Final Examples

Announcements

Trees

Tree-Structured Data

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```
def tree(label, branches=[]):
    return [label] + list(branches)

def label(tree):
    return tree[0]

def branches(tree):
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class Tree:
    def __init__(self, label, branches=[]):
        self.label = label
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Tree processing often involves recursive calls on subtrees

Tree Processing

Solving Tree Problems

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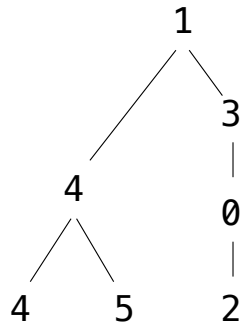

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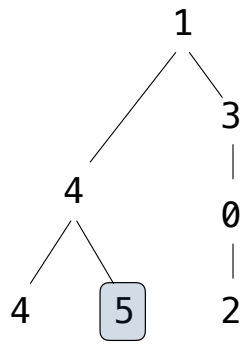

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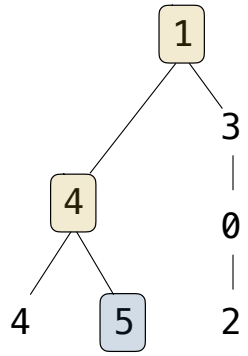

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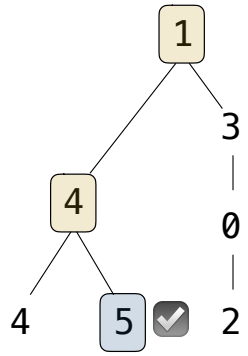

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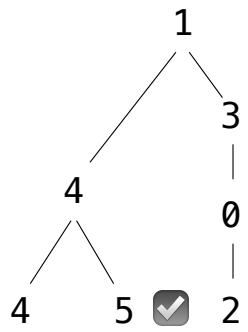

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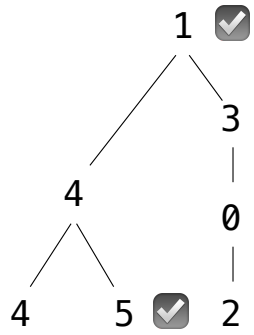

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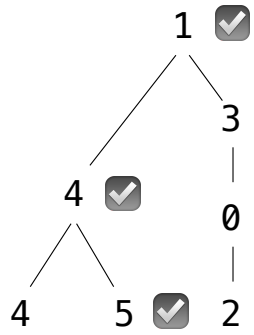

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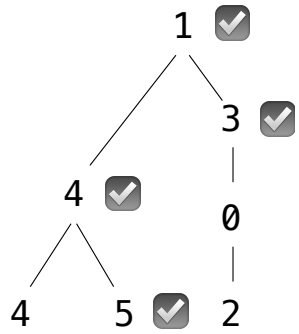

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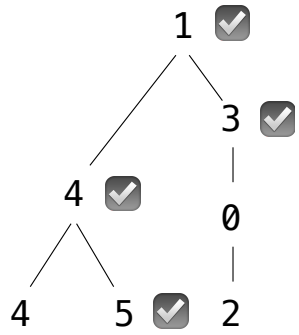

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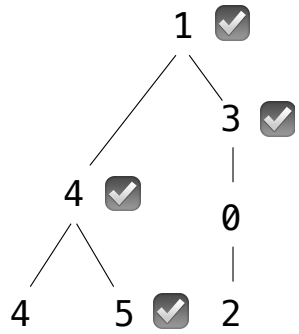

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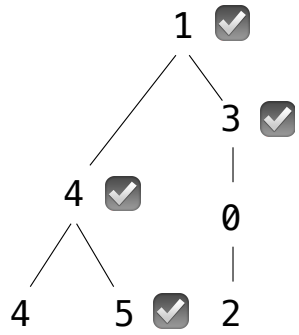

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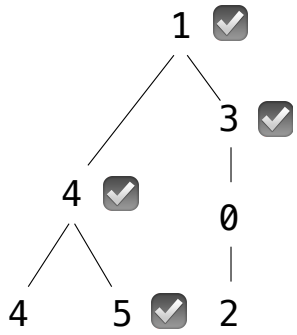

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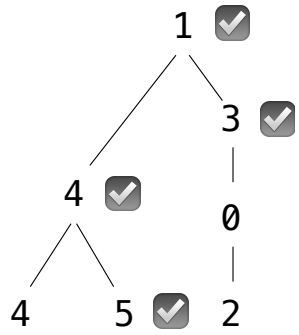

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if node.label > max(ancestors):
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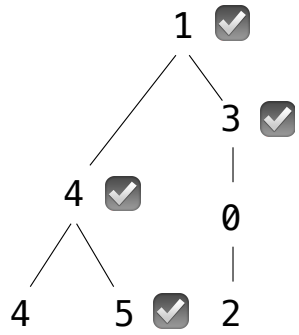

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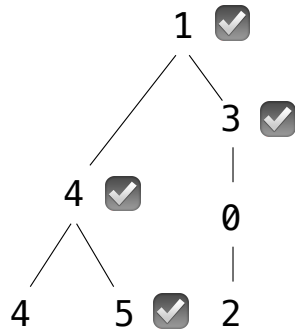

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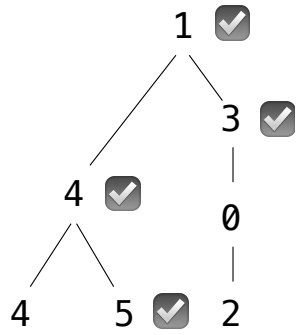

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            return 1 + ____________________________________________

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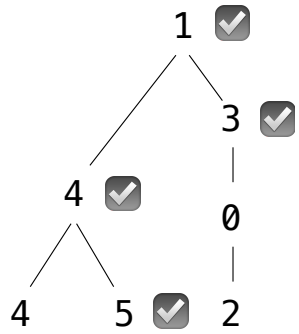

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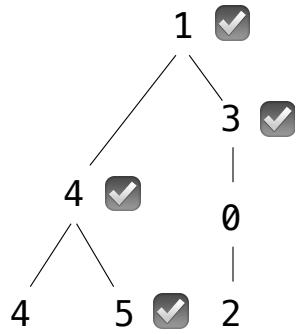

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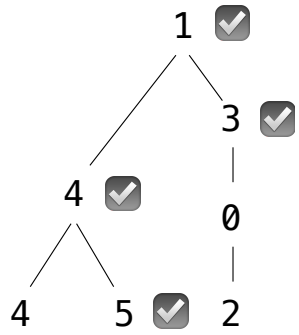

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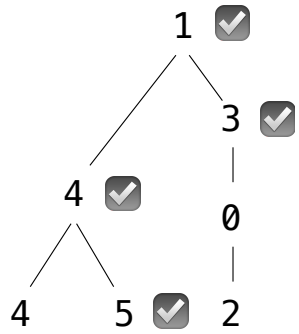

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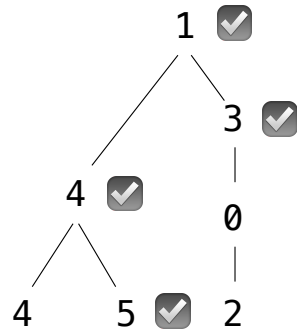

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        if a.label > x:
            return 1 + f(t, a.label)
        else:
            return f(t, x)
    return f(t, min(t.label - 1, -1))
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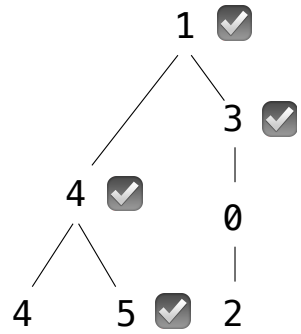

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Implement **bigs**, which takes a Tree instance t containing integer labels. It returns the number of nodes in t whose labels are larger than any labels of their ancestor nodes.

```
def bigs(t):
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    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
    def f(a, x):
        if a.label > x:
            return 1 + _____
        else:
            return _____
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```

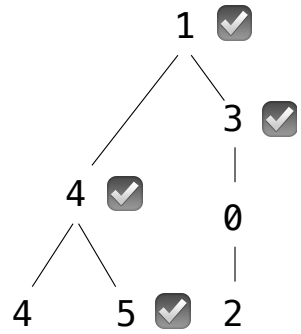
Somehow track the largest ancestor

A node in t

max_ancestor

node.label > max_ancestors

Some initial value for the largest ancestor so far...



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Somehow track the largest ancestor

A node in t — max_ancestor

node.label > max_ancestors

Somehow increment the total count

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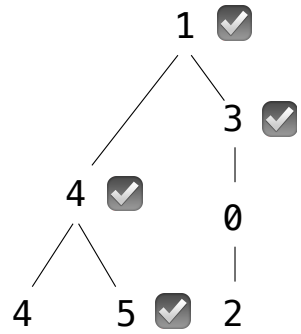

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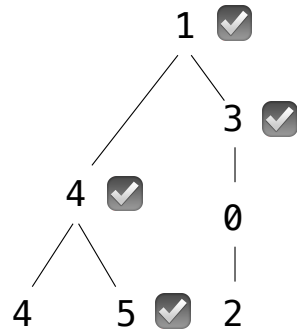

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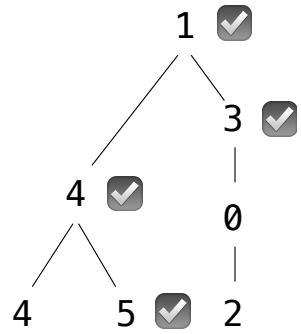

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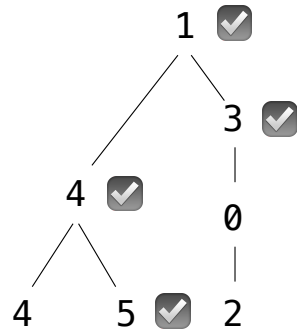

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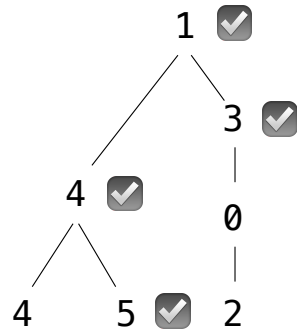

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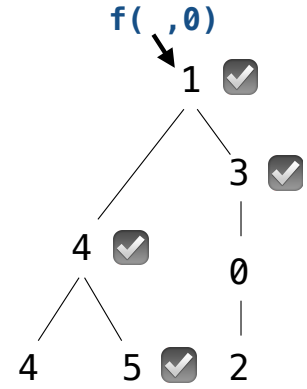

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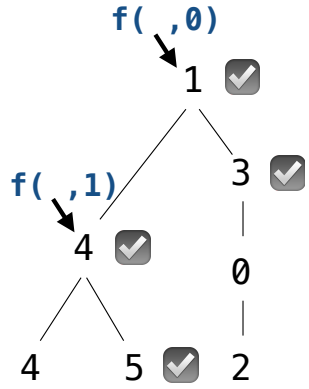

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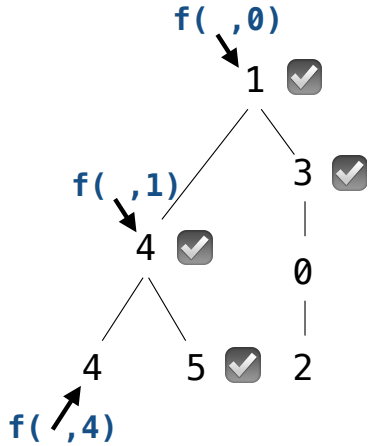

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Somehow track the largest ancestor

A node in t — max_ancestor

node.label > max_ancestors

Somehow increment the total count

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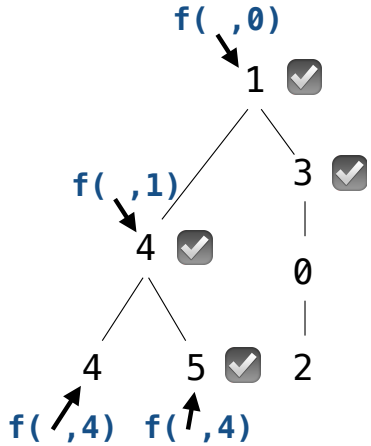

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```

Somehow track the largest ancestor

A node in t

max_ancestor

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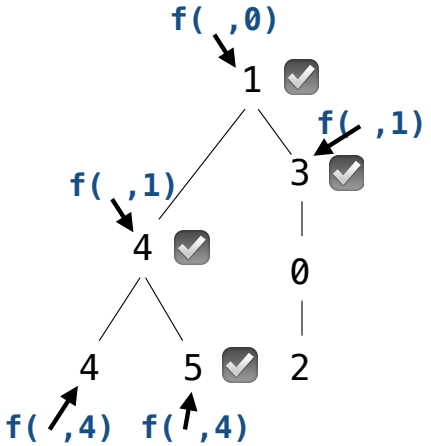
Somehow increment the total count

Root label is always larger than its ancestors

Some initial value for the largest ancestor so far...



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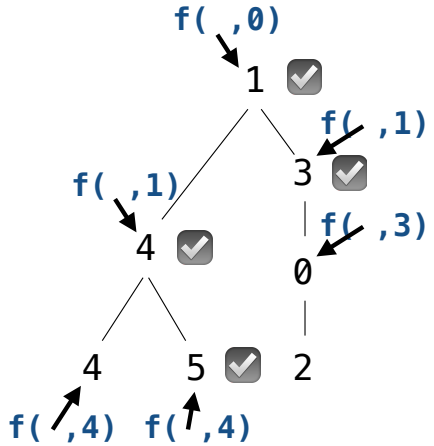
    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
    def f(a, x):                                  # Somehow track the largest ancestor
        if a.label > x:                           # A node in t; max_ancestor; node.label > max_ancestors
            return 1 + sum([f(b, a.label) for b in a.branches])
        else:                                     # Somehow increment the total count
            return sum([f(b, x) for b in a.branches])
    return f(t, t.label - 1)                      # Root label is always larger than its ancestors
                                                  # Some initial value for the largest ancestor so far...
```



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```

Somehow track the largest ancestor

A node in t — max_ancestor

node.label > max_ancestors

Somehow increment the total count

Root label is always larger than its ancestors

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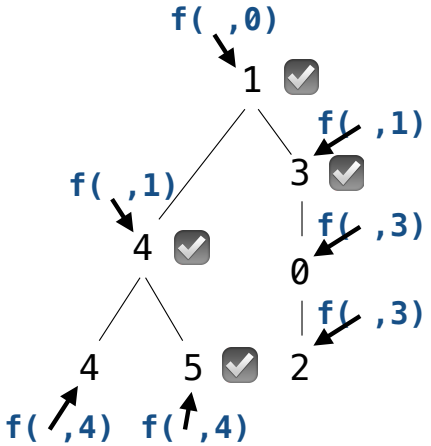

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    """
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        if a.label > x:
            return 1 + sum( f(b, a.label) for b in a.branches )
        else:
            return sum( f(b, x) for b in a.branches )
    return f(t, t.label - 1)
```

Somehow track the largest ancestor

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node.label > max_ancestors

Somehow increment the total count

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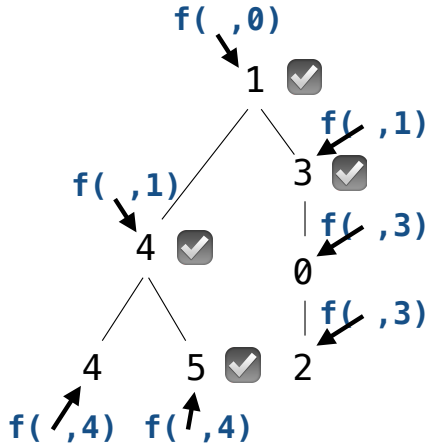

Recursive Accumulation

Solving Tree Problems

Implement **bigs**, which takes a Tree instance t containing integer labels. It returns the number of nodes in t whose labels are larger than any labels of their ancestor nodes.

```
def bigs(t):
    """Return the number of nodes in t that are larger than all their ancestors."""
    n = 0

    def f(a, x):

        ____________________________

        if ____________________________:

            n += 1

        ____________________________:

            f(_____________________)

    ____________________________________

    return n
```

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        _____________________________:
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    _____________________________________
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```

Somehow track the largest ancestor

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        ____________________________:
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    ____________________________
    return n
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Somehow track the largest ancestor

node.label > max_ancestors

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Somehow track the largest ancestor

node.label > max_ancestors

Somehow increment the total count

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        _____________________________:
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Somehow increment the total count

Root label is always larger than its ancestors

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        _____________________________
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            n += 1
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    _____________________________________
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        _____________________________
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        _____________________________:
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    f(t, t.label - 1)
    ____________________________________
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        if a.label > x _____________:
            n += 1
        for b in a.branches ________:
            f(_____________________)
    f(t, t.label - 1) ______________
    return n
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    n = 0
    def f(a, x):
        _____________________________
        if a.label > x _____________:
            n += 1
        for b in a.branches ________:
            f(_b, max(a.label, x)_____)
    f(t, t.label - 1)
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```
def bigs(t):
    """Return the number of nodes in t that are larger than all their ancestors."""
    n = 0
    def f(a, x):
        nonlocal n
        if a.label > x:
            n += 1
        for b in a.branches:
            f(b, max(a.label, x))
    f(t, t.label - 1)
    return n
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Designing Functions

How to Design Programs

https://htdp.org/2018-01-06/Book/

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Function Definition
Fill in the gaps in the function template. Exploit the purpose statement and the examples.

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Identify the information that must be represented and how it is represented in the chosen programming language. Formulate data definitions and illustrate them with examples.

Signature, Purpose Statement, Header
State what kind of data the desired function consumes and produces. Formulate a concise answer to the question *what* the function computes. Define a stub that lives up to the signature.

Functional Examples
Work through examples that illustrate the function's purpose.

Function Template
Translate the data definitions into an outline of the function.

Function Definition
Fill in the gaps in the function template. Exploit the purpose statement and the examples.

Testing
Articulate the examples as tests and ensure that the function passes all. Doing so discovers mistakes. Tests also supplement examples in that they help others read and understand the definition when the need arises—and it will arise for any serious program.

https://htdp.org/2018-01-06/Book/

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Applying the Design Process

Designing a Function

Implement **smalls**, which takes a Tree instance t containing integer labels. It returns the non-leaf nodes in t whose labels are smaller than any labels of their descendant nodes.

```
def smalls(t):
    """Return the non-leaf nodes in t that are smaller than all their descendants.

    >>> a = Tree(1, [Tree(2, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(6)])])])
    >>> sorted([t.label for t in smalls(a)])
    [0, 2]
    """
    result = []
    def process(t):









    process(t)
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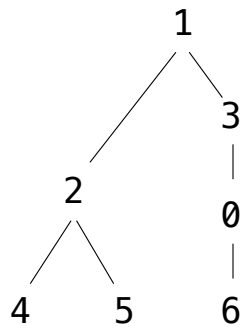

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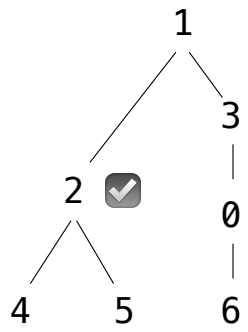

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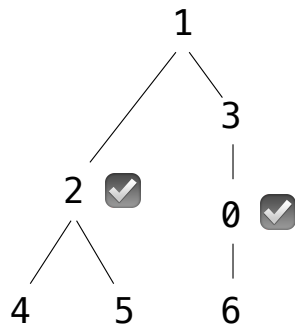

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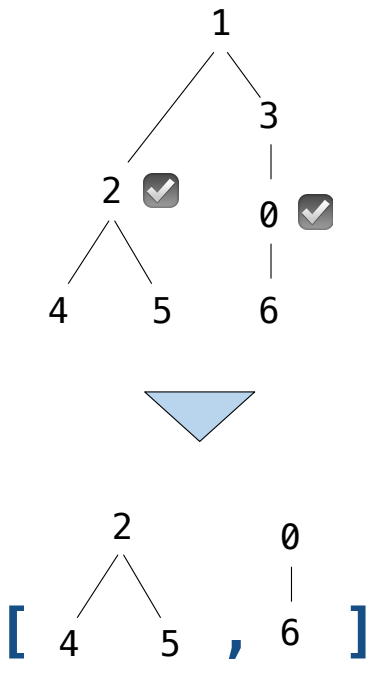

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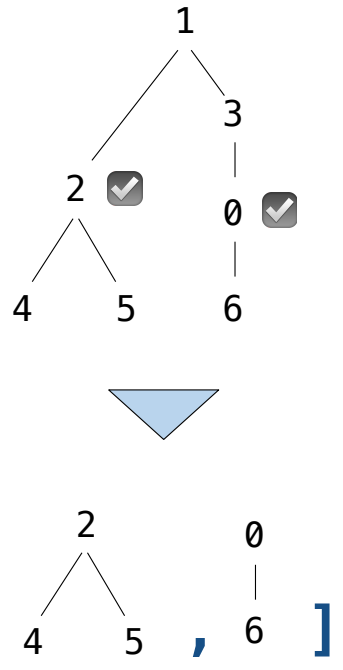
Signature: Tree -> number



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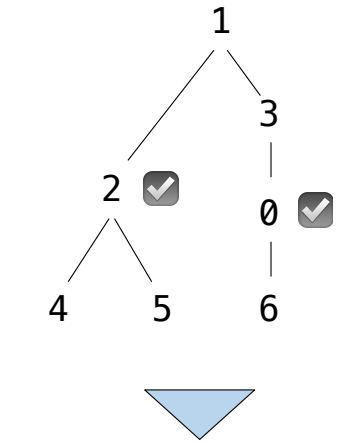
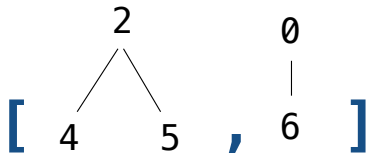
Signature: Tree -> number

"Find smallest label in t & maybe add t to result"





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    """
    result = []
    def process(t):
        if t.is_leaf():
            return t.label
        else:
            return min(...)
    process(t)
    return result
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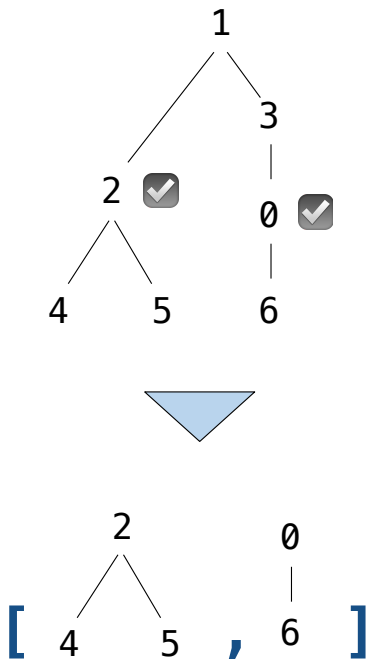
Signature: Tree -> List of Trees

Signature: Tree -> number

"Find smallest label in t & maybe add t to result"



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    """
    result = []
    def process(t):
        if t.is_leaf():
            return _____________________________________________
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            smallest = _____________________________________________
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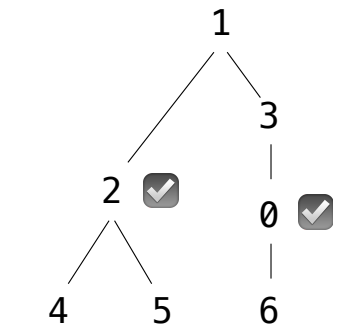

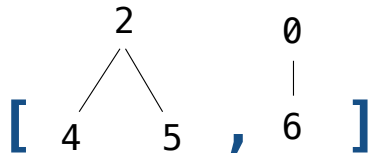

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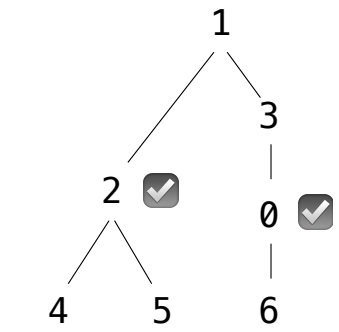

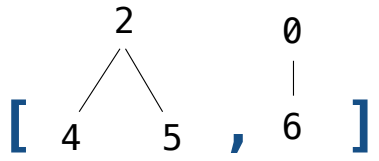

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"Find smallest label in t & maybe add t to result"

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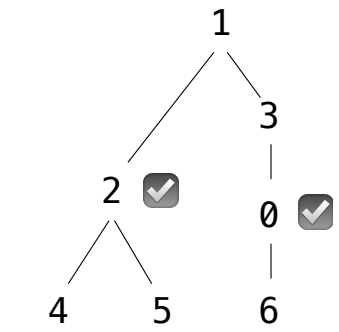

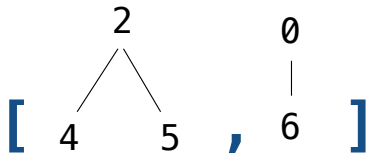

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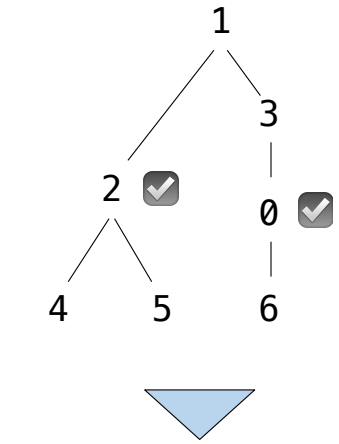

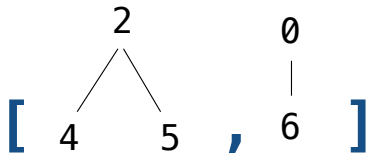

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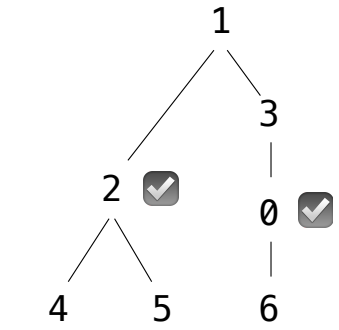

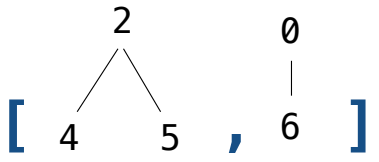

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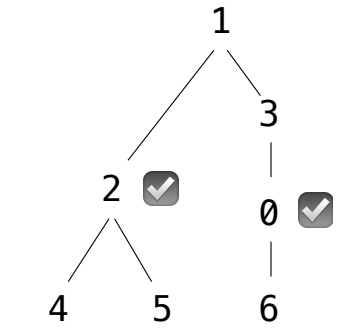

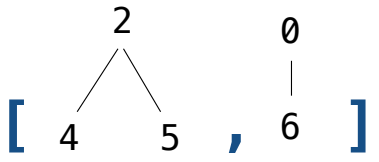

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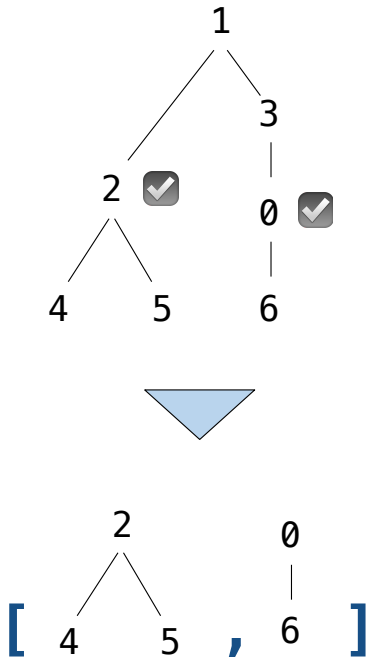

Expression Trees

Interpreter Analysis

How many times does scheme_eval get called when evaluating the following expressions?

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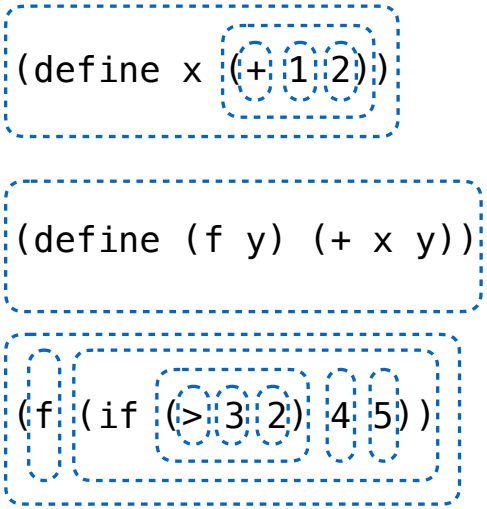

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