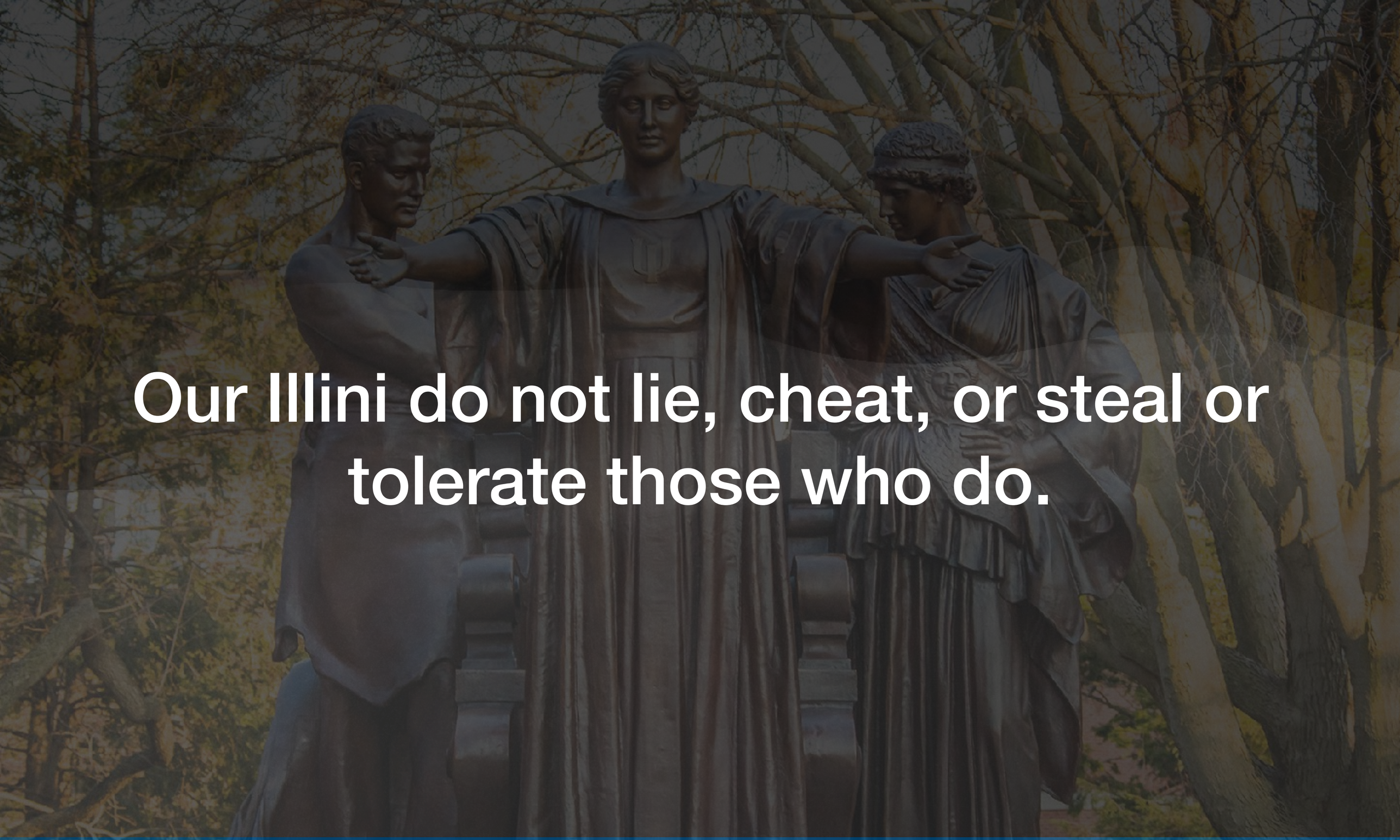
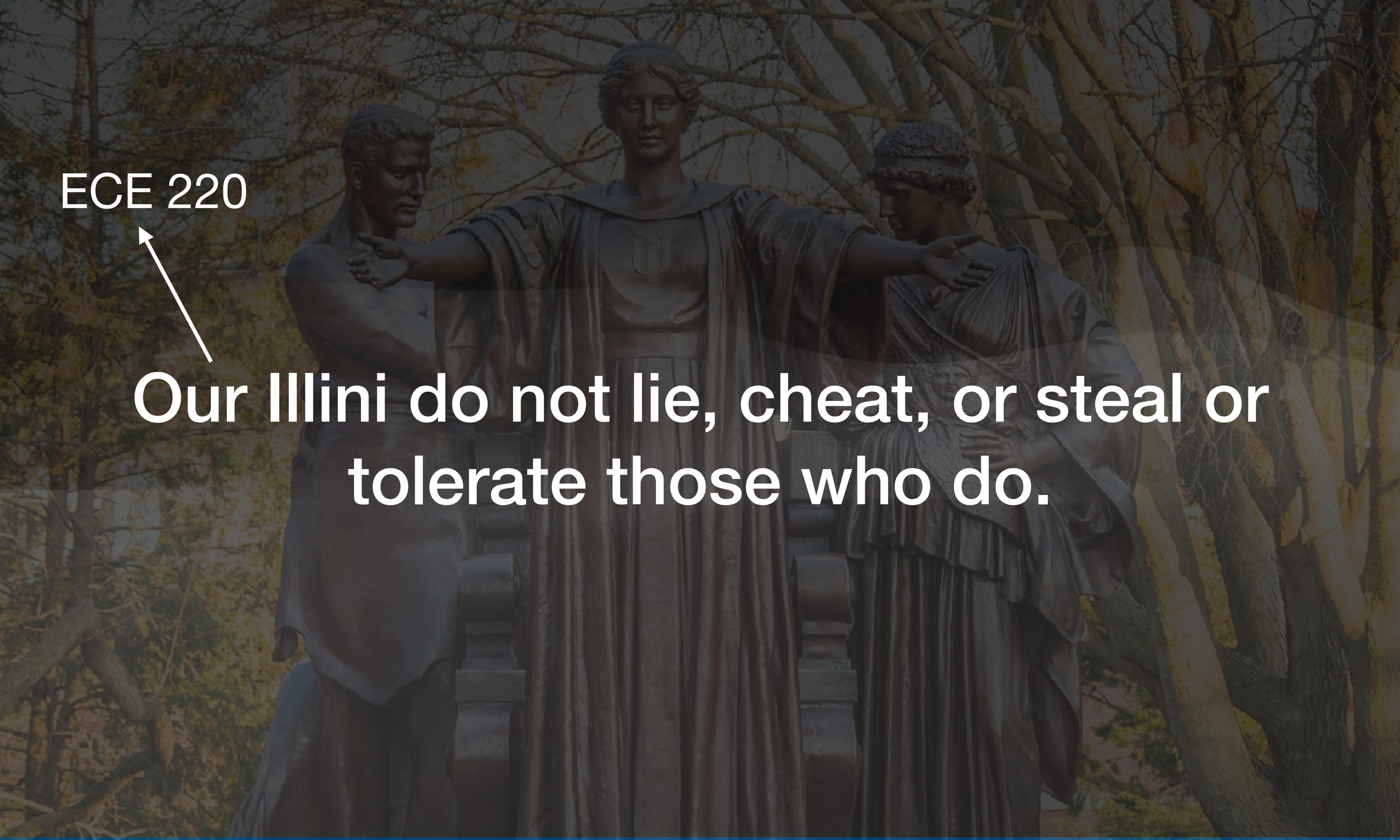
ECE 220

Lecture x0017 - 04/16
More trees (BST) and C++


Our Illini do not lie, cheat, or steal or
tolerate those who do.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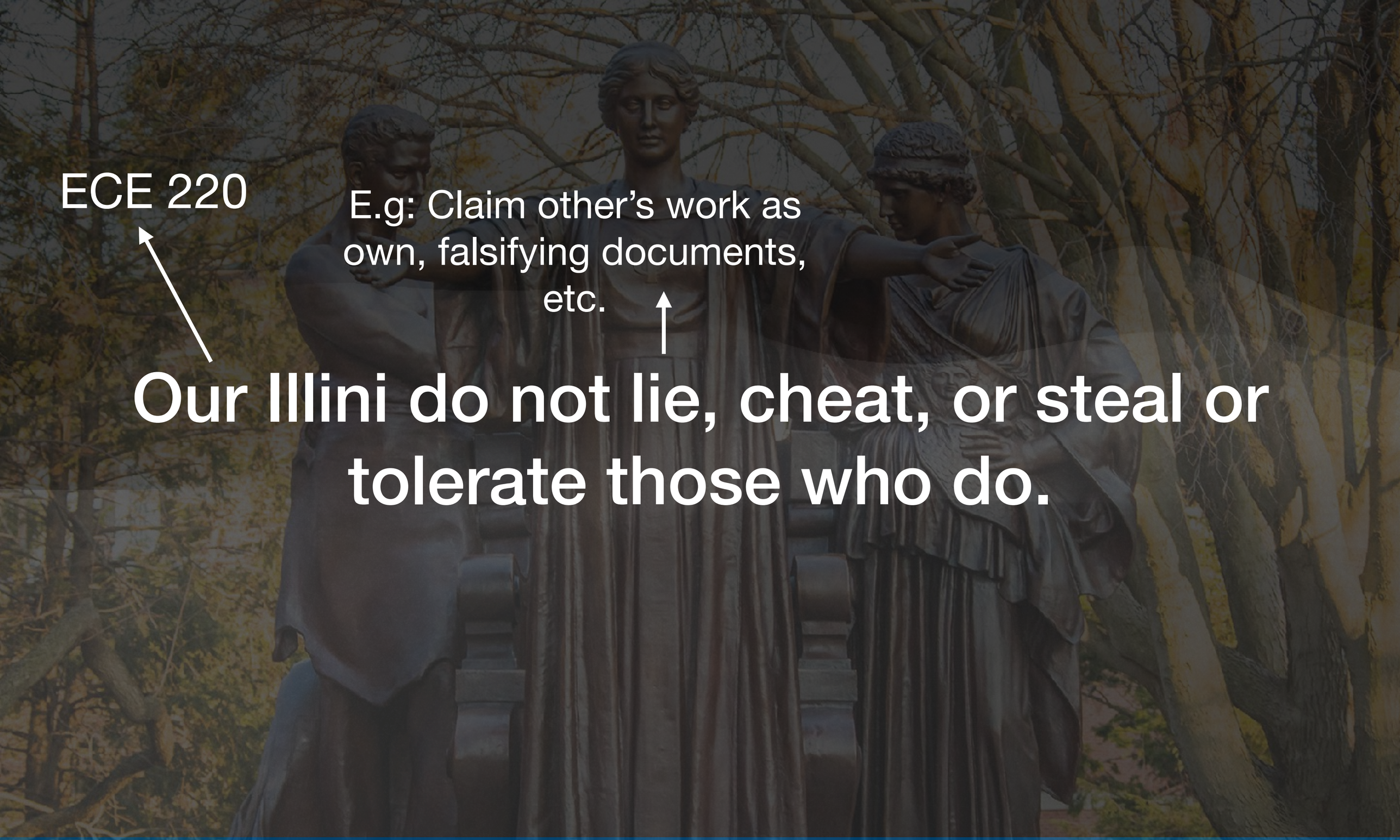
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E.g: Claim other's work as own, falsifying documents, etc.
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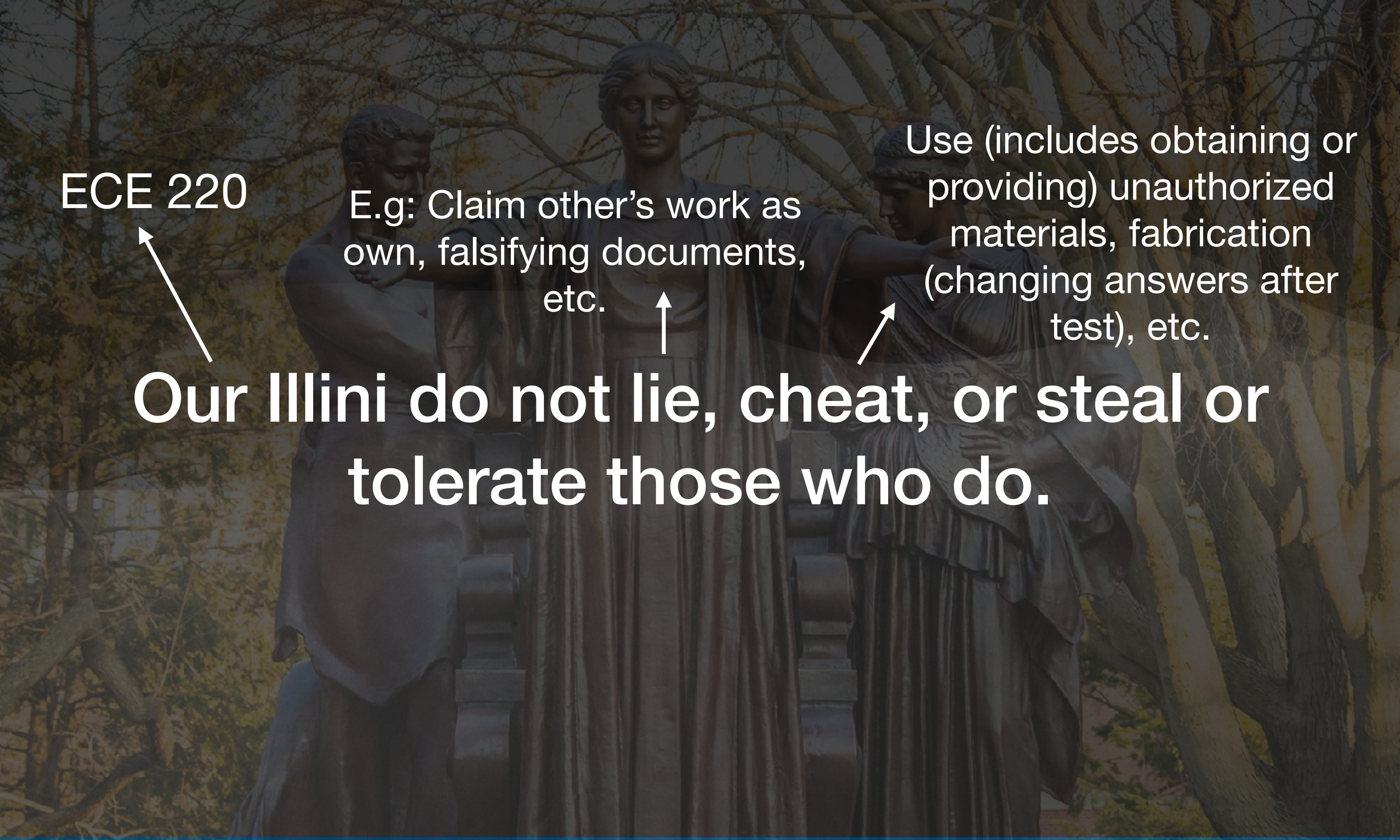
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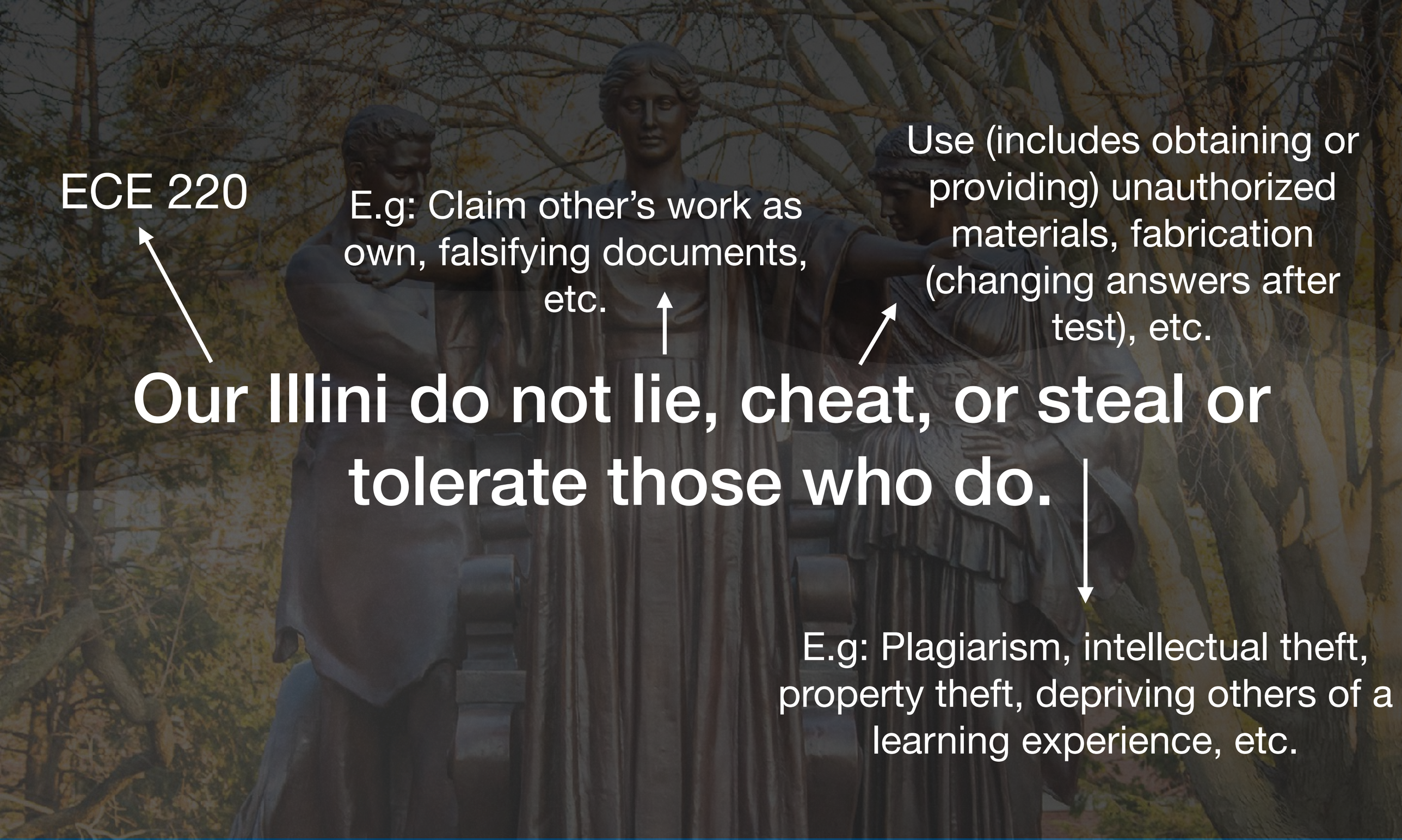
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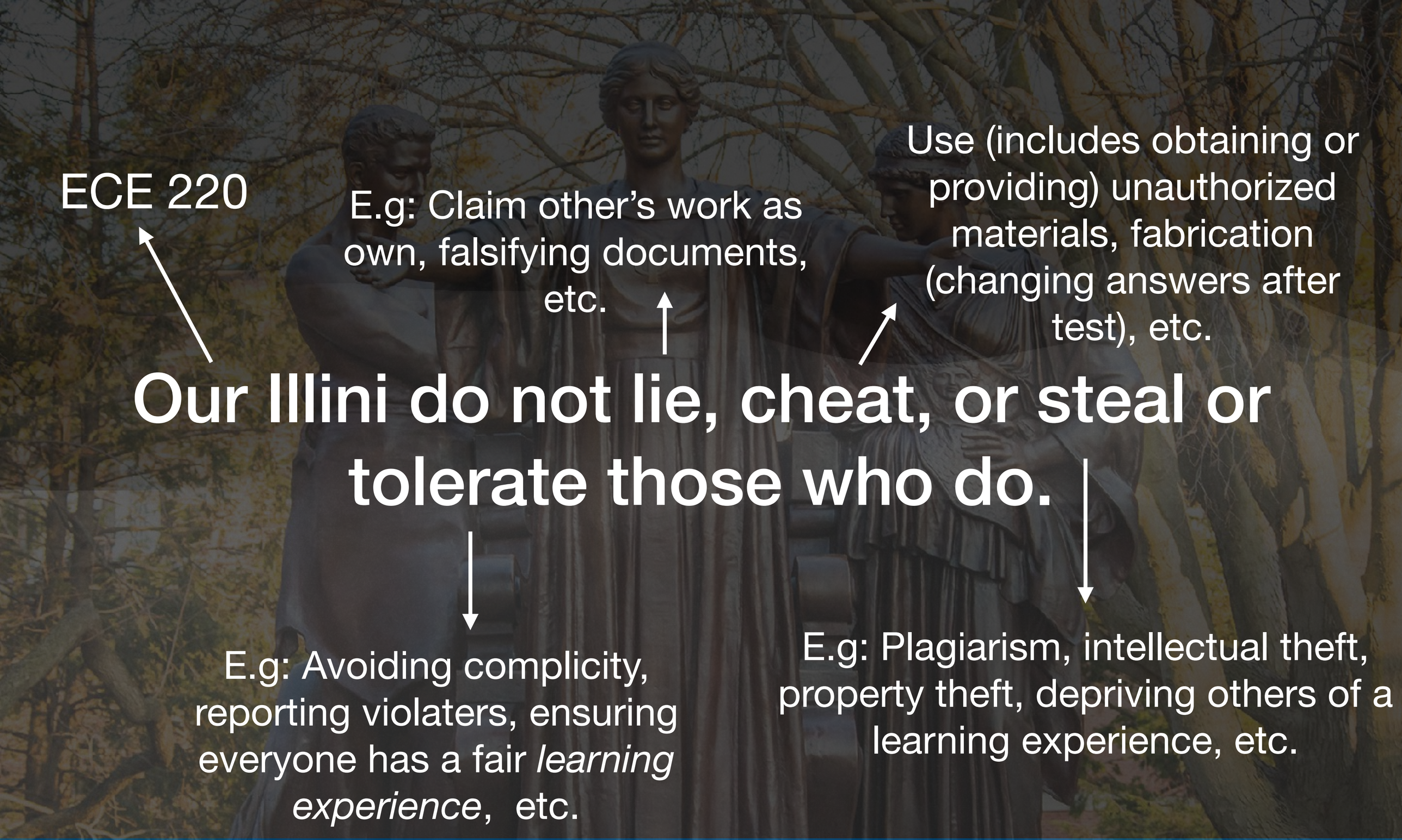
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E.g: Avoiding complicity, reporting violaters, ensuring everyone has a fair *learning experience*, etc.
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Recap

Recap

- Previously

Recap

- Previously
  - Tree & tree concepts

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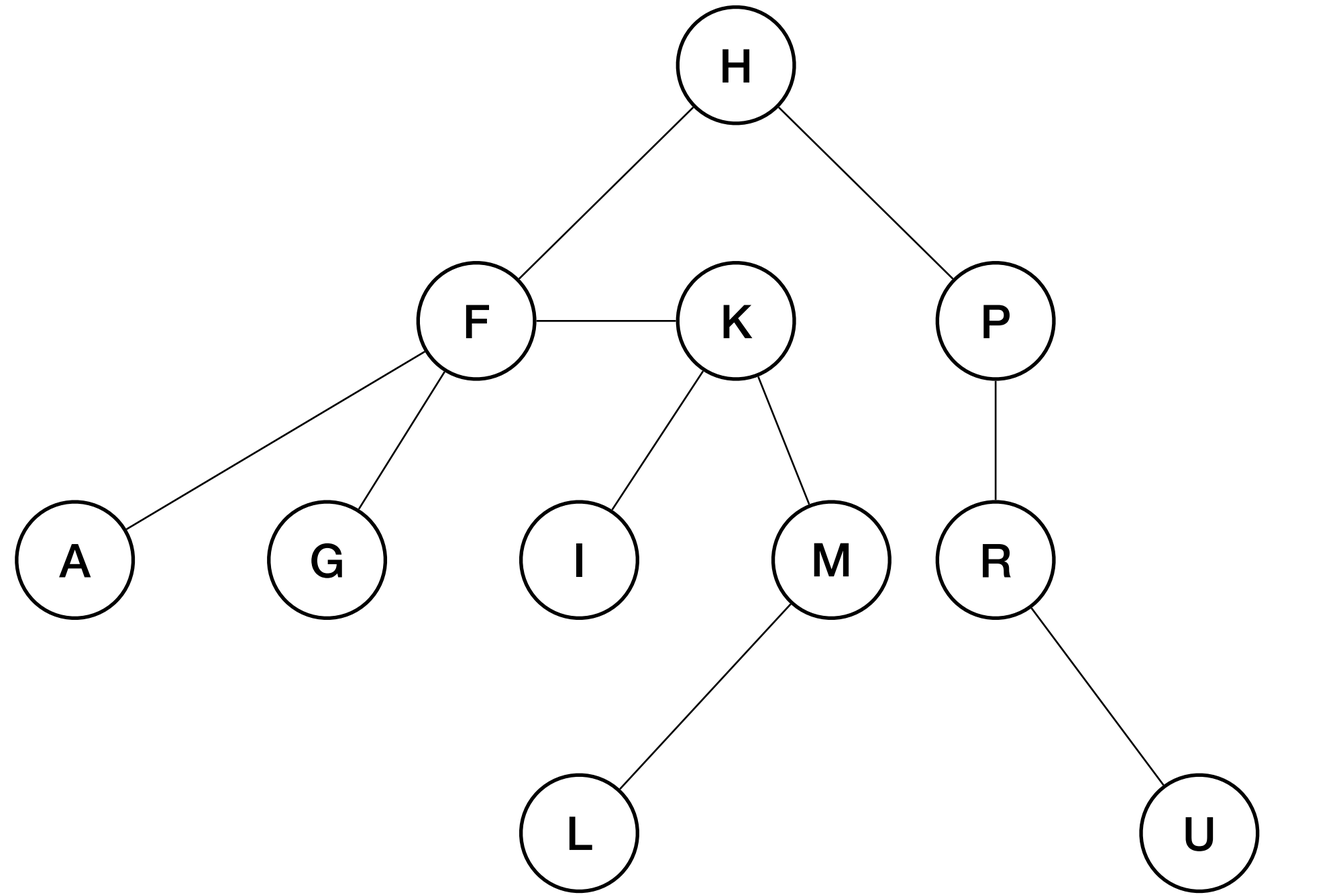
Recap

- Scan QR Code

Recap



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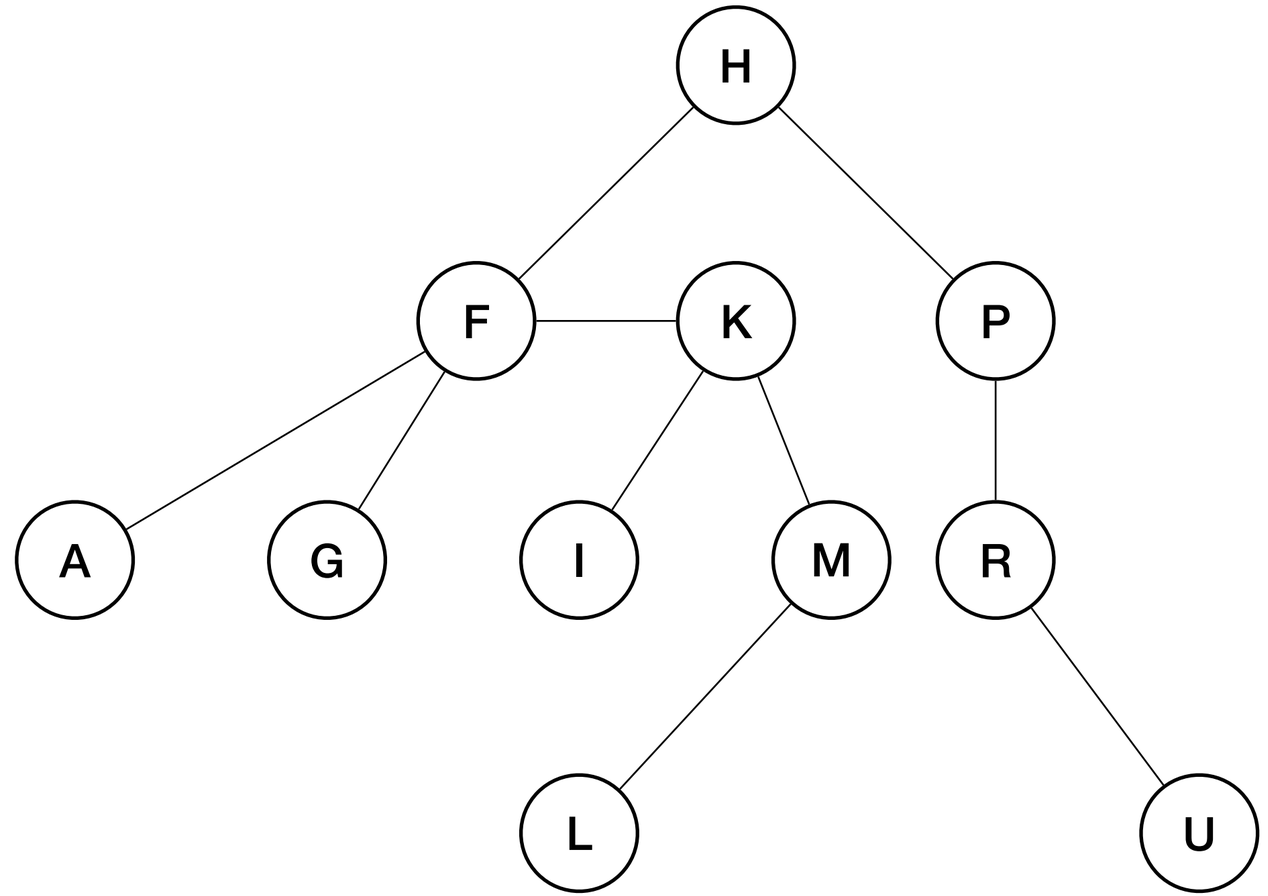
- Who are R's siblings?



Recap

- Who are R's siblings?
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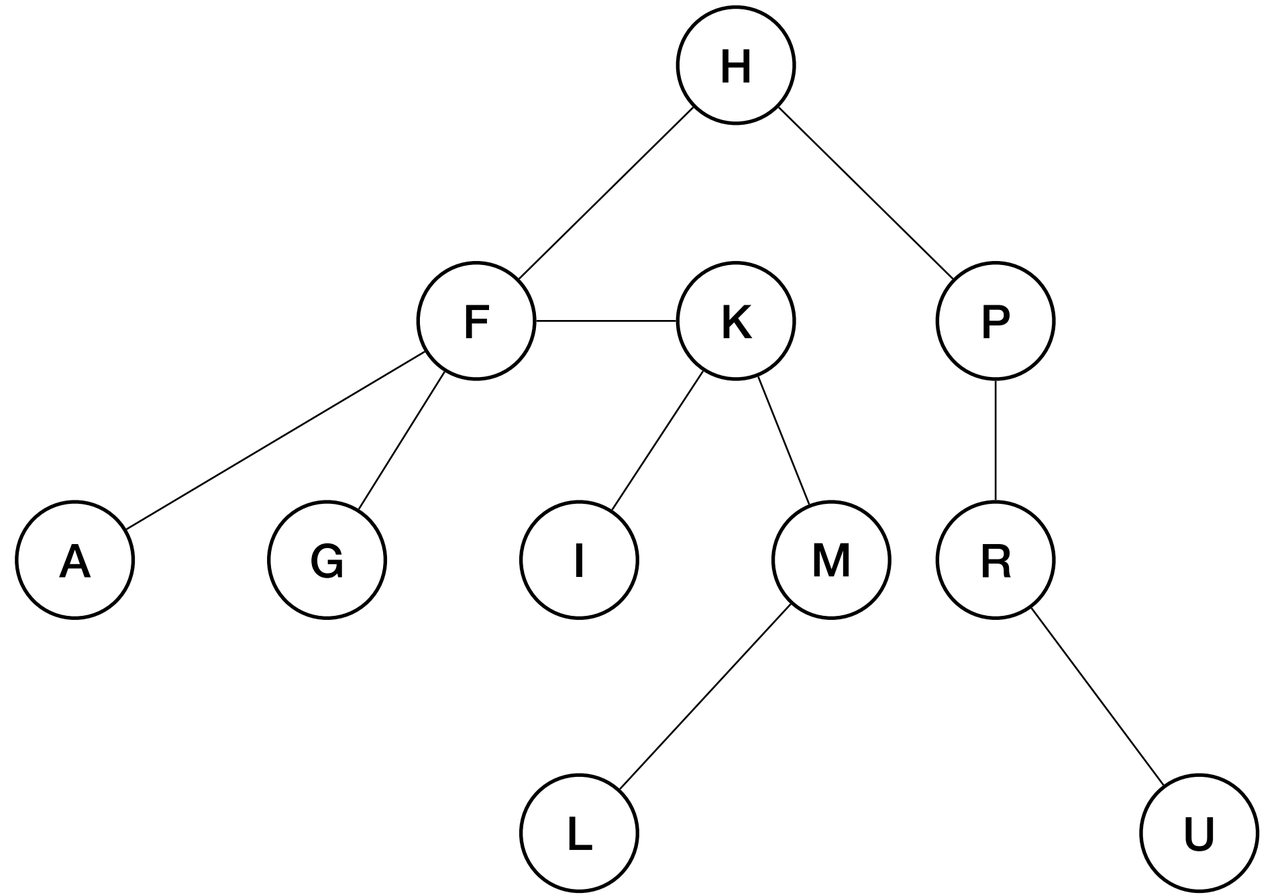

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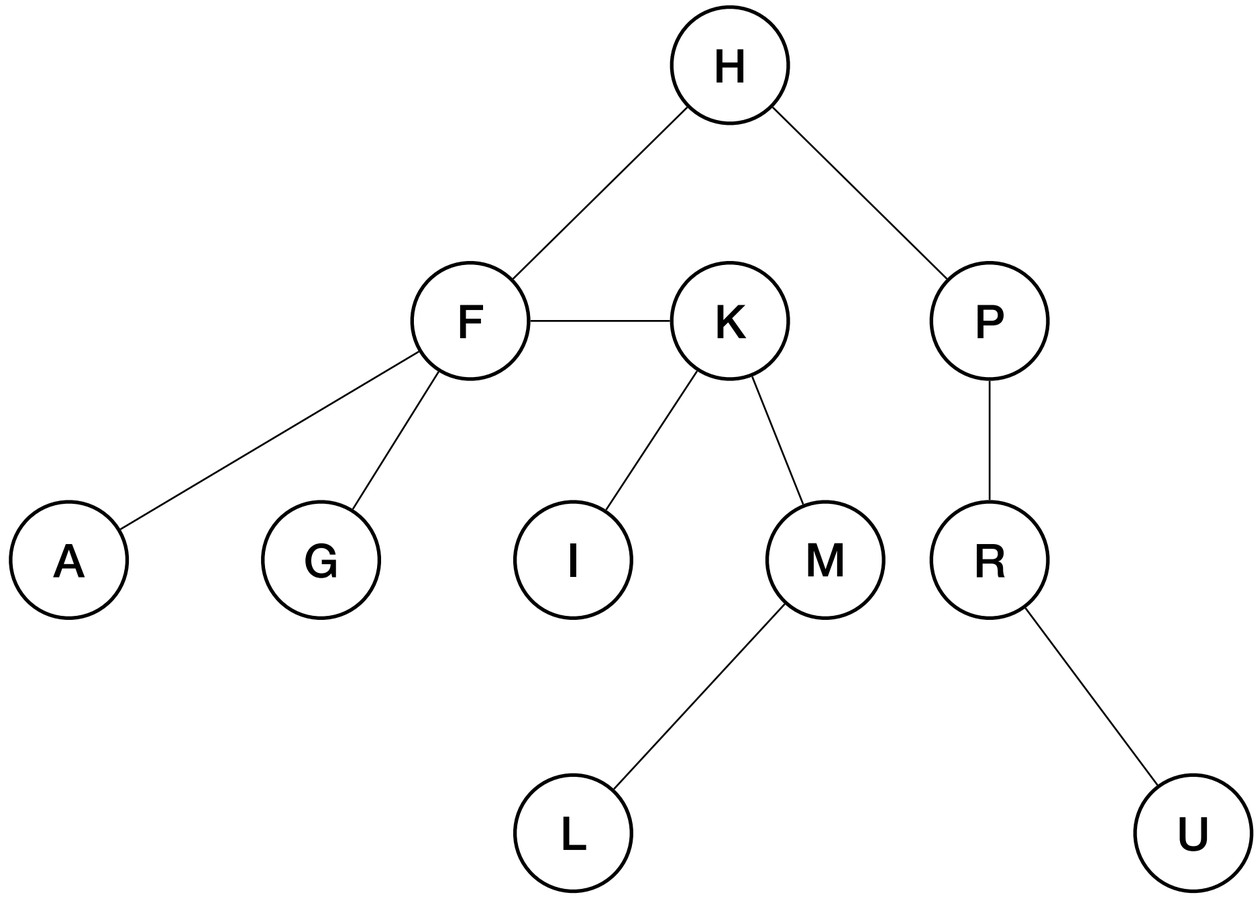

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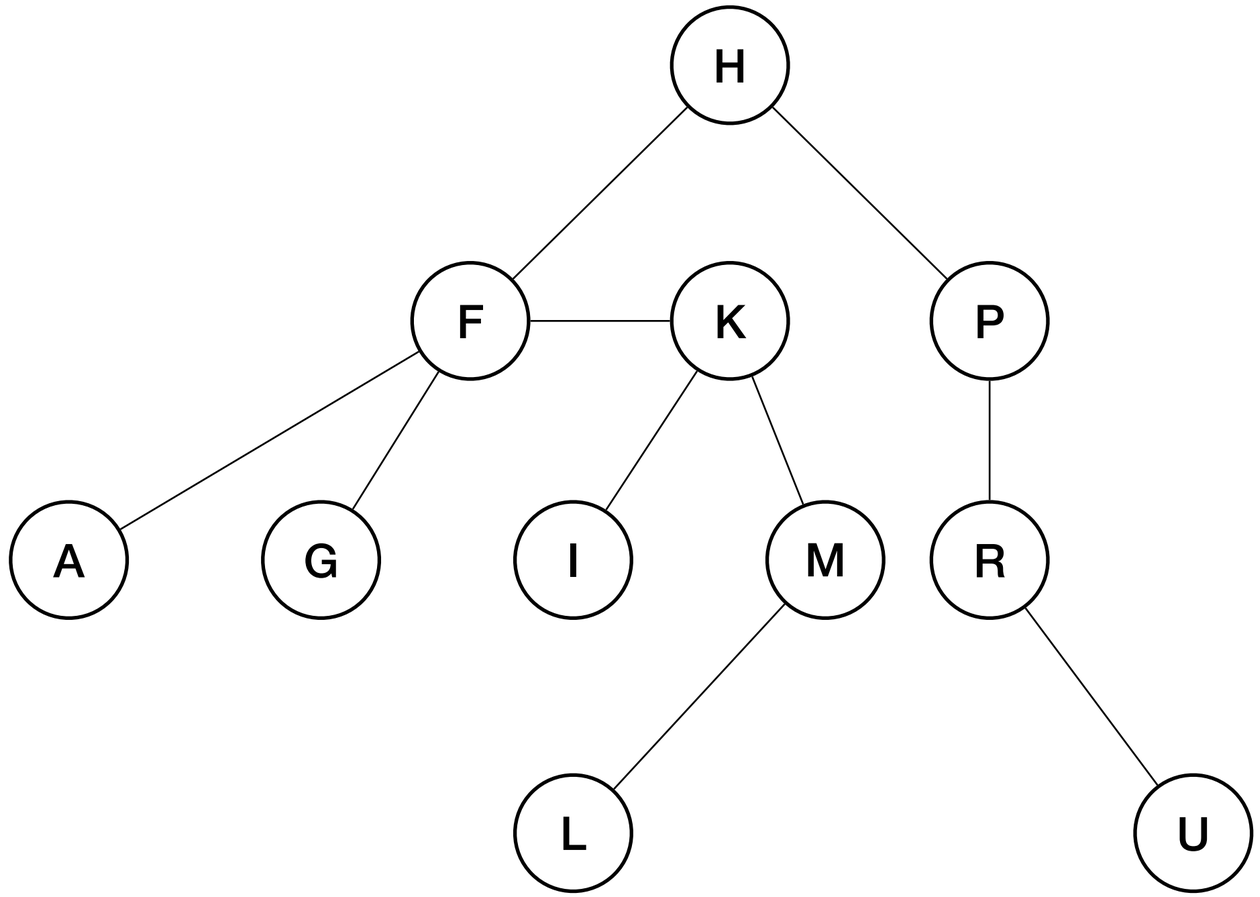

Binary Search Trees

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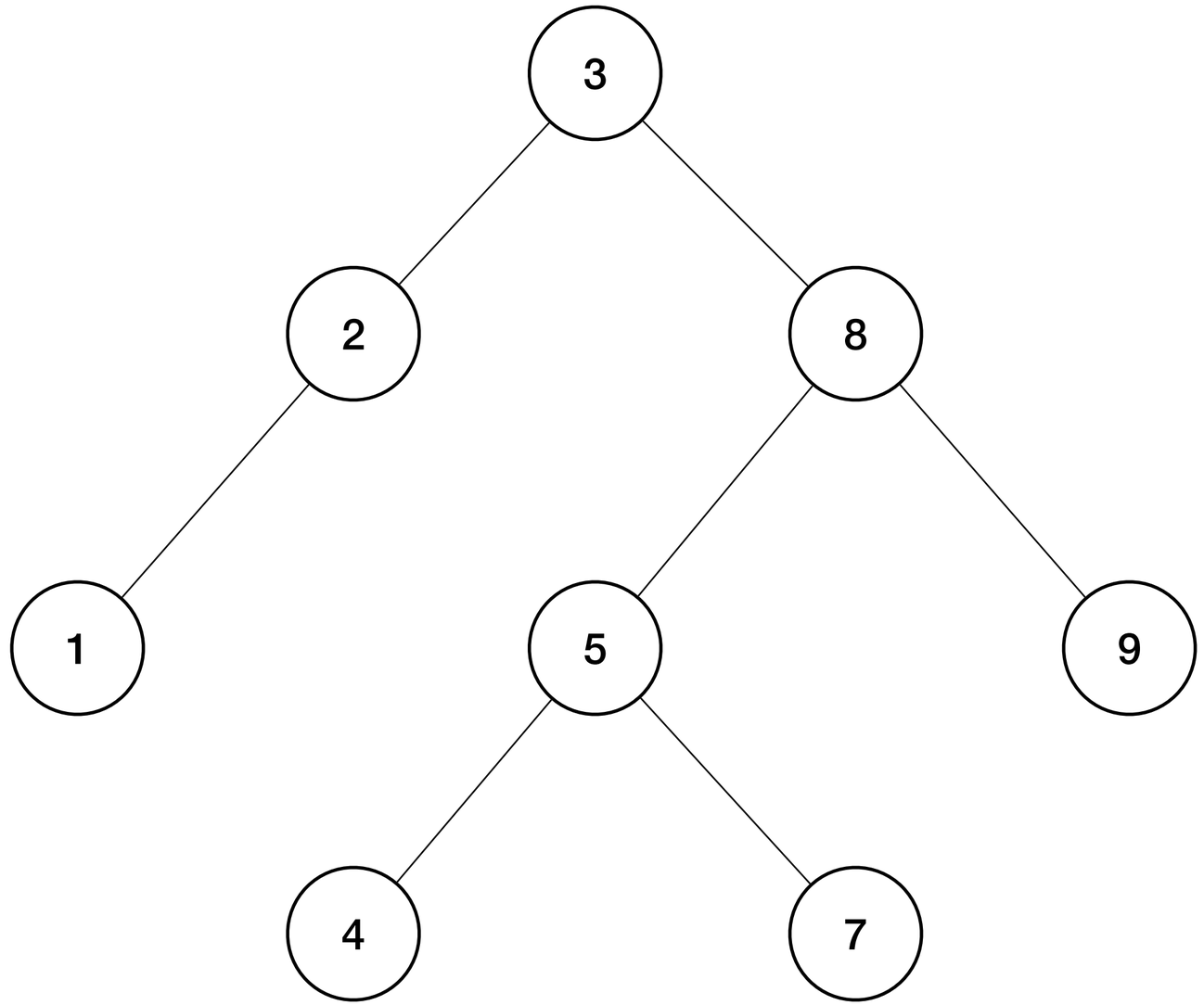
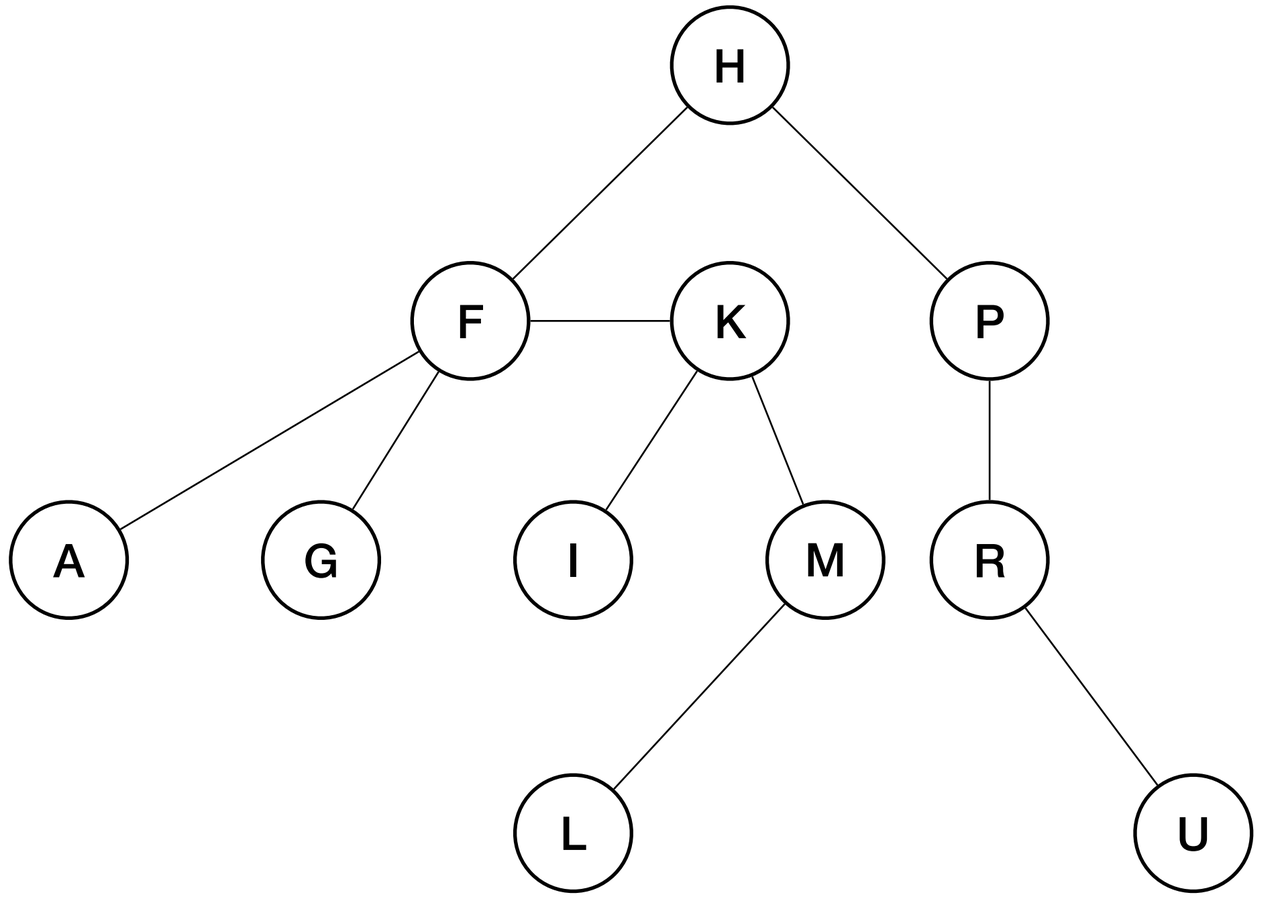


Recap

- Who are the siblings of L?
- What is the depth of node I?
- List the leaf nodes?
- What is the height of the tree?
- Is this a Binary Search Tree?



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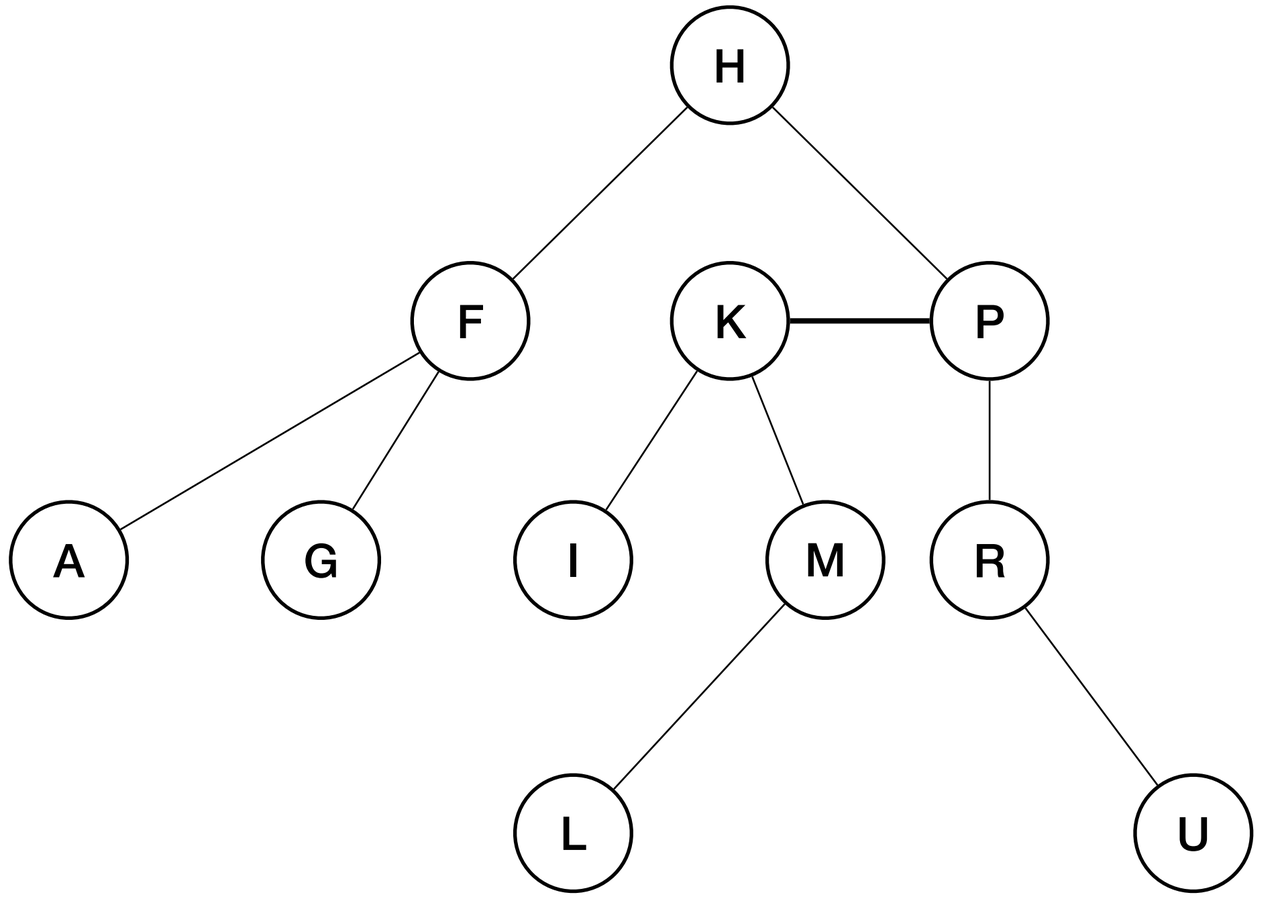

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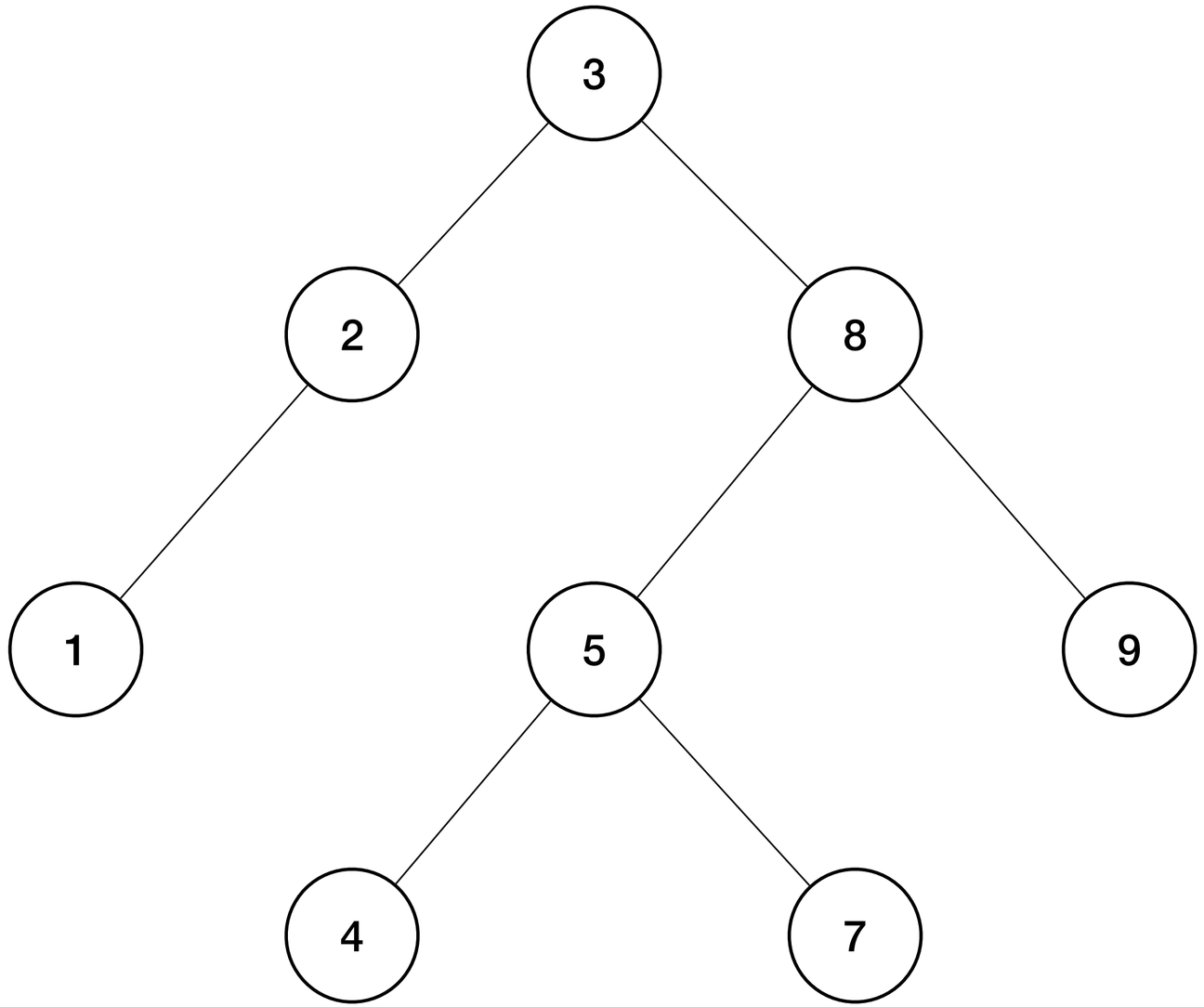
- How can we search a BST for a node?
- How should you insert a new node in a BST?
- How can you find the height of a *general* tree (can also be BST)?

Finding extremals in a BST

Minimum - keep going left

Minimum - keep going right



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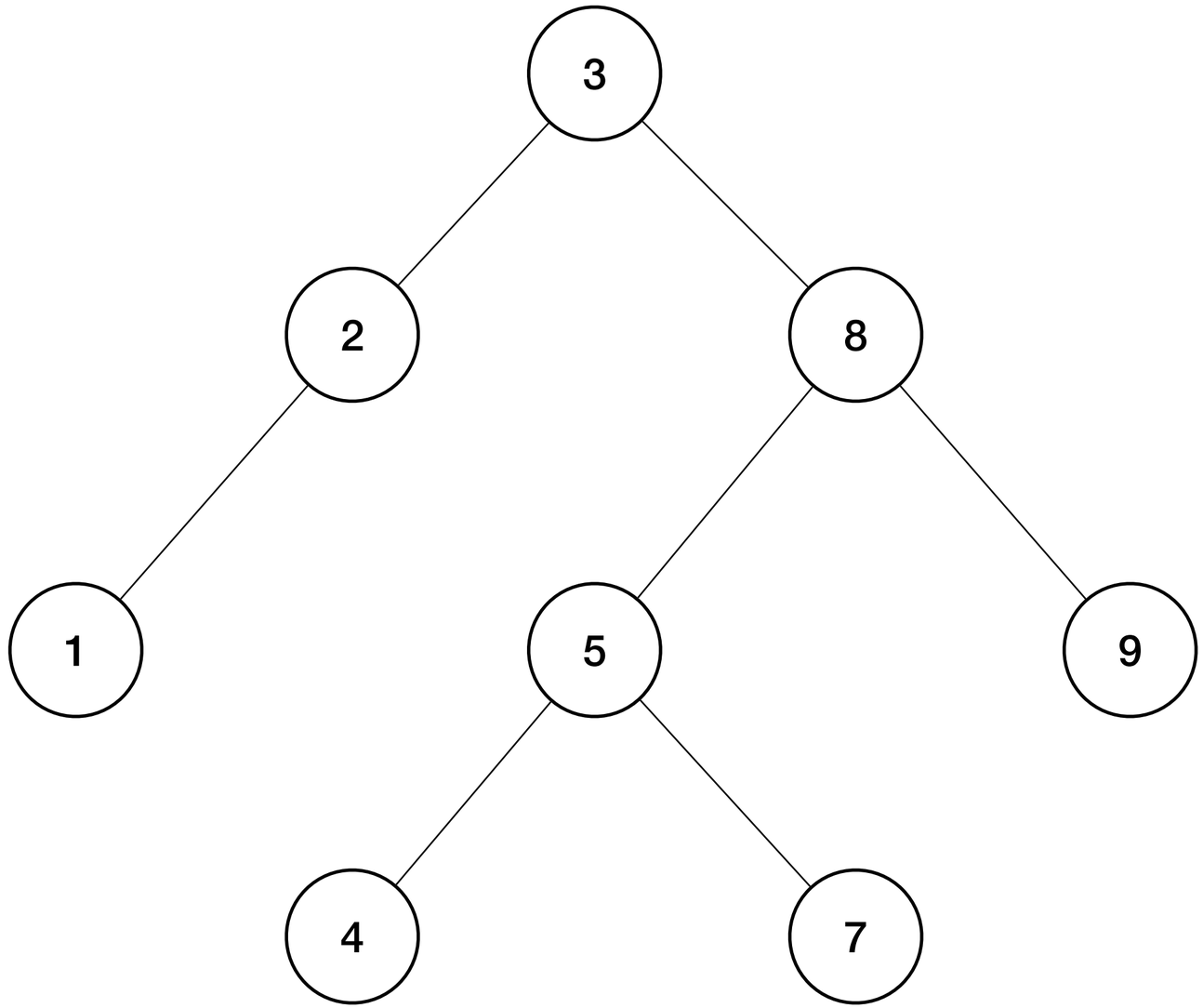

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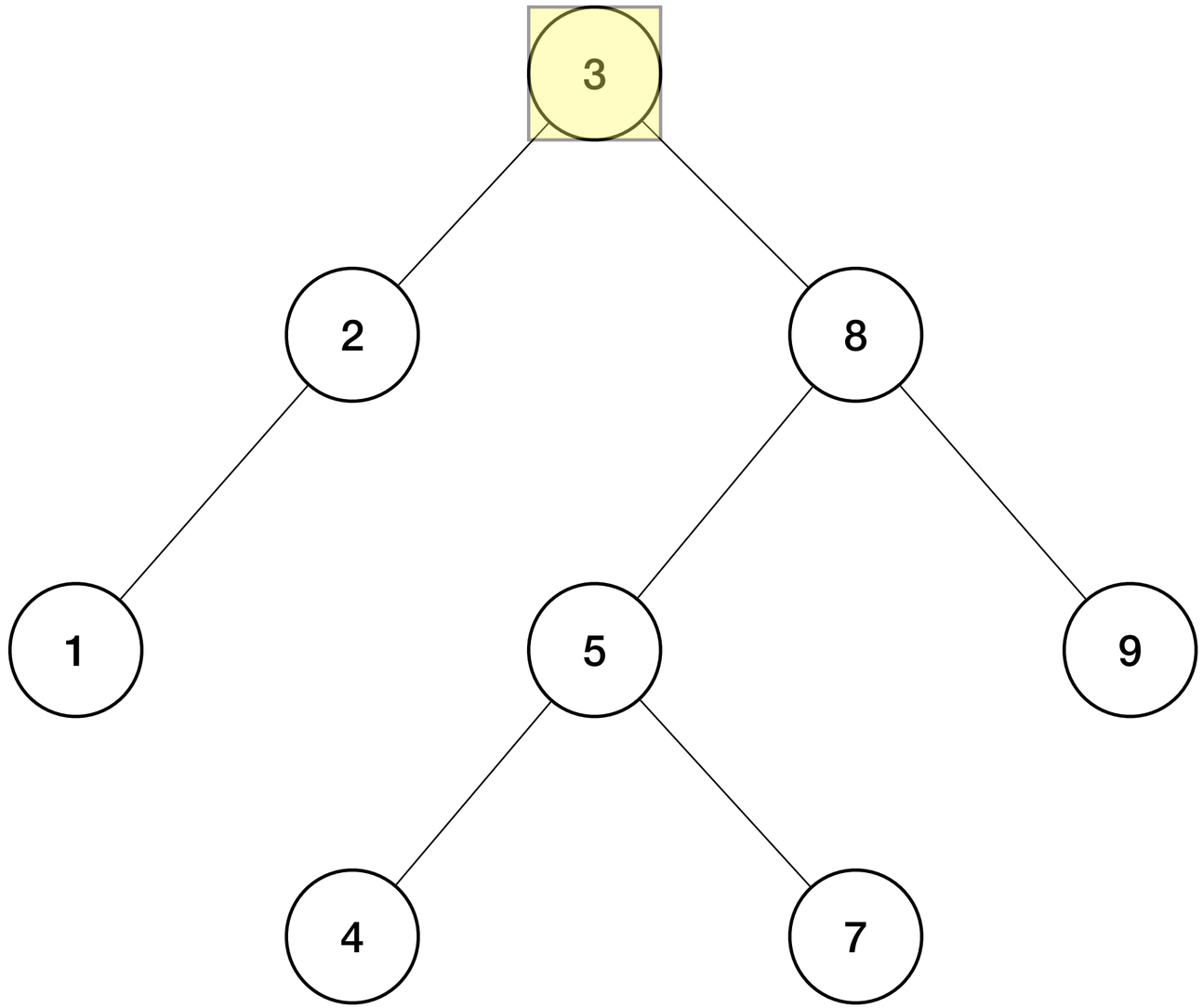

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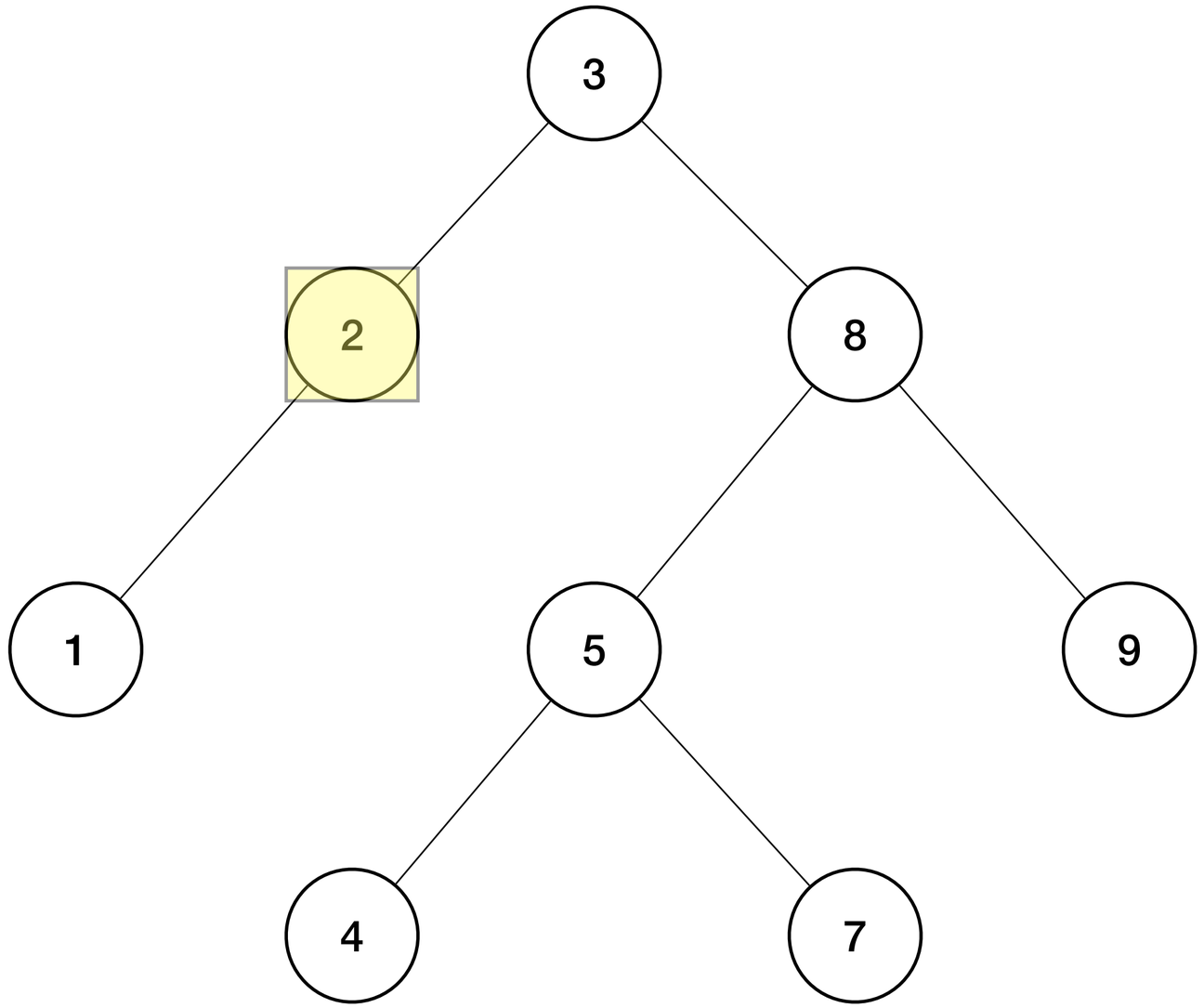

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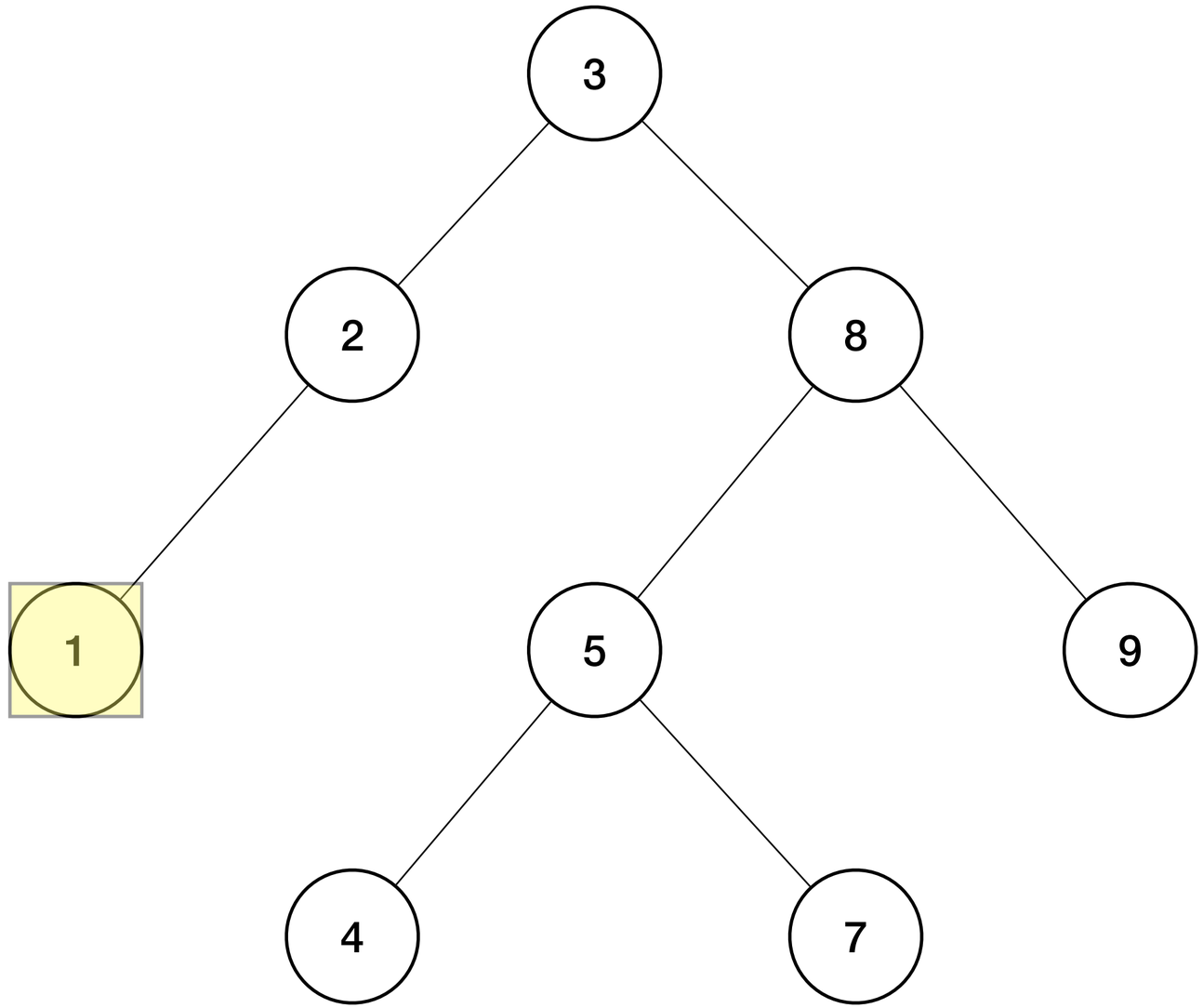

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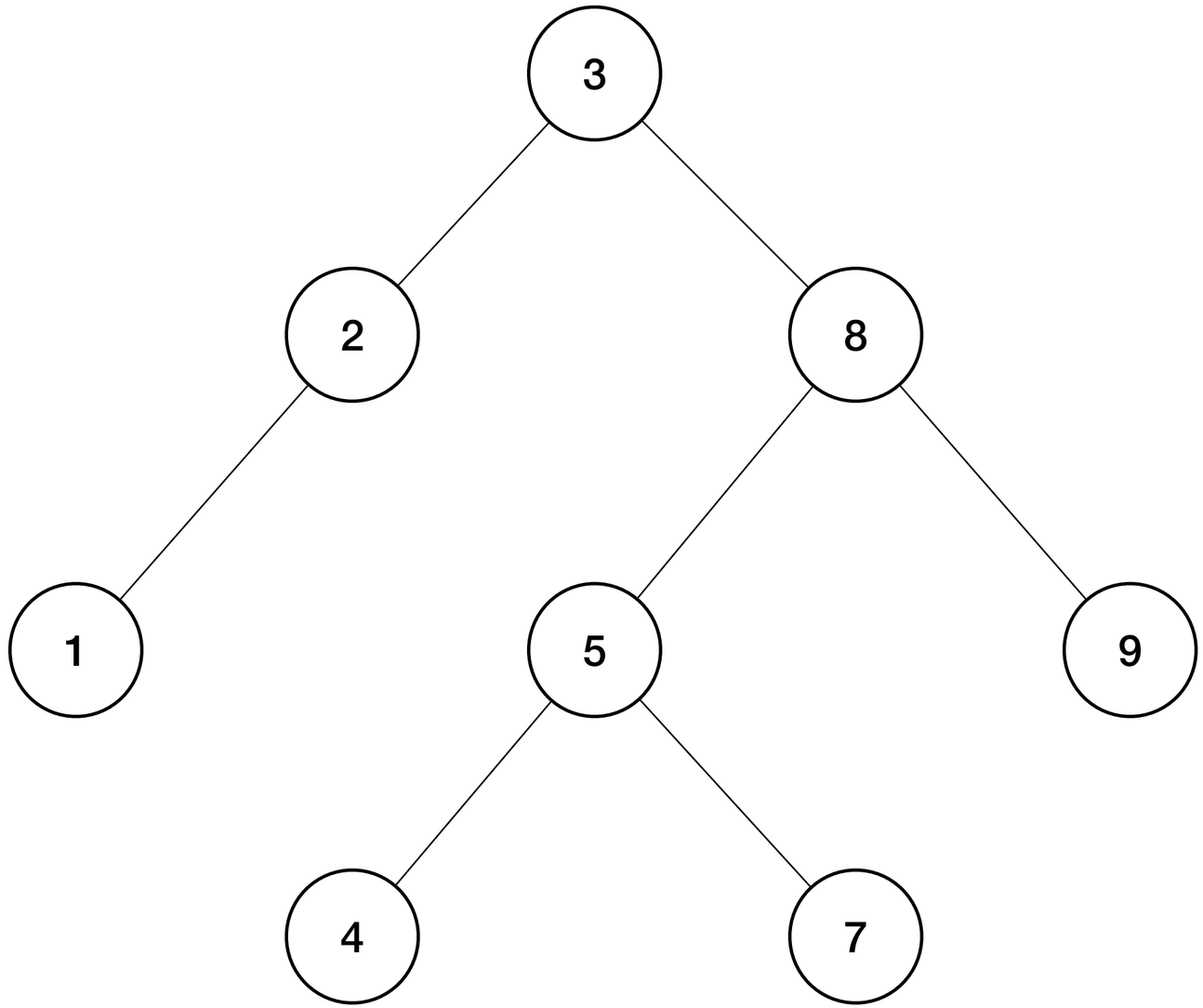

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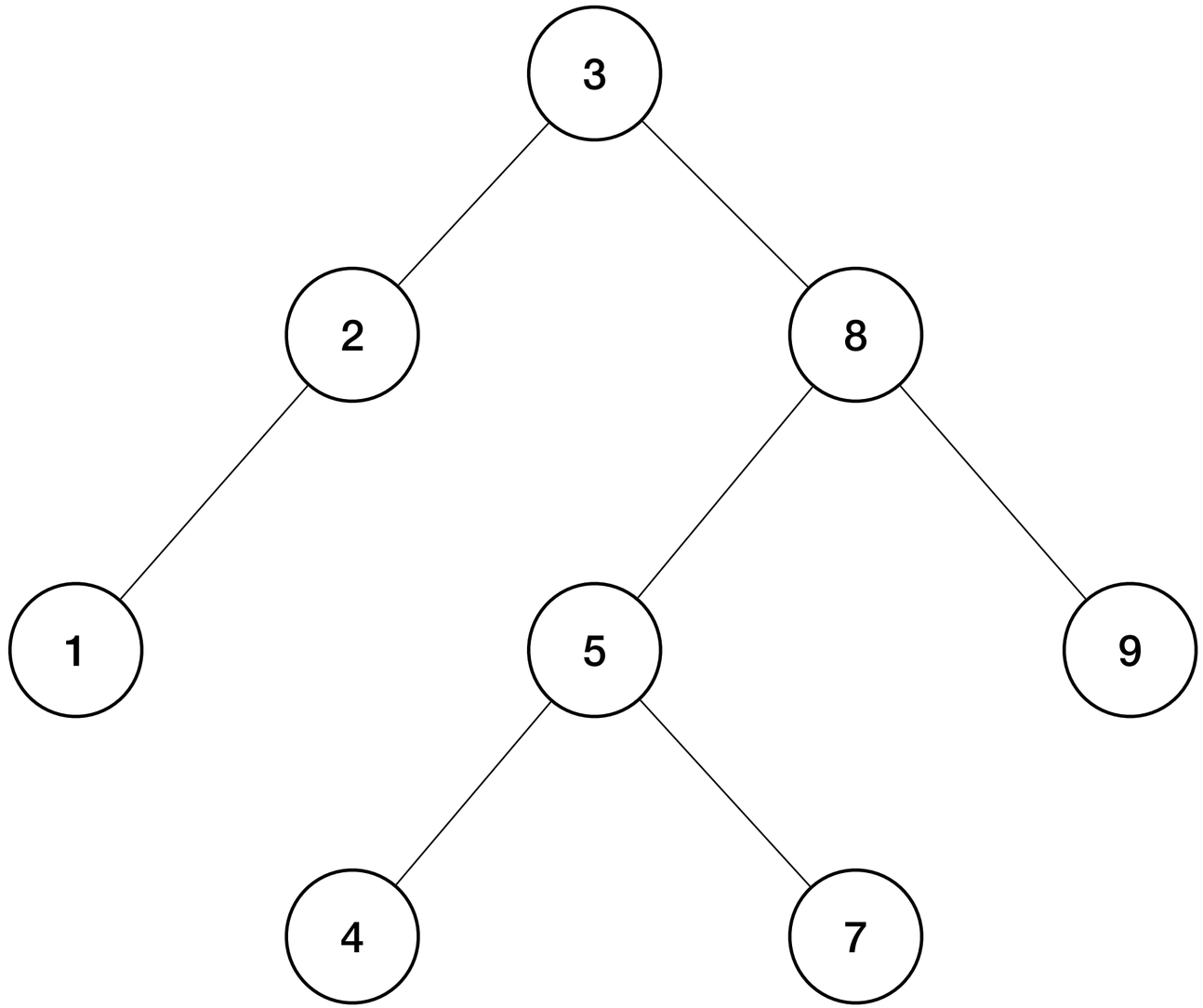

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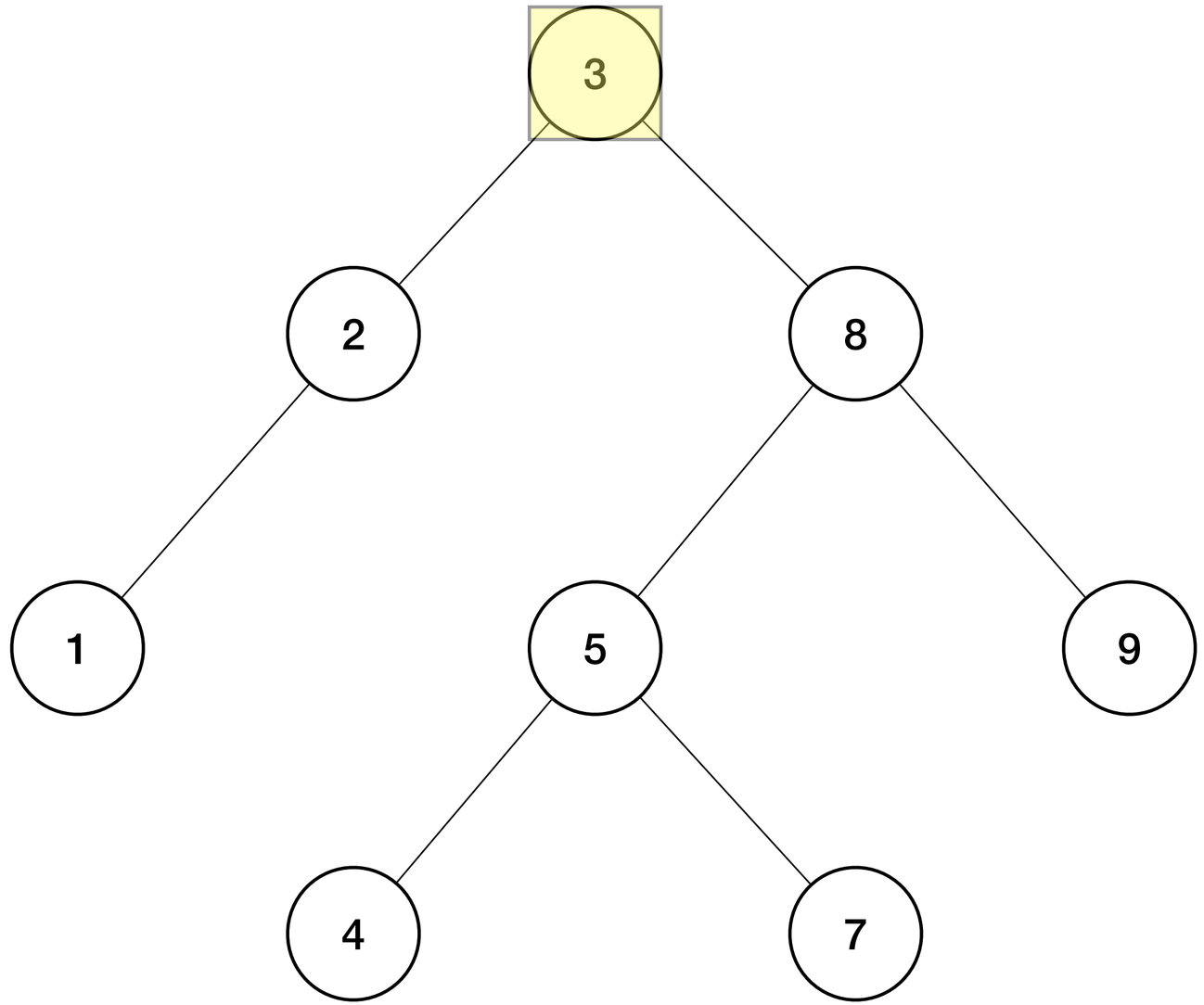

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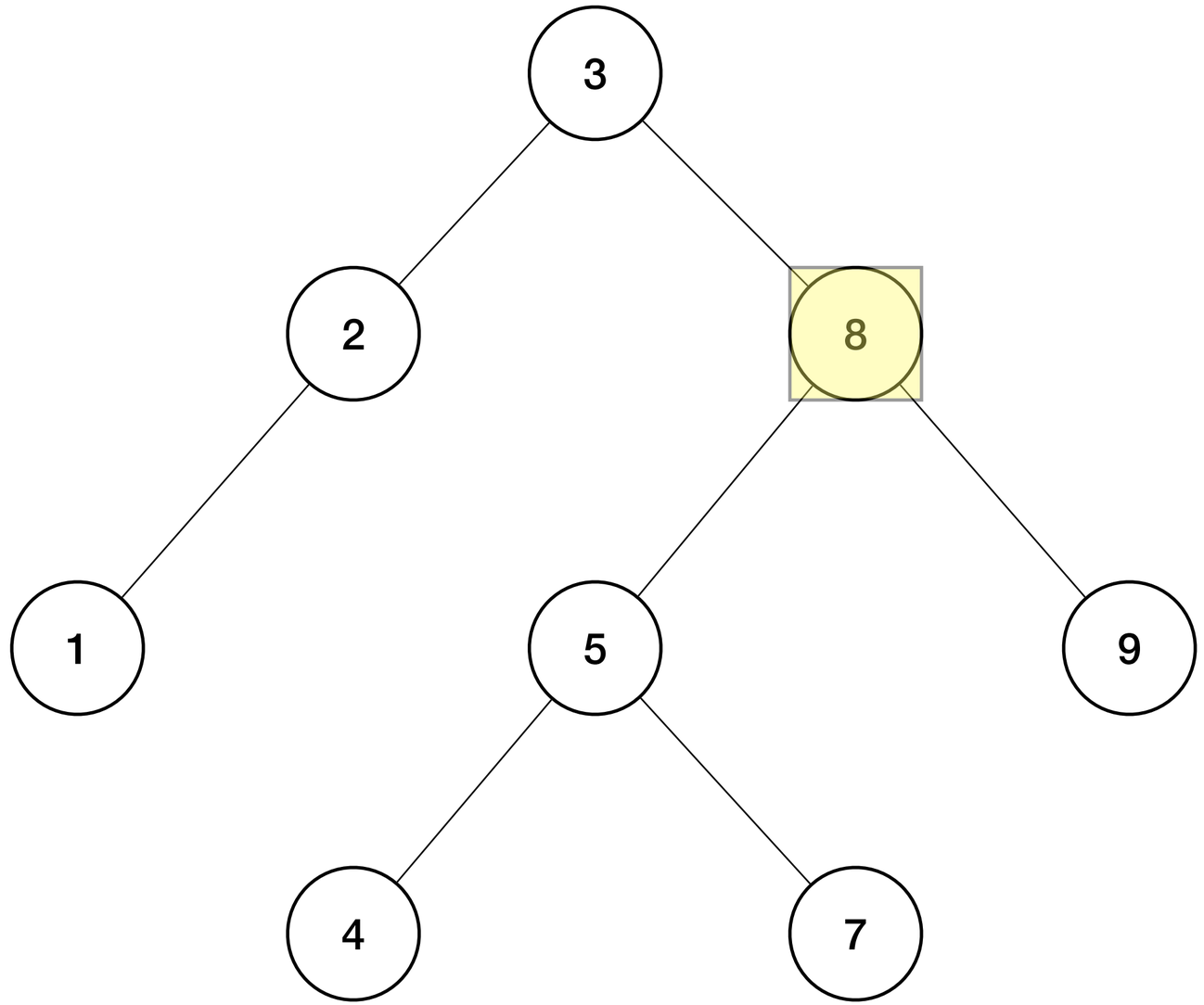

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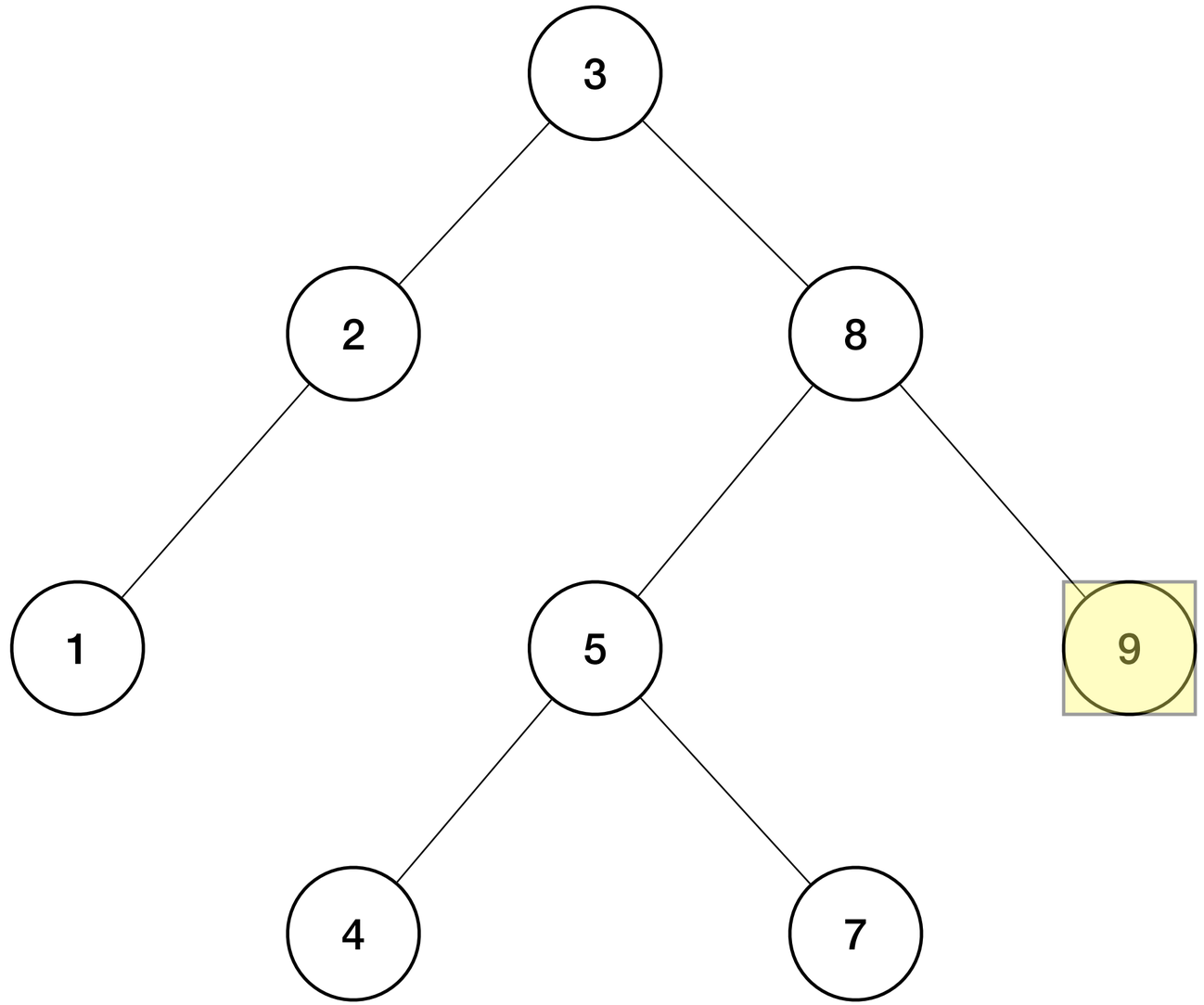

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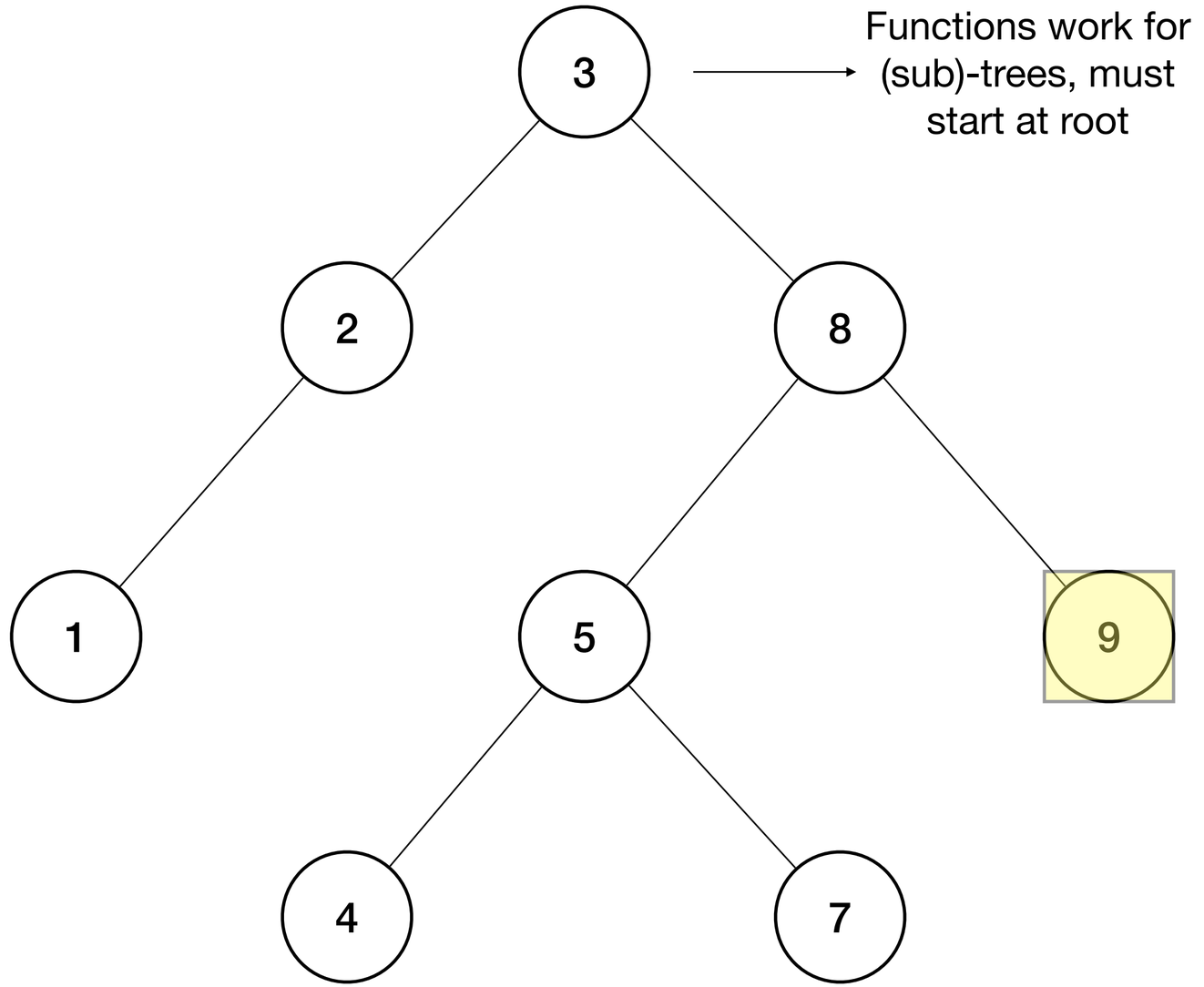

Searching in a BST

```
node * find_elem(node *cursor, int key){
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  else

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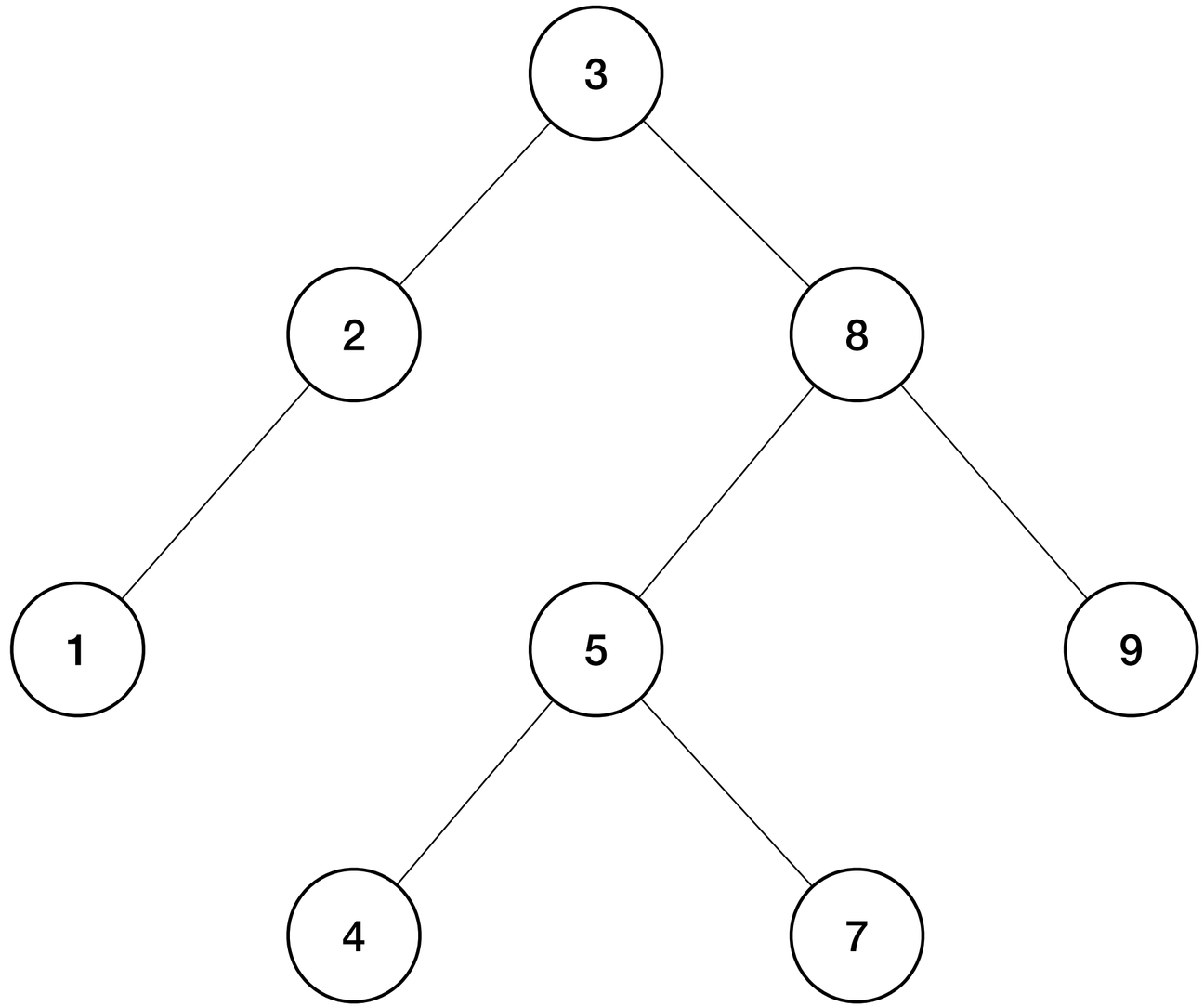

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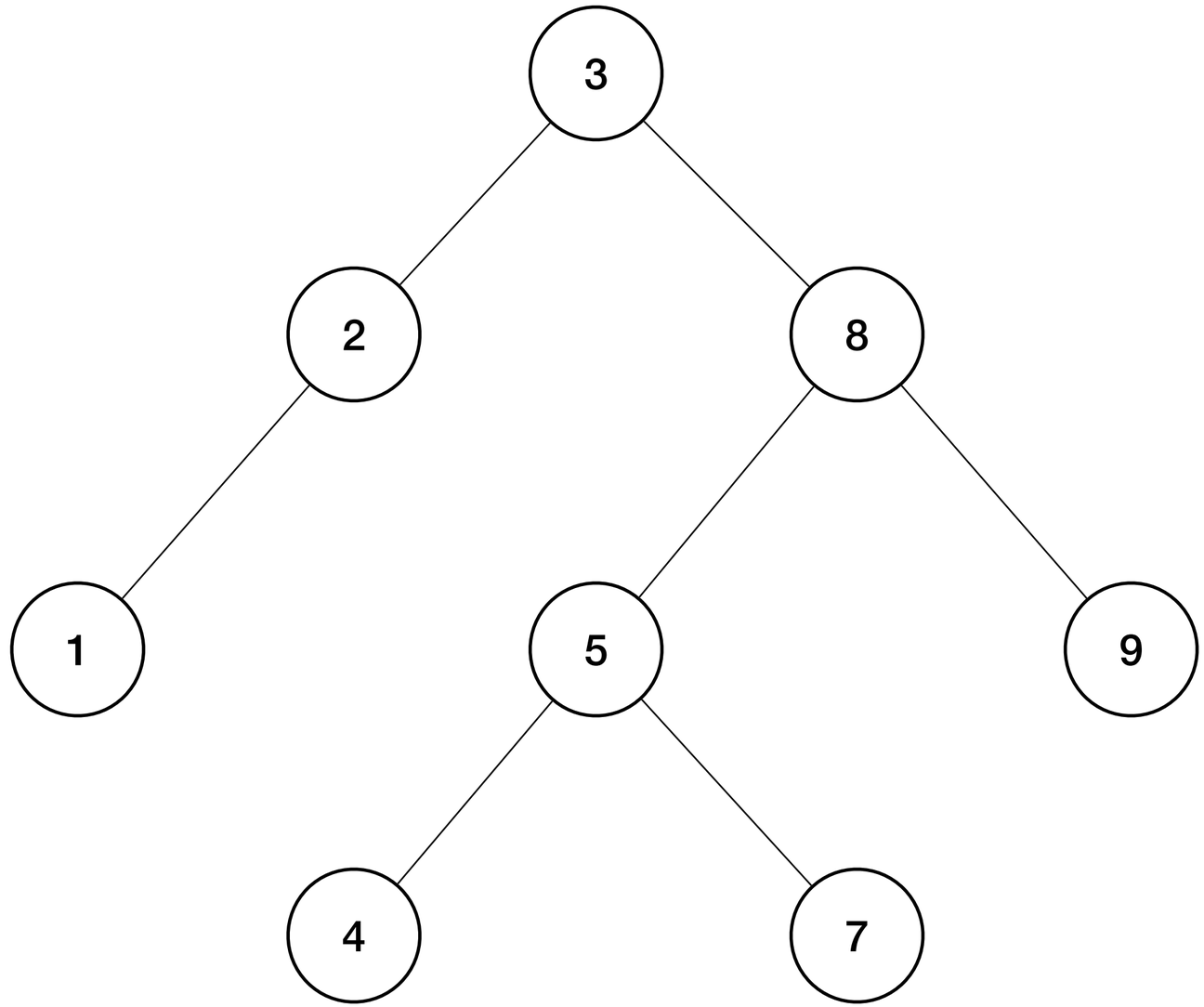

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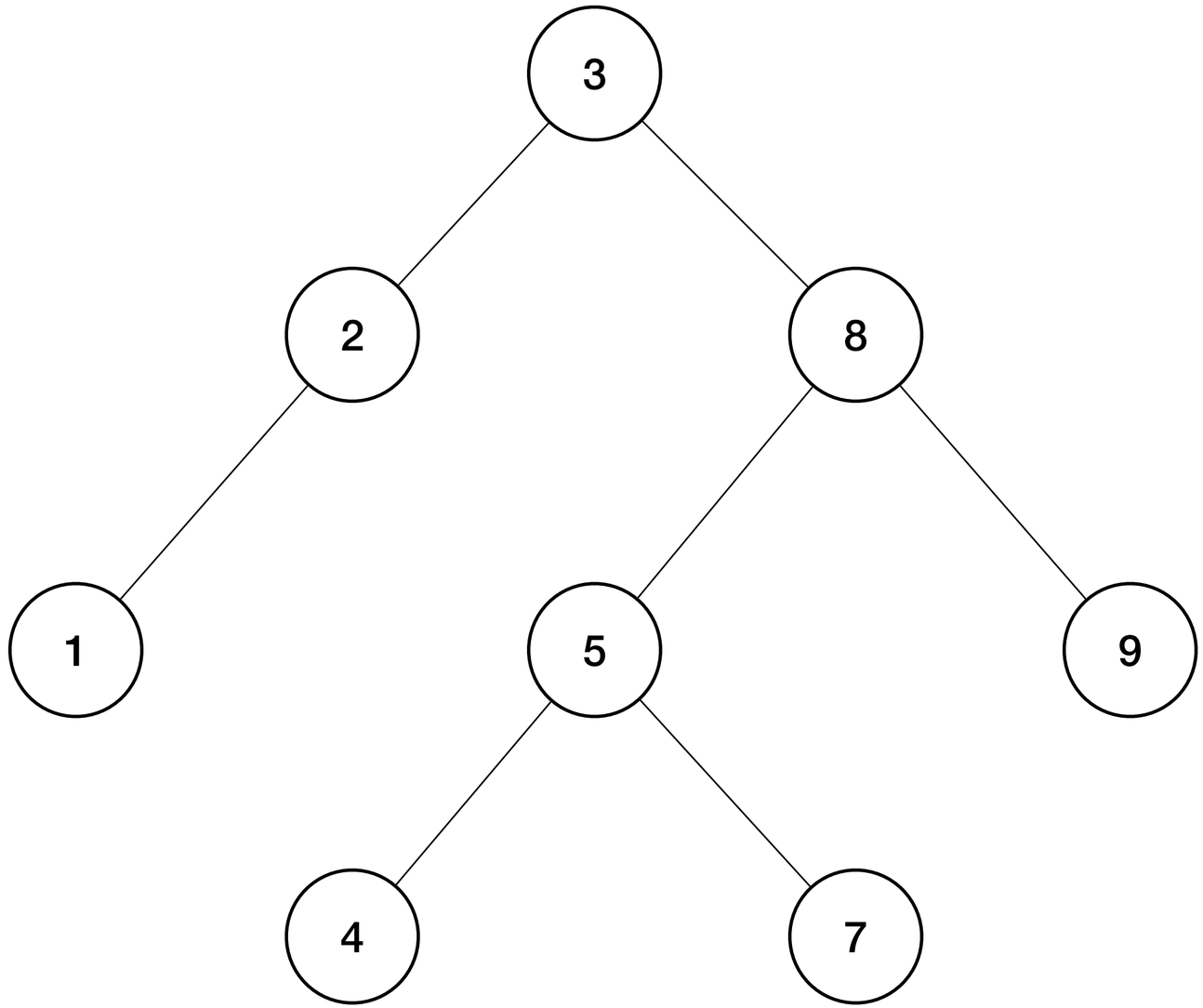

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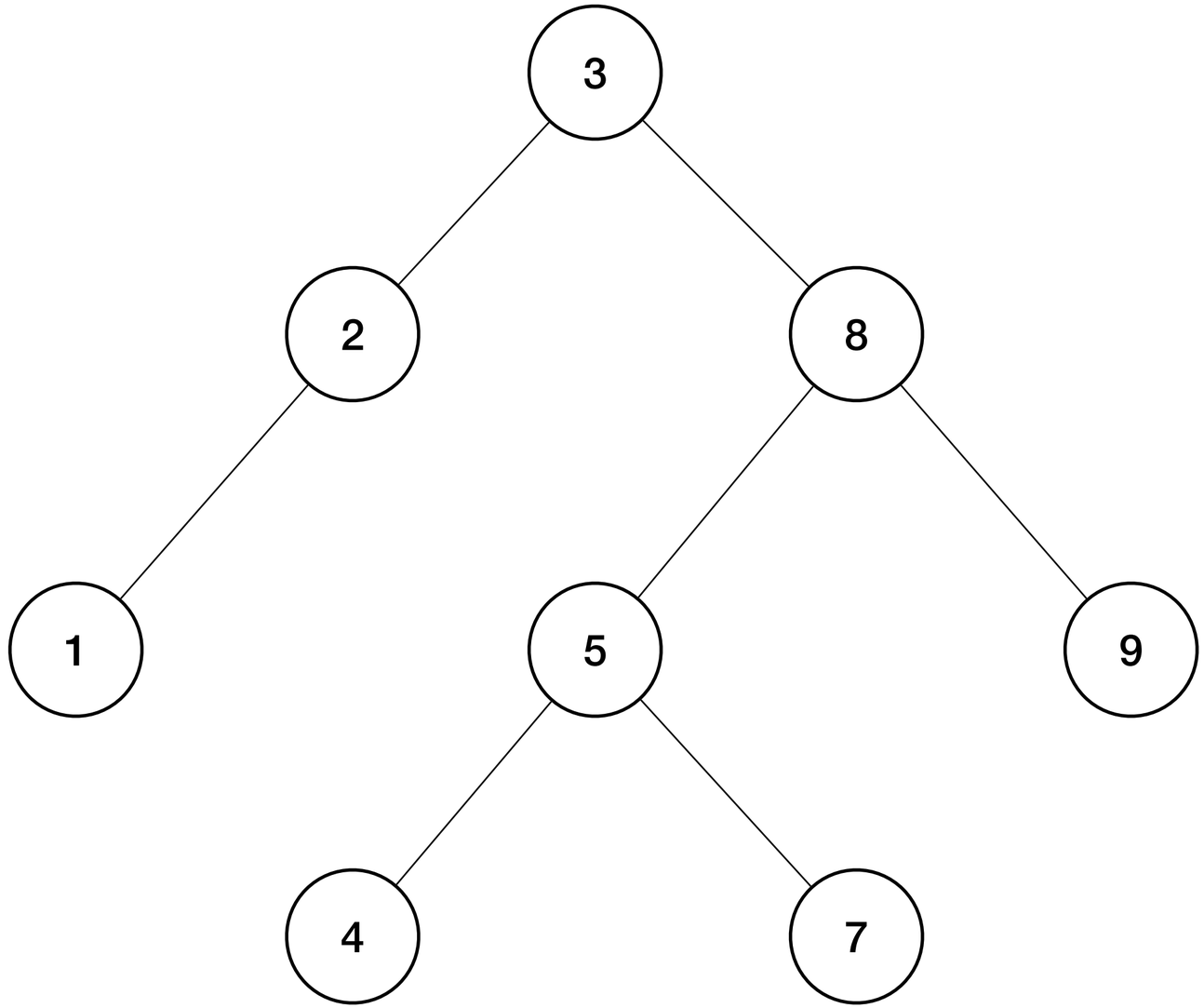

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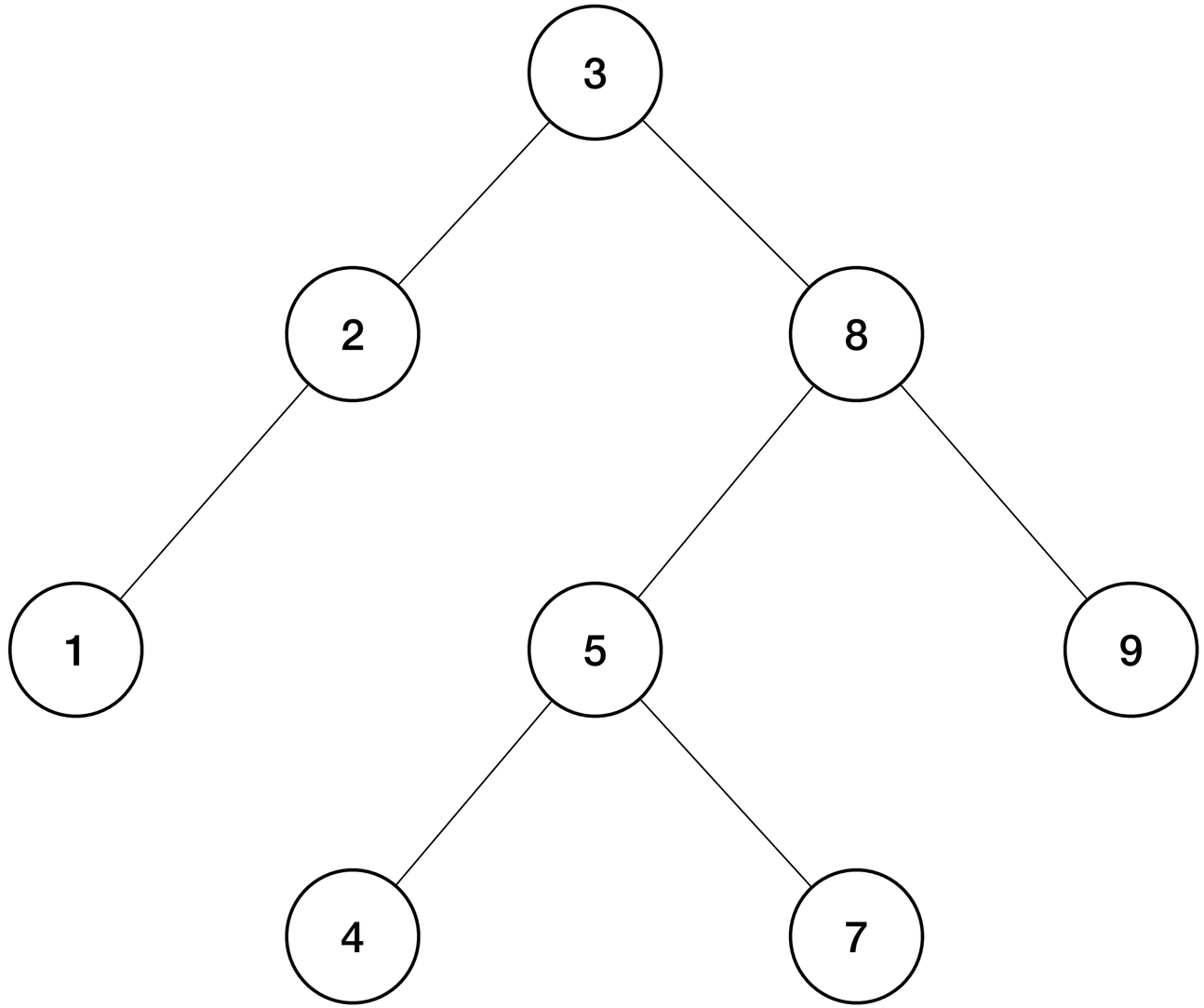

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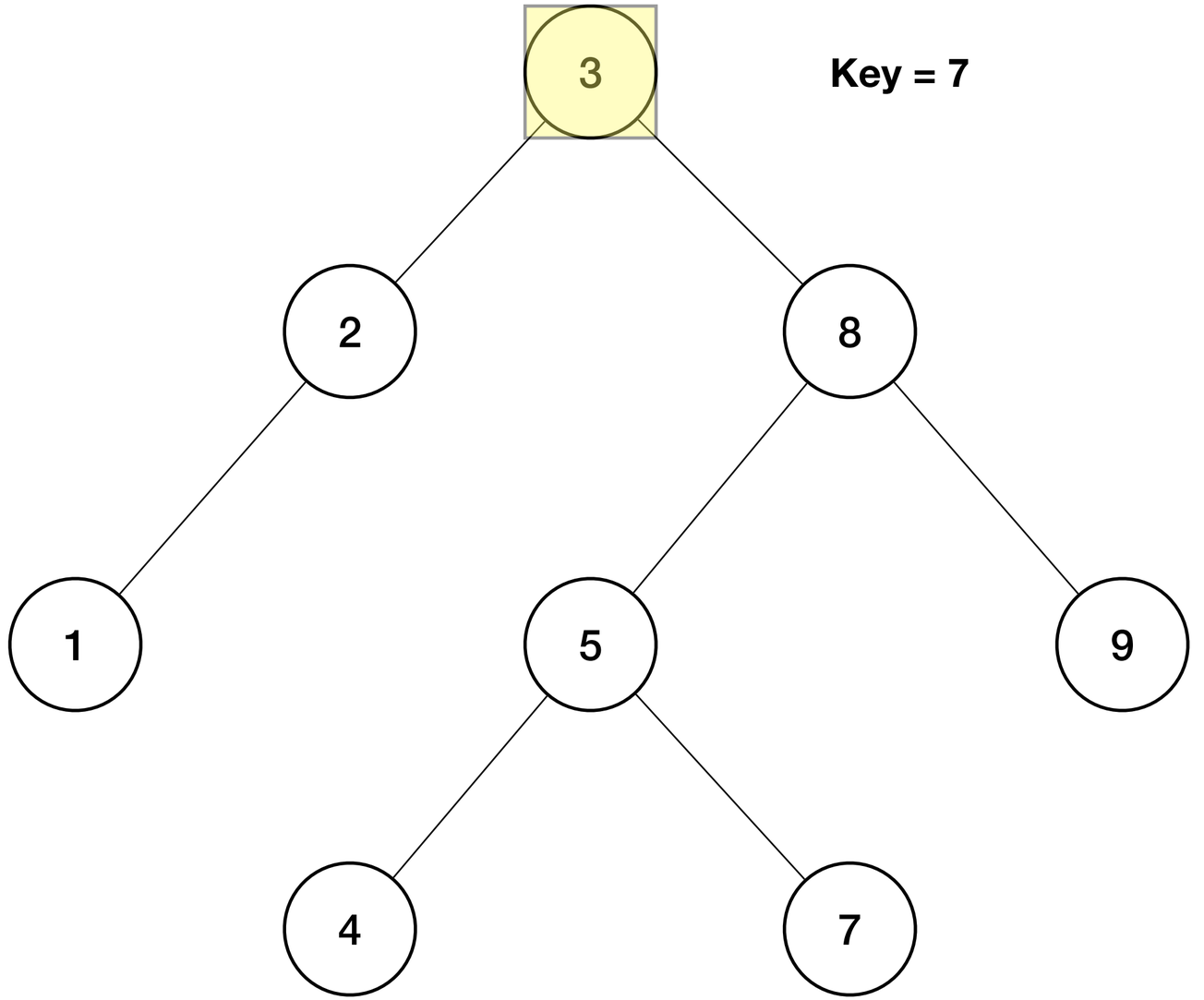

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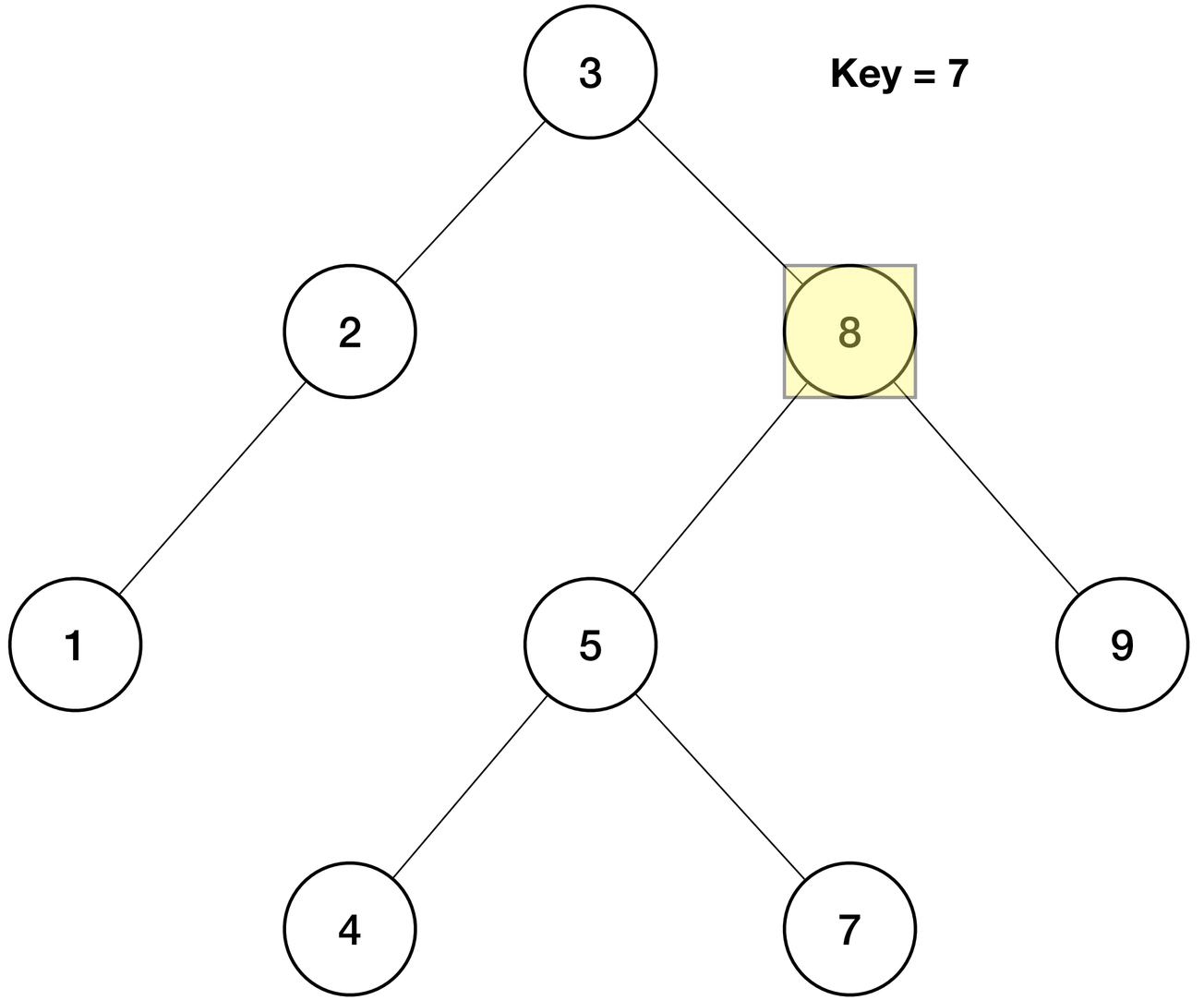

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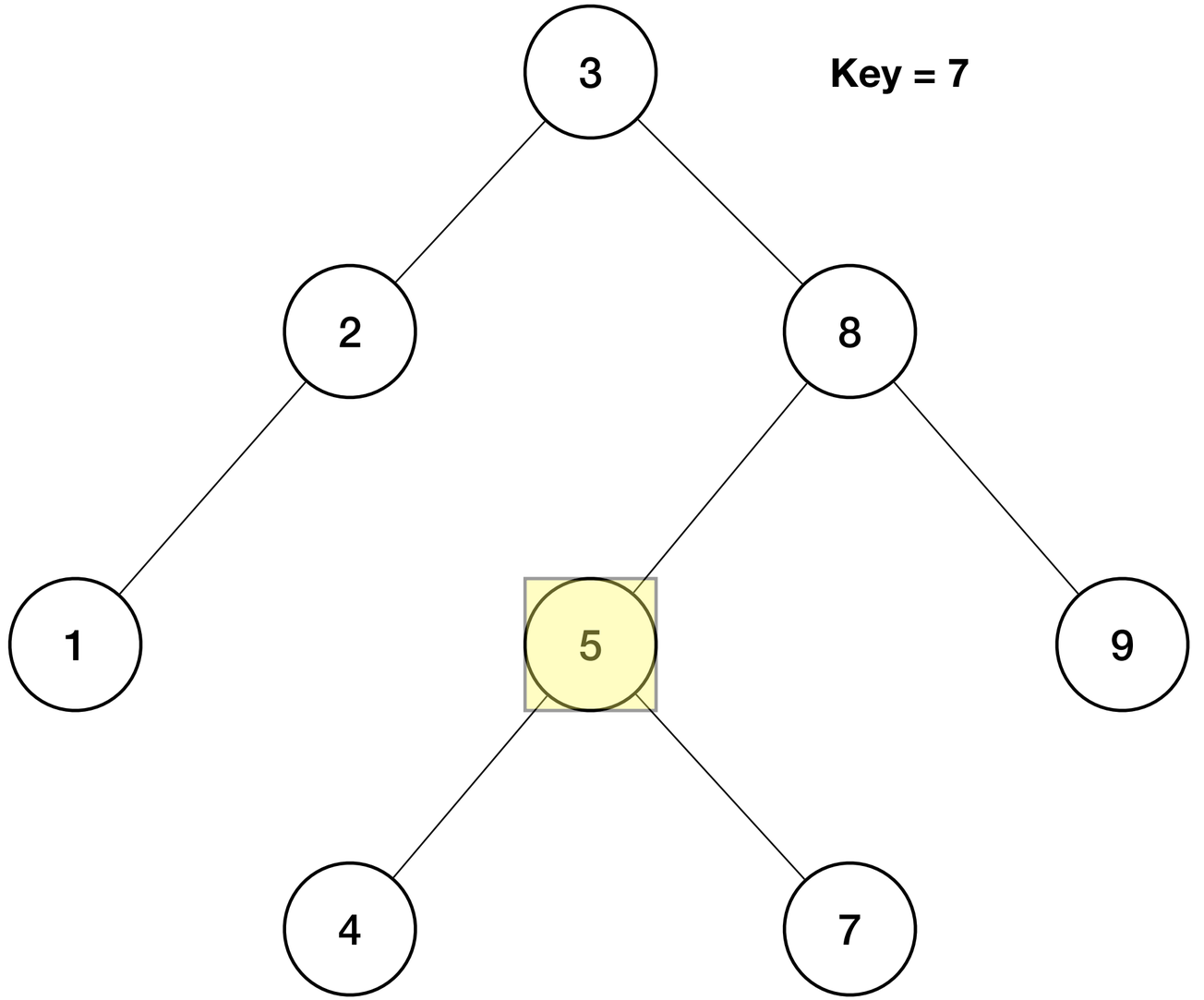

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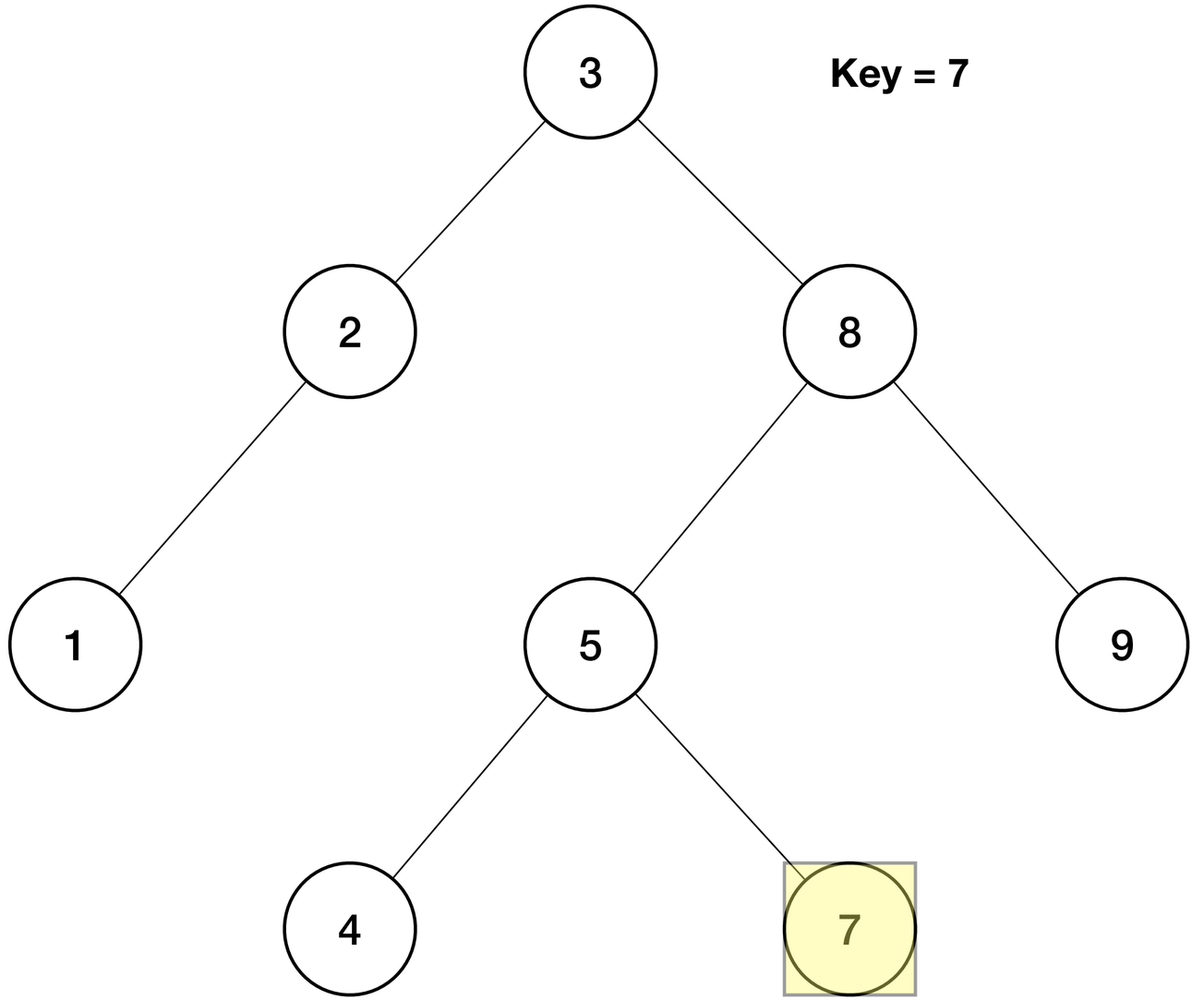
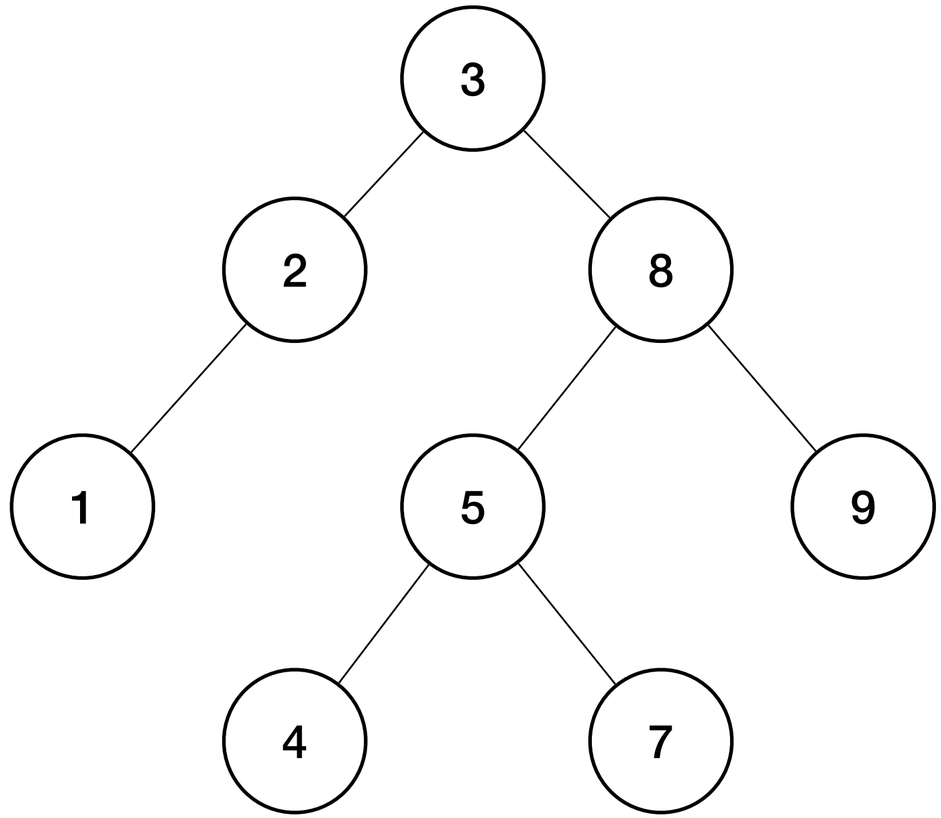
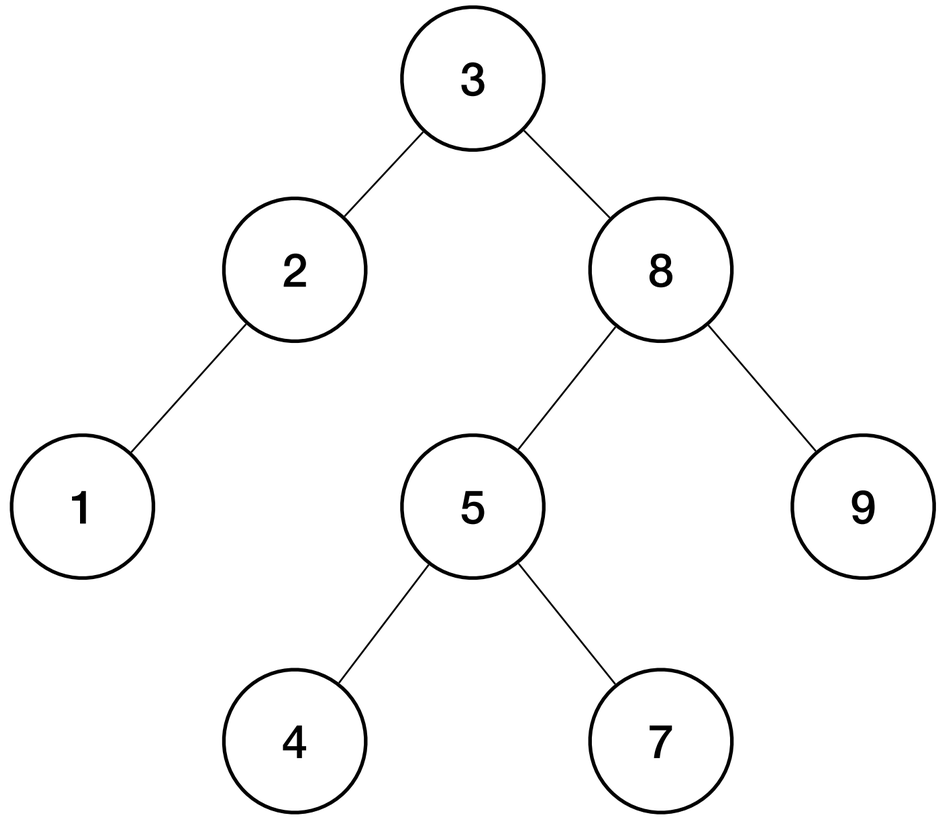


Insertion in a BST



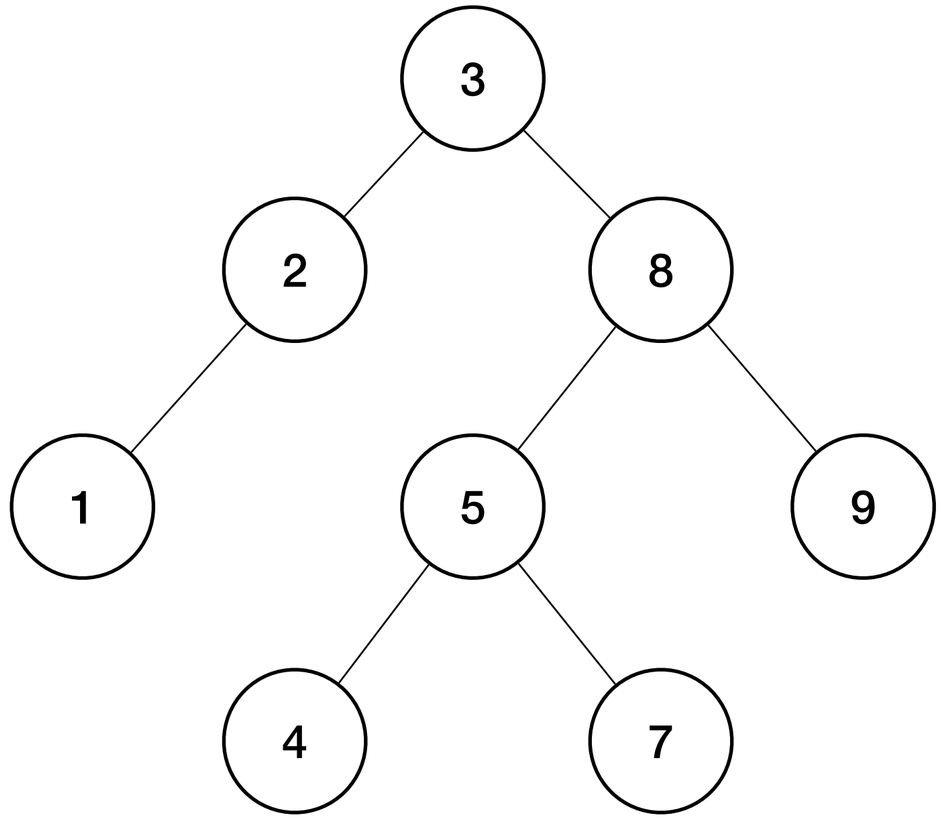
Insertion in a BST

- Insertions need to preserve the BST property



Insertion in a BST

- Insertions need to preserve the BST property
- Add new nodes only as leaf nodes



Insertion in a BST

- Insertions need to preserve the BST property

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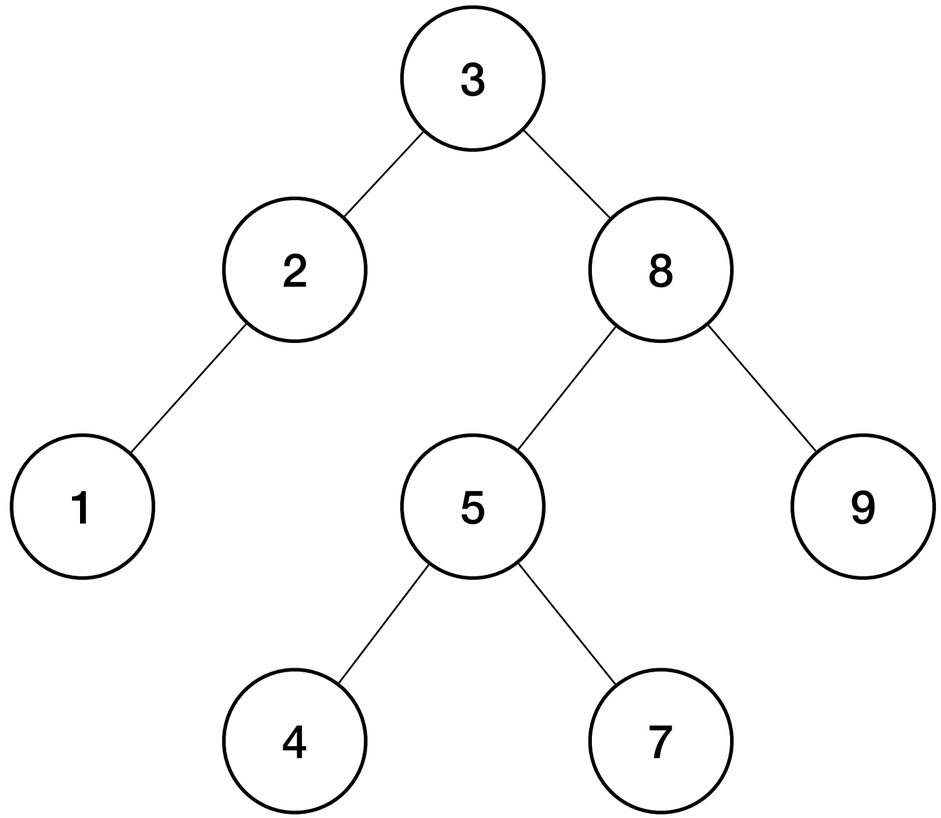
- Consider inserting 6 in the BST on the right …



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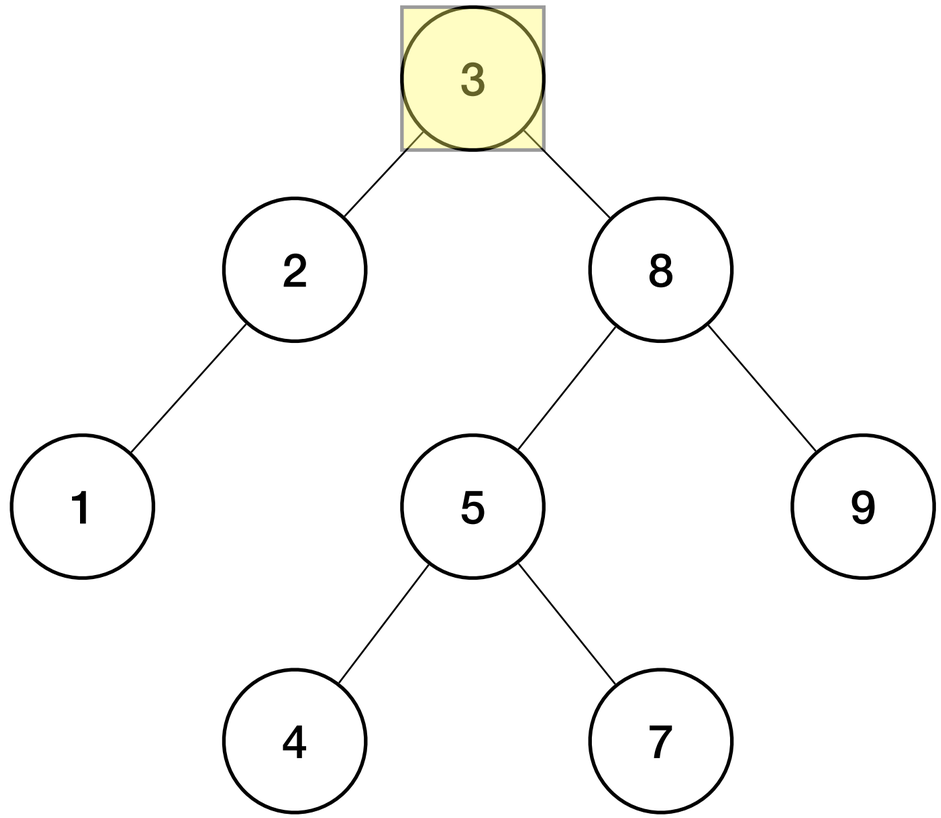

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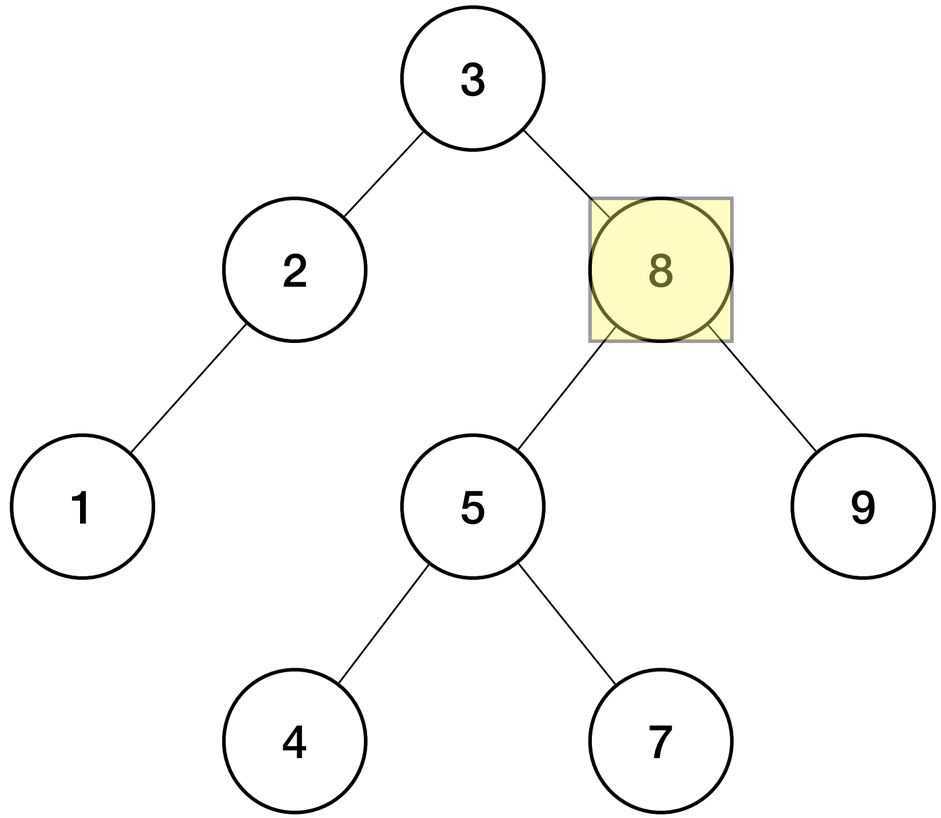

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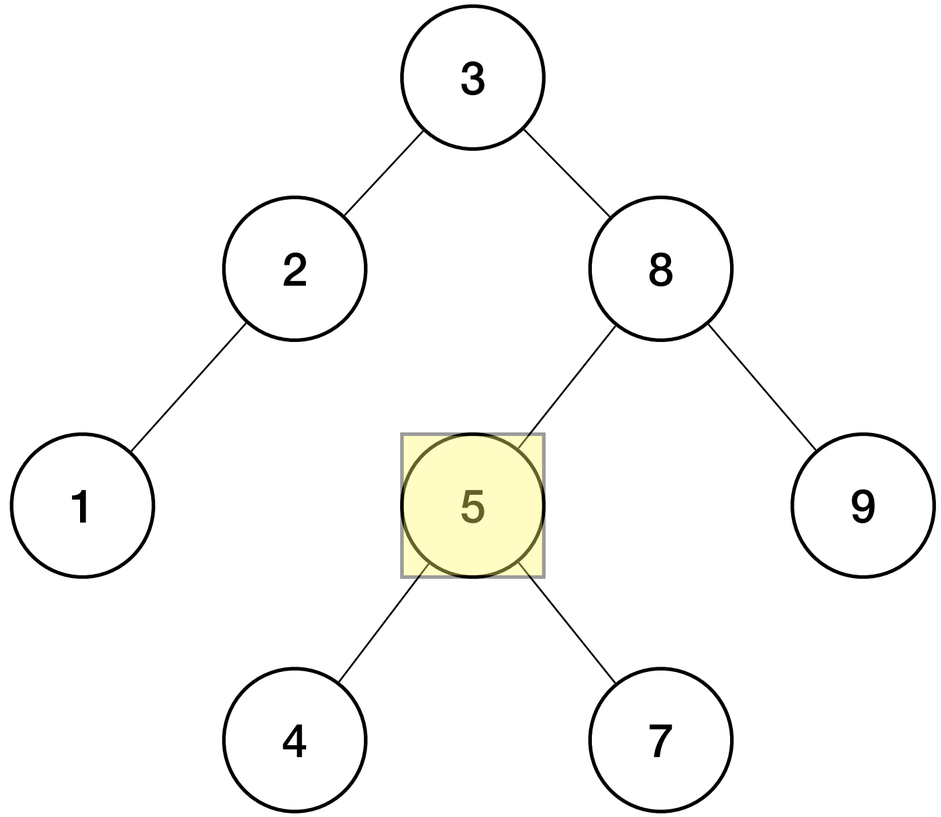

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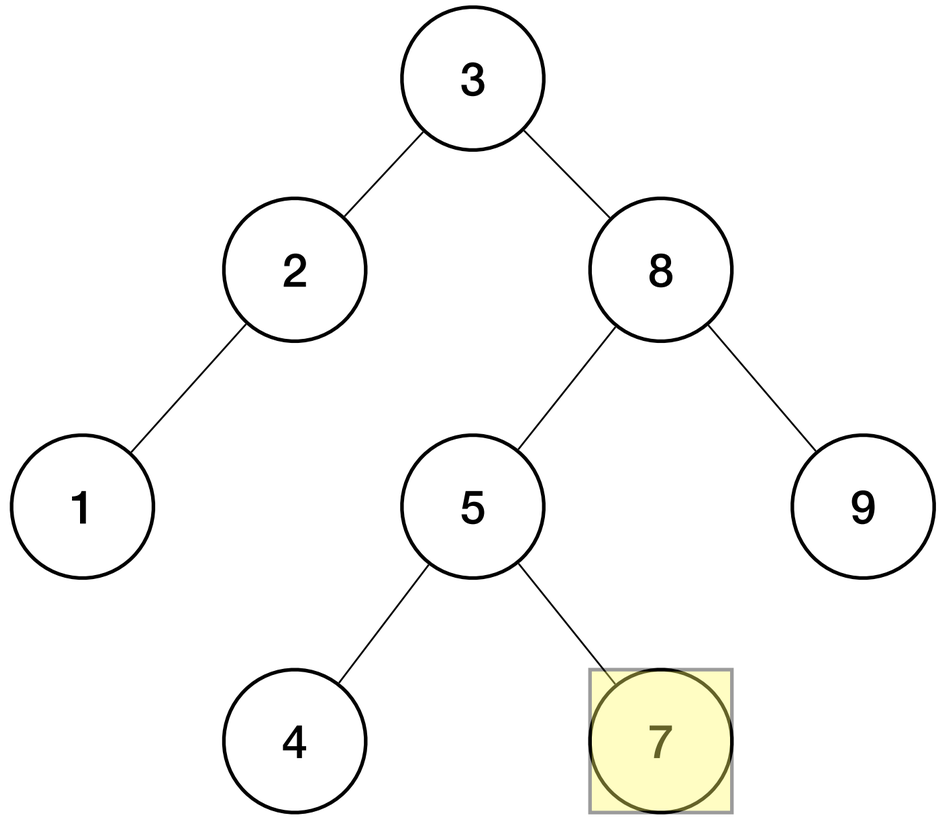

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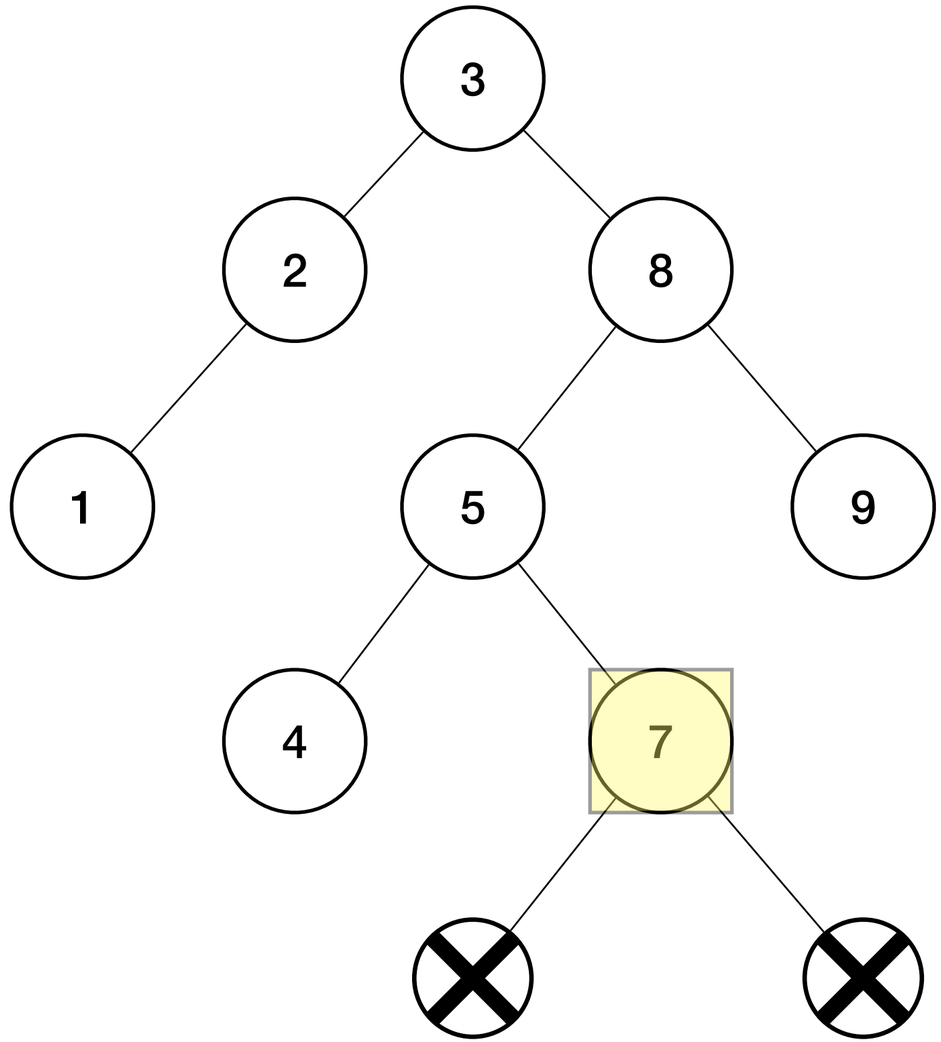

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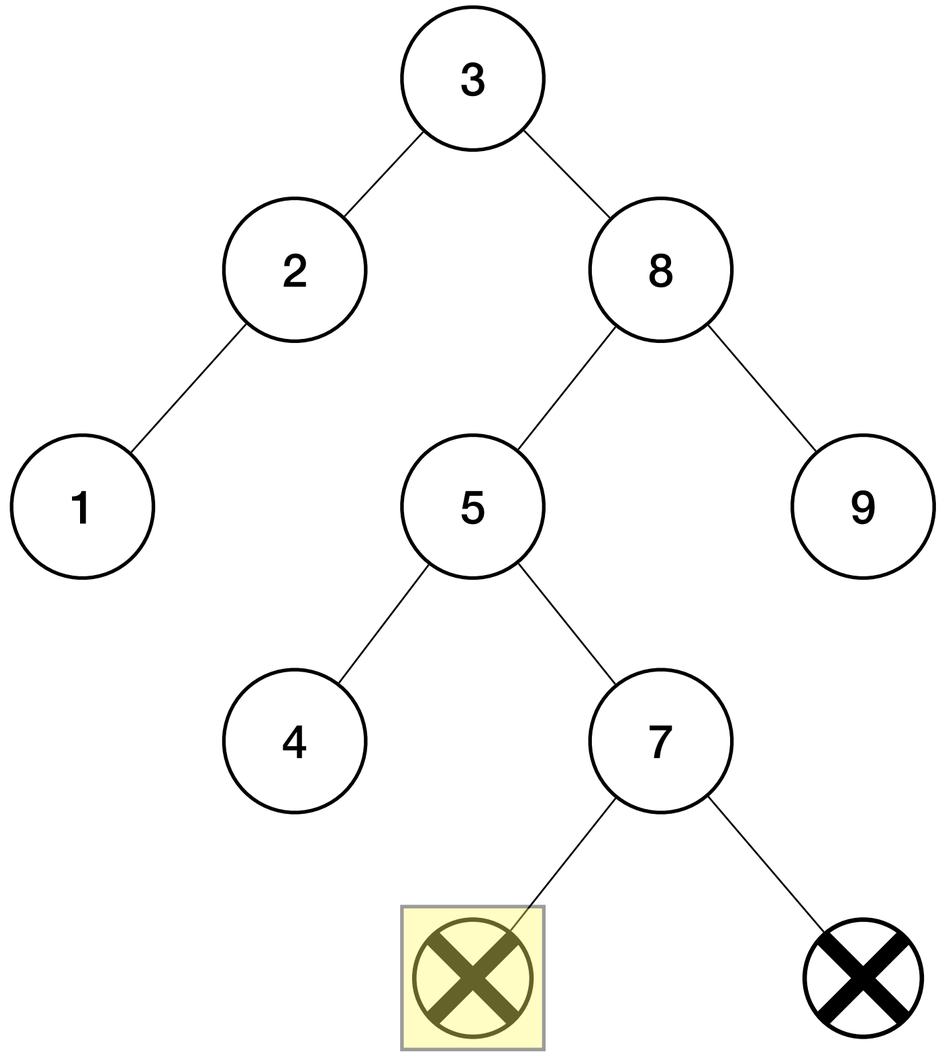

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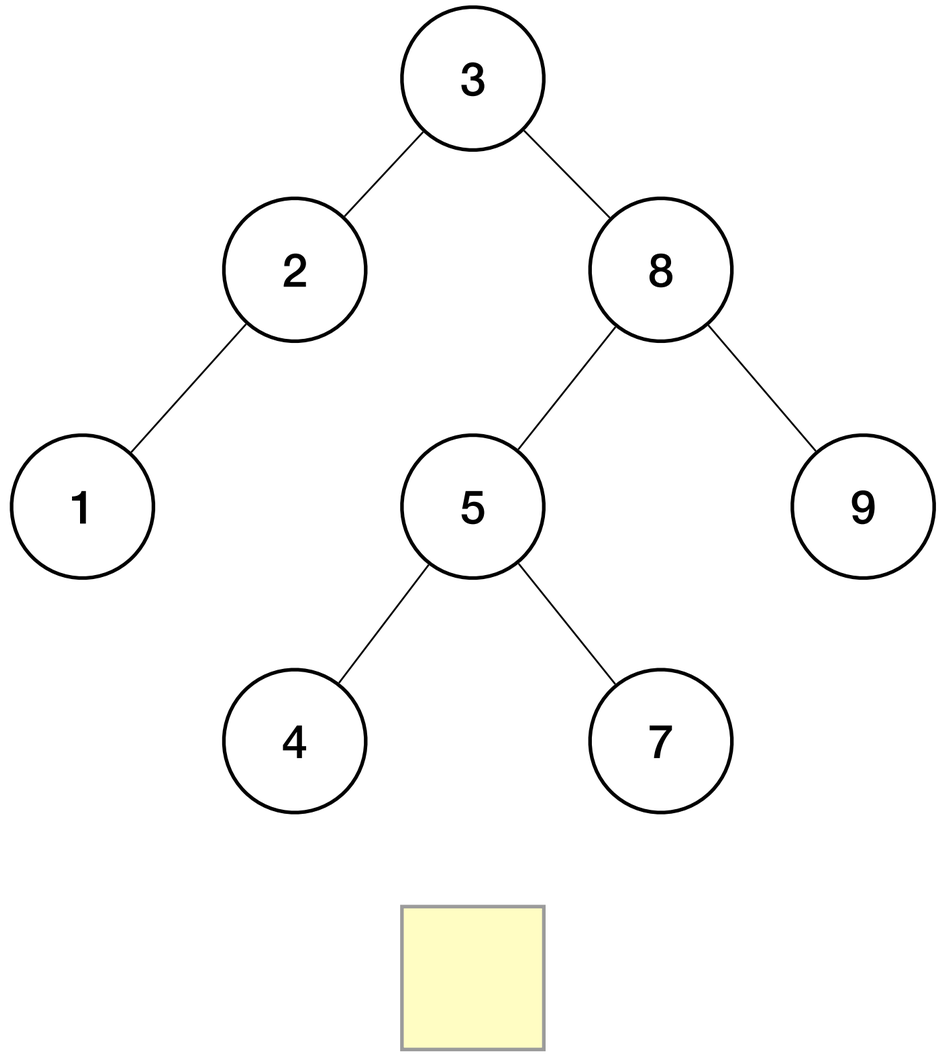

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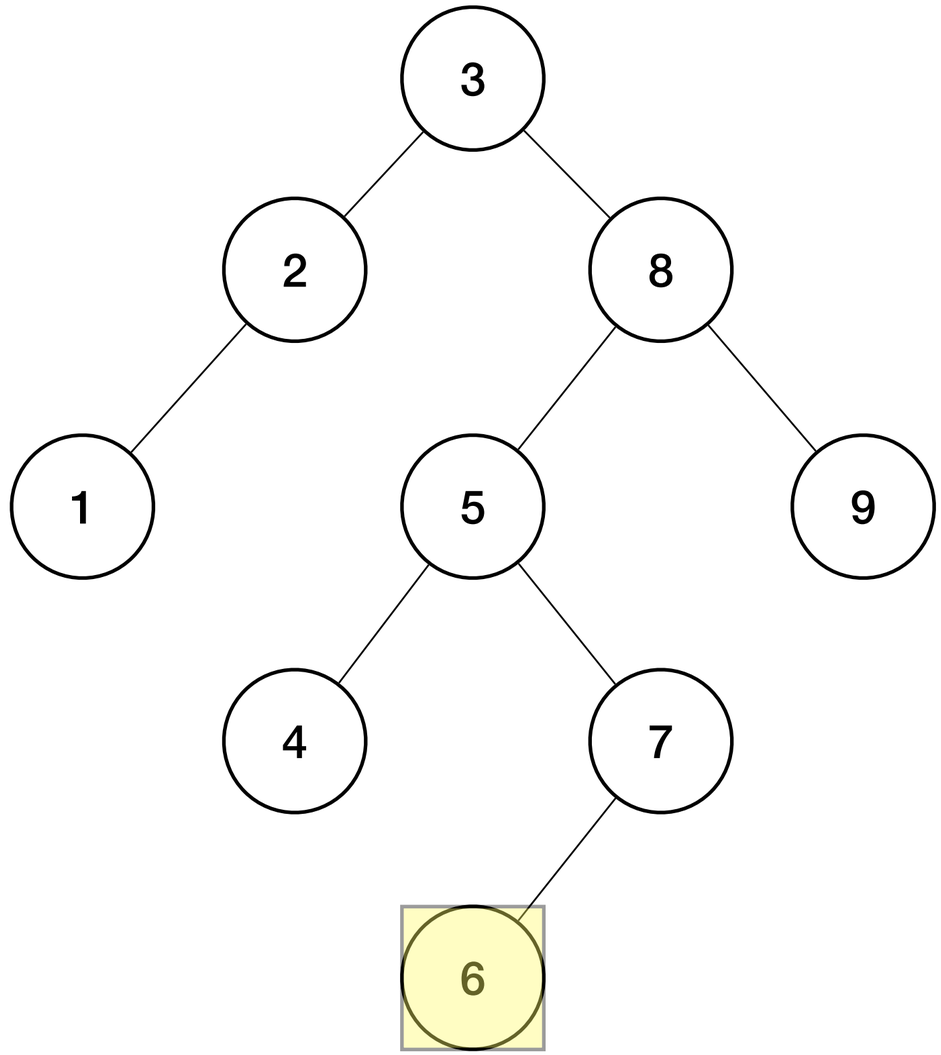
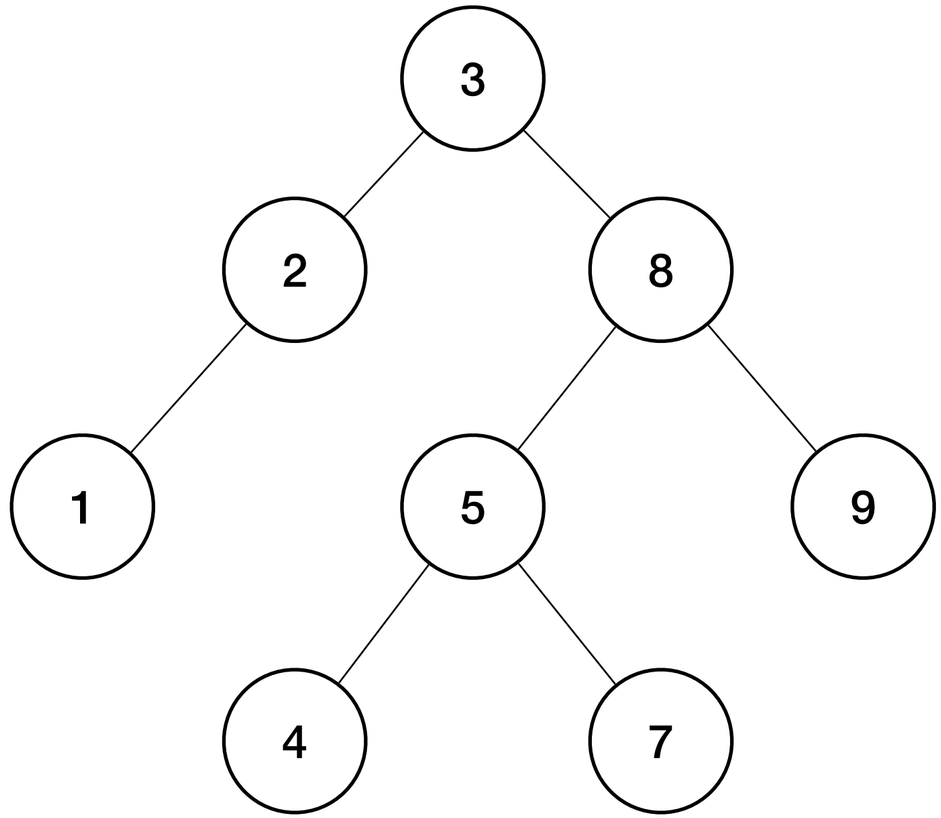


Insertion in a BST

```
node * insert(node *cursor, int data){
if (cursor==NULL)
  return newNode(data);
else{
    if (data < cursor->data)
      cursor->left =
    else
      cursor->right =
    return cursor;
  }
}
```



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    else
      cursor->right =
    return cursor;
  }
}
```

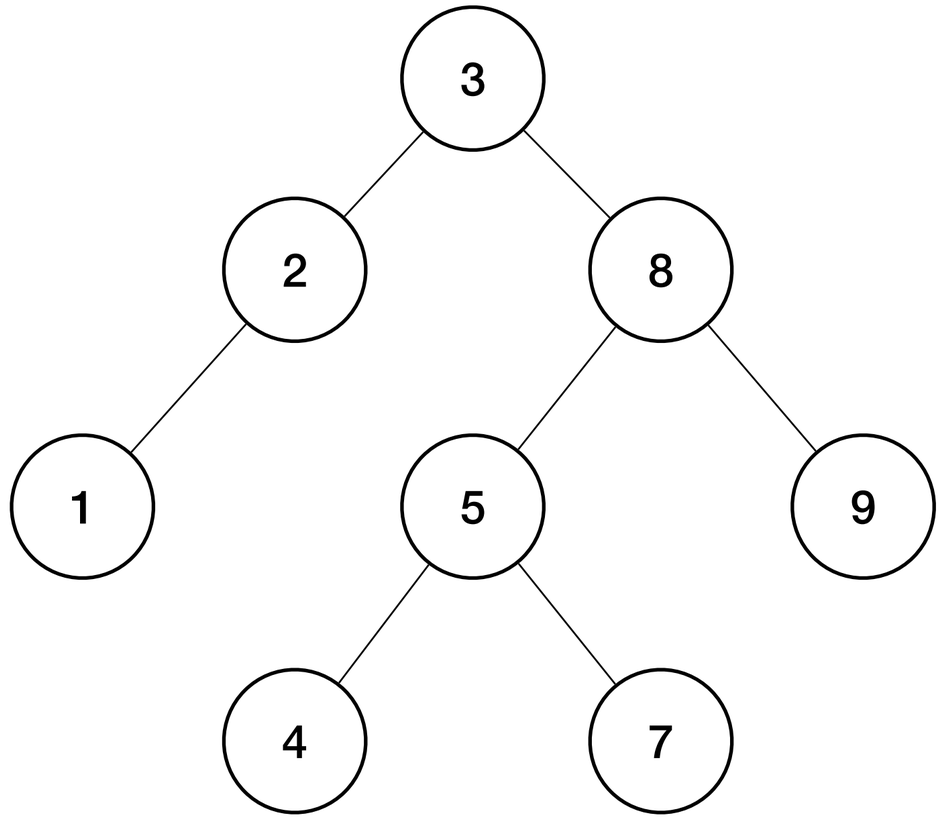

Insertion in a BST

```
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  return newNode(data);
else{
    if (data < cursor->data)
      cursor->left = insert(cursor->left, data);
    else
      cursor->right = insert(cursor->right, data);
    return cursor;
  }
}
```
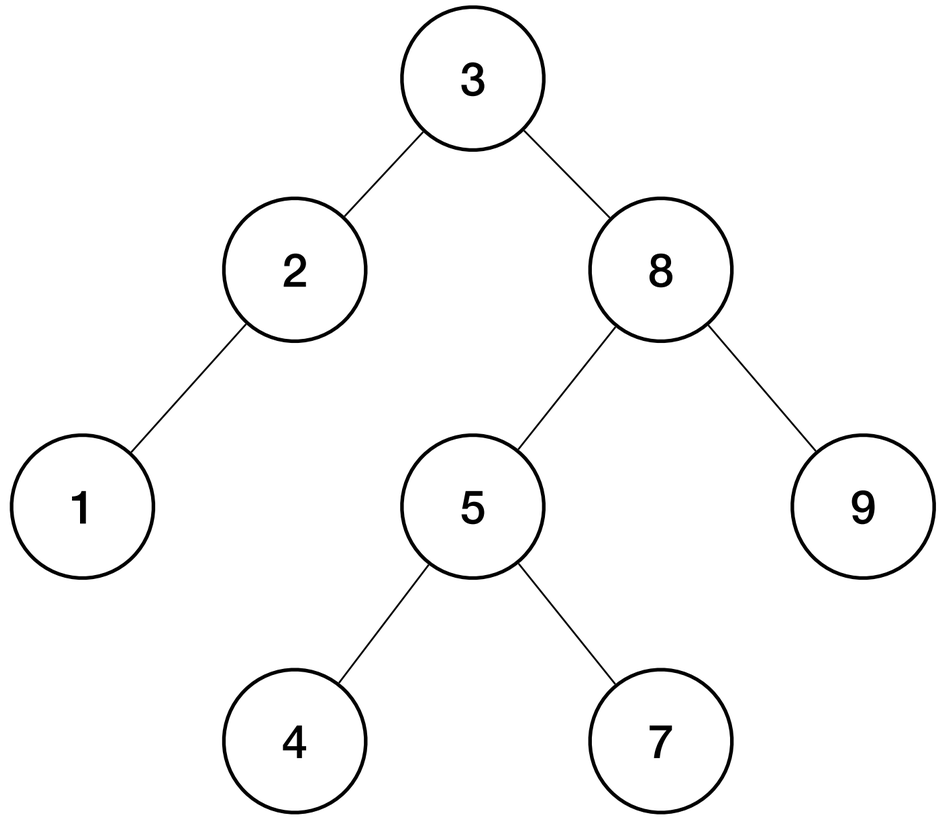
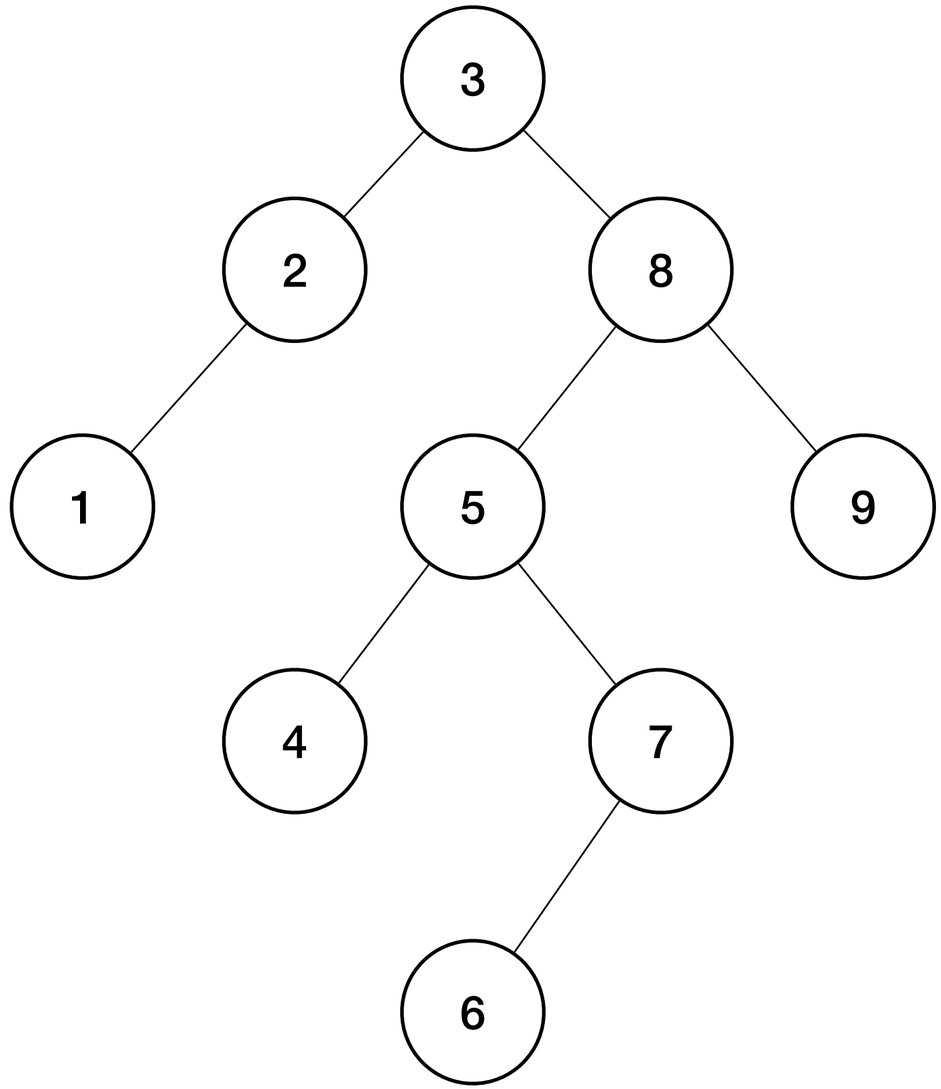
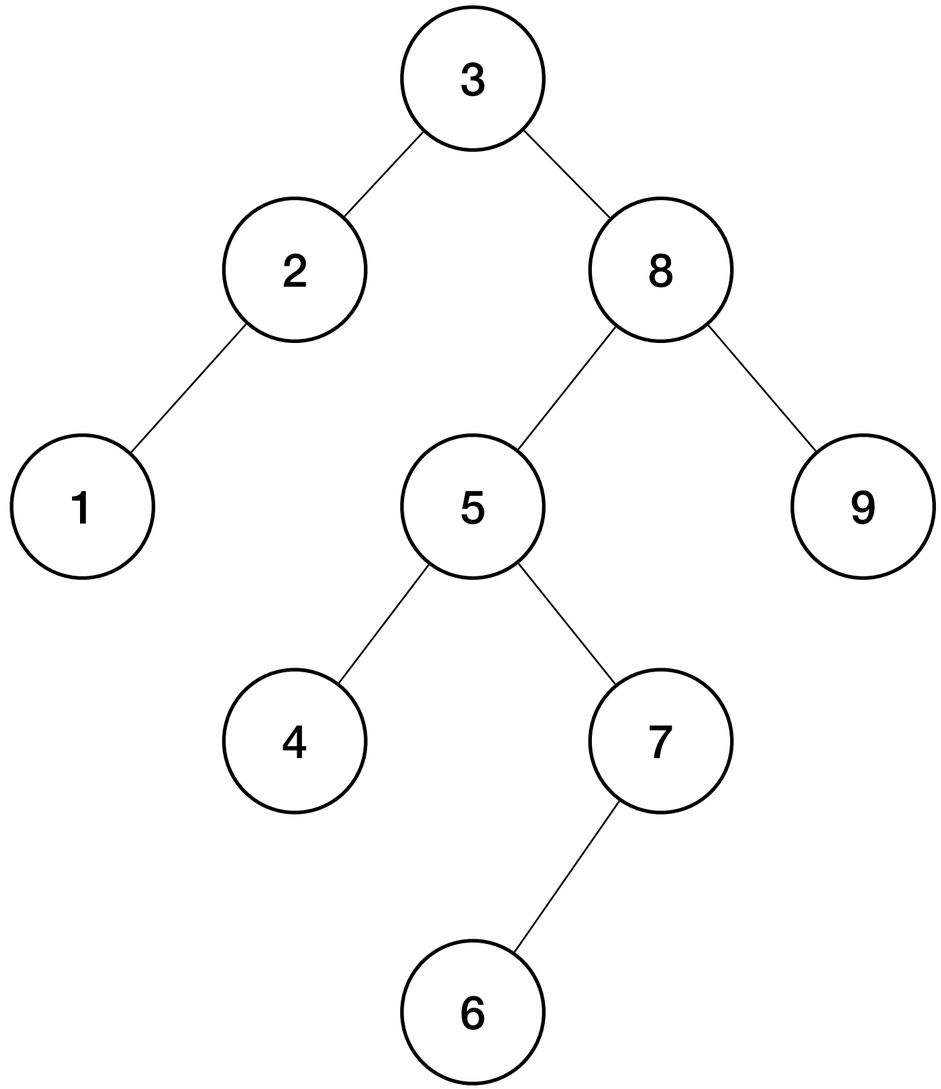



Finding height of a tree



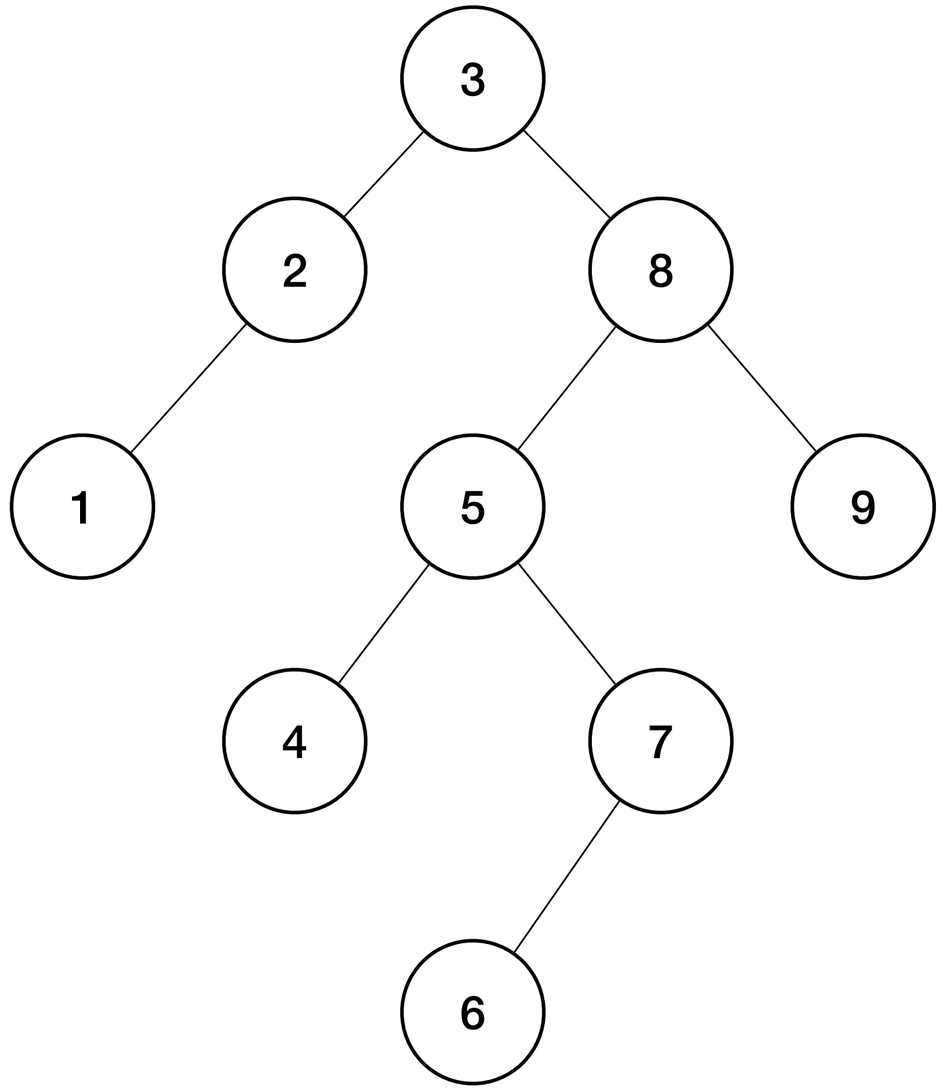
Finding height of a tree

- Height is length of *longest* path from root to leaf(s)



Finding height of a tree

- Height is length of *longest* path from root to leaf(s)
- Recursively calculate: 1 + height of L/R subtree(s)

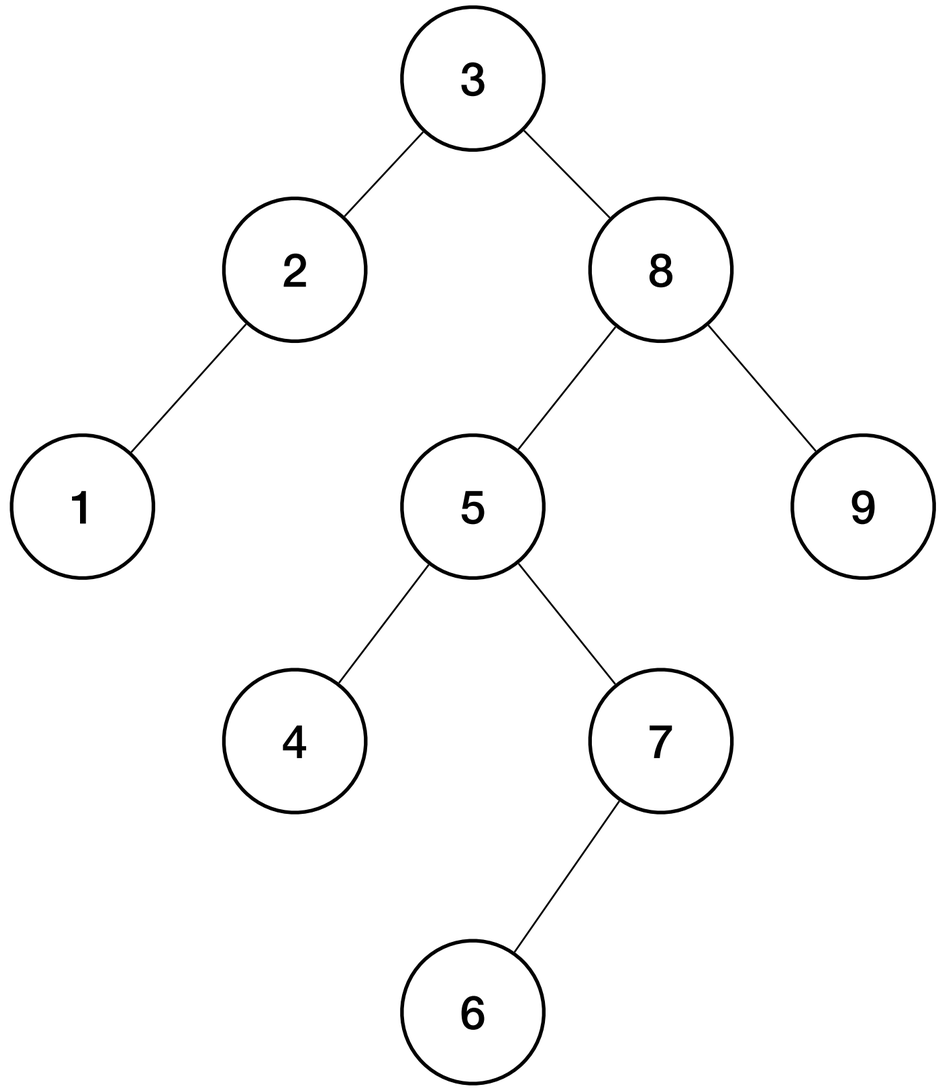


Finding height of a tree

- Height is length of *longest* path from root to leaf(s)

- Recursively calculate: 1 + height of L/R subtree(s)

- Take maximum at each step



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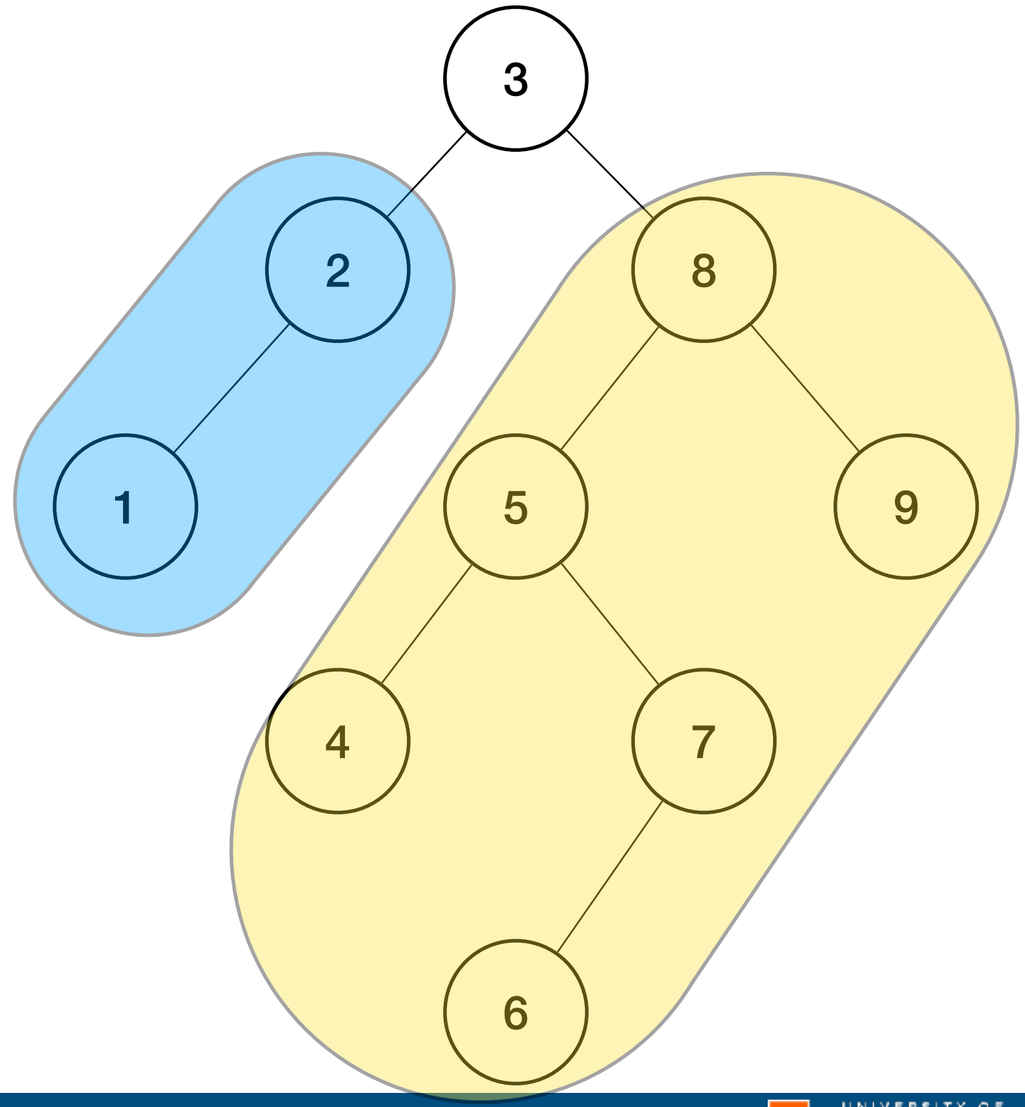

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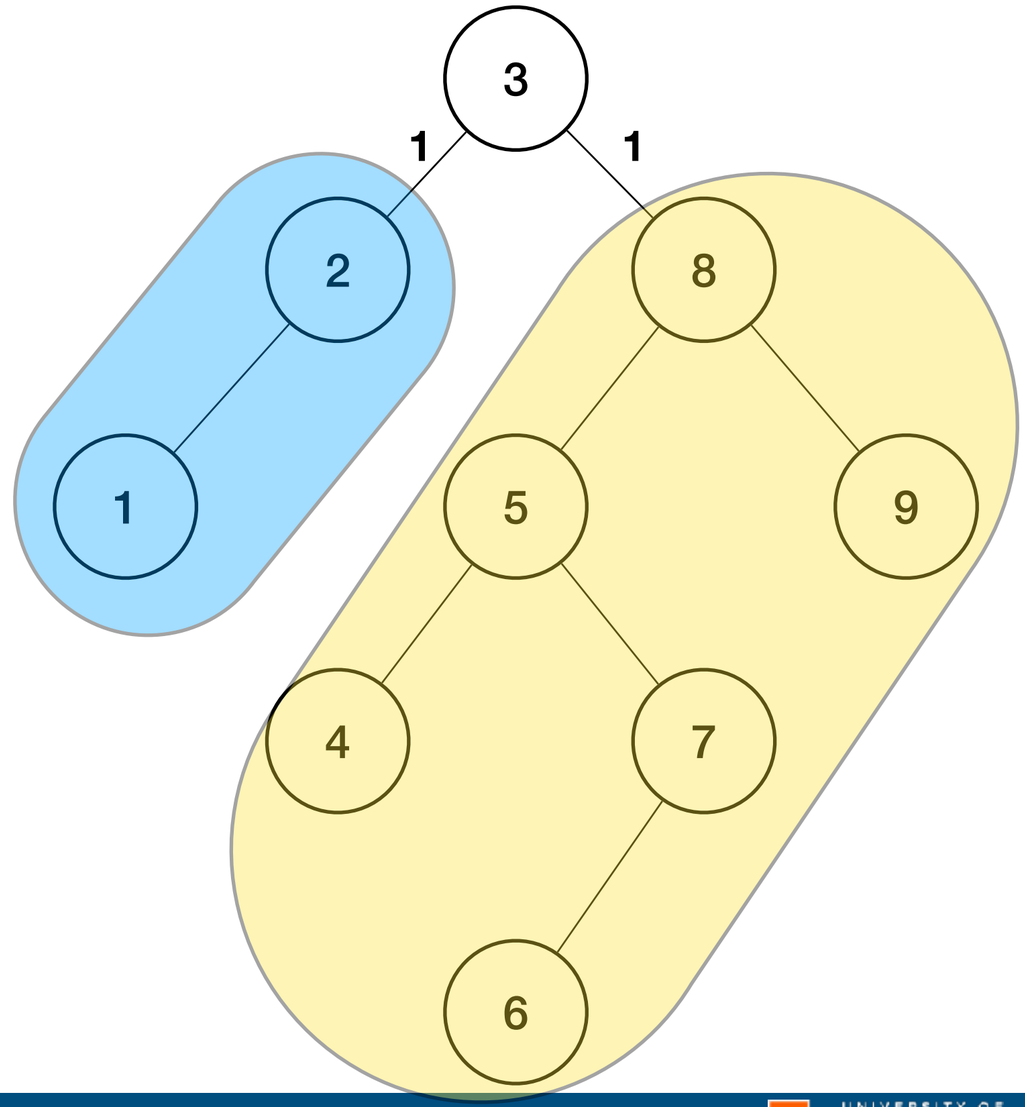

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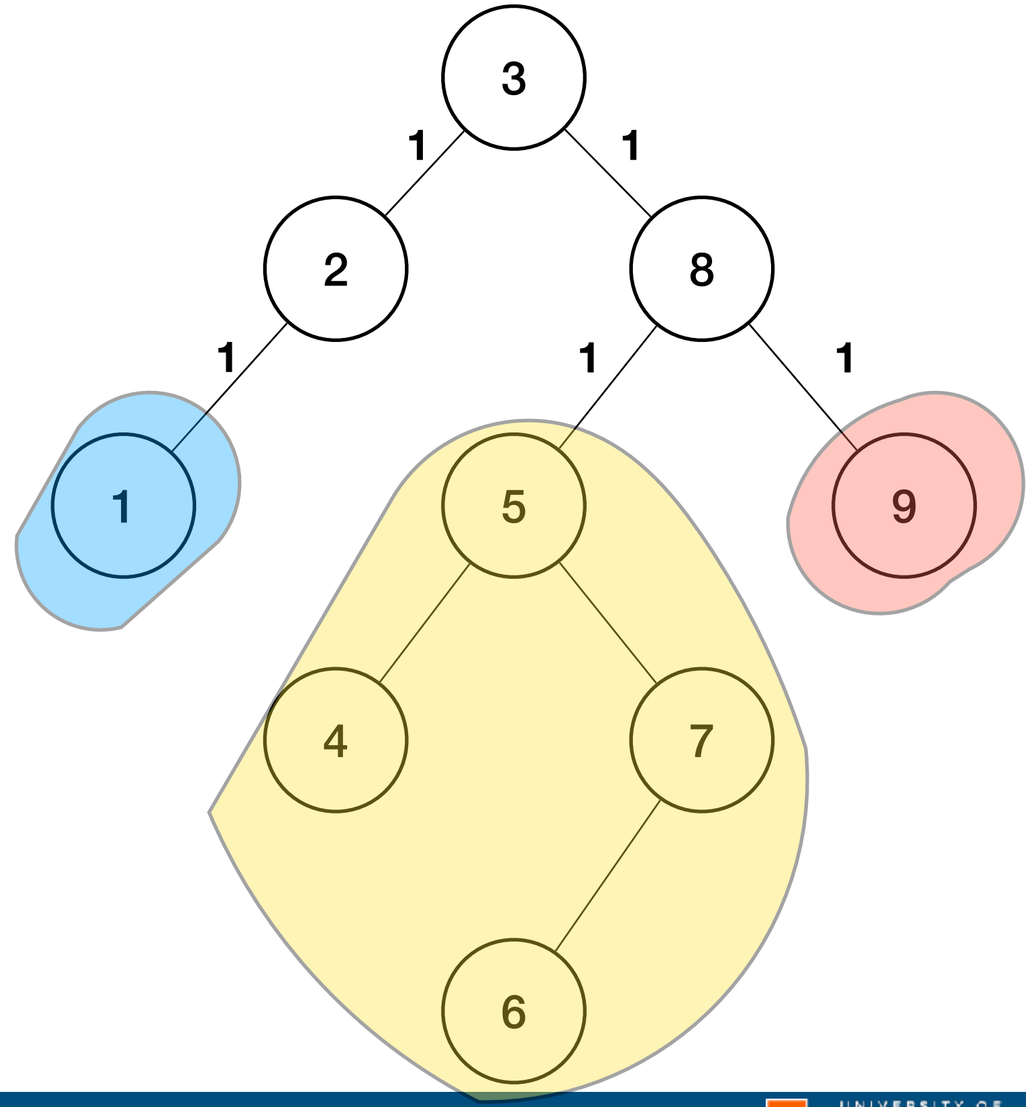

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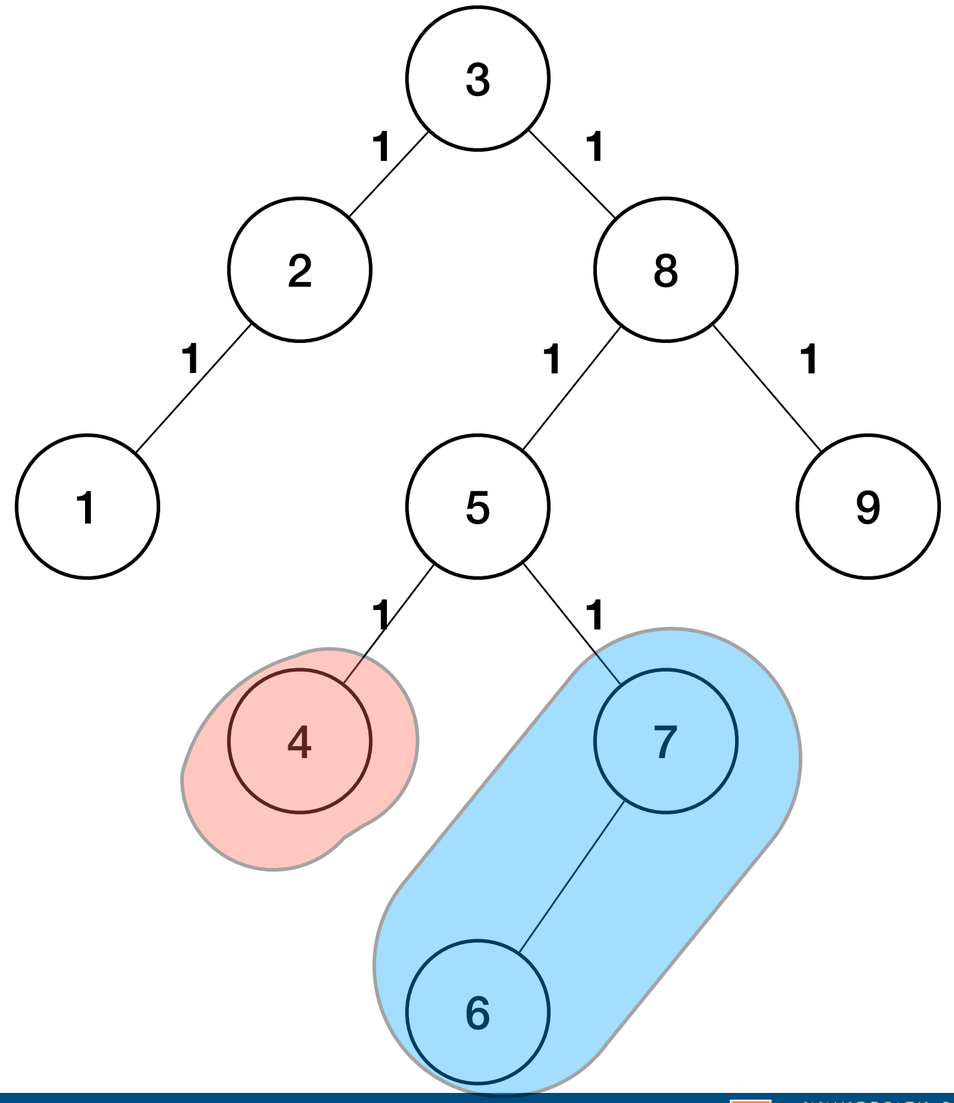

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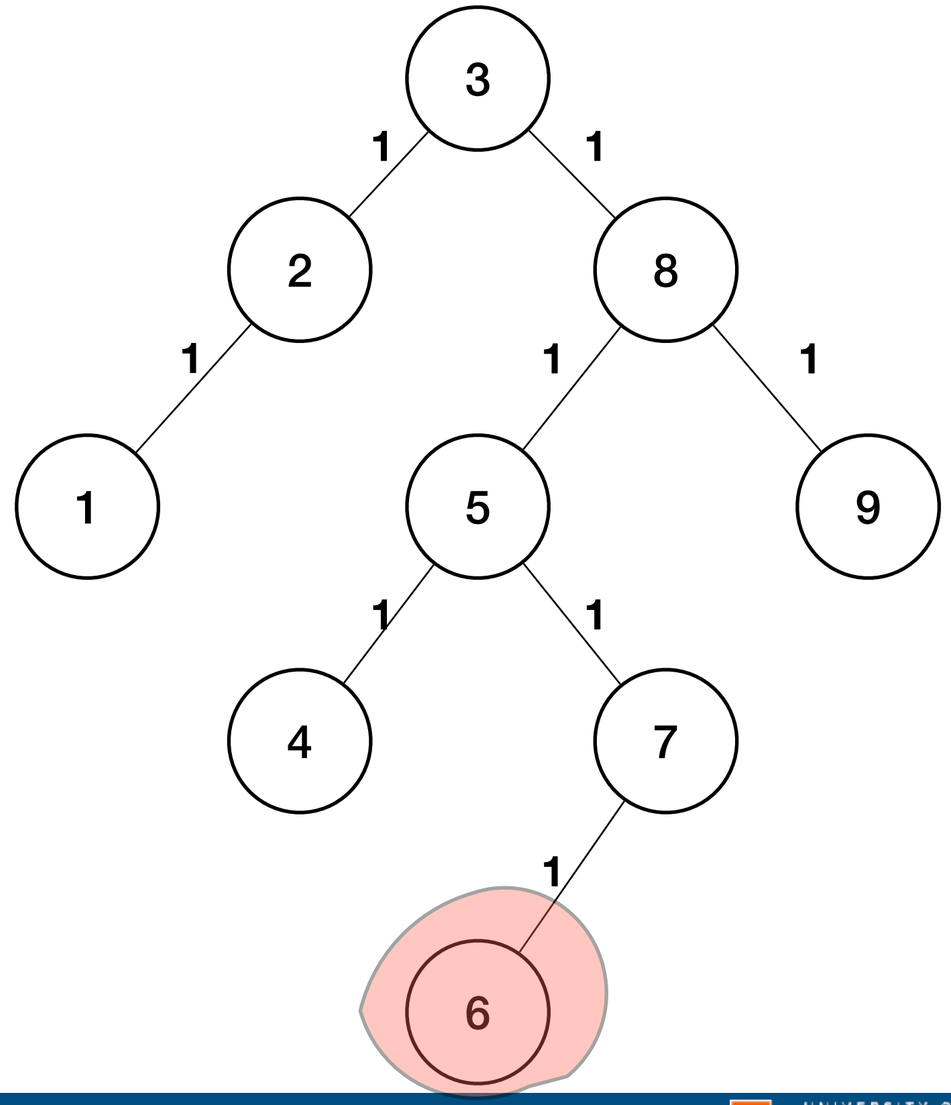

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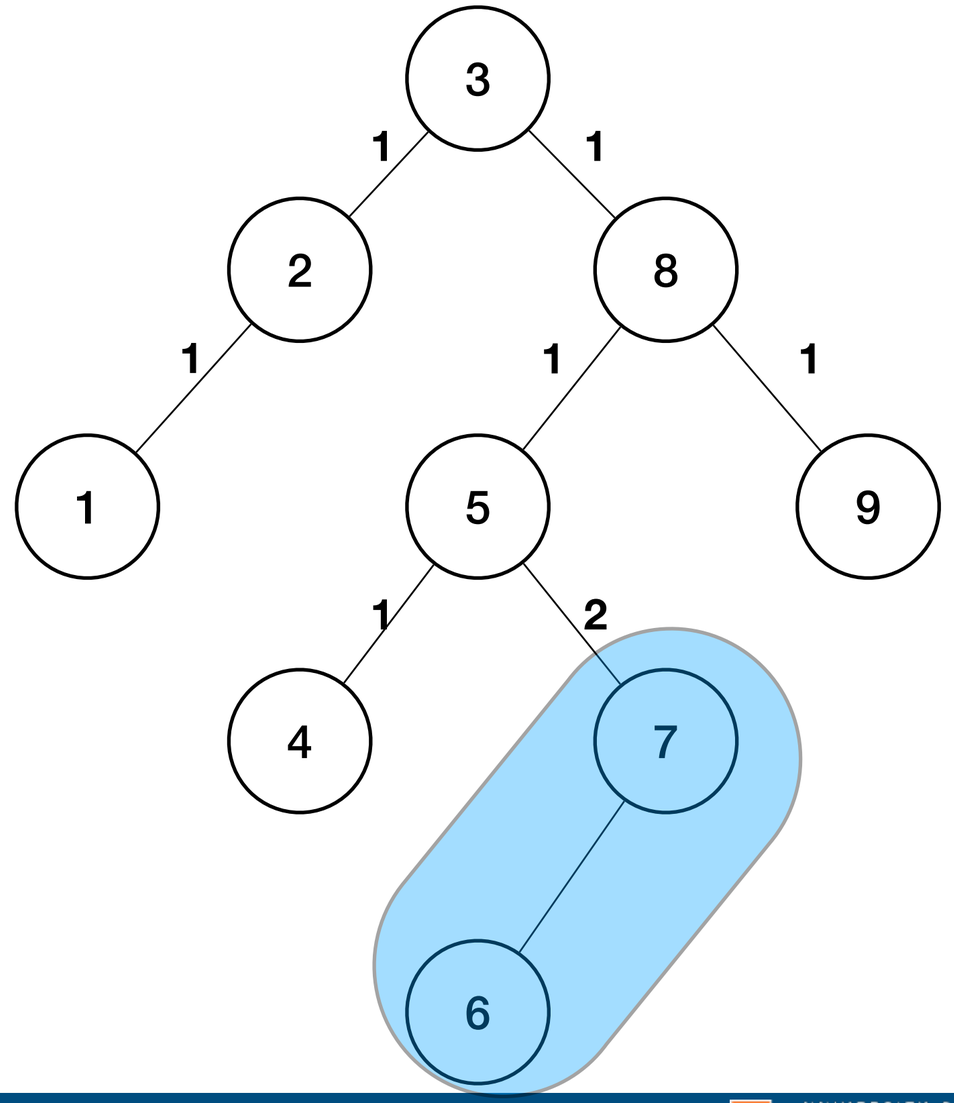

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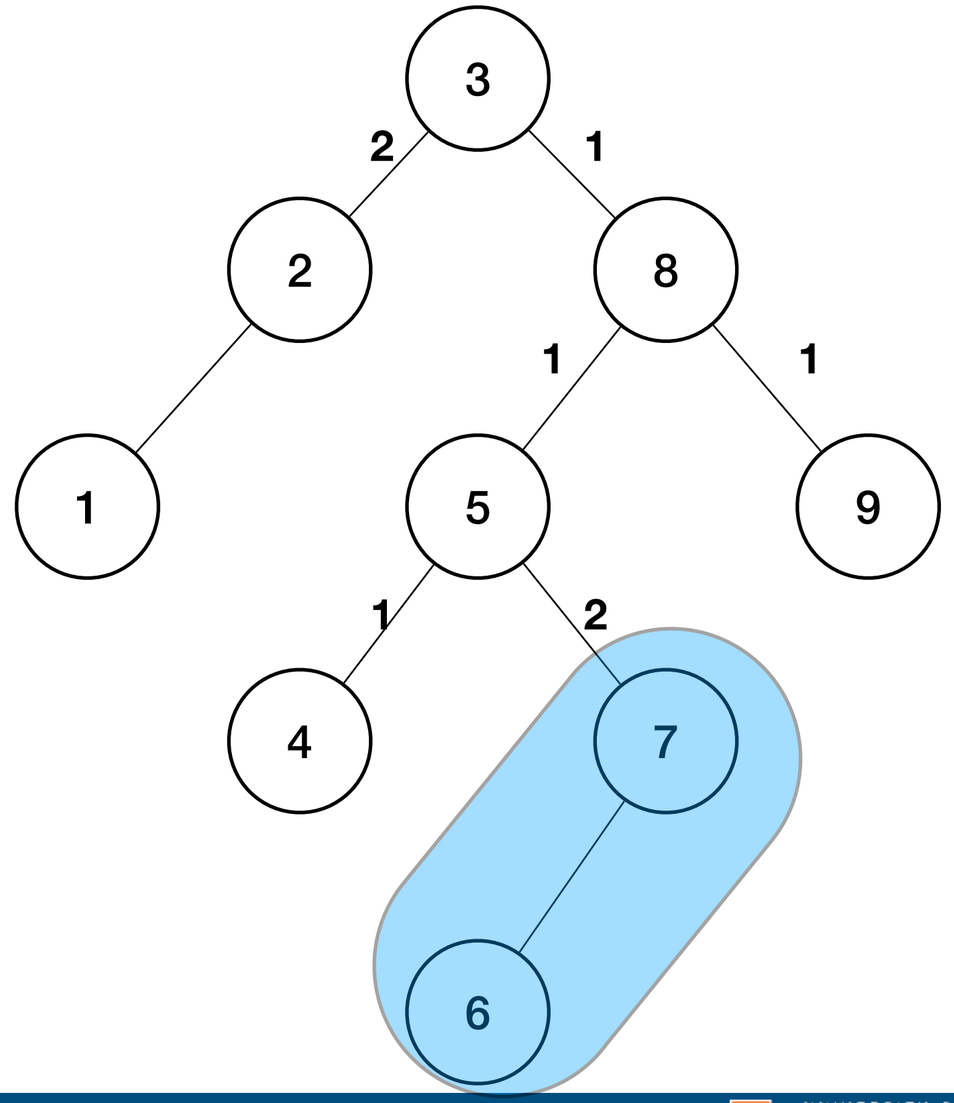

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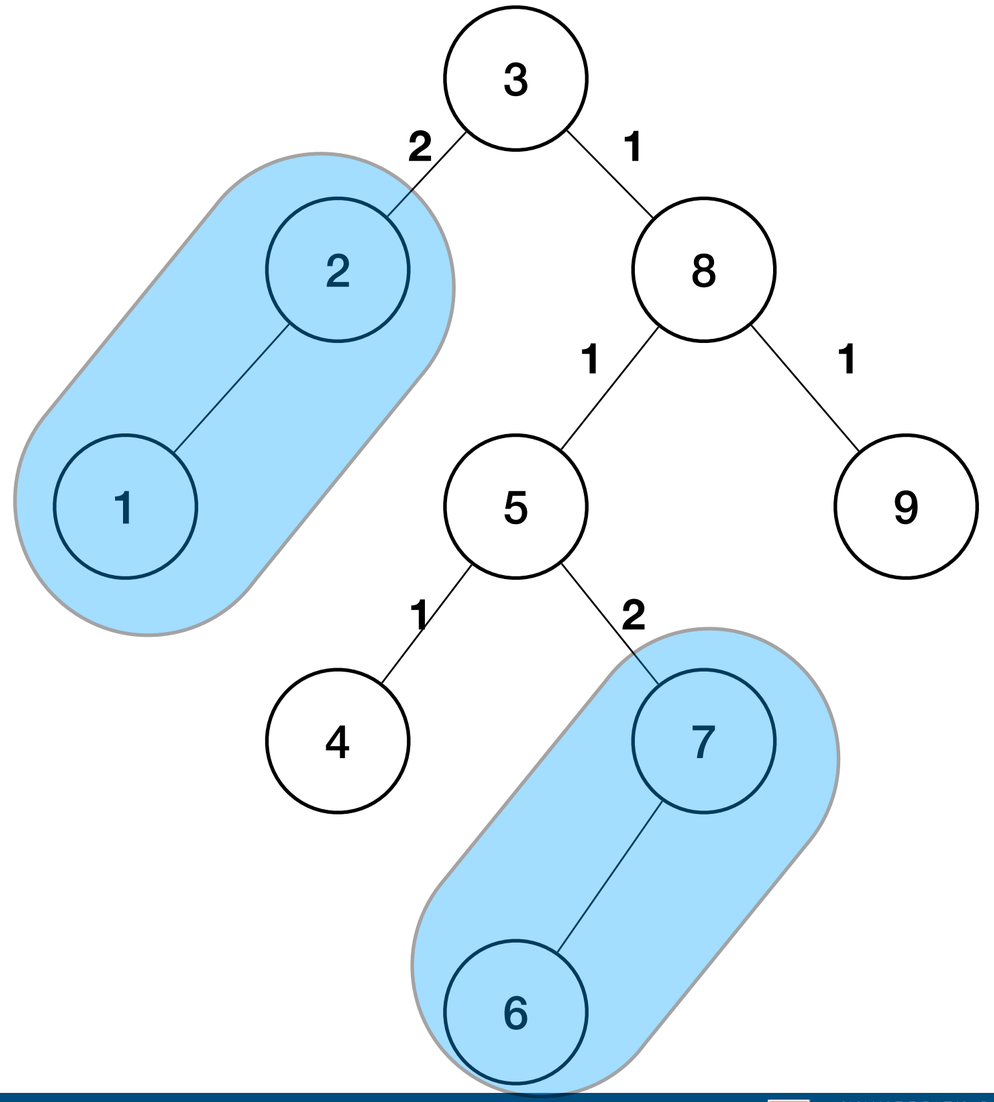

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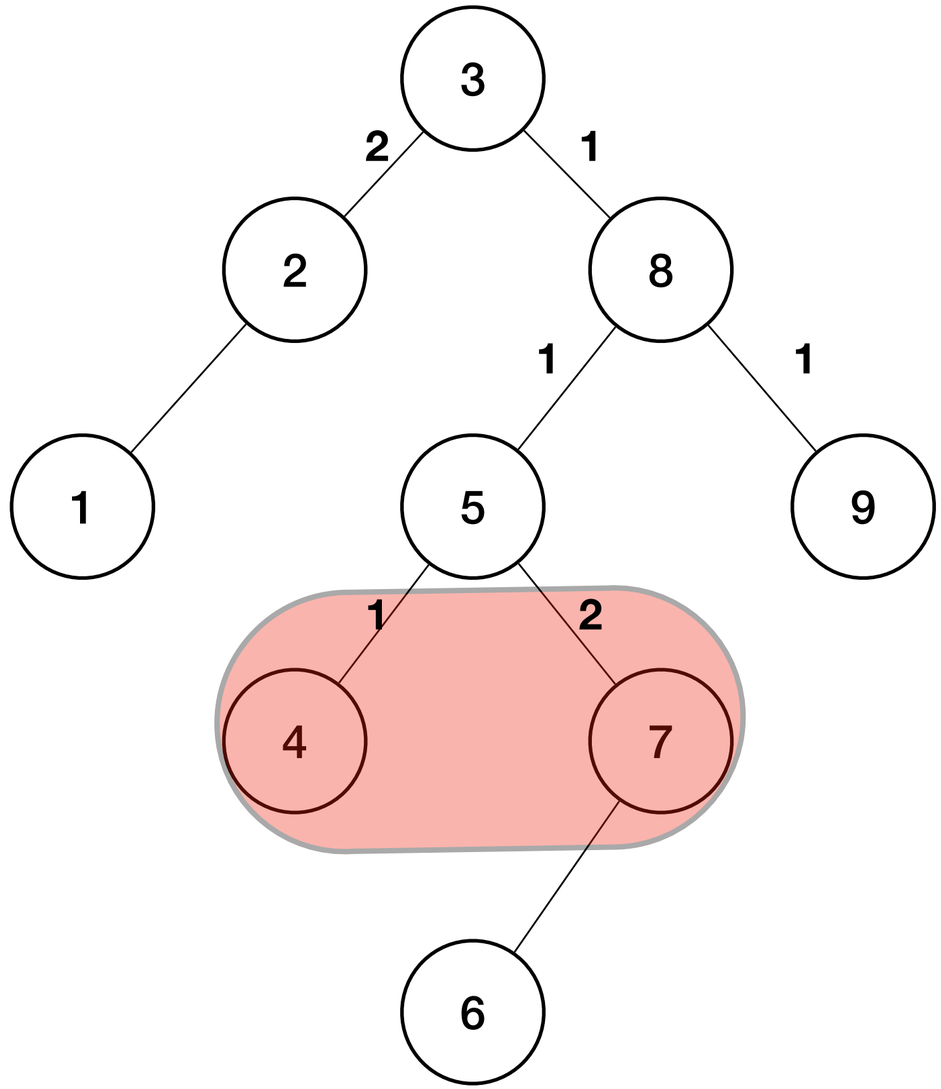

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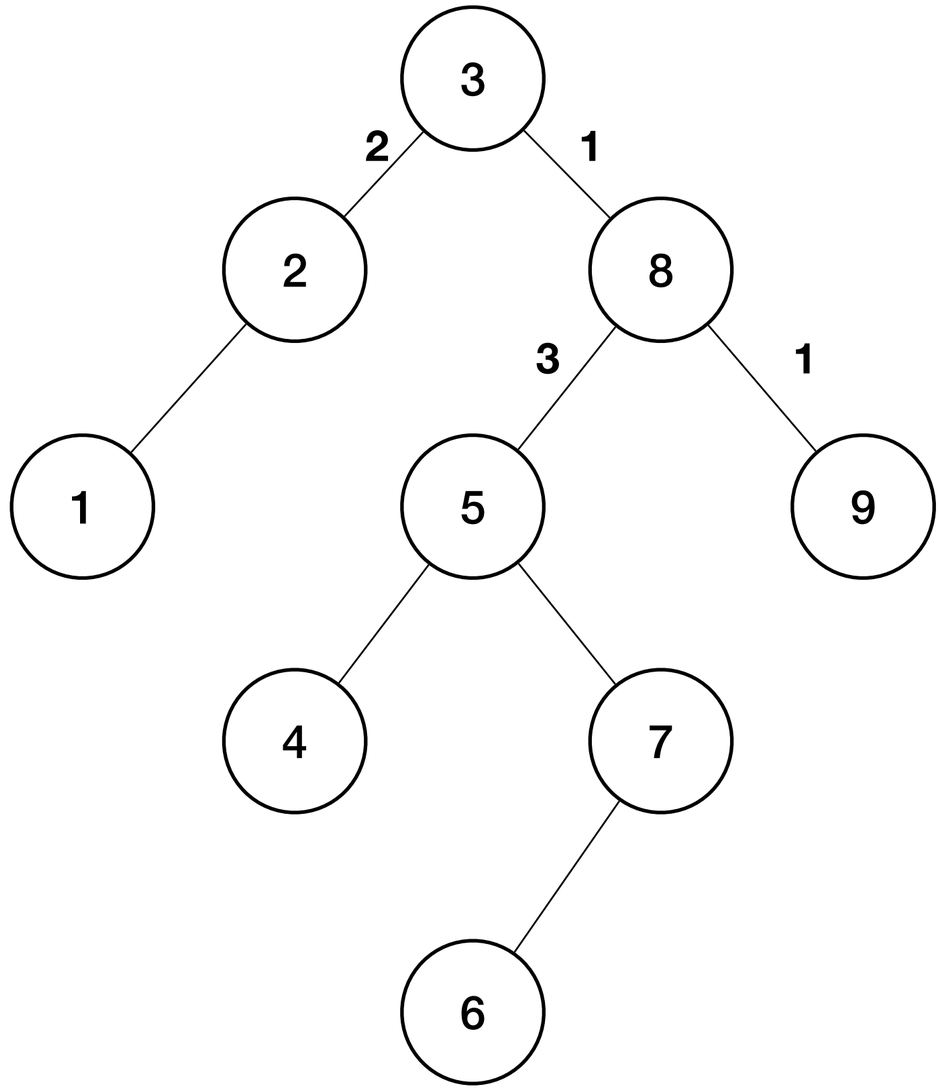

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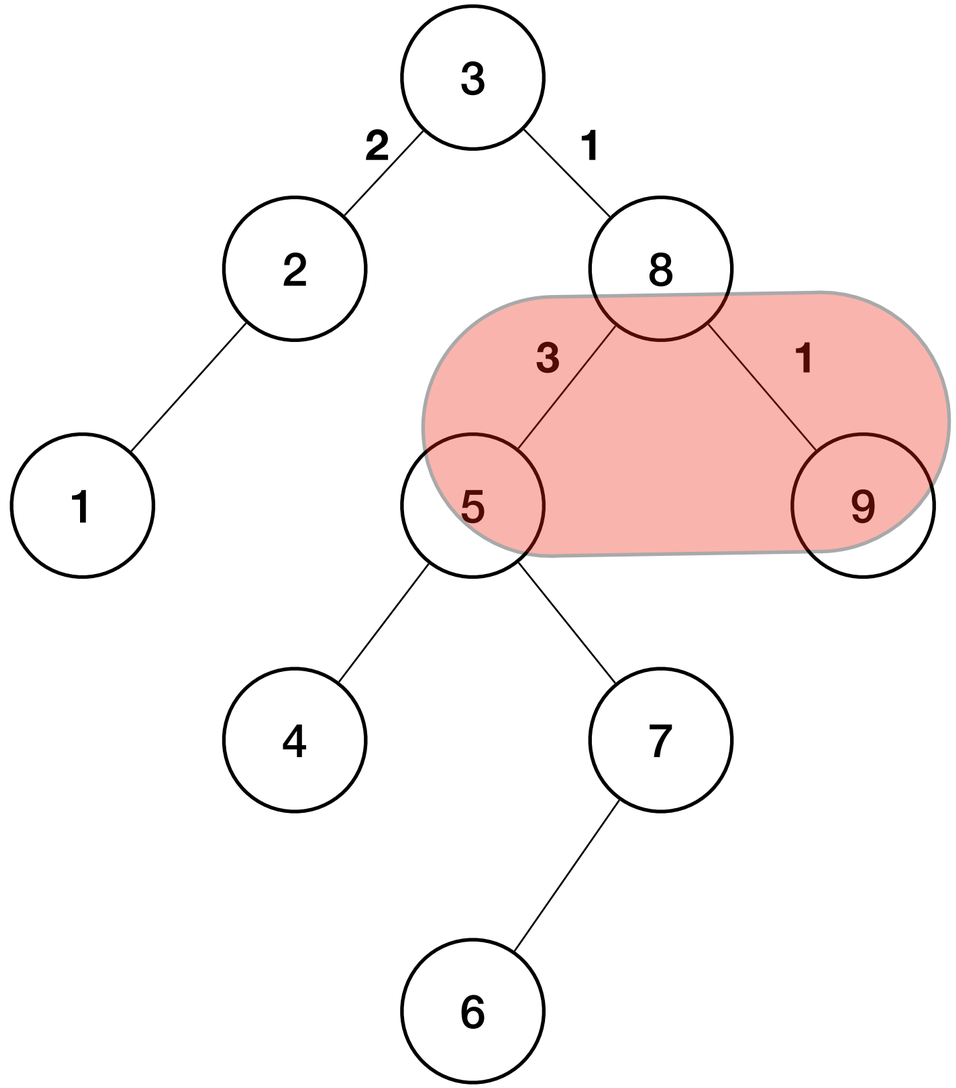

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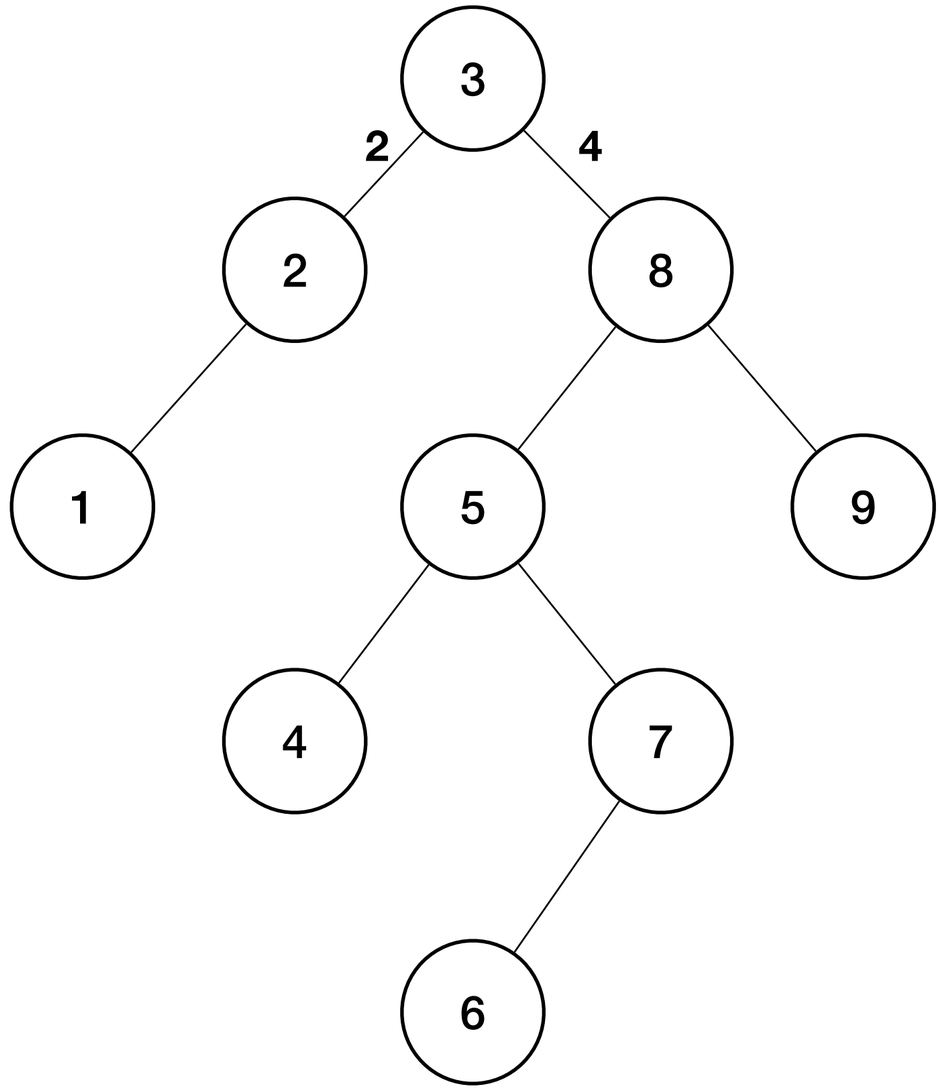

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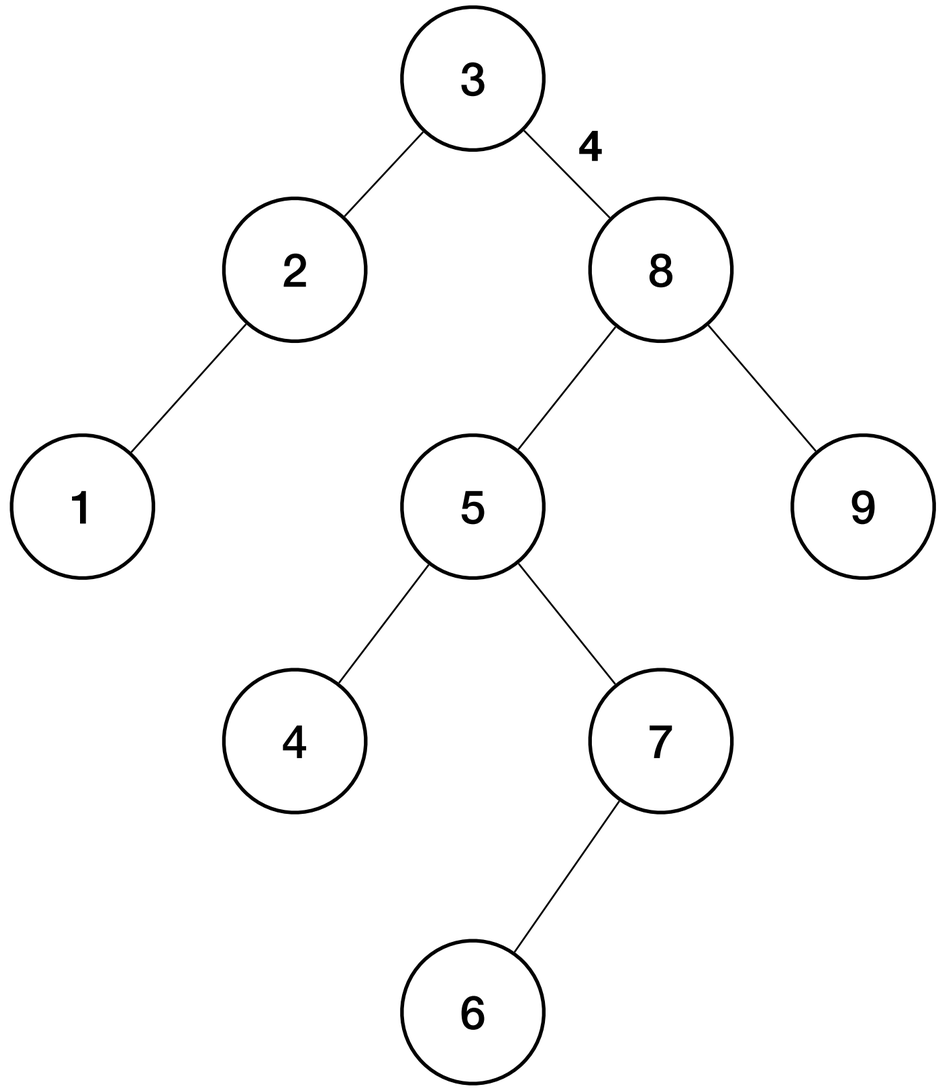

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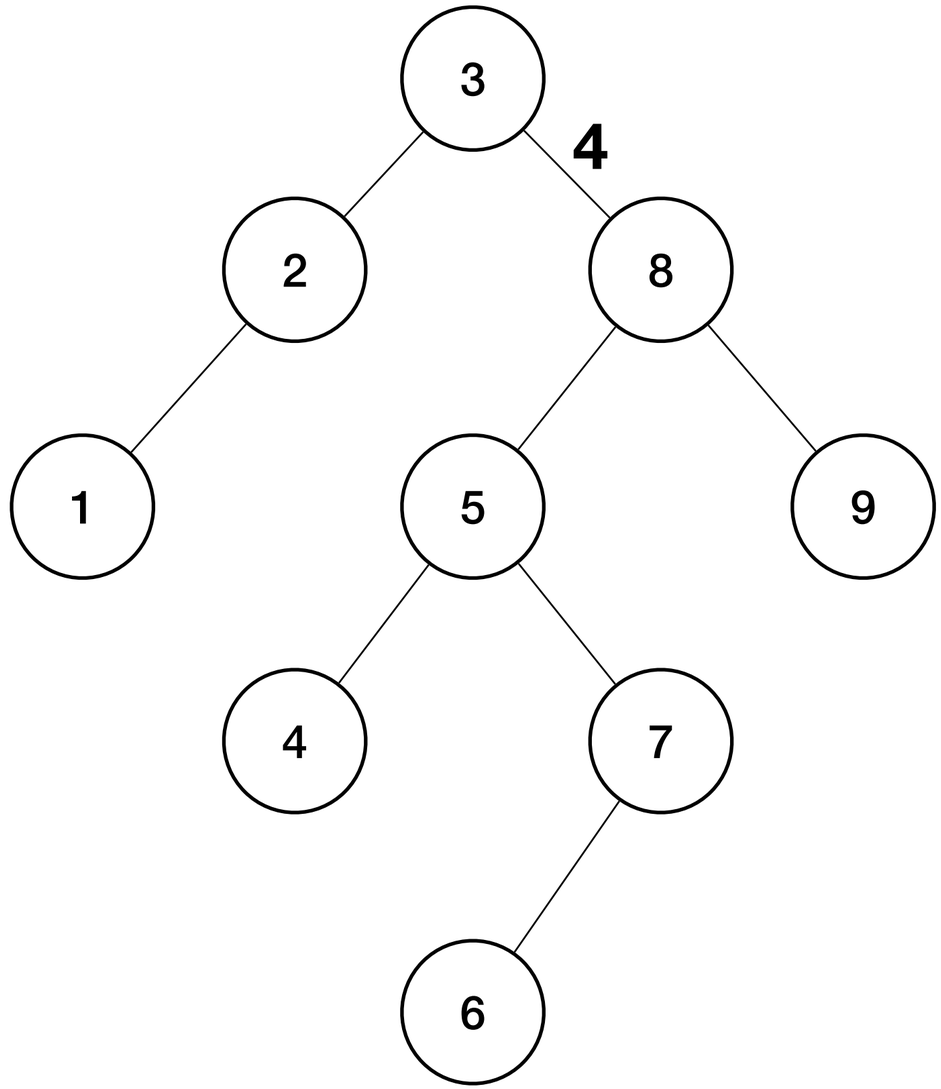
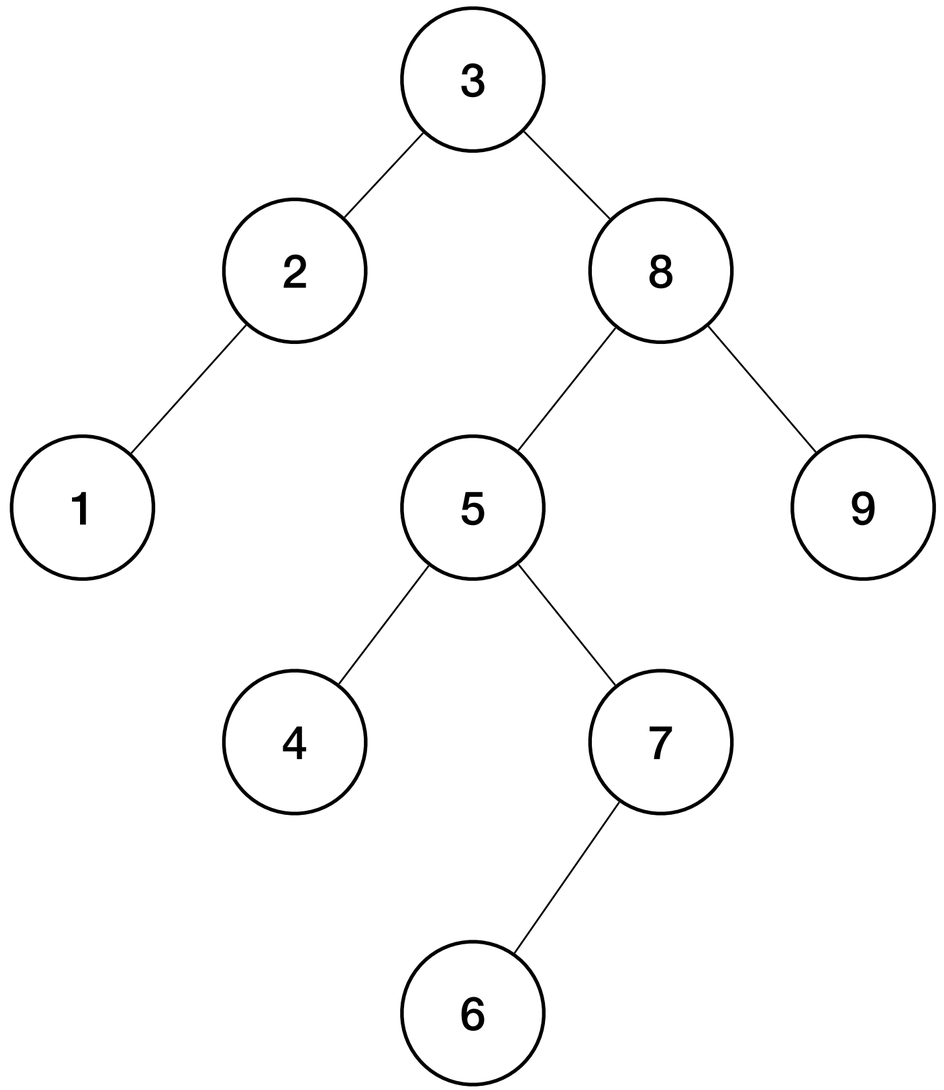


Find height of a tree

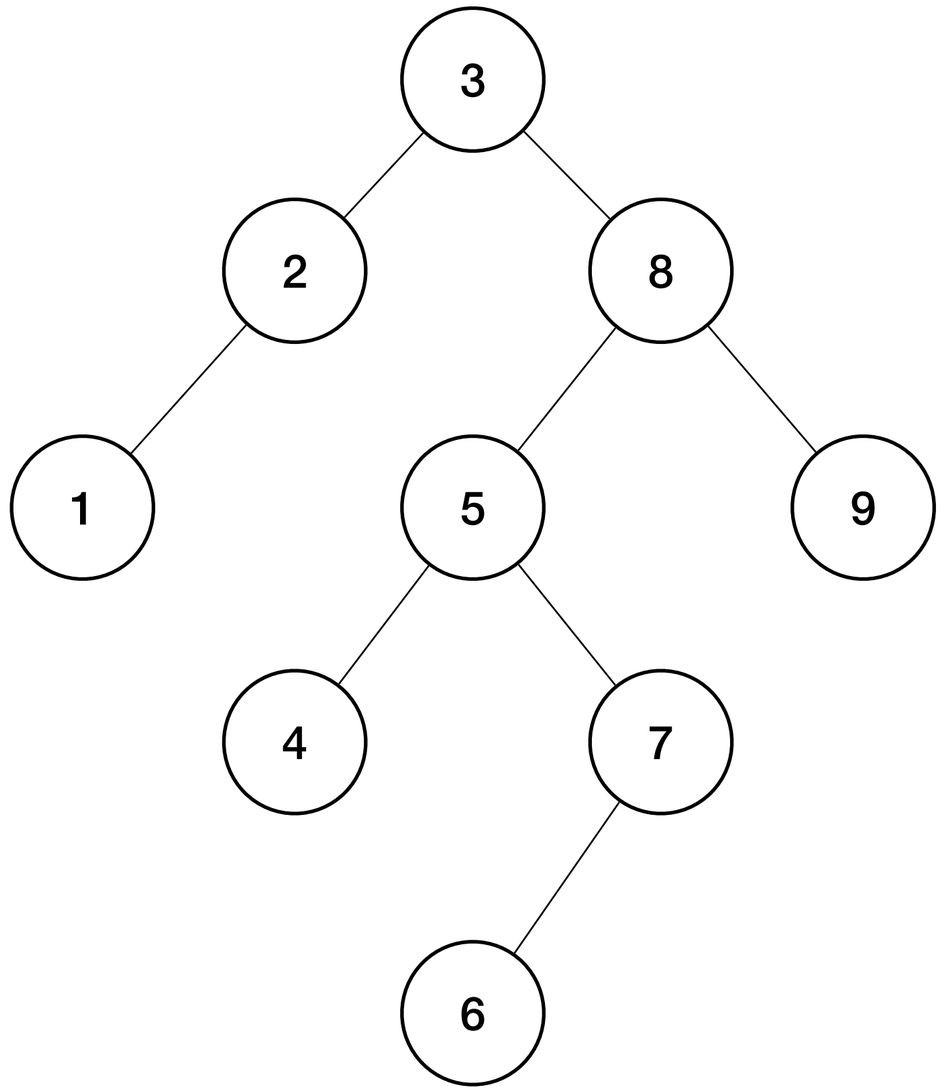
```
int tree_height(node *cursor){
  int lh, rh;
  if (cursor==NULL)

  else{
    lh =
    rh =
    return
  }
}
```



Find height of a tree

```
int tree_height(node *cursor){
  int lh, rh;
  if (cursor==NULL)
    return -1;
  else{
    lh =
    rh =
    return
  }
}
```



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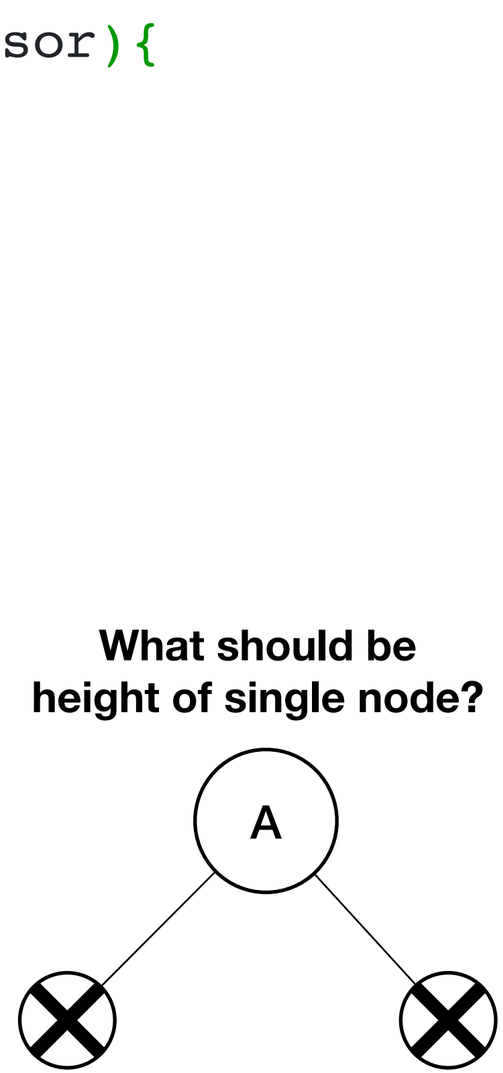
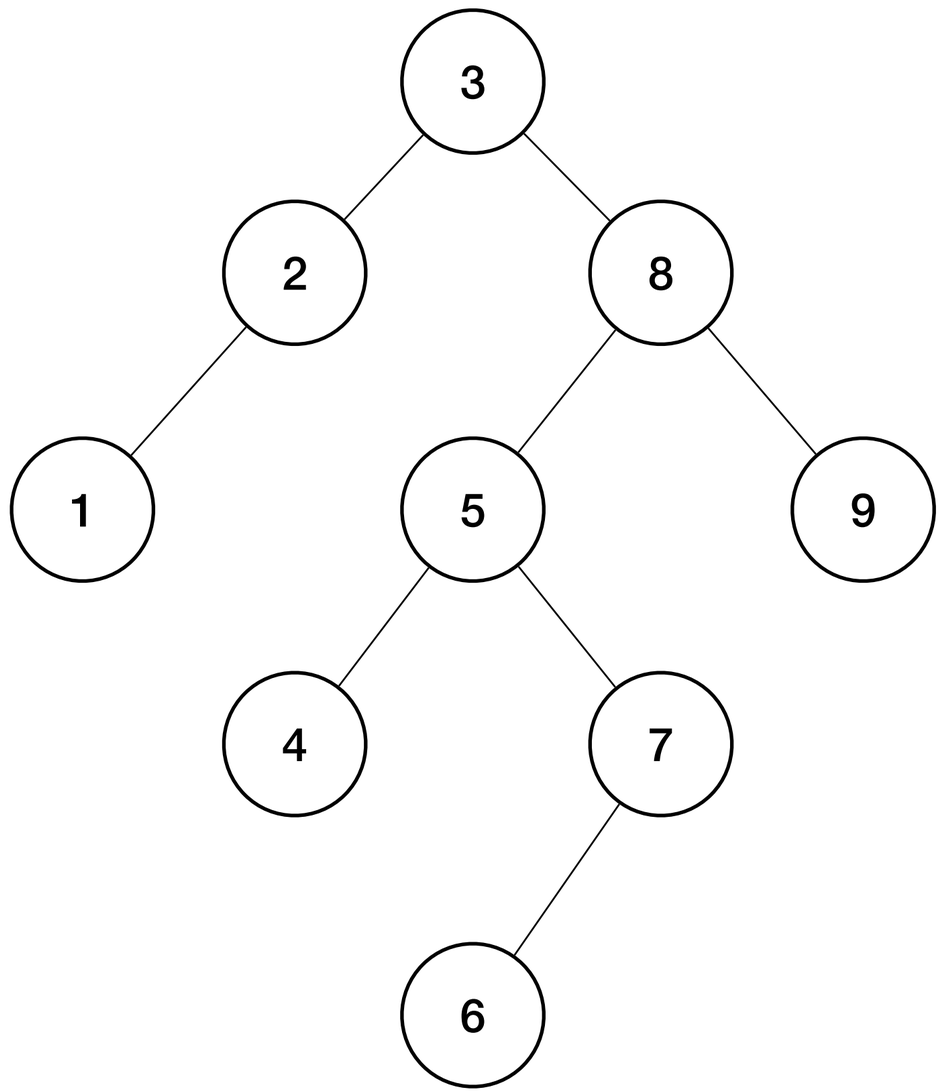
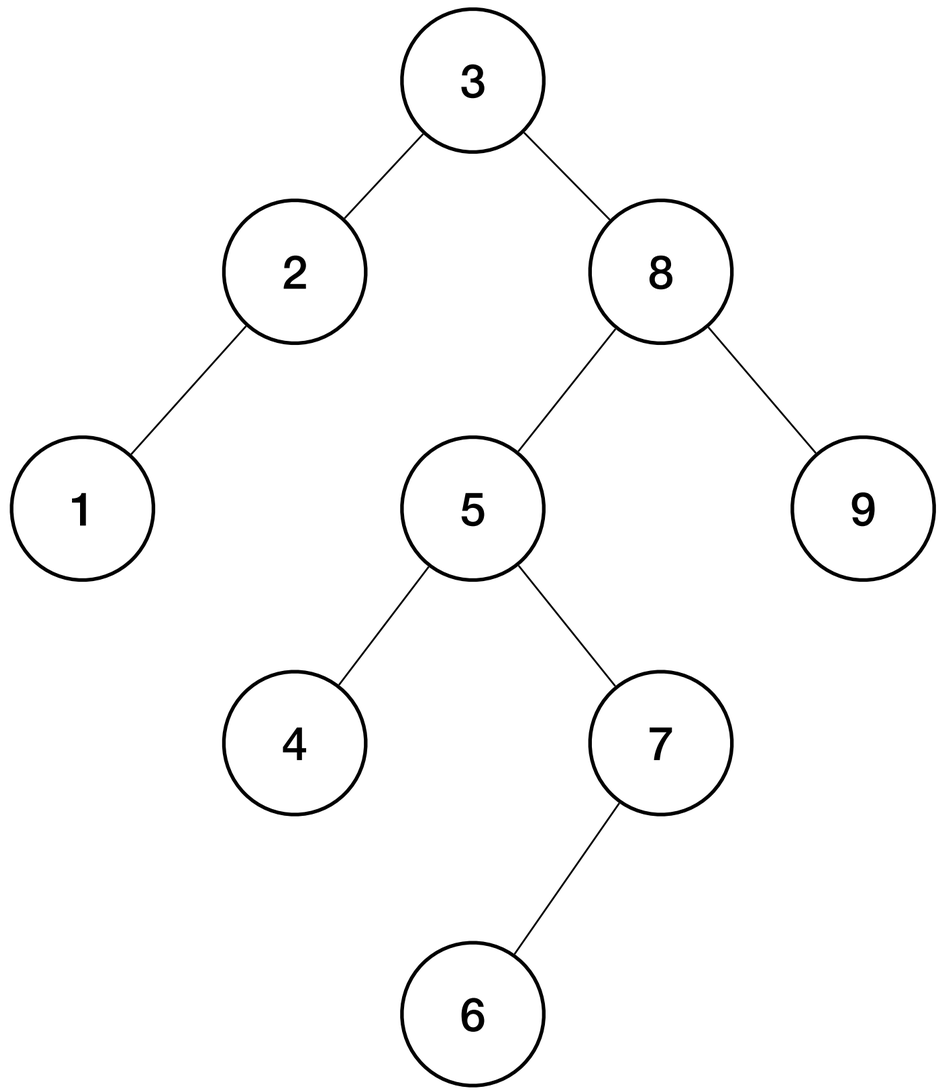


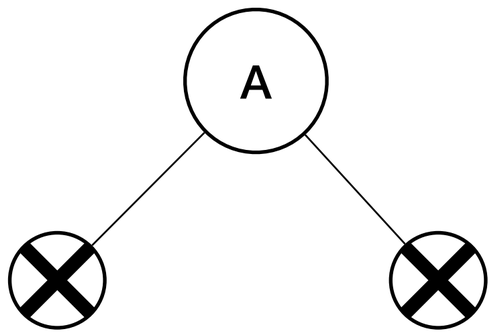


Find height of a tree

```
int tree_height(node *cursor){
  int lh, rh;
  if (cursor==NULL)
    return -1;
  else{
    lh = 1 + tree_height(cursor->left);
    rh =
    return
  }
}
```



What should be height of single node?



Find height of a tree

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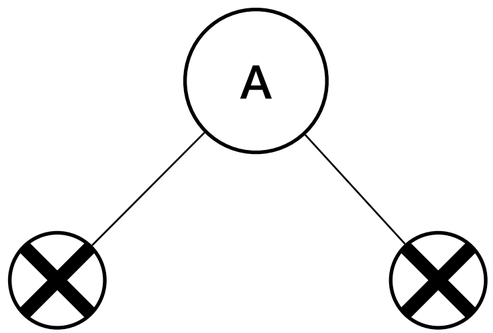
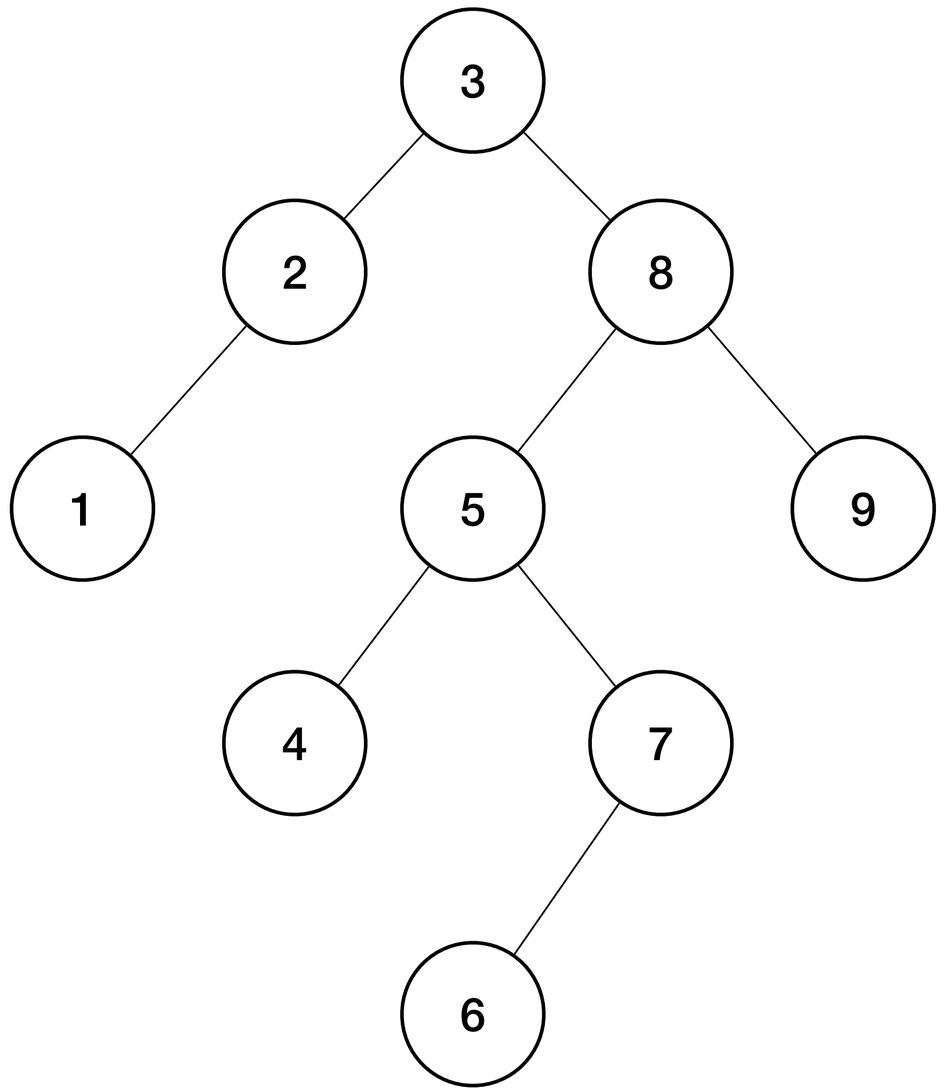
    rh = 1 + tree_height(cursor->right);
    return
  }
}
```

What should be height of single node?

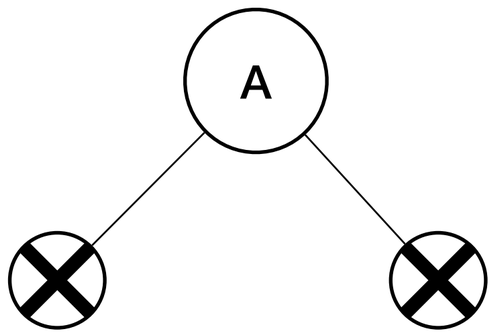


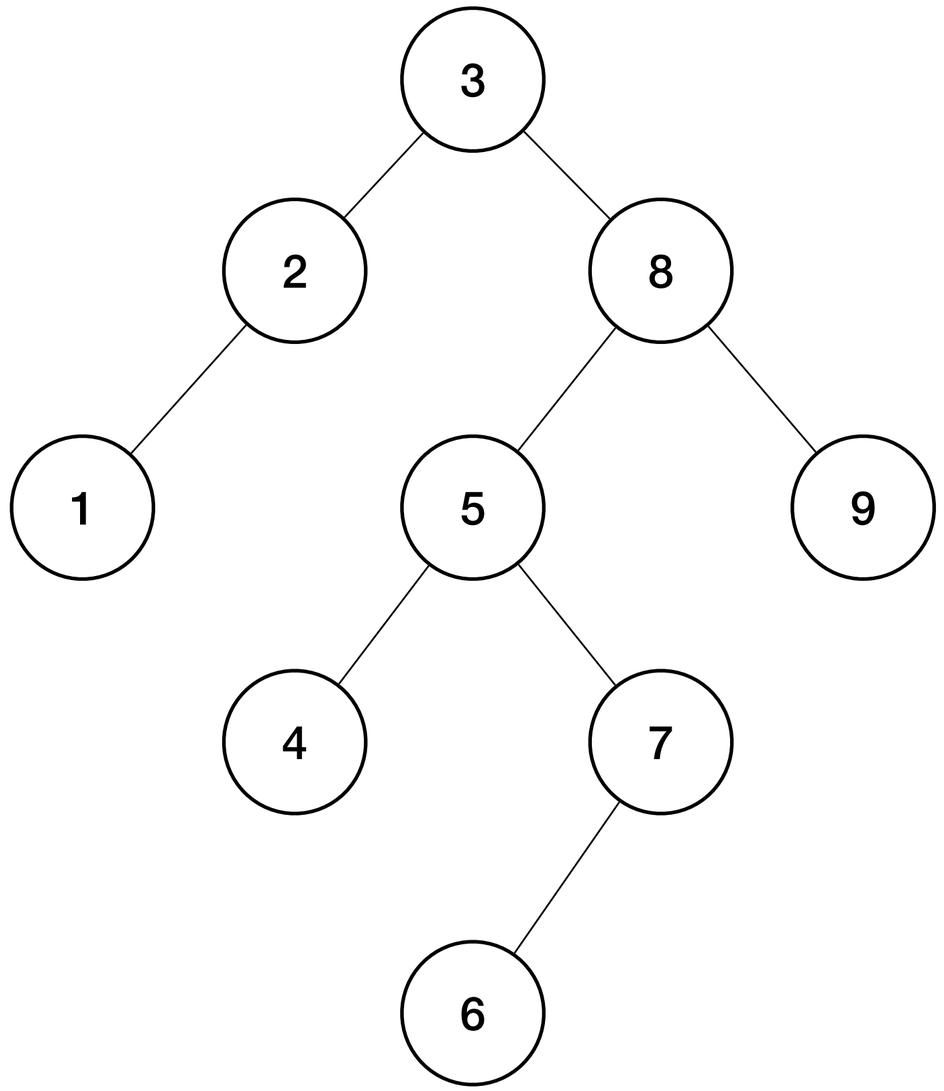


Find height of a tree

```
int tree_height(node *cursor){
  int lh, rh;
  if (cursor==NULL)
    return -1;
  else{
    lh = 1 + tree_height(cursor->left);
    rh = 1 + tree_height(cursor->right);
    return (lh > rh ? lh : rh);
  }
}
```

What should be height of single node?





```
template <typename T>
struct treenode{
  T data;
  treenode *left;
  treenode *right;
};
```

C++ Example

- Using classes in C++, create a BST class and perform or find:

```
template <class N>
class bst{
private:
  …
  …
  …
public:
  bst();
```

```
template <typename T>
struct treenode{
  T data;
  treenode *left;
  treenode *right;
};
```

C++ Example

- Using classes in C++, create a BST class and perform or find:
  - Insertion

```
template <class N>
class bst{
private:
  …
  …
  …
public:
  bst();
  void insert(N data);
```

```
template <typename T>
struct treenode{
  T data;
  treenode *left;
  treenode *right;
};
```

C++ Example

- Using classes in C++, create a BST class and perform or find:
  - Insertion
  - Searching

```
template <class N>
class bst{
private:
  …
  …
  …
public:
  bst();
  void insert(N data);
  treenode<N> *search(N data);
```

```
template <typename T>
struct treenode{
  T data;
  treenode *left;
  treenode *right;
};
```

C++ Example

- Using classes in C++, create a BST class and perform or find:
  - Insertion
  - Searching
  - Traversal

```
template <class N>
class bst{
private:
  …
  …
  …
public:
  bst();
  void insert(N data);
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C++ Example

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```cpp
#include <iostream>
#include "bst.hpp"

using namespace std;

int main(){
  bst <int> tree1;
  cout<<"Building a Binary Search Tree"<<endl;

  tree1.insert(45);
  tree1.insert(50);
  tree1.insert(35);
  tree1.insert(30);
  tree1.insert(70);
  tree1.insert(20);
  tree1.insert(40);
  tree1.insert(80);
  tree1.insert(60);

  cout<<"Total number of nodes in this tree: ";
  cout<<tree1.node_count()<<endl;
  tree1.inorder();
  cout<<endl;
  tree1.print();
  cout<<"The tree height is: "<<tree1.height();
  cout<<endl;

  vector <int> v = tree1.vectorize();
  cout<<"Vectorized in order this is:"<<endl;
  for (auto it= v.begin(); it != v.end(); ++it)
     cout<<*it<<", ";
  return 0;
  }
```

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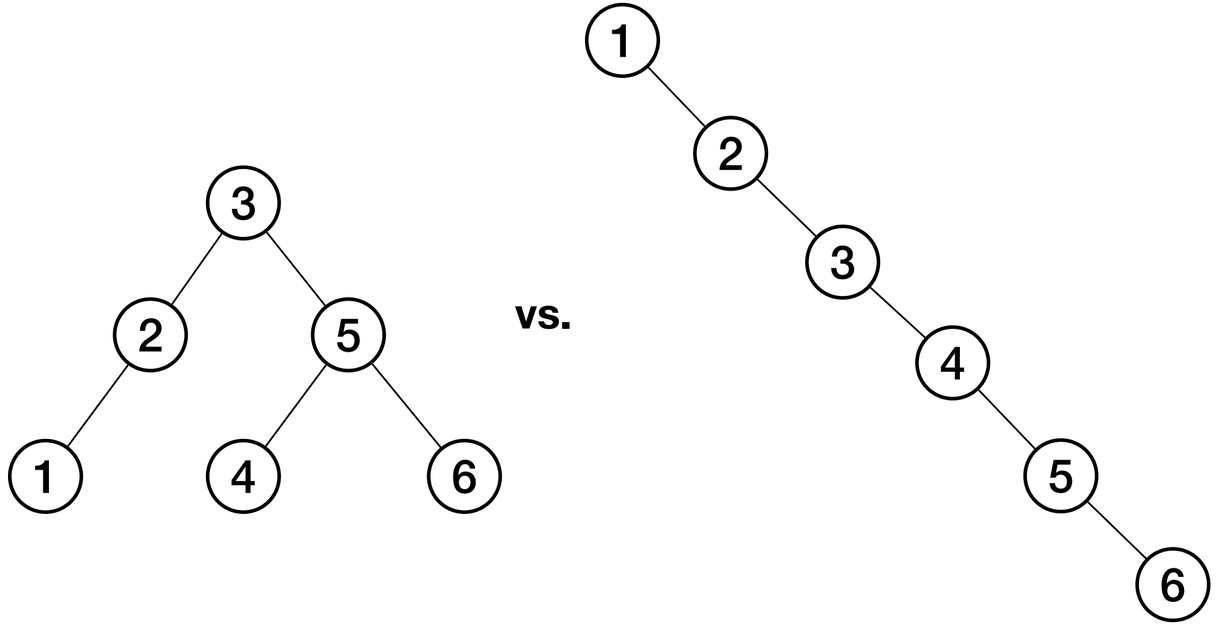

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- How to modify struct definition if tree is no longer binary?

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