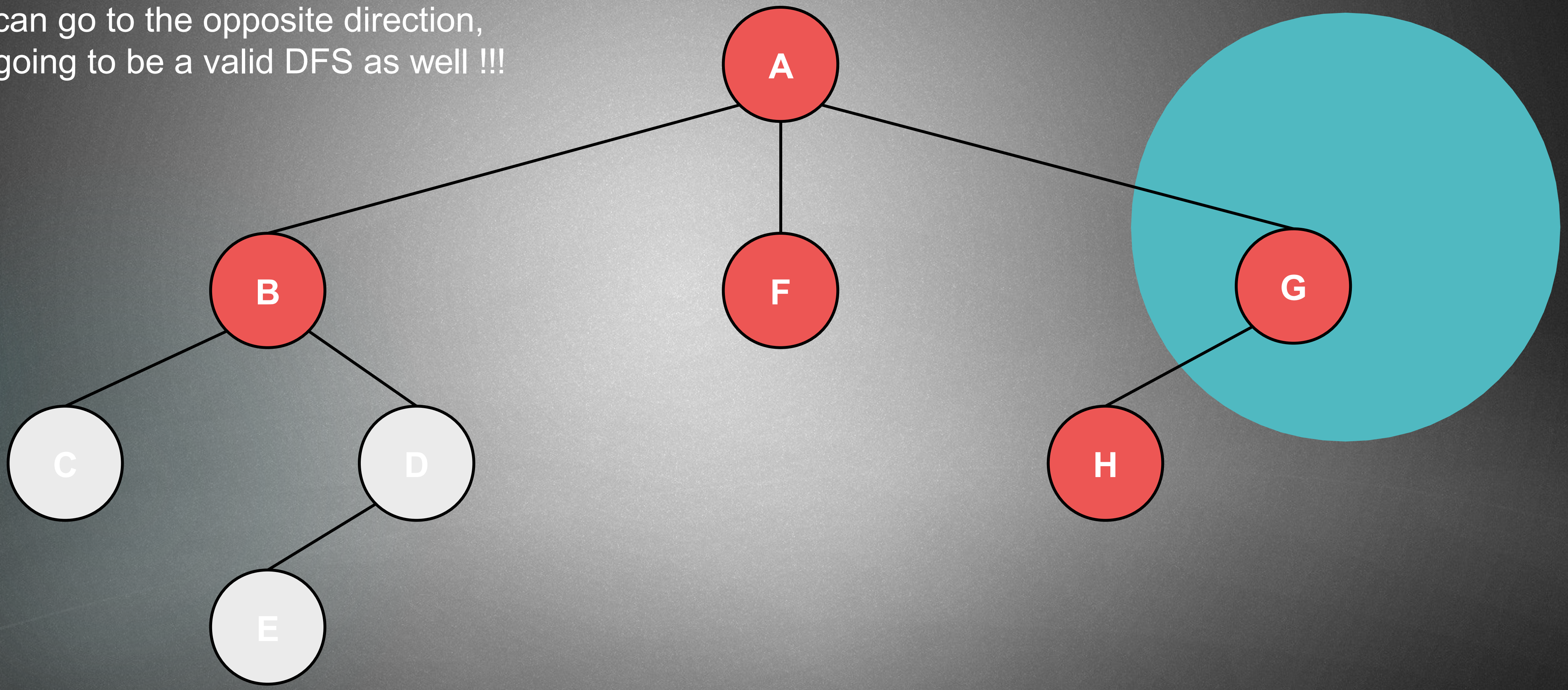

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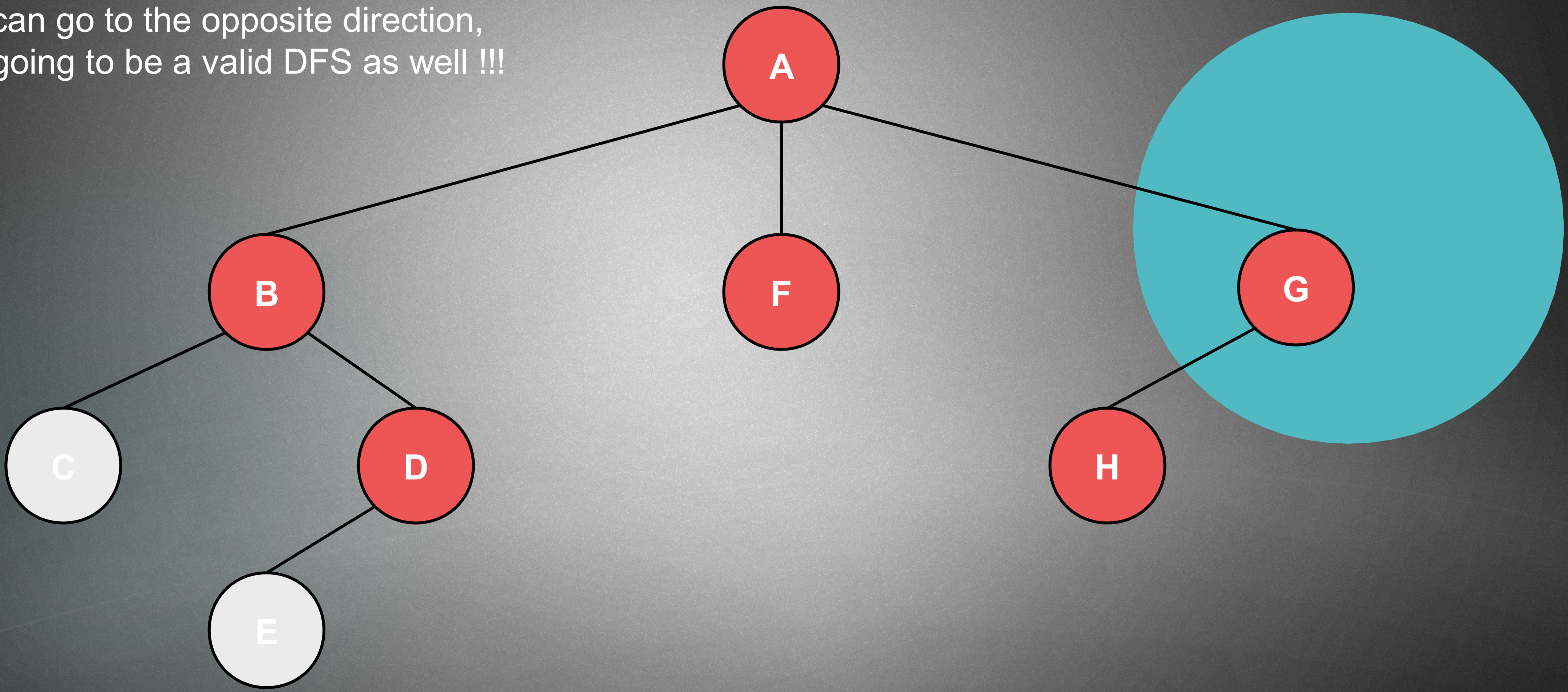
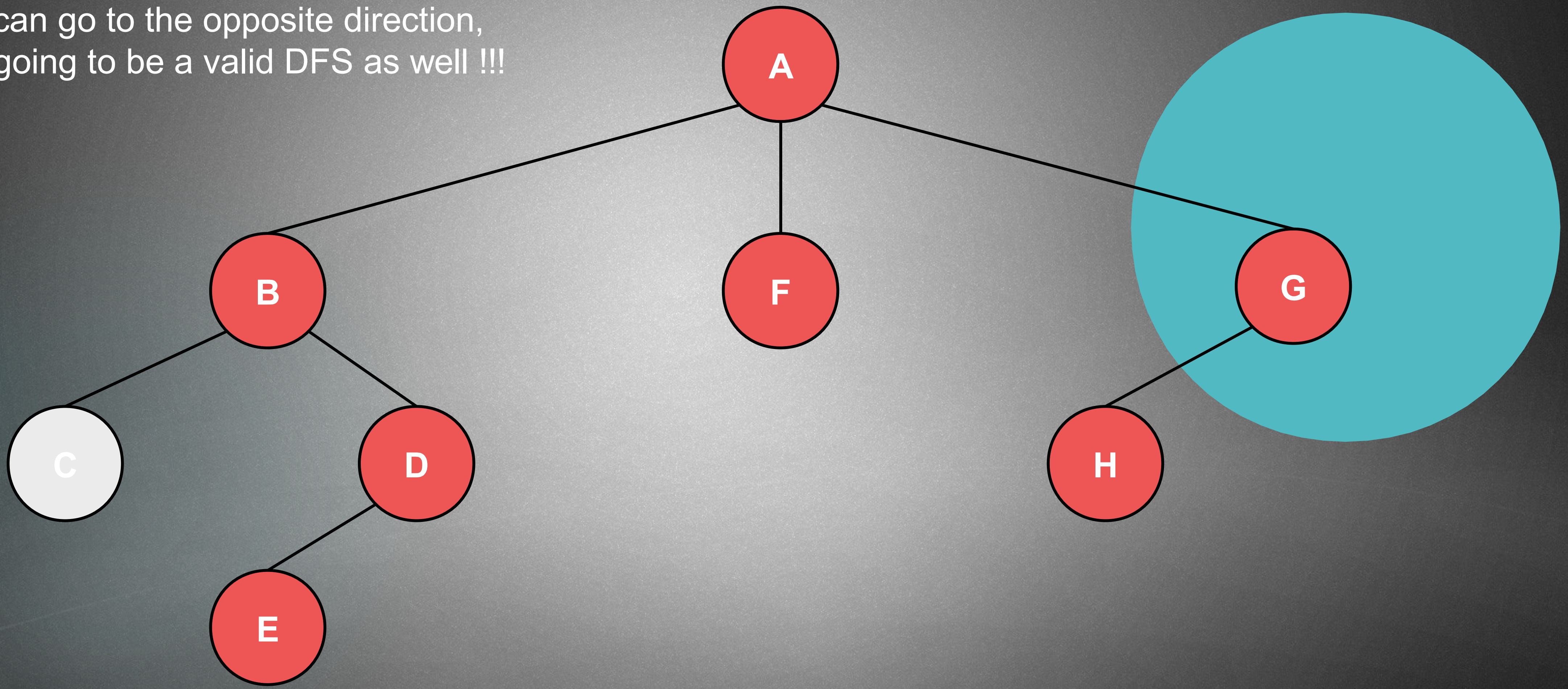


Symmetry in DFS

We can go to the opposite direction,
it is going to be a valid DFS as well !!!



Symmetry in DFS

We can go to the opposite direction,
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