APS106

UNIVERSITY OF TORONTO

binary search trees.

Week 12 | Lecture 2 (12.2)

if nothing else, write #cleancode

This Week's Content

- **Lecture 12.1**
  - Linked lists, binary trees
  - Reading: Chapter 14
- **Lecture 12.2**
  - **Binary search trees**
  - **Reading: Chapter 14**
- **Lecture 12.3**
  - Design Problem: 20 Questions

Clearing things up.

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class LinkedList:

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What are we testing?

- `is` is an identity test.
- It checks whether the right-hand side and the left-hand side are the very same object.

```
>>> a = 'hello world'
>>> b = 'hello world'
>>> a is b
```

```
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What are we testing?

- `is` is an identity test.
- It checks whether the right-hand side and the left-hand side are the very same object.

```
>>> a = 'hello world'
>>> b = 'hello world'
>>> a is b
False

>>> id(a)
1603648396784

>>> id(b)
1603648426160
```

```python
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>>> a = None
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- `is` is an identity test.
- It checks whether the right-hand side and the left-hand side are the very same object.

```
>>> a = None
>>> b = None
>>> a is b
True

>>> id(a)
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>>> id(b)
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while on.next is not None:
```

```
>>> Node() is not None
True

>>> None is not None
False
```

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What are we testing?

- **==** is an equality test.
- It checks whether the right-hand side and the left-hand side are equal objects.

```
>>> a = 'hello world'
>>> b = 'hello world'
>>> a == b
```

What are we testing?

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- == is an equality test.
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What are we testing?

- == is an equality test.
- It checks whether the right-hand side and the left-hand side are equal objects.

```
while on.next != None:
```

```
>>> Node() != None
True

>>> None != None
False
```

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What are we testing?

- Truthy and Falsy Values in Python.
- Expressions with operands and operators evaluate to either **`True`** or **`False`** and they can be used in an **`if`** or **`while`** condition to determine if a code block should run.

```
>>> if 5 > 3:
        print("True")
True
```

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What are we testing?

- Truthy and Falsy Values in Python.
- What do you think would be the output of this code?

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>>> a = 4
>>> if a:
        print(a)
```

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What are we testing?

- Truthy and Falsy Values in Python.
- What do you think would be the output of this code?

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>>> a = 0
>>> if a:
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```

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What are we testing?

- Truthy and Falsy Values in Python.
- In Python, individual values can evaluate to either True or False.
- They do not necessarily have to be part of a larger expression to evaluate to a truth value because they already have one that has been determined by the rules of the Python language?
  - Values that evaluate to `False` are considered **Falsy**.
  - Values that evaluate to `True` are considered **Truthy**.

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What are we testing?

- **Falsy Values**
- **Sequences and Collections**
  - Empty lists `[]`
  - Empty tuples `()`
  - Empty dictionaries `{}`
  - Empty sets `set()`
  - Empty strings `""`
  - Empty ranges `range(0)`
- **Numbers**
  - Zero of any numeric type.
  - Integer: `0`
  - Float: `0.0`
  - Complex: `0j`
- **Constants**
  - `None`
  - `False`

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What are we testing?

- **Truthy Values**
- By default, an object is considered `True`.
- **Non-empty** sequences or collections (`lists`, `tuples`, `strings`, `dictionaries`, `sets`).
- **Numeric values** that are **not zero**.
- `True`

Clearing things up

- When in **doubt**, try it **out**!

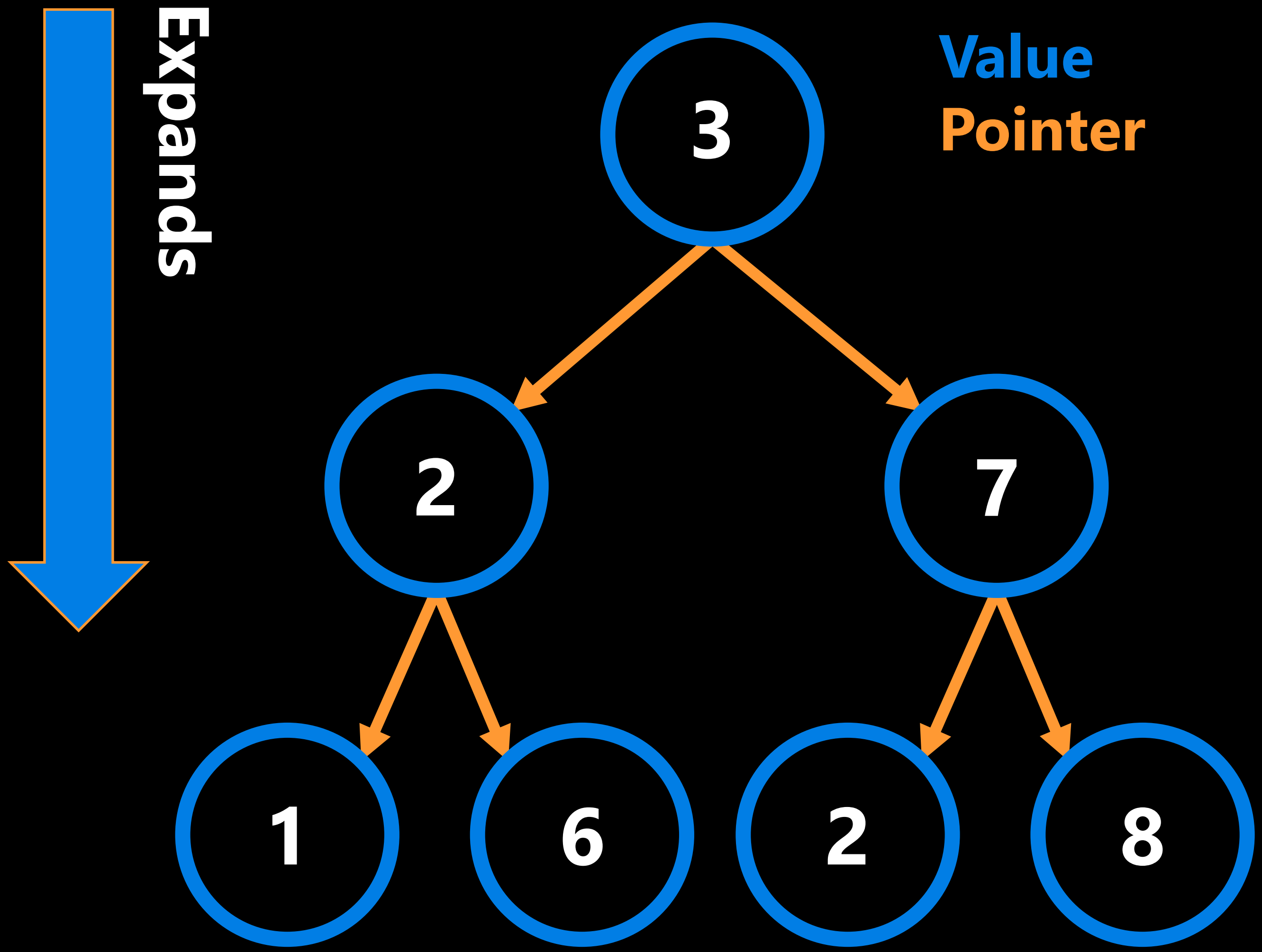
Open your notebook

Click Link:

1. Truthy and Falsy Values

Trees

- **Trees expand in one direction.**
- Trees are made up of parents and children.
  - These are relative terms for nodes.
  - Every parent can be a child.



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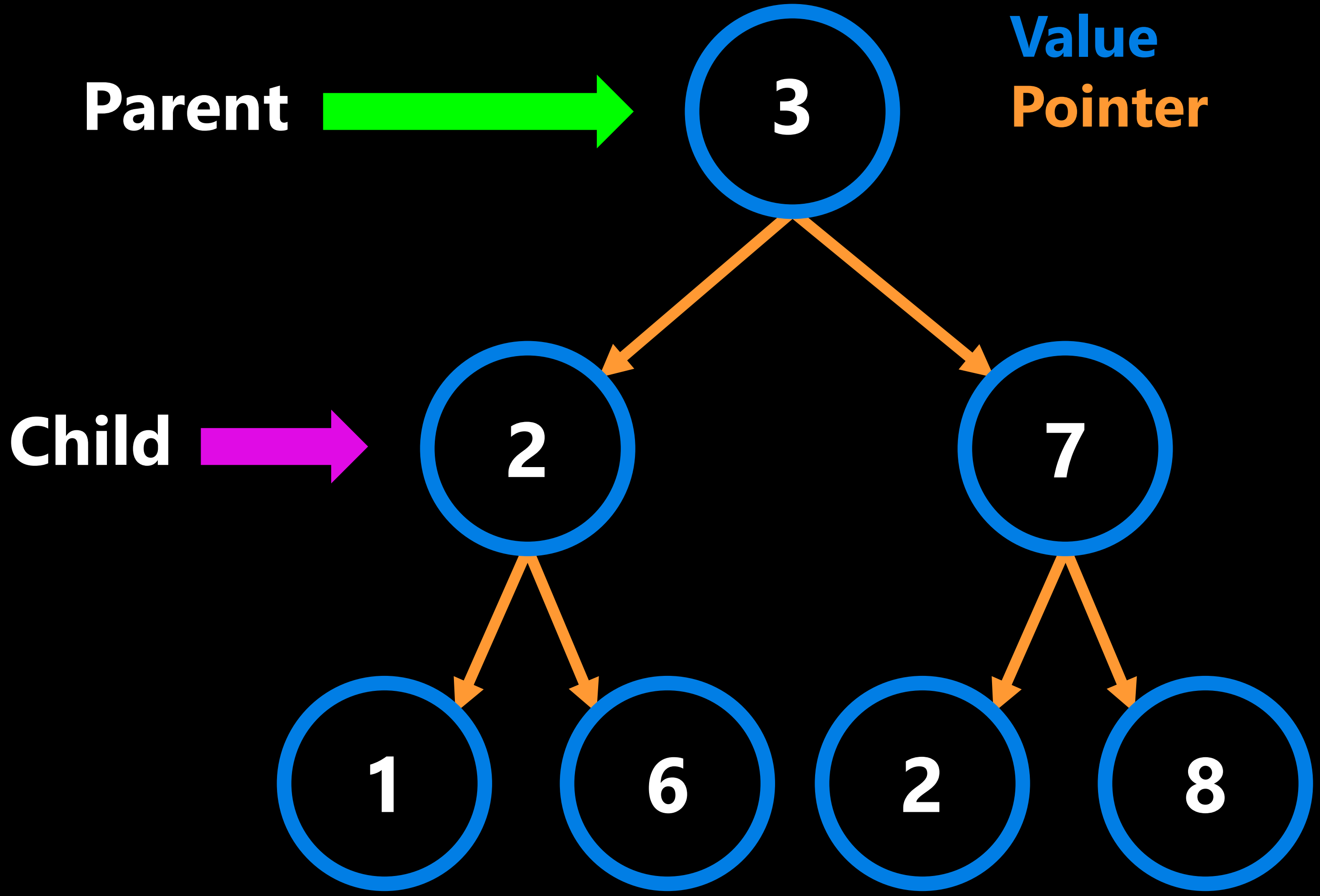

Trees

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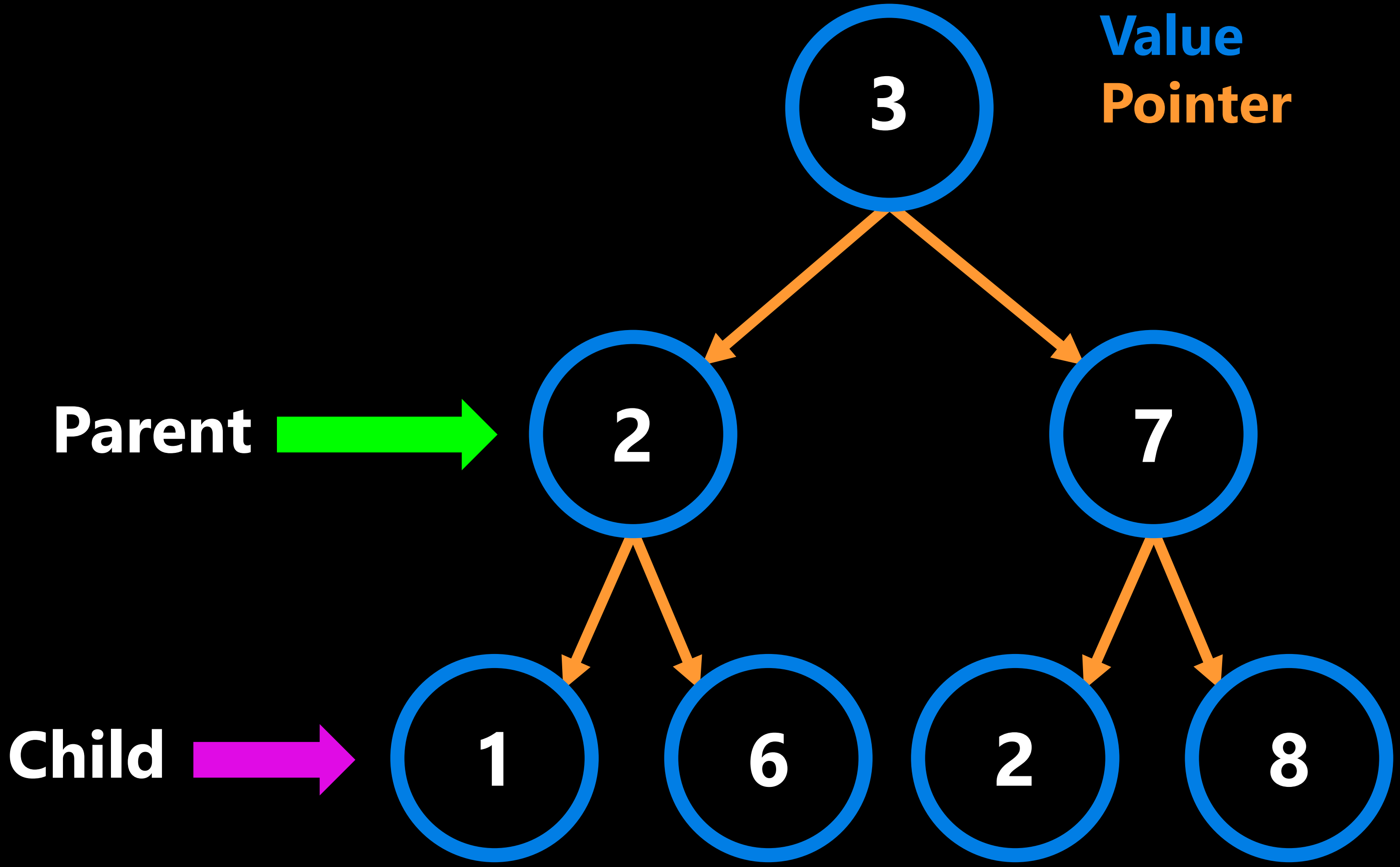
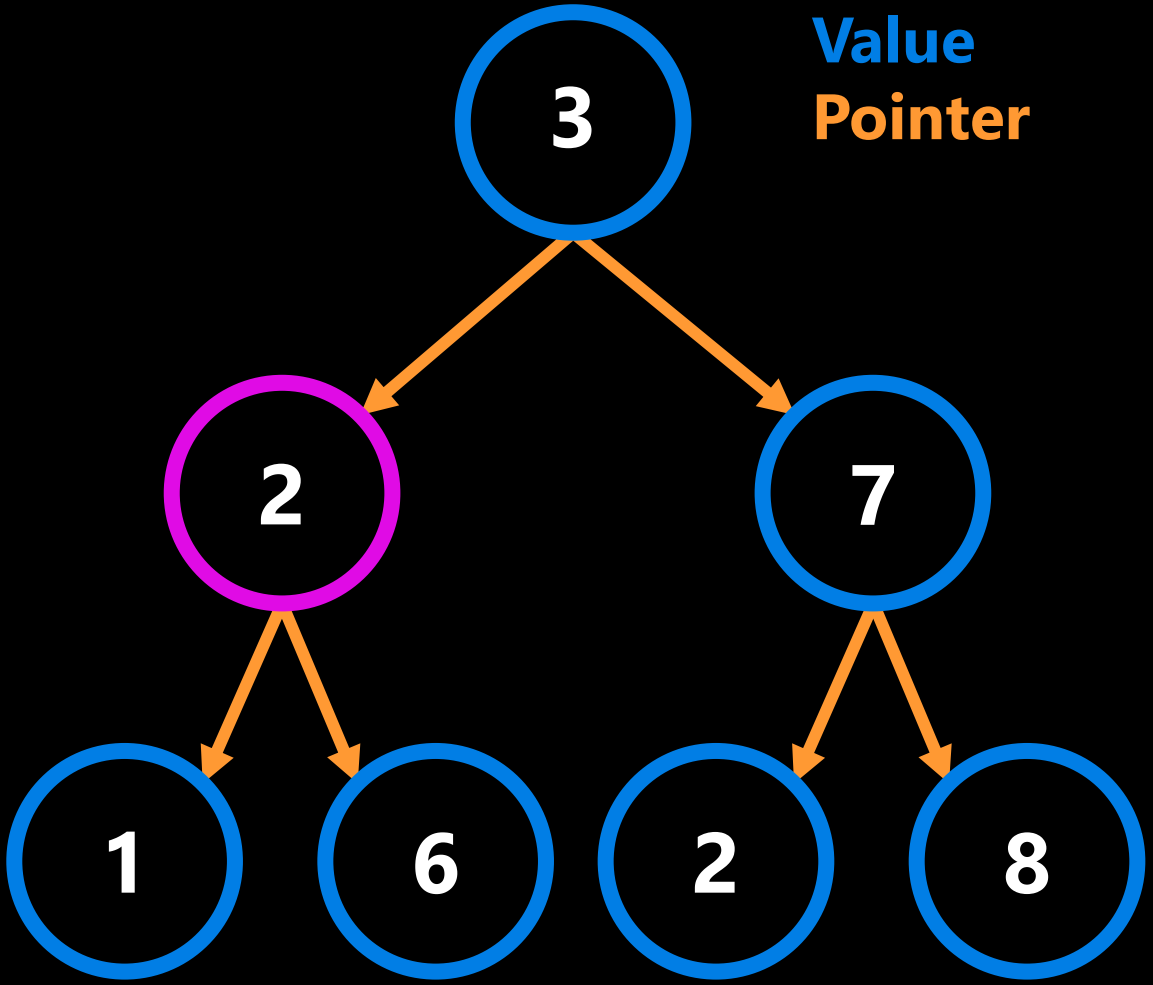


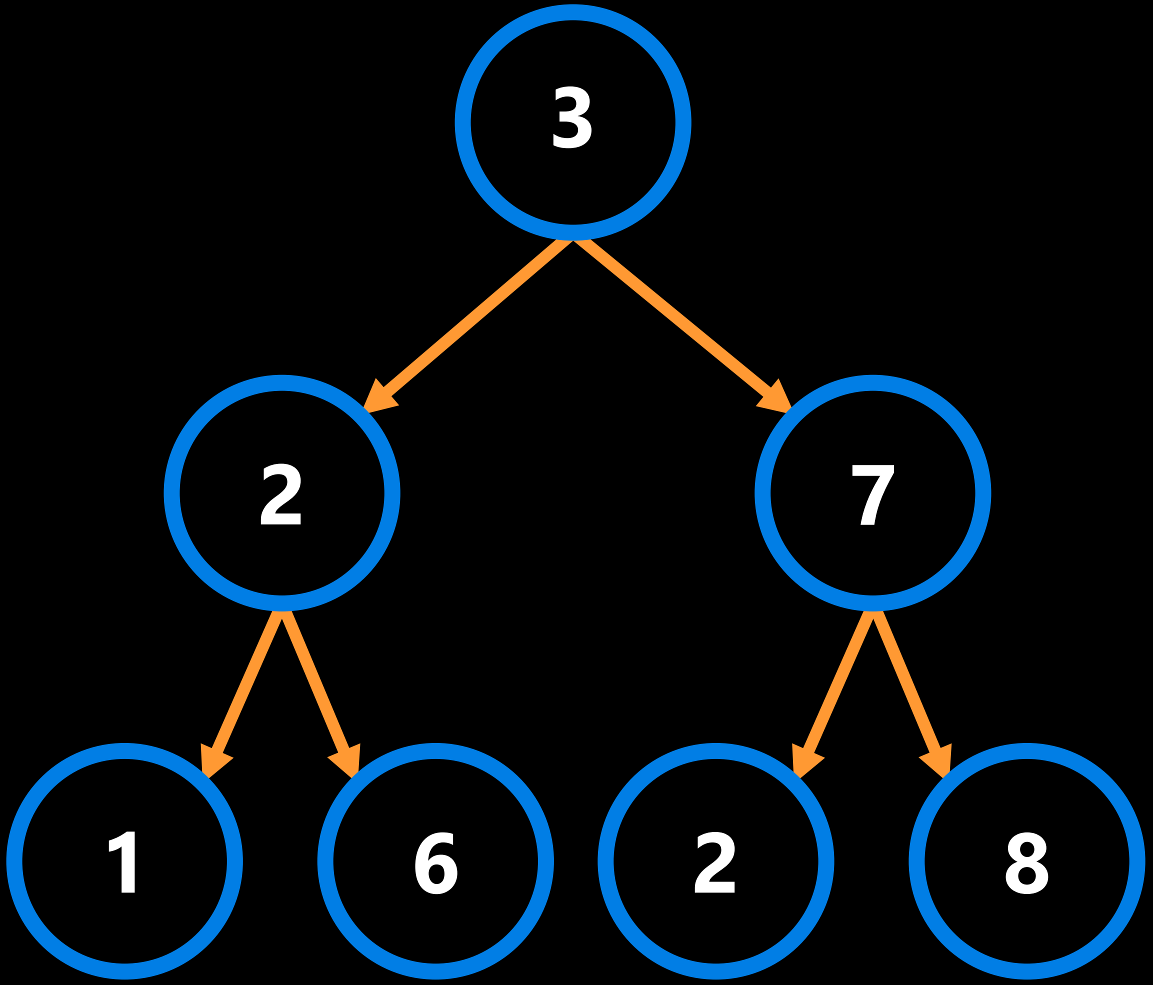
Trees

- Node 2 is a child of Node 3 and a parent of Node 1 and Node 6.
- Every node can only have one parent but can have many children.



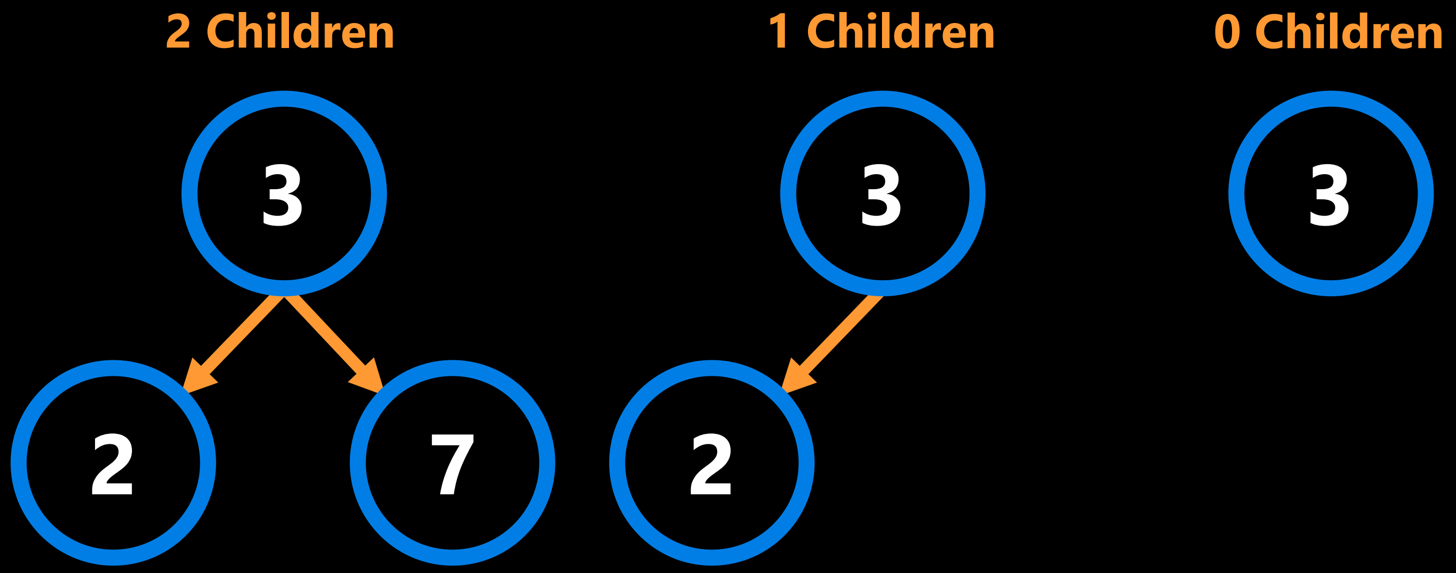
Trees

- There are many different types of trees.
  - Family Trees.
  - Decision Trees.
  - Heaps.
  - Tries.
  - HTML Trees.
  - **Binary Trees (We will focus on these).**



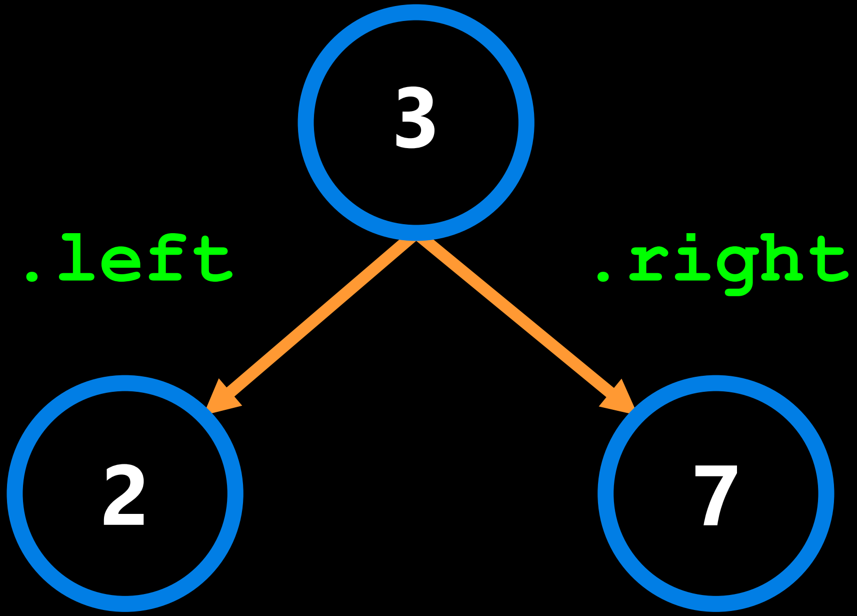
Binary Trees

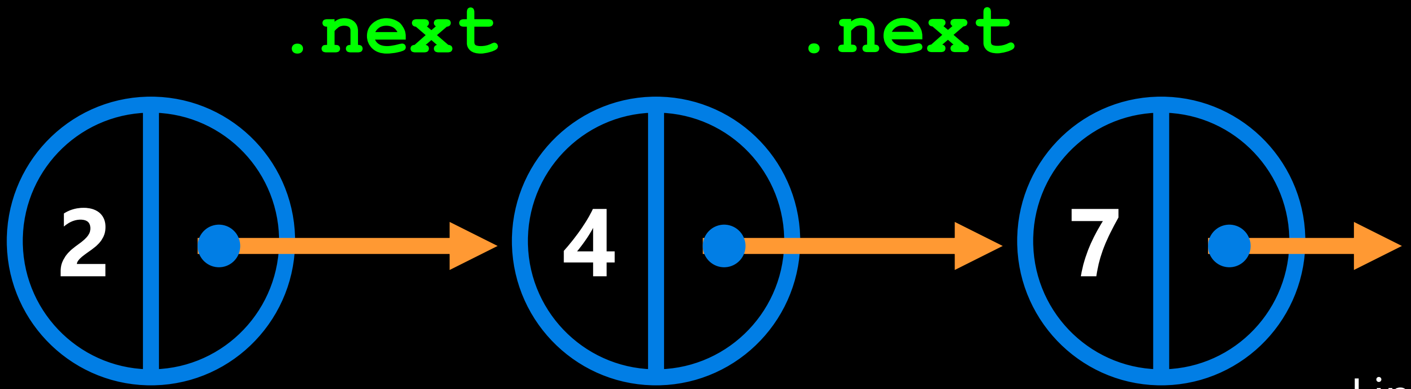
- Main Rule:
  - Each Node can have a maximum of two children (Pointers).
    - **0 Children**
    - **1 Children**
    - **2 Children**



Binary Trees

- Children are represented using `.left` and `.right`.

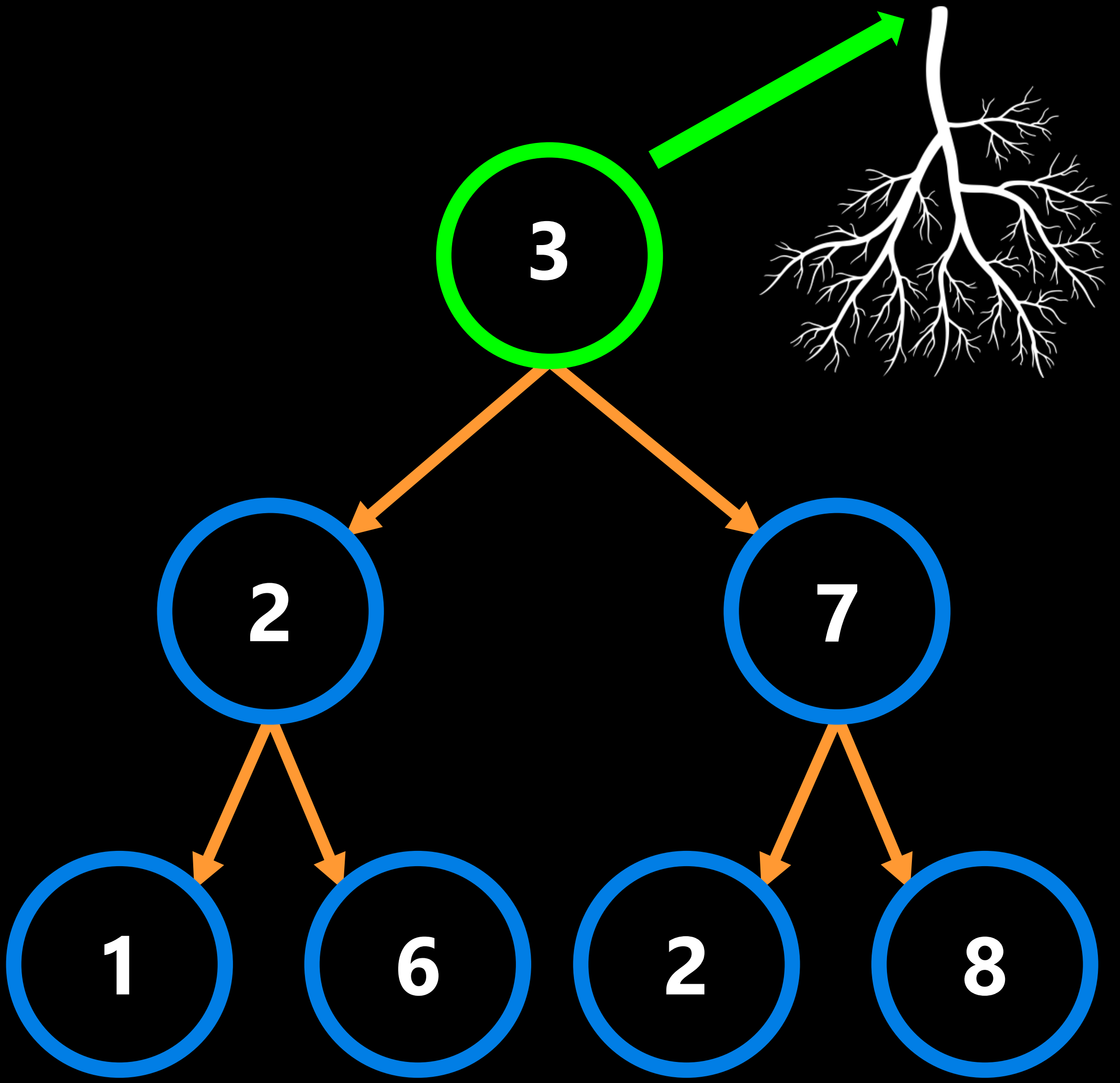




Linked list for reference.

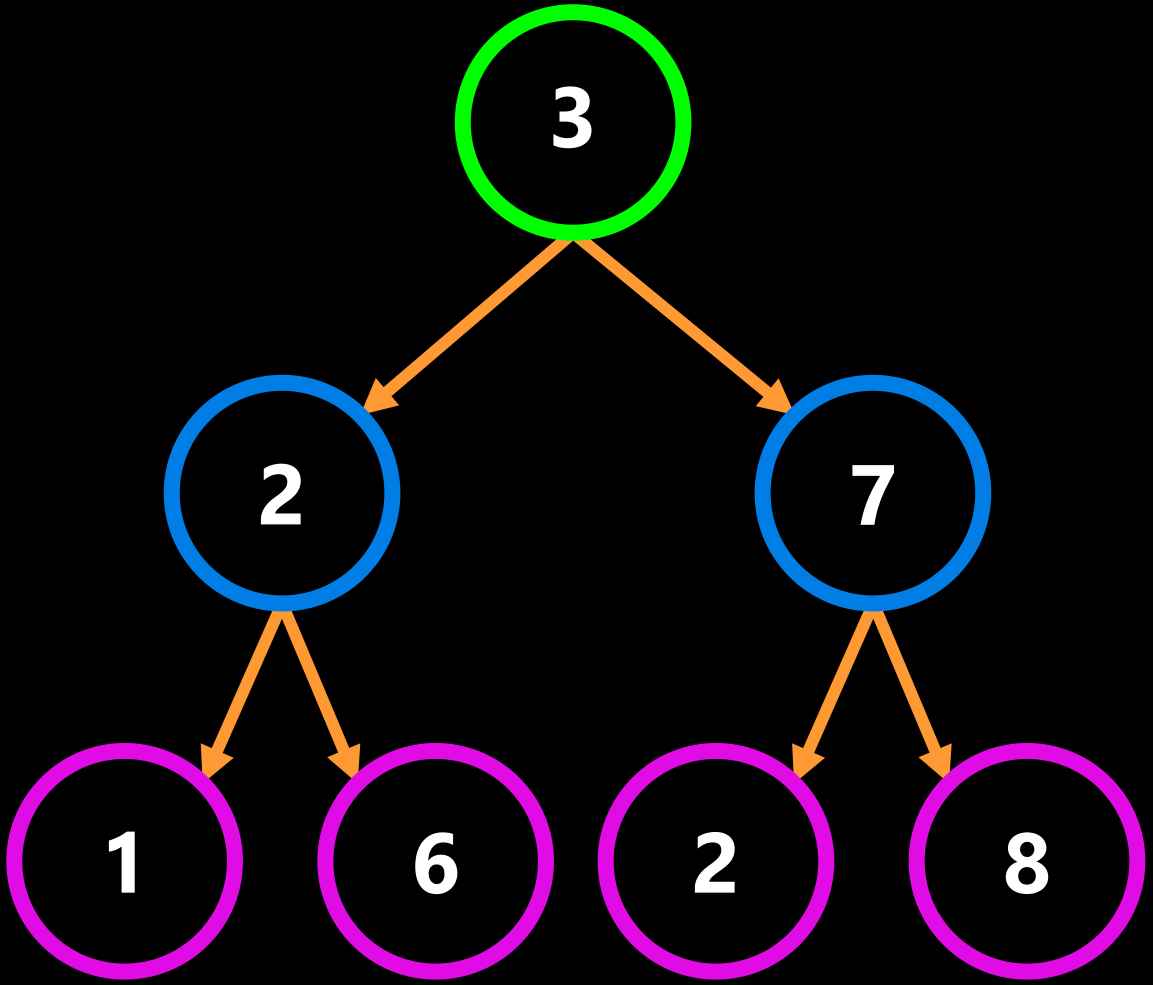
Binary Trees

- **Terminology**
- The top node is called the **root node**.
- Any node without children is called a leaf node.
- The path between the root node and a leaf node is called a branch.



Binary Trees

- **Terminology**
- The top node is called the **root node**.
- Any node without children is called a **leaf node**.
- The path between the root node and a leaf node is called a branch.



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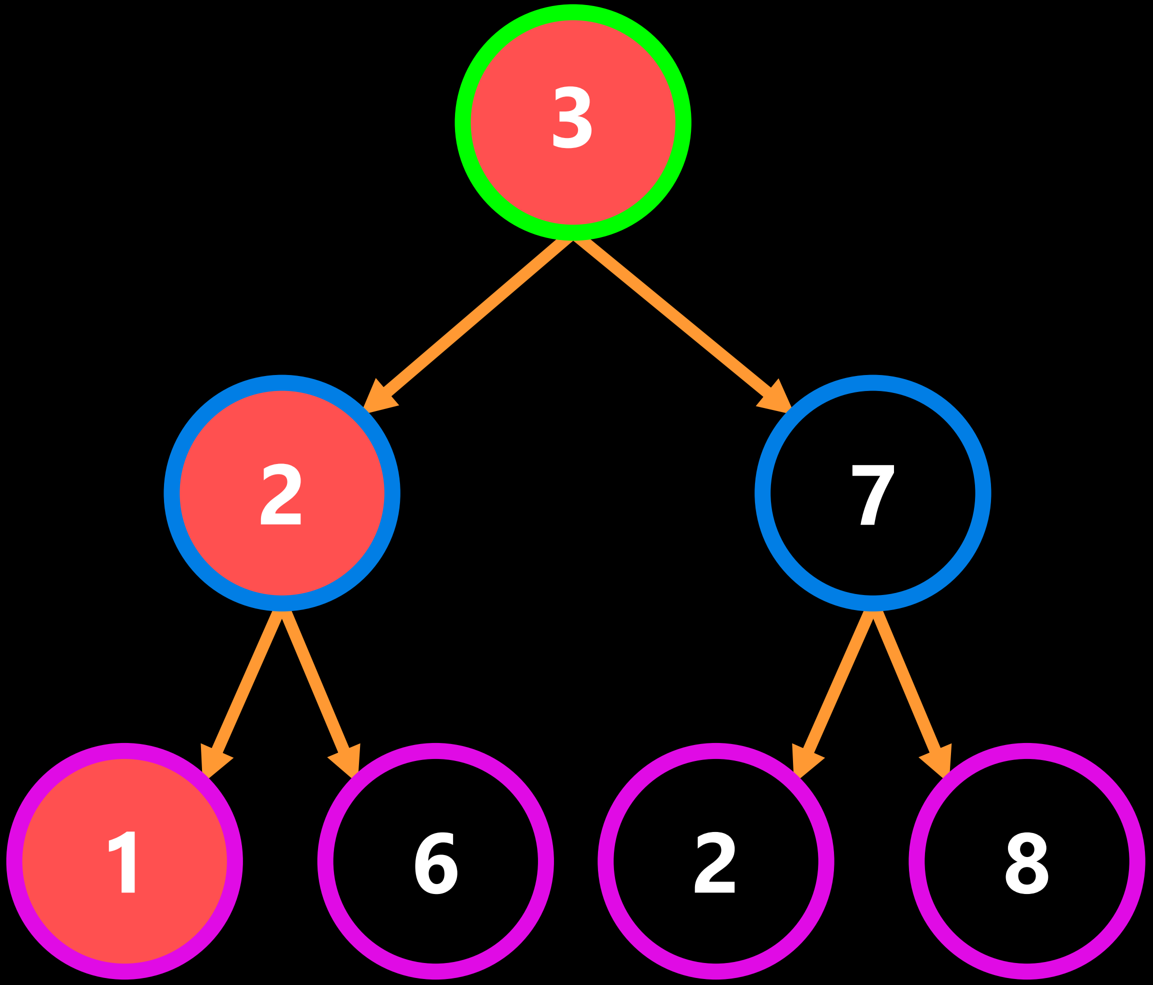

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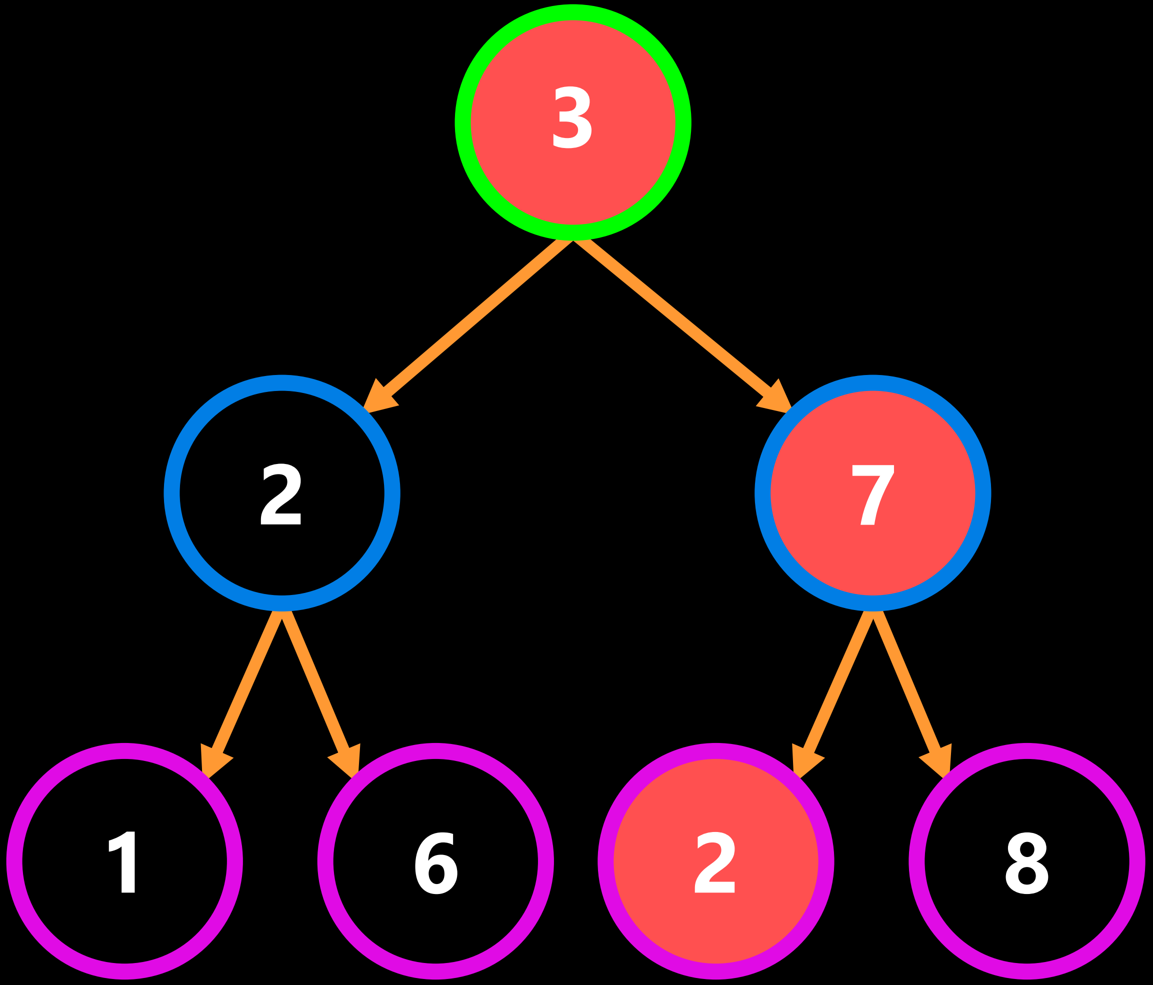
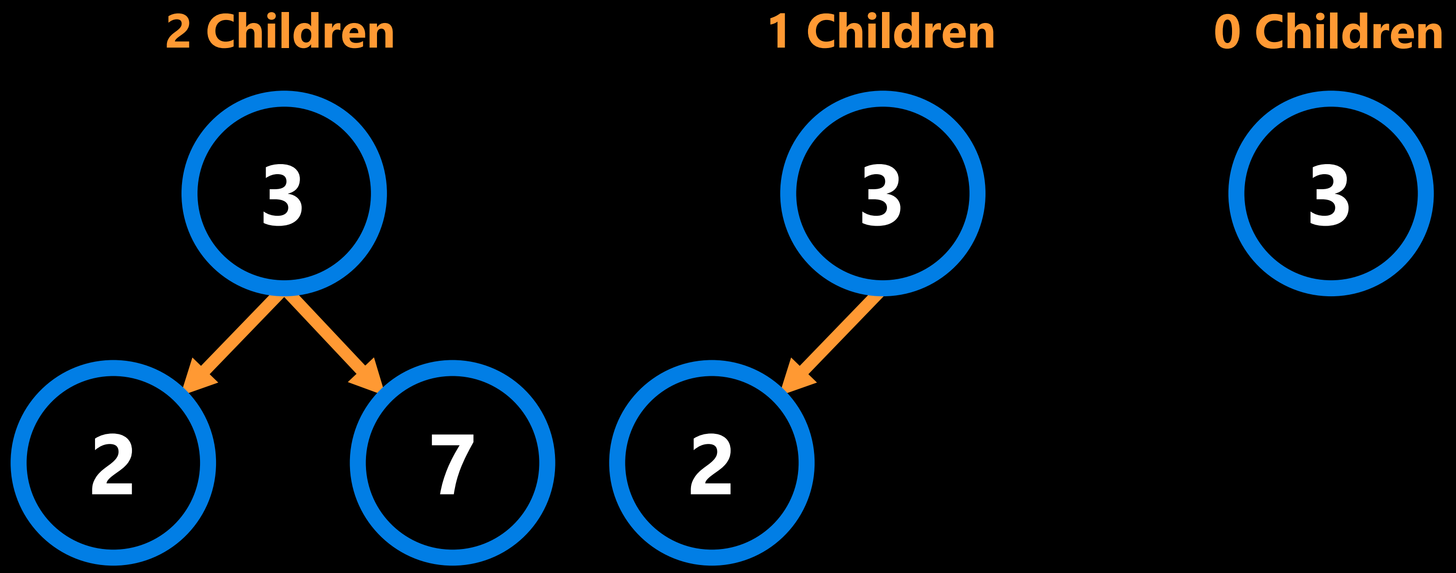


Binary Trees

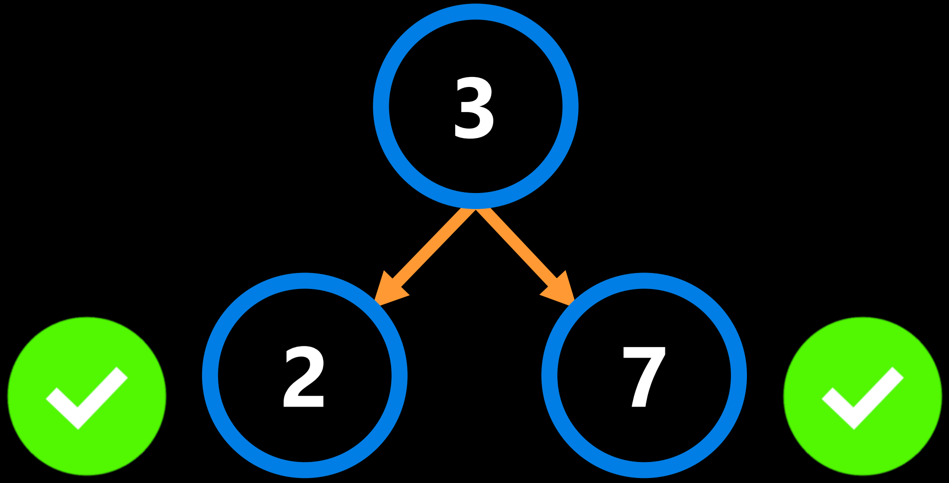
- Main Rule:
  - Each Node can have a maximum of two children (Pointers).
    - **0 Children**
    - **1 Children**
    - **2 Children**



Binary Search Trees

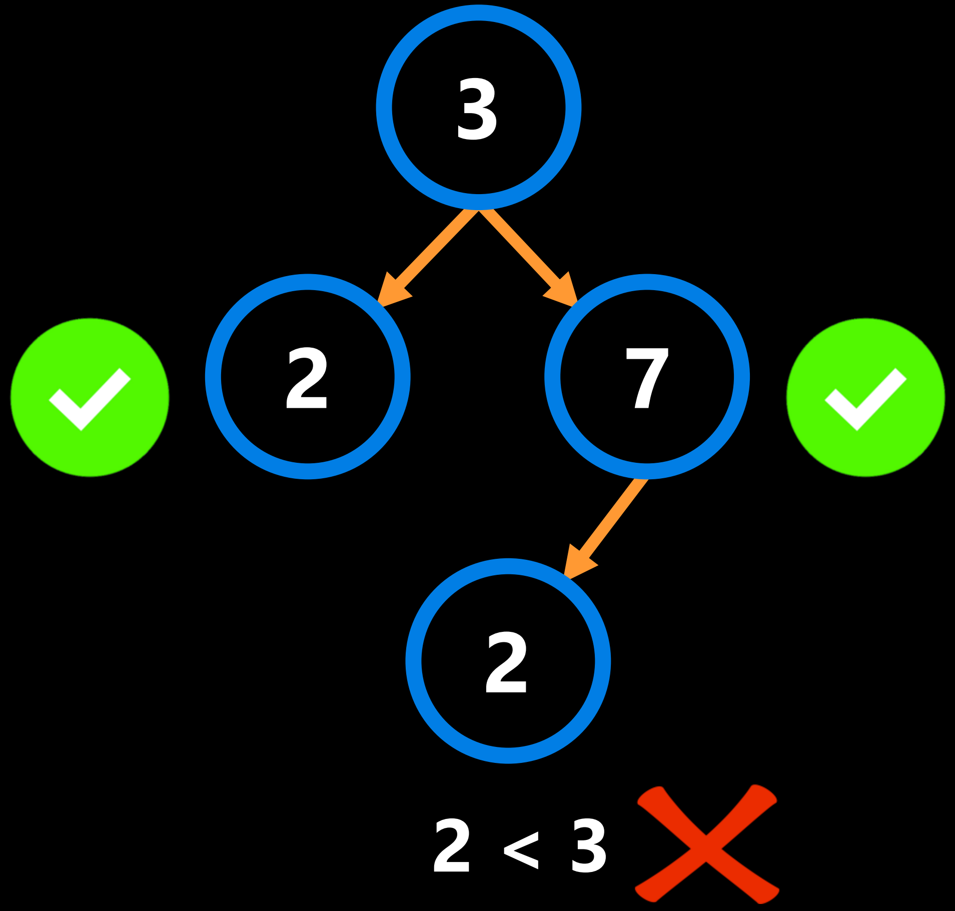
A special case of the binary tree.

- Main Rule:
  - Each Node can have a maximum of two children (Pointers).
    - 0 Children
    - 1 Children
    - 2 Children
  - `node.cargo` must be more than `node.left.cargo` and less than `node.right.cargo`.
    - 3 > 2
    - 3 < 7



Binary Search Trees

- Main Rule:
  - Each Node can have a maximum of two children (Pointers).
    - **0 Children**
    - **1 Children**
    - **2 Children**
  - `node.cargo` must be more than `node.left.cargo` and less than `node.right.cargo`.
    - **3 > 2**
    - **3 < 7**
  - This rule must be true for the entire tree.
    - Everything to the right of 3 must be greater than 3.



The Binary Search Tree Class

- Let's check out the BinarySearchTree class functionality.

Open your notebook

Click Link:

2. BinarySearchTree Class

Let's try with a valid binary search tree.

```
class BinarySearchTree:
    """A Node class used by a binary search tree class."""

    def __init__(self, root=None):
        """
        (self) -> NoneType
        Create an empty binary tree.
        """
        self.root = root

    def print_tree(self): ...

    def is_valid(self):
        """
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        """
        on = self.root
        stack = []
        prev = None

        while len(stack) > 0 or on is not None:

            while on is not None:
                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
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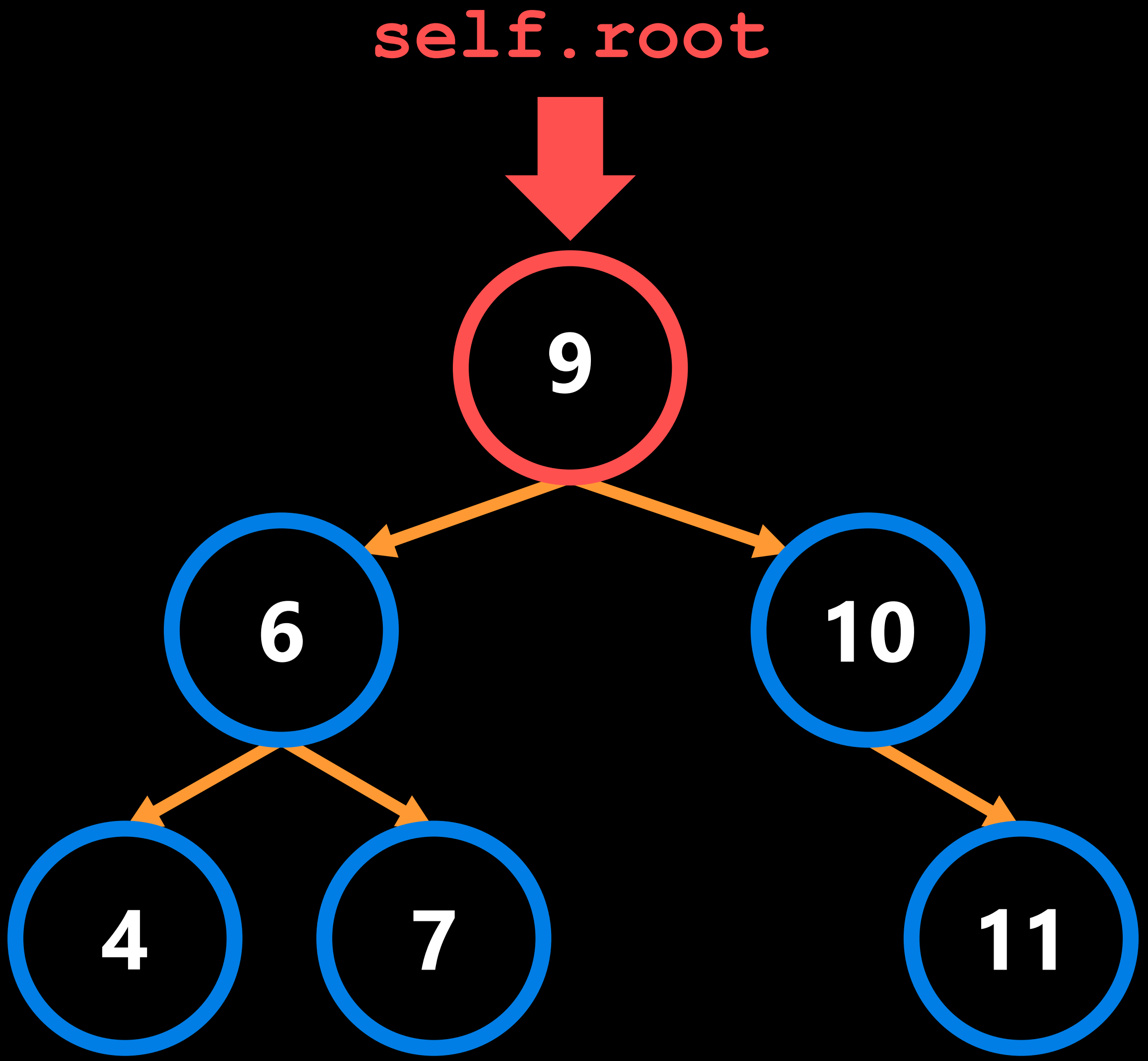
            prev = on
            on = on.right

        return True
```

This is a Valid Tree



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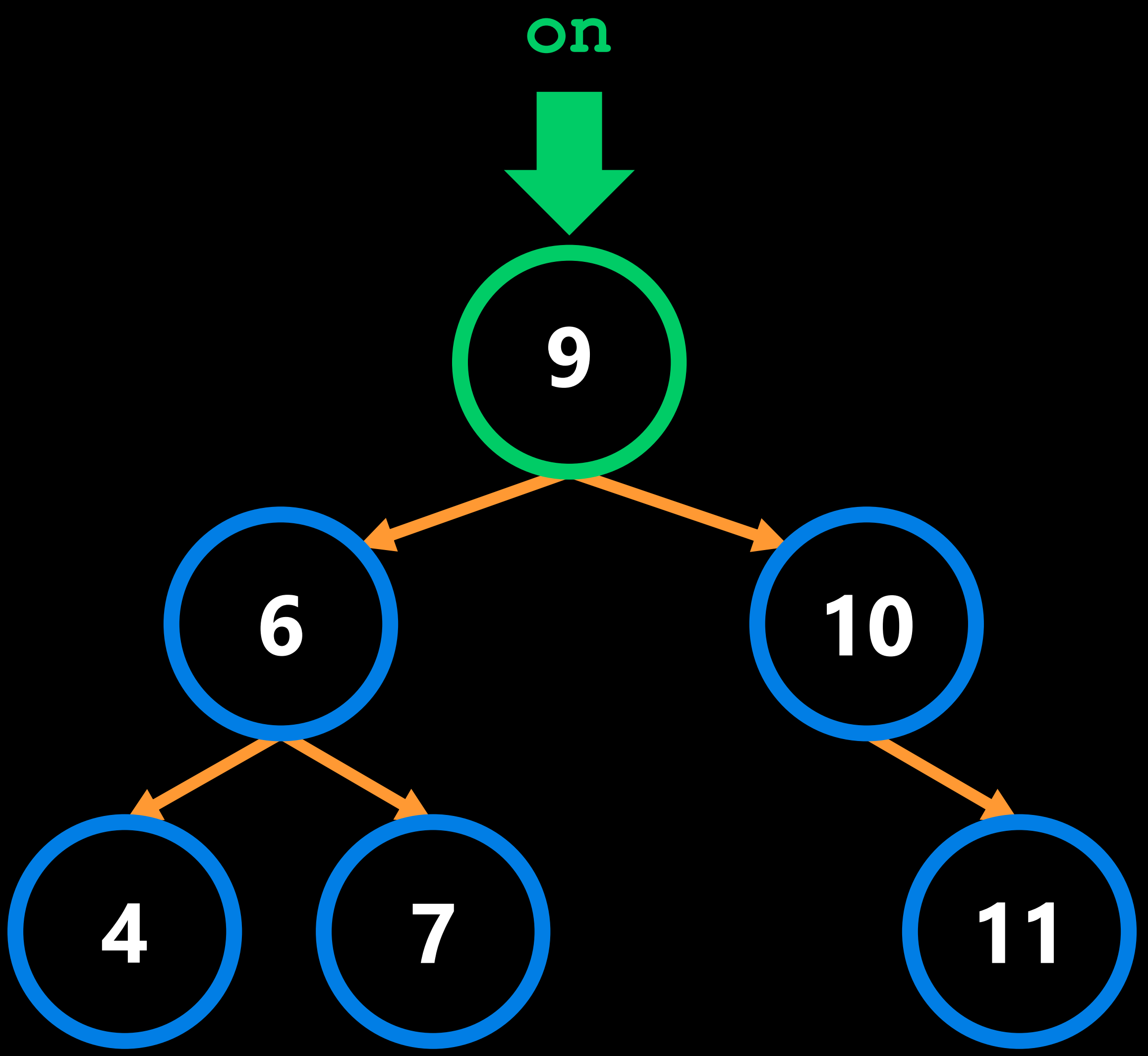
```

Set on position.



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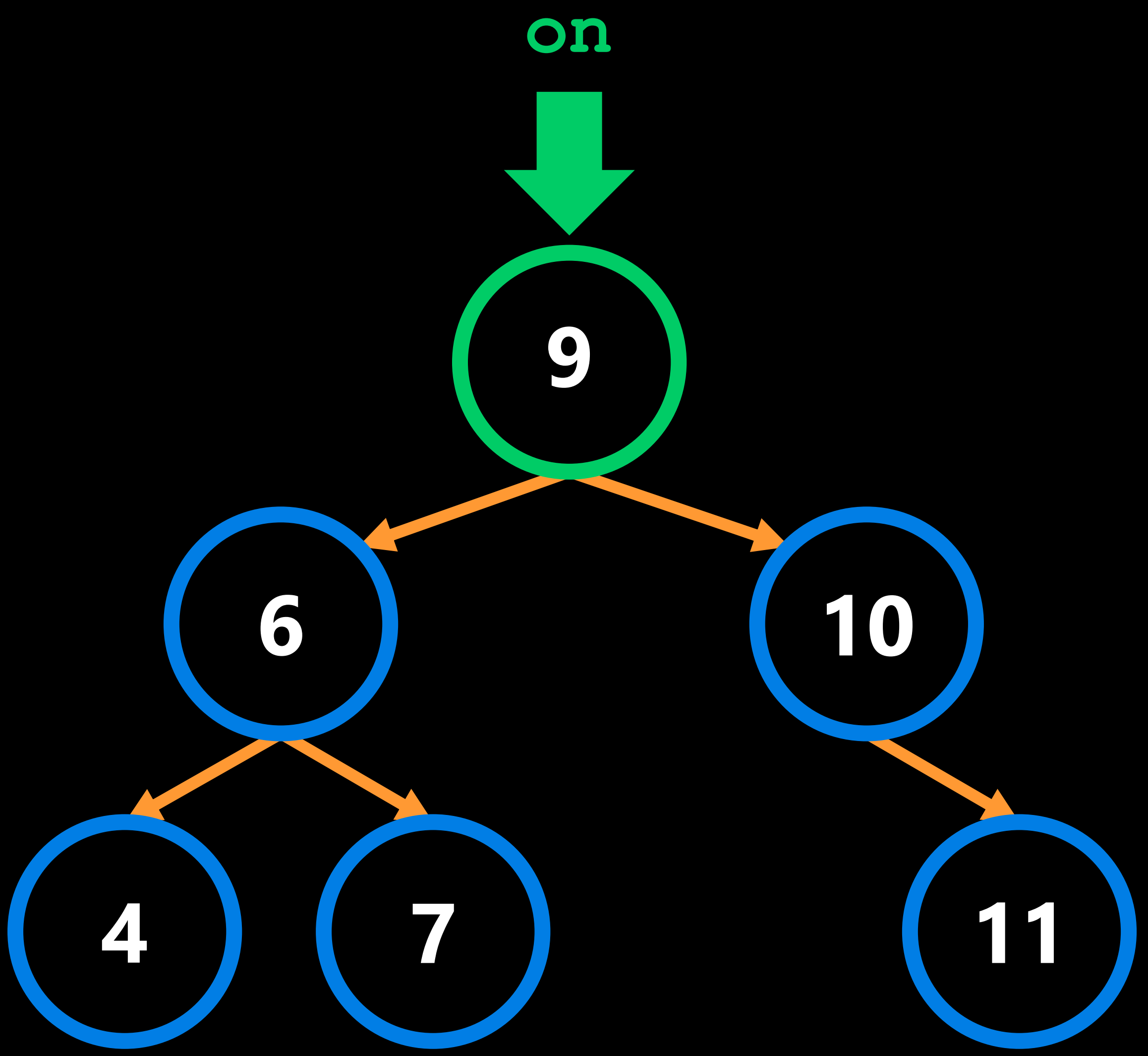
            on = on.right

        return True
```

Create stack list.

stack = [ ]



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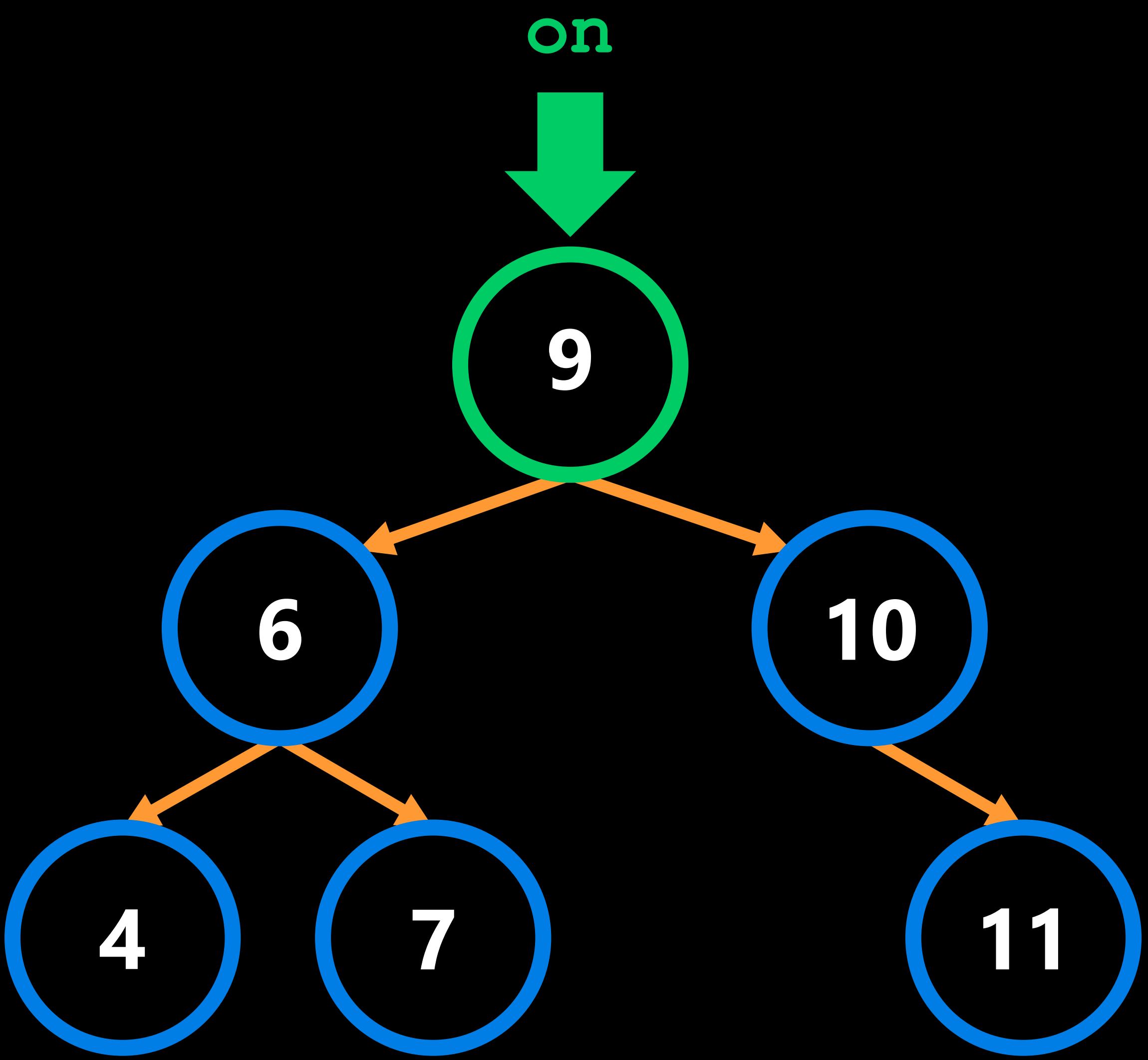
```

Initialize previous node.

stack = [ ]



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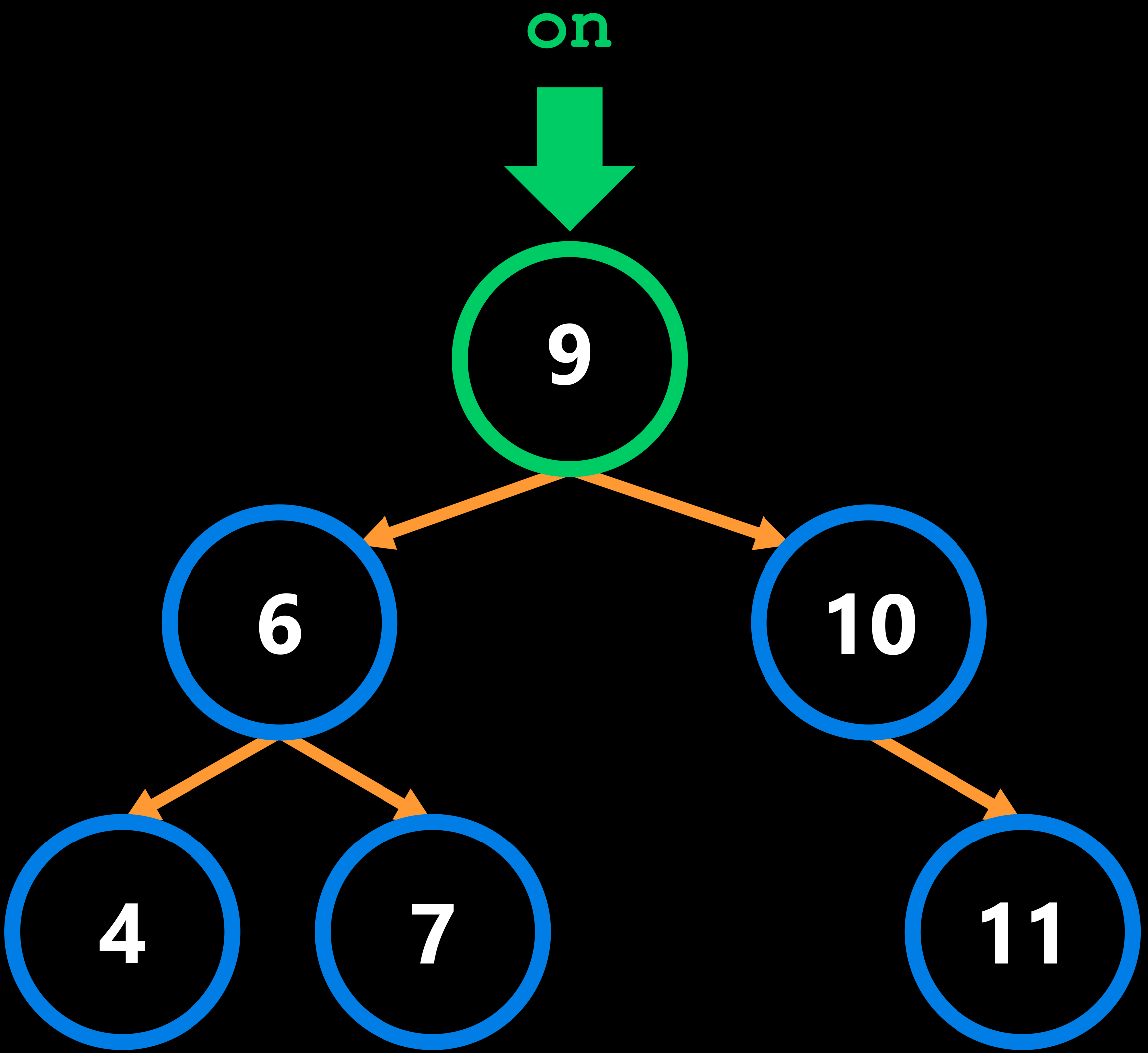
        return True
```

True

stack = [ ]



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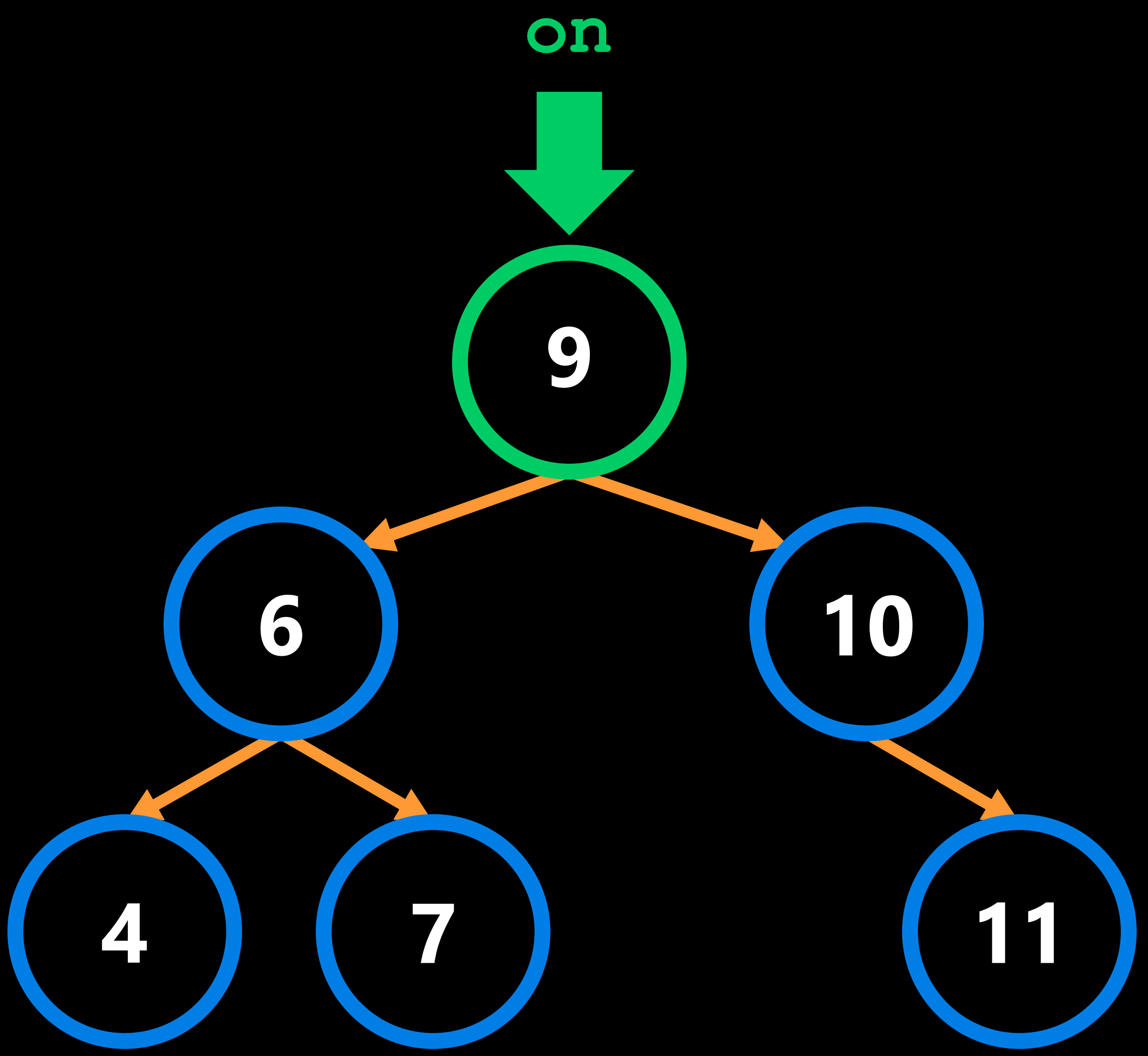
        return True
```

stack = []



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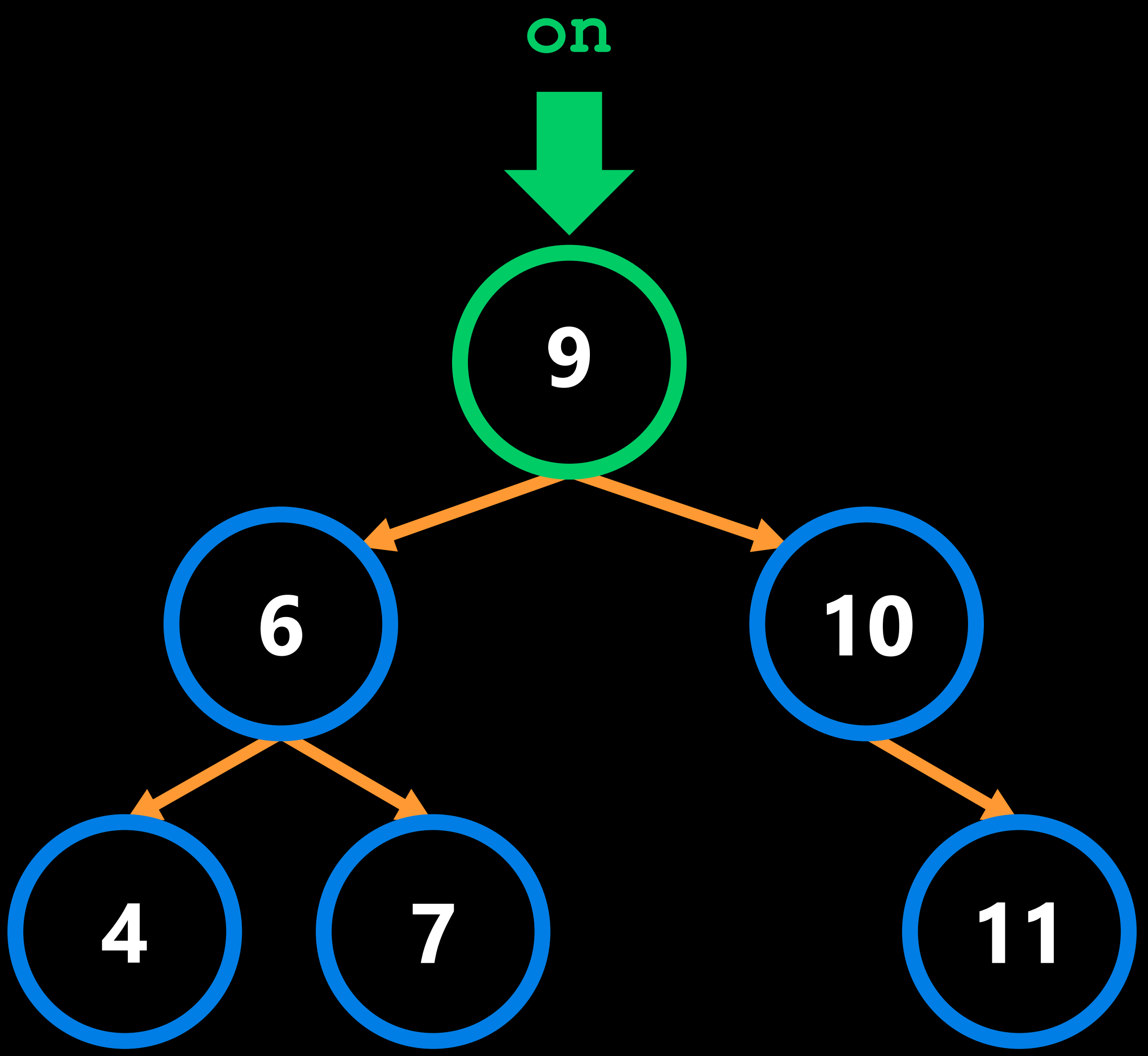
        return True
```

True

True

Add on to stack.

stack = [9]



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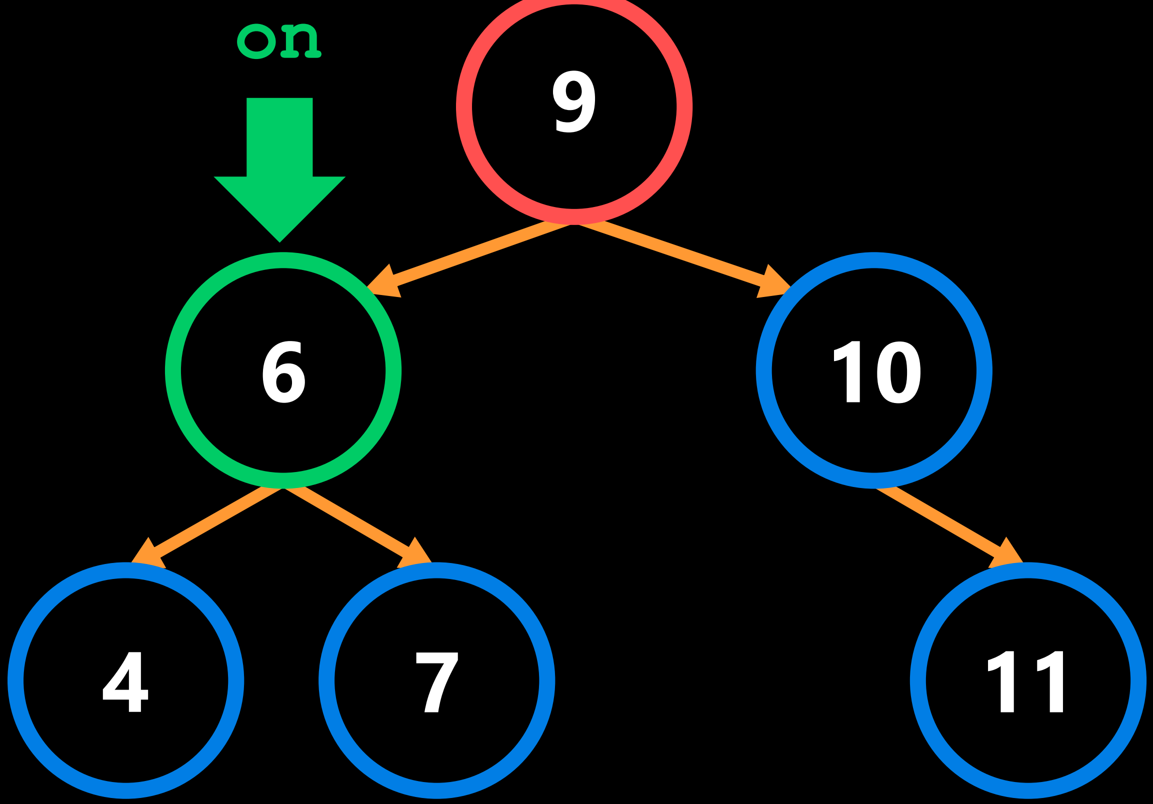
        return True
```

True

True

Move on to left node pointer.

stack = [9]



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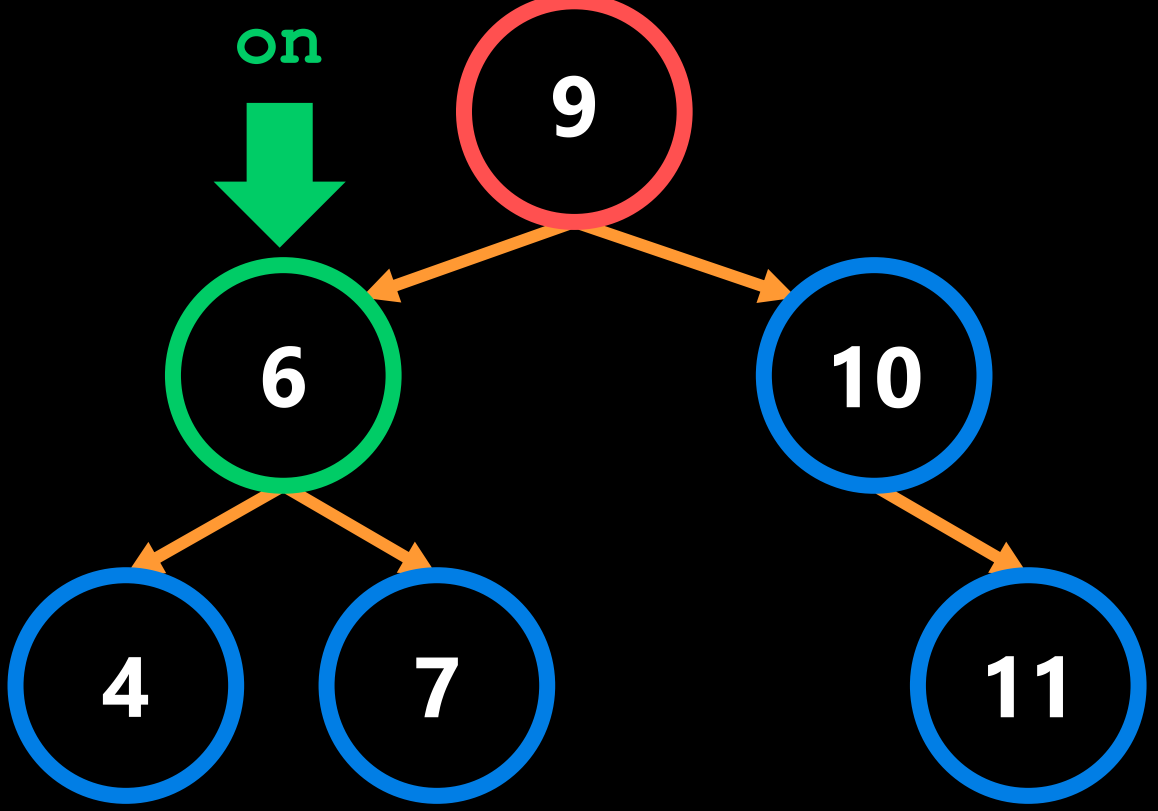
        return True
```

True

True

Add on to stack.

stack = [9 6]



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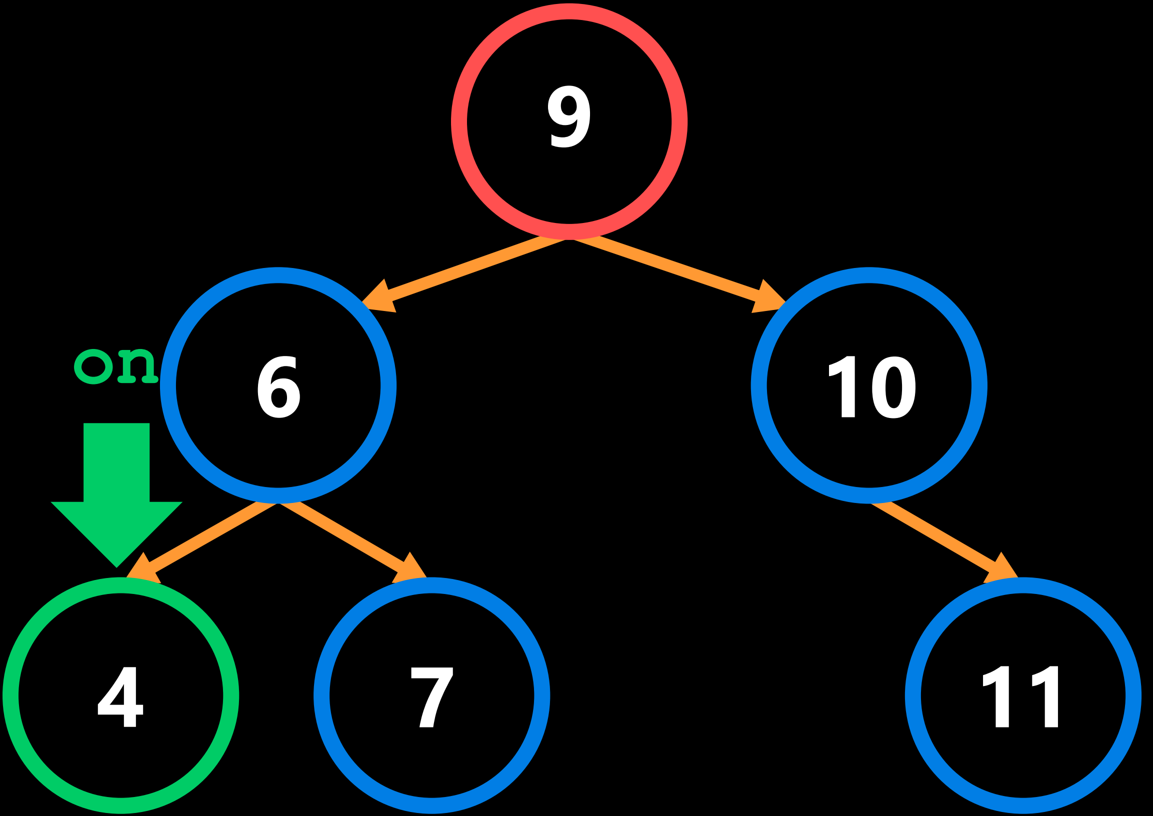
        return True
```

stack = [9 6]

True

True

Move on to left node pointer.



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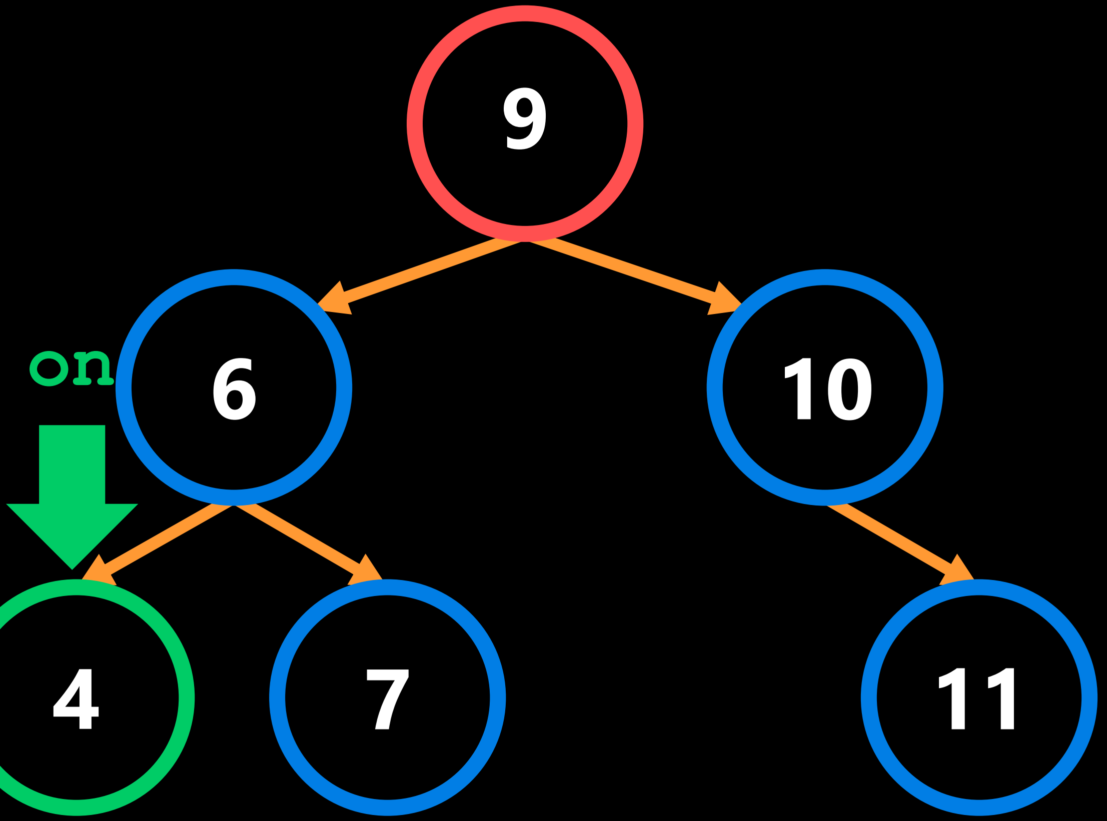
        return True
```

True

True

Add on to stack.

stack = [9 6 4]



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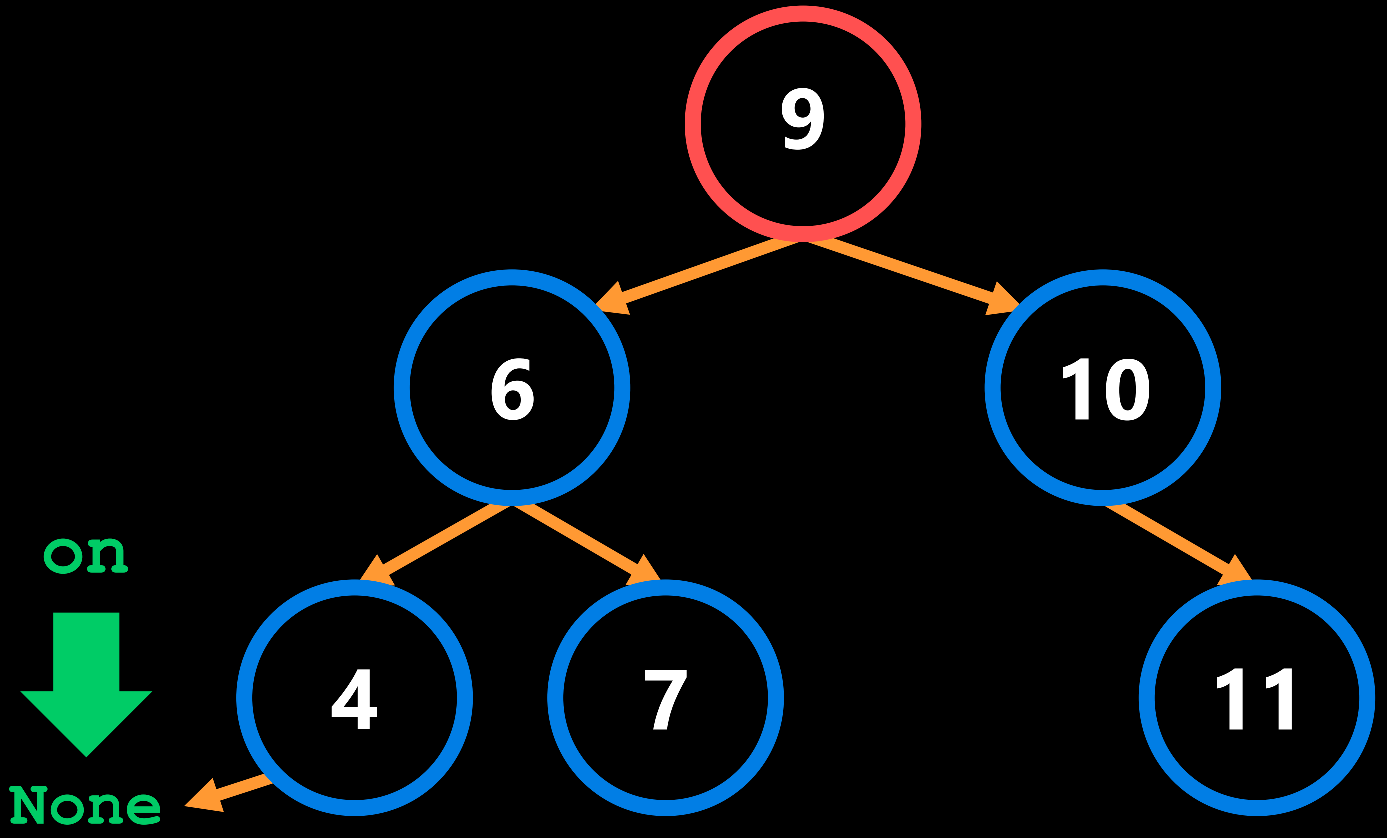
        return True
```

stack = [9 6 4]

True

True

Move on to left node pointer.



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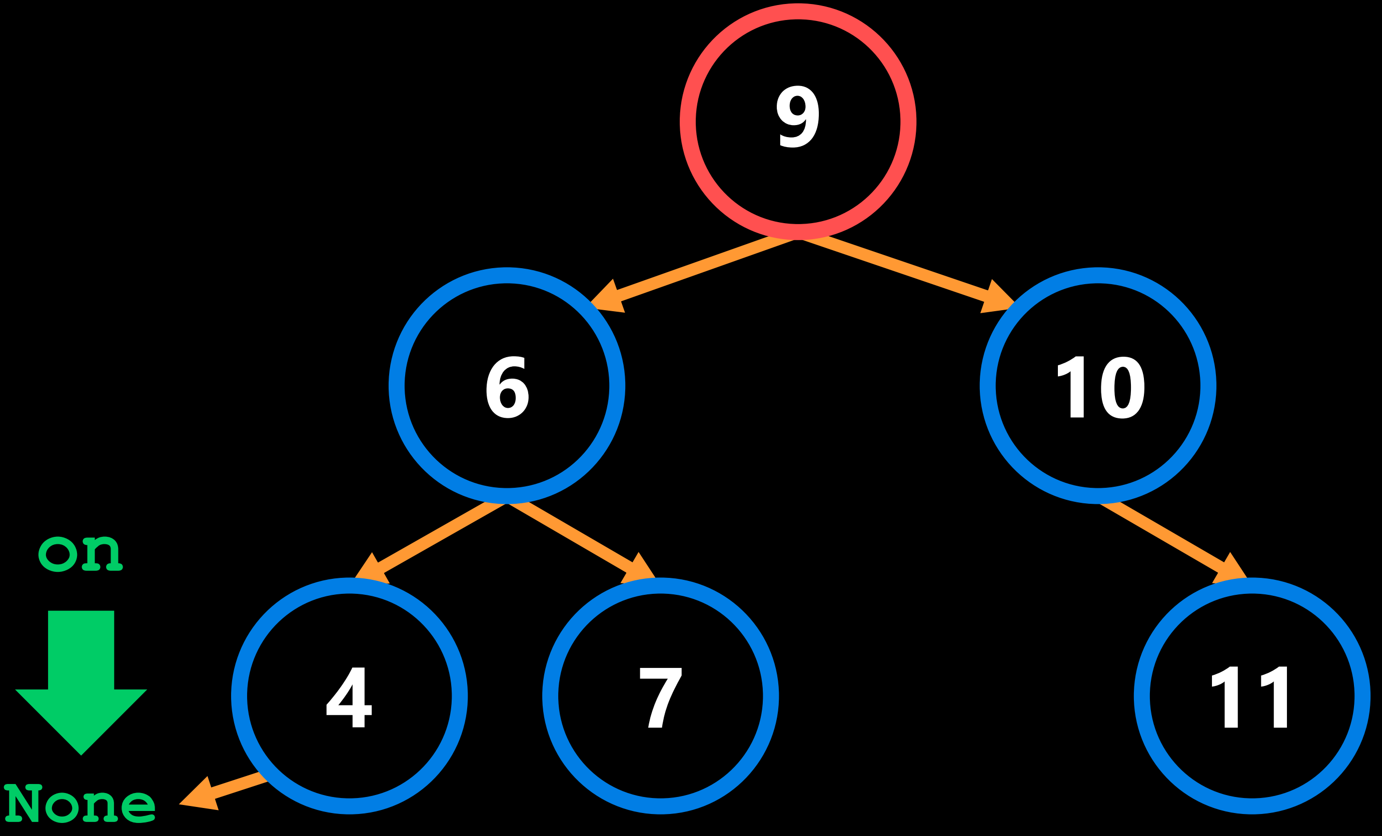
```

stack = [9 6 4]



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
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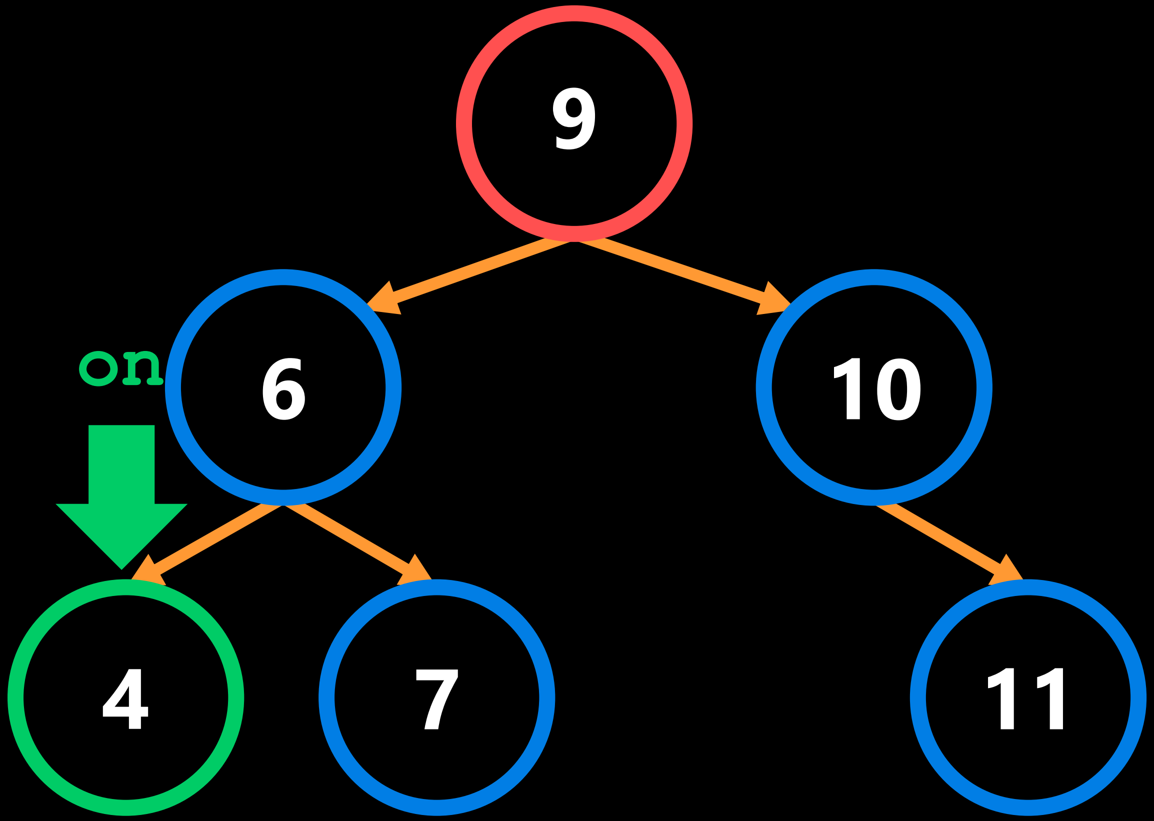
        return True
```

stack = [9 6]

Set on to left node in stack.



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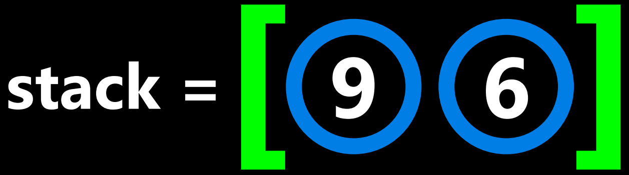

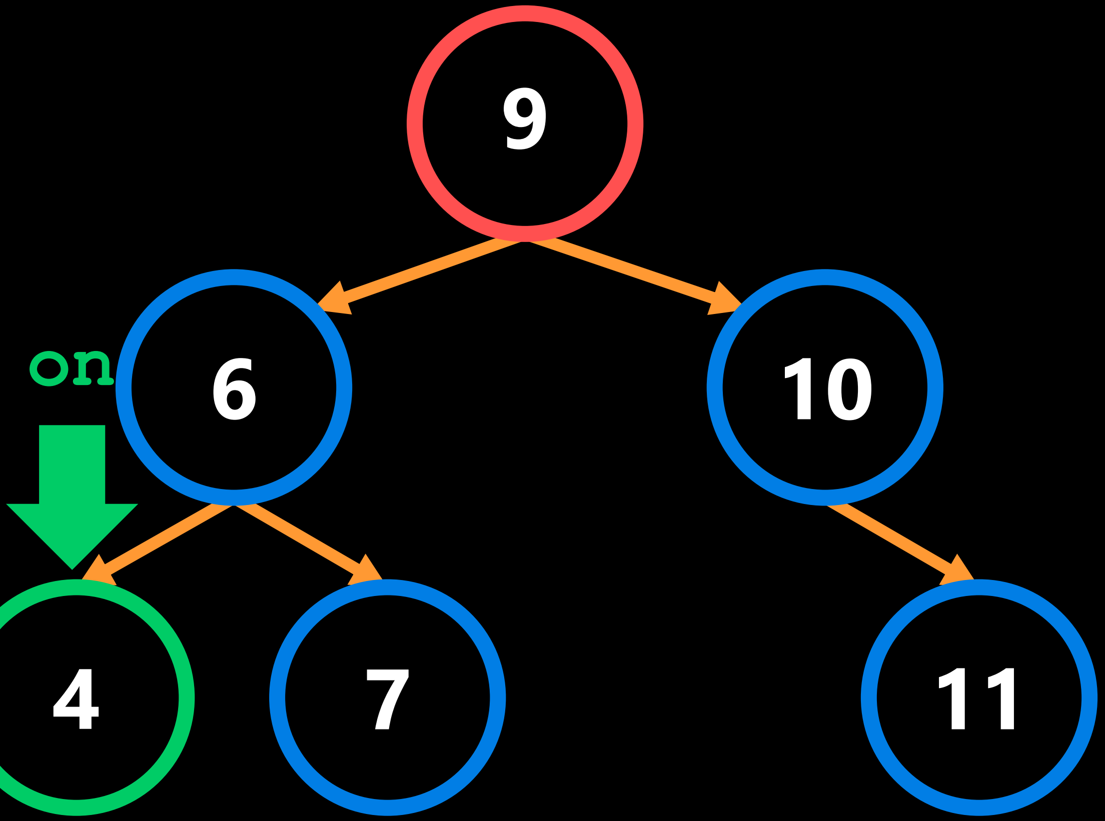

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```

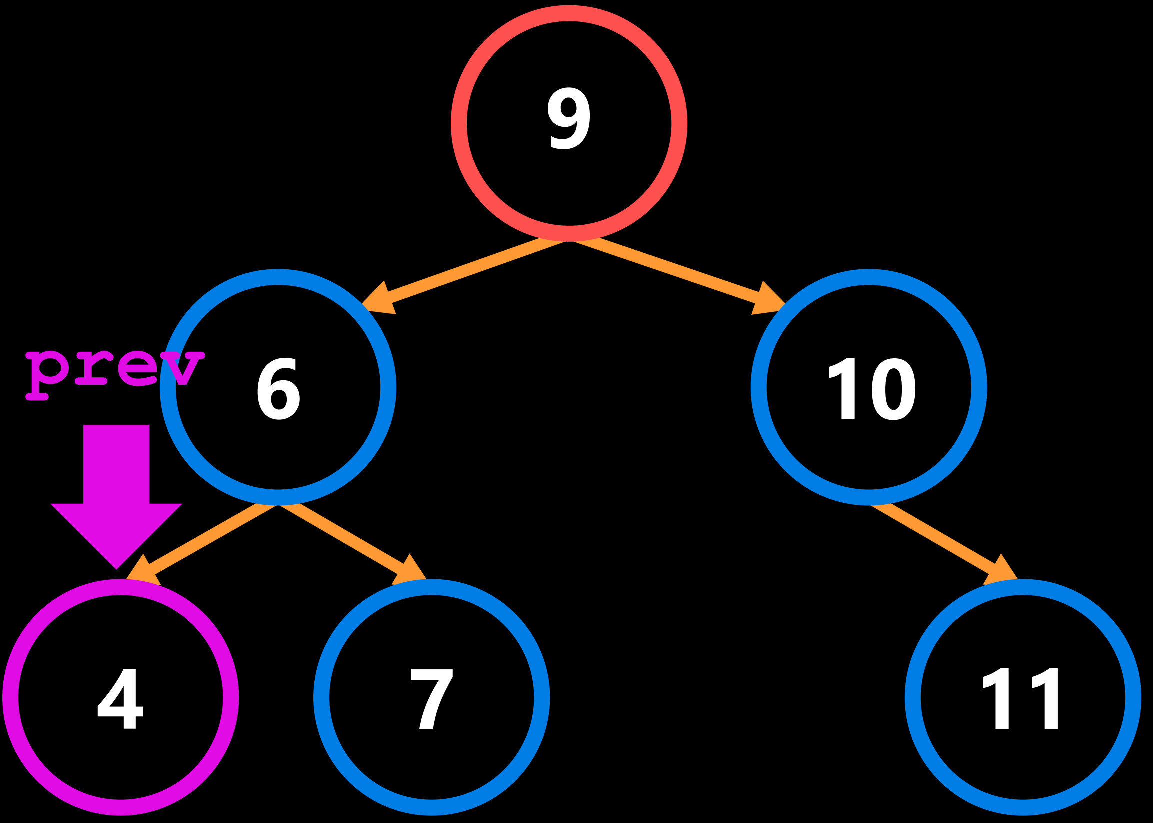
True

False

False

Set prev to on.

stack = [9 6]



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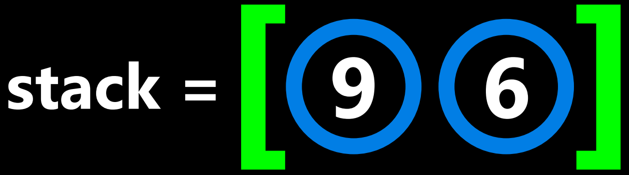
```

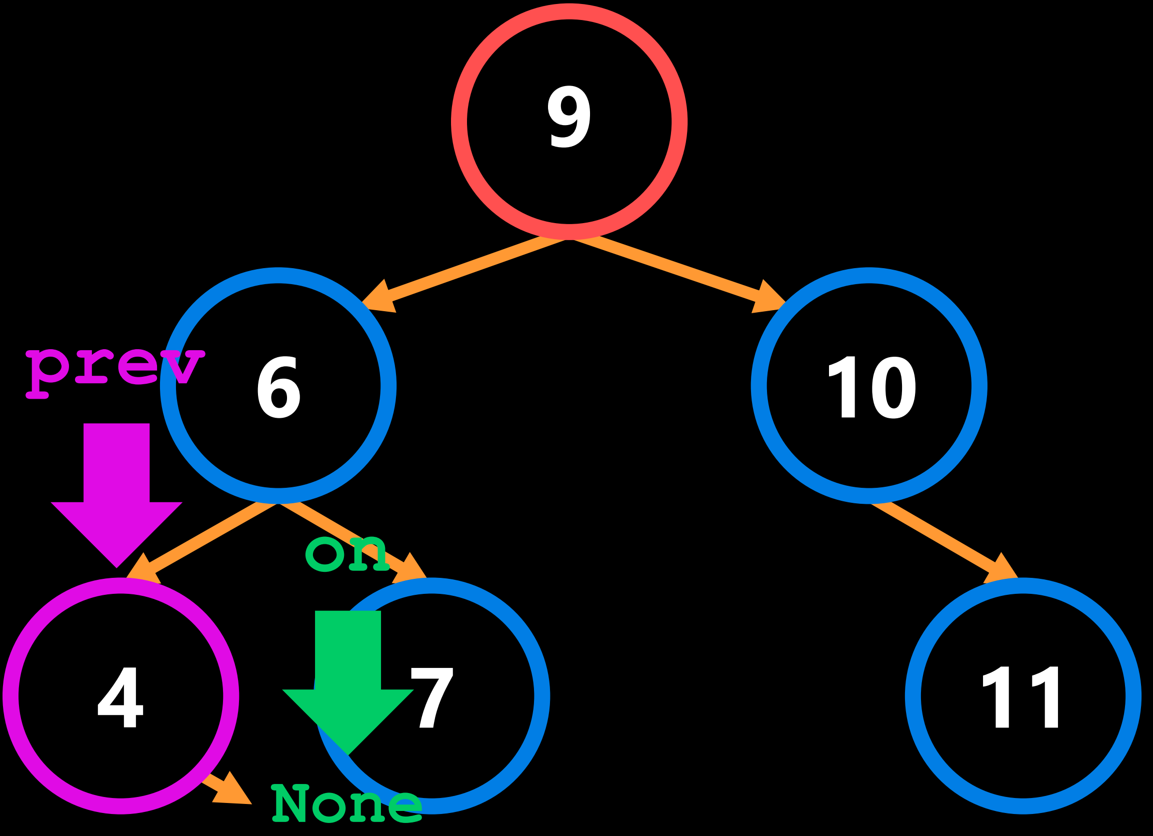
True

False

False

Move **on** to the right pointer.





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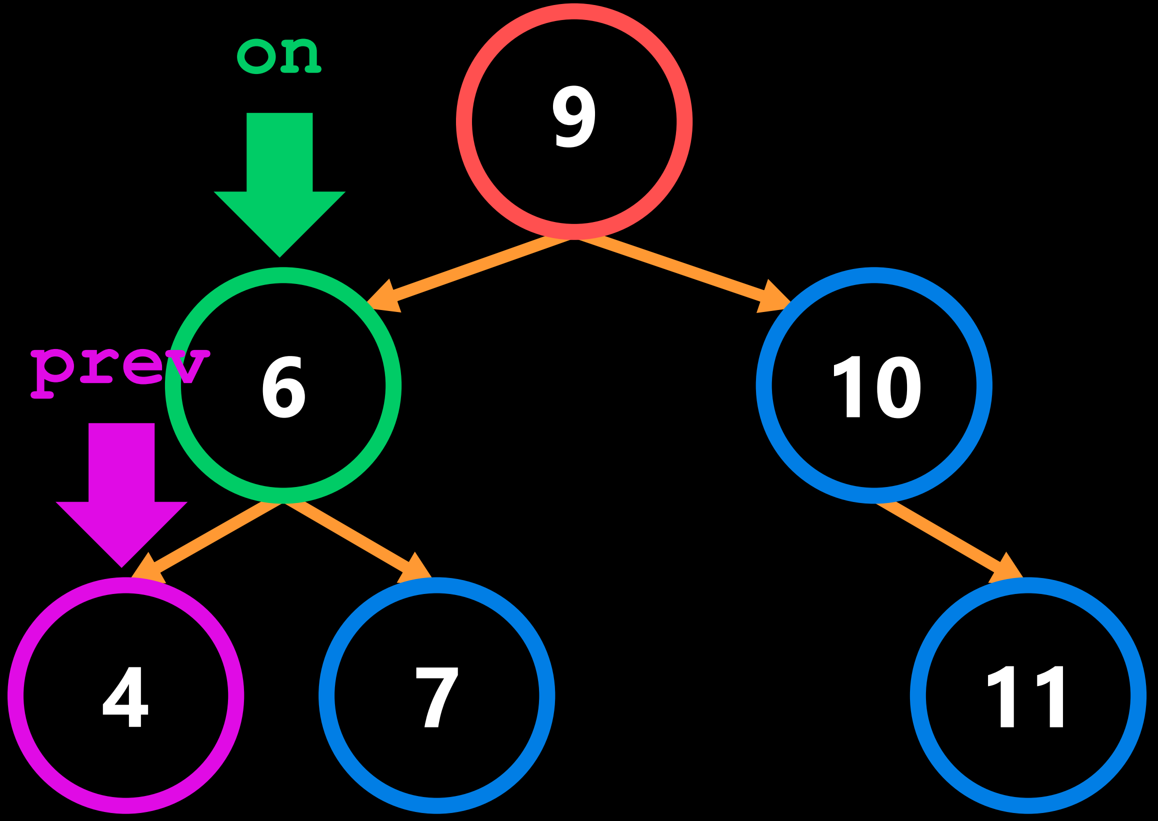
        return True
```

stack = [9]

True

False

Set on to left node in stack.



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        while len(stack) > 0 or on is not None:  ← True

            while on is not None:  ← False
                stack.append(on)
                on = on.left

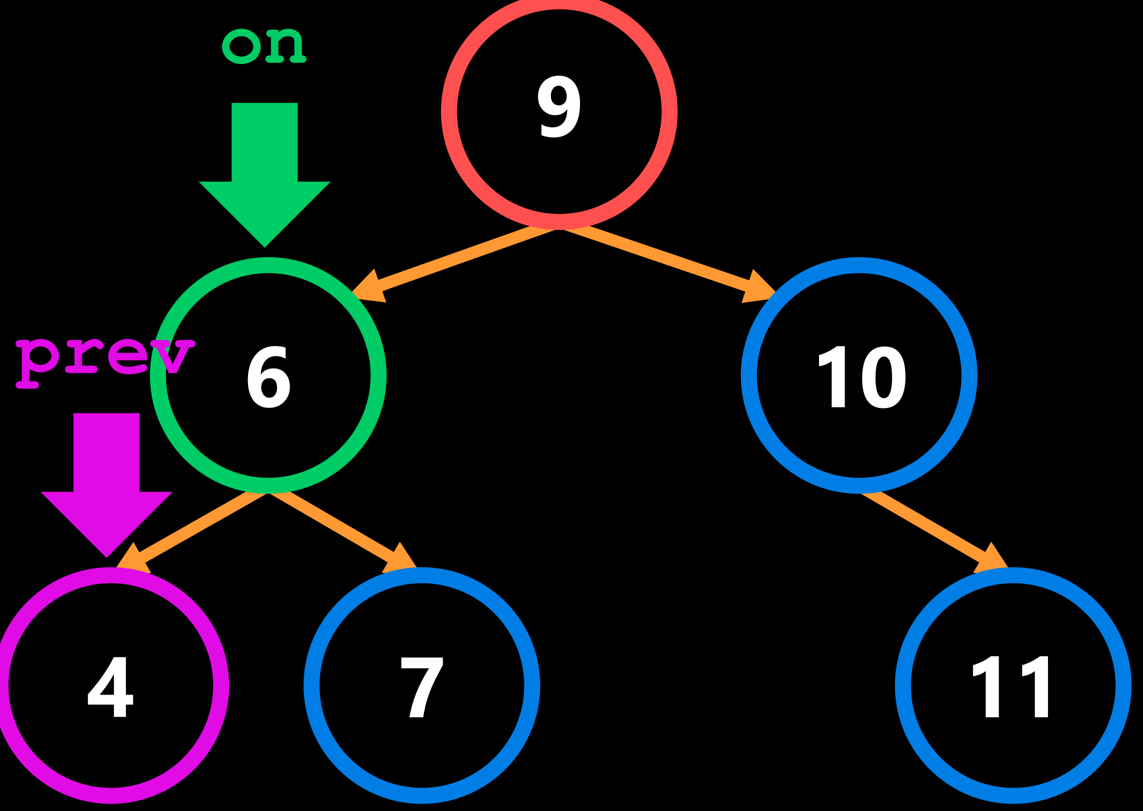
            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:  ← False
                return False

            prev = on
            on = on.right

        return True
```

stack = [9]



```
class BinarySearchTree:
    """A Node class used by a binary search tree class."""

    def __init__(self, root=None):
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        (self) -> NoneType
        Create an empty binary tree.
        """
        self.root = root

    def print_tree(self): ...

    def is_valid(self):
        """
        (self) -> NoneType
        Checks if self.root is a valid binary search tree.
        """
        on = self.root
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        while len(stack) > 0 or on is not None:

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                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

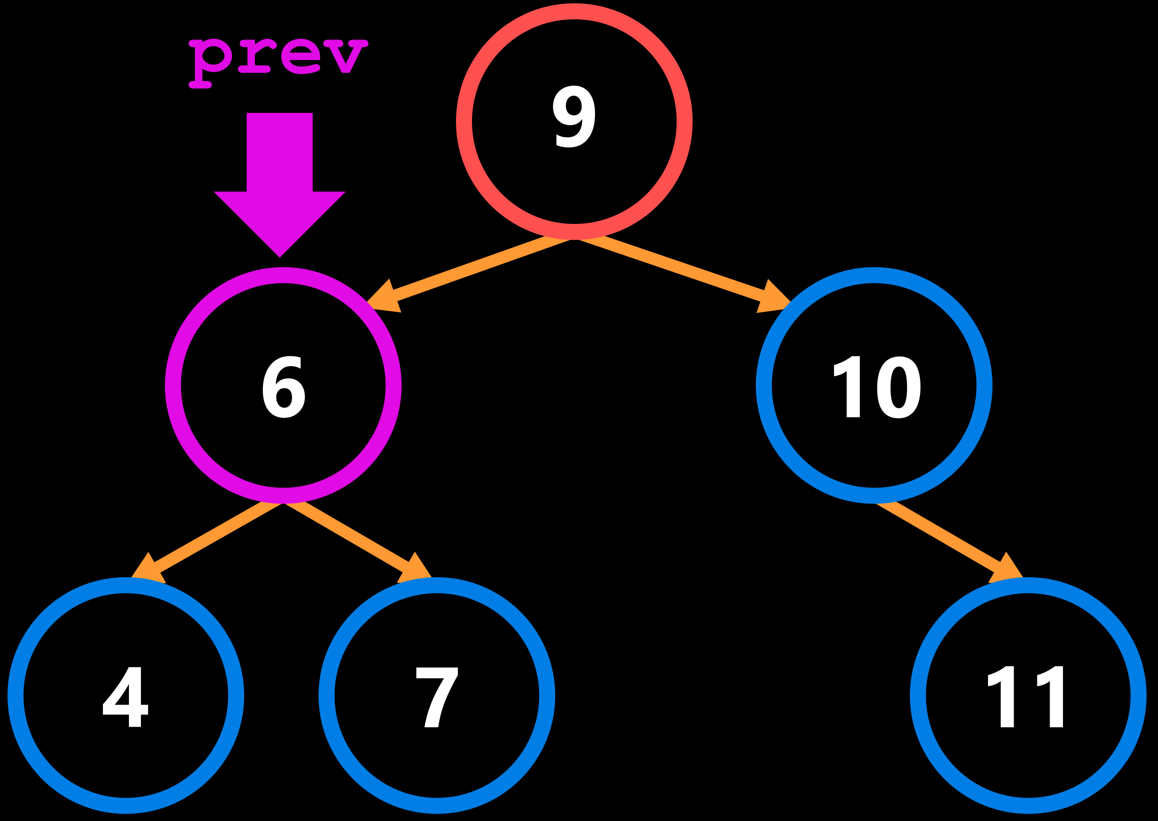
while len(stack) > 0 or on is not None: ← True

while on is not None: ← False

if prev is not None and on.cargo <= prev.cargo: ← False

prev = on ← Set prev to on.

stack = [9]



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                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

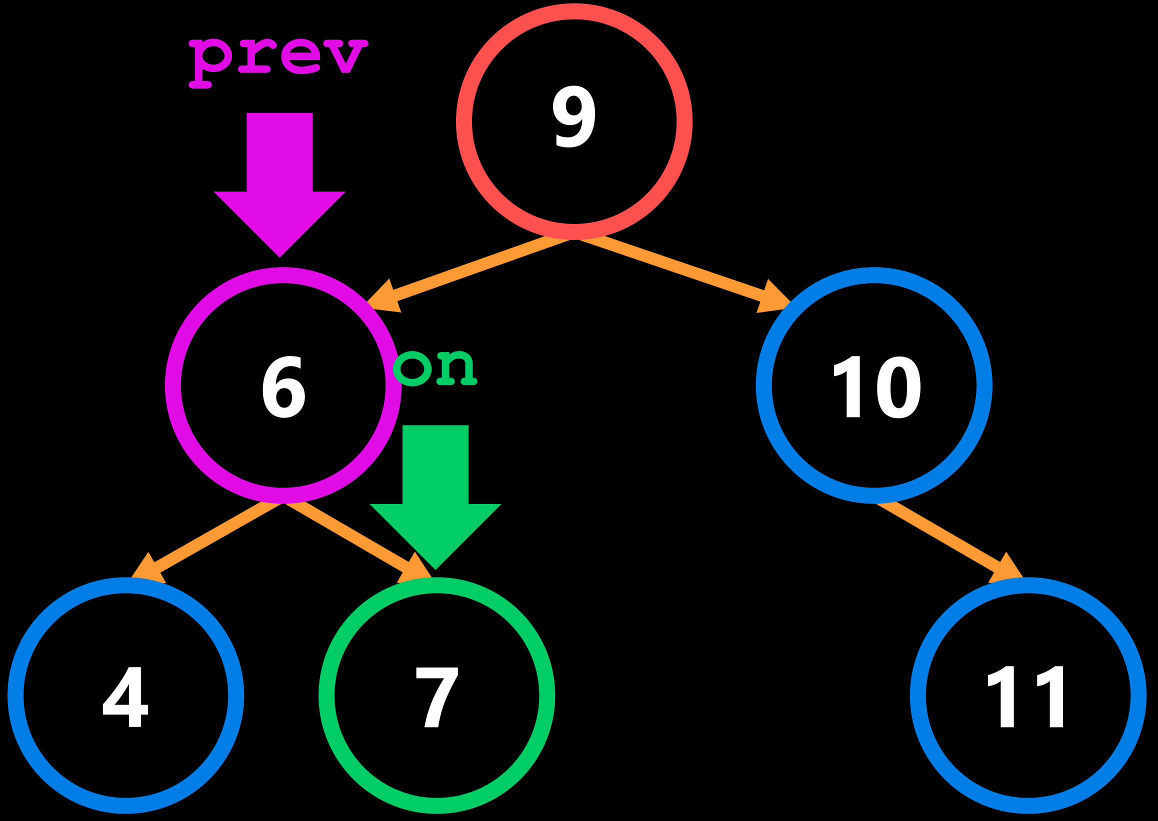
True

False

False

Move on to the right pointer.

stack = [9]



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            on = stack.pop()

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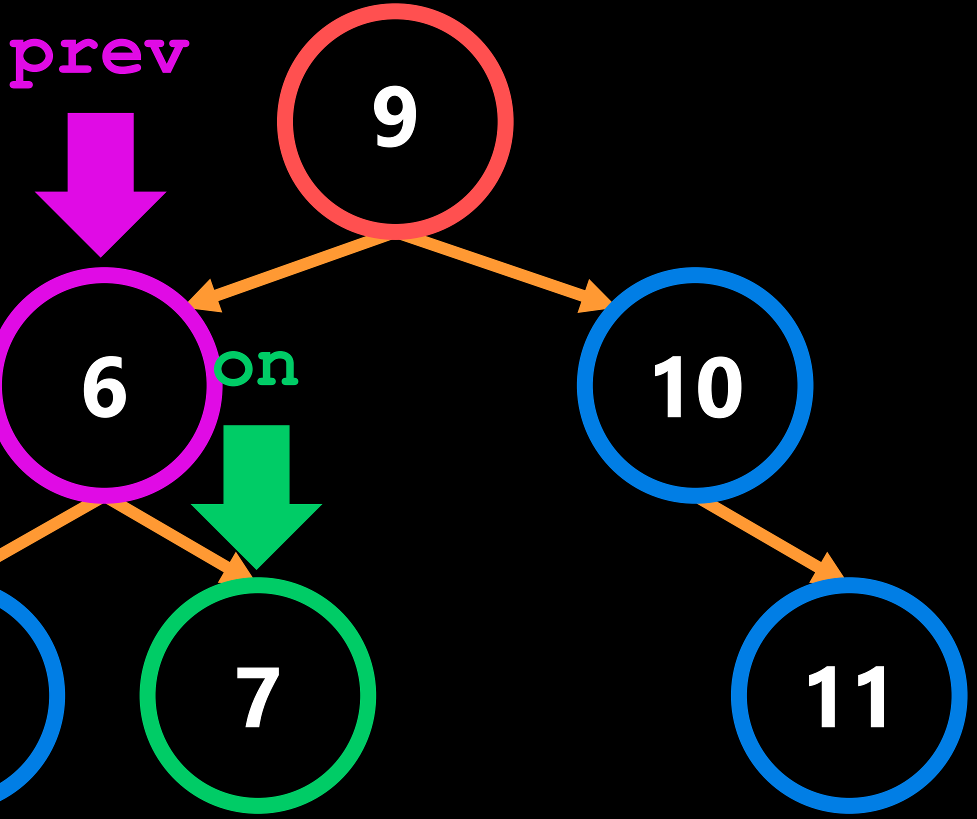
            prev = on
            on = on.right

        return True
```

stack = [9]



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        on = self.root
        stack = []
        prev = None

        while len(stack) > 0 or on is not None:   True

            while on is not None:   True
                stack.append(on)
                on = on.left

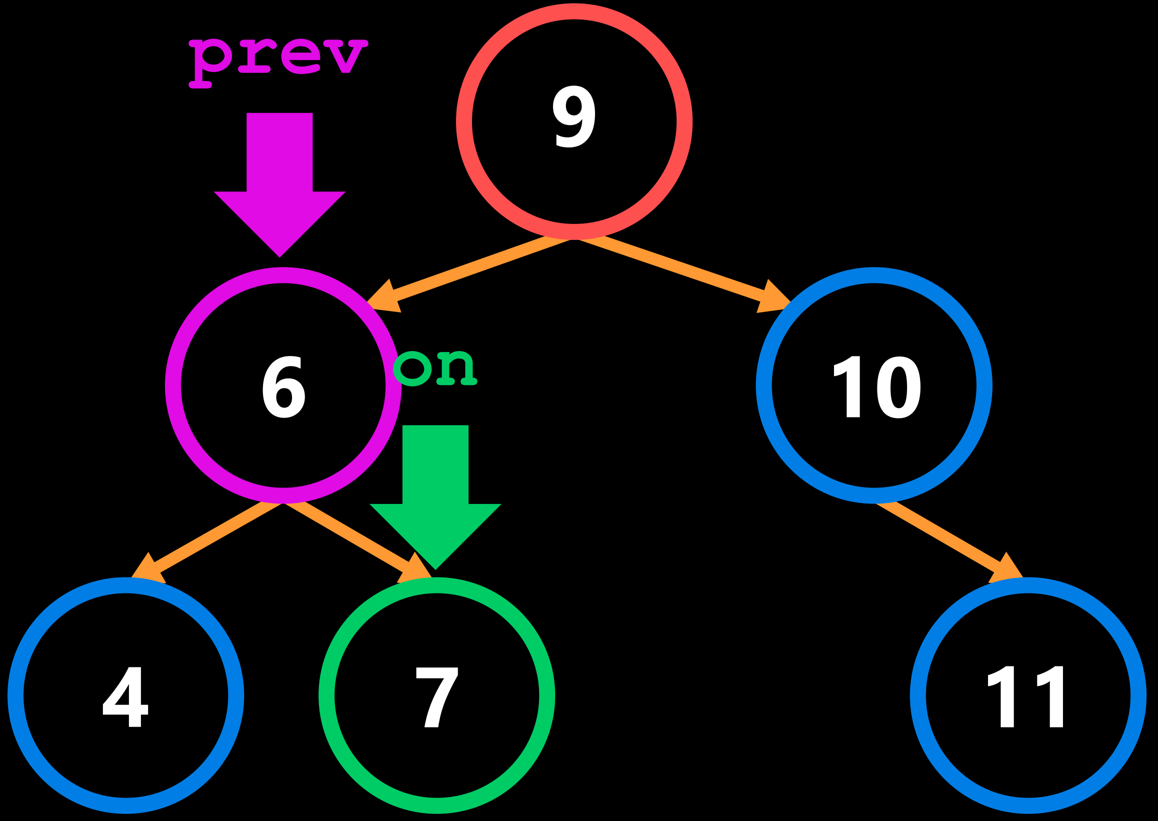
            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

stack = [9]



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        """
        on = self.root
        stack = []
        prev = None

        while len(stack) > 0 or on is not None:
            
            while on is not None:
                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

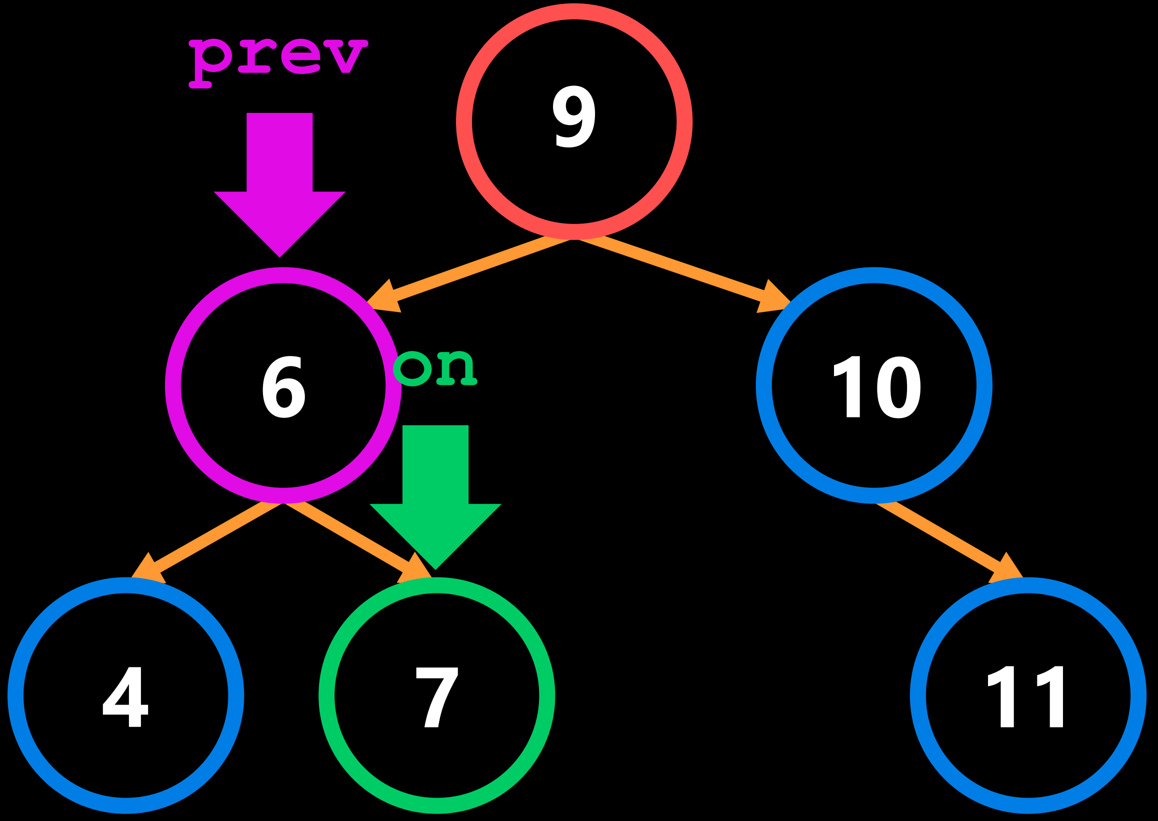
        return True
```

True

True

Add on to stack.

stack = [9 7]



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

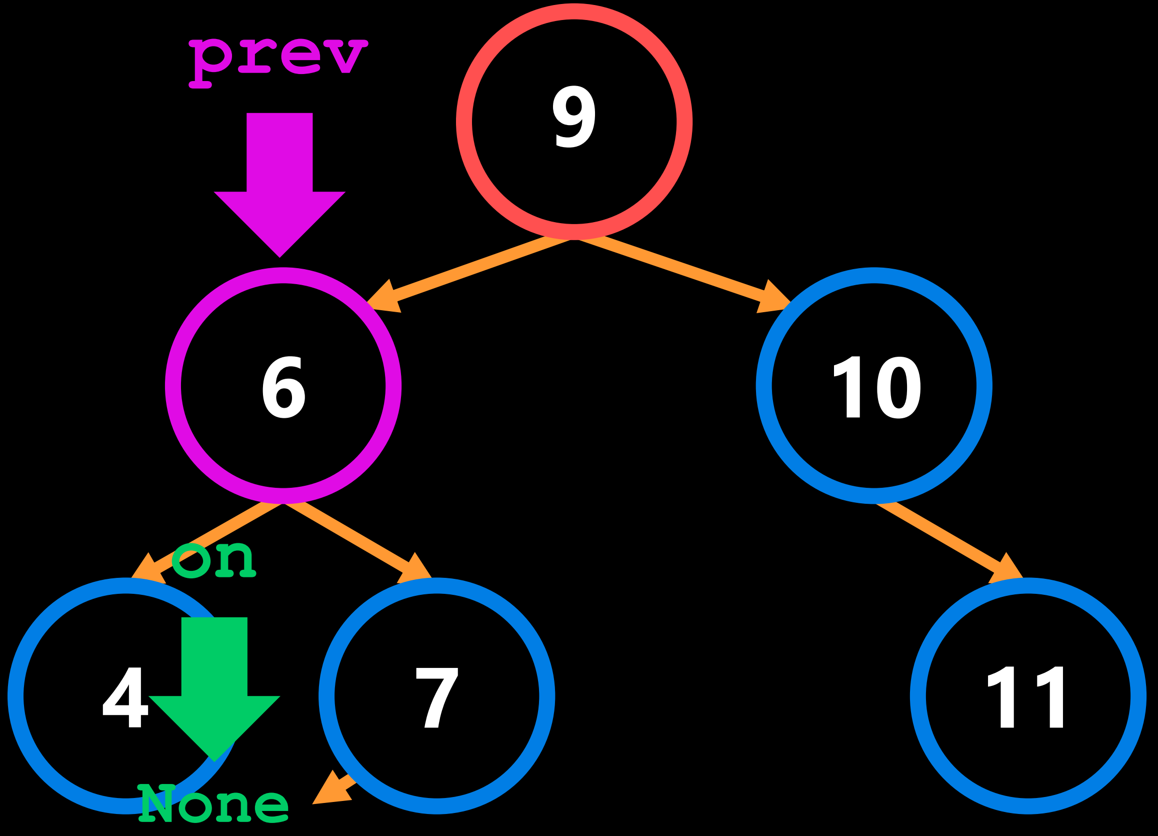
        return True
```

True

True

Move on to left node pointer.

stack = [9 7]



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                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

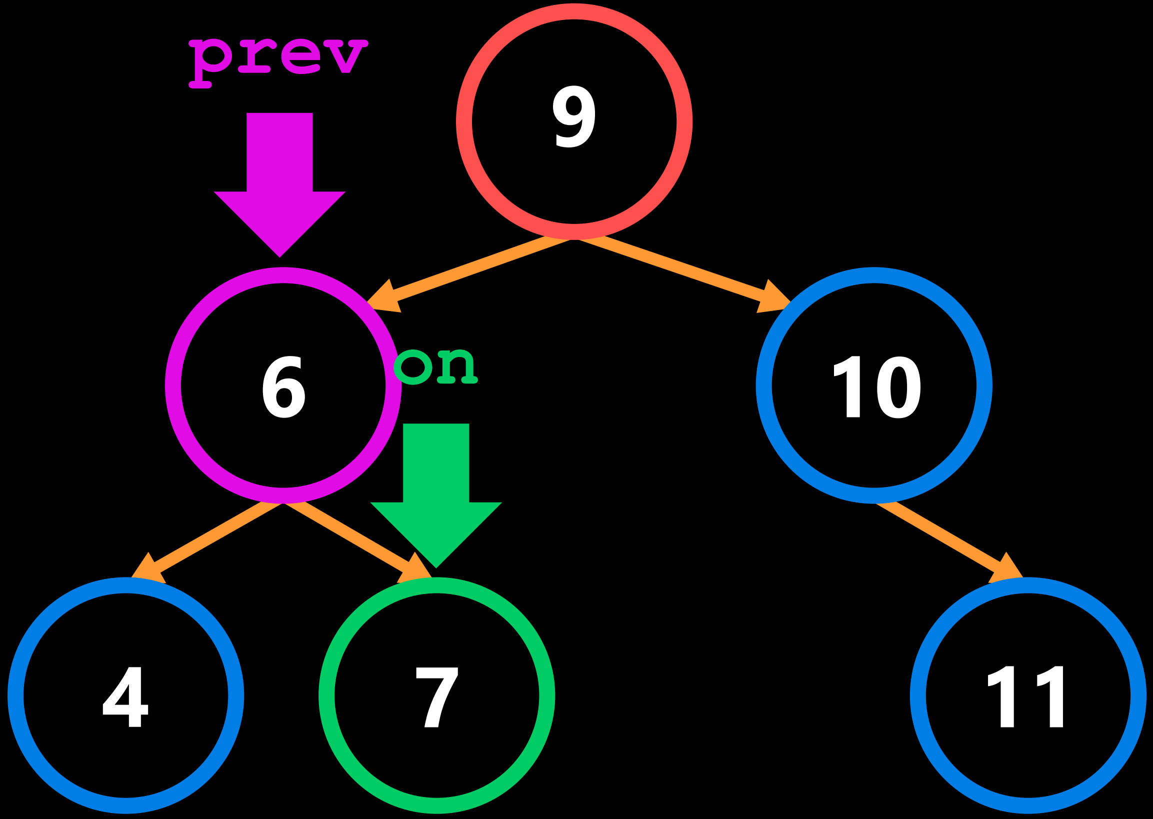
        return True
```

stack = [9]

True

True

Set on to left node in stack.



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                on = on.left

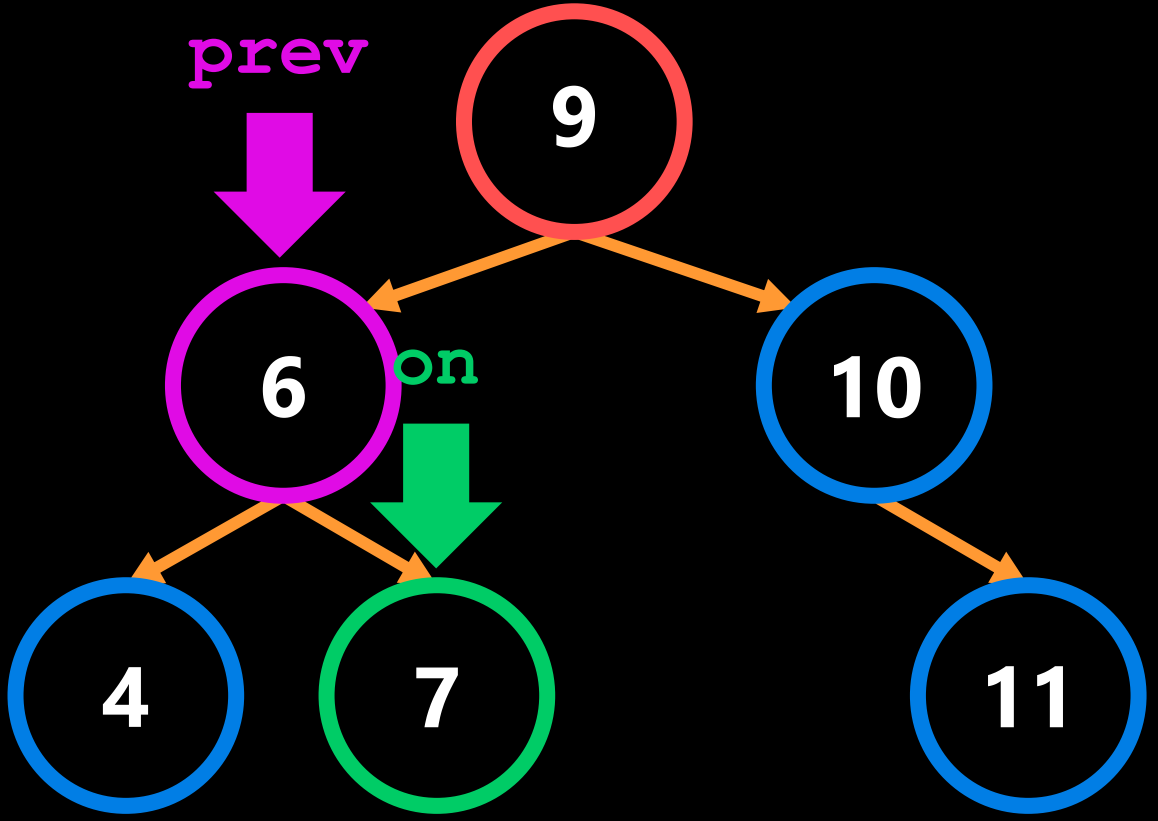
            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:  ← False
                return False

            prev = on
            on = on.right

        return True
```

stack = [9]



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                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

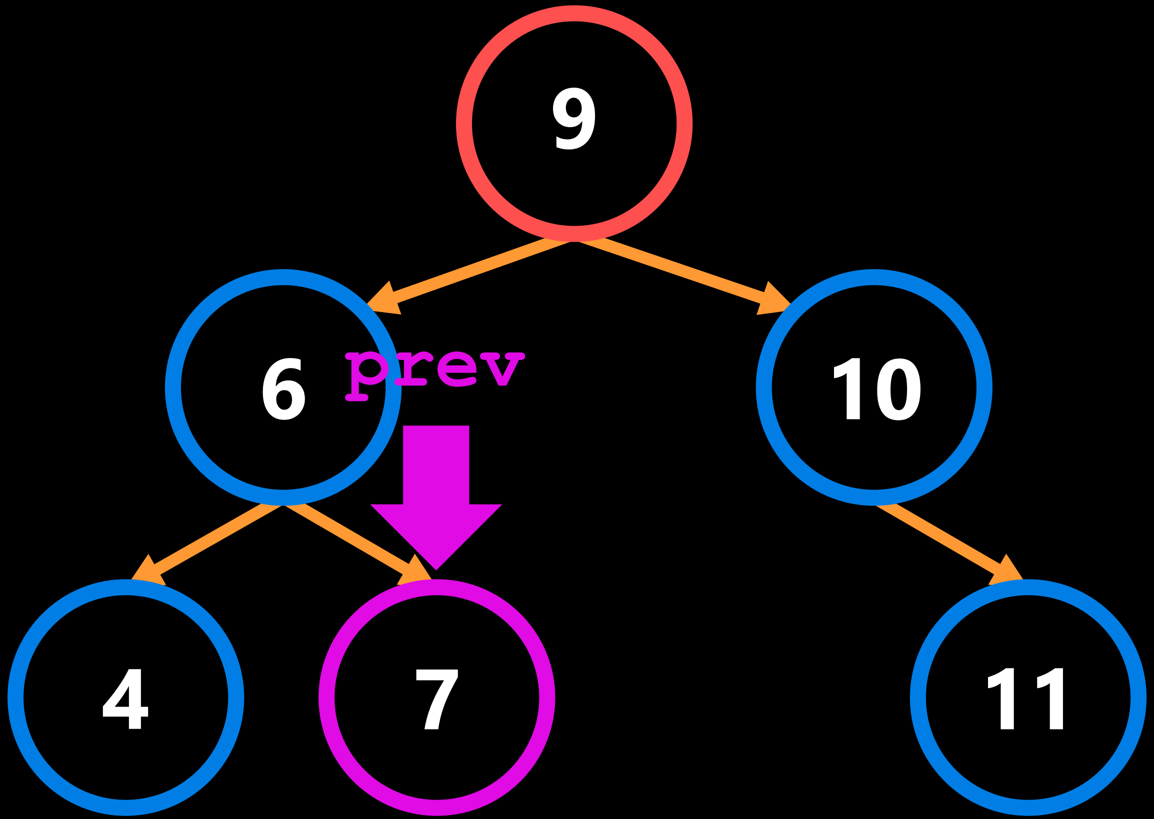
True

True

False

Set prev to on.

stack = [9]



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

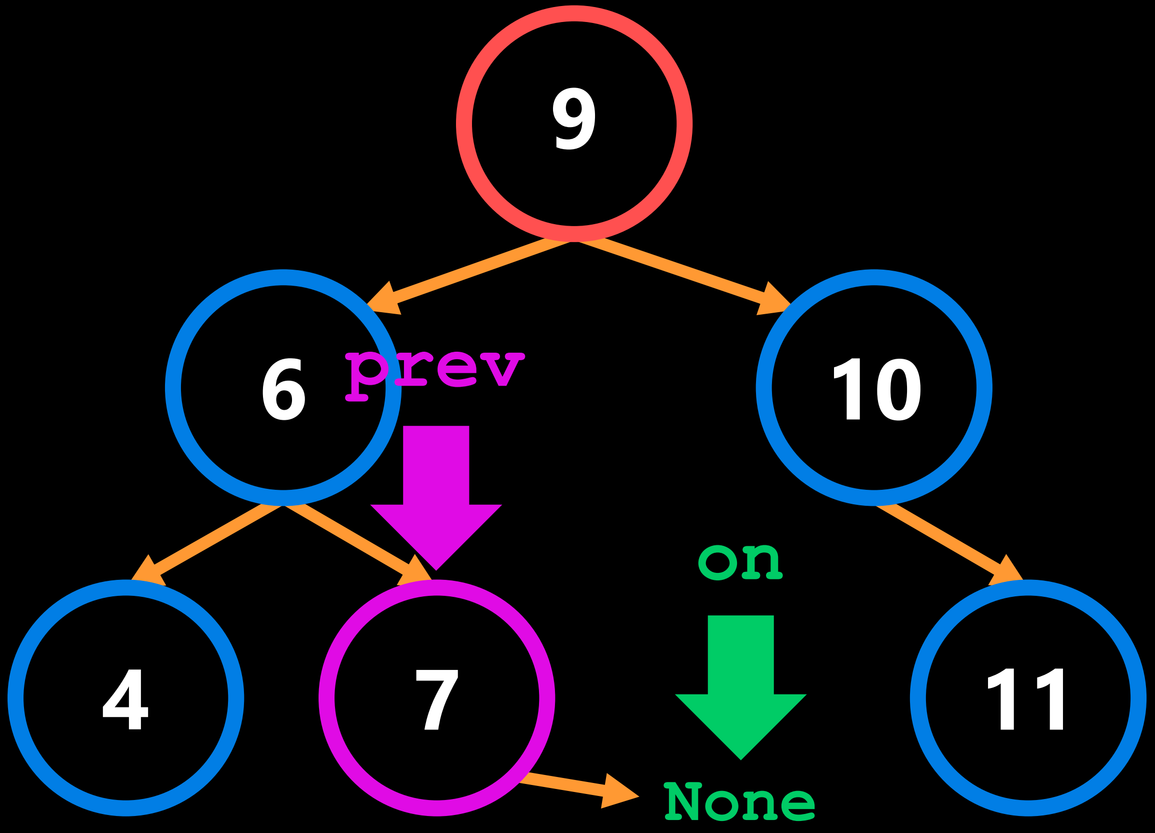
stack = [9]

True

True

False

Move on to the right pointer.



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

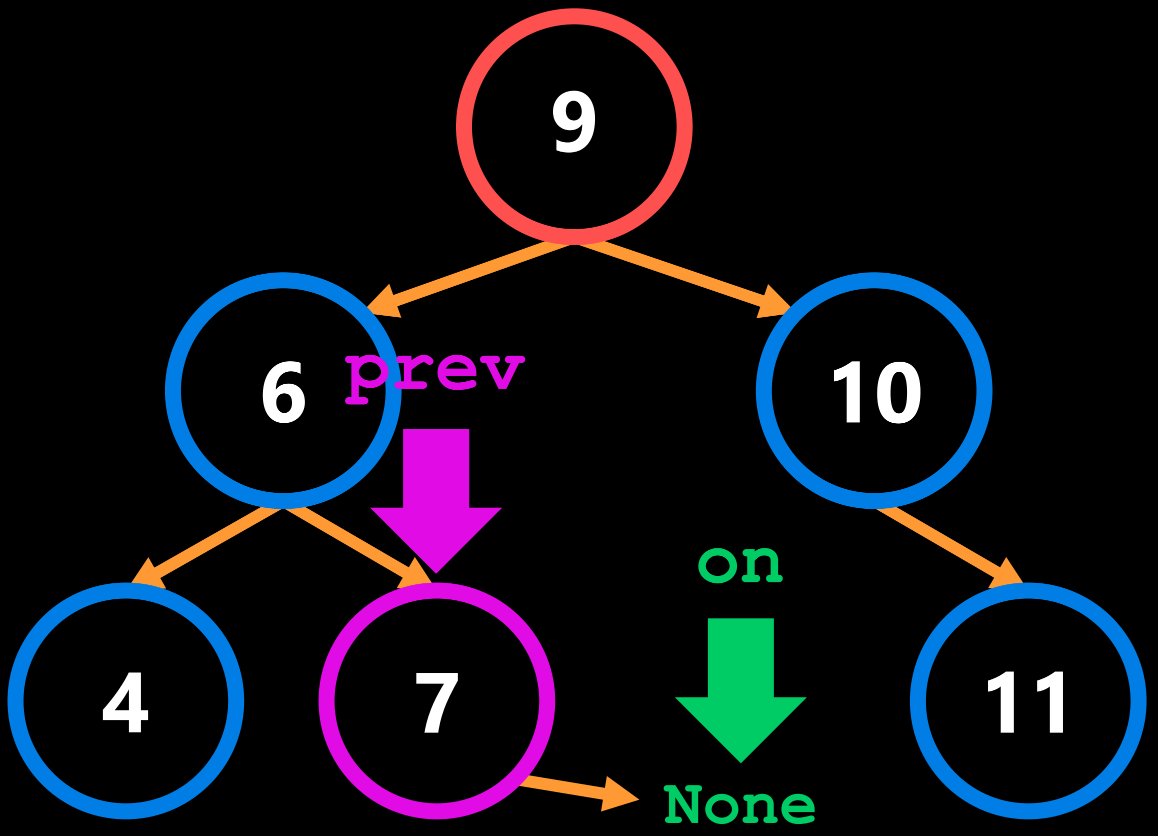
            prev = on
            on = on.right

        return True
```

True

False

stack = [9]



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                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

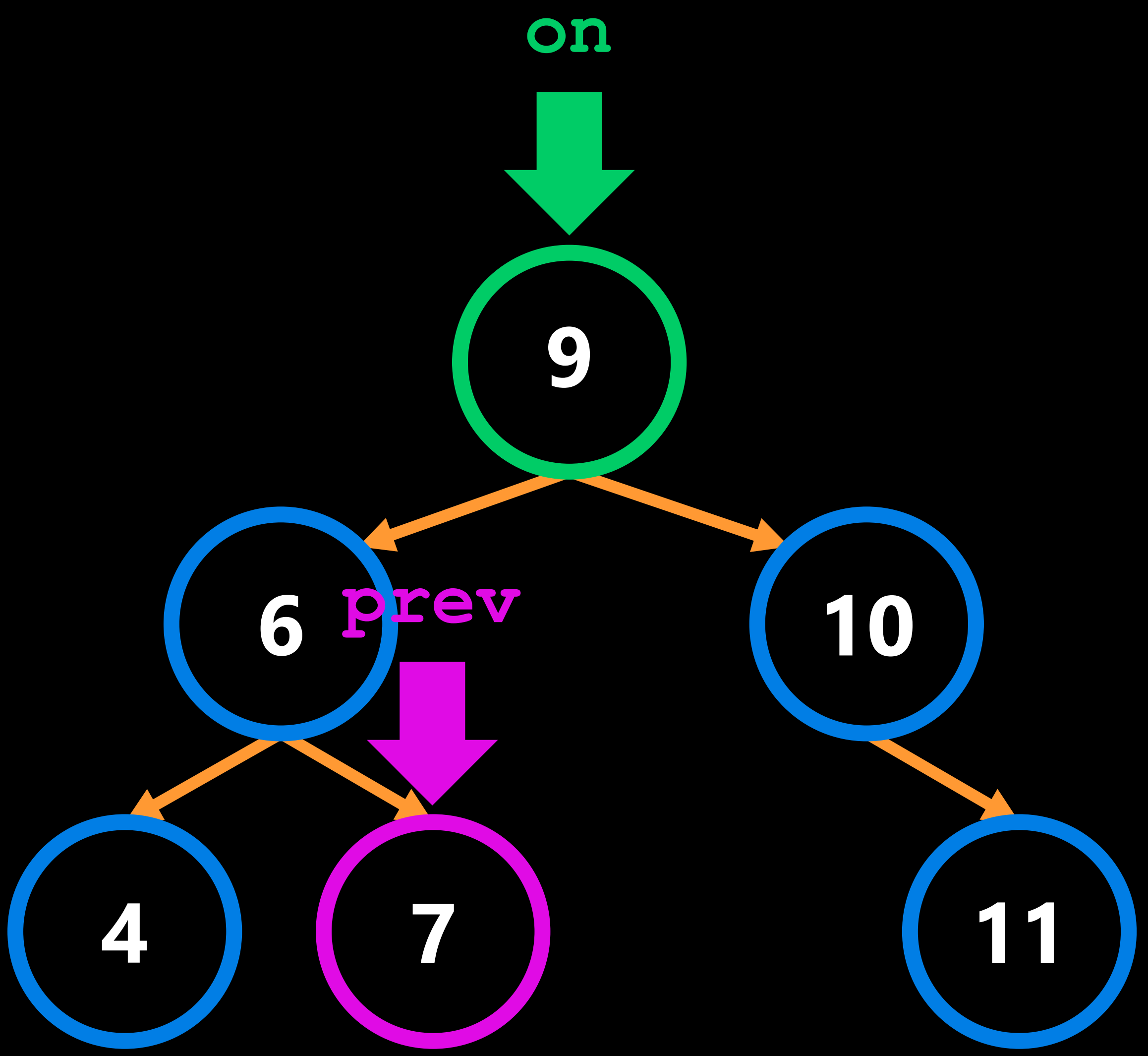
        return True
```

stack = []

True

False

Set on to left node in stack.



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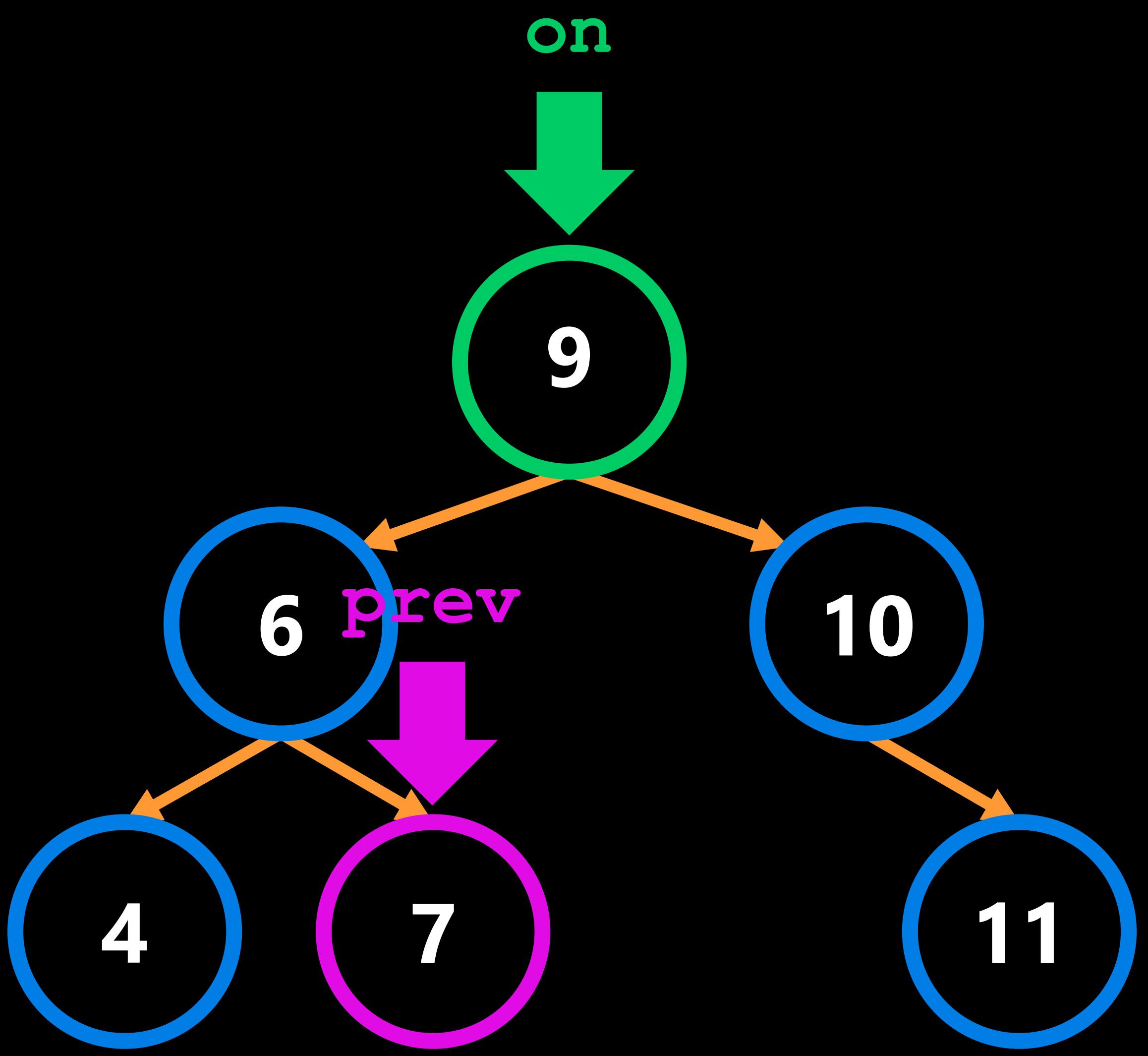
            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:  ◀ False
                return False

            prev = on
            on = on.right

        return True
```

stack = [ ]



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            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

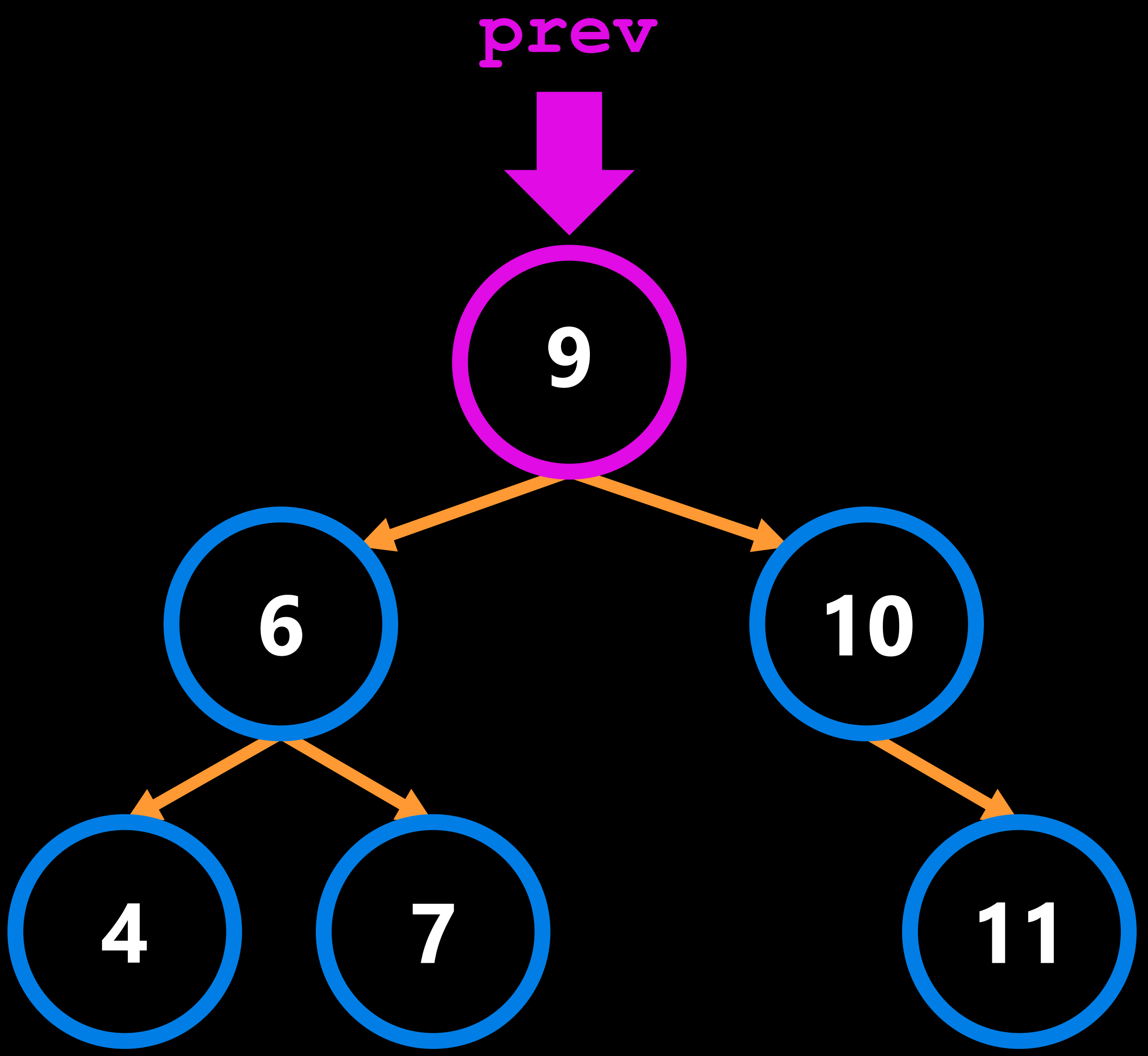
True

False

False

Set prev to on.

stack = [ ]



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            if prev is not None and on.cargo <= prev.cargo:
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            prev = on
            on = on.right

        return True
```

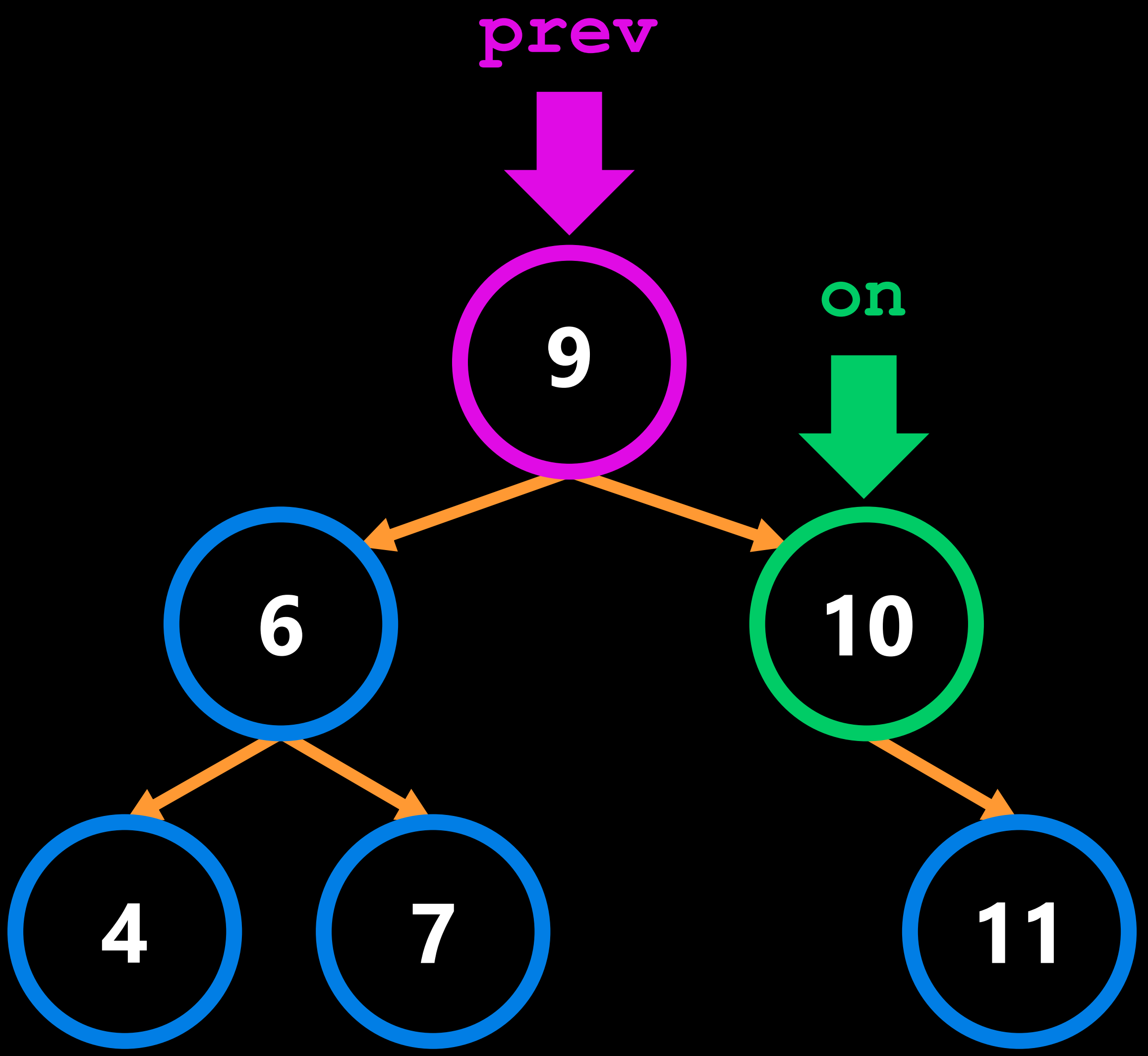
stack = []

True

False

False

Move **on** to the right pointer.



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
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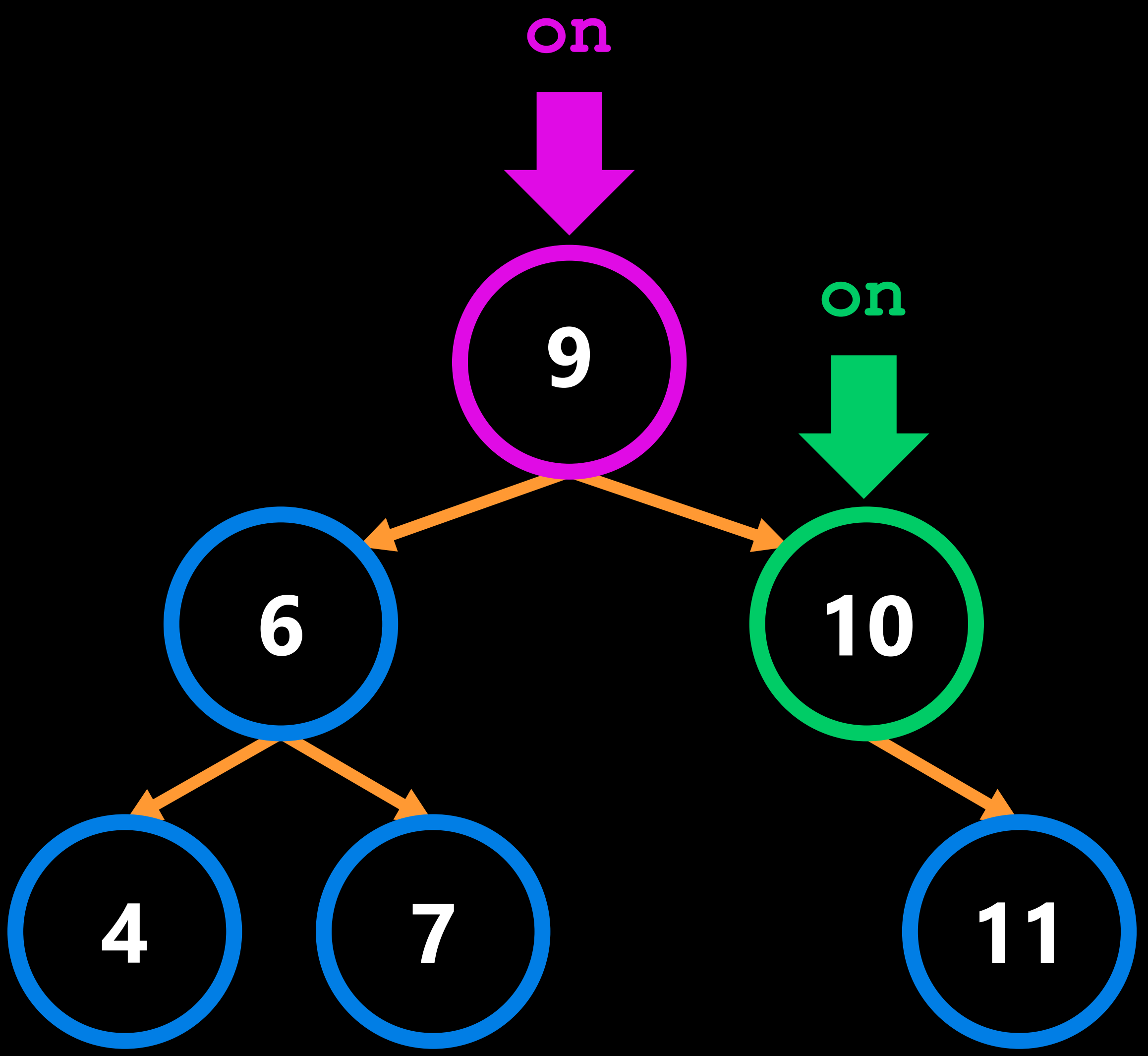
            prev = on
            on = on.right

        return True
```

True

True

stack = [ ]



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            if prev is not None and on.cargo <= prev.cargo:
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            prev = on
            on = on.right

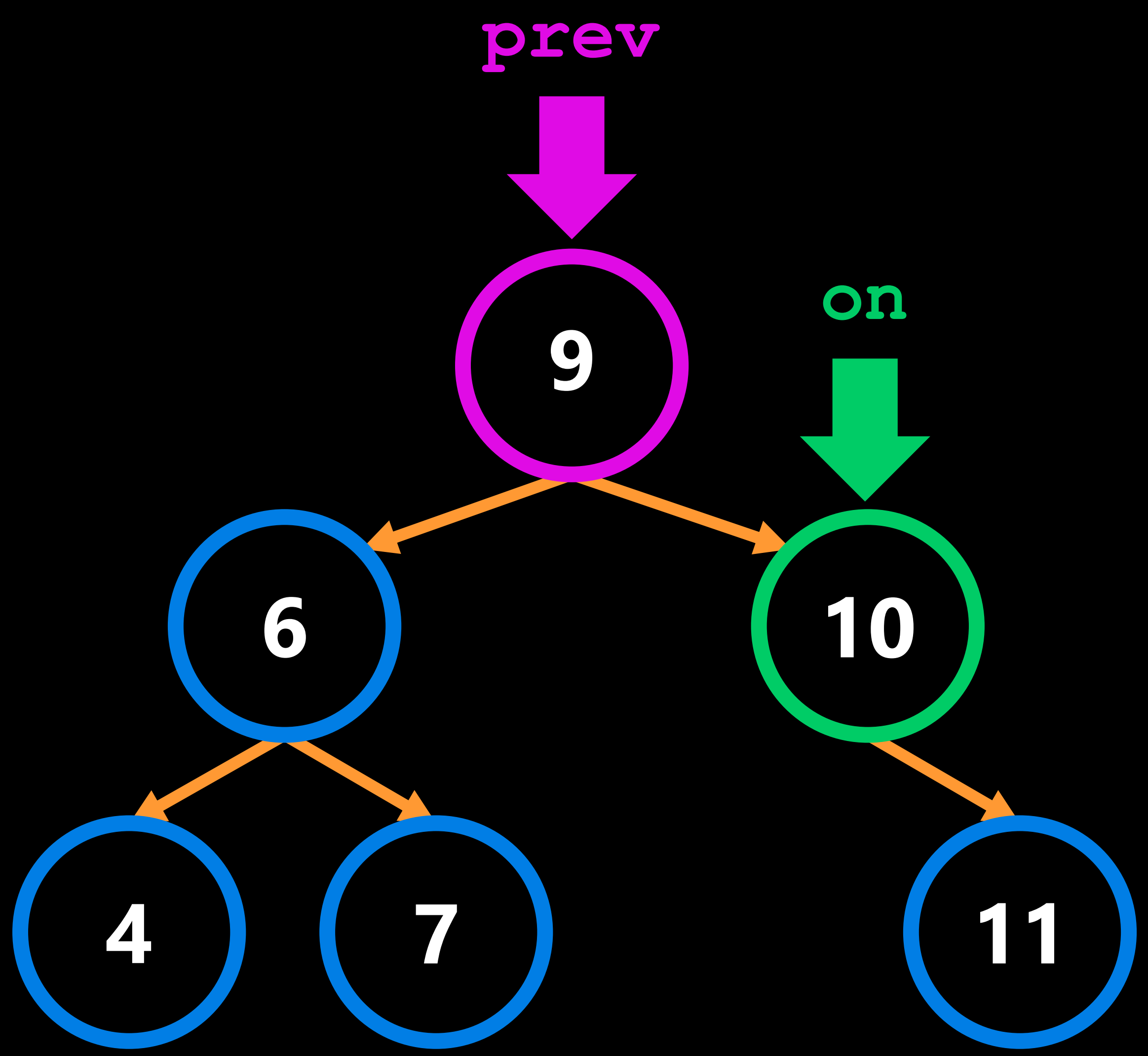
        return True
```

True

True

Add on to stack.

stack = [10]



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
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            prev = on
            on = on.right

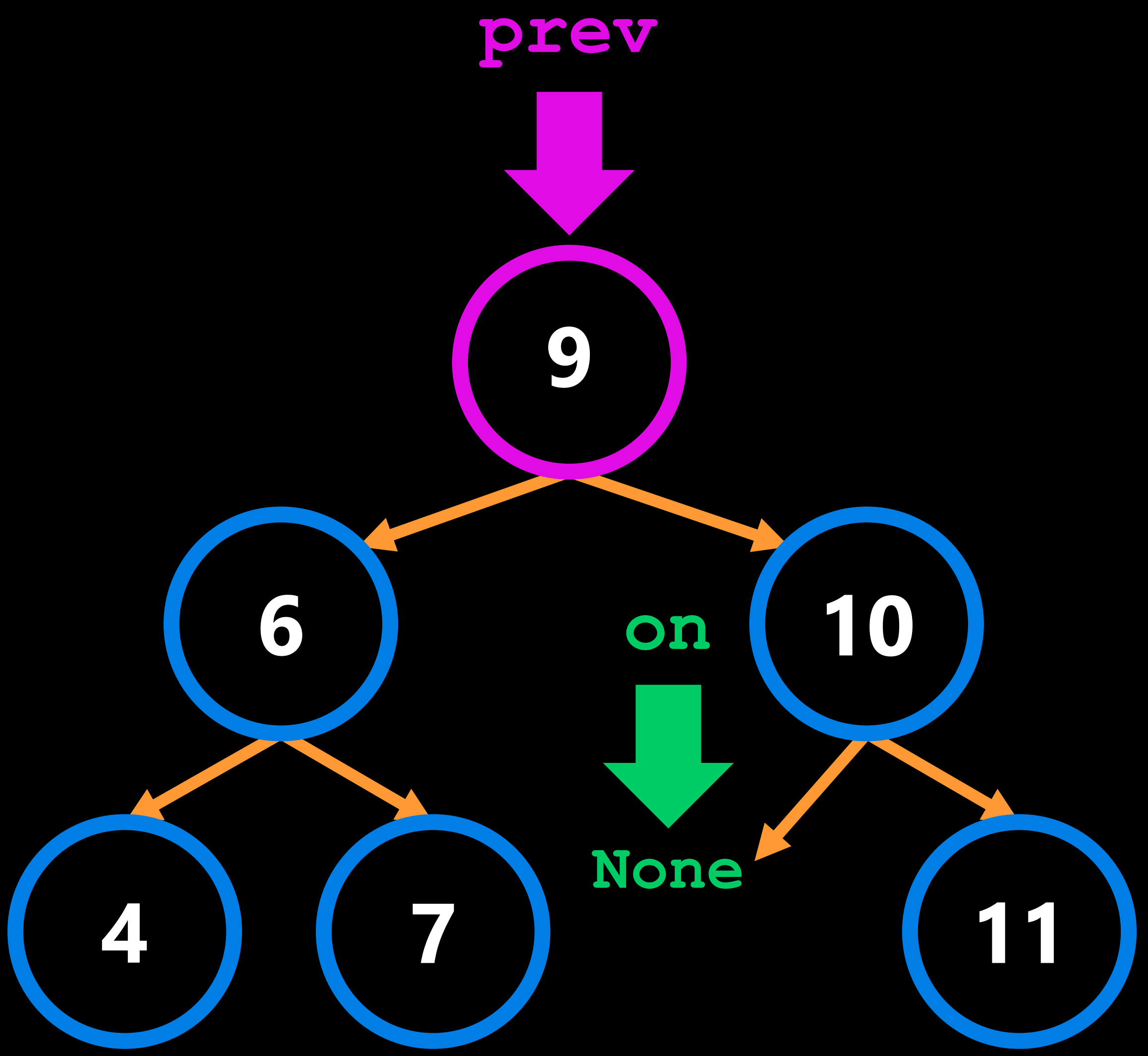
        return True
```

True

True

Move on to left node pointer.

stack = [10]



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            prev = on
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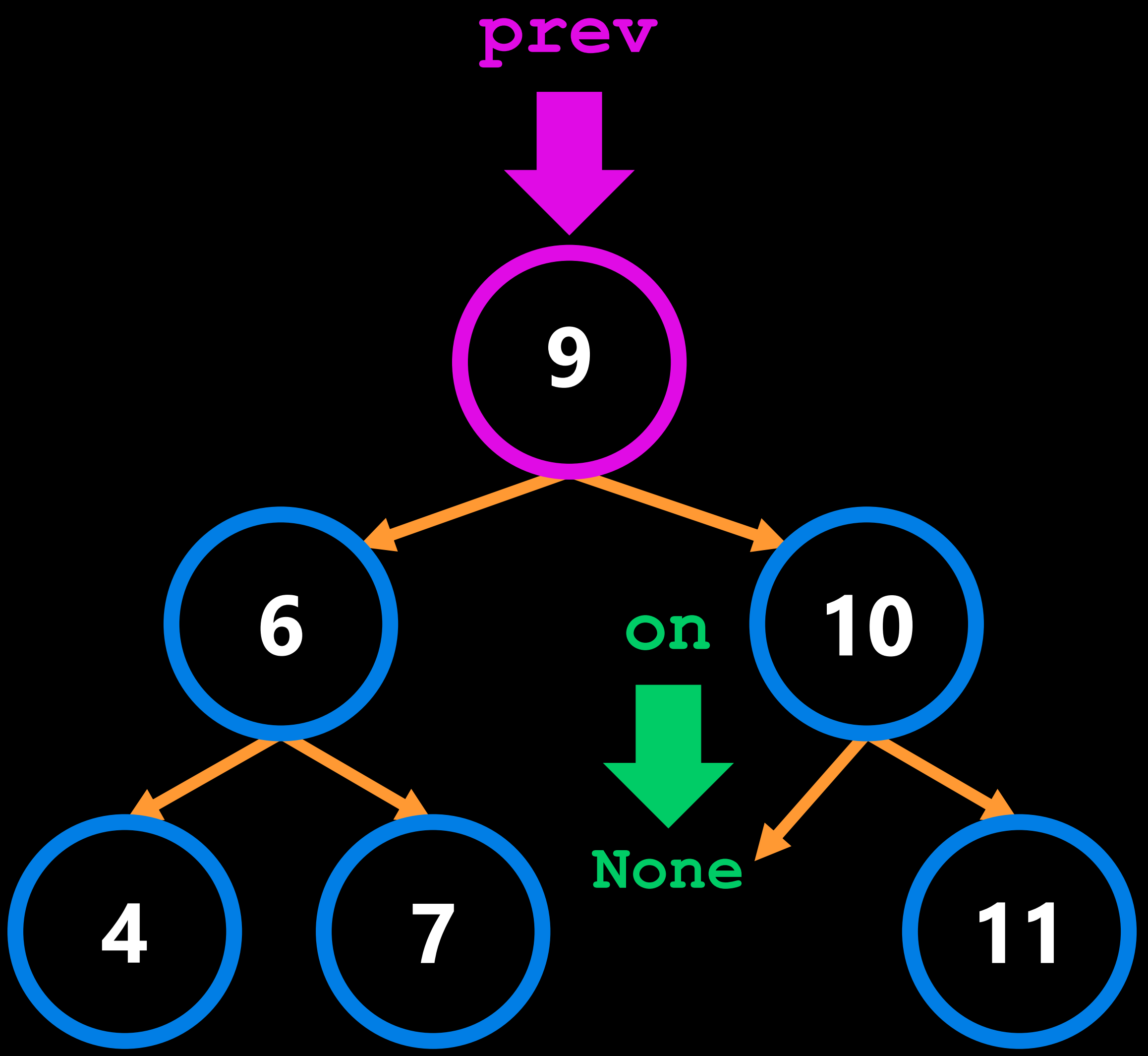
        return True
```

while len(stack) > 0 or on is not None: ← True

while on is not None: ← False

stack = [10]



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            if prev is not None and on.cargo <= prev.cargo:
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            prev = on
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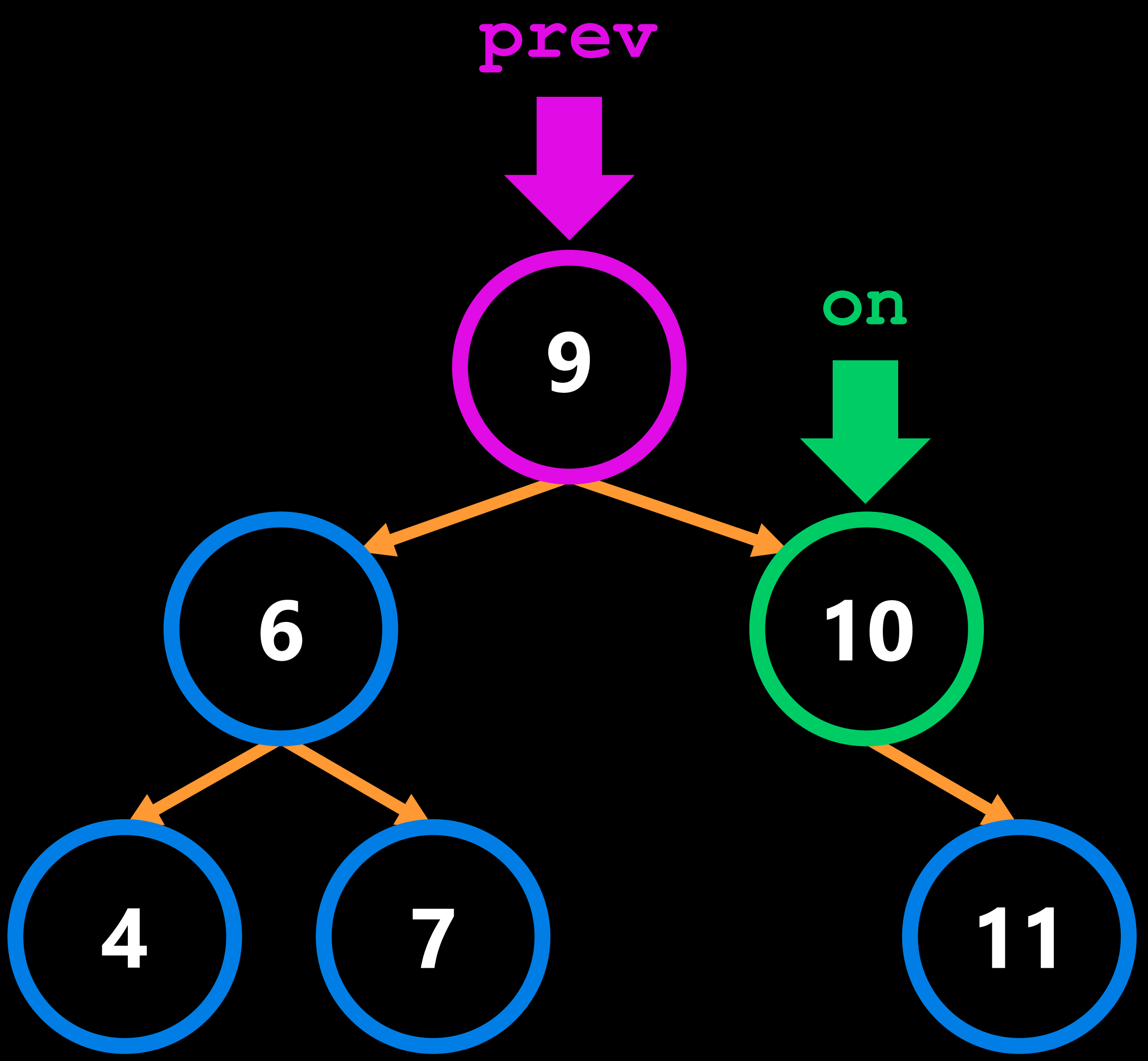
        return True
```

stack = [ ]

True

False

Set on to left node in stack.



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            while on is not None:     False
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                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:     False
                return False

            prev = on
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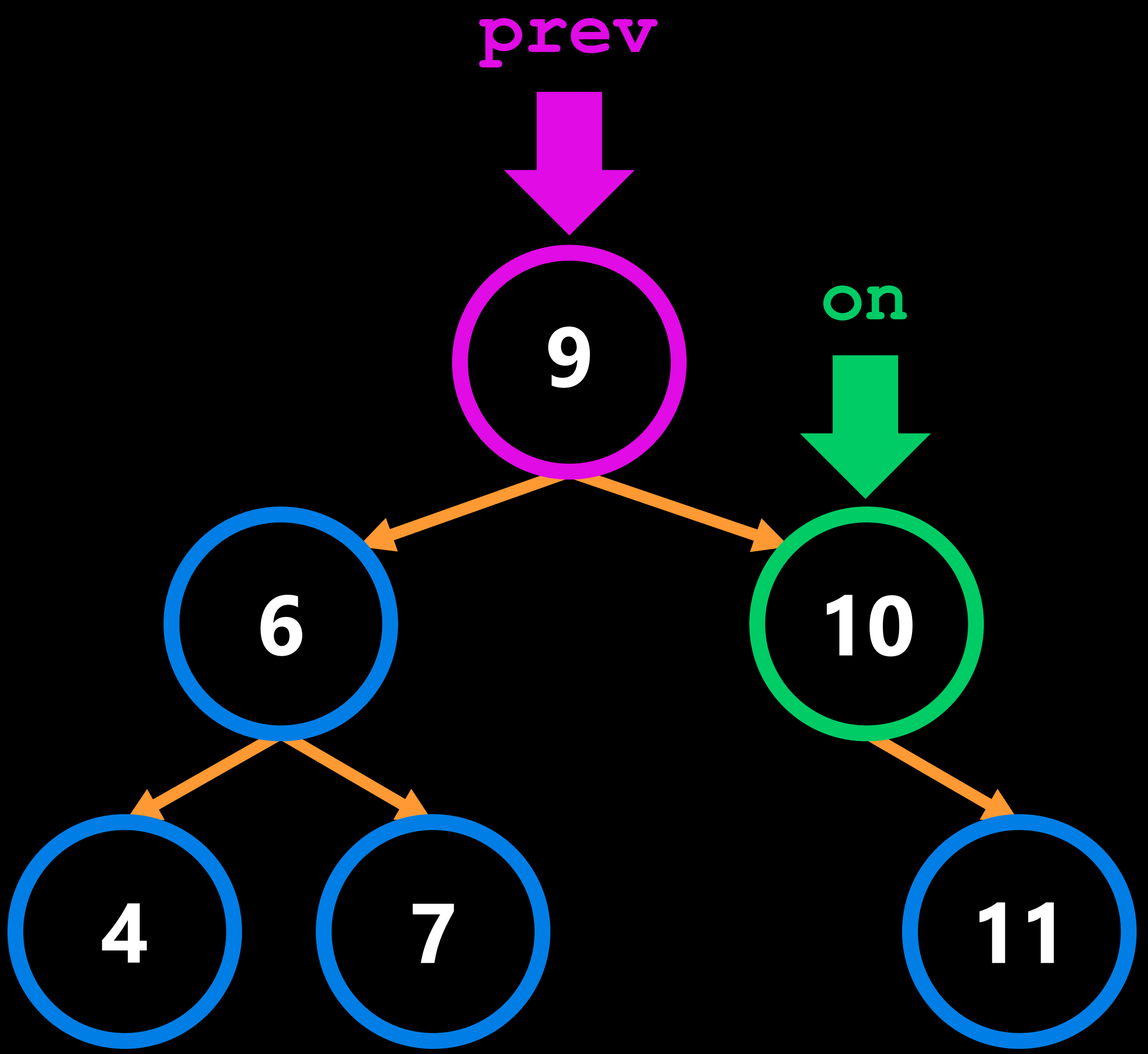
        return True
```

stack = [ ]



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        while len(stack) > 0 or on is not None:  ← True

            while on is not None:  ← False
                stack.append(on)
                on = on.left

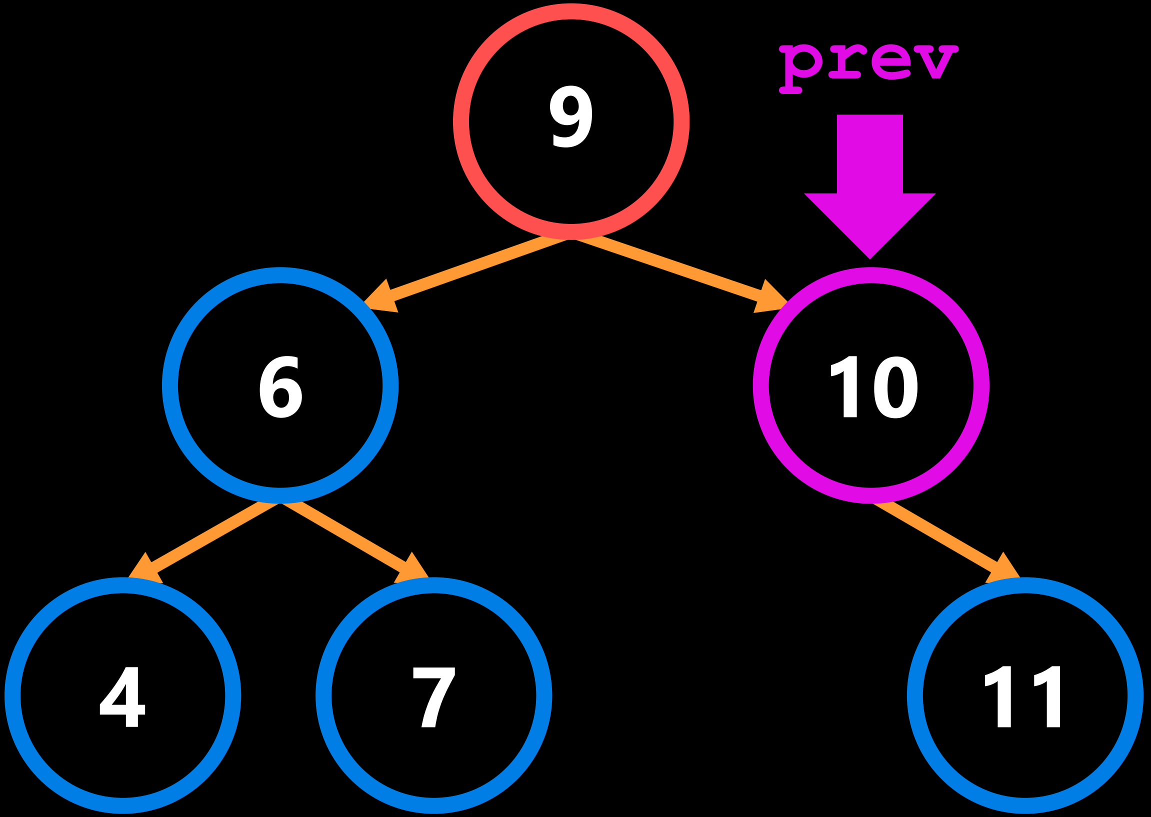
            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:  ← False
                return False

            prev = on  ← Set prev to on.
            on = on.right

        return True
```

stack = [ ]



```
class BinarySearchTree:
    """A Node class used by a binary search tree class."""

    def __init__(self, root=None):
        """
        (self) -> NoneType
        Create an empty binary tree.
        """
        self.root = root

    def print_tree(self): ...

    def is_valid(self):
        """
        (self) -> NoneType
        Checks if self.root is a valid binary search tree.
        """
        on = self.root
        stack = []
        prev = None

        while len(stack) > 0 or on is not None:

            while on is not None:
                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

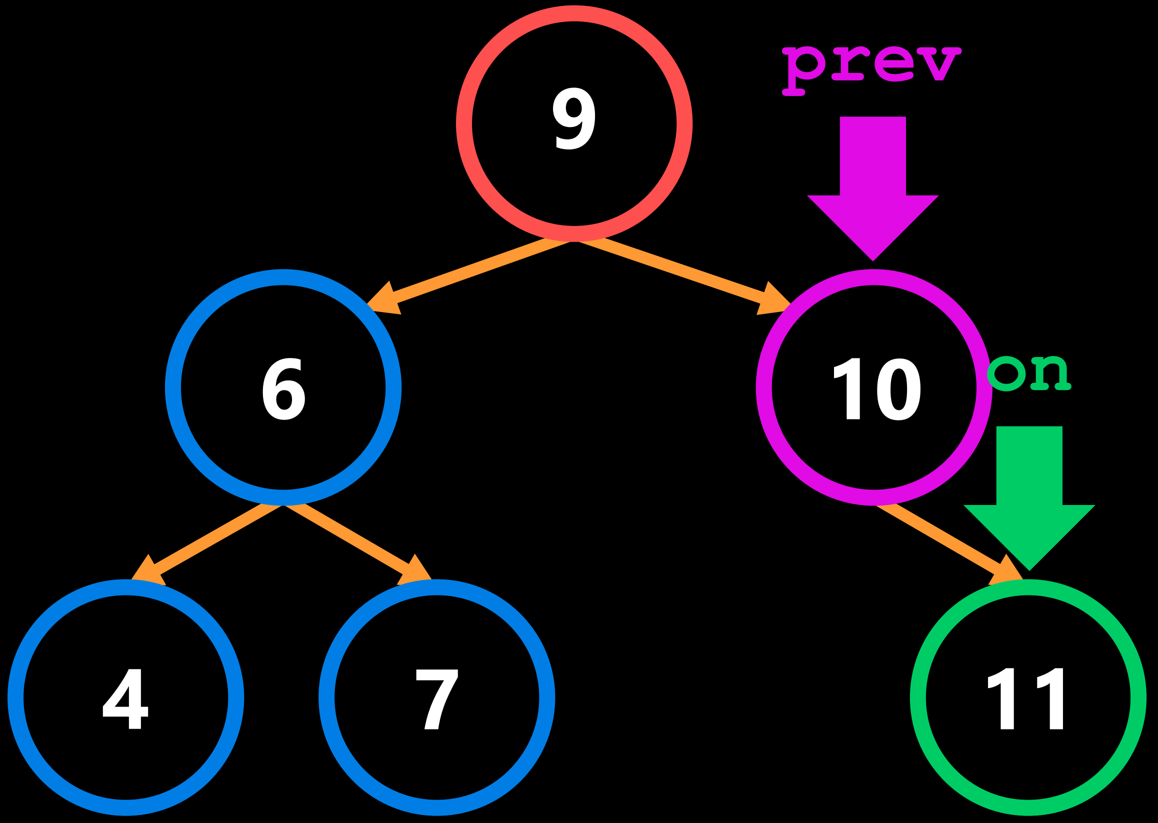
stack = [ ]

True

False

False

Move **on** to the right pointer.



```
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            while on is not None:
                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

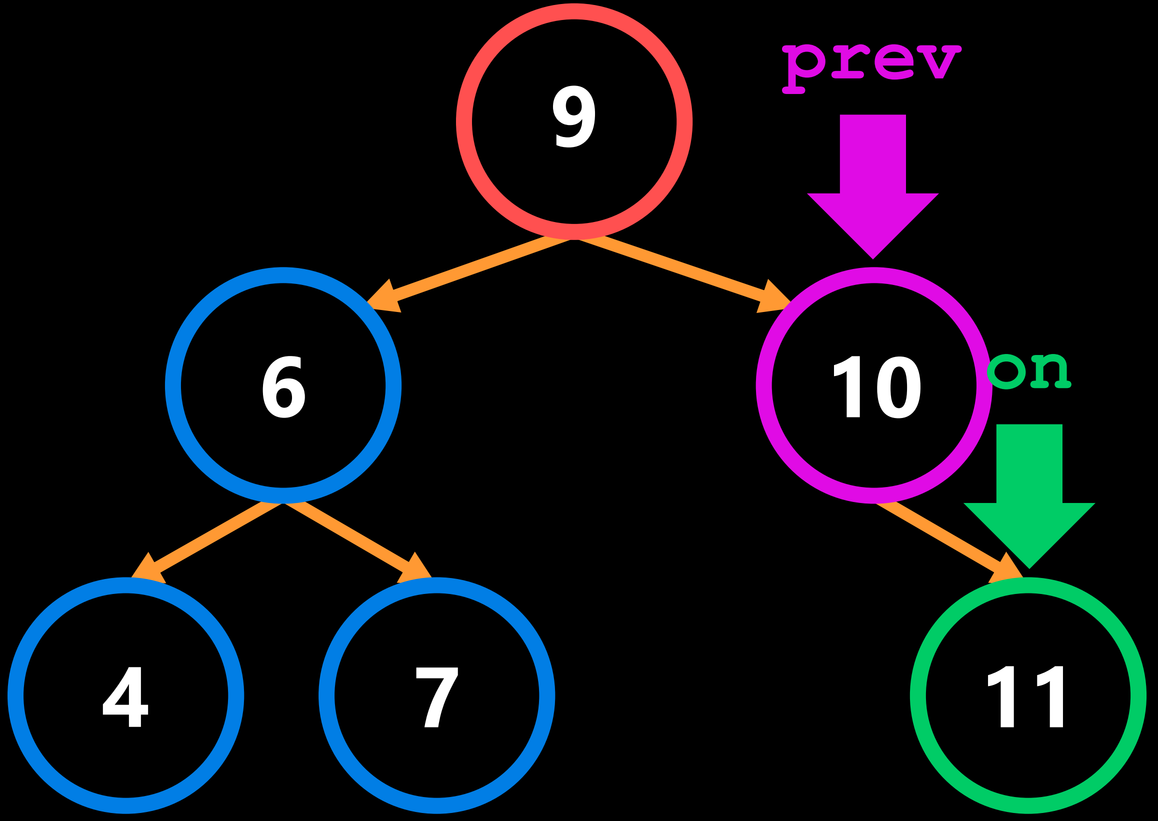
            prev = on
            on = on.right

        return True
```

True

True

stack = [ ]



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        while len(stack) > 0 or on is not None:

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                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

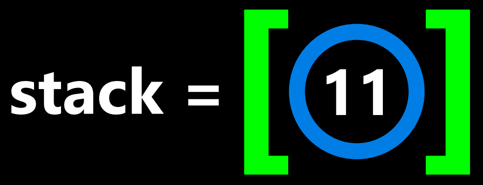
            prev = on
            on = on.right

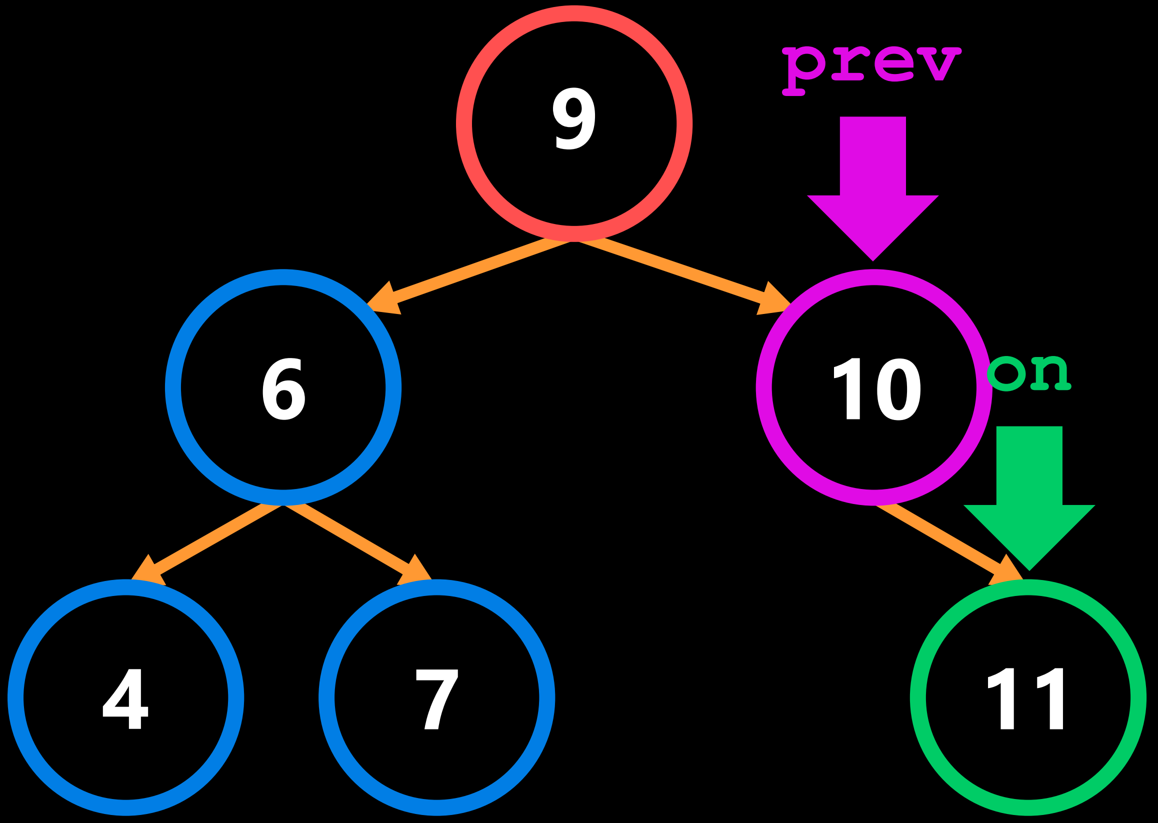
        return True
```

True

True

Add on to stack.





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        while len(stack) > 0 or on is not None:

            while on is not None:
                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

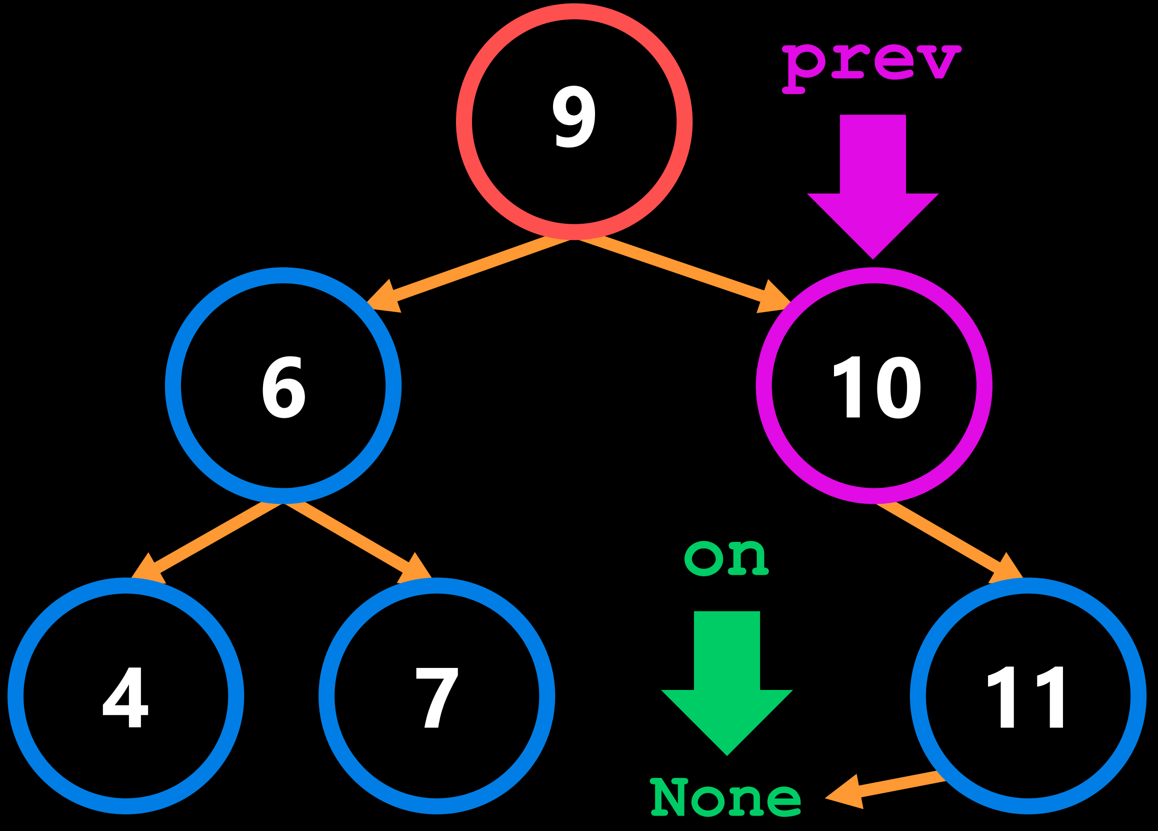
        return True
```

True

True

Move on to left node pointer.

stack = [11]



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            while on is not None:
                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

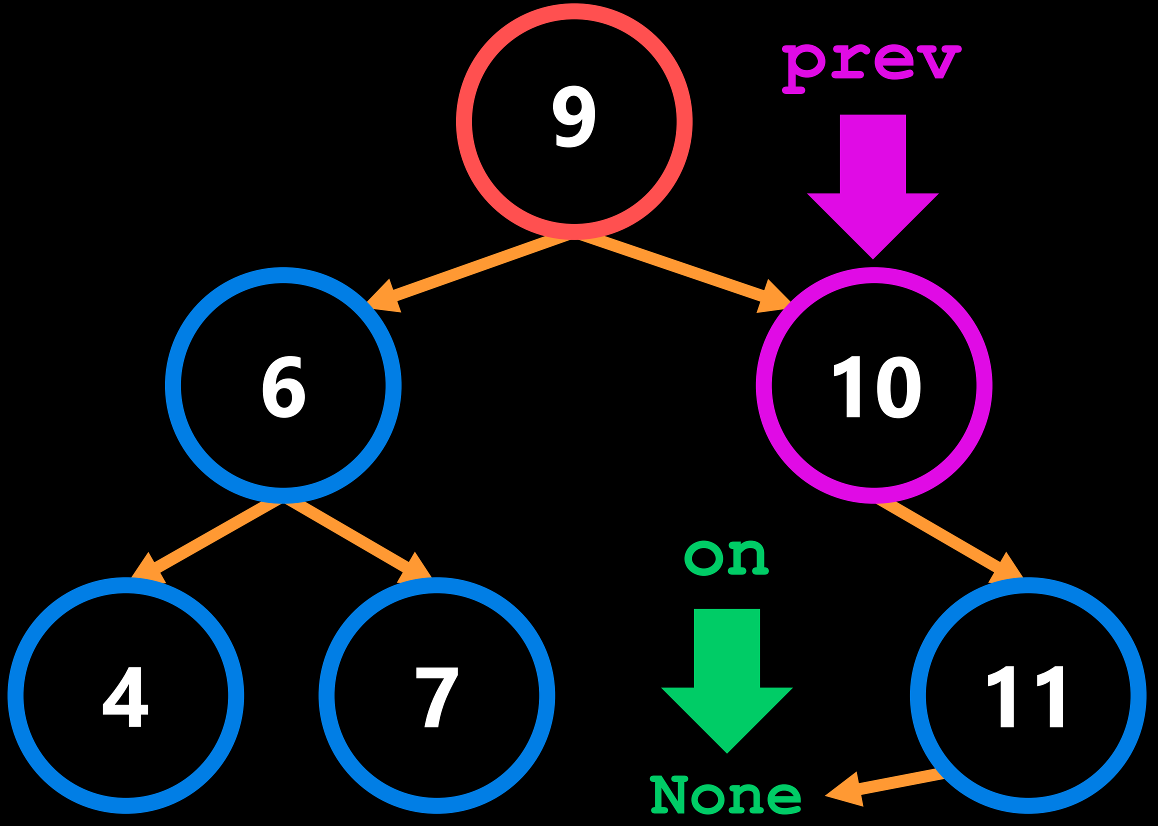
            prev = on
            on = on.right

        return True
```

True

False

stack = [11]



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    """A Node class used by a binary search tree class."""

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        self.root = root

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    def is_valid(self):
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        on = self.root
        stack = []
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        while len(stack) > 0 or on is not None:

            while on is not None:
                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

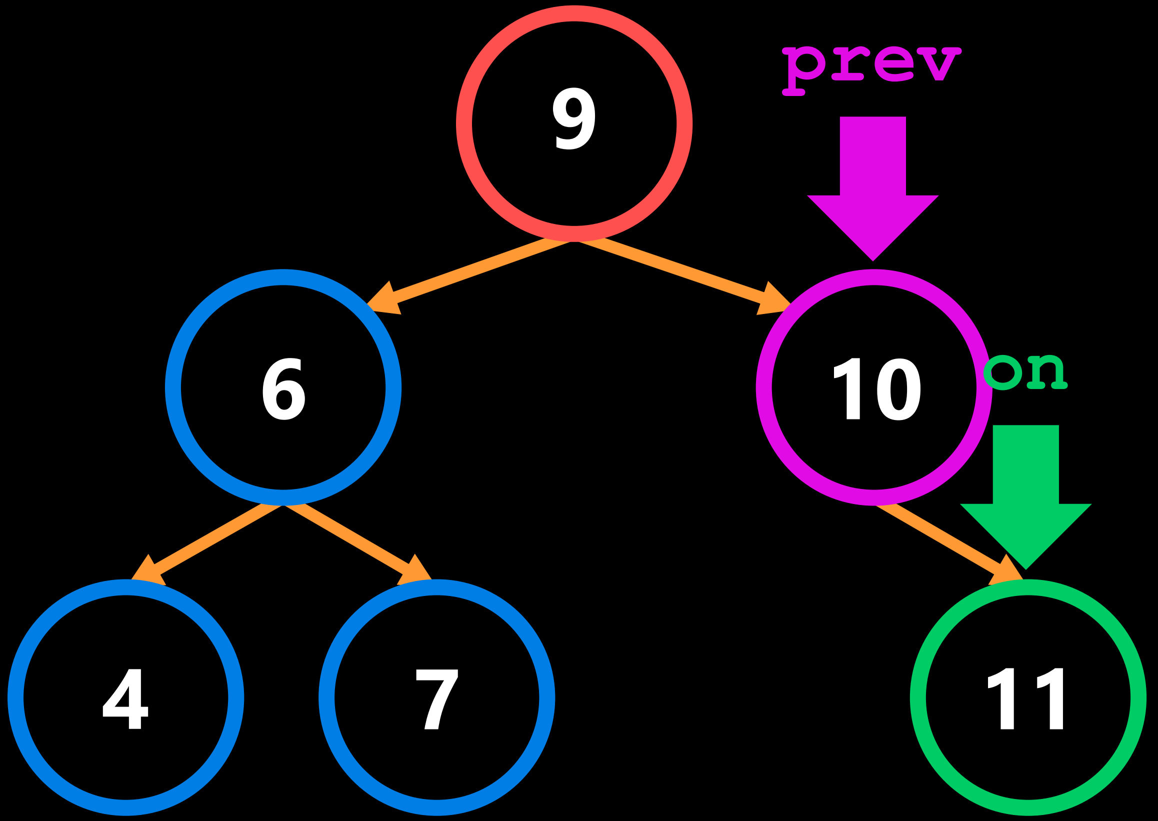
        return True
```

stack = [ ]

True

False

Set on to left node in stack.



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        Checks if self.root is a valid binary search tree.
        """
        on = self.root
        stack = []
        prev = None

        while len(stack) > 0 or on is not None:  ⇦ True

            while on is not None:  ⇦ False
                stack.append(on)
                on = on.left

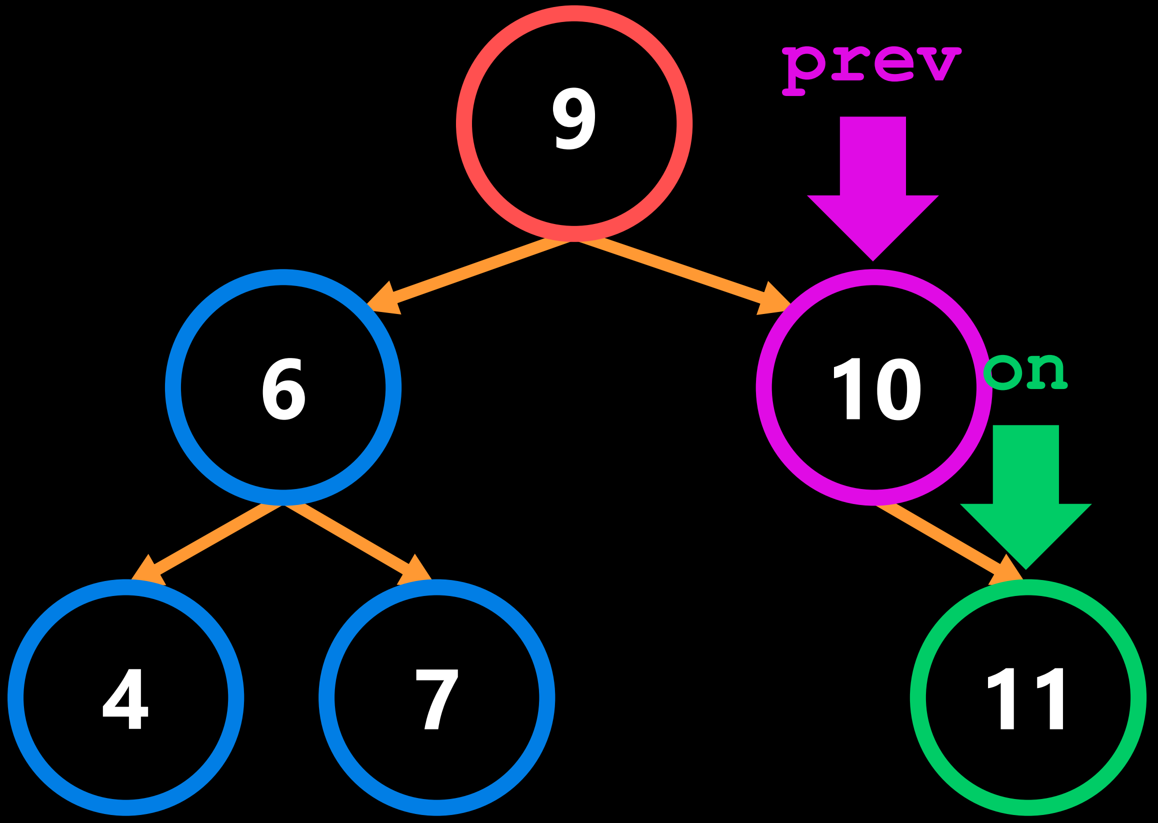
            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:  ⇦ False
                return False

            prev = on
            on = on.right

        return True
```

stack = [ ]



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        on = self.root
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            while on is not None:
                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

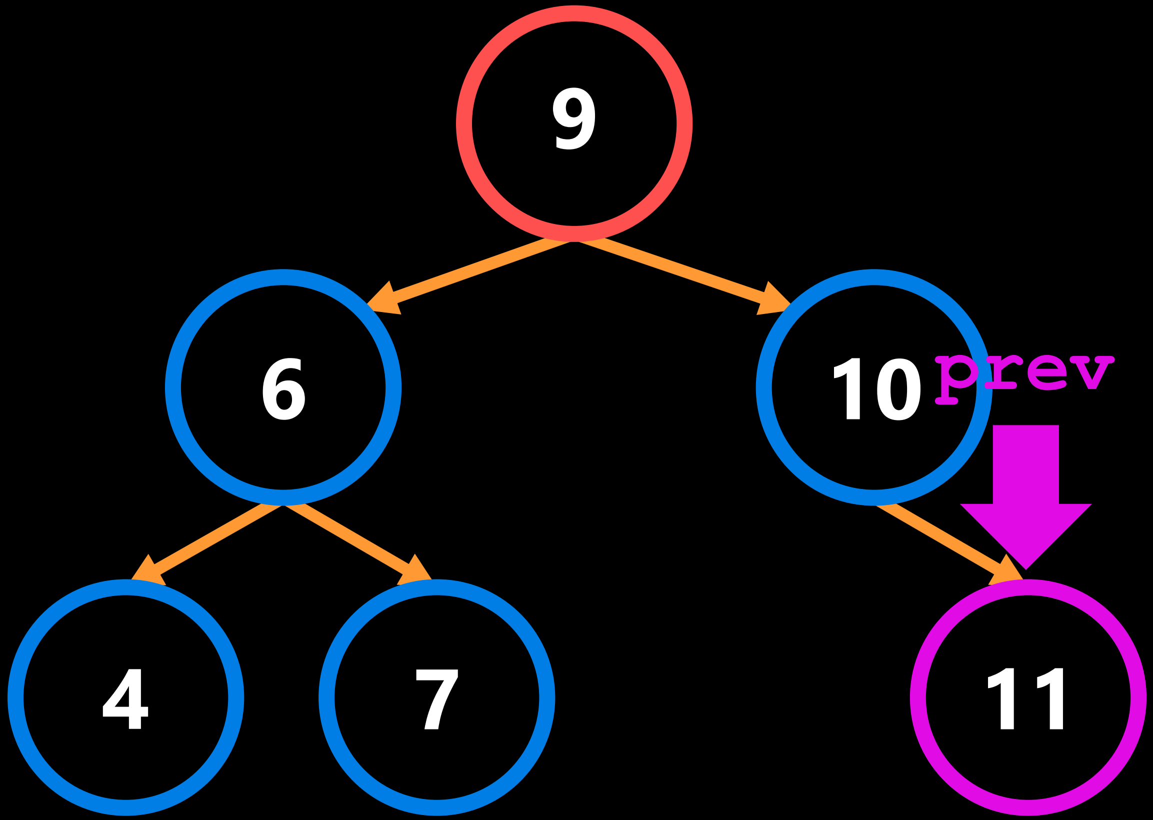
stack = [ ]

True

False

False

Set prev to on.



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        """
        (self) -> NoneType
        Checks if self.root is a valid binary search tree.
        """
        on = self.root
        stack = []
        prev = None

        while len(stack) > 0 or on is not None:   <- True

            while on is not None:   <- False
                stack.append(on)
                on = on.left

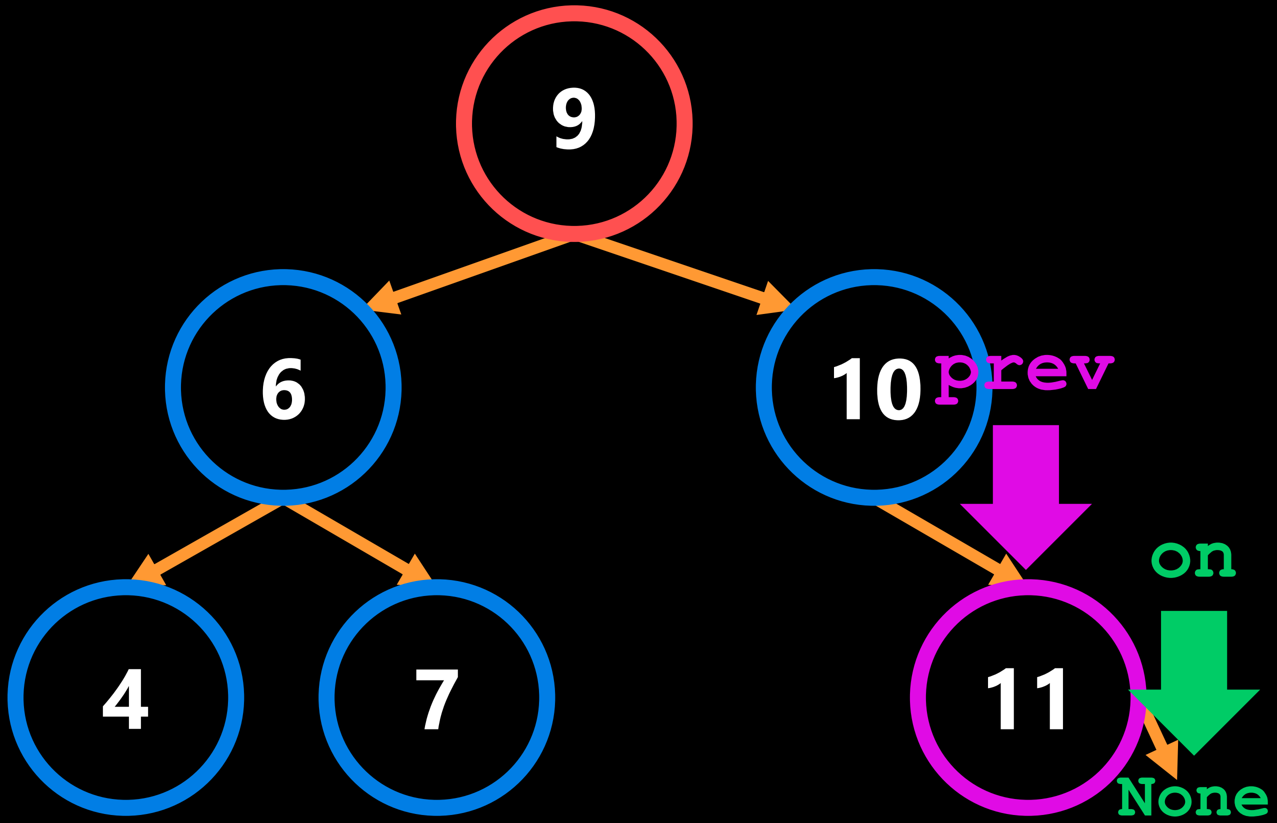
            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:   <- False
                return False

            prev = on
            on = on.right   <- Move on to the right pointer.

        return True
```

stack = [ ]



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                on = on.left

            on = stack.pop()

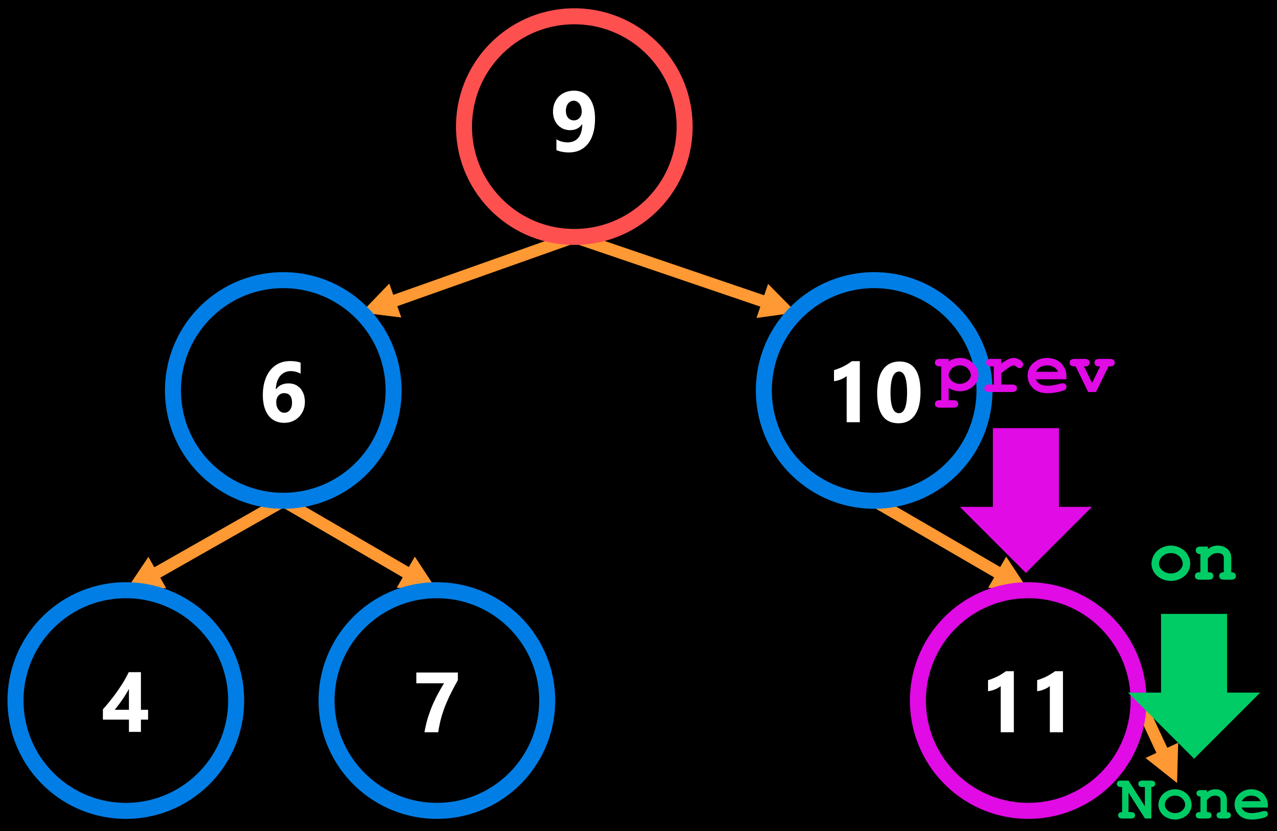
            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

stack = [ ]

False



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        stack = []
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        while len(stack) > 0 or on is not None:

            while on is not None:
                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

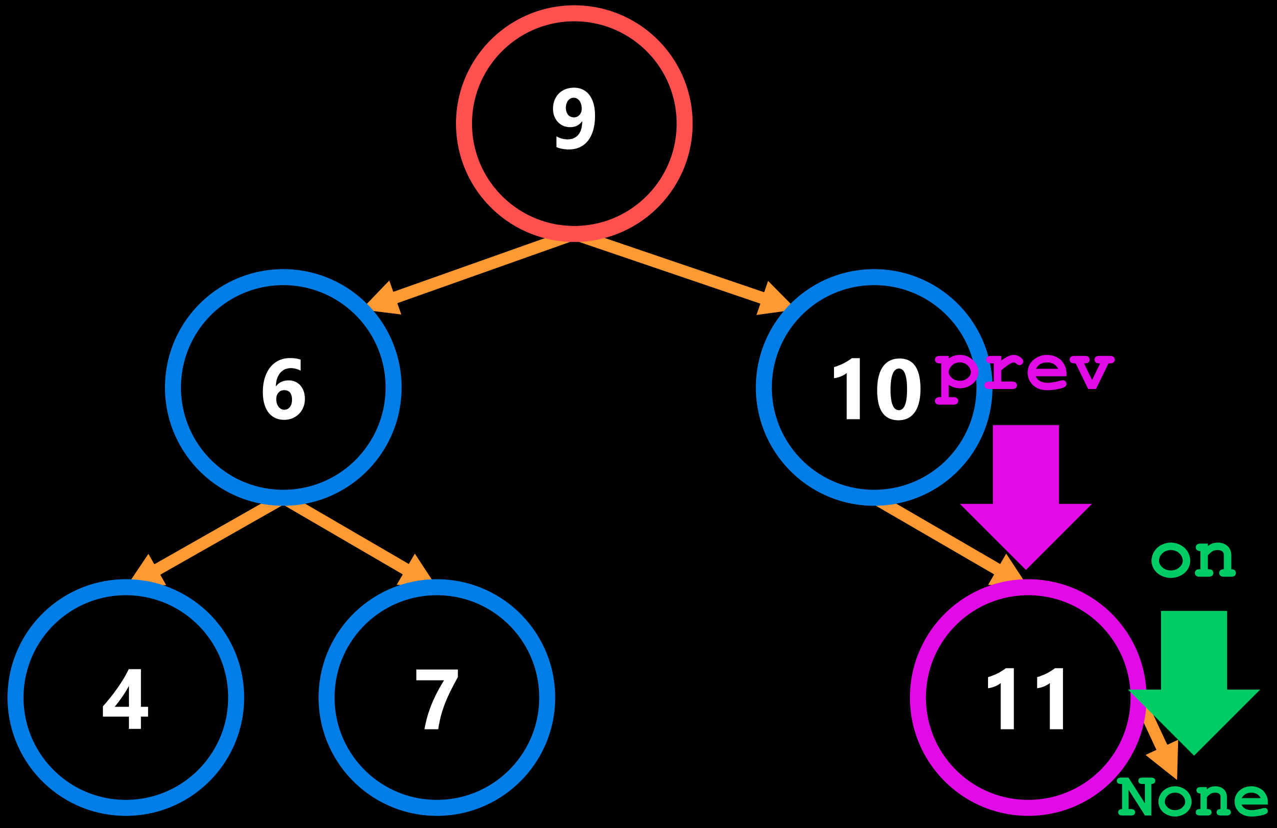
            prev = on
            on = on.right

        return True
```

Return True.

stack = [ ]

This is a Valid Binary Search Tree!



Let's try with an invalid binary search tree.

```
class BinarySearchTree:
    """A Node class used by a binary search tree class."""

    def __init__(self, root=None):
        """
        (self) -> NoneType
        Create an empty binary tree.
        """
        self.root = root

    def print_tree(self): ...

    def is_valid(self):
        """
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        on = self.root
        stack = []
        prev = None

        while len(stack) > 0 or on is not None:

            while on is not None:
                stack.append(on)
                on = on.left

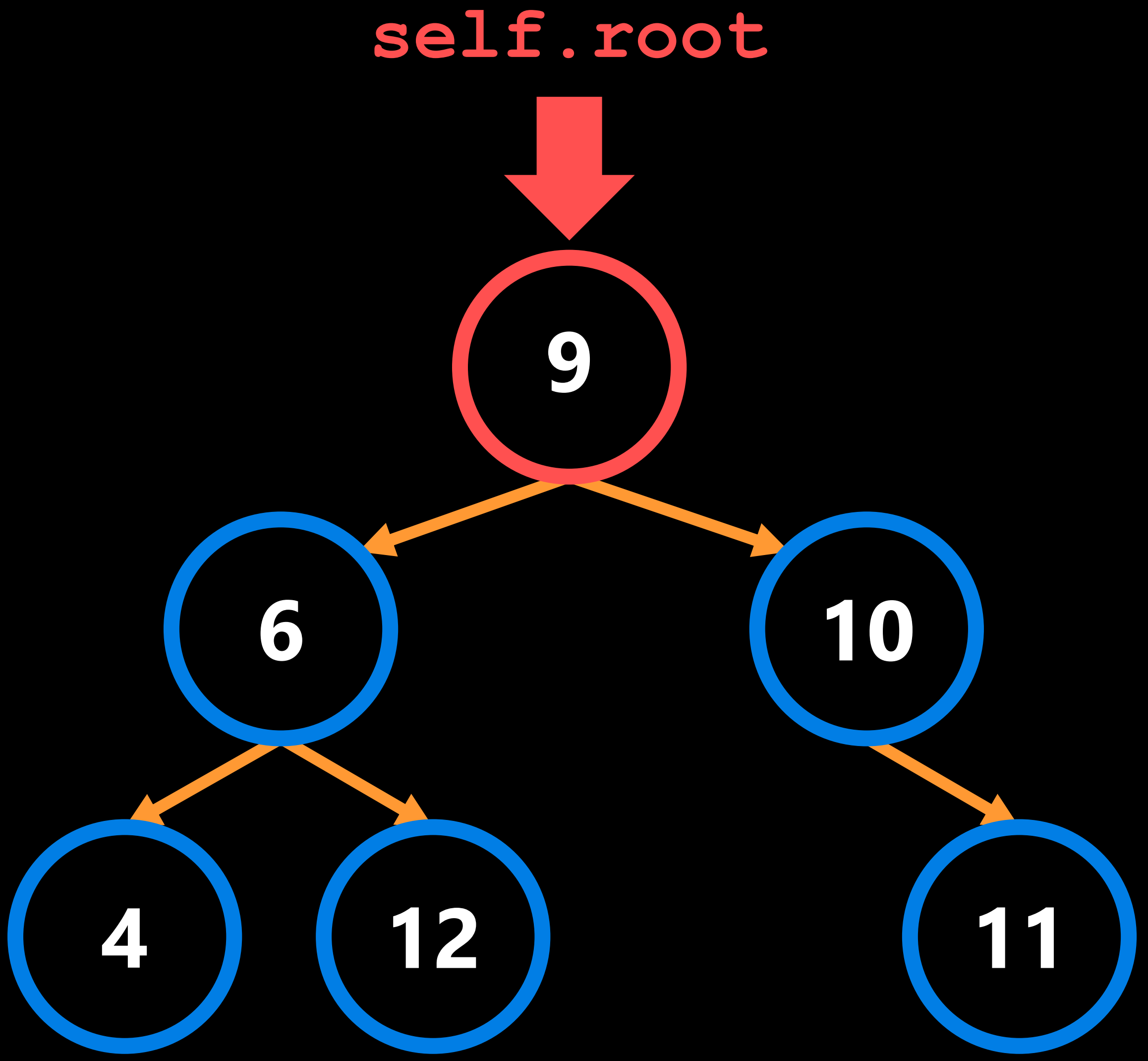
            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

This is an Invalid Tree



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                on = on.left

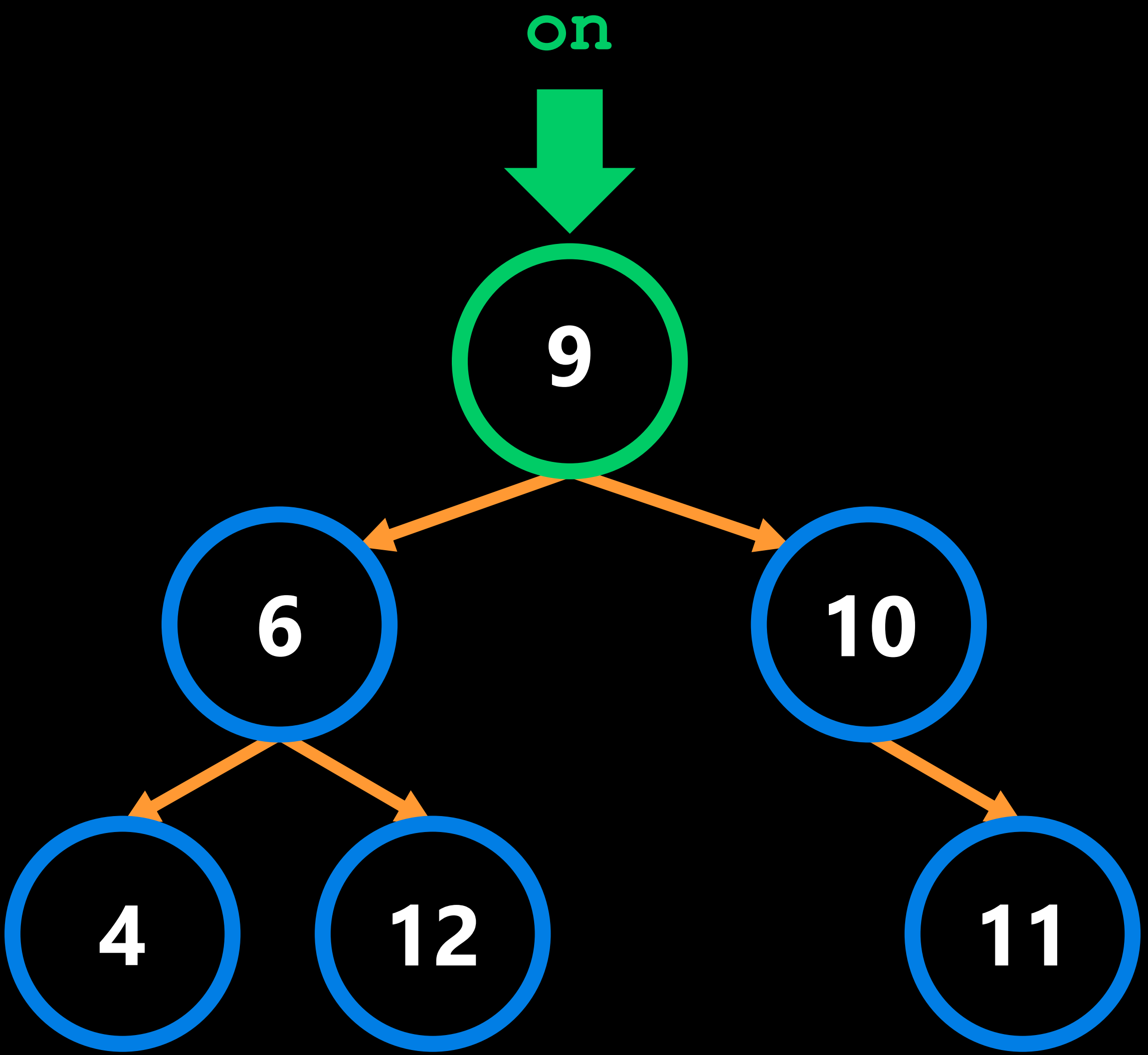
            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

Set on position.



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                on = on.left

            on = stack.pop()

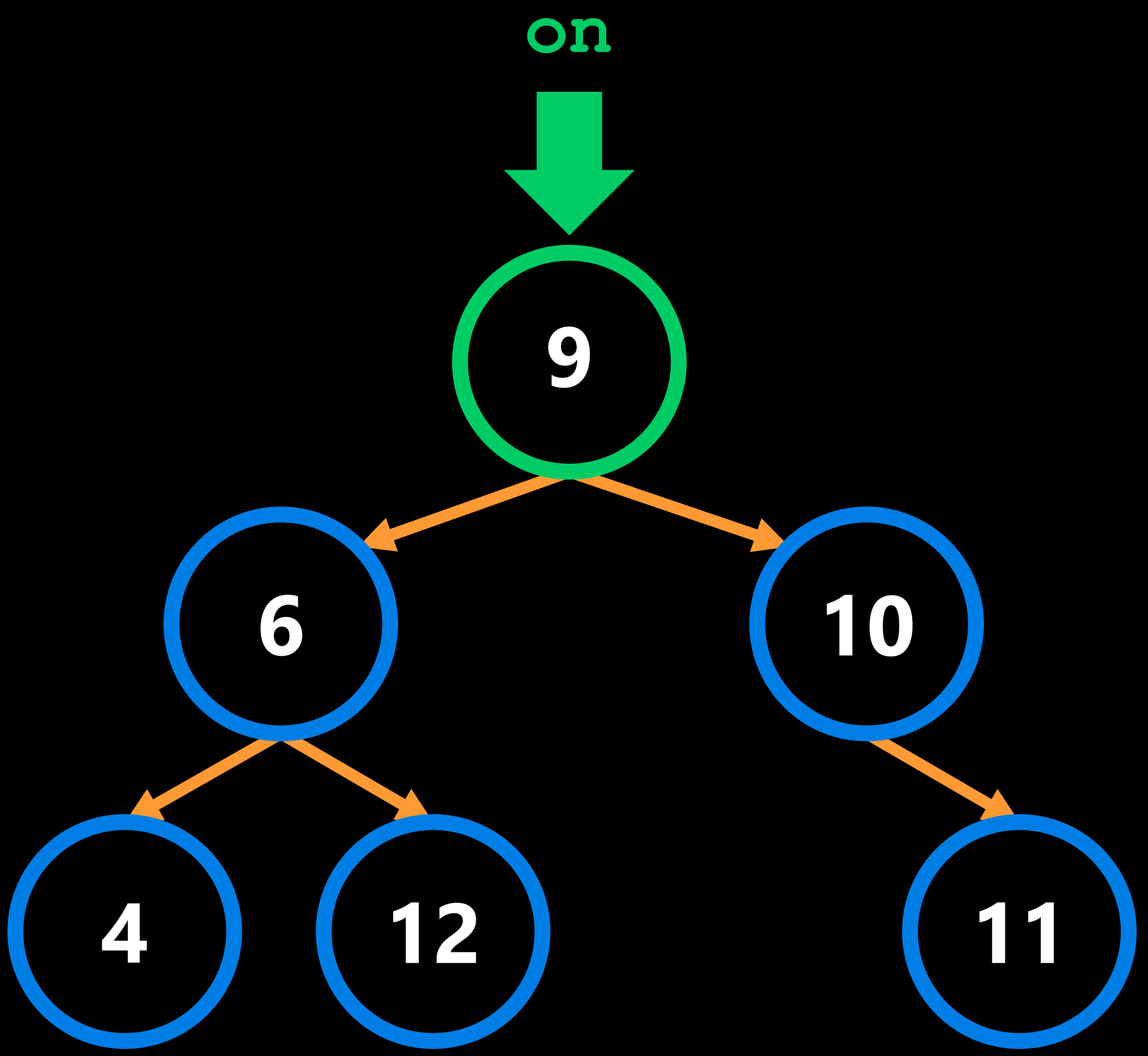
            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

Create stack list.

stack = [ ]



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                stack.append(on)
                on = on.left

            on = stack.pop()

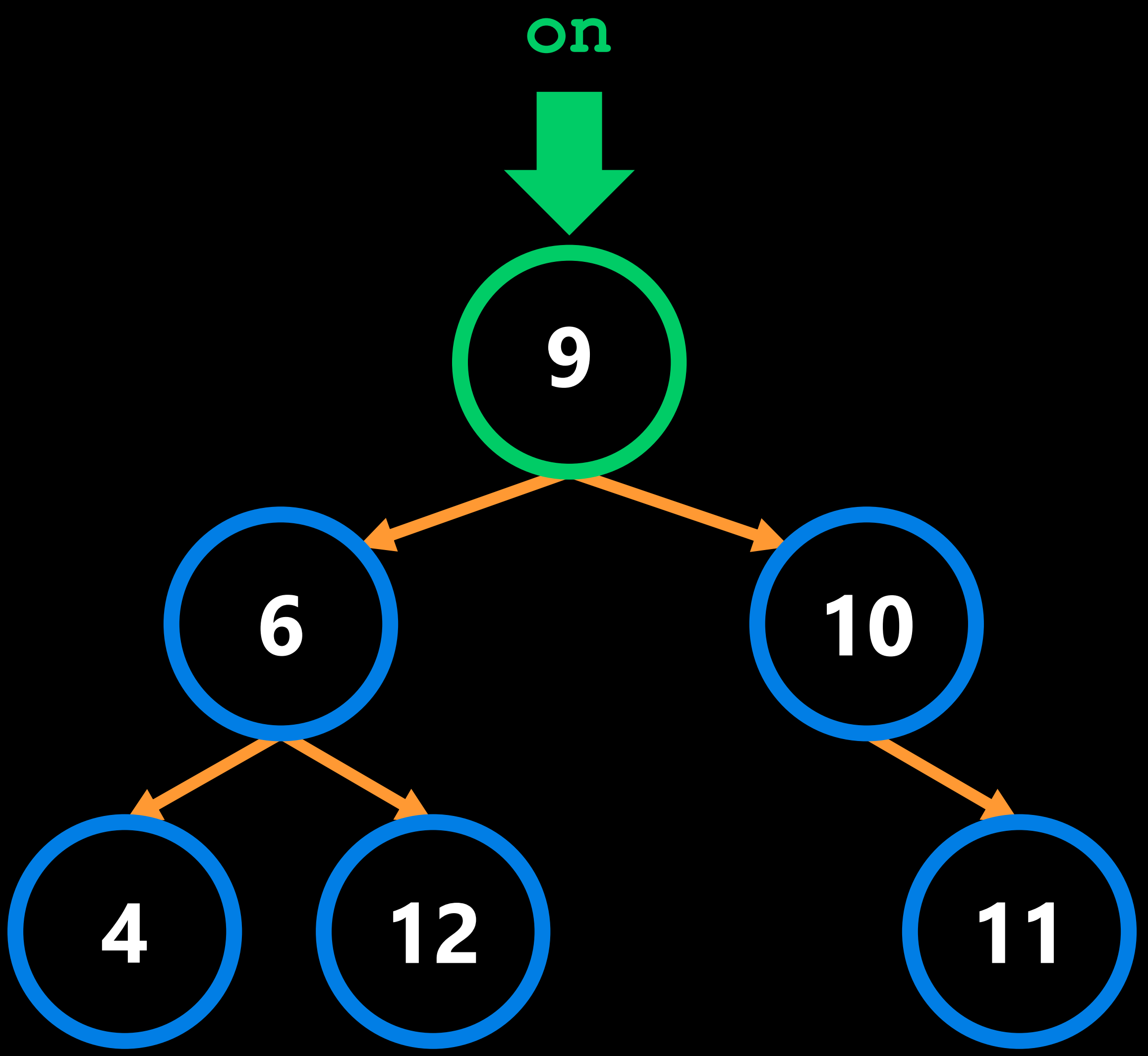
            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

Initialize previous node.

stack = [ ]



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        """
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            on = stack.pop()

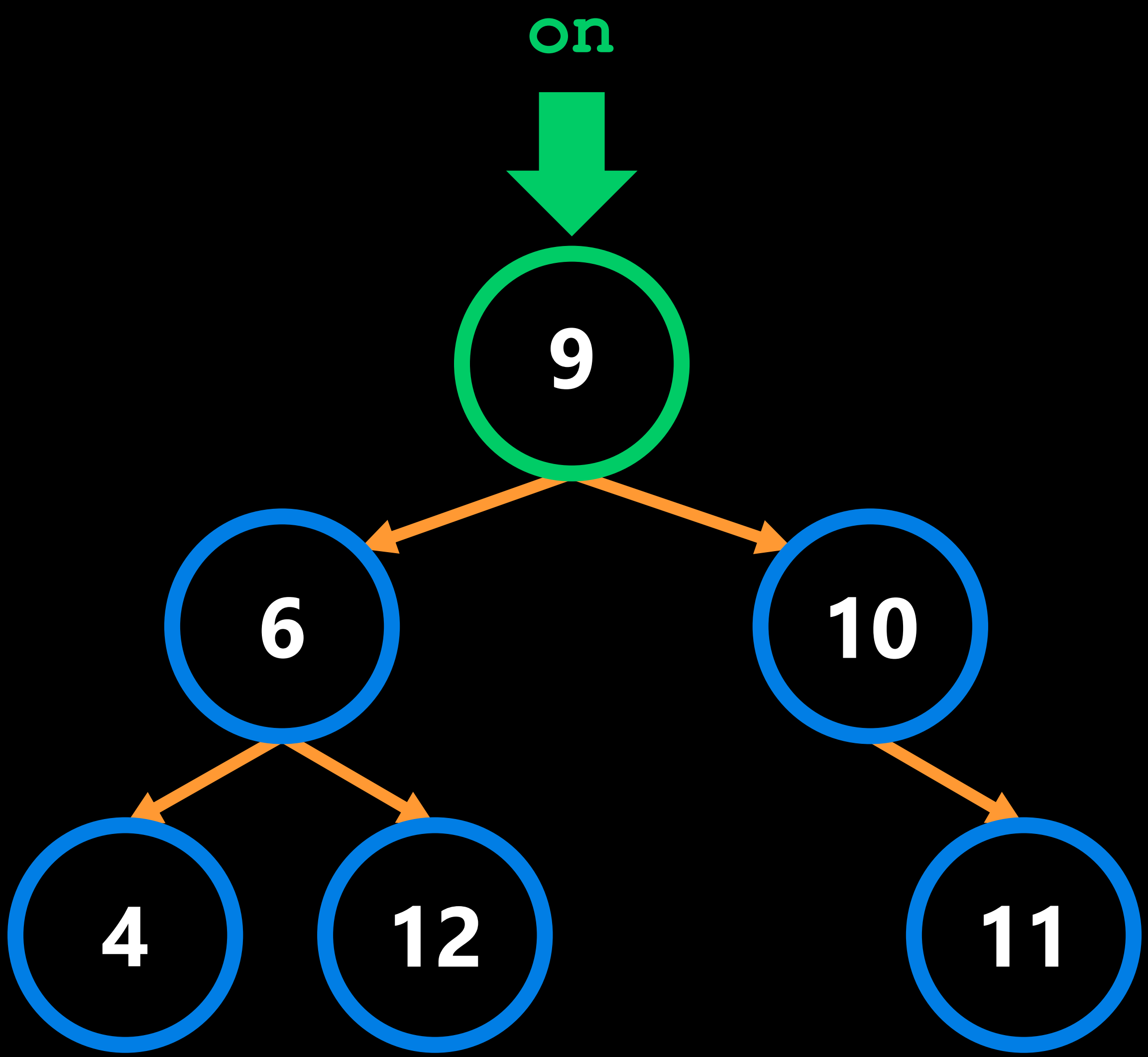
            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

True

stack = [ ]



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        """
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        stack = []
        prev = None

        while len(stack) > 0 or on is not None:  ← True

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                stack.append(on)
                on = on.left

            on = stack.pop()

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            prev = on
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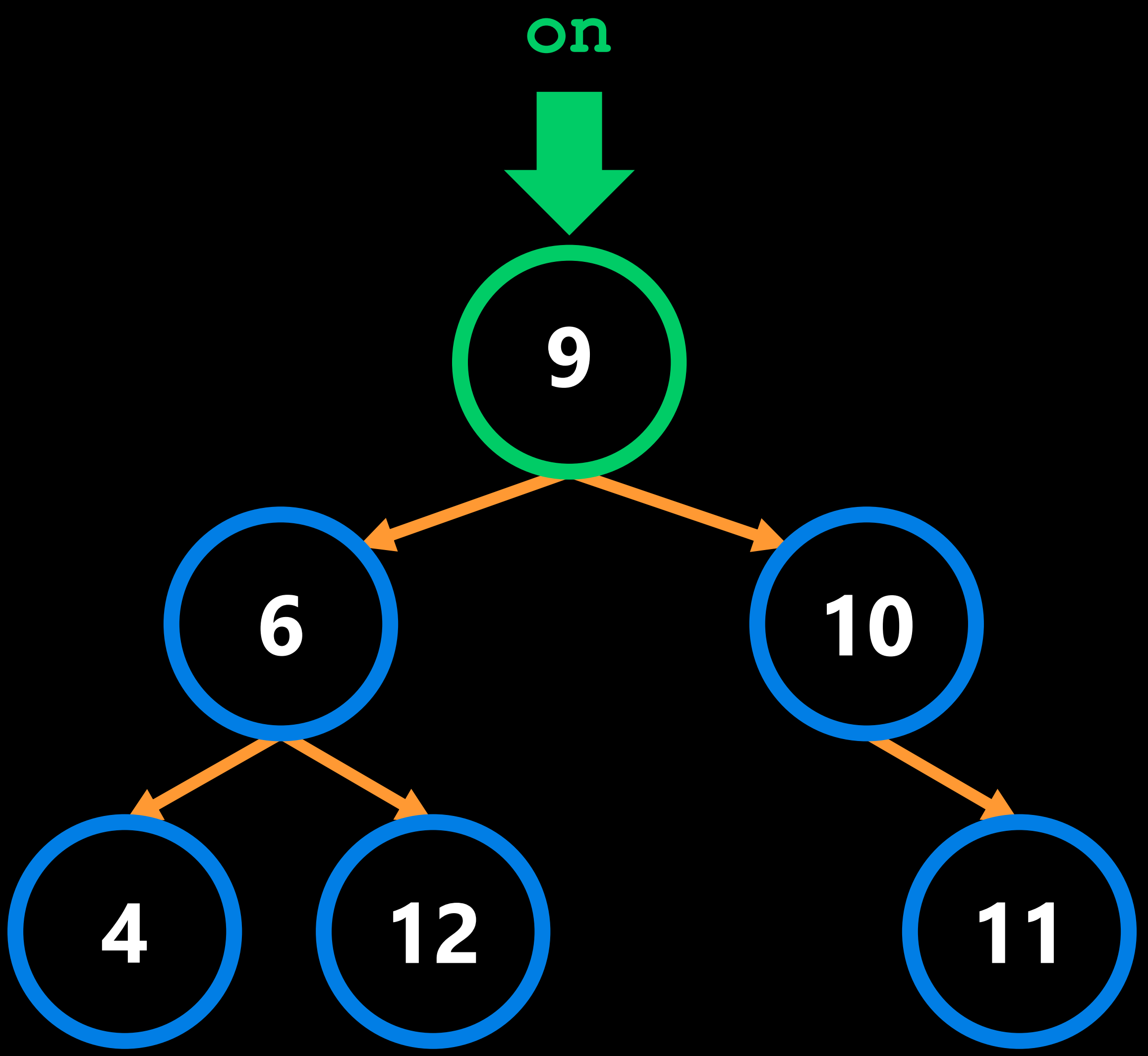
        return True
```

stack = [ ]



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

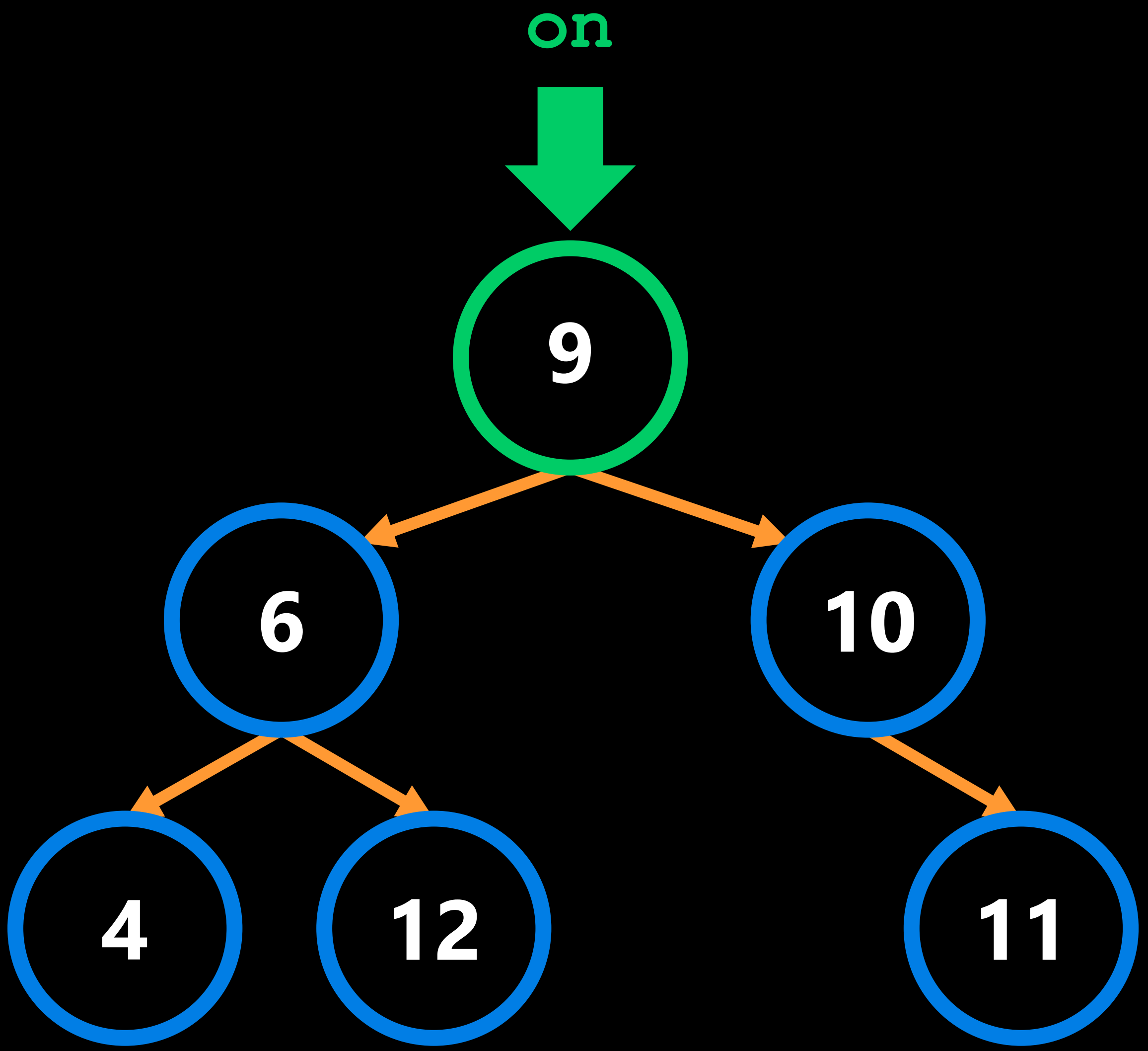
        return True
```

True

True

Add on to stack.

stack = [9]



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

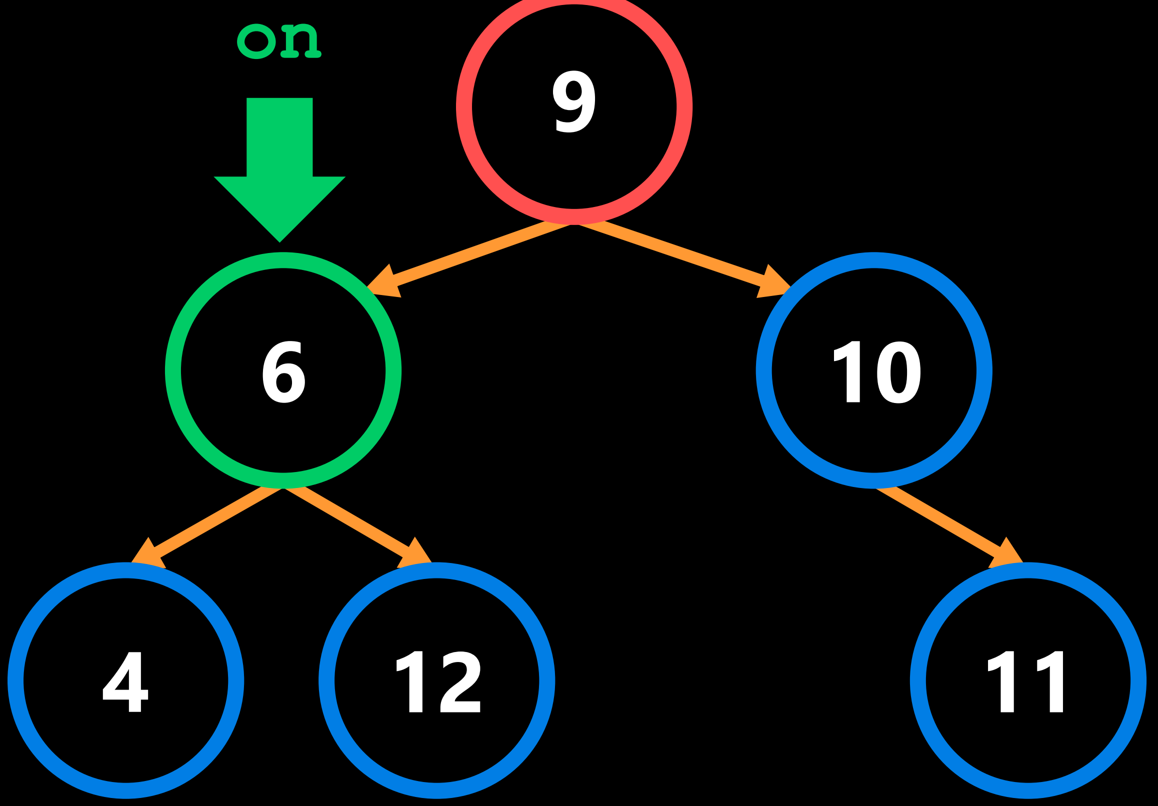
        return True
```

True

True

Move on to left node pointer.

stack = [9]



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

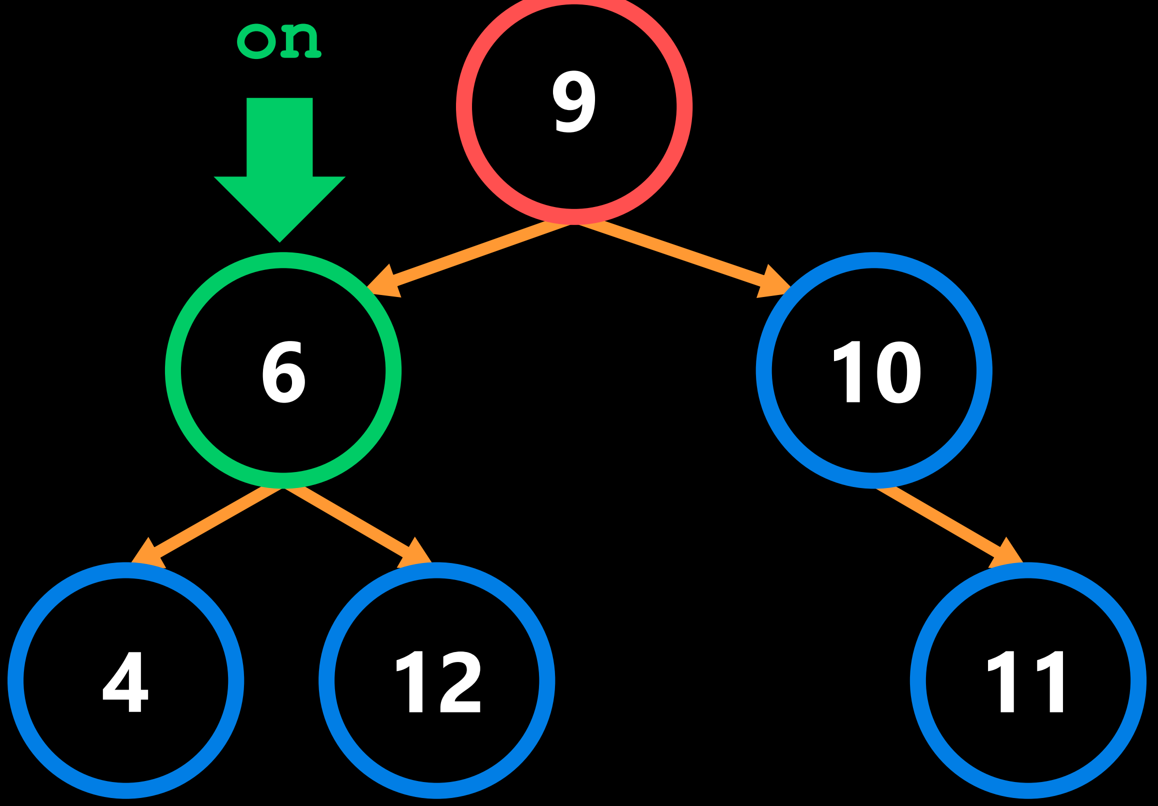
        return True
```

True

True

Add on to stack.

stack = [9 6]



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        while len(stack) > 0 or on is not None:

            while on is not None:
                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

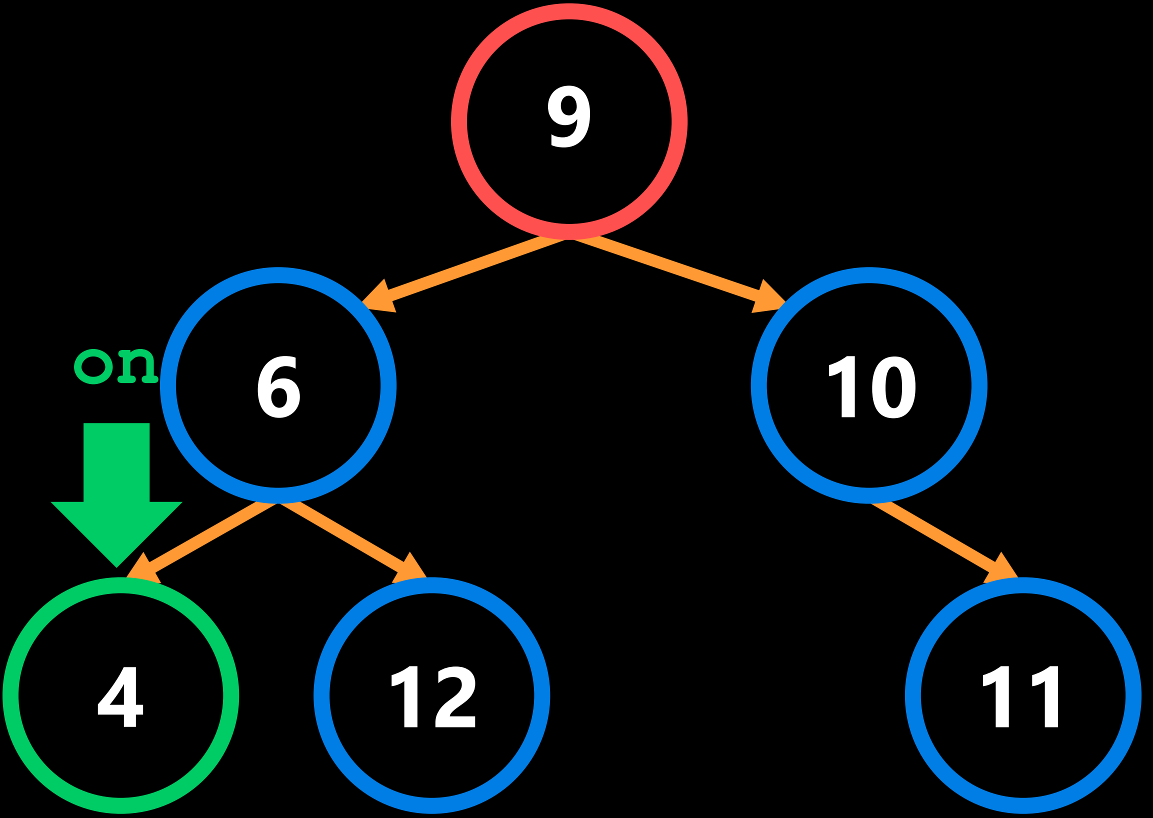
        return True
```

stack = [9 6]

True

True

Move on to left node pointer.



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                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

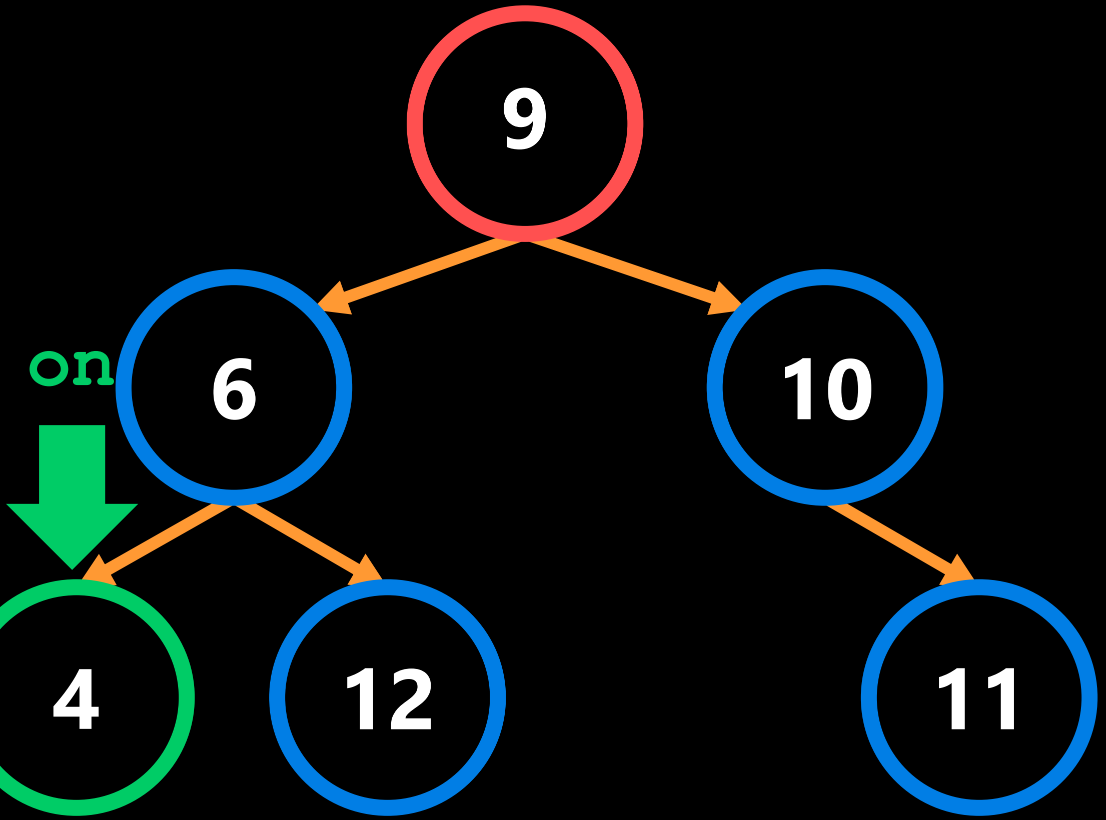
        return True
```

True

True

Add **on** to stack.

stack = [9 6 4]



```
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    """A Node class used by a binary search tree class."""

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        (self) -> NoneType
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        """
        self.root = root

    def print_tree(self): ...

    def is_valid(self):
        """
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        Checks if self.root is a valid binary search tree.
        """
        on = self.root
        stack = []
        prev = None

        while len(stack) > 0 or on is not None:

            while on is not None:
                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

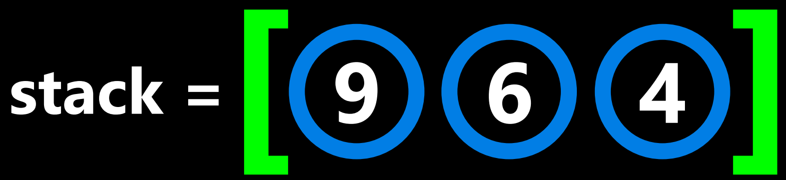
            prev = on
            on = on.right

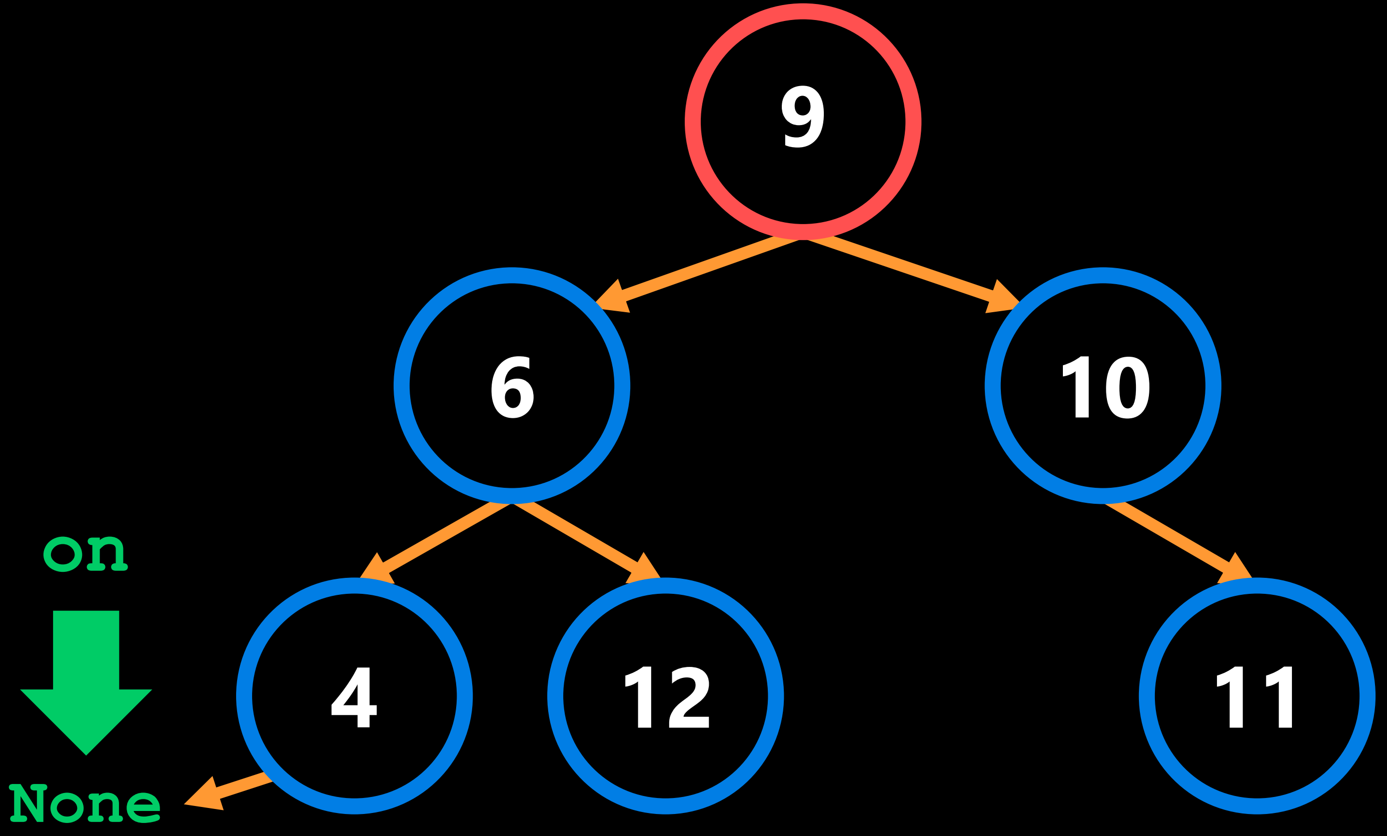
        return True
```

True

True

Move on to left node pointer.





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        """
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        stack = []
        prev = None

        while len(stack) > 0 or on is not None:  ⇐ True

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            prev = on
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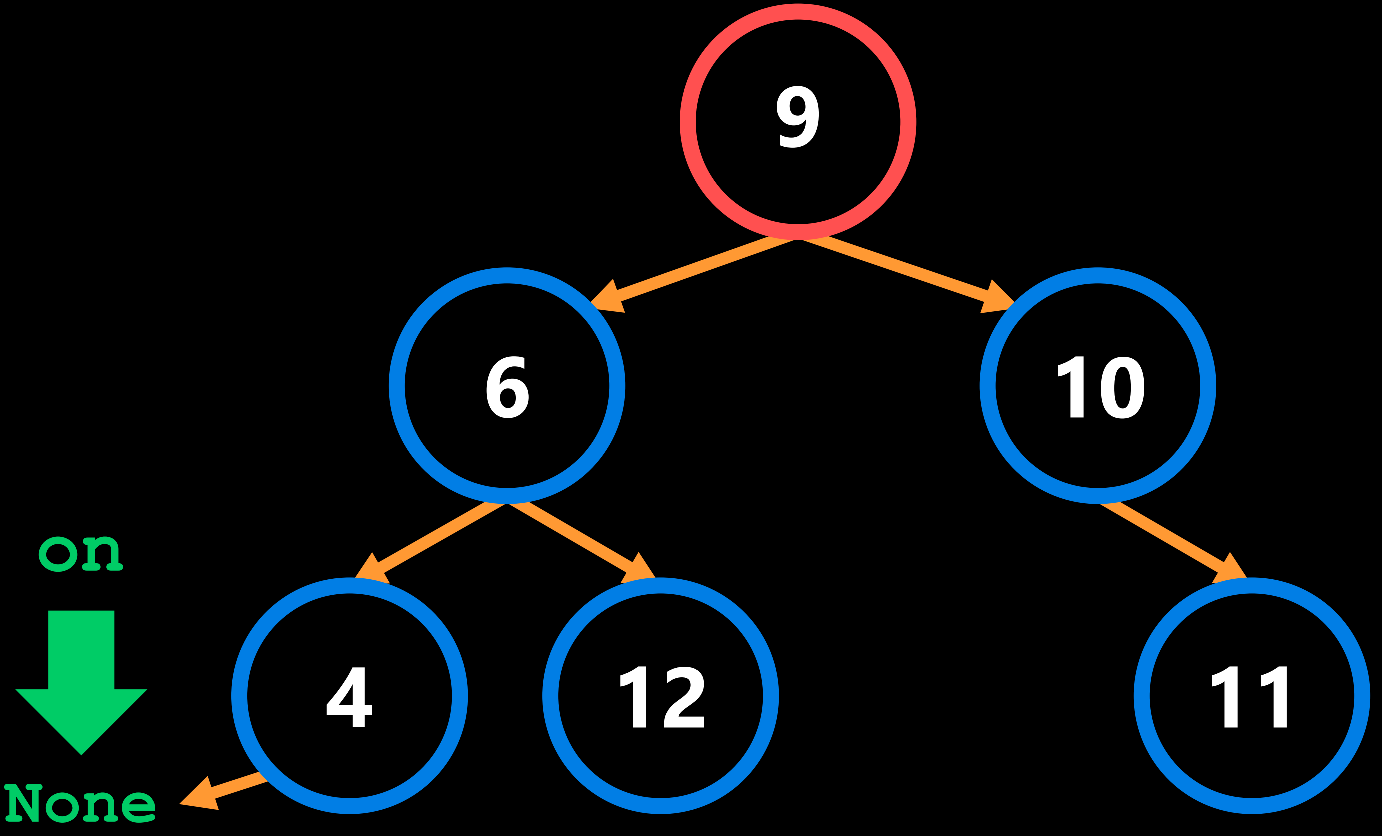
        return True
```

stack = [9 6 4]



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

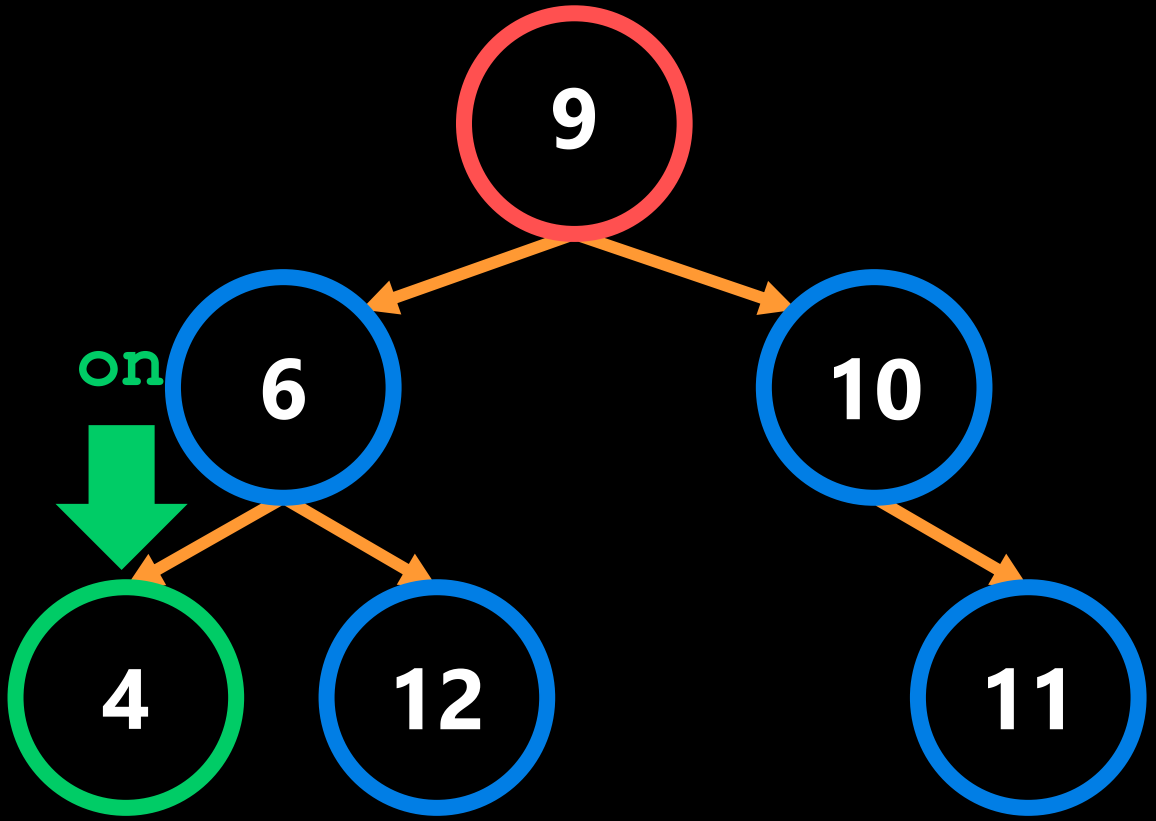
        return True
```

stack = [9 6]

True

False

Set on to left node in stack.



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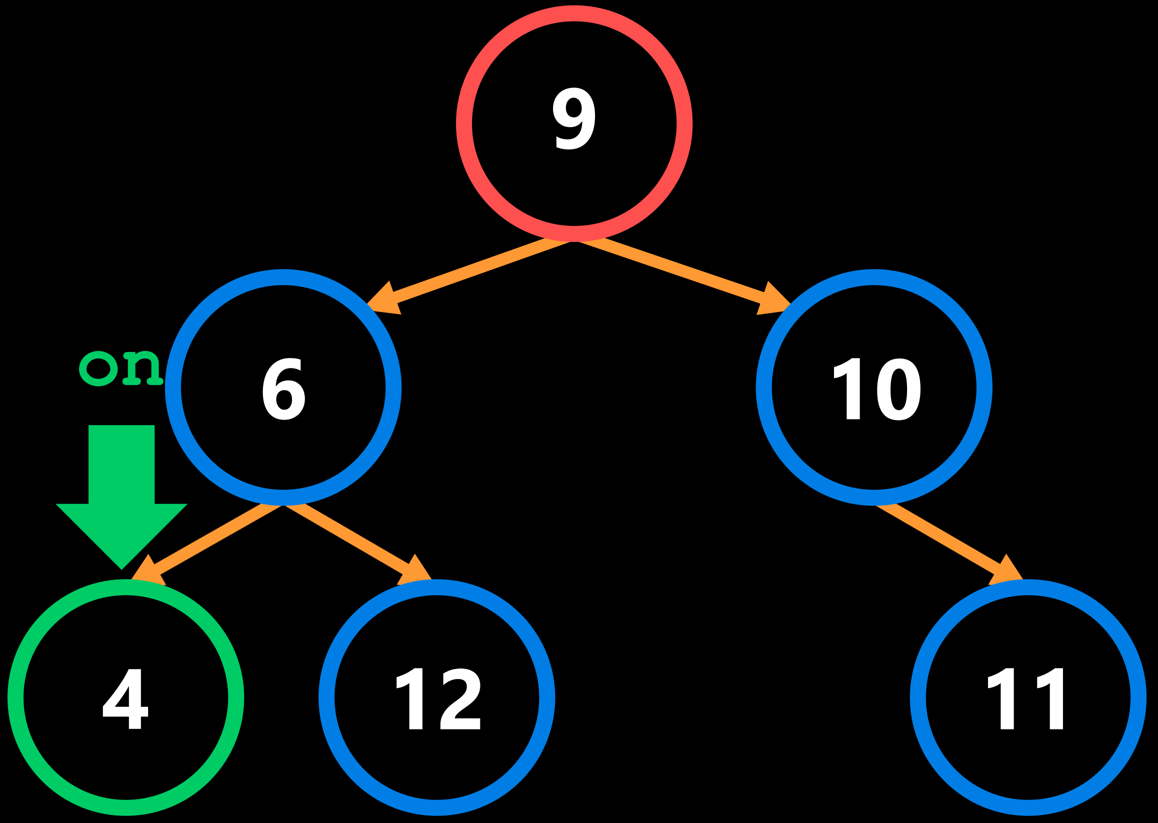
        return True
```

stack = [9 6]



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            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

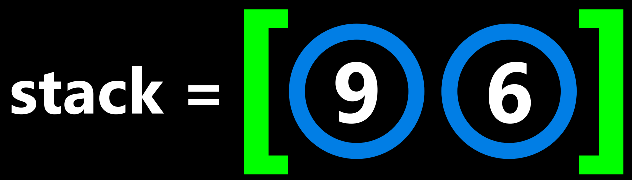
        return True
```

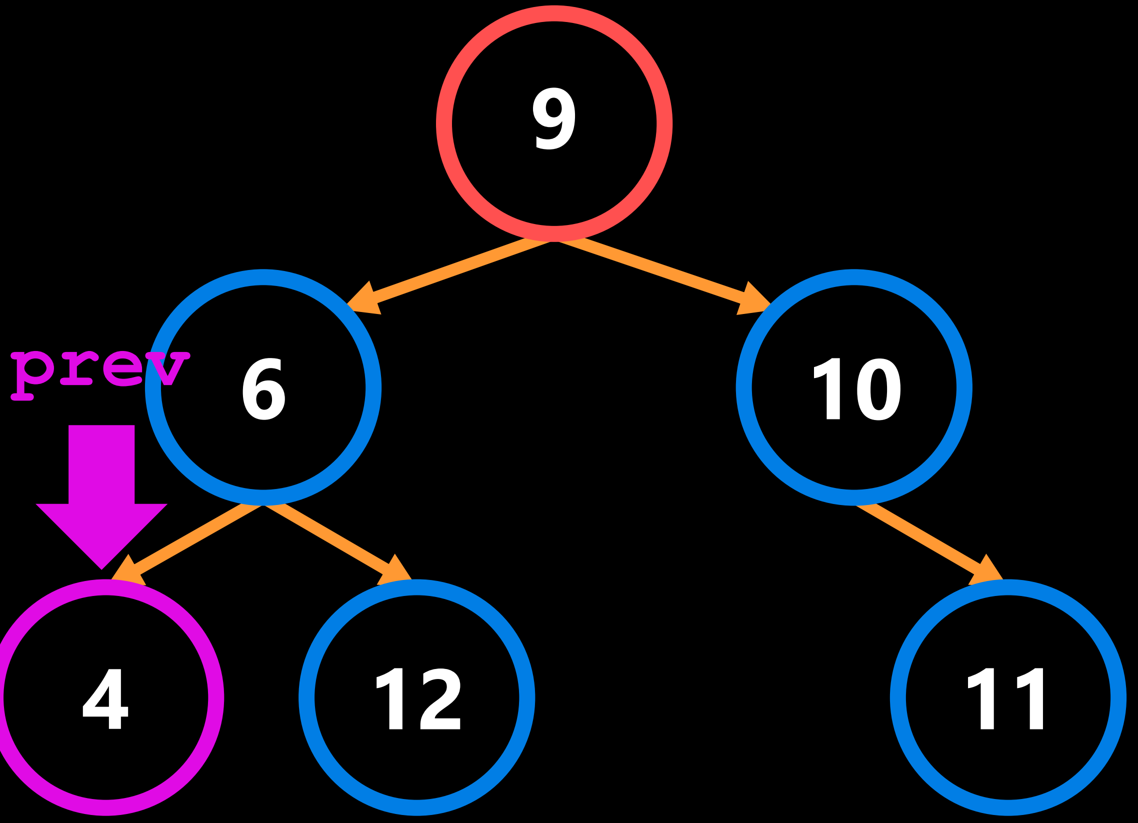
True

False

False

Set prev to on.





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        while len(stack) > 0 or on is not None:

            while on is not None:
                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

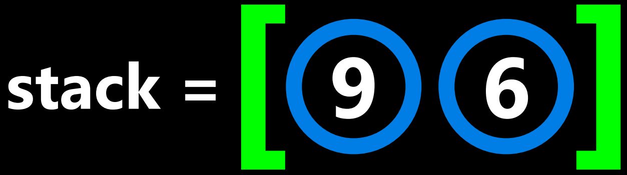
        return True
```

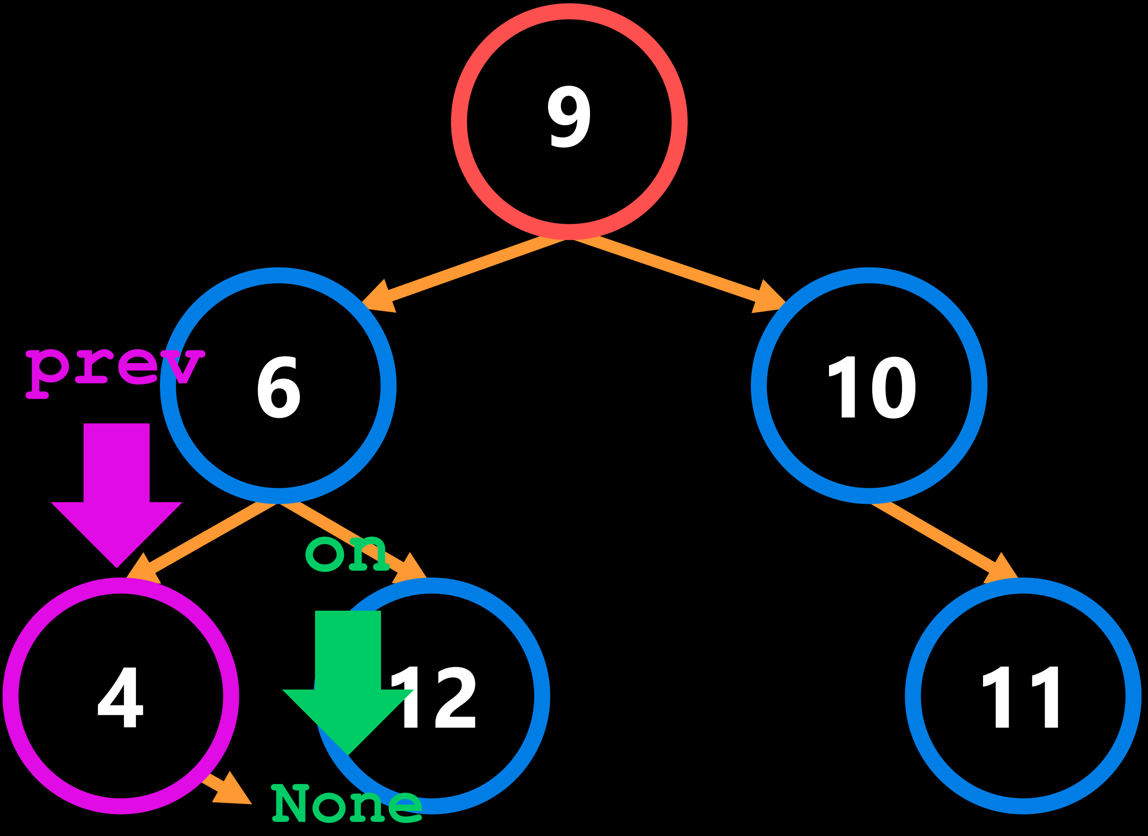
True

False

False

Move **on** to the right pointer.





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                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

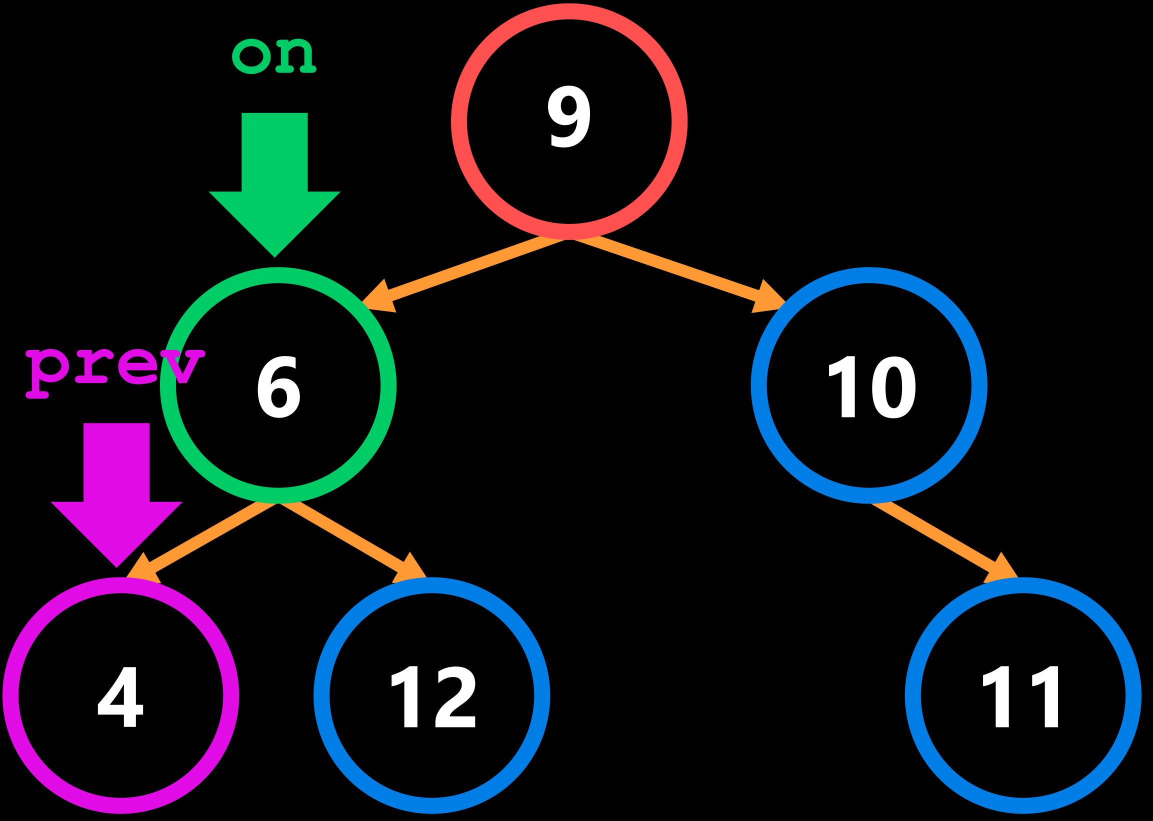
        return True
```

True

False

Set on to left node in stack.

stack = [9]



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        """
        on = self.root
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                stack.append(on)
                on = on.left

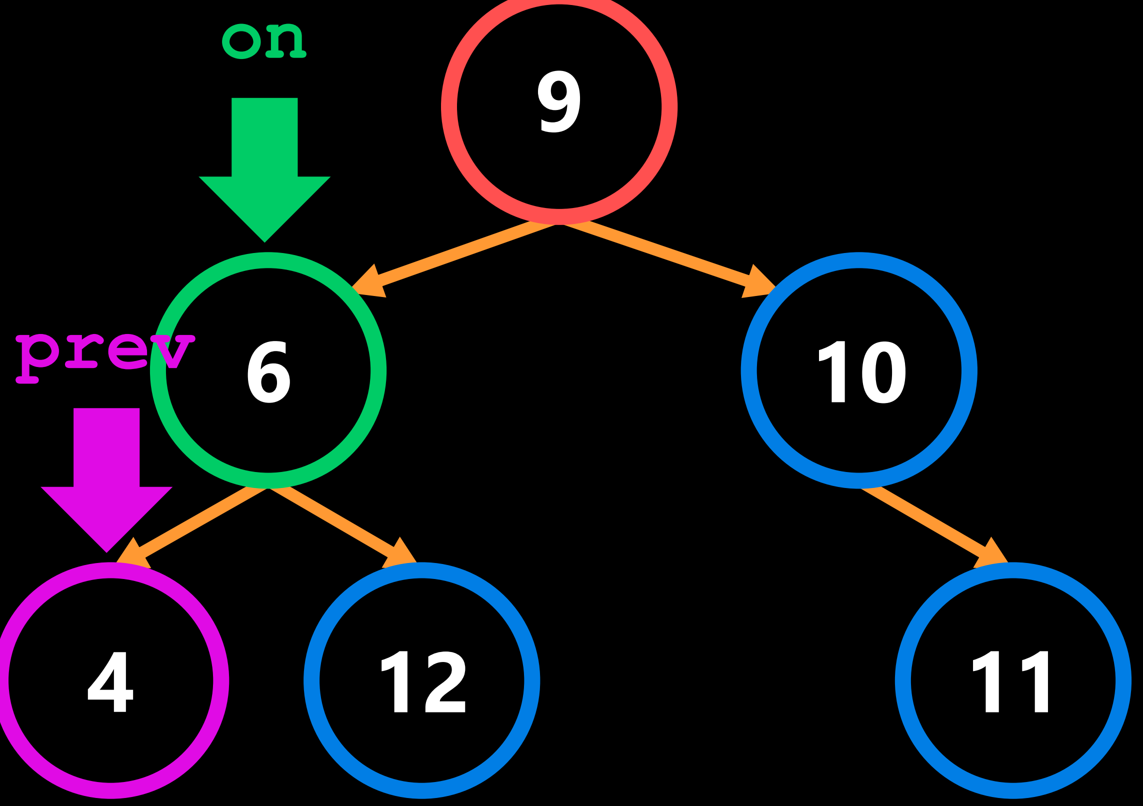
            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:  ← False
                return False

            prev = on
            on = on.right

        return True
```

stack = [9]



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

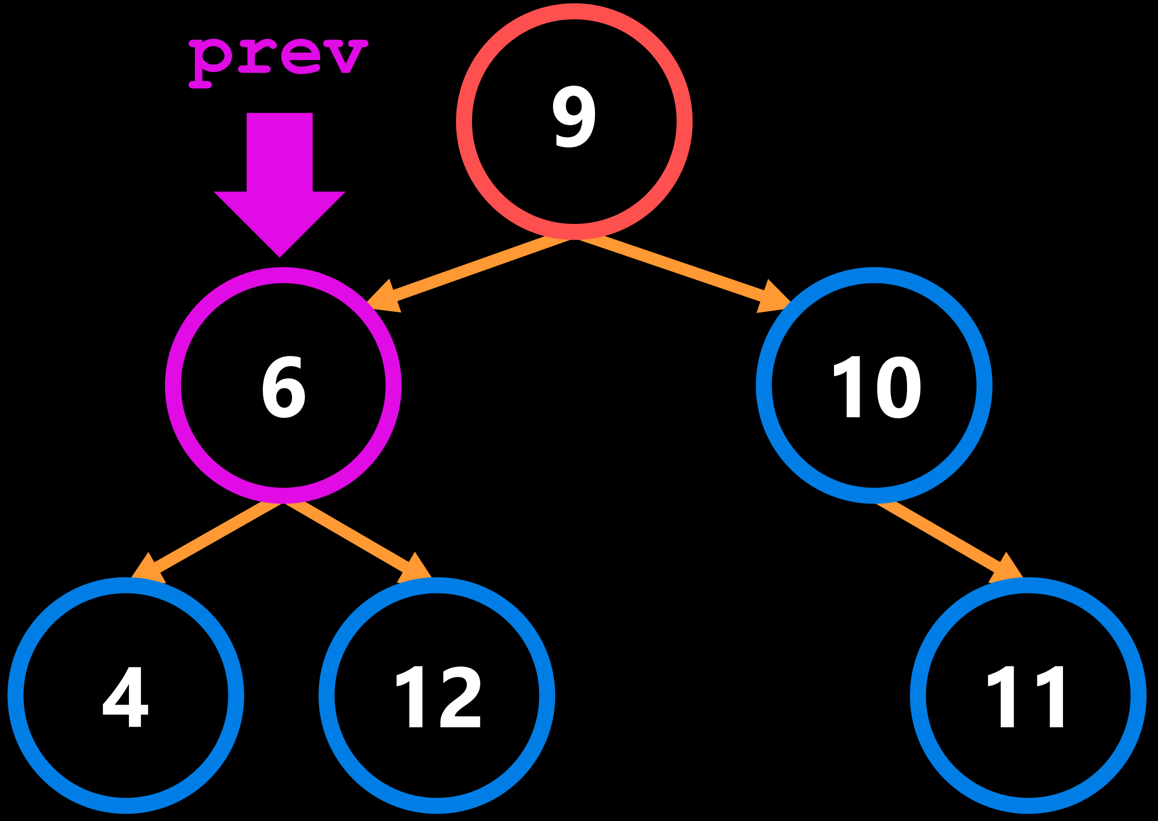
True

False

False

Set prev to on.

stack = [9]



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        """
        on = self.root
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        while len(stack) > 0 or on is not None:          True

            while on is not None:          False
                stack.append(on)
                on = on.left

            on = stack.pop()

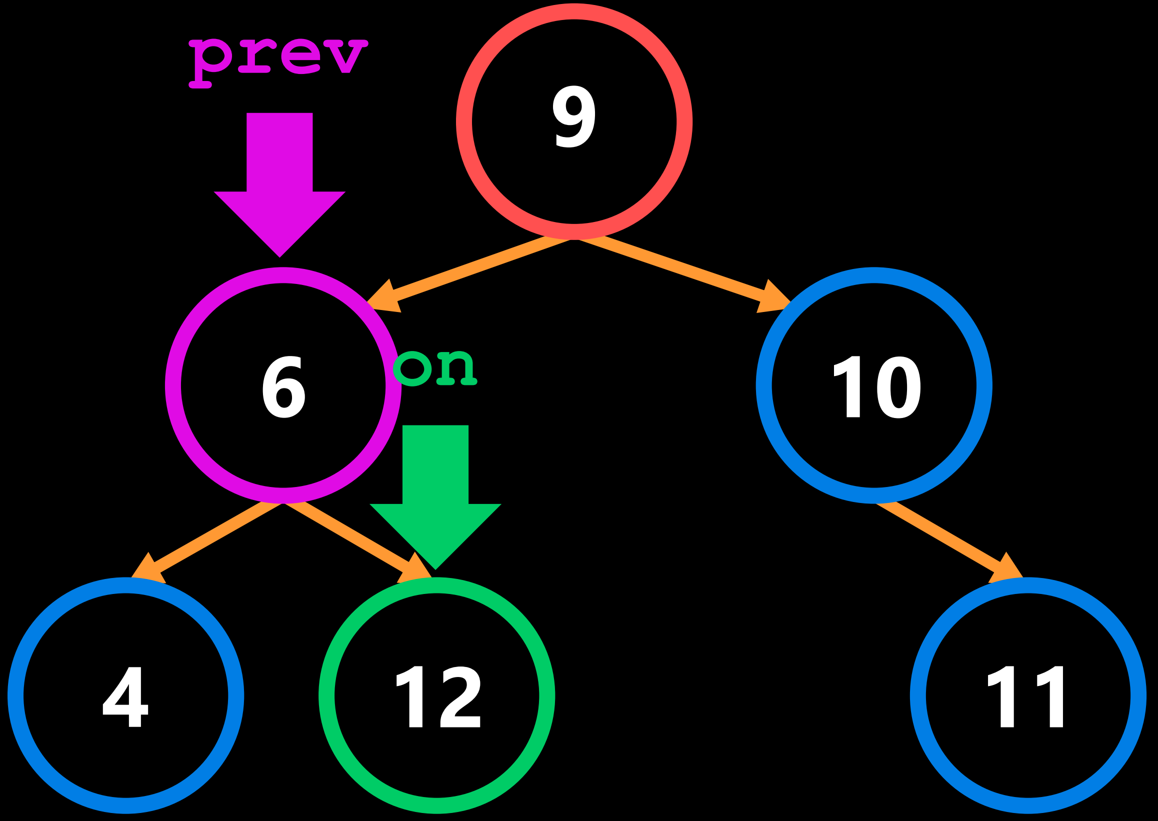
            if prev is not None and on.cargo <= prev.cargo:          False
                return False

            prev = on
            on = on.right

        return True
```

stack = [9]

Move **on** to the right pointer.



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            if prev is not None and on.cargo <= prev.cargo:
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            prev = on
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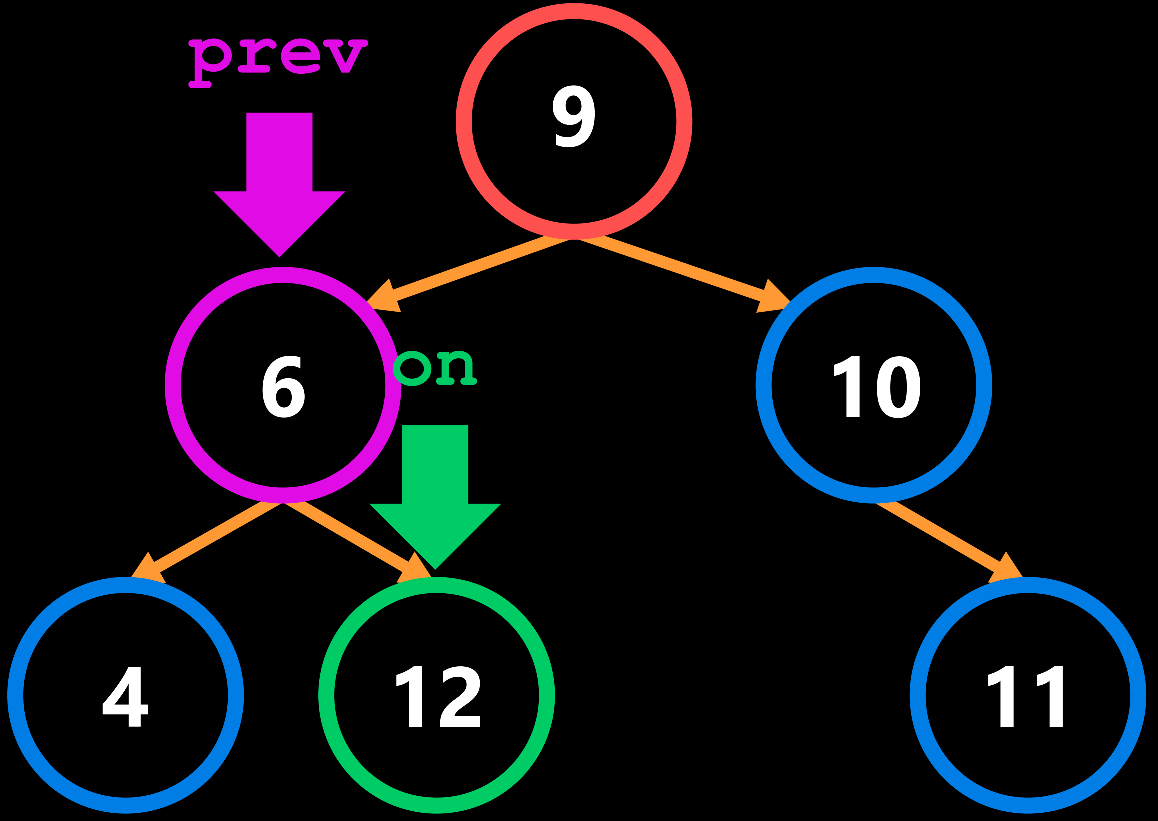
        return True
```

stack = [9]



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            if prev is not None and on.cargo <= prev.cargo:
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            prev = on
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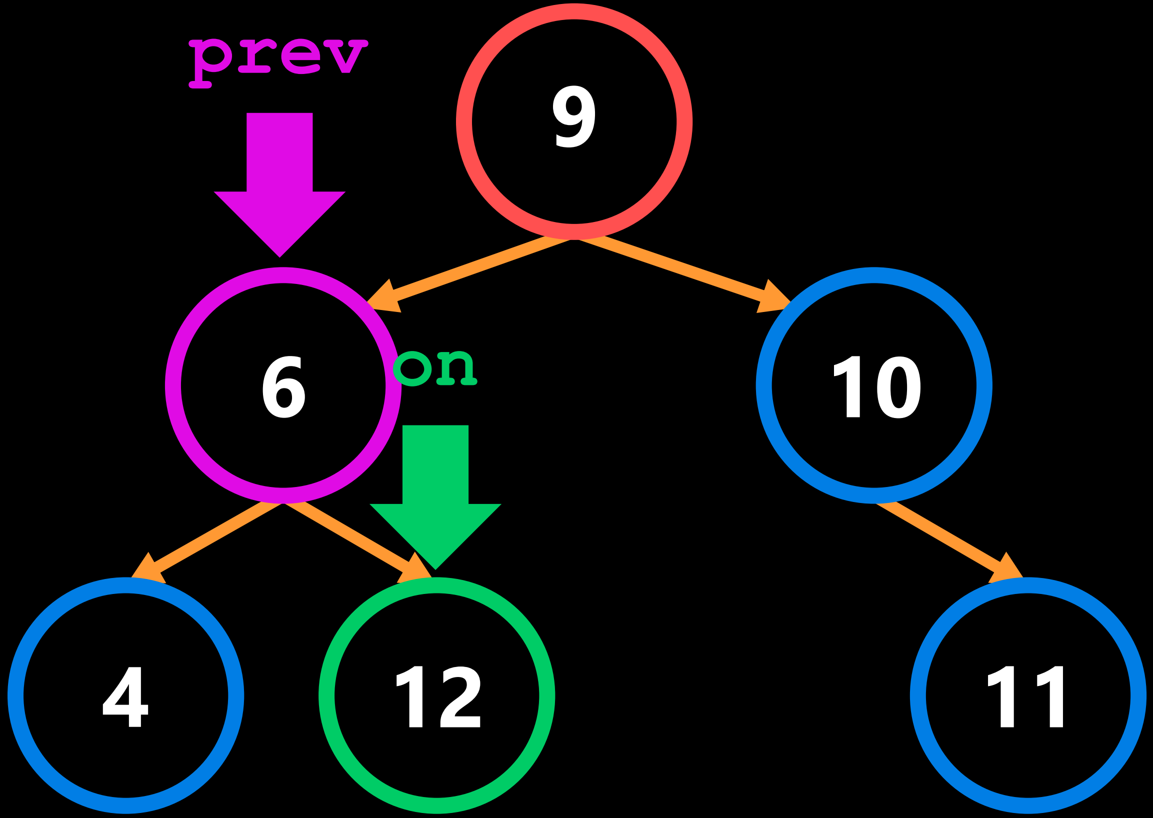
        return True
```

stack = [9]



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

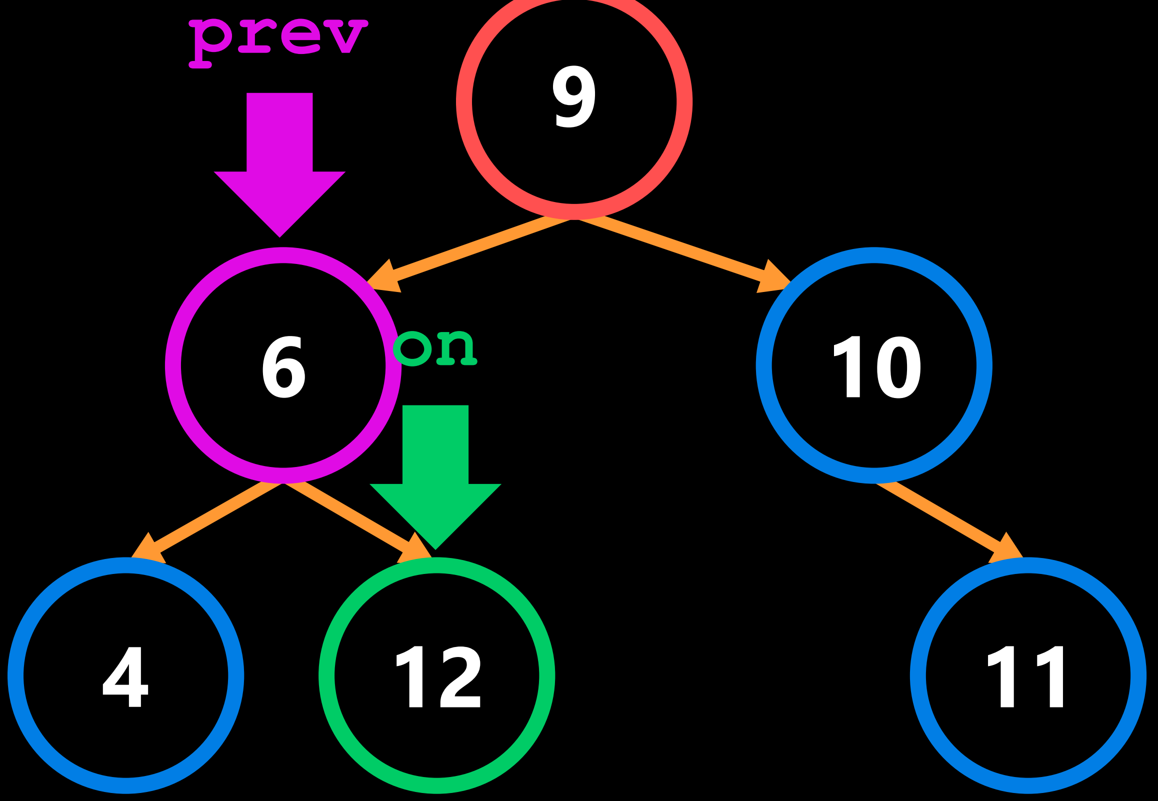
        return True
```

True

True

Add on to stack.

stack = [9 12]



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

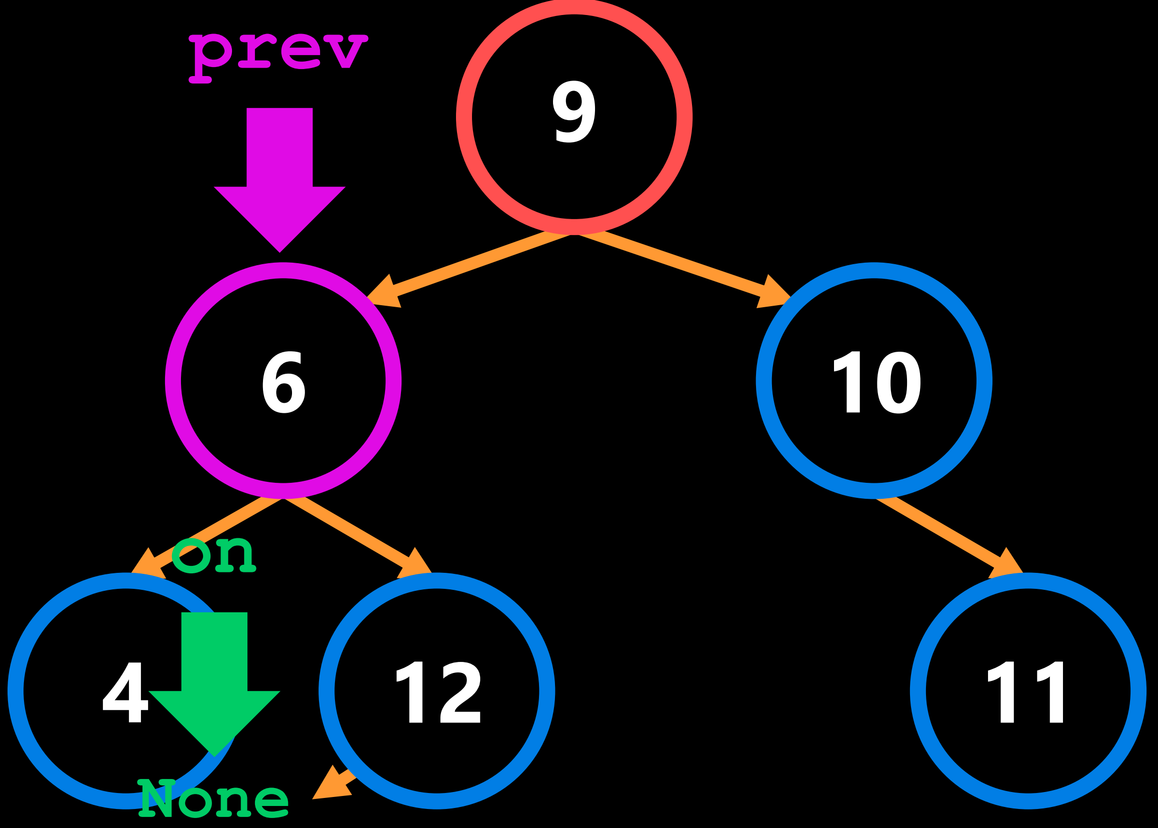
        return True
```

True

True

Move on to left node pointer.

stack = [9 12]



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            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

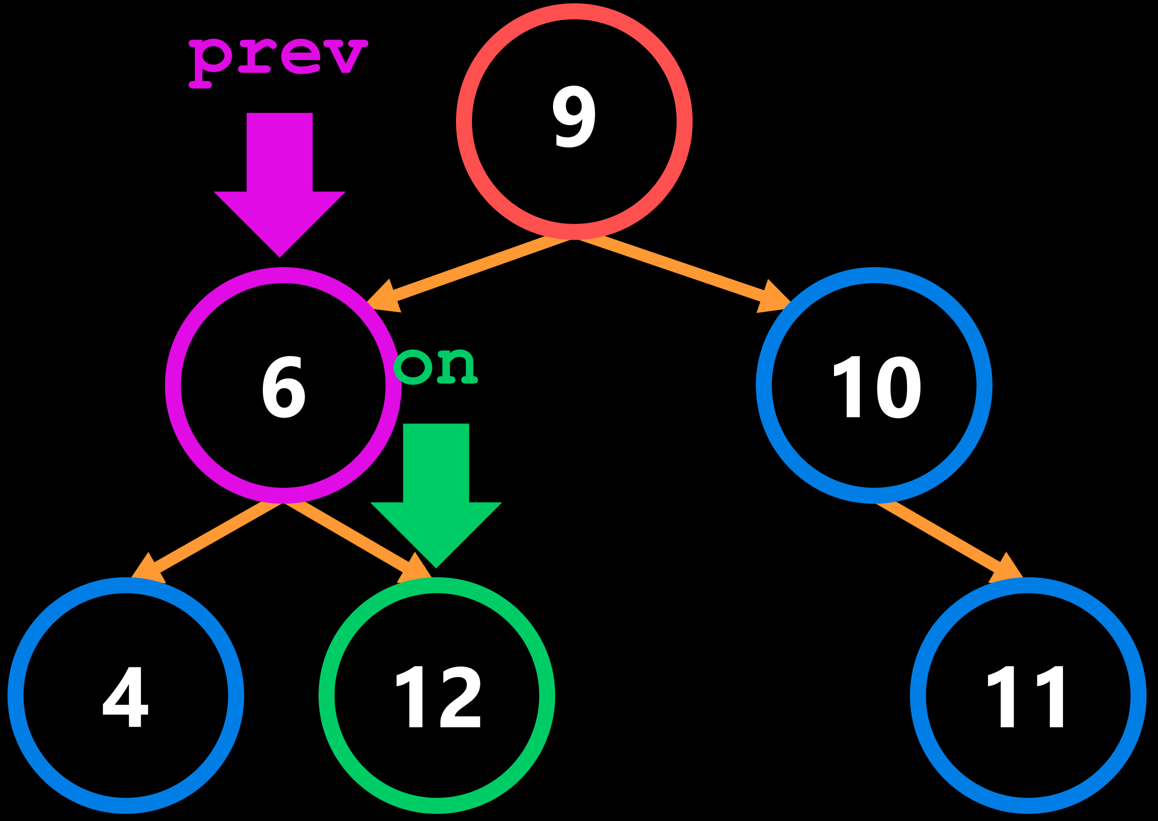
        return True
```

stack = [9]

True

True

Set on to left node in stack.



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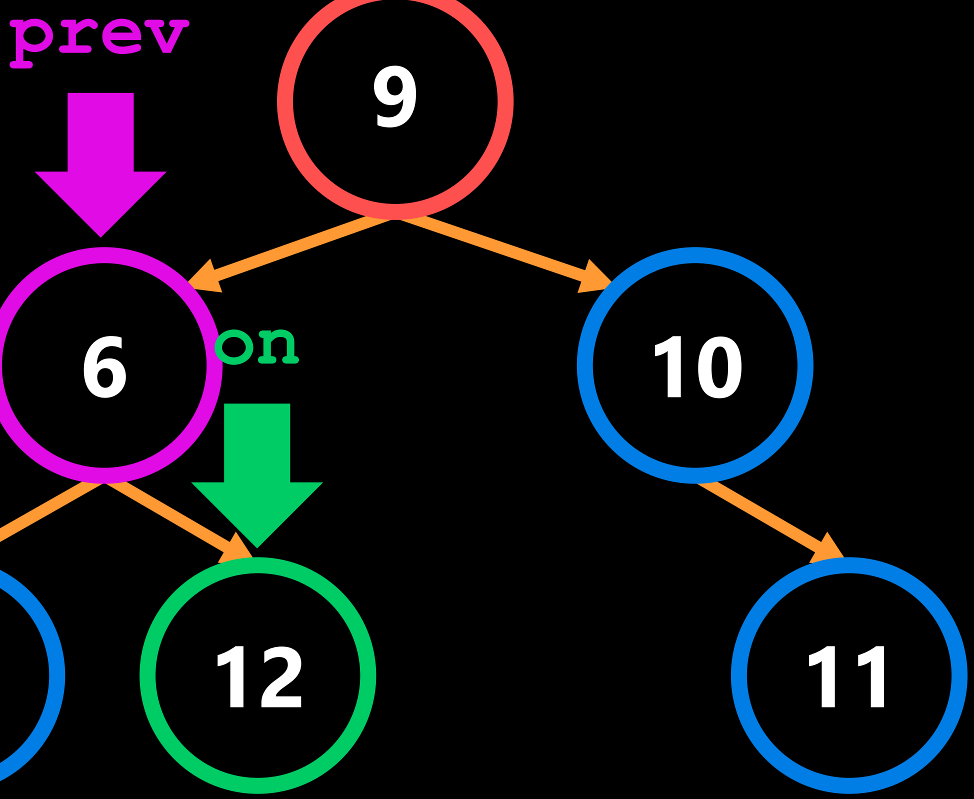
```

stack = [9]



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            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
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        return True
```

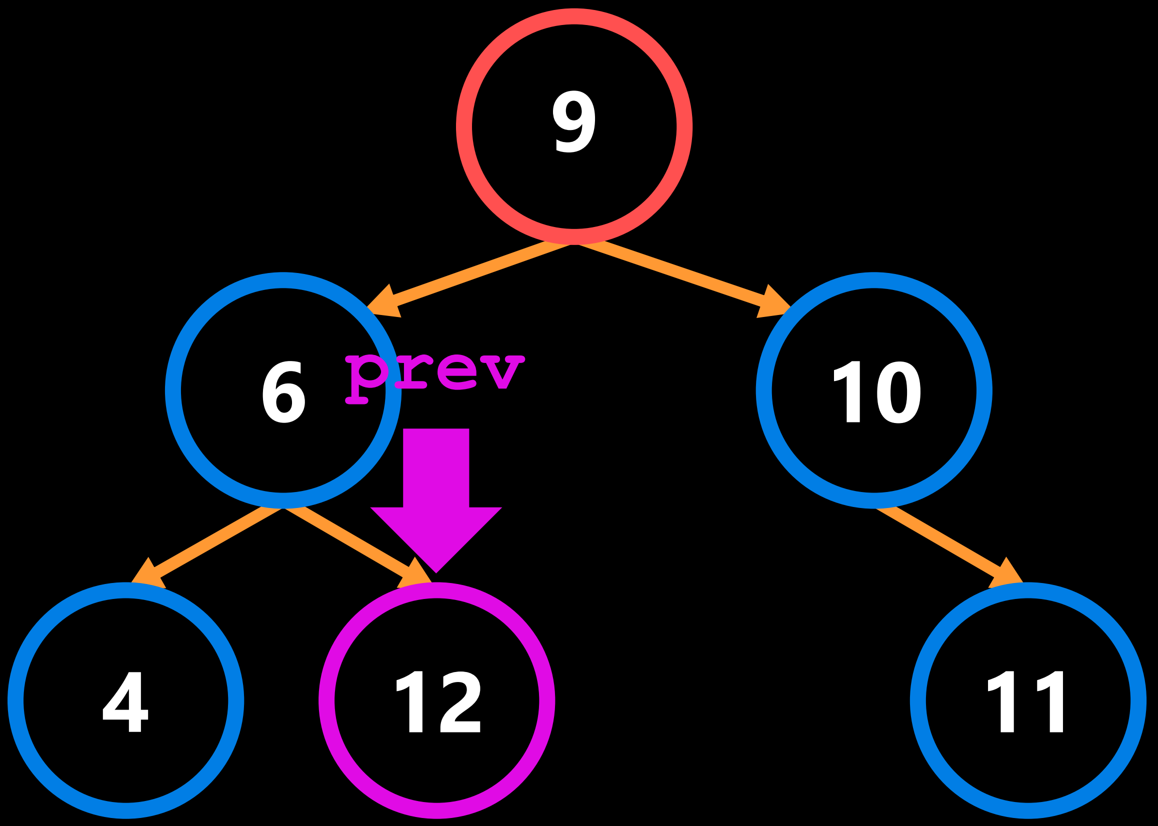
True

True

False

Set prev to on.

stack = [9]



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            on = stack.pop()

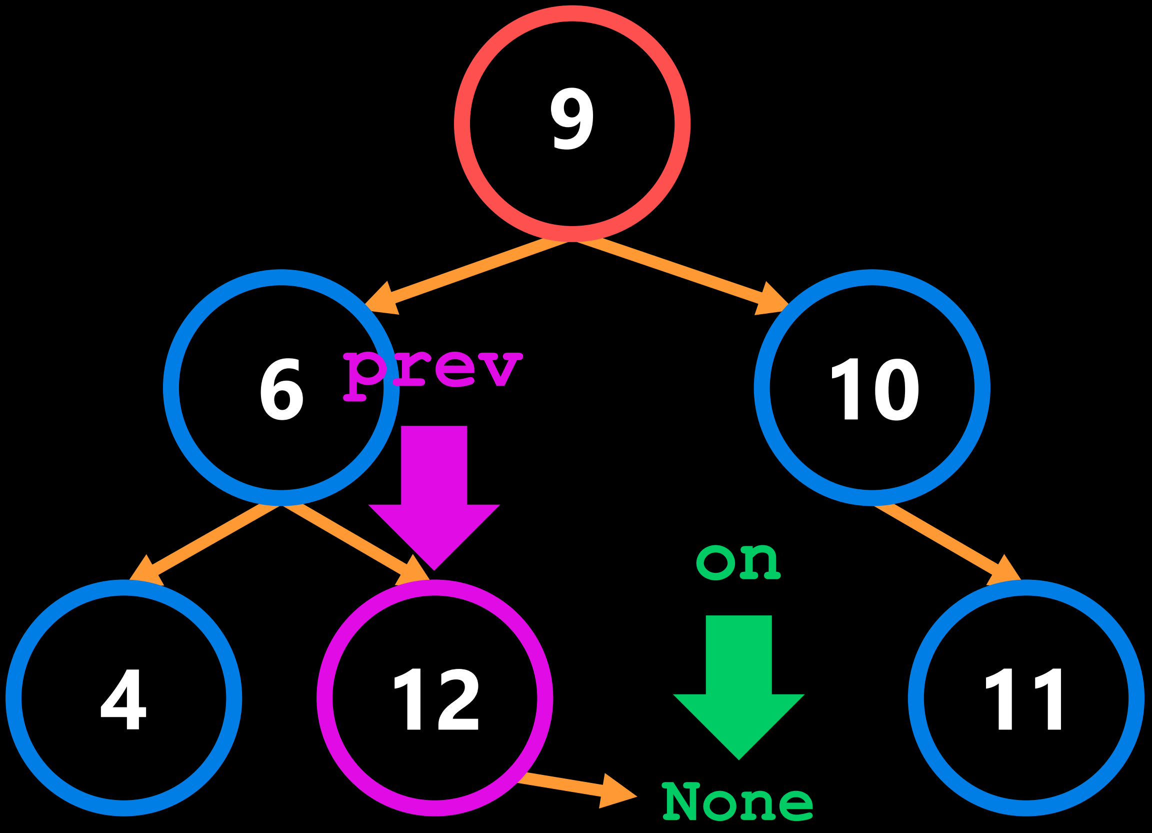
            if prev is not None and on.cargo <= prev.cargo:   False
                return False

            prev = on
            on = on.right

        return True
```

stack = [9]

Move on to the right pointer.



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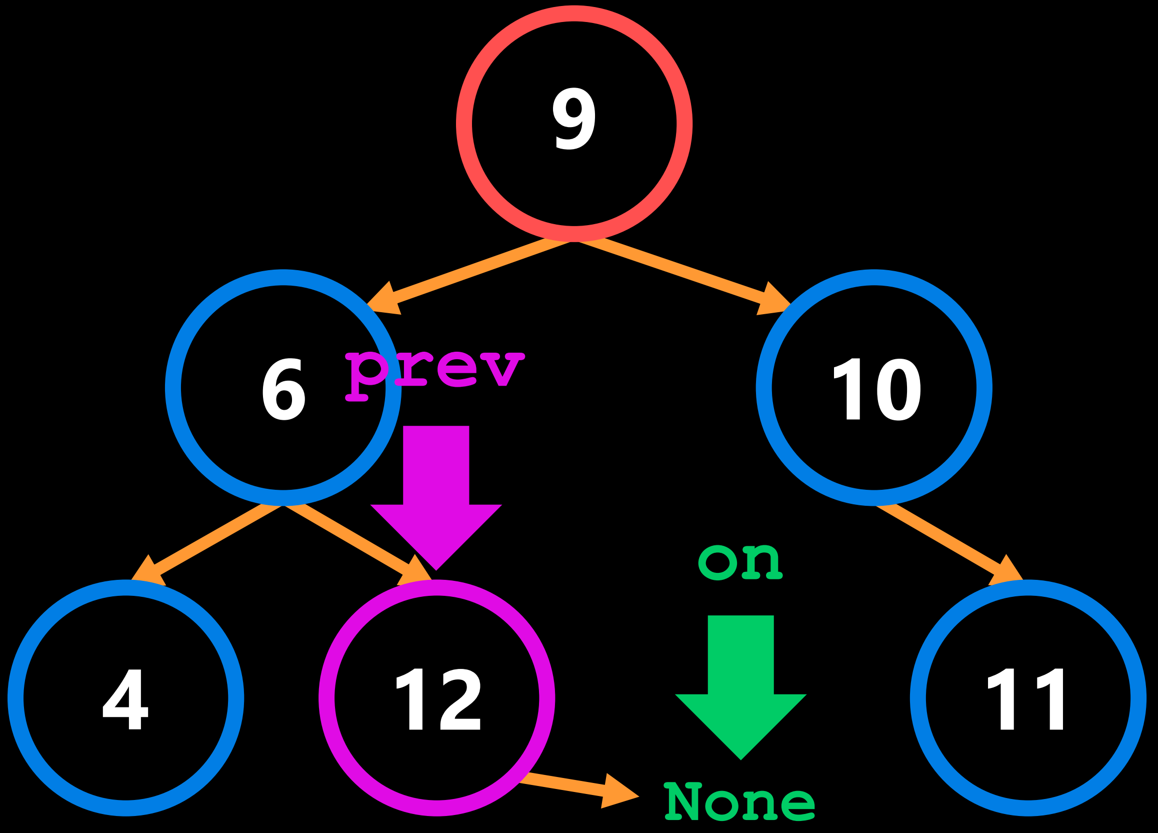
        return True
```

stack = [9]



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            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

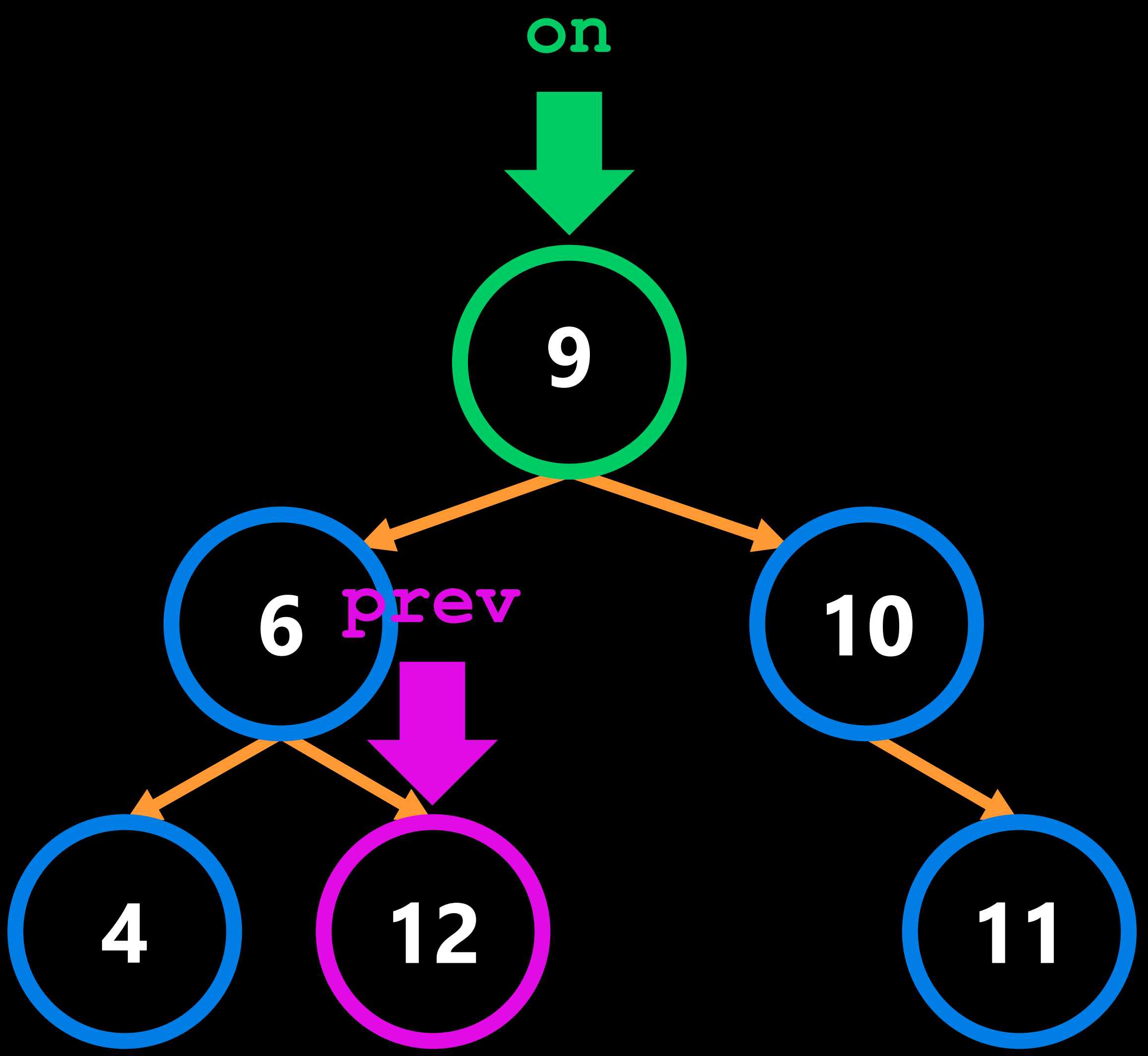
        return True
```

True

False

Set on to left node in stack.

stack = []



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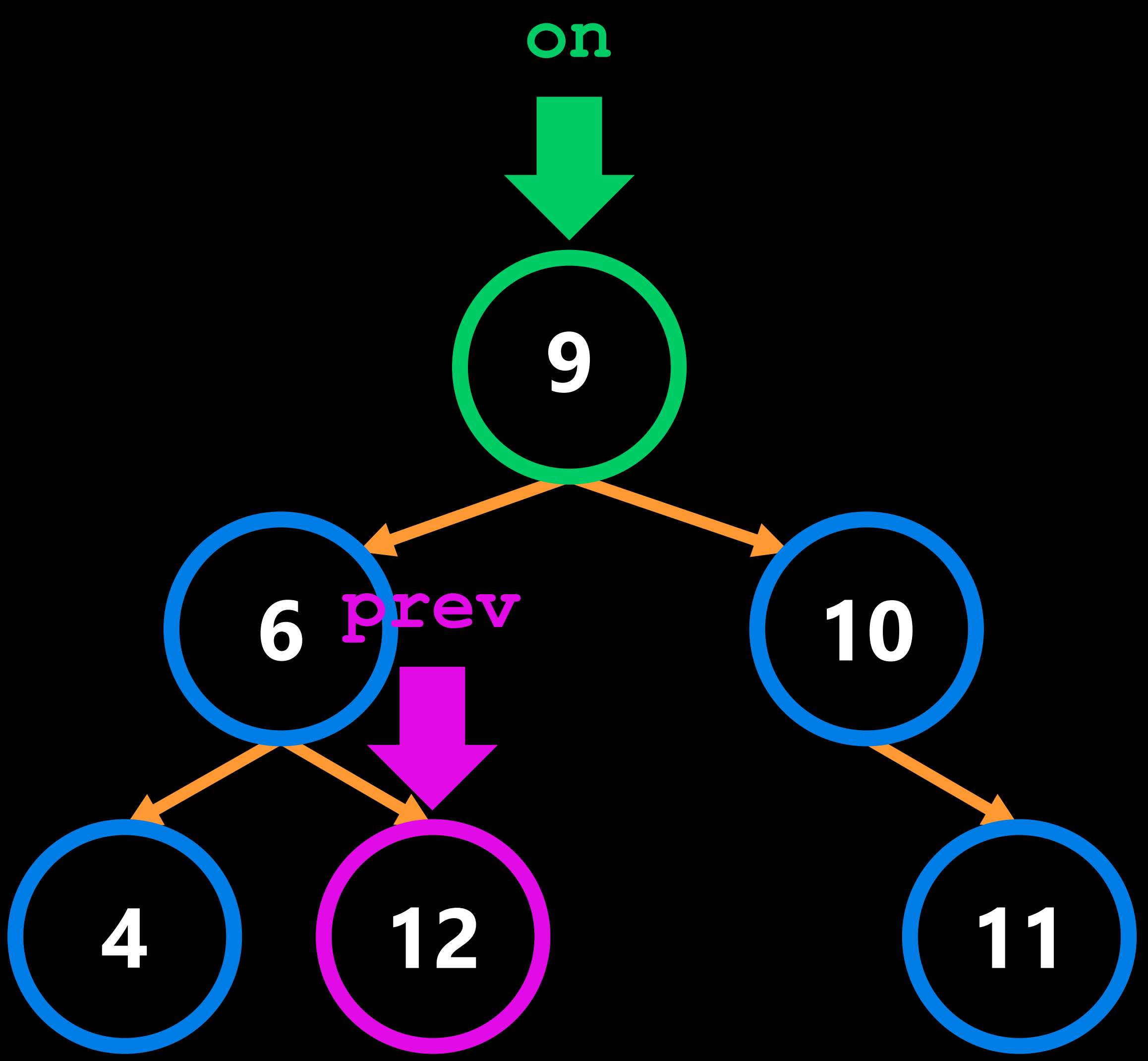
        return True
```

stack = [ ]



```
class BinarySearchTree:
    """A Node class used by a binary search tree class."""

    def __init__(self, root=None):
        """
        (self) -> NoneType
        Create an empty binary tree.
        """
        self.root = root

    def print_tree(self): ...

    def is_valid(self):
        """
        (self) -> NoneType
        Checks if self.root is a valid binary search tree.
        """
        on = self.root
        stack = []
        prev = None

        while len(stack) > 0 or on is not None:

            while on is not None:
                stack.append(on)
                on = on.left

            on = stack.pop()

            if prev is not None and on.cargo <= prev.cargo:
                return False

            prev = on
            on = on.right

        return True
```

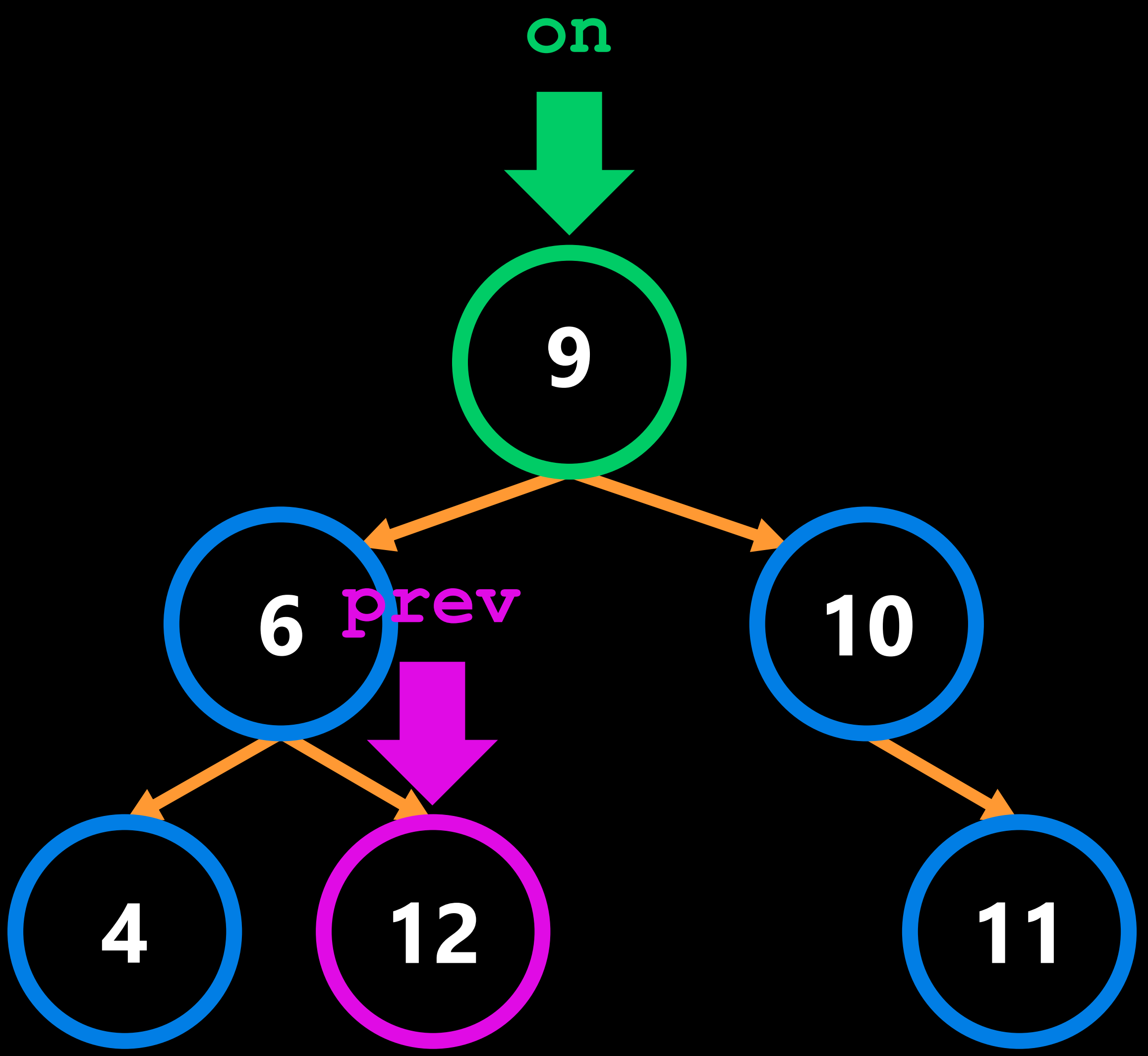
stack = [ ]

True

False

True

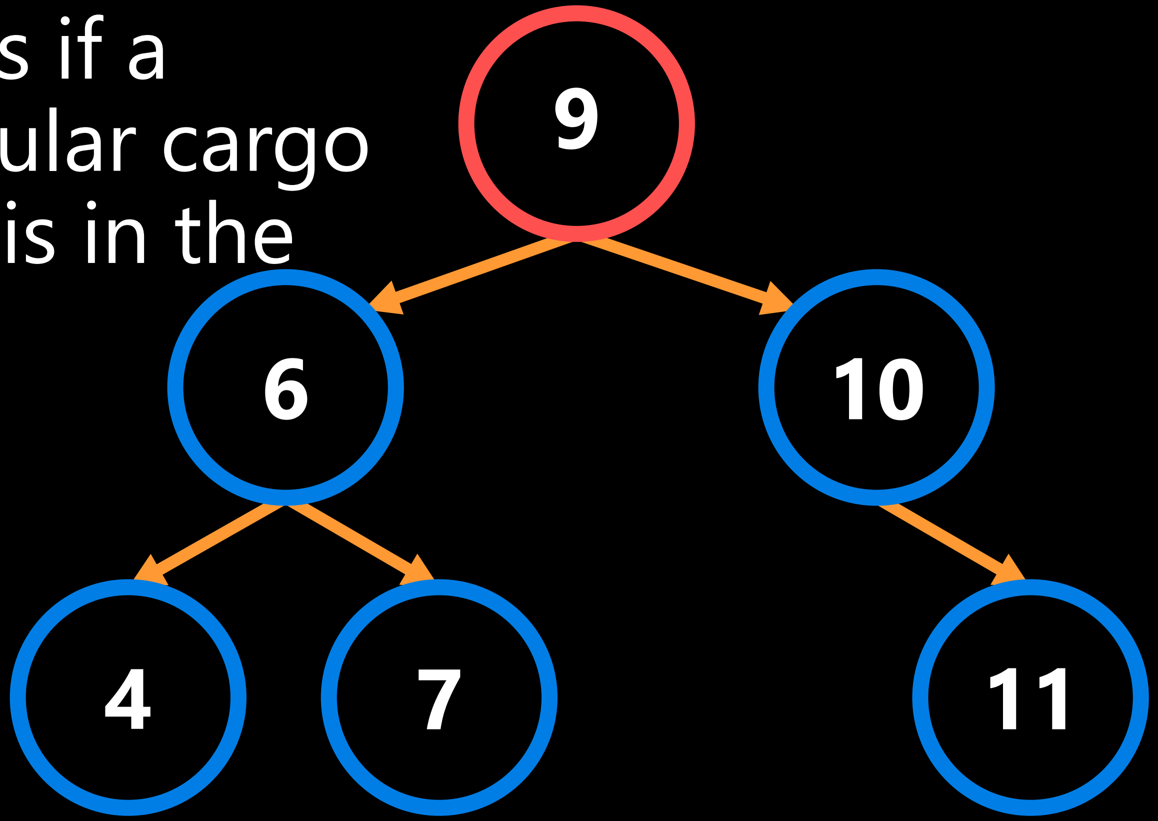
Return False.



Breakout Session

- Create a new method that checks if a particular cargo value is in the tree.

```
tree.find(14)
```



Open your notebook

Click Link:
3. Breakout Session

```
class BinarySearchTree:
    """A Node class used by a binary search tree class."""
    def __init__(self, root=None):
        """
        (self) -> NoneType
        Create an empty binary tree.
        """
        self.root = root
        if not self.is_valid():
            print('This is not a valid binary search tree.')

    def print_tree(self): ...

    def is_valid(self): ...

    def find(self, cargo):
        """
        (self, number) -> bool
        Checks if cargo value is in the tree.
        """
        on = self.root

        while on is not None:

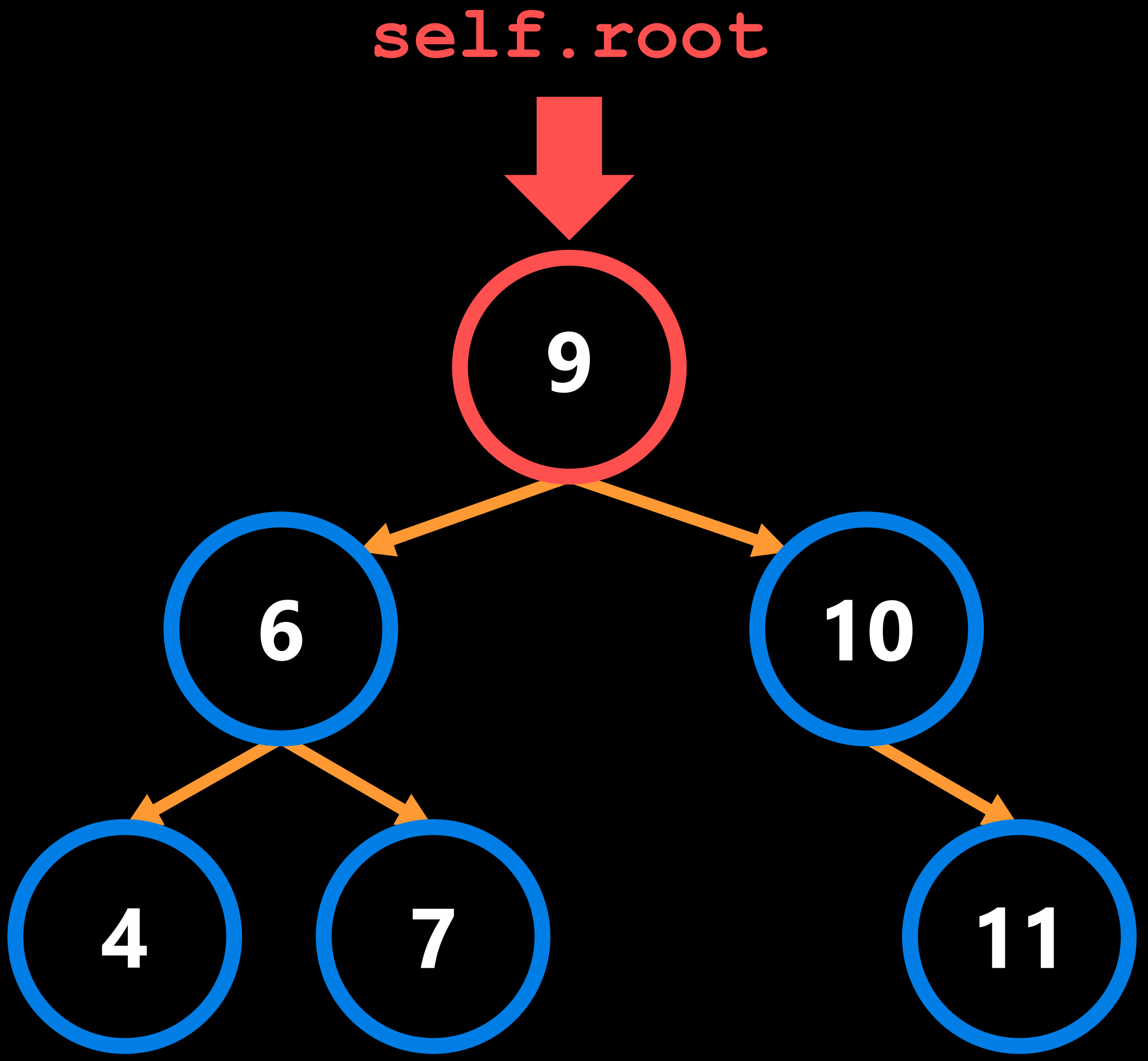
            if cargo > on.cargo:
                on = on.right

            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

tree.find(14)



```
class BinarySearchTree:
    """A Node class used by a binary search tree class."""
    def __init__(self, root=None):
        """
        (self) -> NoneType
        Create an empty binary tree.
        """
        self.root = root
        if not self.is_valid():
            print('This is not a valid binary search tree.')

    def print_tree(self): ...

    def is_valid(self): ...

    def find(self, cargo):
        """
        (self, number) -> bool
        Checks if cargo value is in the tree.
        """
        on = self.root

        while on is not None:

            if cargo > on.cargo:
                on = on.right

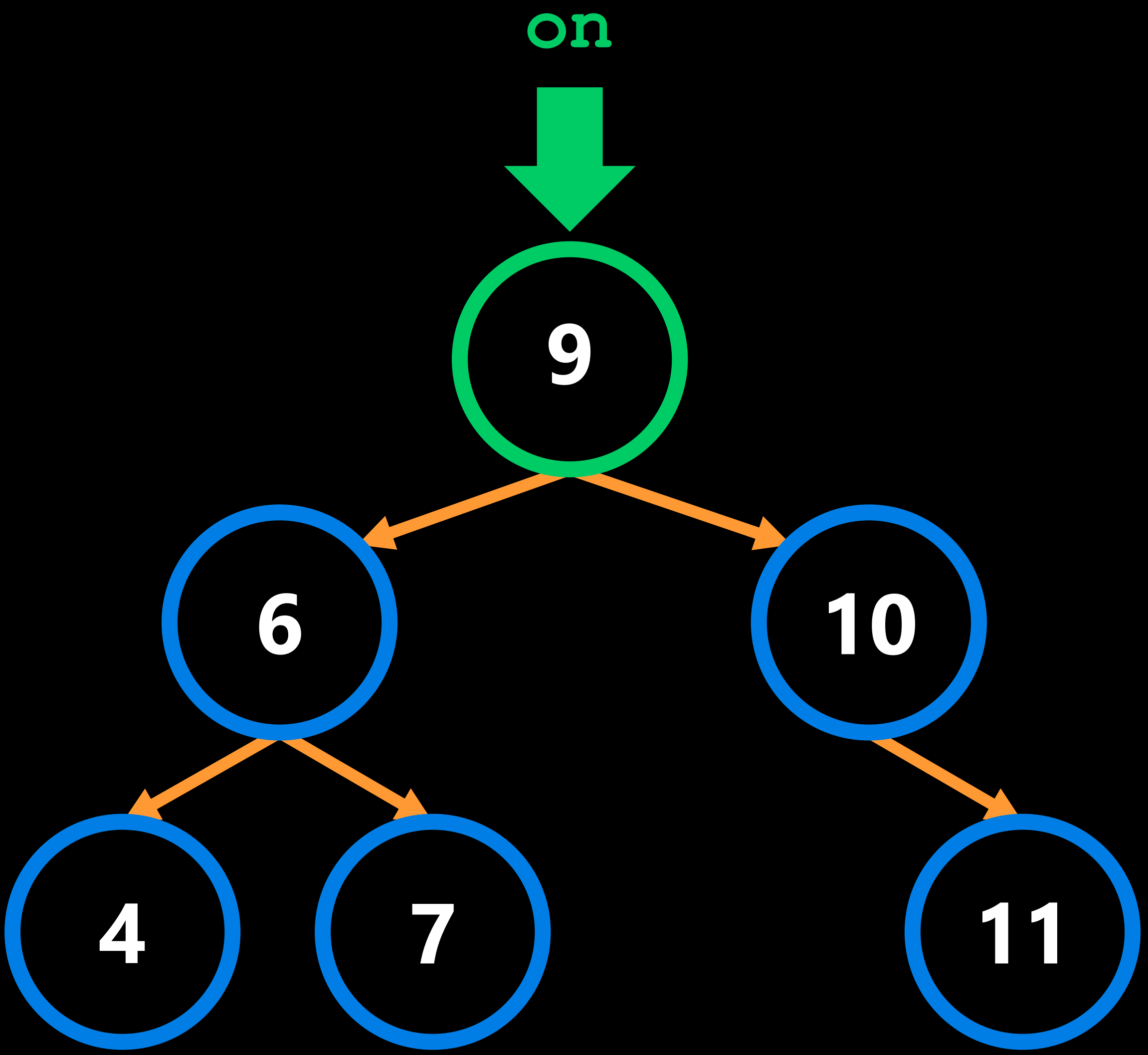
            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

Set on position.

tree.find(14)



```
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    """A Node class used by a binary search tree class."""
    def __init__(self, root=None):
        """
        (self) -> NoneType
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        """
        self.root = root
        if not self.is_valid():
            print('This is not a valid binary search tree.')

    def print_tree(self): ...

    def is_valid(self): ...

    def find(self, cargo):
        """
        (self, number) -> bool
        Checks if cargo value is in the tree.
        """
        on = self.root

        while on is not None:

            if cargo > on.cargo:
                on = on.right

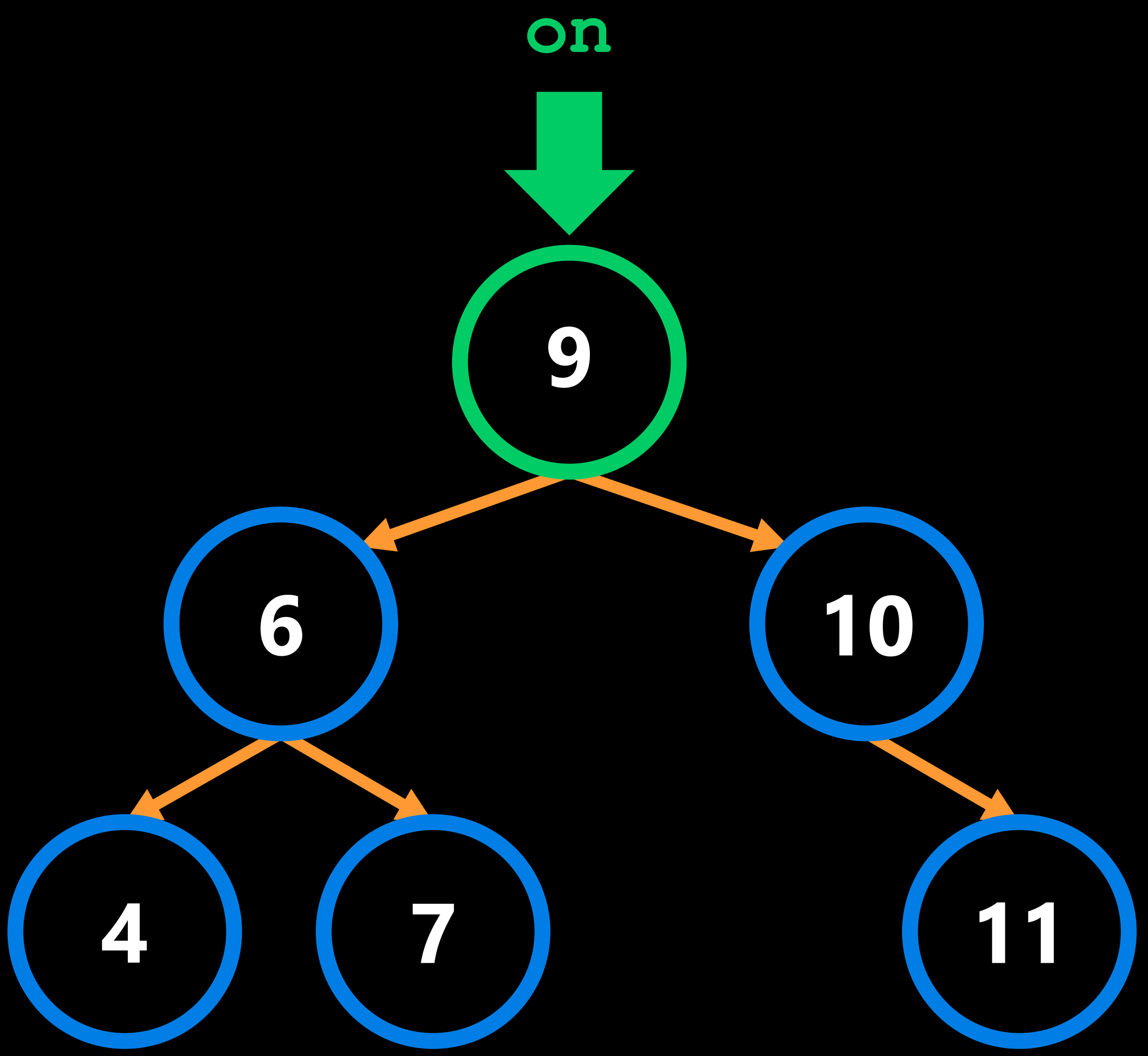
            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

True

tree.find(14)



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    def __init__(self, root=None):
        """
        (self) -> NoneType
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        """
        self.root = root
        if not self.is_valid():
            print('This is not a valid binary search tree.')

    def print_tree(self): ...

    def is_valid(self): ...

    def find(self, cargo):
        """
        (self, number) -> bool
        Checks if cargo value is in the tree.
        """
        on = self.root

        while on is not None:  ← True

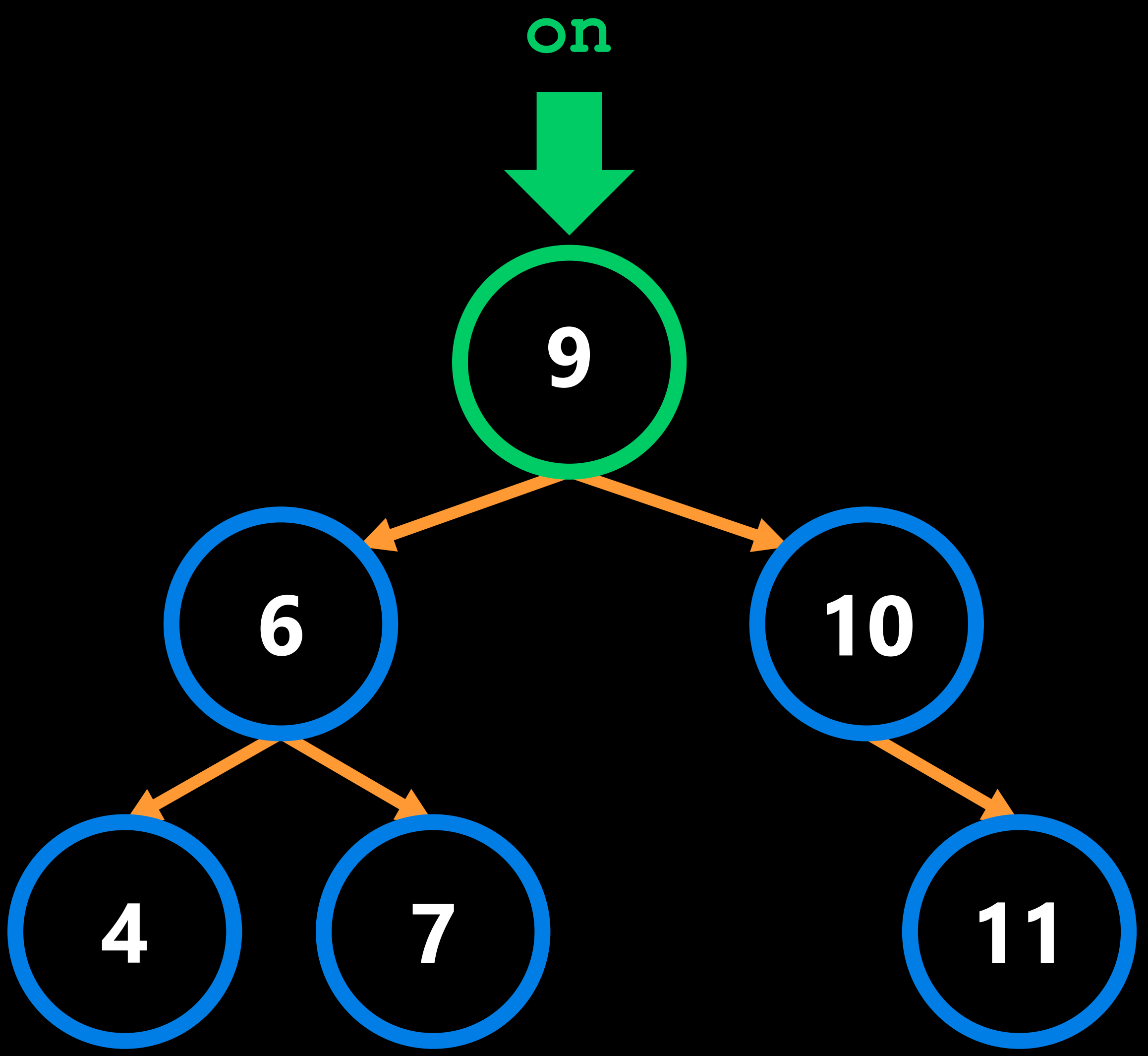
            if cargo > on.cargo:  ← True  (14 > 9)
                on = on.right

            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

tree.find(14)



tree.find(14)

```
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    def __init__(self, root=None):
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        """
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    def print_tree(self): ...

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    def find(self, cargo):
        """
        (self, number) -> bool
        Checks if cargo value is in the tree.
        """
        on = self.root

        while on is not None:

            if cargo > on.cargo:
                on = on.right

            elif cargo < on.cargo:
                on = on.left

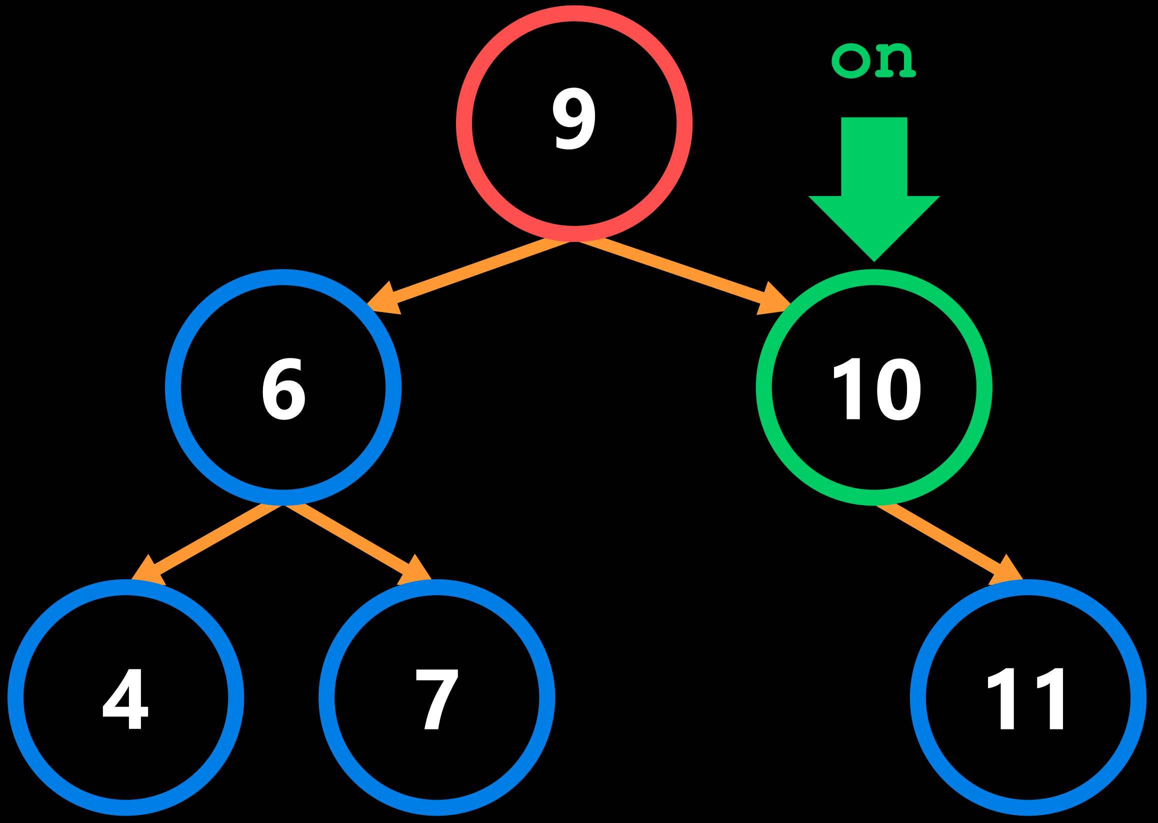
            else:
                return True

        return False
```

True

True (14 > 9)

Move on to the right.



```python
class BinarySearchTree:
    """A Node class used by a binary search tree class."""
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        """
        self.root = root
        if not self.is_valid():
            print('This is not a valid binary search tree.')

    def print_tree(self): ...

    def is_valid(self): ...

    def find(self, cargo):
        """
        (self, number) -> bool
        Checks if cargo value is in the tree.
        """
        on = self.root

        while on is not None:

            if cargo > on.cargo:
                on = on.right

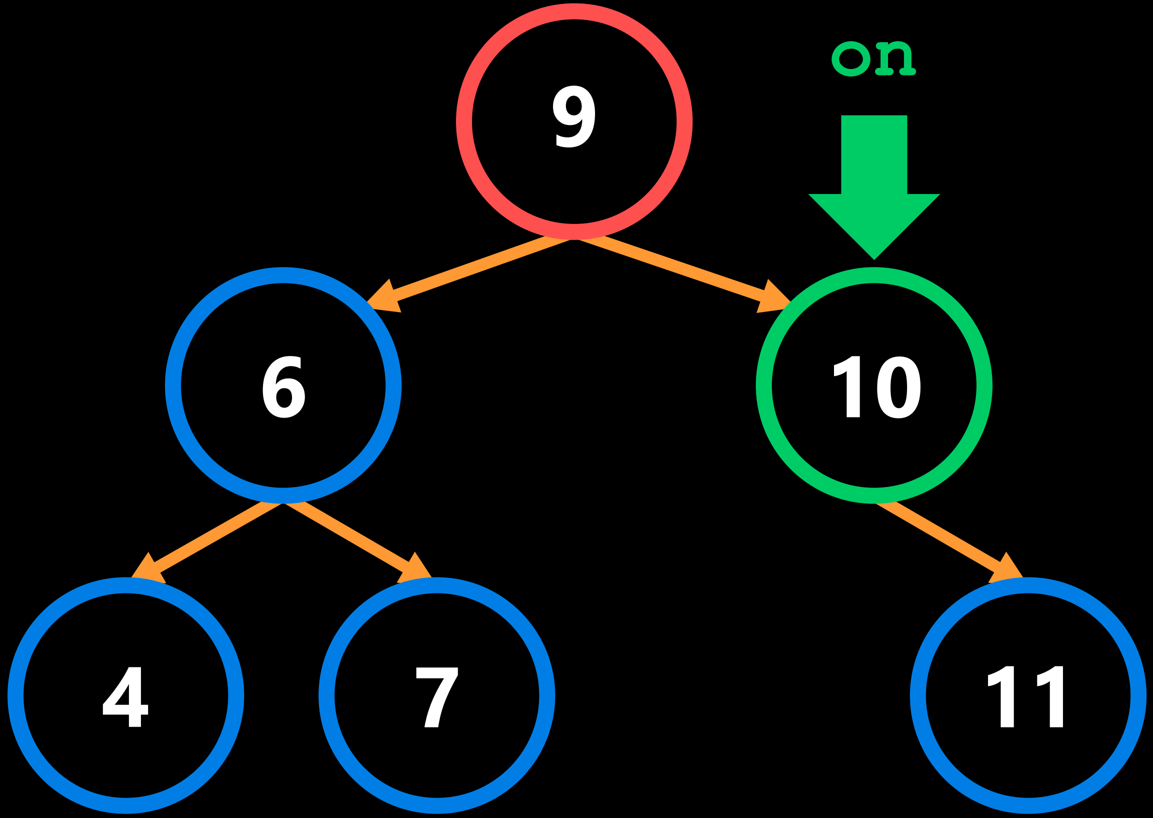
            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

True

tree.find(14)



tree.find(14)

```
class BinarySearchTree:
    """A Node class used by a binary search tree class."""
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        """
        self.root = root
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            print('This is not a valid binary search tree.')

    def print_tree(self): ...

    def is_valid(self): ...

    def find(self, cargo):
        """
        (self, number) -> bool
        Checks if cargo value is in the tree.
        """
        on = self.root

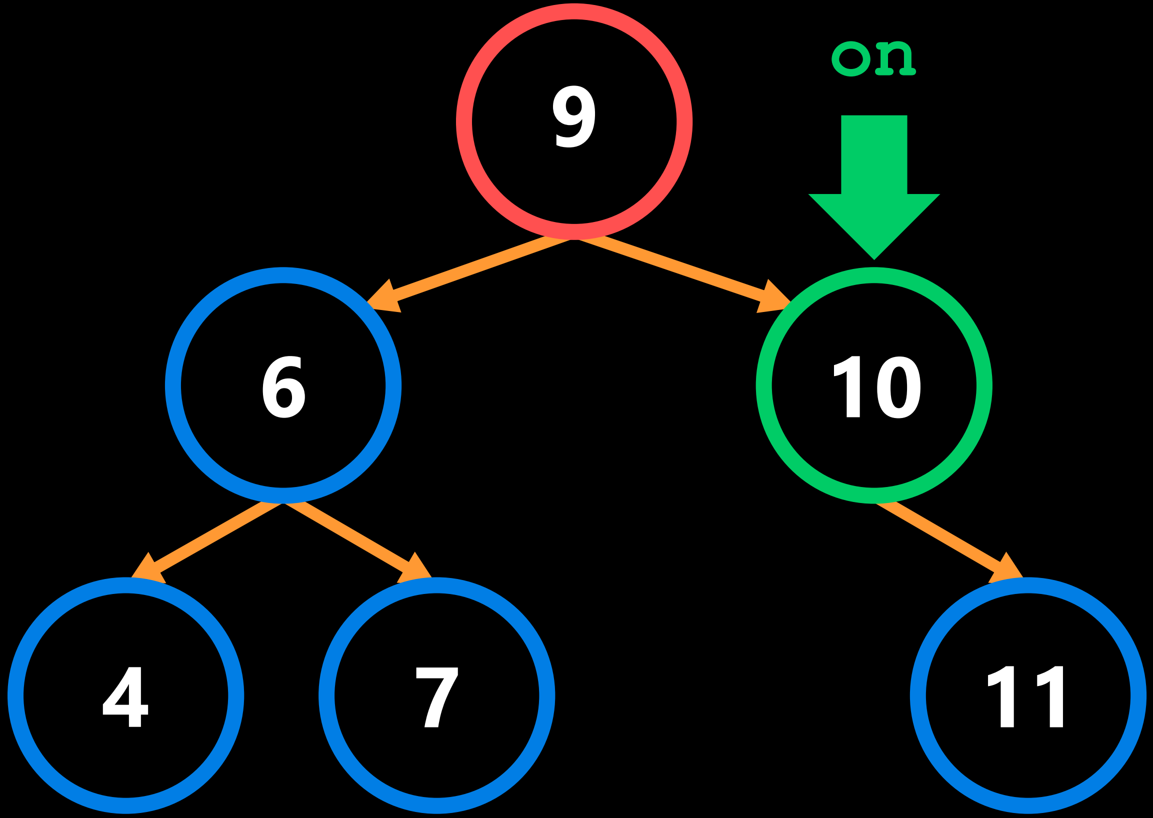
        while on is not None:  ←  True

            if cargo > on.cargo:  ←  True  (14 > 10)
                on = on.right

            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```



tree.find(14)

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        (self) -> NoneType
        Create an empty binary tree.
        """
        self.root = root
        if not self.is_valid():
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    def print_tree(self): ...

    def is_valid(self): ...

    def find(self, cargo):
        """
        (self, number) -> bool
        Checks if cargo value is in the tree.
        """
        on = self.root

        while on is not None:

            if cargo > on.cargo:
                on = on.right

            elif cargo < on.cargo:
                on = on.left

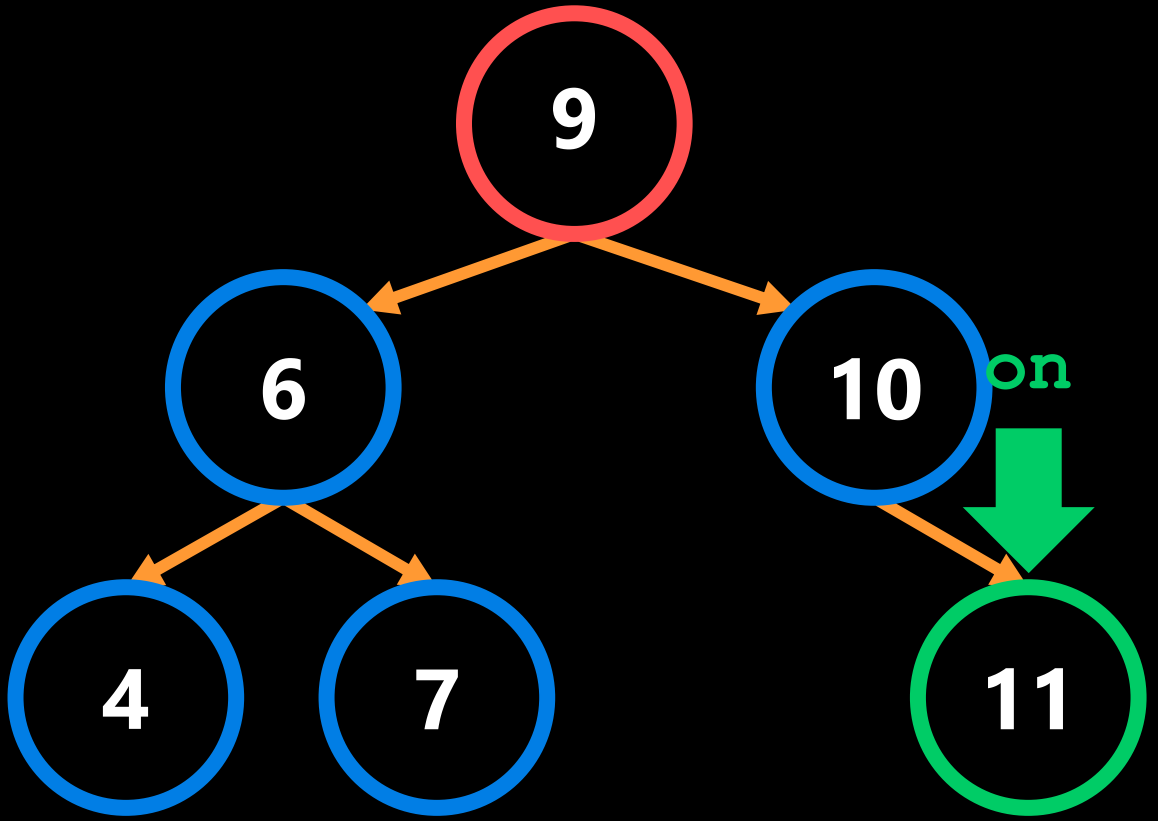
            else:
                return True

        return False
```

True

True (14 > 10)

Move on to the right.



tree.find(14)

```
class BinarySearchTree:
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        self.root = root
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    def find(self, cargo):
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        Checks if cargo value is in the tree.
        """
        on = self.root

        while on is not None:  ⬅ True

            if cargo > on.cargo:
                on = on.right

            elif cargo < on.cargo:
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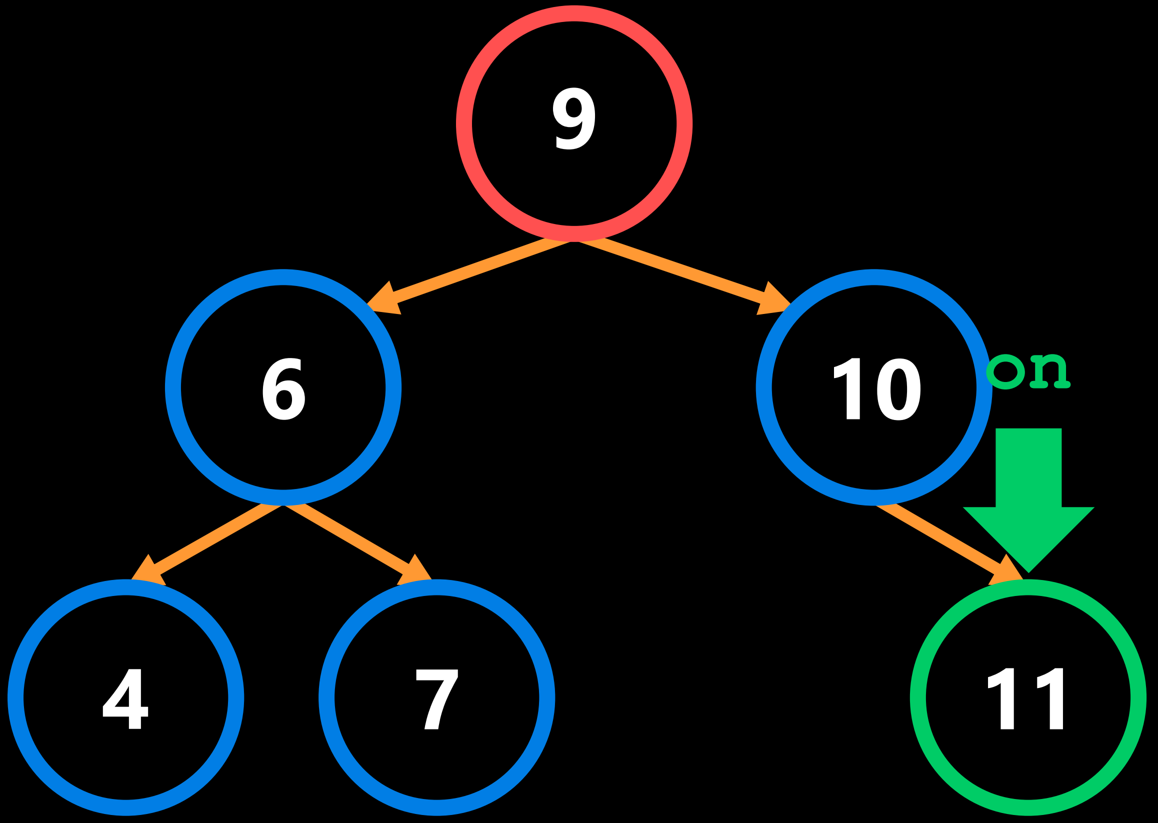
            else:
                return True

        return False
```



tree.find(14)

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    def print_tree(self): ...

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    def find(self, cargo):
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        (self, number) -> bool
        Checks if cargo value is in the tree.
        """
        on = self.root

        while on is not None:

            if cargo > on.cargo:
                on = on.right

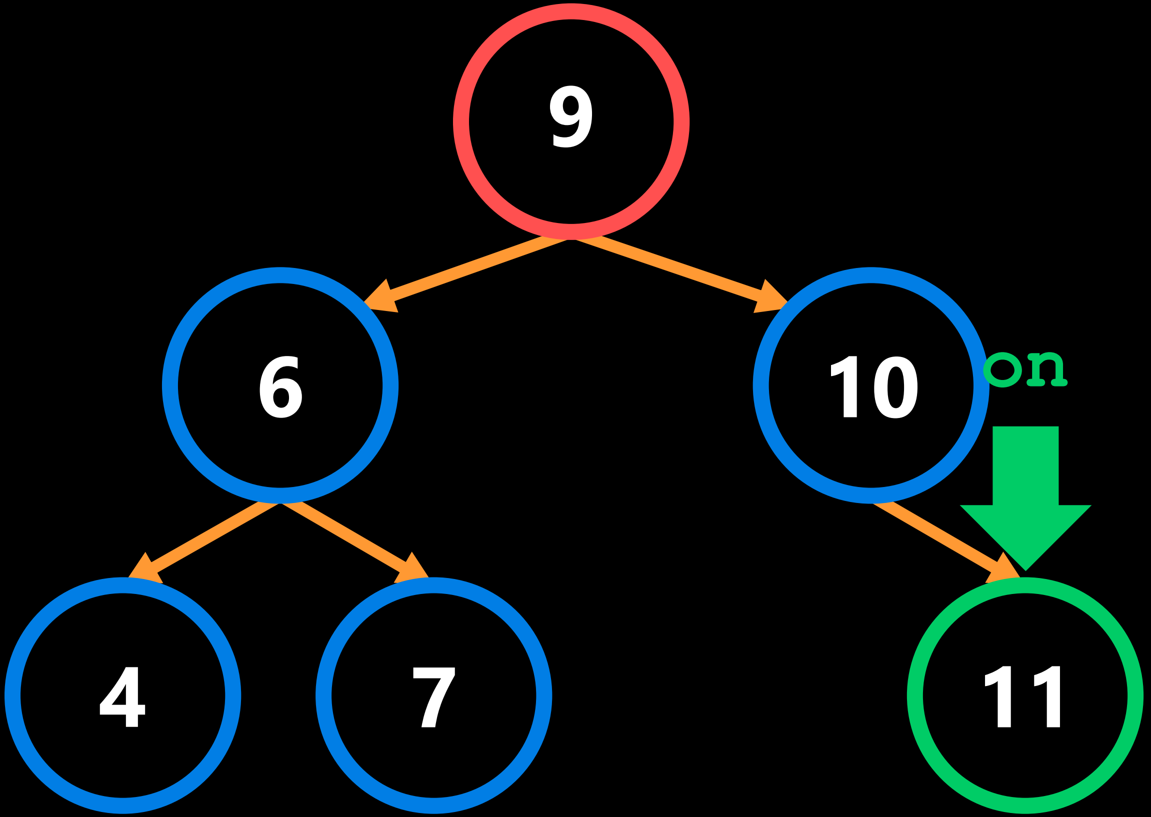
            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

True

True (14 > 11)



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    def print_tree(self): ...

    def is_valid(self): ...

    def find(self, cargo):
        """
        (self, number) -> bool
        Checks if cargo value is in the tree.
        """
        on = self.root

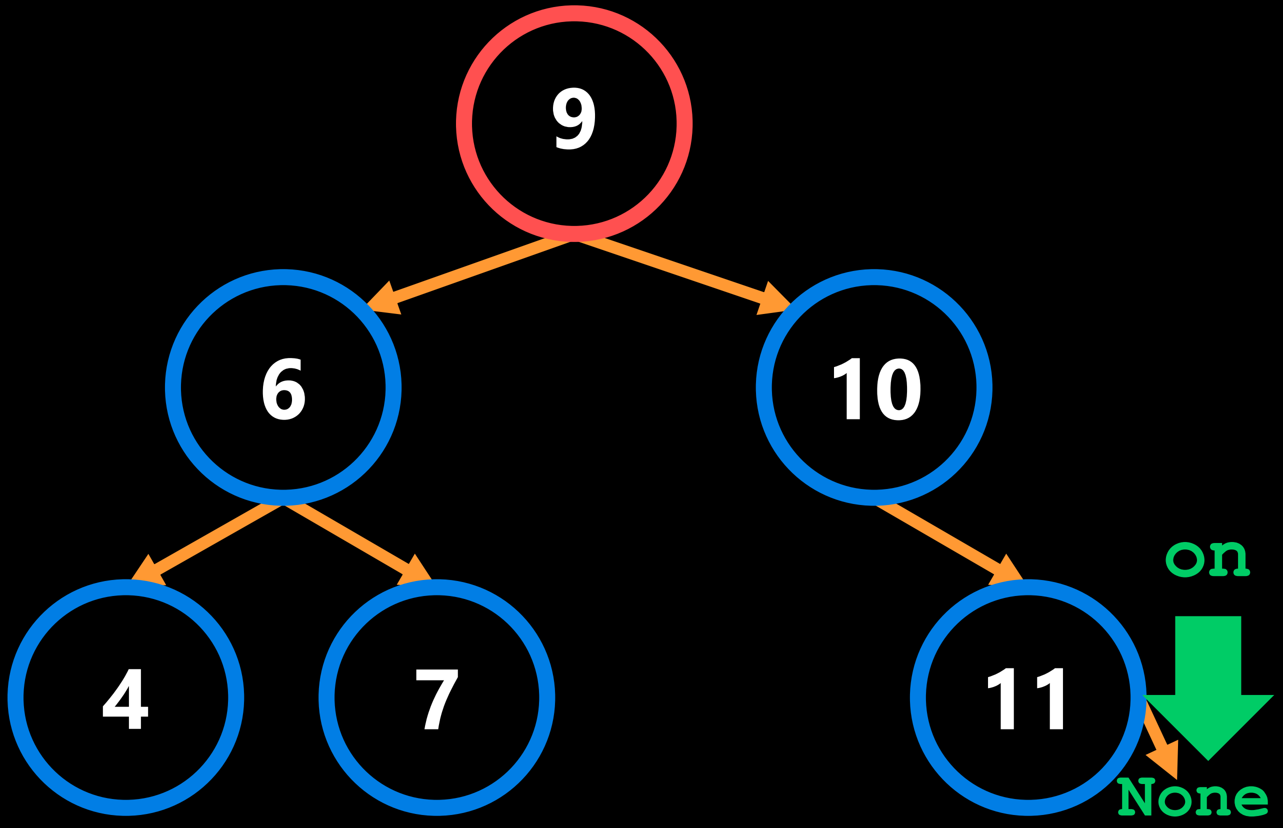
        while on is not None:   True

            if cargo > on.cargo:   True  (14 > 11)
                on = on.right      Move on to
                                   the right.
            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

tree.find(14)



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    def find(self, cargo):
        """
        (self, number) -> bool
        Checks if cargo value is in the tree.
        """
        on = self.root

        while on is not None:  ⬅ False

            if cargo > on.cargo:
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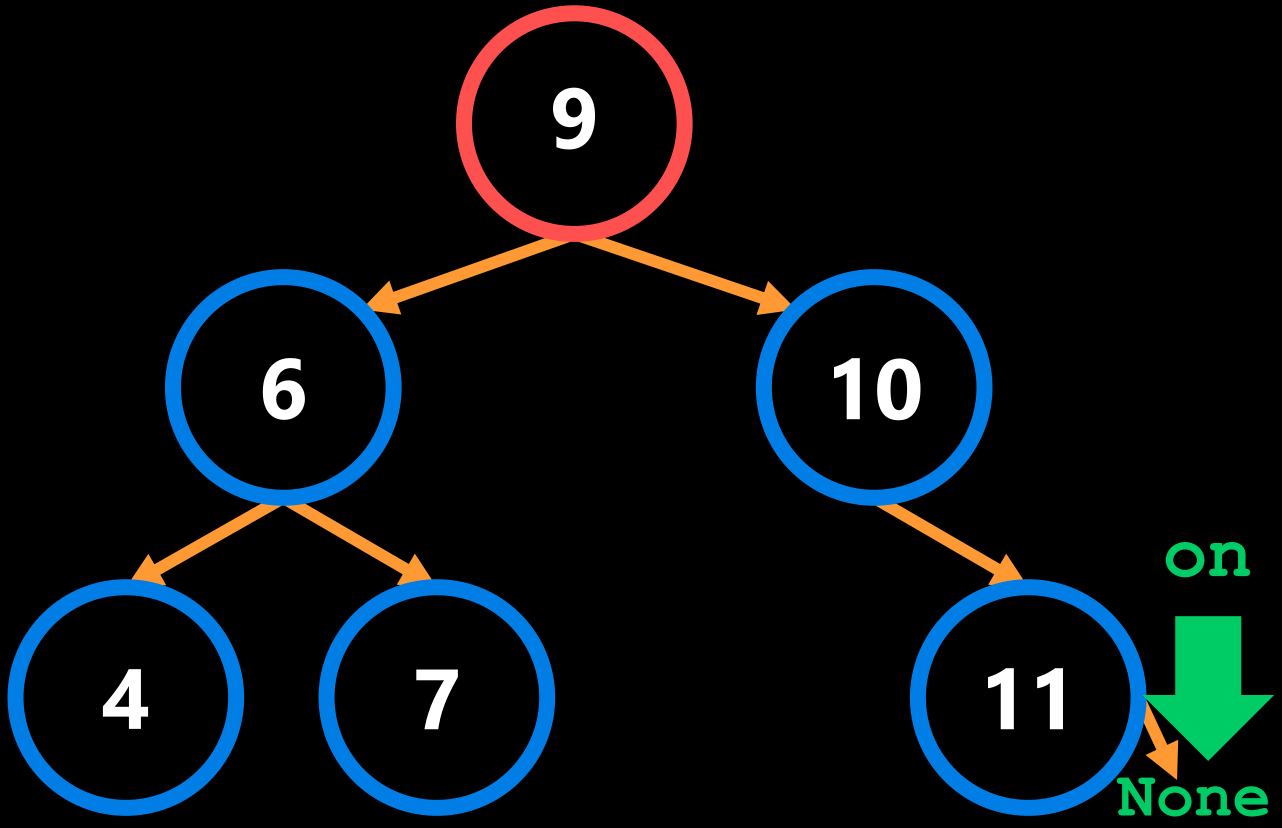
            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

tree.find(14)



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        while on is not None:

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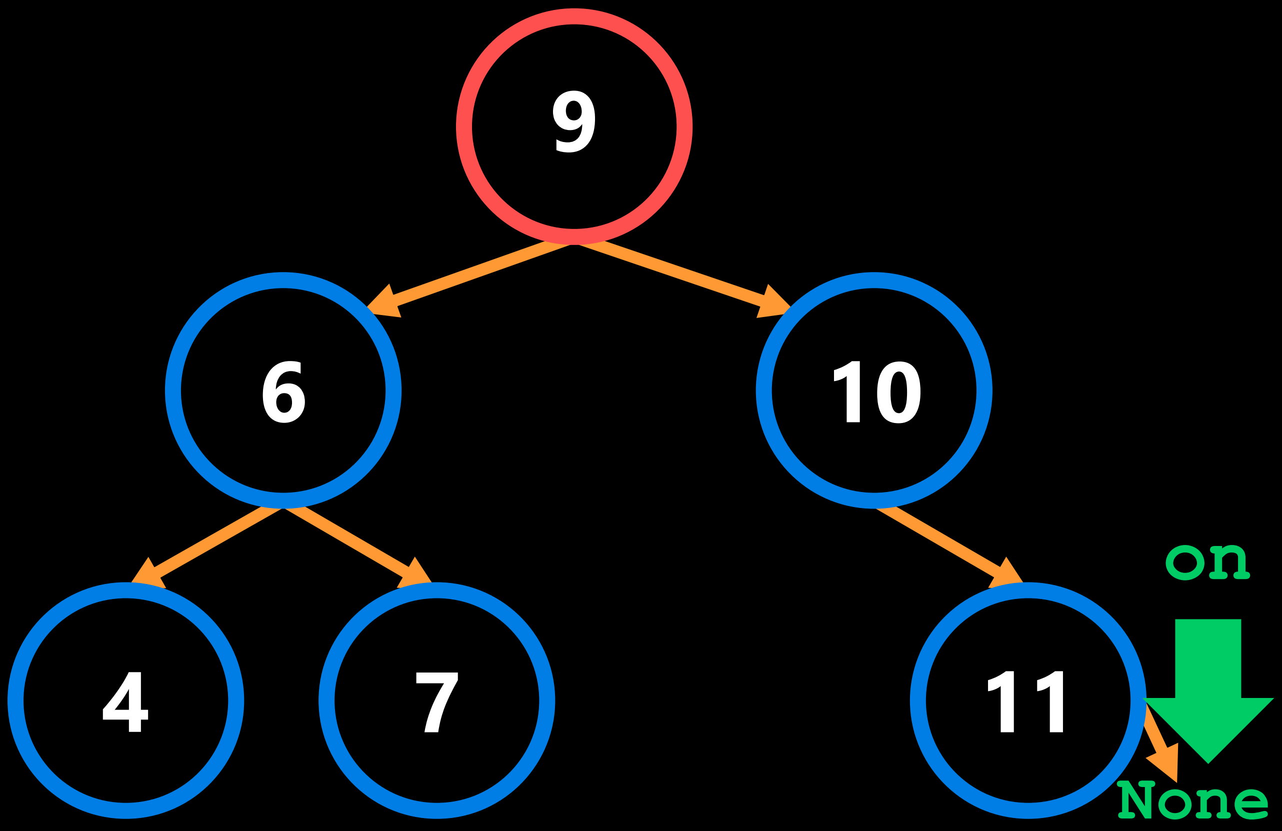
            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

Didn't find the value.

tree.find(14)



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        """
        on = self.root

        while on is not None:

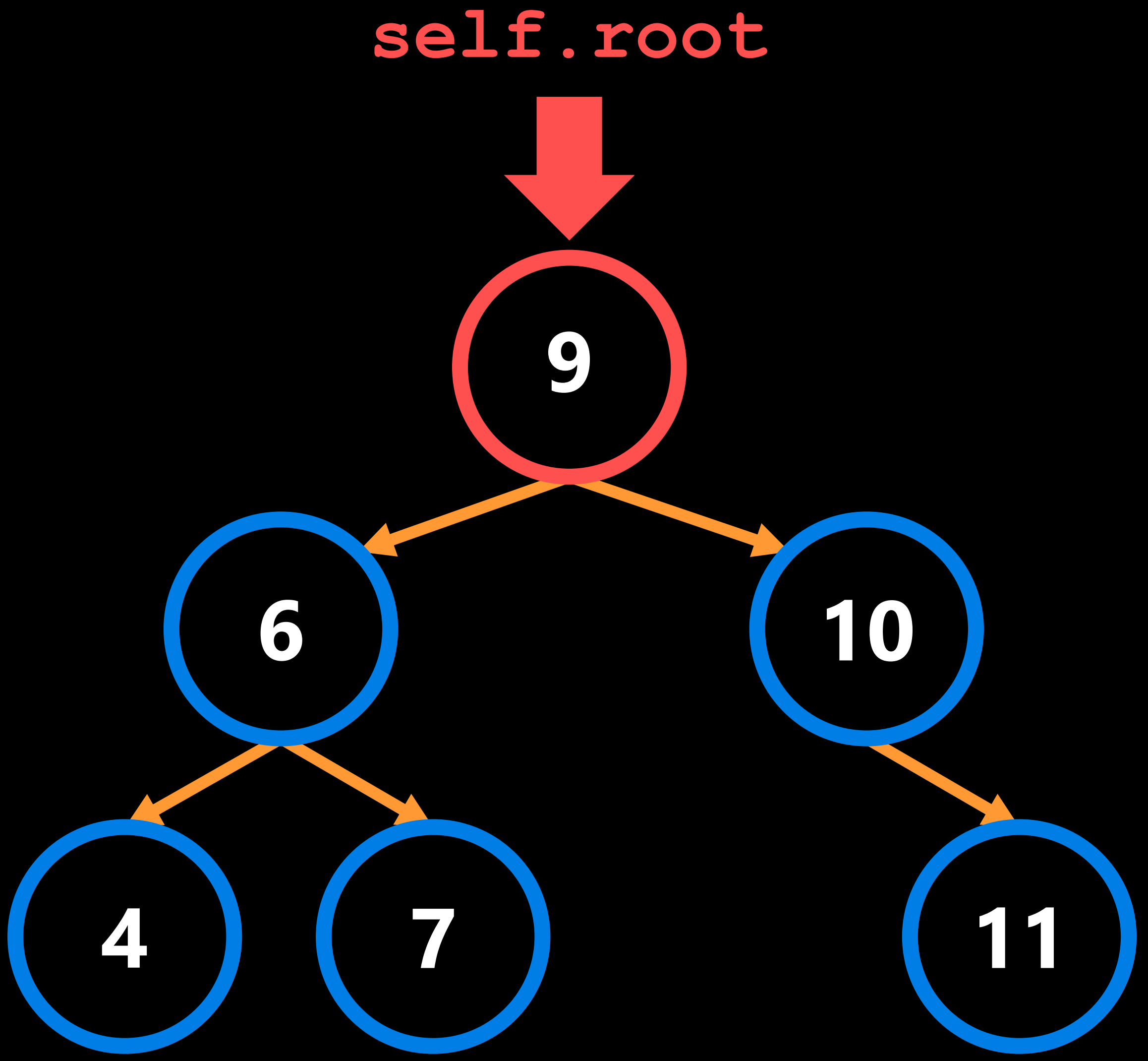
            if cargo > on.cargo:
                on = on.right

            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

tree.find(4)



```
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        on = self.root

        while on is not None:

            if cargo > on.cargo:
                on = on.right

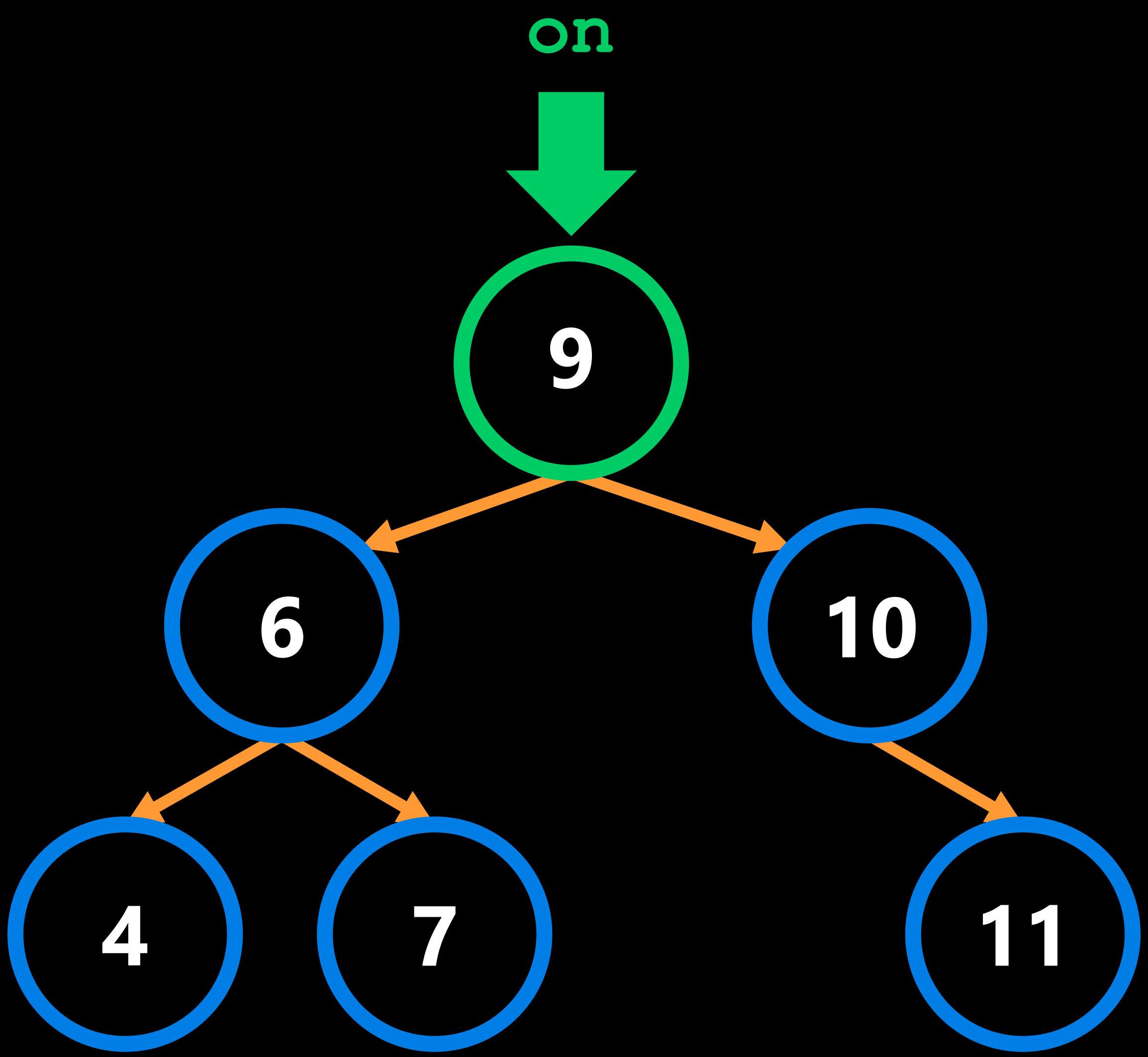
            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

Set on position.

tree.find(4)



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        """
        on = self.root

        while on is not None:

            if cargo > on.cargo:
                on = on.right

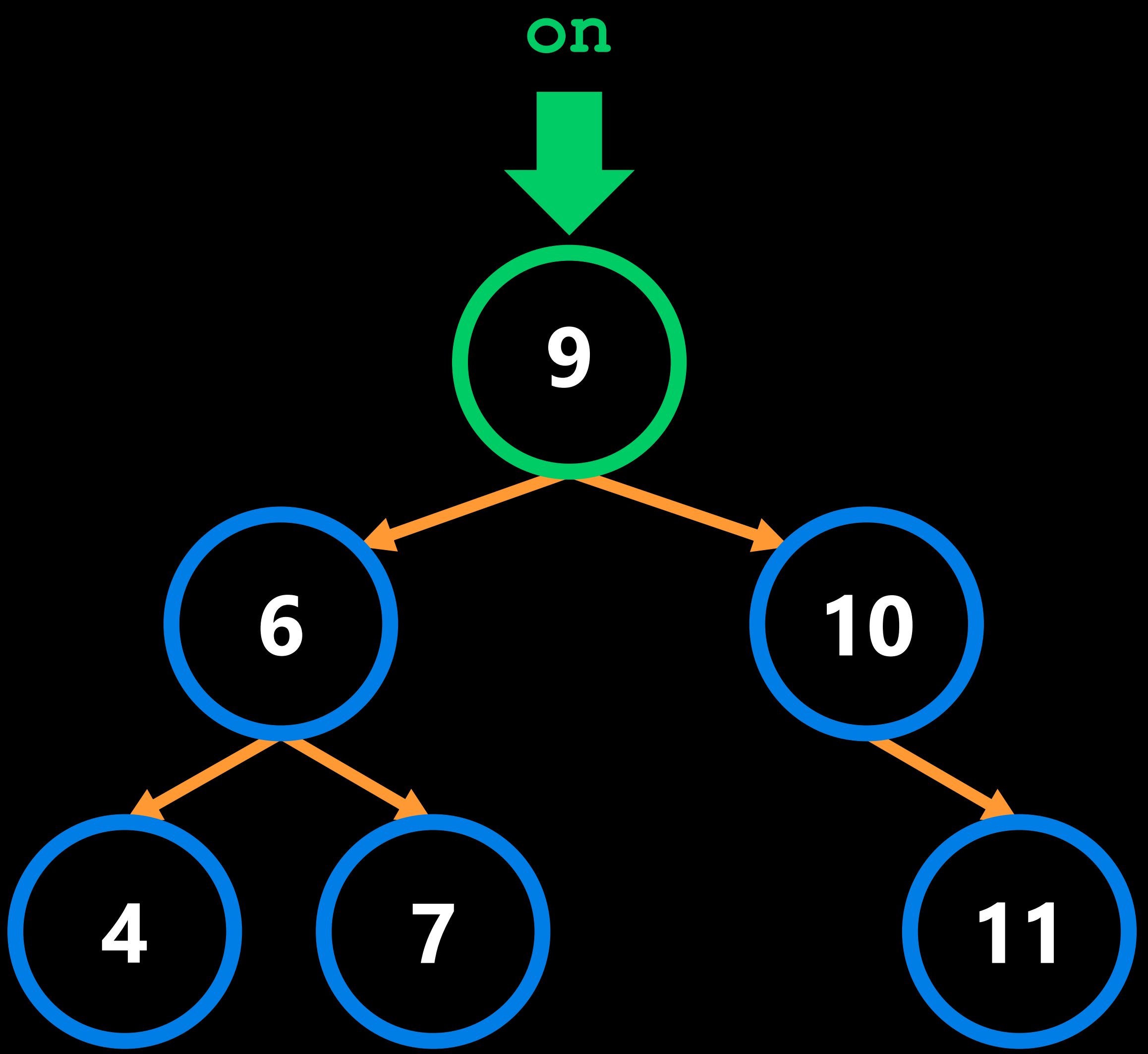
            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

True

tree.find(4)



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        on = self.root

        while on is not None:

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                on = on.right

            elif cargo < on.cargo:
                on = on.left

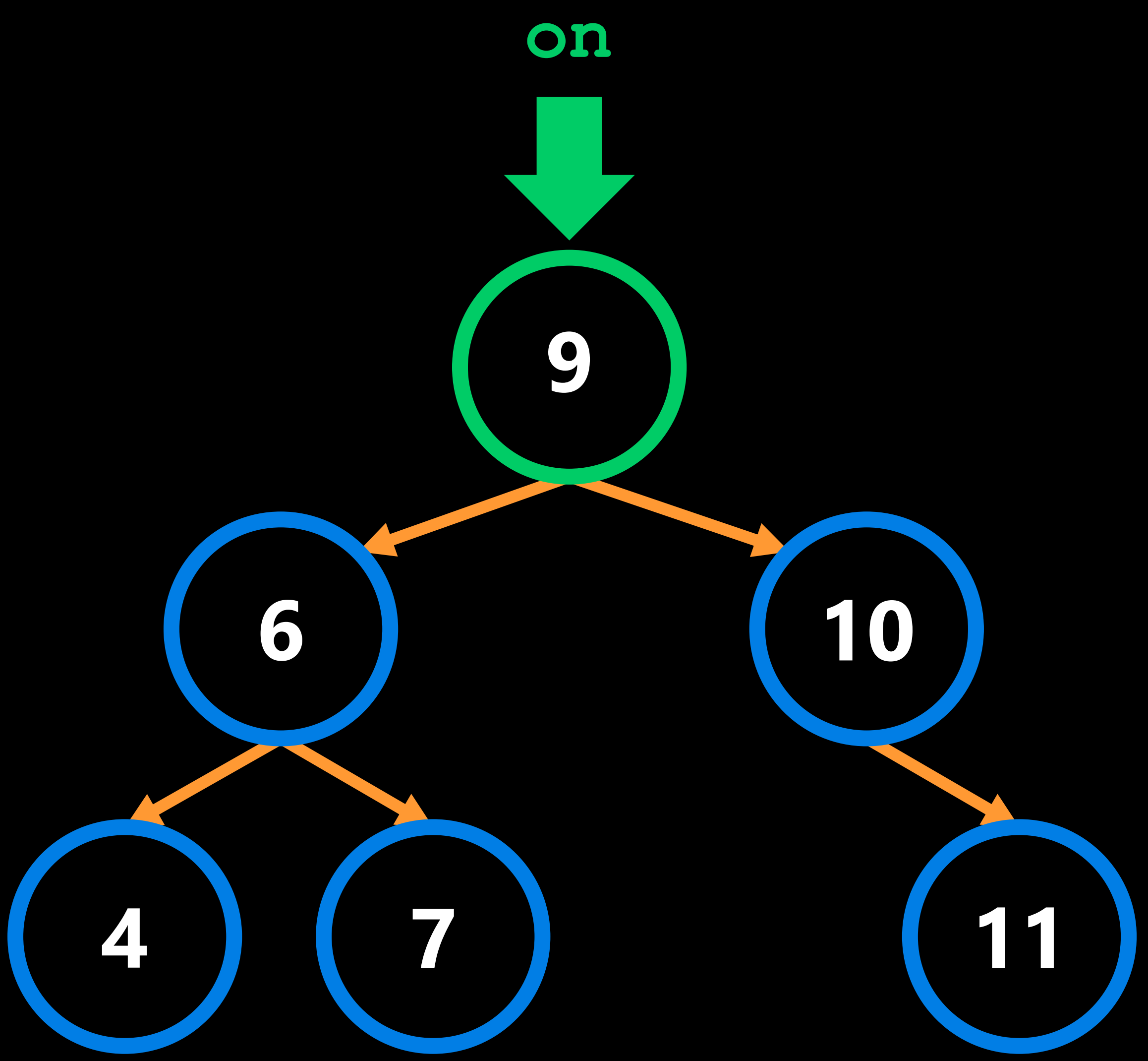
            else:
                return True

        return False
```

True

False (4 !> 9)

tree.find(4)



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    def print_tree(self): ...

    def is_valid(self): ...

    def find(self, cargo):
        """
        (self, number) -> bool
        Checks if cargo value is in the tree.
        """
        on = self.root

        while on is not None:  ⬅ True

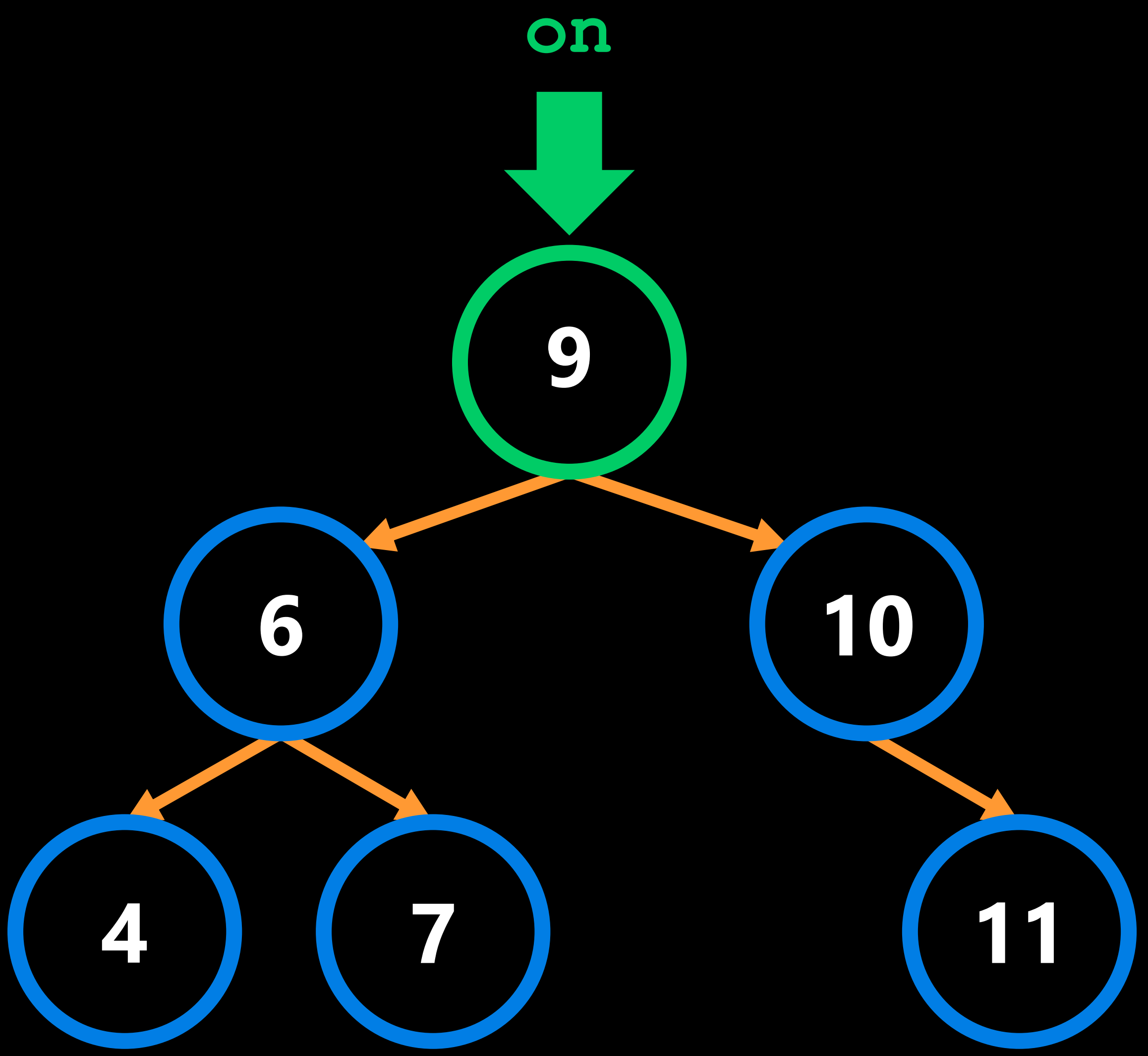
            if cargo > on.cargo:  ⬅ False (4 !> 9)
                on = on.right

            elif cargo < on.cargo:  ⬅ True (4 < 9)
                on = on.left

            else:
                return True

        return False
```

tree.find(4)



tree.find(4)

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        on = self.root

        while on is not None:

            if cargo > on.cargo:
                on = on.right

            elif cargo < on.cargo:
                on = on.left

            else:
                return True

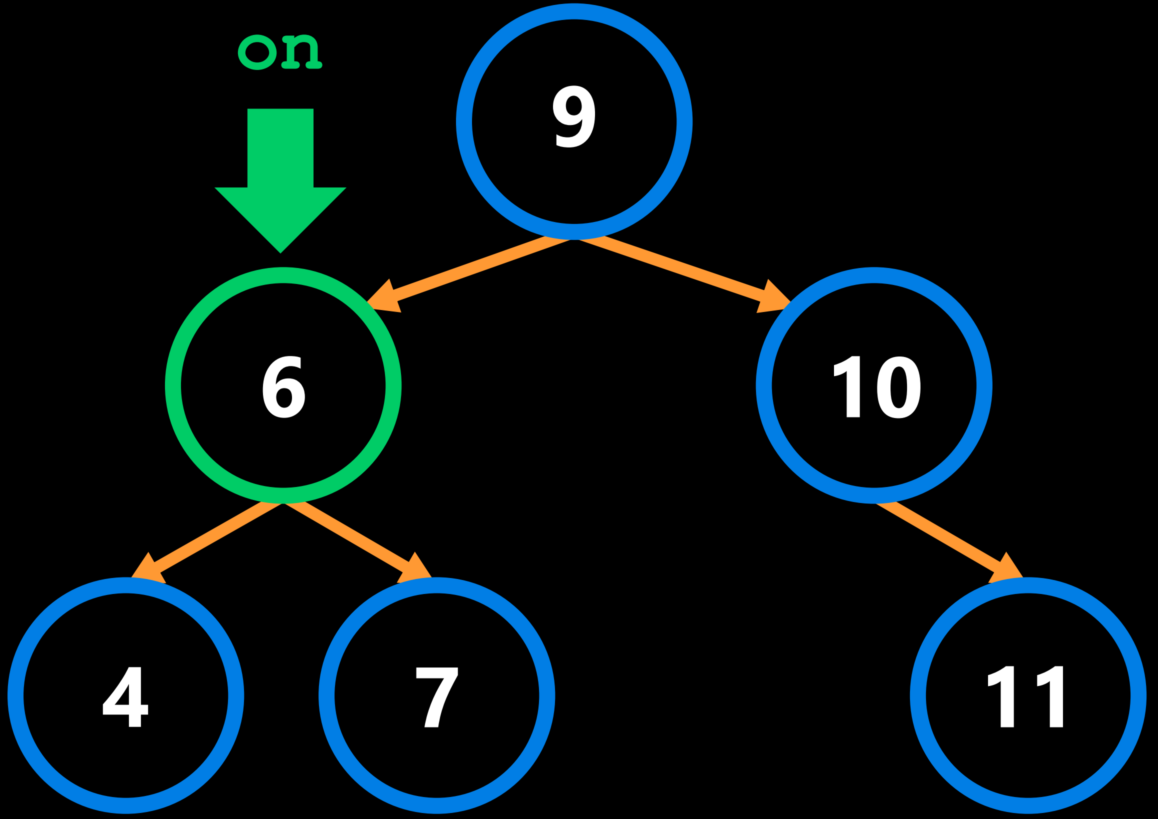
        return False
```

True

False (4 !> 9)

True (4 < 9)

Move on to the left.



tree.find(4)

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        while on is not None:

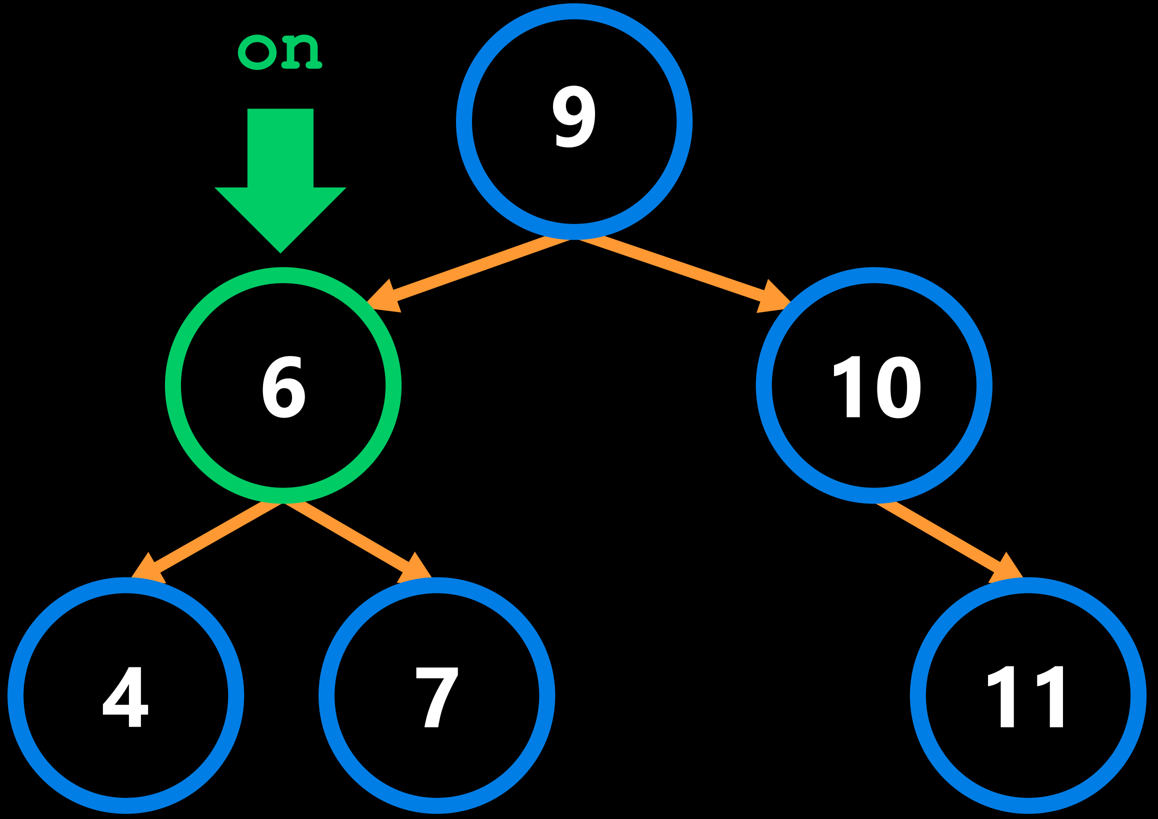
            if cargo > on.cargo:
                on = on.right

            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

True



tree.find(4)

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        """
        on = self.root

        while on is not None:

            if cargo > on.cargo:
                on = on.right

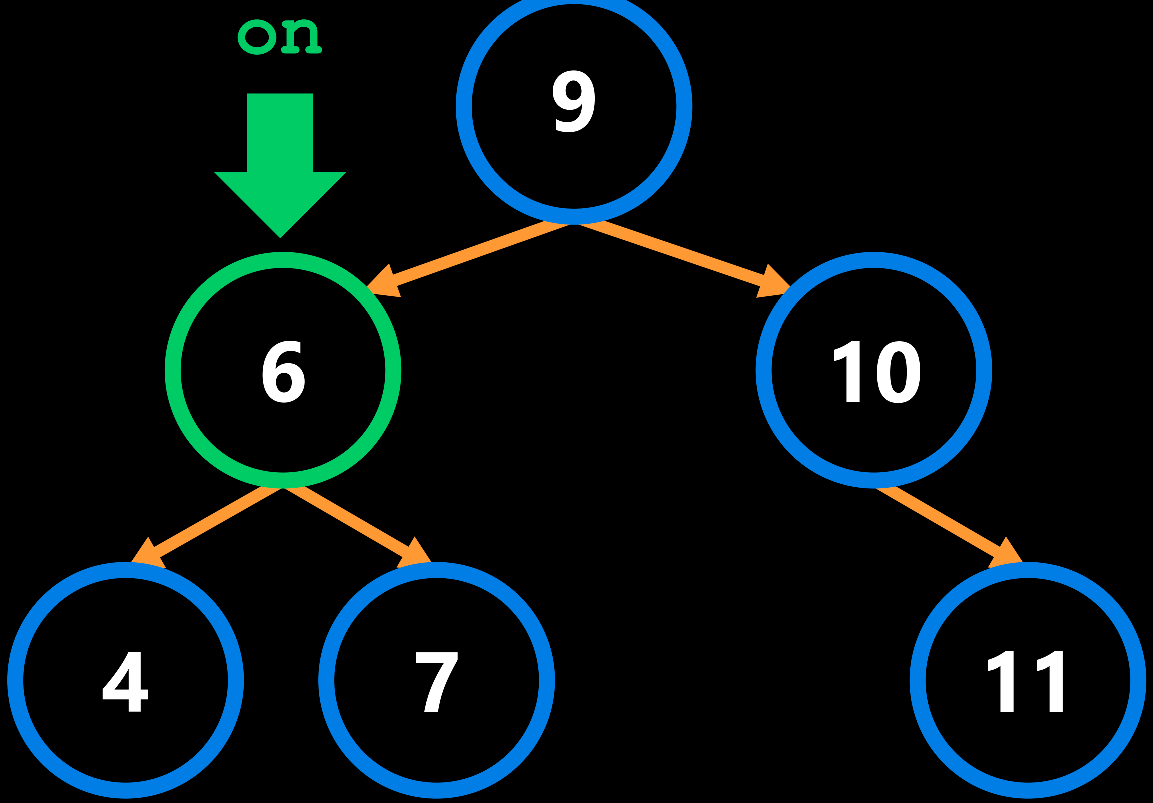
            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

True

False (4 !> 6)



```
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        """
        self.root = root
        if not self.is_valid():
            print('This is not a valid binary search tree.')

    def print_tree(self): ...

    def is_valid(self): ...

    def find(self, cargo):
        """
        (self, number) -> bool
        Checks if cargo value is in the tree.
        """
        on = self.root

        while on is not None:  ← True

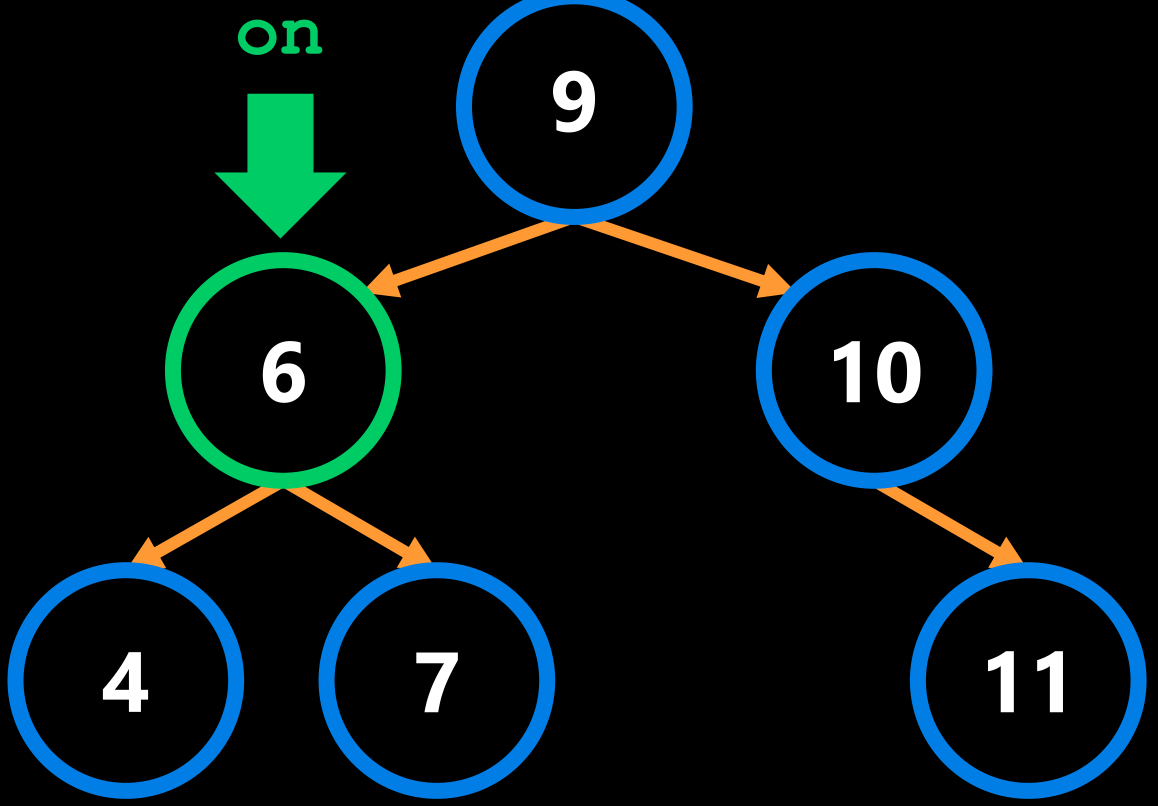
            if cargo > on.cargo:  ← False (4 !> 6)
                on = on.right

            elif cargo < on.cargo:  ← True (4 < 6)
                on = on.left

            else:
                return True

        return False
```

tree.find(4)



tree.find(4)

```
class BinarySearchTree:
    """A Node class used by a binary search tree class."""
    def __init__(self, root=None):
        """
        (self) -> NoneType
        Create an empty binary tree.
        """
        self.root = root
        if not self.is_valid():
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    def print_tree(self): ...

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                on = on.right

            elif cargo < on.cargo:
                on = on.left

            else:
                return True

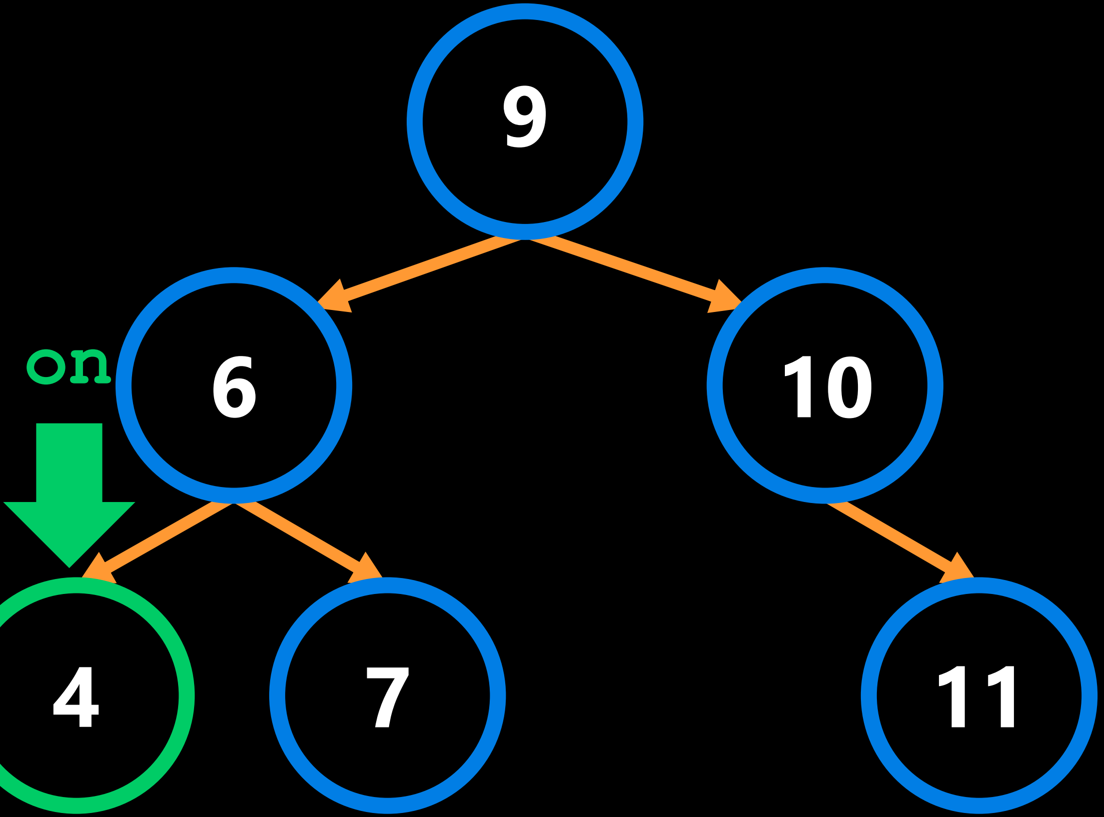
        return False
```

True

False (4 !> 6)

True (4 < 6)

Move on to the left.



tree.find(4)

```
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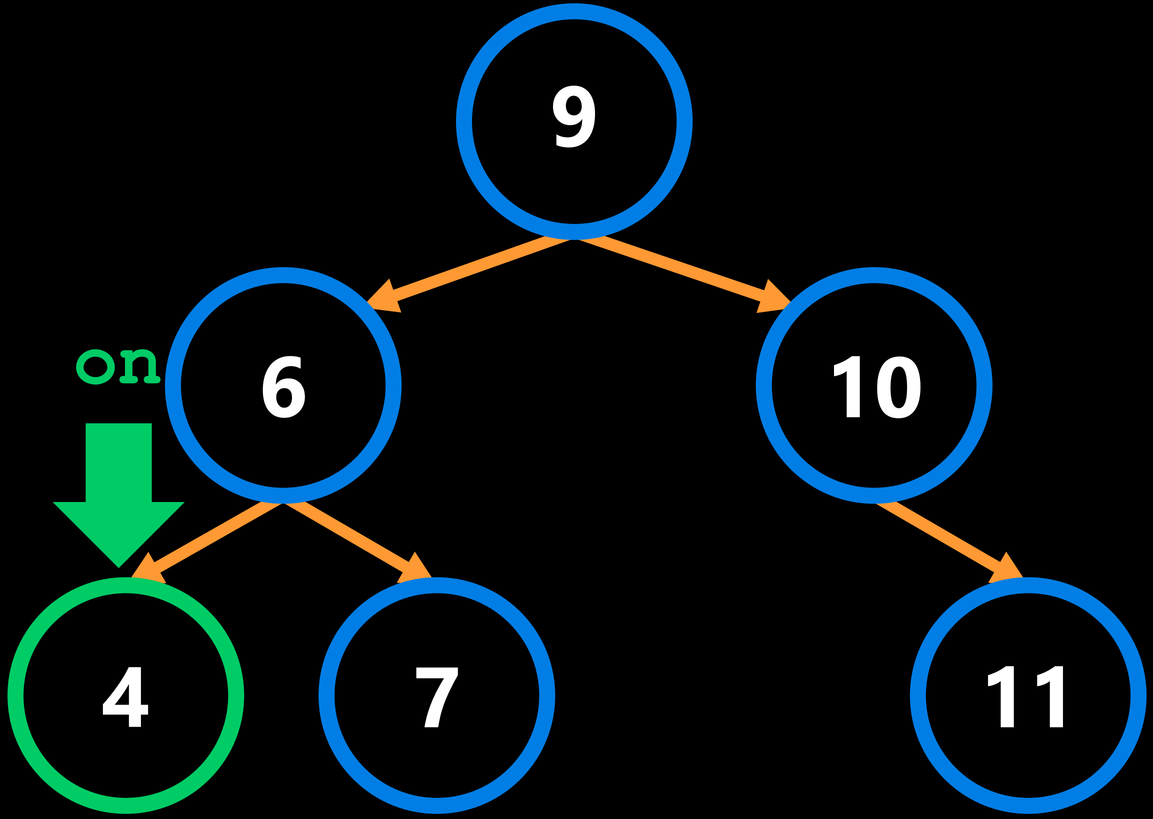
                on = on.right

            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

True



```
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        Checks if cargo value is in the tree.
        """
        on = self.root

        while on is not None:  ⇐ True

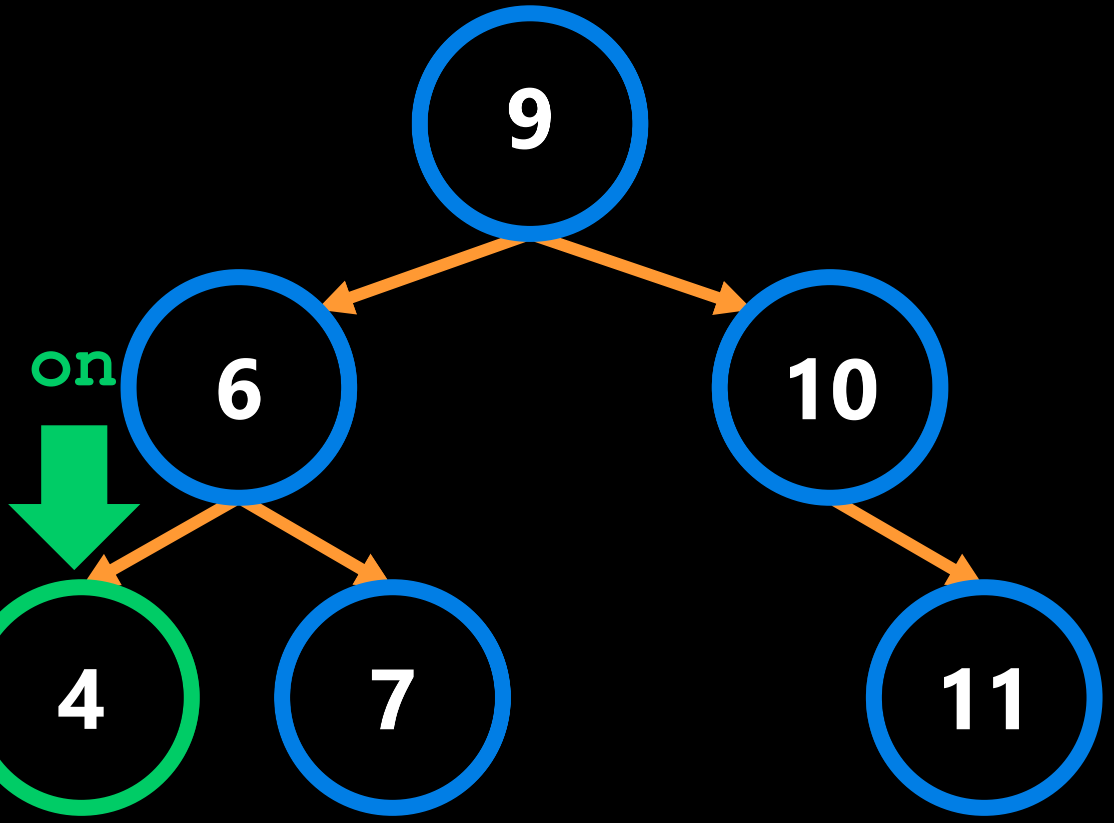
            if cargo > on.cargo:  ⇐ False  (4 !> 4)
                on = on.right

            elif cargo < on.cargo:
                on = on.left

            else:
                return True

        return False
```

tree.find(4)



tree.find(4)

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                on = on.right

            elif cargo < on.cargo:
                on = on.left

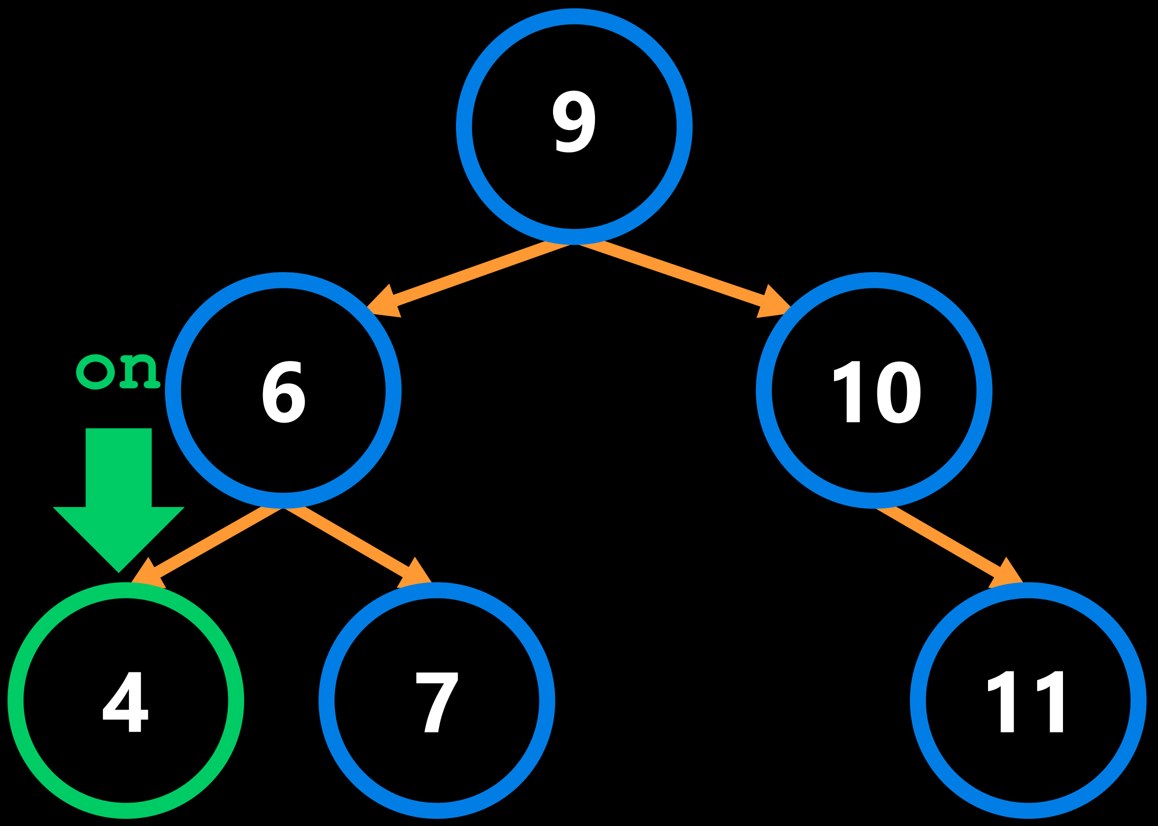
            else:
                return True

        return False
```

True

False (4 !> 4)

False (4 !< 4)



tree.find(4)

```
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        """
        on = self.root

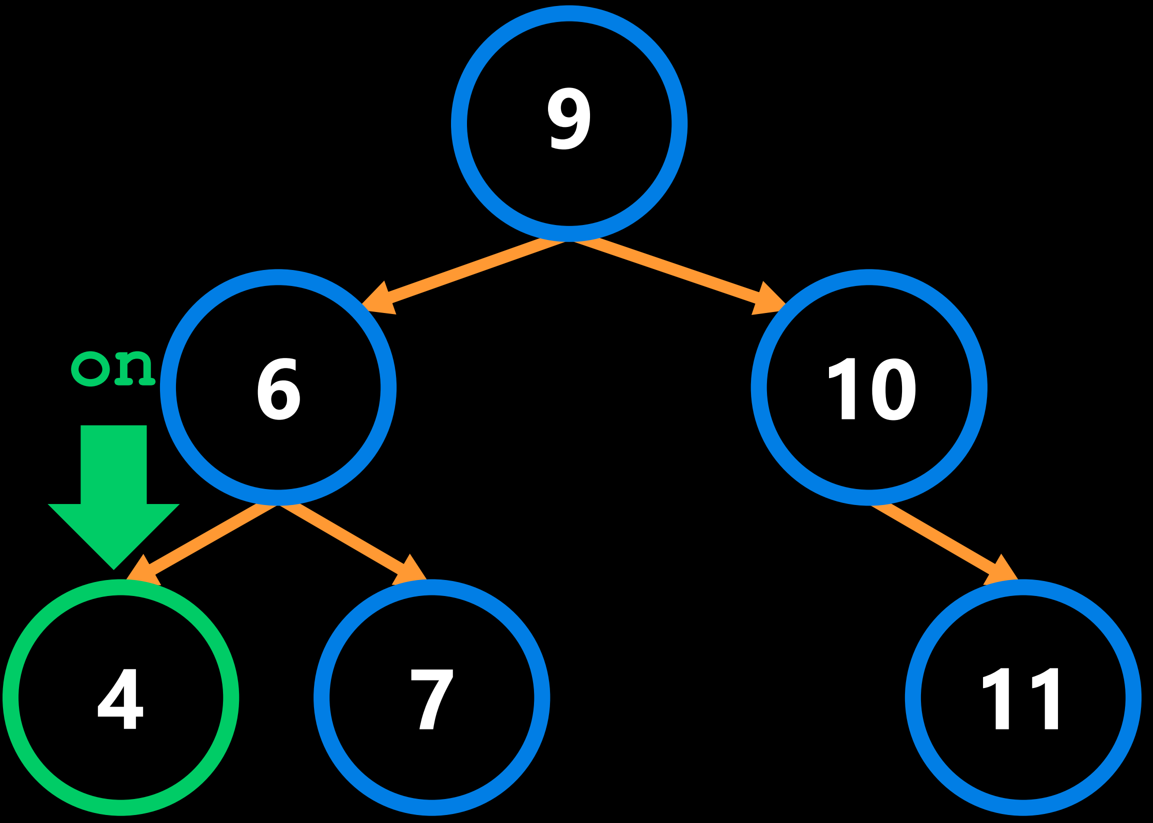
        while on is not None:  ← True

            if cargo > on.cargo:  ← False (4 !> 4)
                on = on.right

            elif cargo < on.cargo:  ← False (4 !< 4)
                on = on.left

            else:
                return True  ← Value is in the tree.

        return False
```



APS106

UNIVERSITY OF TORONTO

binary search trees.

Week 12 | Lecture 2 (12.2)

if nothing else, write #cleancode