

# LECTURE 17

## BINARY SEARCH TREES

MCS 275 Spring 2023

David Dumas

# LECTURE 17: BINARY SEARCH TREES

Reminders and announcements:

- Project 2 due at 6pm on Friday
- Project 1 solutions posted

# SAMPLE CODE

Tree-related examples will go in the new directory [datastructures](#) in the course sample code repository.

# GOALS

Learn about **search** and **insert** operations on binary search trees.

Implement in Python.

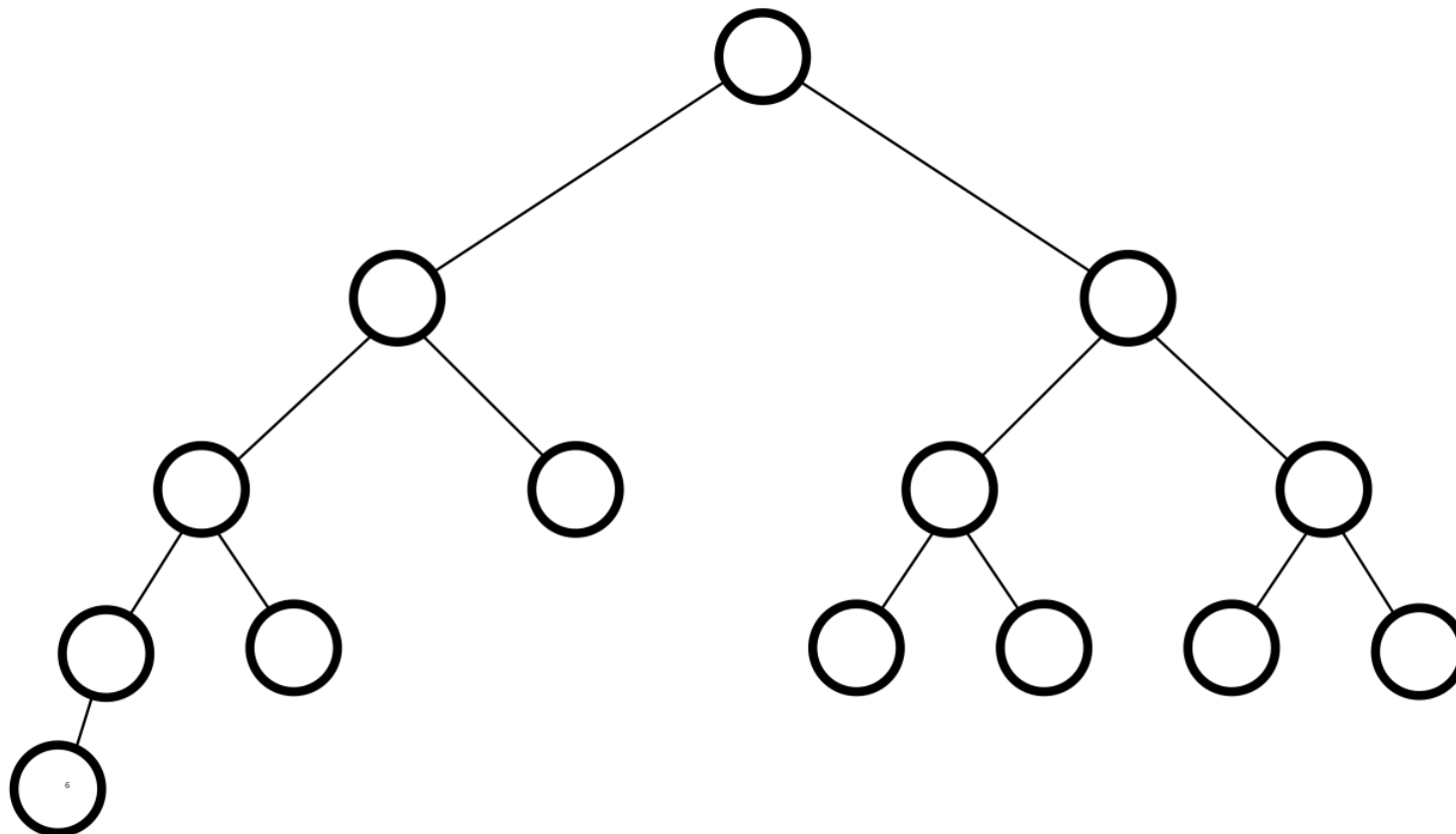
Explore application to a fast data structure for storing a set of integers.

# BINARY SEARCH TREE (BST)

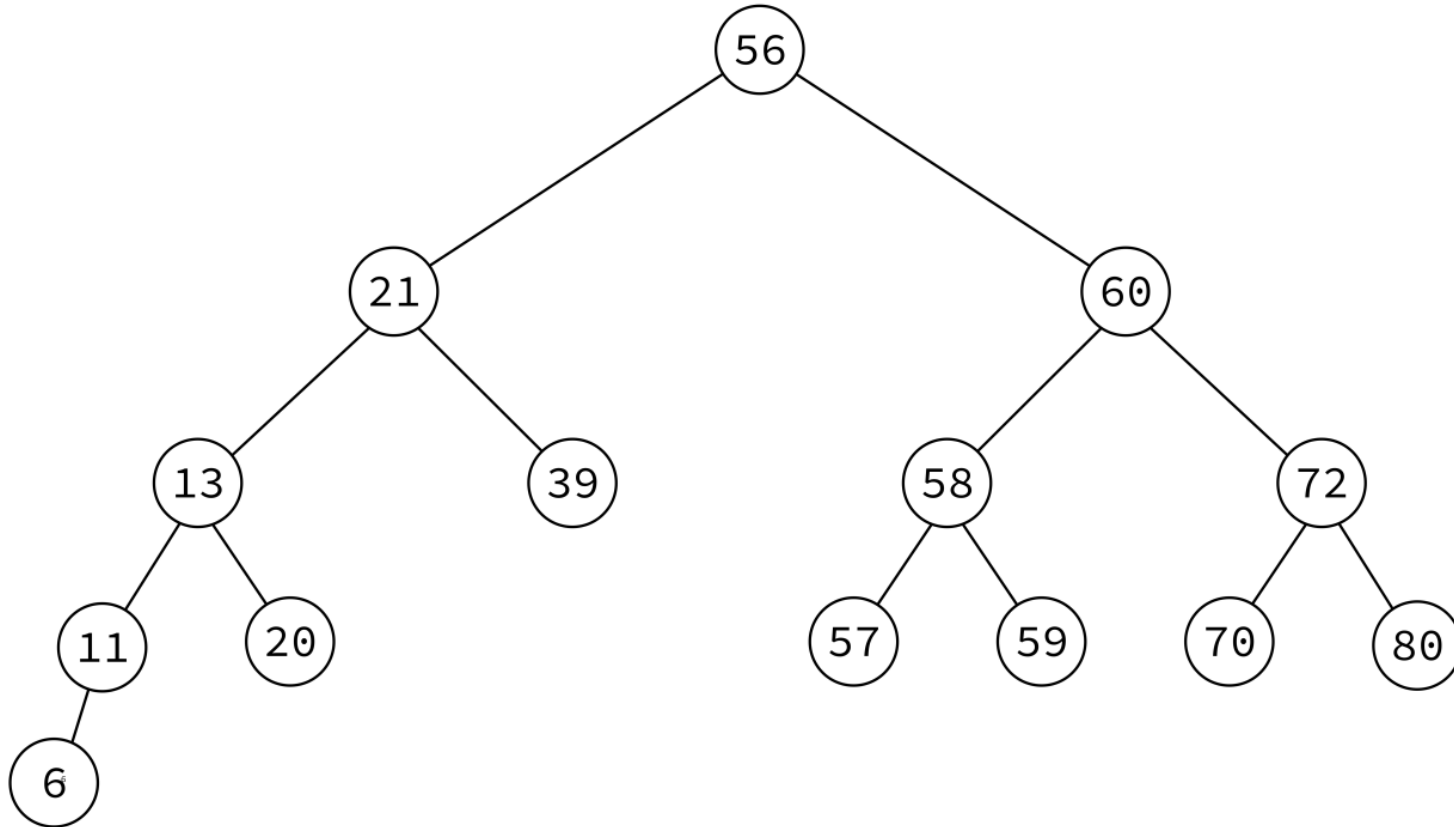
A binary tree in which:

- Nodes have **keys** that can be compared
- The key of a node is greater than or equal to any key in its left subtree.
- The key of a node is less than or equal to any key in its right subtree.

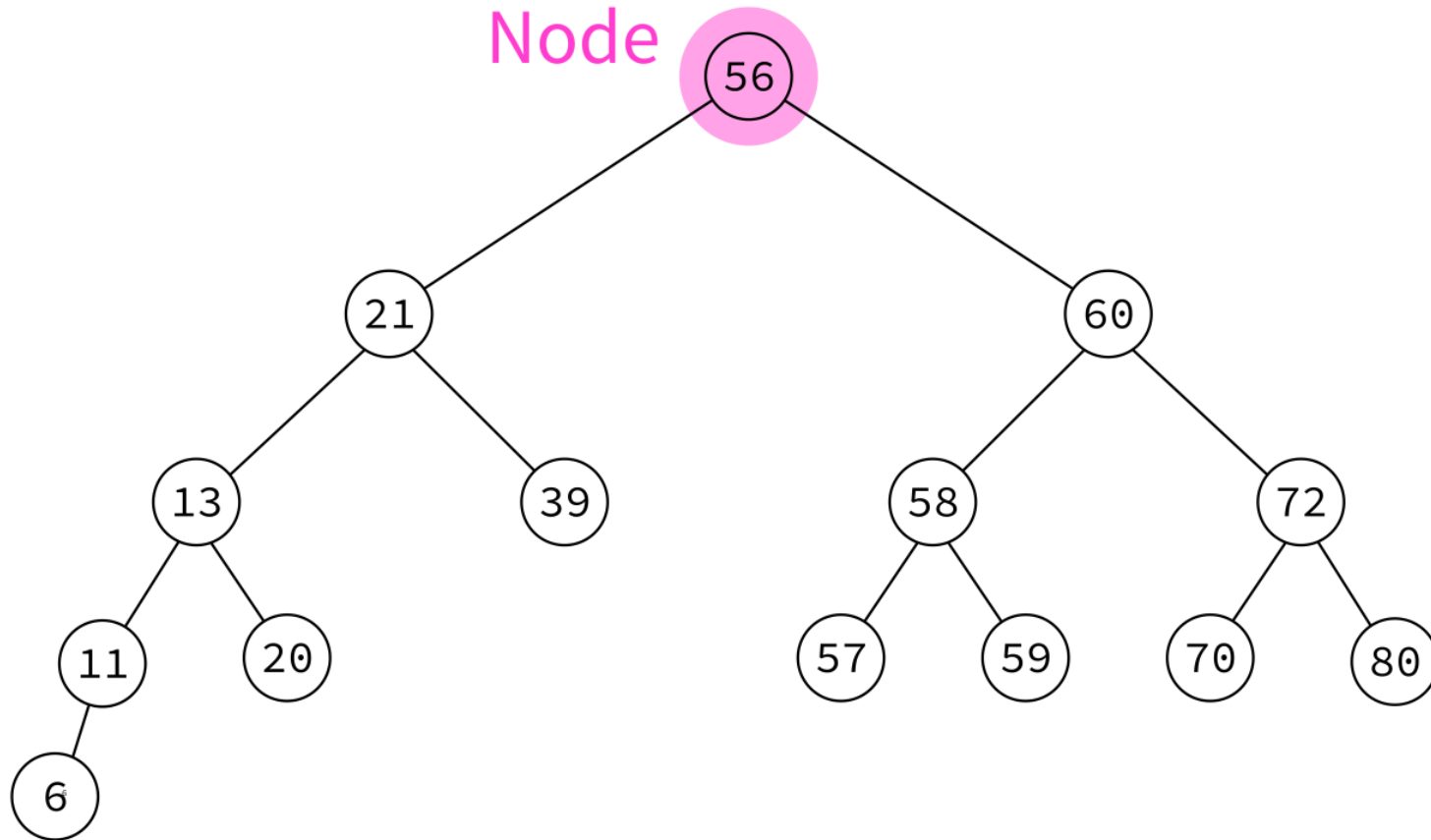
# BINARY TREE



# BST

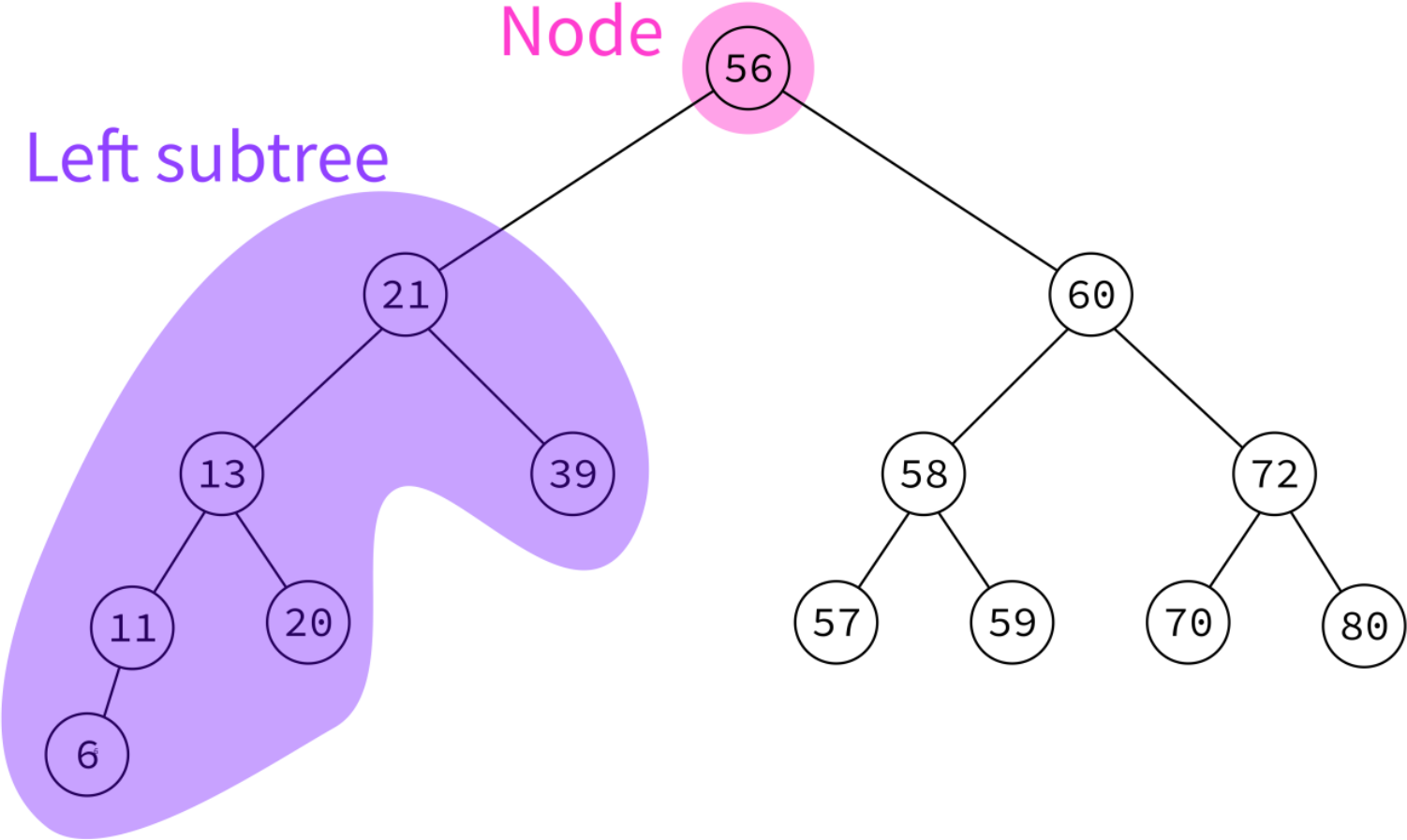


# BST

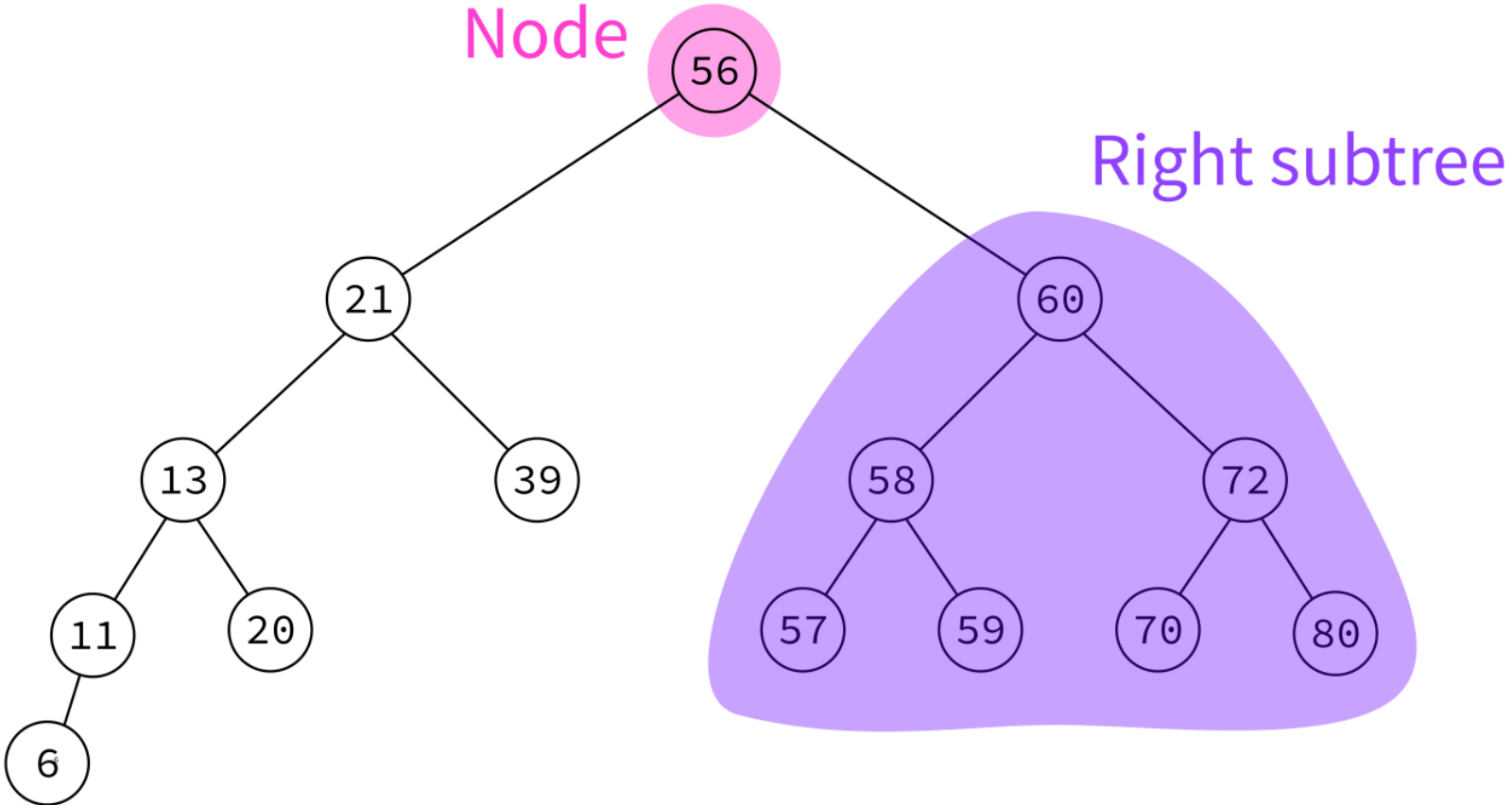




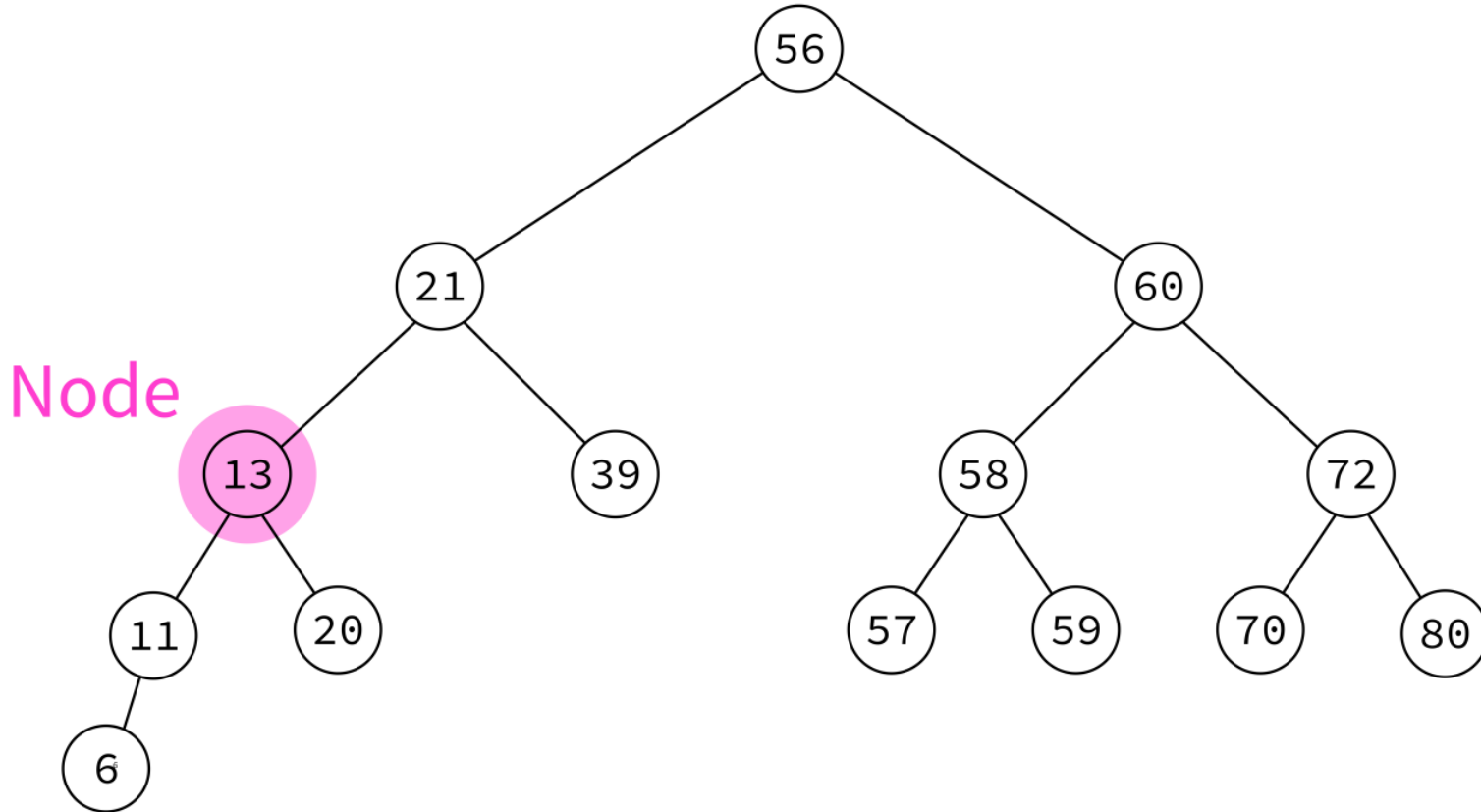
# BST



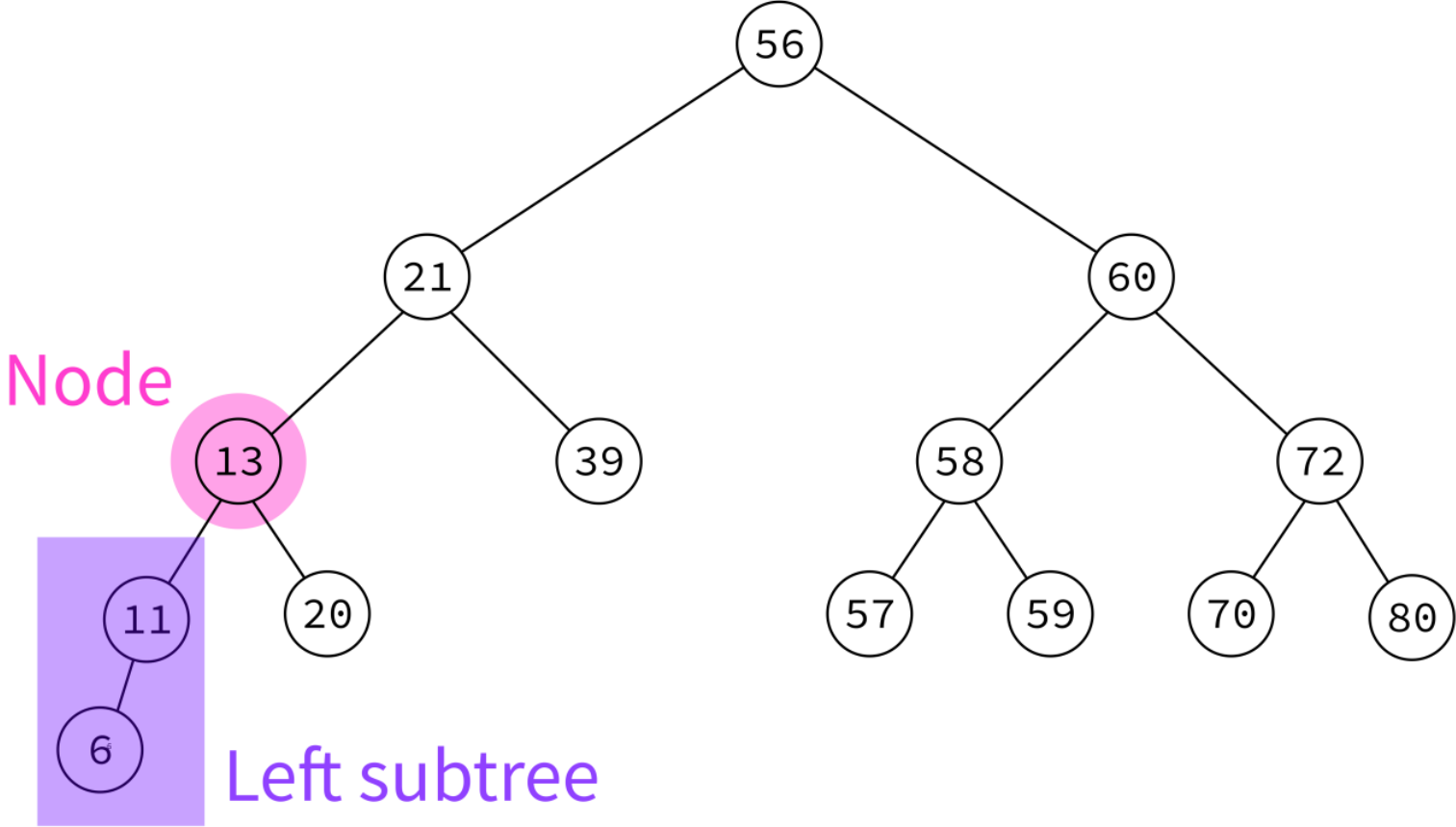
# BST



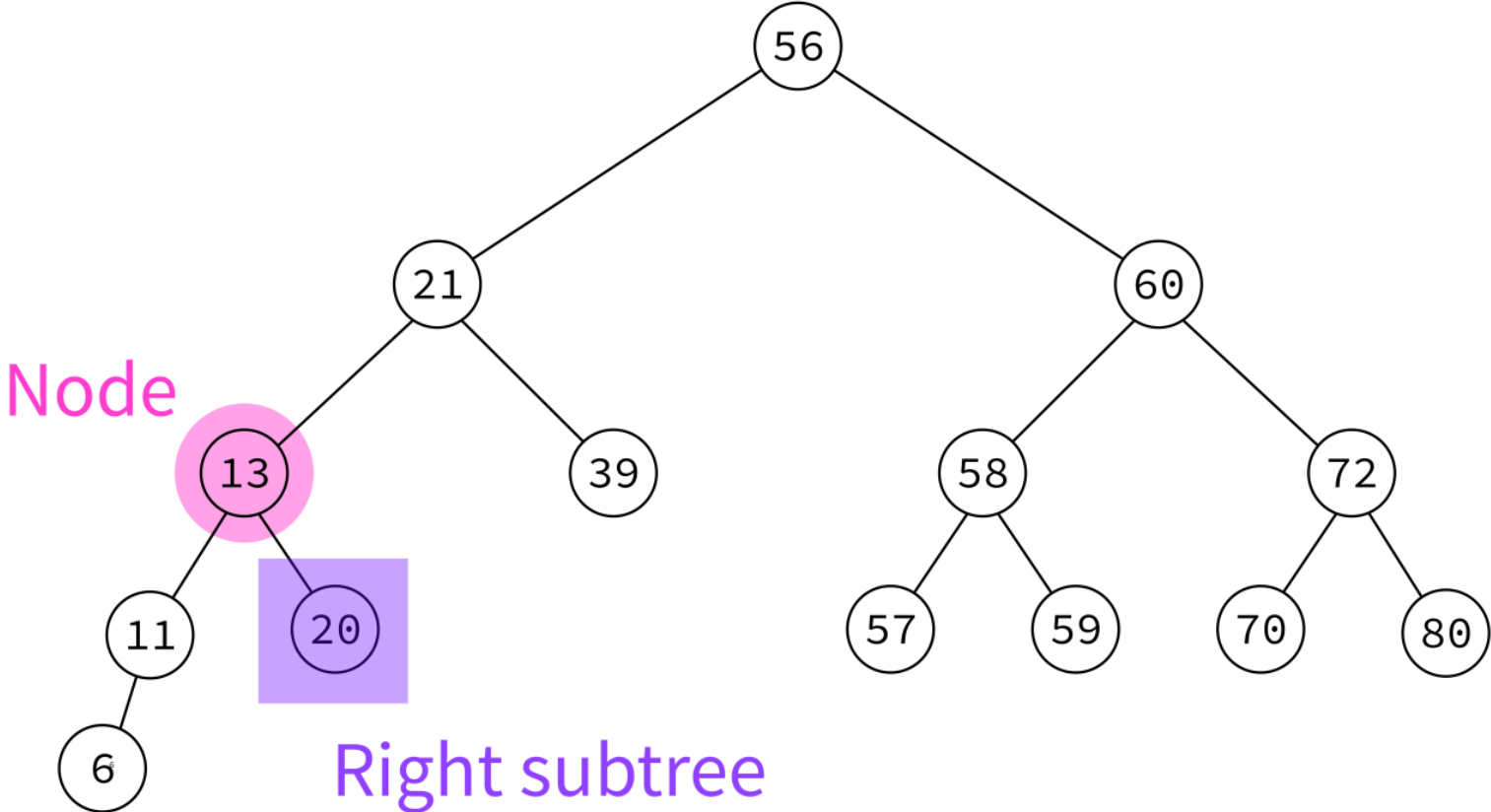
# BST



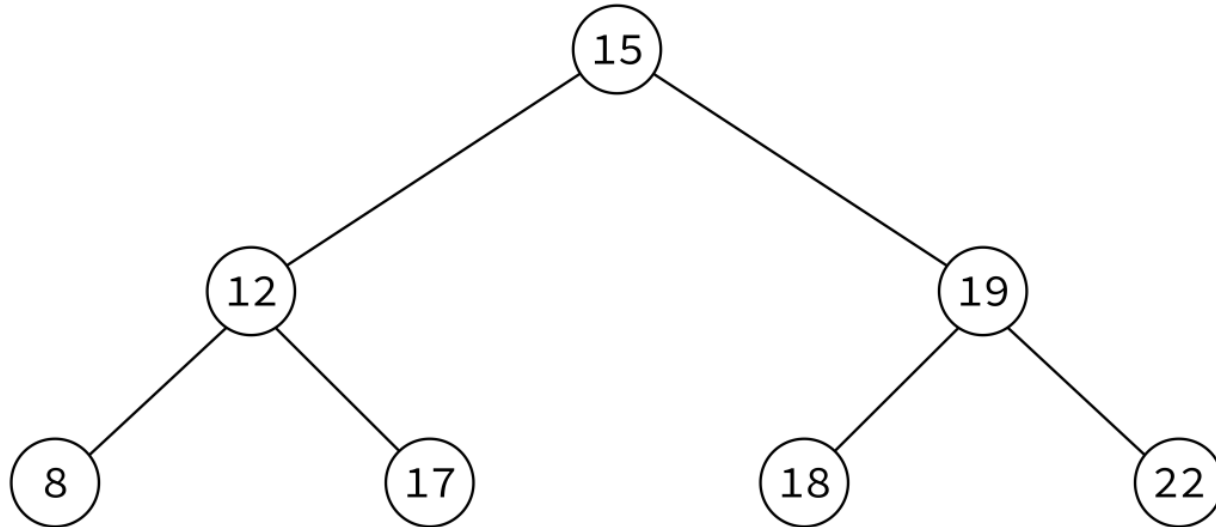
# BST



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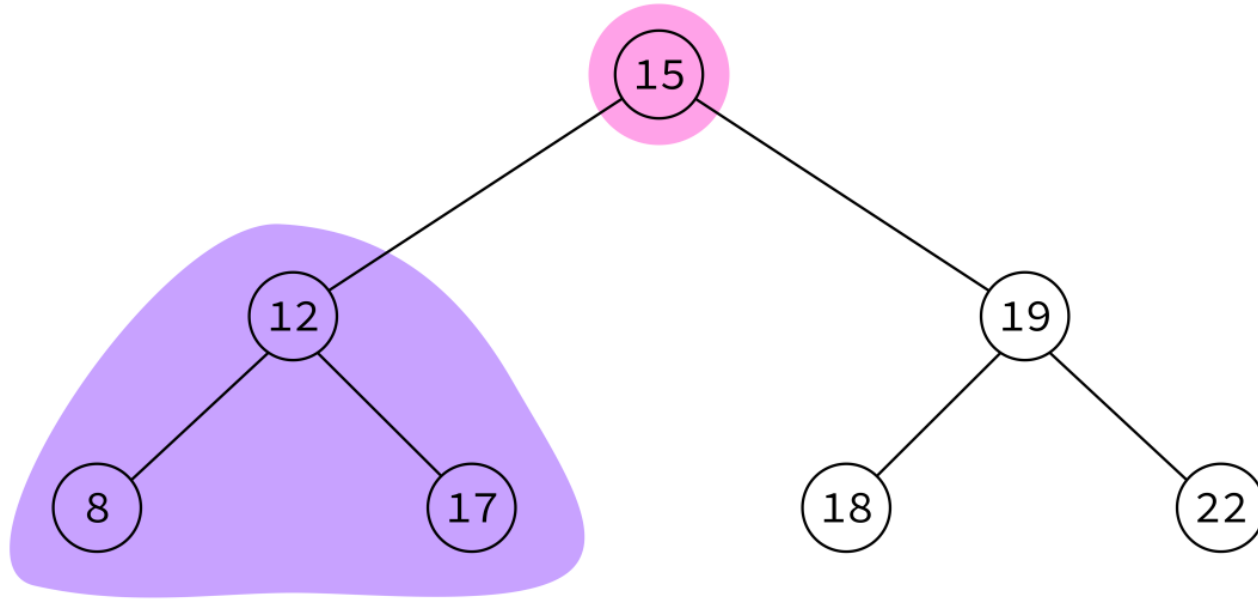


# NOT A BST



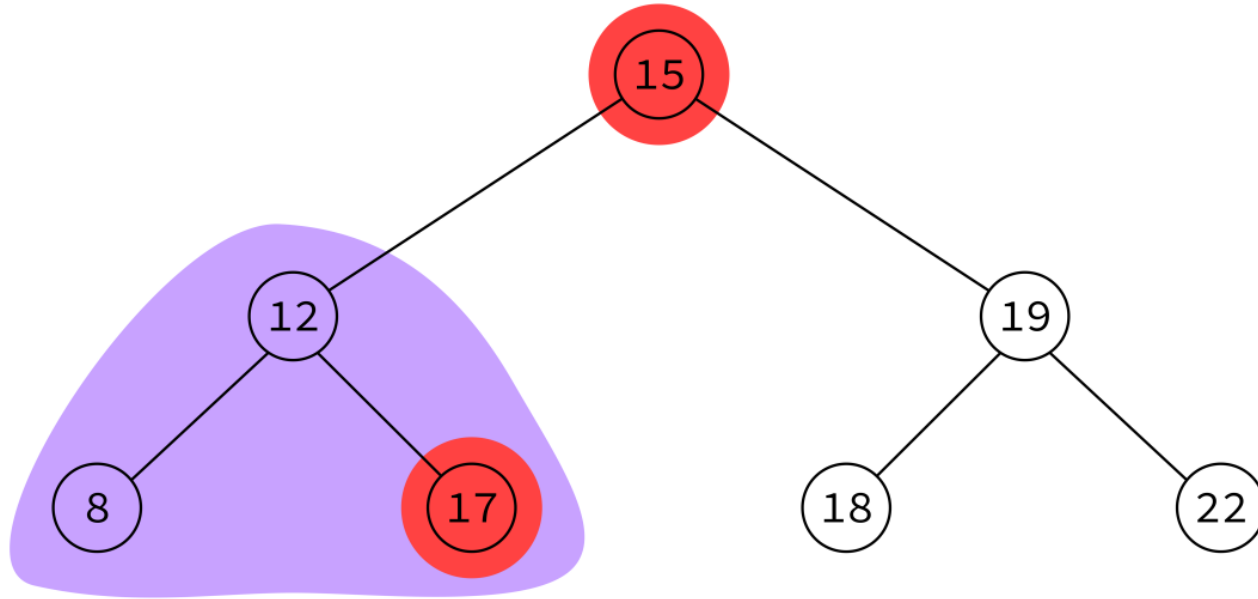
This "just" is a binary tree with keys.

# NOT A BST



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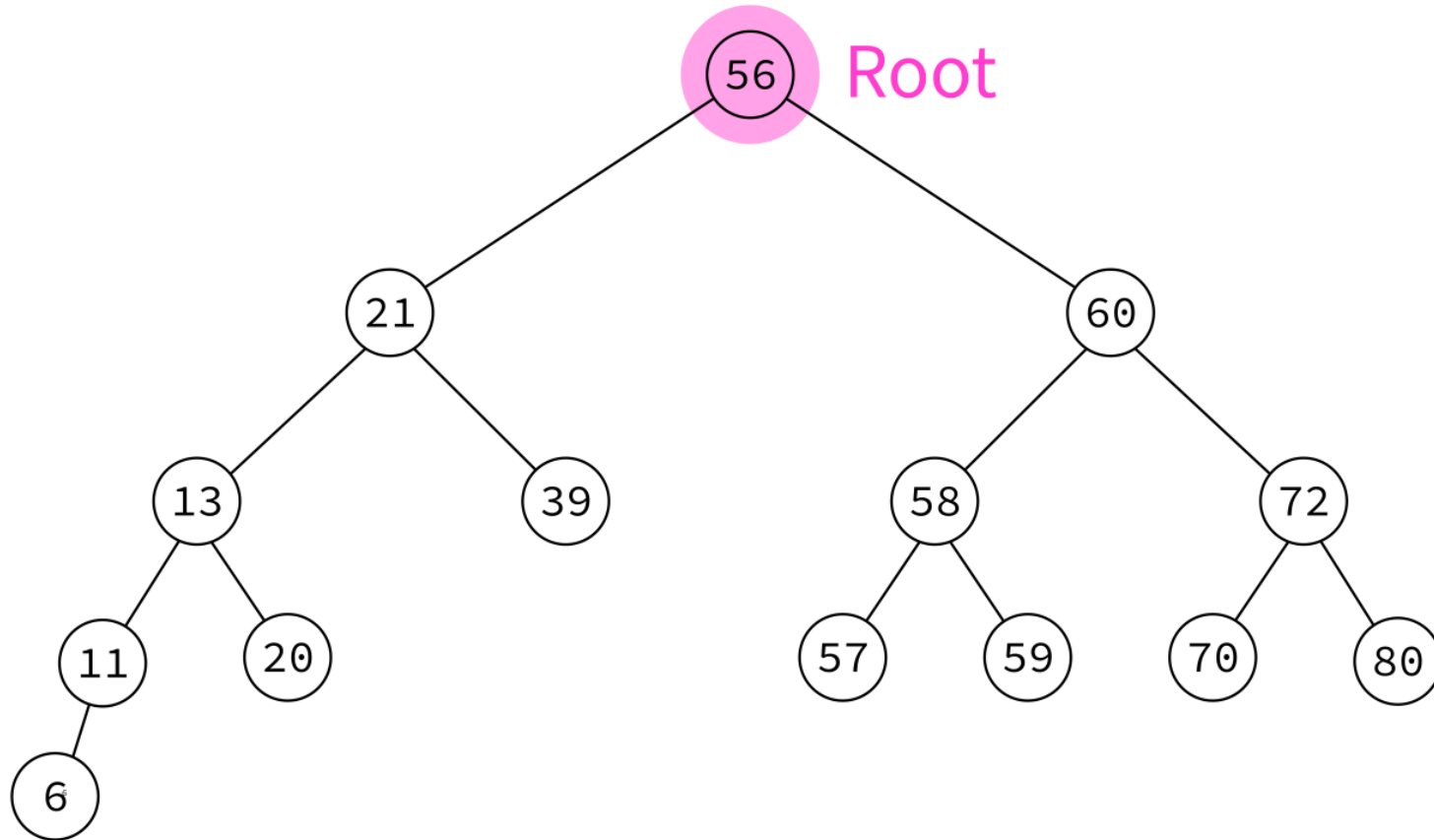
# NOT A BST



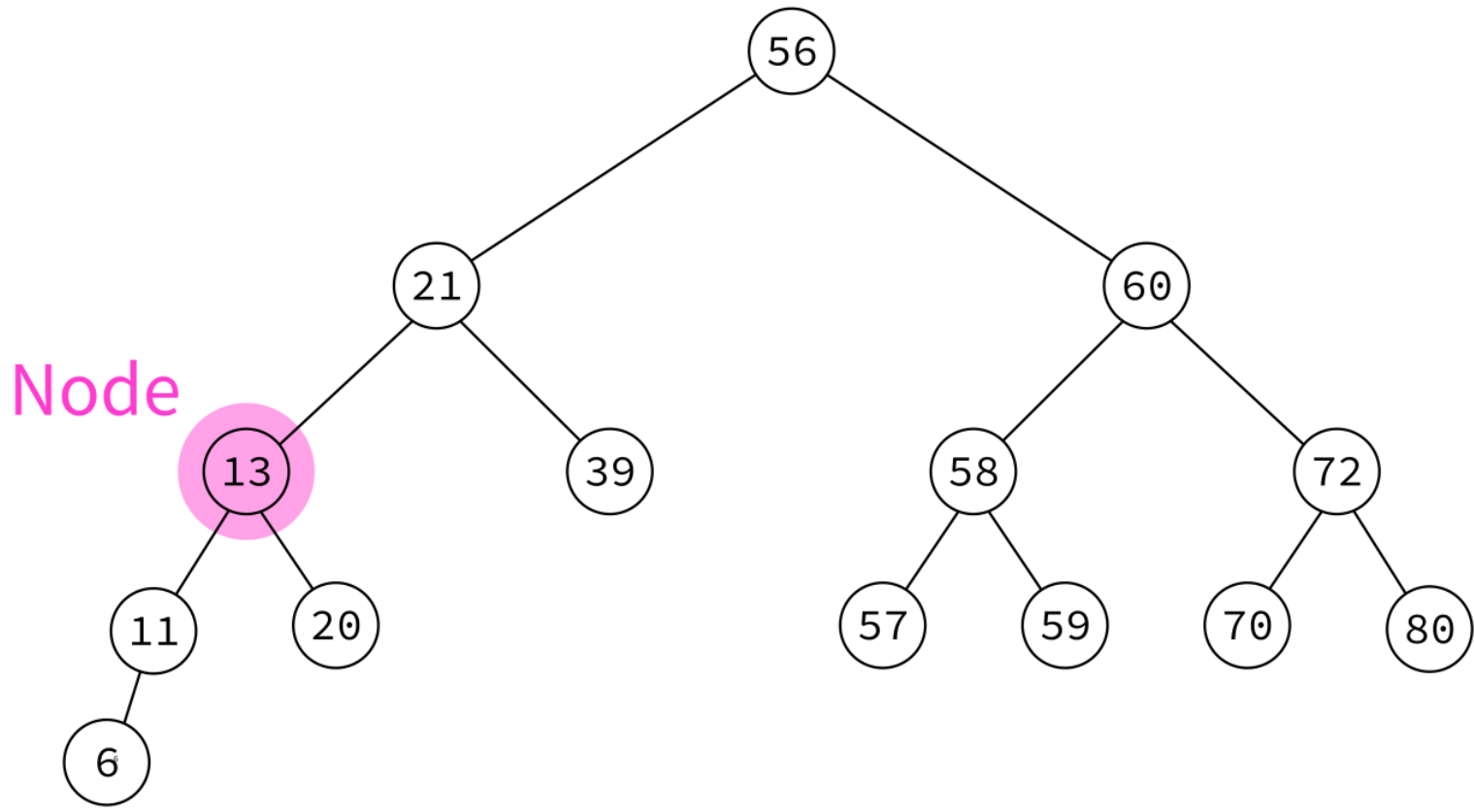
This "just" is a binary tree with keys.



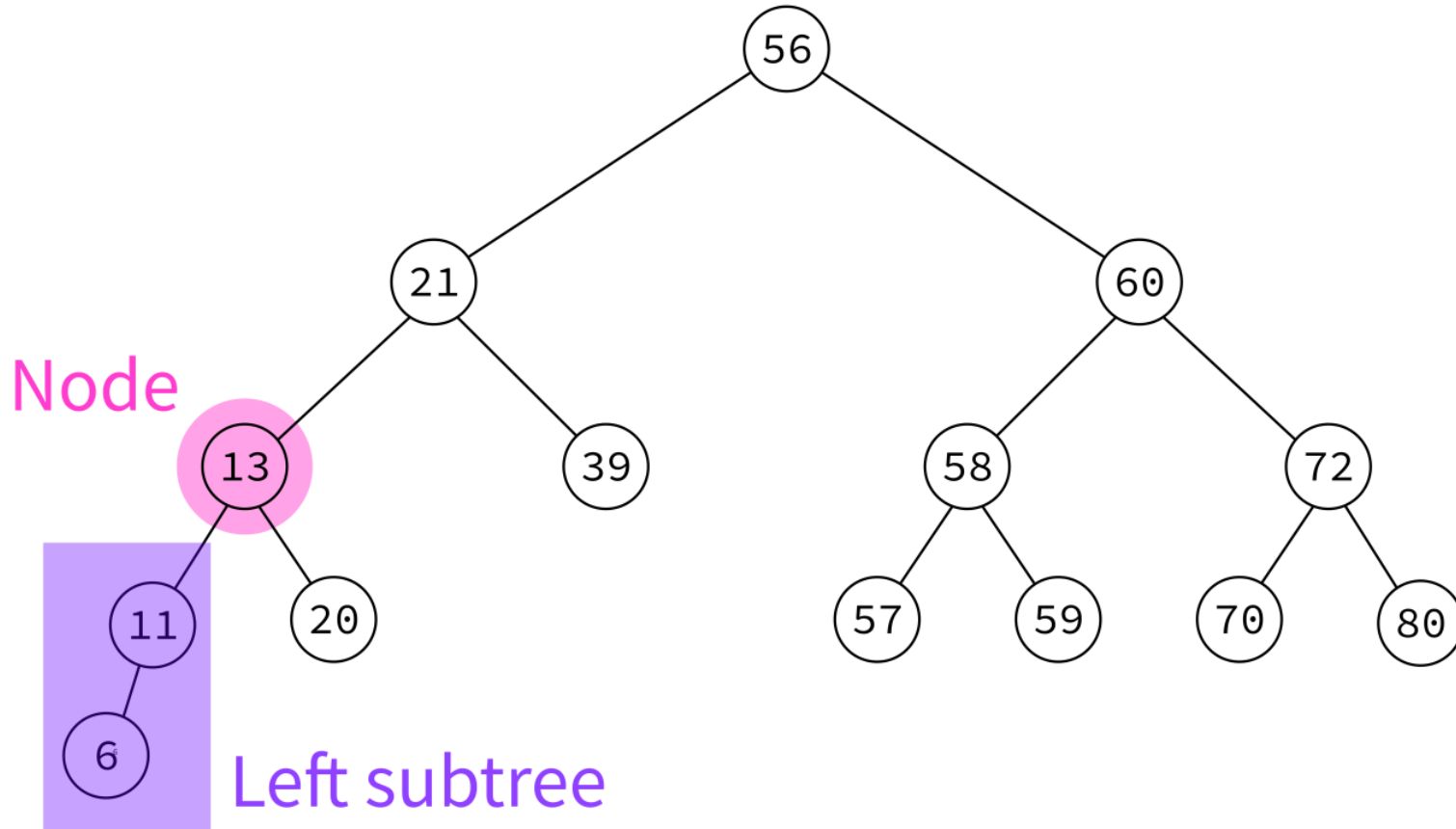
# TREE TERMS



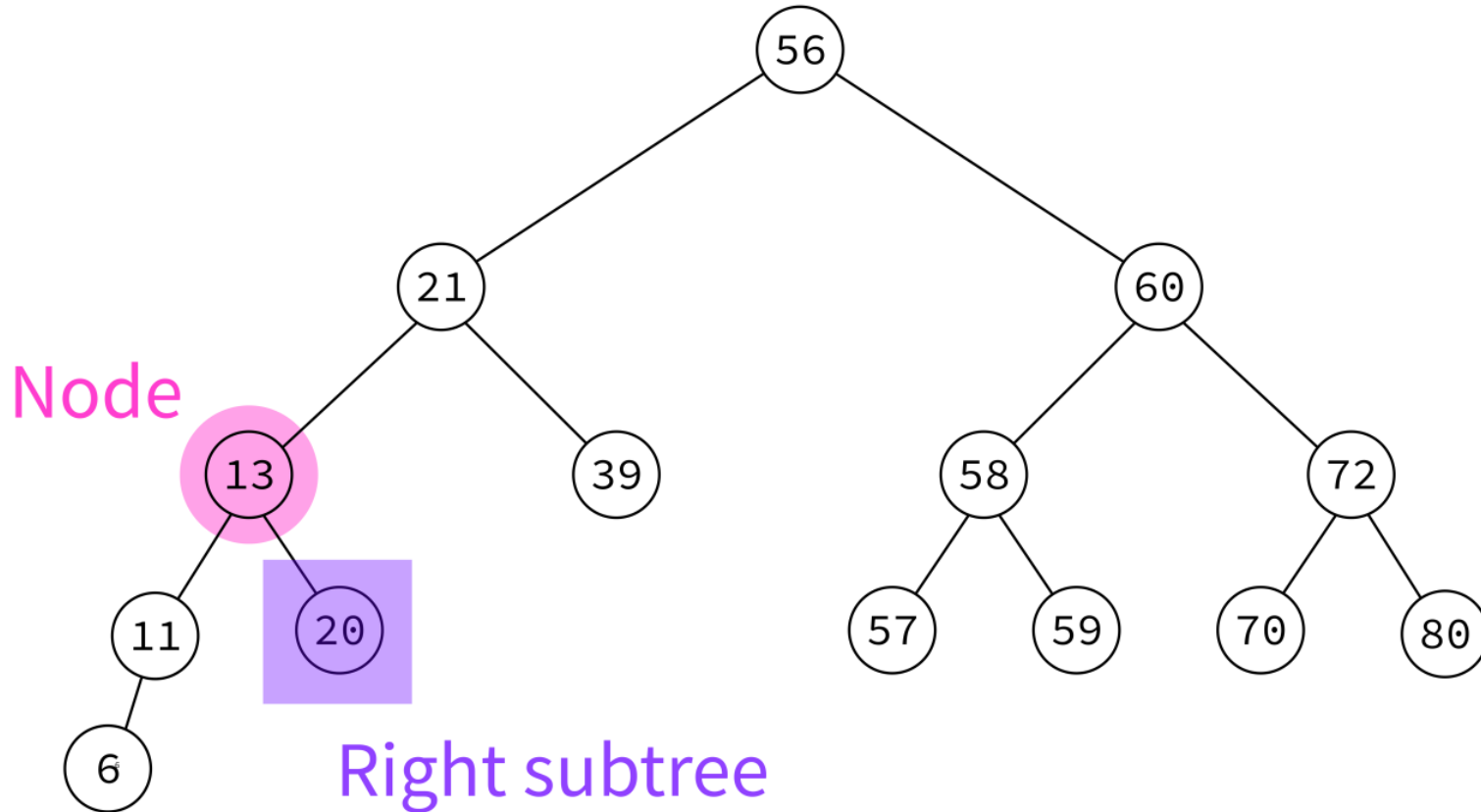
# TREE TERMS



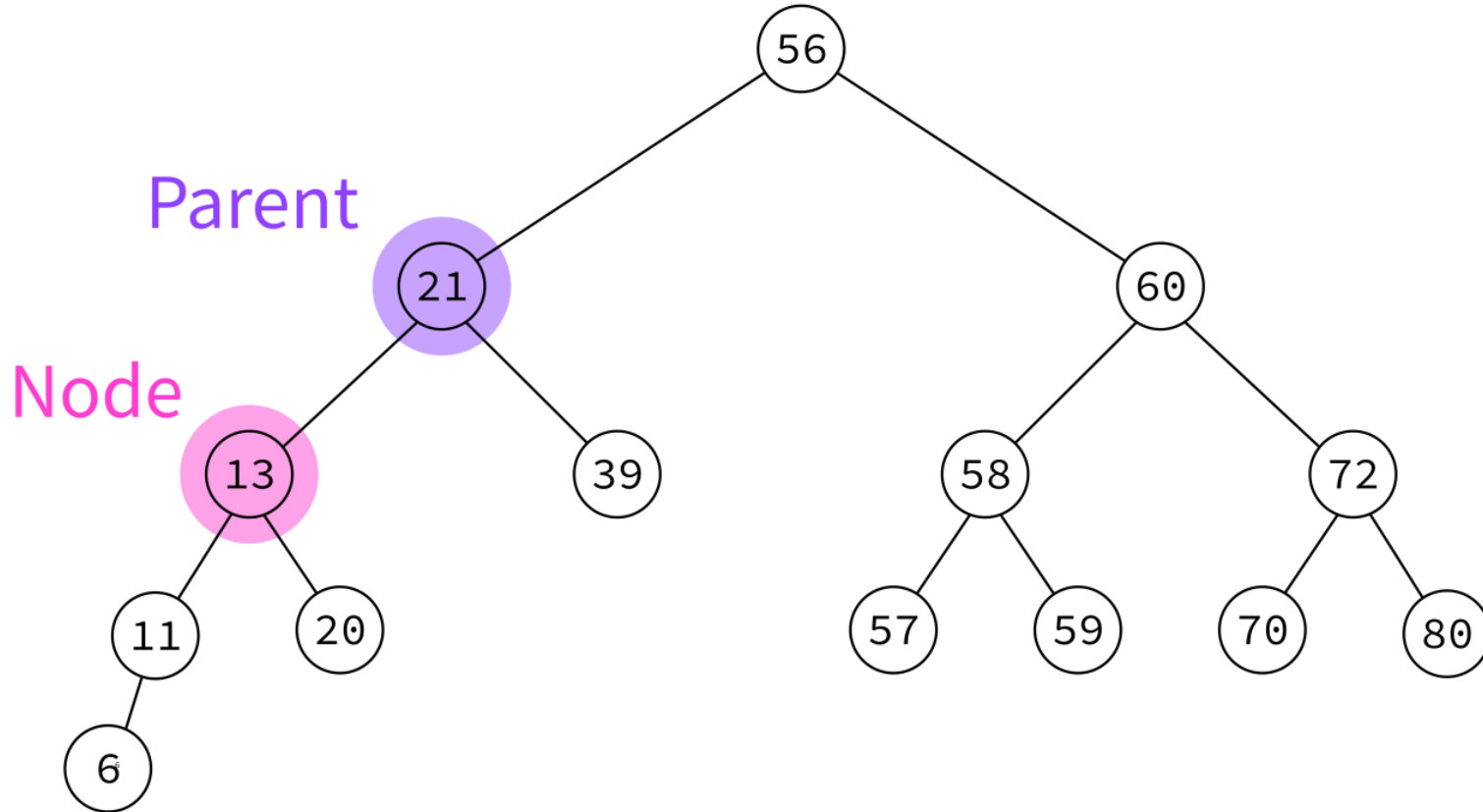
# TREE TERMS



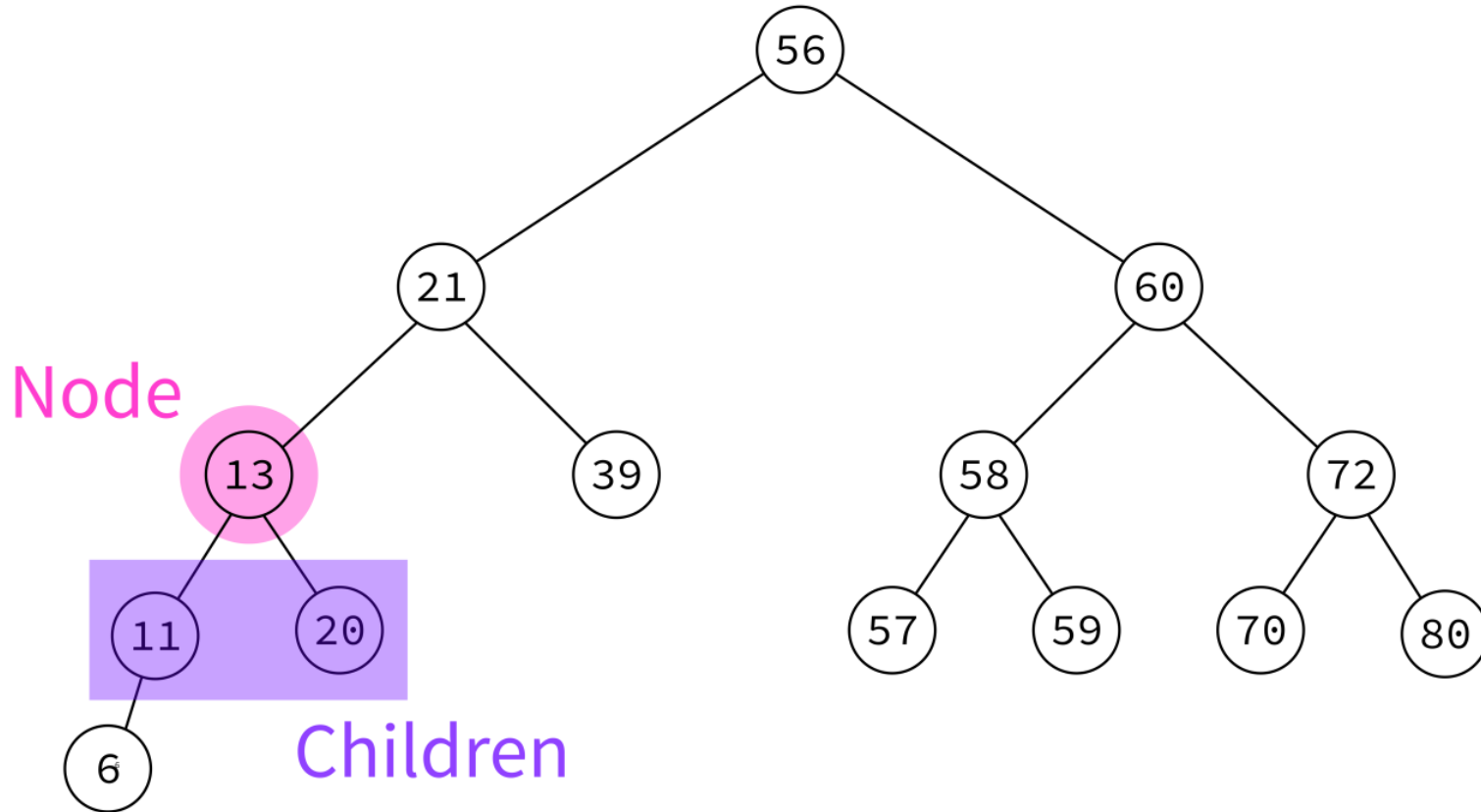
# TREE TERMS



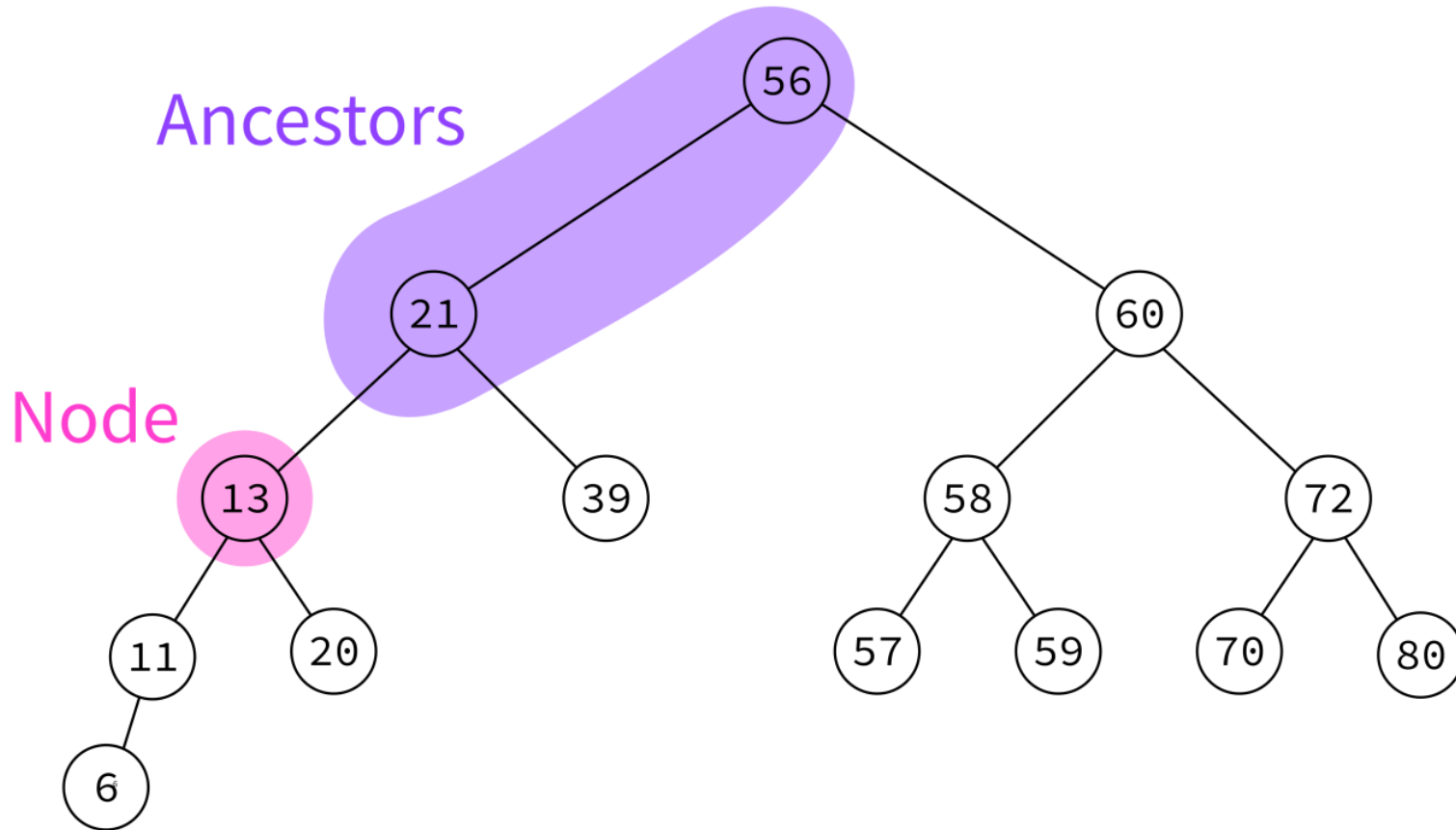
# TREE TERMS



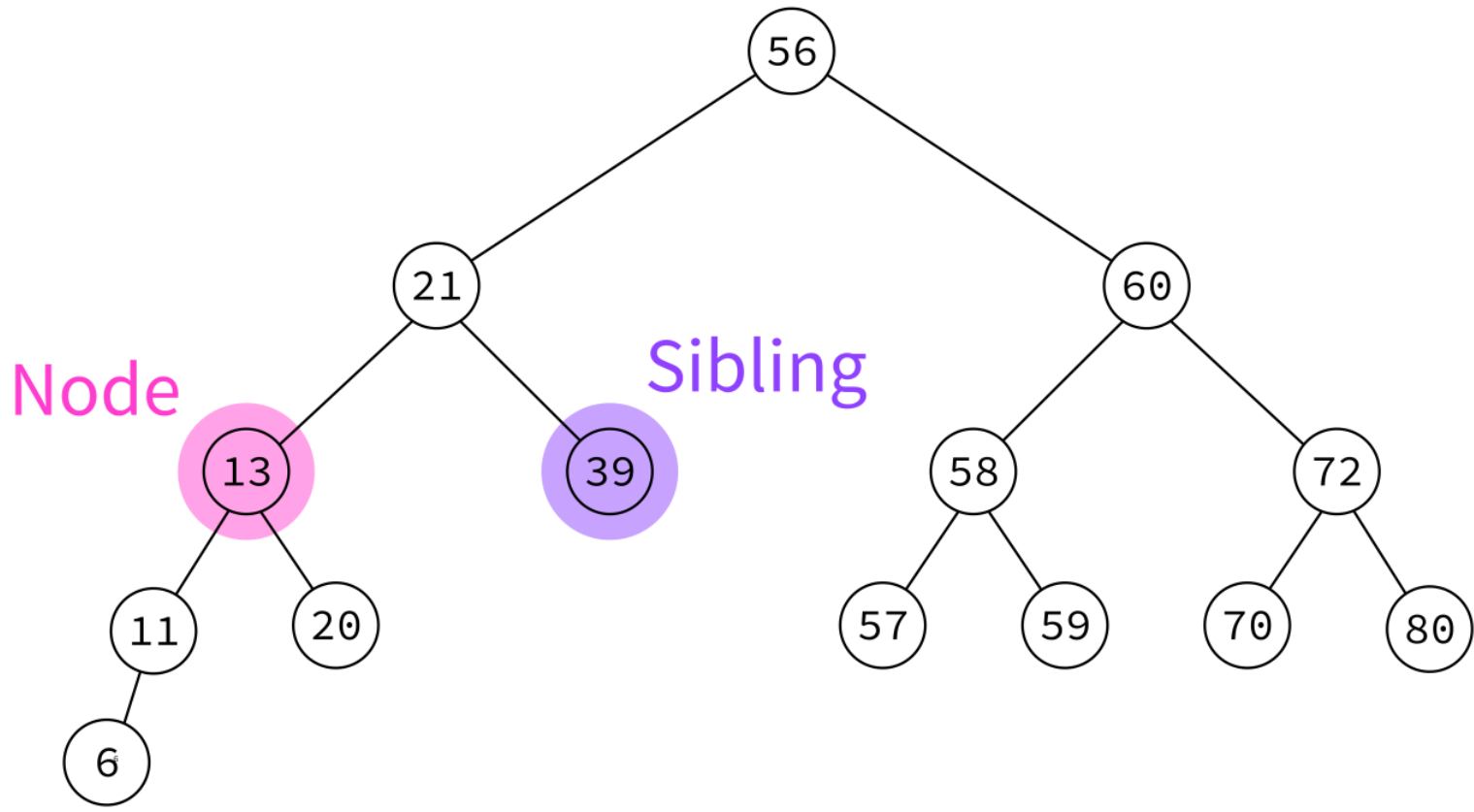
# TREE TERMS



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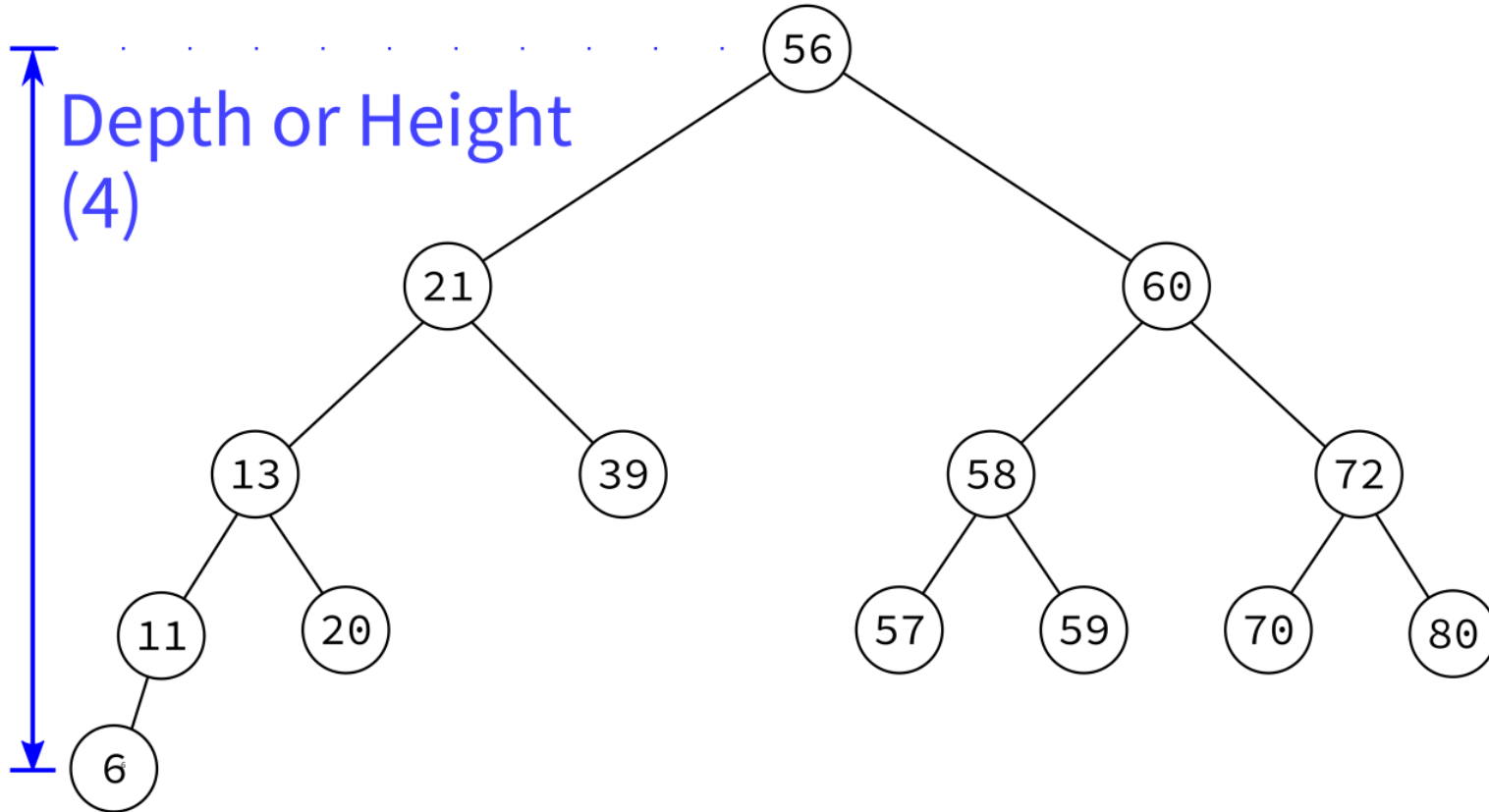


# TREE TERMS





# TREE TERMS



# CODING

Let's build a class to represent nodes of a binary tree that also store keys.

# TREEVIS

I provide a module `treevis` in the sample code repository that can "pretty print" a tree with the function `treeprint(root_node)`.

Challenge: Read the source of `treevis` and figure out how it works!

# FROM TREE TO BST

Now let's build a subclass of `Node` to represent a BST.

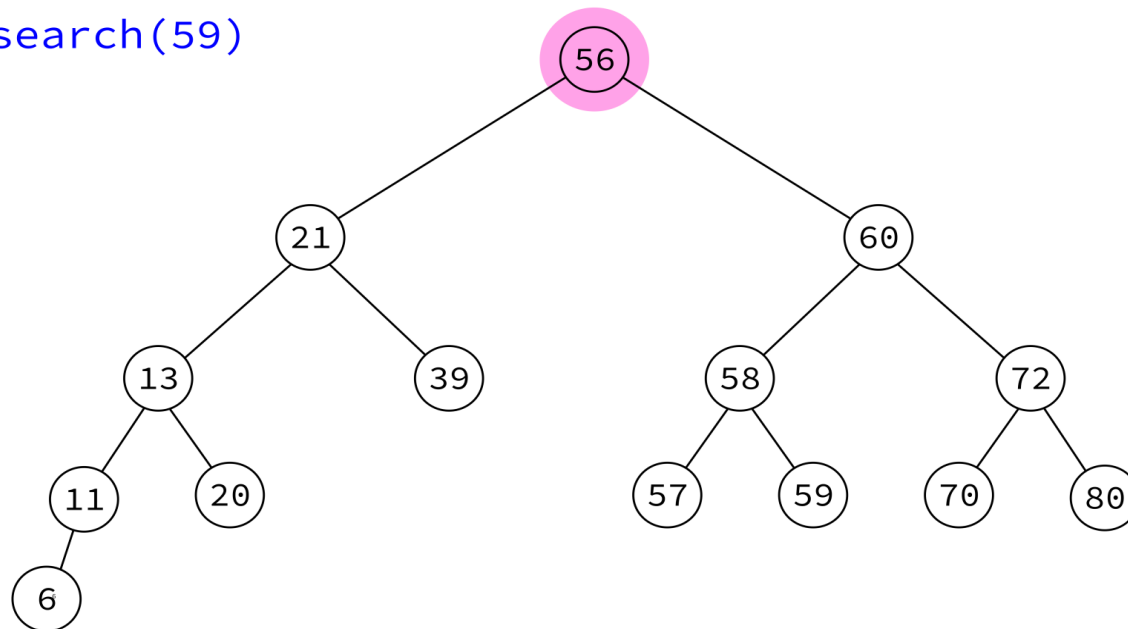
Desired features:

- Insert nodes (maintaining BST property)
- Search for nodes by key

# SEARCH

Given  $x$ , find and return a node with key  $x$ . Return None if no such node exists.

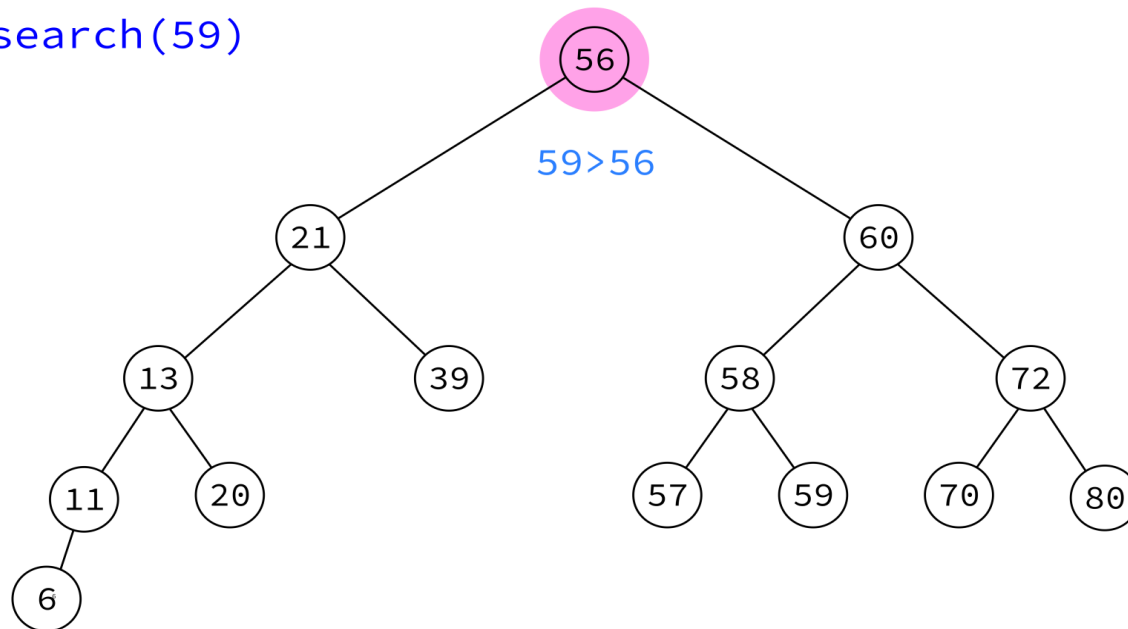
search(59)



# SEARCH

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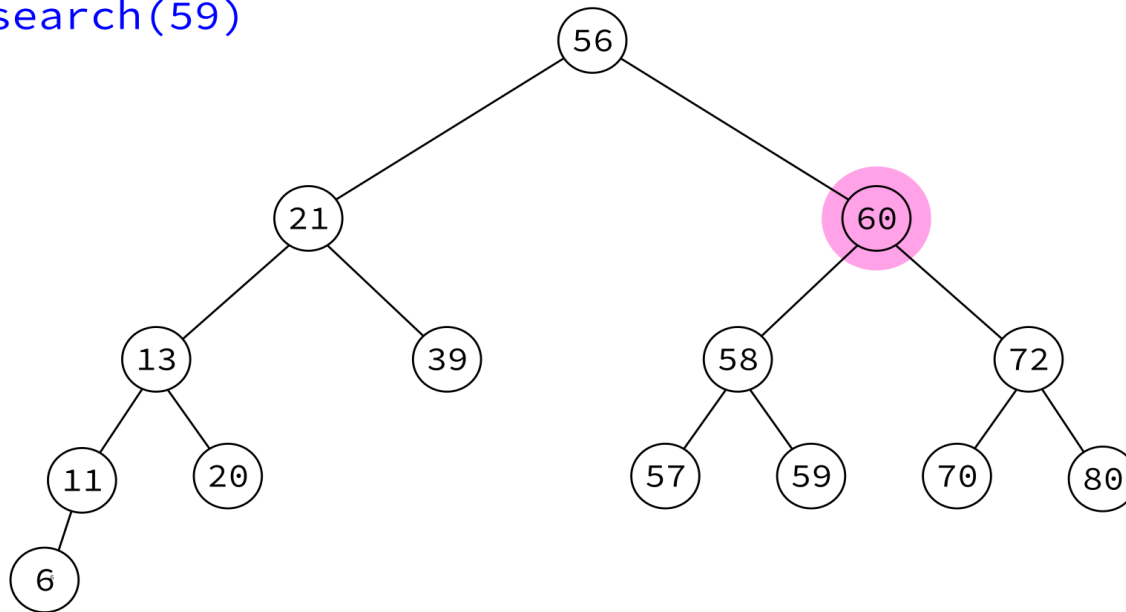
search(59)



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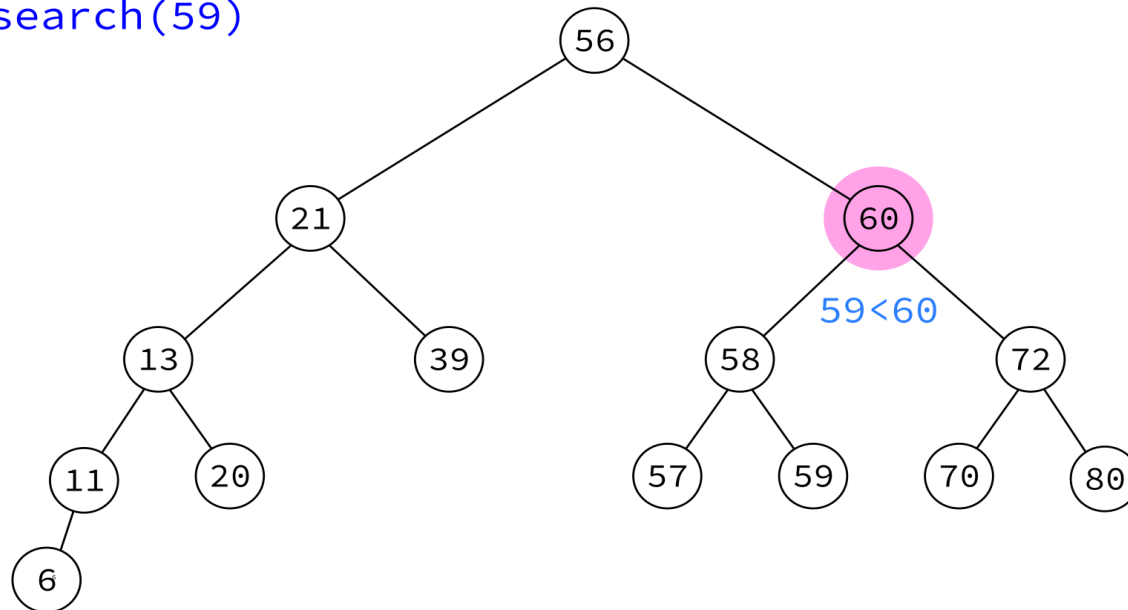
search(59)



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search(59)

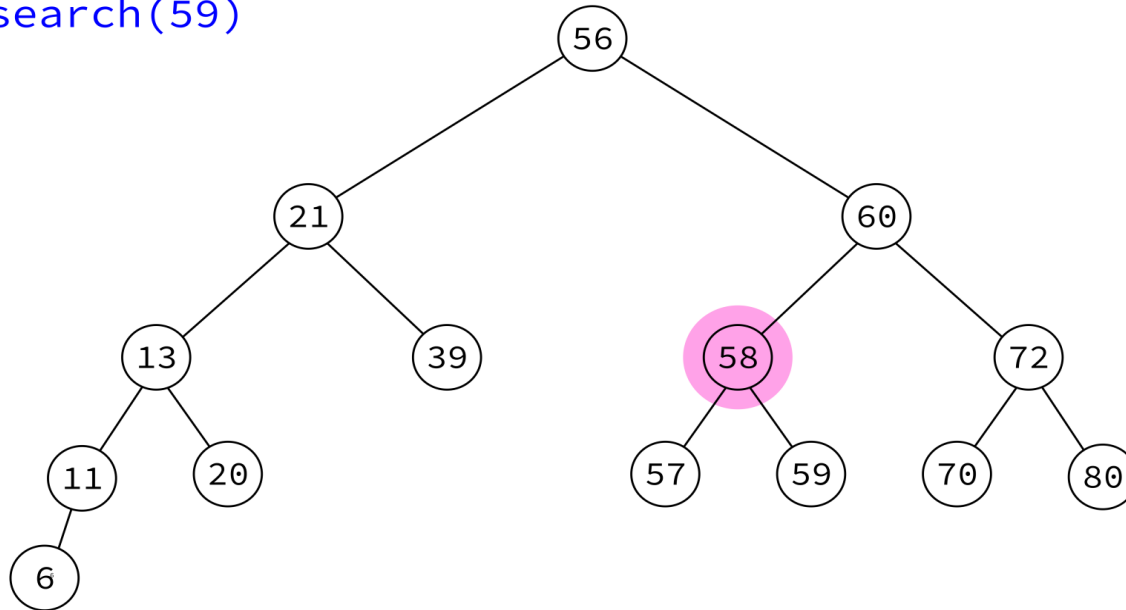




# SEARCH

Given  $x$ , find and return a node with key  $x$ . Return `None` if no such node exists.

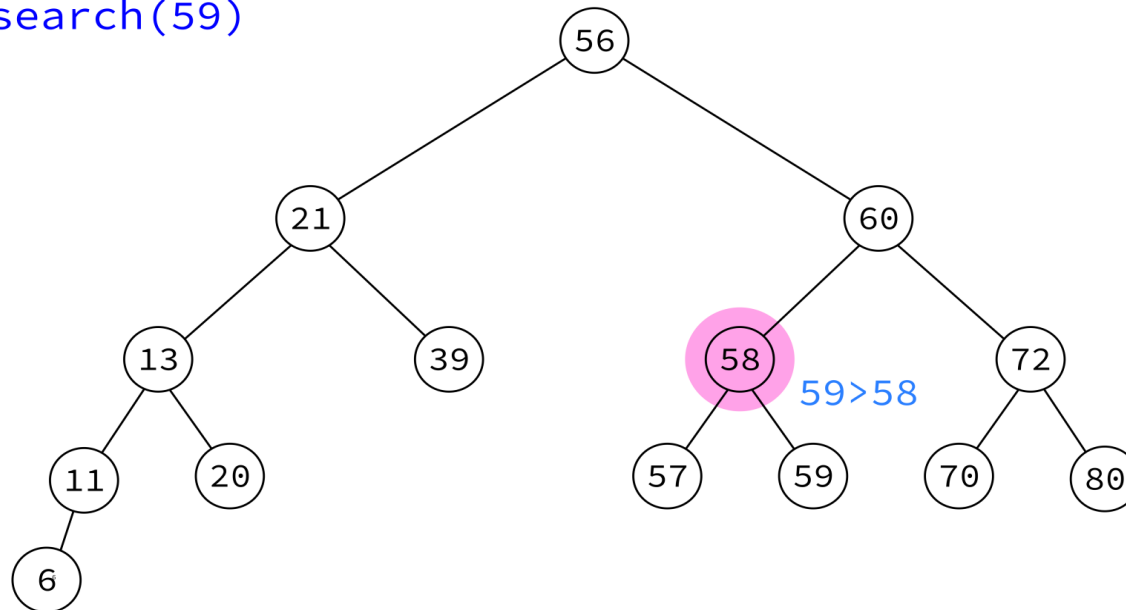
search(59)



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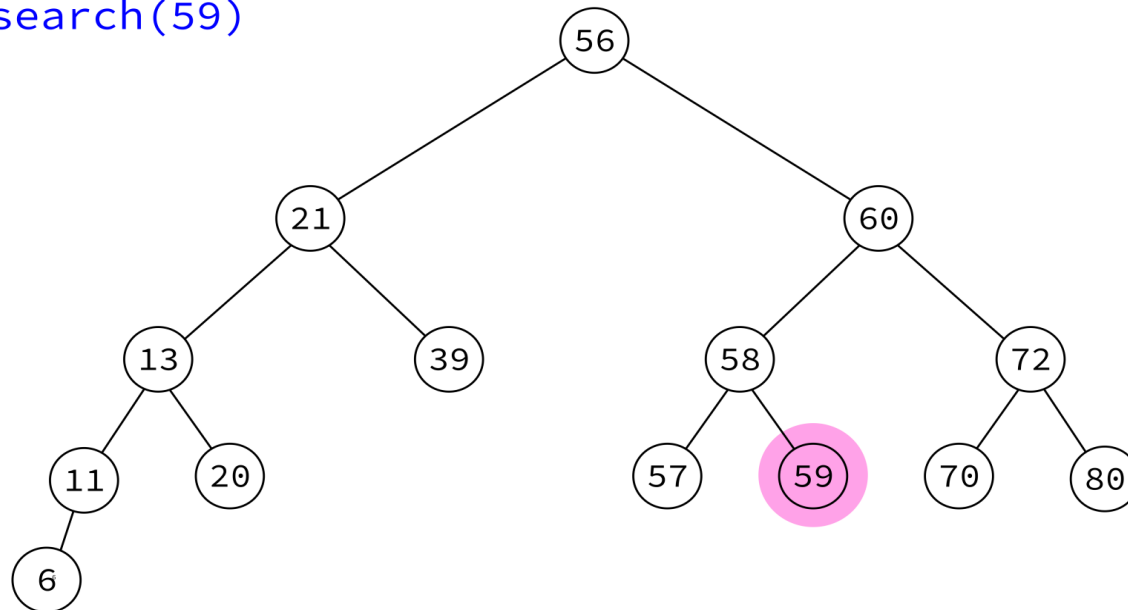
search(59)



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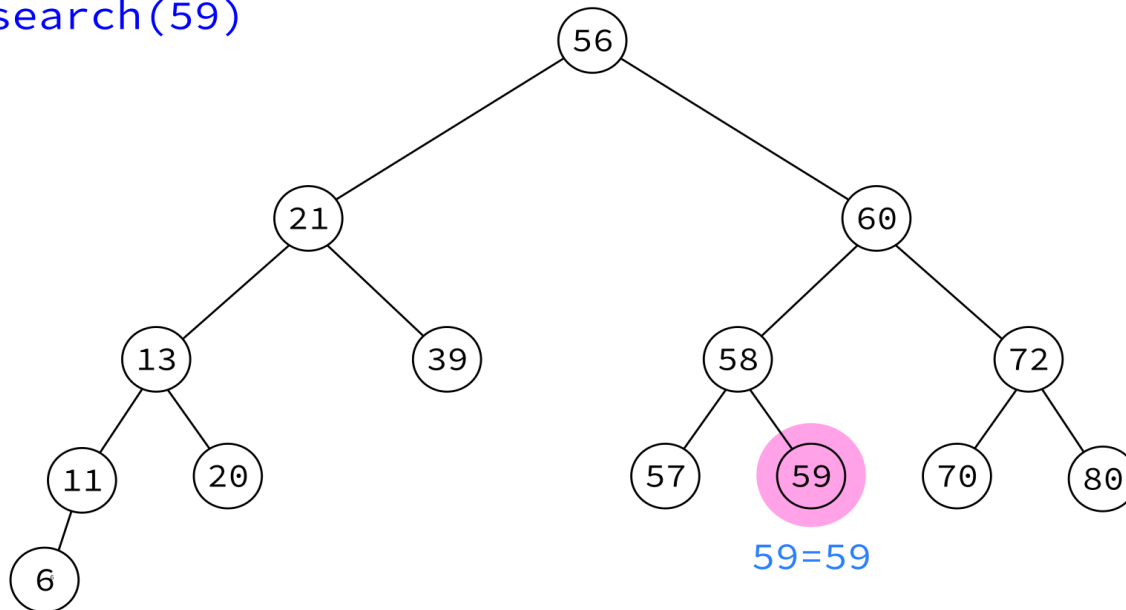
search(59)



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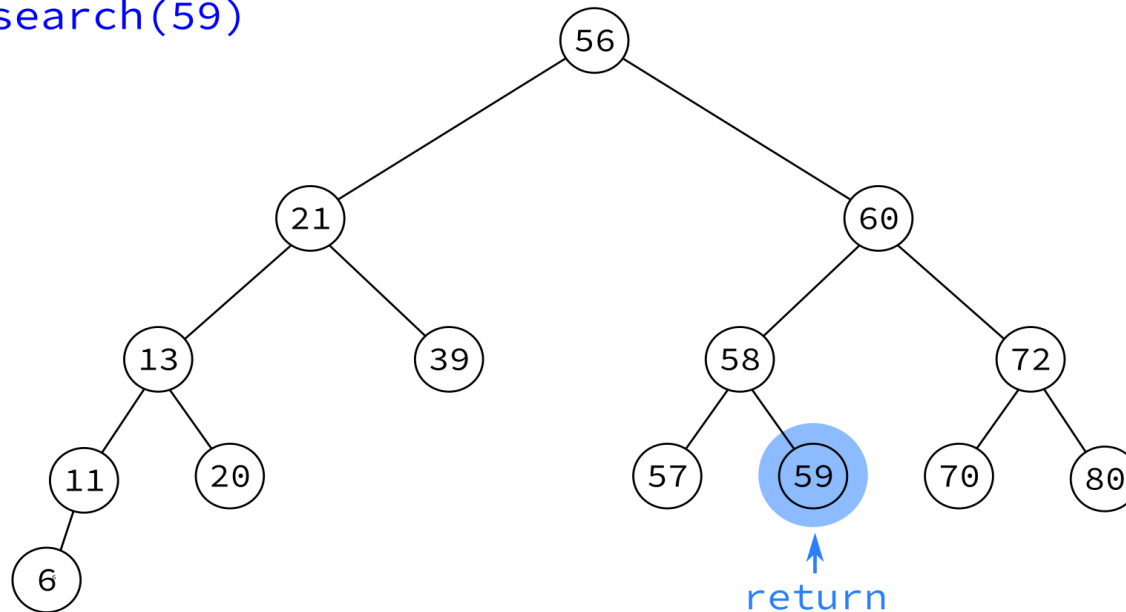
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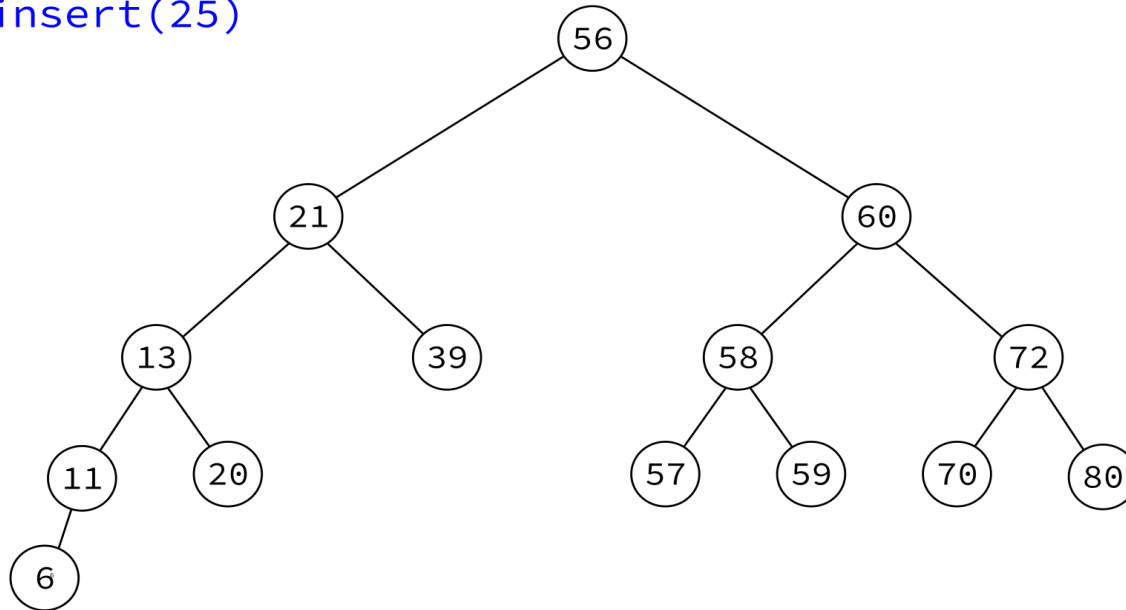
search(59)



# INSERT

Given a key, add a node to the tree with that key, maintaining the BST property.

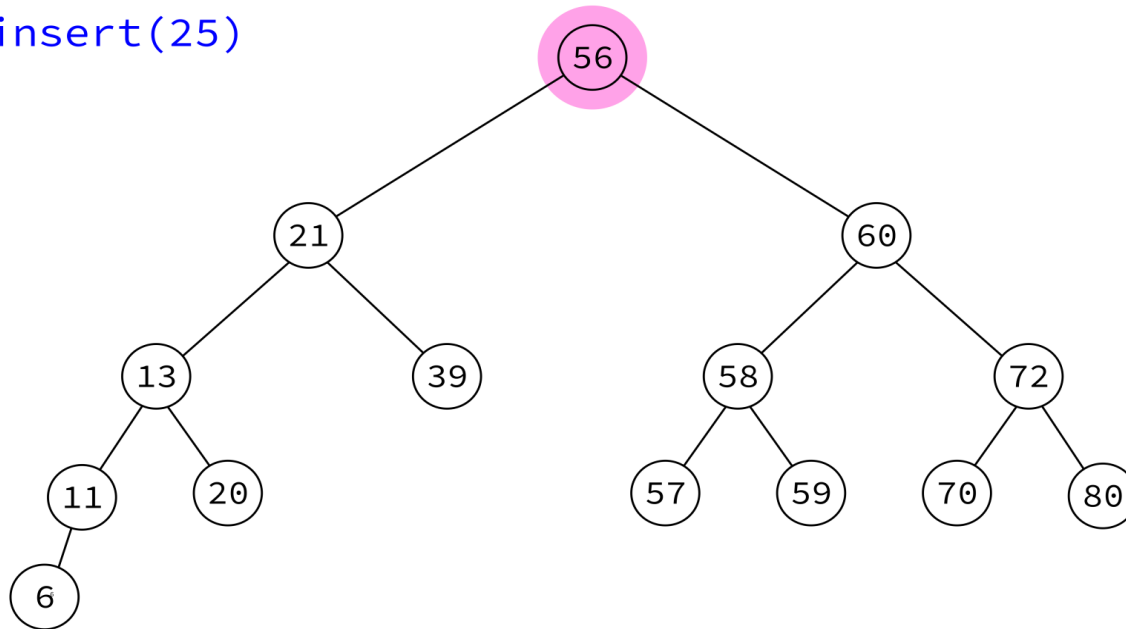
`insert(25)`



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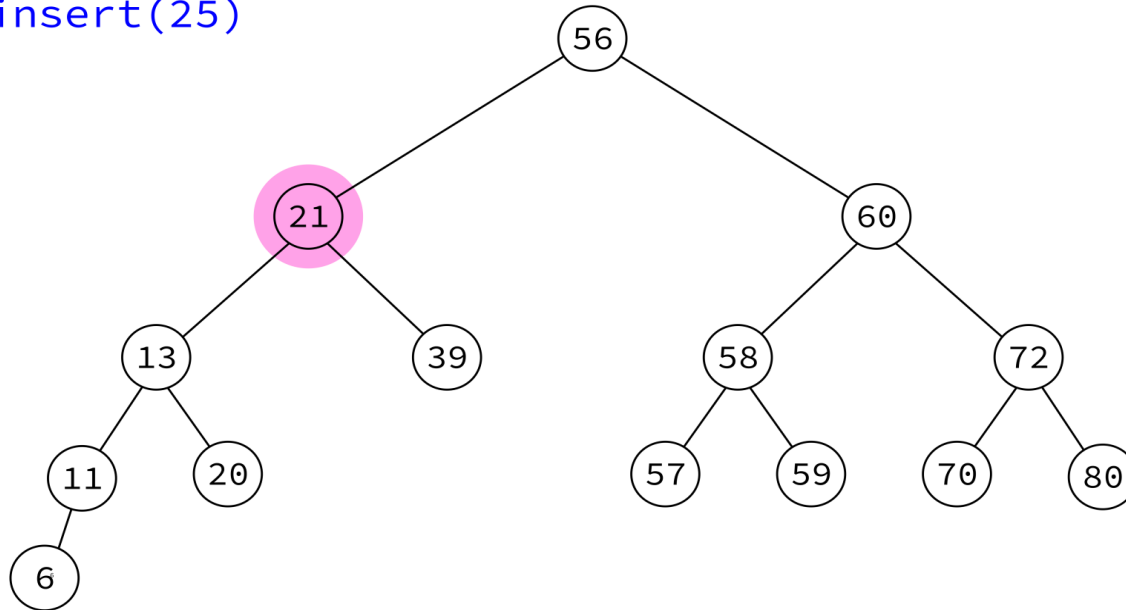
`insert(25)`



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`insert(25)`

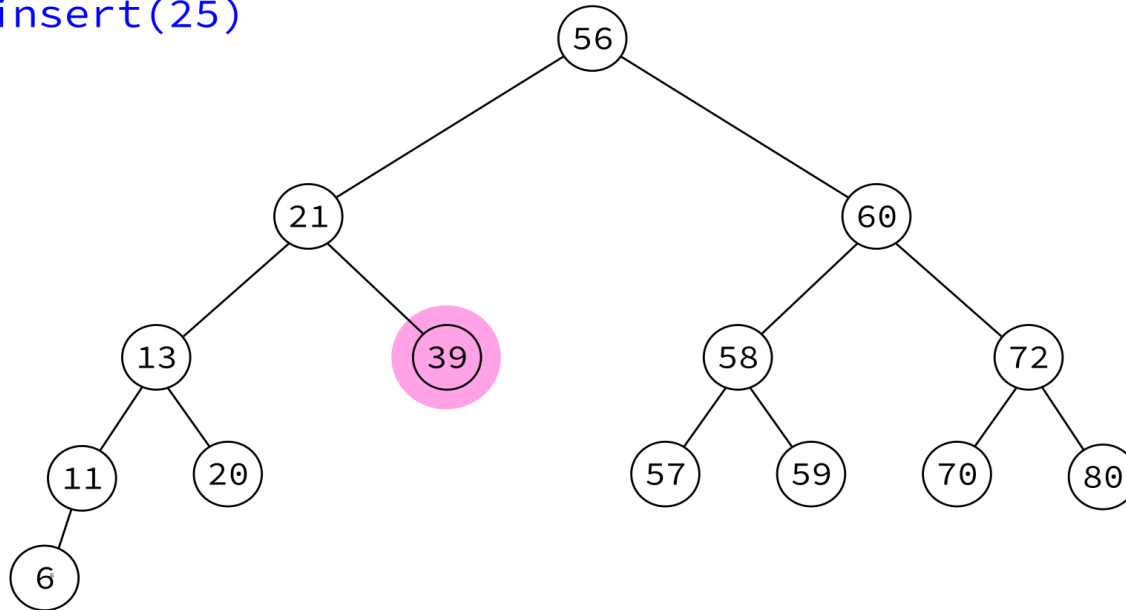




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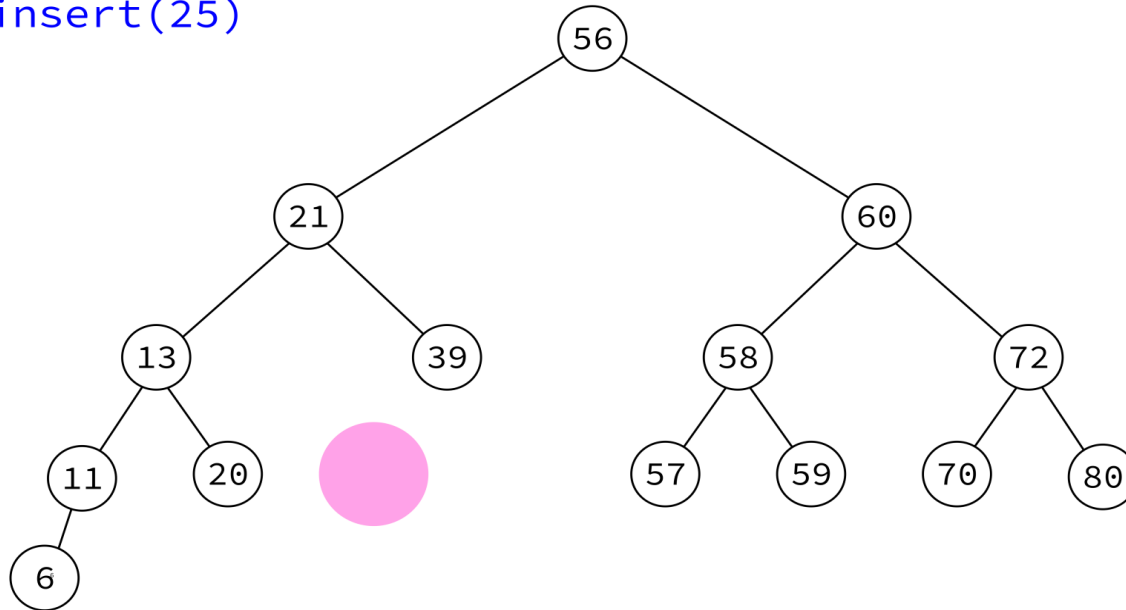
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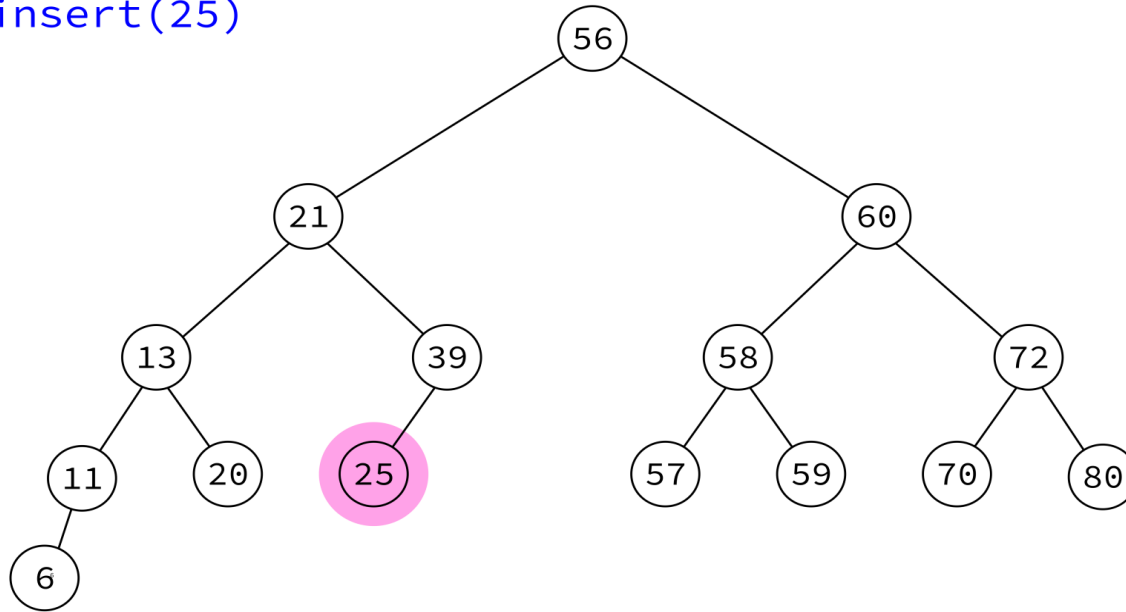
`insert(25)`



# INSERT

Given a key, add a node to the tree with that key, maintaining the BST property.

`insert(25)`



# INTEGERSET

Let's use this to build a class to store a collection of integers that supports fast insertion and membership testing.

# IMPLEMENTATION HIDING

`IntegerSet` has many possible implementations (e.g. a list, a tree, ...), and a user of the class doesn't need to know about which one it uses.

# REFERENCES

- In optional course texts:
  - [Problem Solving with Algorithms and Data Structures using Python](#) by Miller and Ranum, discusses binary trees in [Chapter 7](#).
- Elsewhere:
  - [Cormen, Leiserson, Rivest, and Stein](#) discusses graph theory and trees in Appendices B.4 and B.5, and binary search trees in Chapter 12.

# REVISION HISTORY

- 2022-02-24 Last year's lecture on this topic finalized
- 2023-02-20 Updated for 2023

