Binary Trees Traversal, BST

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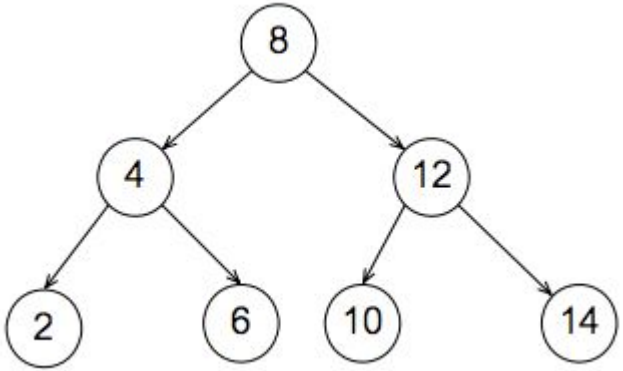
Agenda

1. Arithmetic expression tree **parenthesize**()
2. Binary Tree Traversal
3. Binary Search Trees

Parenthesizing expression trees

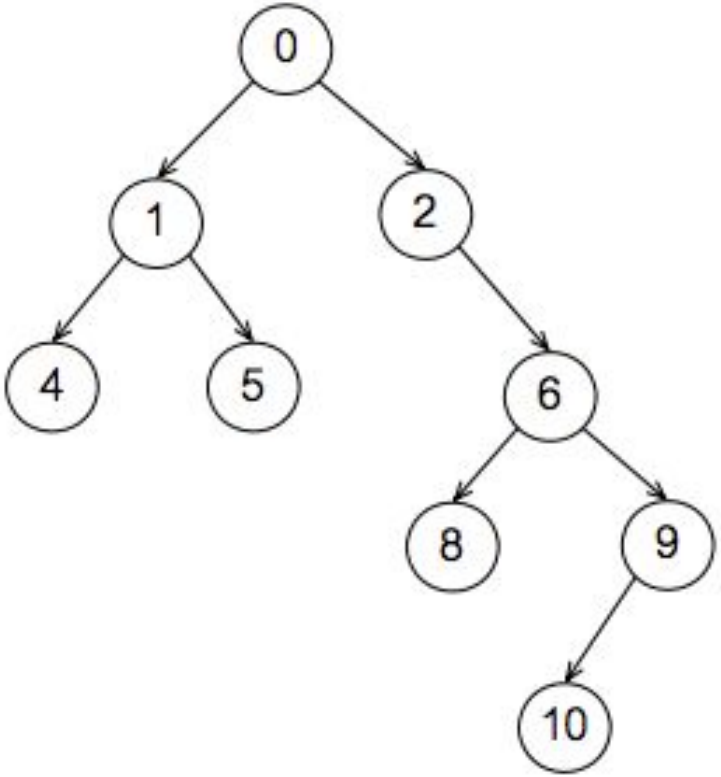
```
def parenthesize(b:BinaryTree) -> str:
    """
    Parenthesize the expression rooted at b.  If b is a leaf,
    return its float value.  Otherwise, parenthesize b.left and
    b.right and combine them with b.value.

    Assume:  -- b is a non-empty binary tree
             -- interior nodes contain value in {"+", "-", "*", "/"}
             -- interior nodes always have two children
             -- leaves contain float value

     @param BinaryTree b: binary tree representing arithmetic expression
     @rtype: str

    >>> b = BinaryTree(3.0)
    >>> print(parenthesize(b))
    3.0
    >>> b = BinaryTree("+", BinaryTree("*", BinaryTree(3.0), BinaryTree(4.0)), BinaryTree(7.0))
    >>> print(parenthesize(b))
    ((3.0 * 4.0) + 7.0)
    """
```

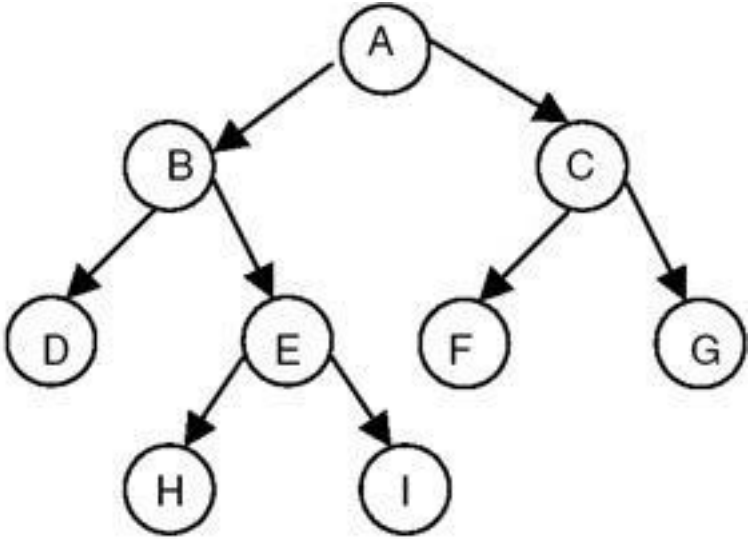
Binary Tree: Inorder Traversal



- A recursive definition:
  - visit the left subtree inorder
  - visit this node itself
  - visit the right subtree inorder
- The code is almost identical to the definition

Exercise: Inorder Traversal

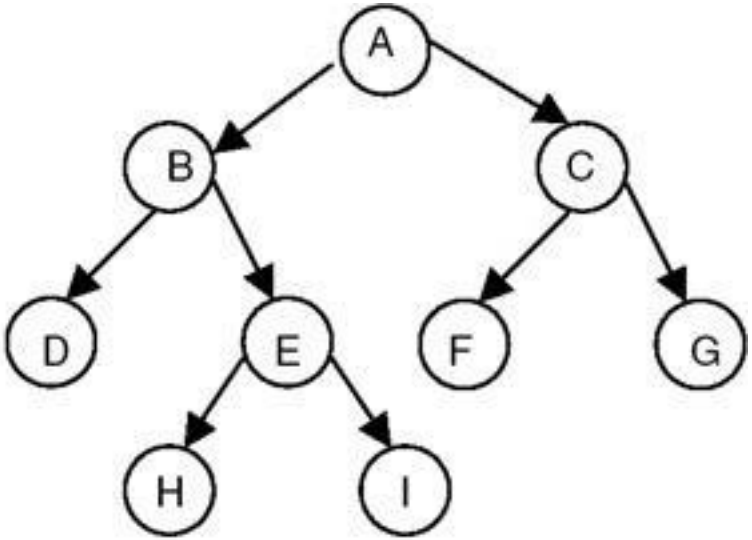




Implementing inorder

```
def inorder_visit(b, act):
    """
    Visit each node of binary tree rooted at root in order and act.

    @param BinaryTree|None root: binary tree to visit
    @param (BinaryTree)->object act: function to execute on visit
    @rtype: None

    >>> def f(node): print(node.value)
    >>> b = None
    >>> inorder_visit(b, f) is None
    True
    >>> b = BinaryTree("+", BinaryTree("*", BinaryTree(3.0), BinaryTree(4.0)), BinaryTree(7.0))
    >>> inorder_visit(b, f)
    3.0
    *
    4.0
    +
    7.0
    """
```

Implementing pre and post order



When to use pre, post and in-order

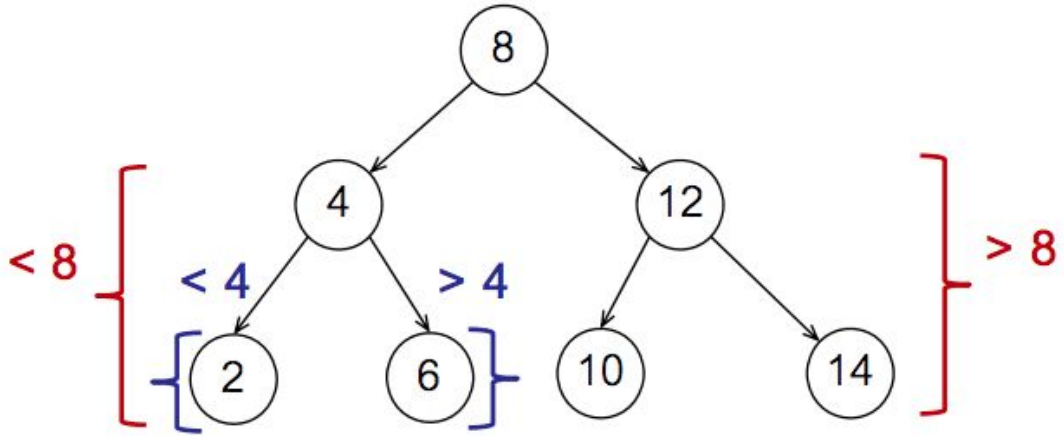
Post-order: Deleting a Binary tree

In-order: For generating human understandable equation from expression tree

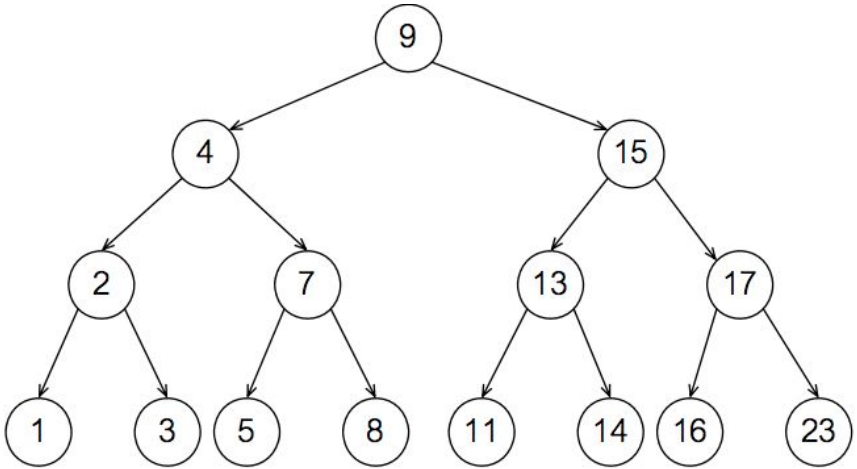
Pre-order: While duplicating a binary tree

Definition

- Add ordering conditions to a binary tree:
  - data are *comparable*
  - data in **left** subtree are **less** than node.data
  - data in **right** subtree are **more** than node.data



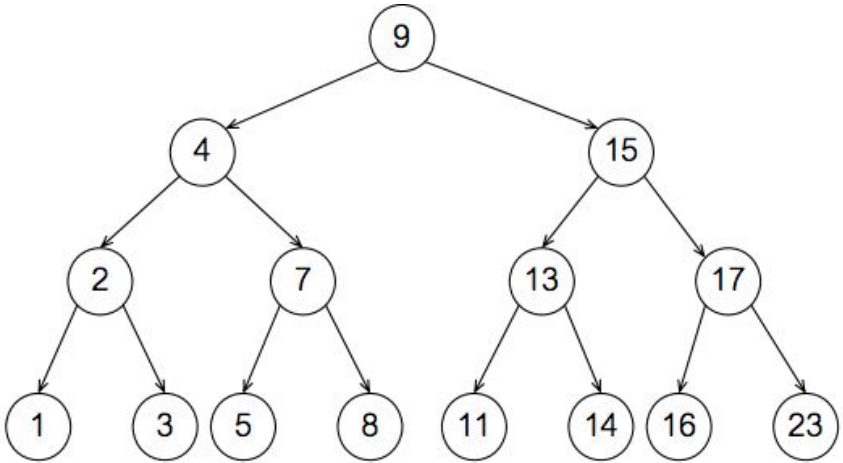
Find a value in a regular Binary Tree



How many nodes do we visit to find out the following:

- Find value 5, if present...
- Find value 13, if present...
- Find value 12, if present...

Find a value in a BST



How many nodes do we visit (say, in preorder) to find out the following:

- Find value 5, if present...
- Find value 13, if present...
- Find value 12, if present...

Why binary search trees?

Searches that are directed along a single path are efficient:

- a BST with 1 node has height 1
- a BST with 3 nodes may have height 2
- a BST with 7 nodes may have height 3
- a BST with 15 nodes may have height 4
- a BST with n nodes may have height $\log_2 n$
  - **1,000,000 nodes => height < 20!**

If the BST is “balanced”, then we can check whether an element is present in about $\log n$ node accesses

Demo