Final Examples

Announcements

Trees

Tree-Structured Data

Tree-Structured Data

```
def tree(label, branches=[]):
    return [label] + list(branches)
def label(tree):
    return tree[0]
def branches(tree):
    return tree[1:]
```

Tree-Structured Data

```
def tree(label, branches=[]):
    return [label] + list(branches)
def label(tree):
    return tree[0]
def branches(tree):
    return tree[1:]

class Tree:
    def __init__(self, label, branches=[]):
        self.label = label
        self.branches = list(branches)
```

Tree-Structured Data

```
def tree(label, branches=[]):
    return [label] + list(branches)
def label(tree):
    return tree[0]
def branches(tree):
    return tree[1:]

class Tree:
    def __init__(self, label, branches=[]):
        self.label = label
        self.branches = list(branches)

class BTree(Tree):
    empty = Tree(None)
    def __init__(self, label, left=empty, right=empty):
        Tree.__init__(self, label, [left, right])
    @property
    def left(self):
        return self.branches[0]
    @property
    def right(self):
        return self.branches[1]
```

Tree-Structured Data

```
def tree(label, branches=[]):
    return [label] + list(branches)
def label(tree):
    return tree[0]
def branches(tree):
    return tree[1:]

class Tree:
    def __init__(self, label, branches=[]):
        self.label = label
        self.branches = list(branches)

class BTree(Tree):
    empty = Tree(None)
    def __init__(self, label, left=empty, right=empty):
        Tree.__init__(self, label, [left, right])
    @property
    def left(self):
        return self.branches[0]
    @property
    def right(self):
        return self.branches[1]
```

Tree-Structured Data

```
def tree(label, branches=[]):
    return [label] + list(branches)
def label(tree):
    return tree[0]
def branches(tree):
    return tree[1:]

class Tree:
    def __init__(self, label, branches=[]):
        self.label = label
        self.branches = list(branches)

class BTree(Tree):
    empty = Tree(None)
    def __init__(self, label, left=empty, right=empty):
        Tree.__init__(self, label, [left, right])
    @property
    def left(self):
        return self.branches[0]
    @property
    def right(self):
        return self.branches[1]
```

A tree can contains other trees:

Tree-Structured Data

```
def tree(label, branches=[]):
    return [label] + list(branches)
def label(tree):
    return tree[0]
def branches(tree):
    return tree[1:]

class Tree:
    def __init__(self, label, branches=[]):
        self.label = label
        self.branches = list(branches)

class BTree(Tree):
    empty = Tree(None)
    def __init__(self, label, left=empty, right=empty):
        Tree.__init__(self, label, [left, right])
    @property
    def left(self):
        return self.branches[0]
    @property
    def right(self):
        return self.branches[1]
```

A tree can contains other trees:

```
[5, [6, 7], 8, [[9], 10]]
```

Tree-Structured Data

```
def tree(label, branches=[]):
    return [label] + list(branches)
def label(tree):
    return tree[0]
def branches(tree):
    return tree[1:]

class Tree:
    def __init__(self, label, branches=[]):
        self.label = label
        self.branches = list(branches)

class BTree(Tree):
    empty = Tree(None)
    def __init__(self, label, left=empty, right=empty):
        Tree.__init__(self, label, [left, right])
    @property
    def left(self):
        return self.branches[0]
    @property
    def right(self):
        return self.branches[1]
```

```
A tree can contains other trees:

[5, [6, 7], 8, [[9], 10]]

(+ 5 (- 6 7) 8 (* (- 9) 10))
```

Tree-Structured Data

```
def tree(label, branches=[]):
    return [label] + list(branches)
def label(tree):
    return tree[0]
def branches(tree):
    return tree[1:]

class Tree:
    def __init__(self, label, branches=[]):
        self.label = label
        self.branches = list(branches)

class BTree(Tree):
    empty = Tree(None)
    def __init__(self, label, left=empty, right=empty):
        Tree.__init__(self, label, [left, right])
    @property
    def left(self):
        return self.branches[0]
    @property
    def right(self):
        return self.branches[1]
```

A tree can contains other trees:

```
[5, [6, 7], 8, [[9], 10]]

(+ 5 (- 6 7) 8 (* (- 9) 10))

(S
  (NP (JJ Short) (NNS cuts))
  (VP (VBP make)
      (NP (JJ long) (NNS delays)))
  (. .))
```

Tree-Structured Data

```
def tree(label, branches=[]):
    return [label] + list(branches)
def label(tree):
    return tree[0]
def branches(tree):
    return tree[1:]

class Tree:
    def __init__(self, label, branches=[]):
        self.label = label
        self.branches = list(branches)

class BTree(Tree):
    empty = Tree(None)
    def __init__(self, label, left=empty, right=empty):
        Tree.__init__(self, label, [left, right])
    @property
    def left(self):
        return self.branches[0]
    @property
    def right(self):
        return self.branches[1]
```

A tree can contains other trees:

```
[5, [6, 7], 8, [[9], 10]]

(+ 5 (- 6 7) 8 (* (- 9) 10))

(S
  (NP (JJ Short) (NNS cuts))
  (VP (VBP make)
      (NP (JJ long) (NNS delays)))
  (. .))

<ul>
  <li>Midterm <b>1</b></li>
  <li>Midterm <b>2</b></li>
</ul>
```

Tree-Structured Data

```
def tree(label, branches=[]):
    return [label] + list(branches)
def label(tree):
    return tree[0]
def branches(tree):
    return tree[1:]

class Tree:
    def __init__(self, label, branches=[]):
        self.label = label
        self.branches = list(branches)

class BTree(Tree):
    empty = Tree(None)
    def __init__(self, label, left=empty, right=empty):
        Tree.__init__(self, label, [left, right])
    @property
    def left(self):
        return self.branches[0]
    @property
    def right(self):
        return self.branches[1]
```

A tree can contains other trees:

```
[5, [6, 7], 8, [[9], 10]]
```

```
(+ 5 (- 6 7) 8 (* (- 9) 10))
```

```
(S
  (NP (JJ Short) (NNS cuts))
  (VP (VBP make)
      (NP (JJ long) (NNS delays)))
  (. .))
```

```
<ul>
  <li>Midterm <b>1</b></li>
  <li>Midterm <b>2</b></li>
</ul>
```

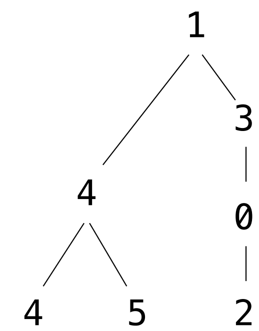
Tree processing often involves recursive calls on subtrees

Tree Processing

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.

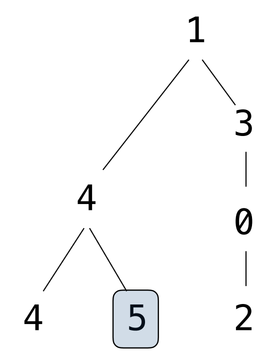
```
def bigs(t):
    """Return the number of nodes in t that are larger than all their ancestors.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



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.

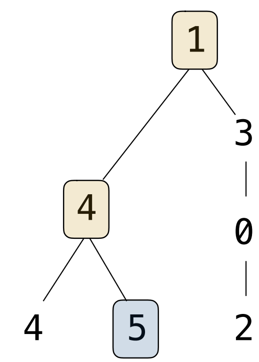
```
def bigs(t):
    """Return the number of nodes in t that are larger than all their ancestors.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



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.

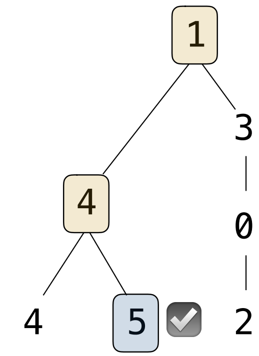
```
def bigs(t):
    """Return the number of nodes in t that are larger than all their ancestors.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



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.

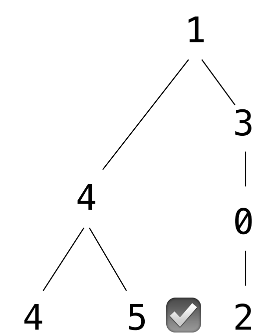
```
def bigs(t):
    """Return the number of nodes in t that are larger than all their ancestors.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



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.

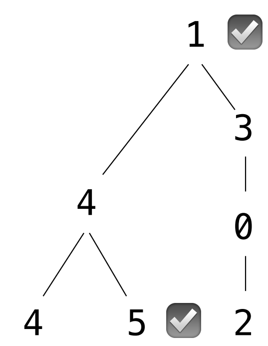
```
def bigs(t):
    """Return the number of nodes in t that are larger than all their ancestors.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



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.

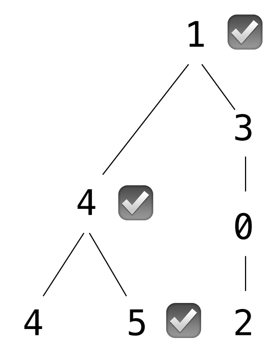
```
def bigs(t):
    """Return the number of nodes in t that are larger than all their ancestors.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



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.

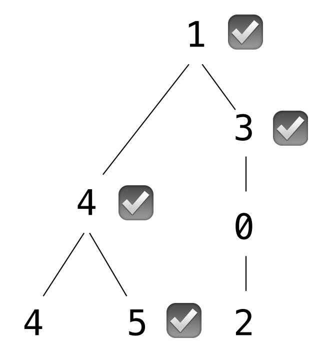
```
def bigs(t):
    """Return the number of nodes in t that are larger than all their ancestors.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



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.

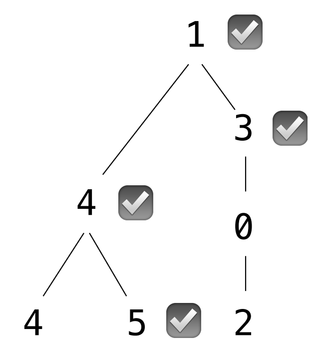
```
def bigs(t):
    """Return the number of nodes in t that are larger than all their ancestors.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



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.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```

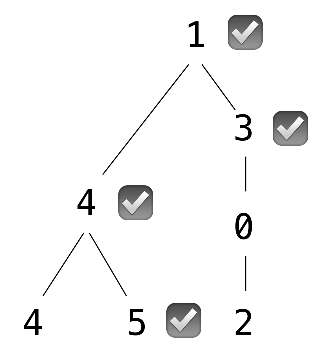


The root label is always larger than all of its ancestors

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.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



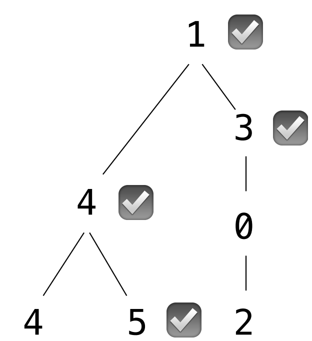
The root label is always larger than all of its ancestors

```
if t.is_leaf():
    return ___
else:
    return ___([___ for b in t.branches])
```

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.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



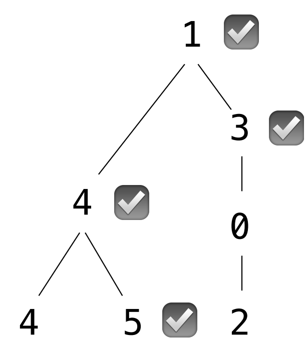
The root label is always larger than all of its ancestors

```
if t.is_leaf():
    return ___
else:
    return ___([___ for b in t.branches])
```

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.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



The root label is always larger than all of its ancestors

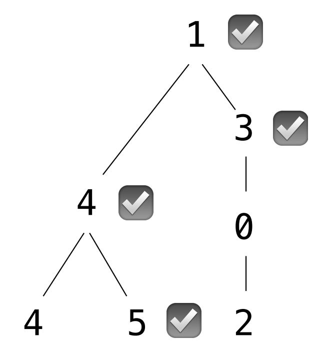
```
if t.is_leaf():
    return ___
else:
    return ___([___ for b in t.branches])
```

Somehow increment the total count

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.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



The root label is always larger than all of its ancestors

```
if t.is_leaf():
    return ___
else:
    return ___([___ for b in t.branches])
```

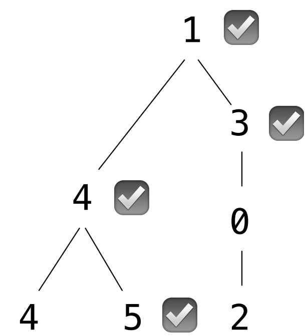
Somehow increment the total count

```
if node.label > max(ancestors):
```

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.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



The root label is always larger than all of its ancestors

```
if t.is_leaf():
    return ___
else:
    return ___([___ for b in t.branches])
```

Somehow increment the total count

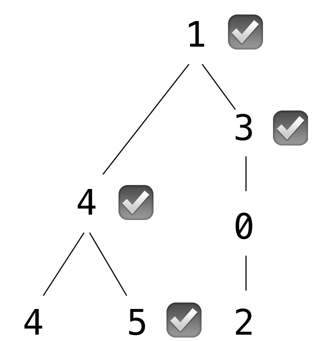
Somehow track a list of ancestors

```
if node.label > max(ancestors):
```

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.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



The root label is always larger than all of its ancestors

```
if t.is_leaf():
    return ___
else:
    return ___([___ for b in t.branches])
```

Somehow increment the total count

Somehow track a list of ancestors

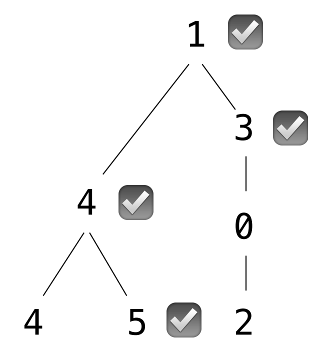
```
if node.label > max(ancestors):
```

```
if node.label > max_ancestors:
```

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.

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

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
```



The root label is always larger than all of its ancestors

```python
if t.is_leaf():
    return ___
else:
    return ___([___ for b in t.branches])
```

Somehow increment the total count

Somehow track a list of ancestors

```python
if node.label > max(ancestors):
```

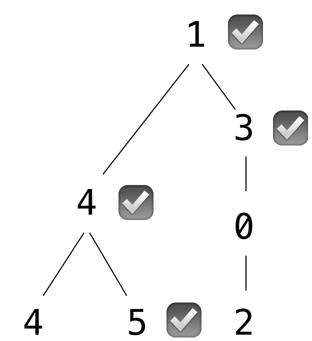
Somehow track the largest ancestor

```python
if node.label > max_ancestors:
```

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.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
    def f(a, x):

        if ____________________________________________:

            return 1 + _________________________________

        else:

            return _____________________________________

    return _____________________________________________
```

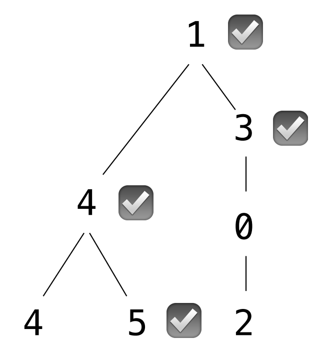


Solving Tree Problems

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.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
    def f(a, x):

        if ____________________________________________:

            return 1 + ______________________________

        else:

            return _________________________________

    return ____________________________________________
```

Somehow track the largest ancestor



Solving Tree Problems

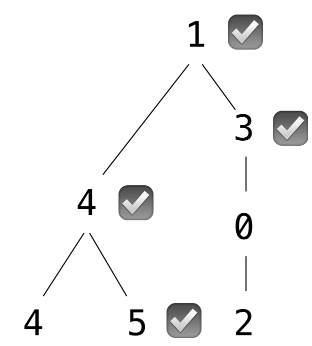
Implement **bigs**, which takes a Tree instance t containing integer labels. It returns the number of nodes in t whose labels are larger than any labels of their ancestor nodes.

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

    >>> 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

node.label > max_ancestors

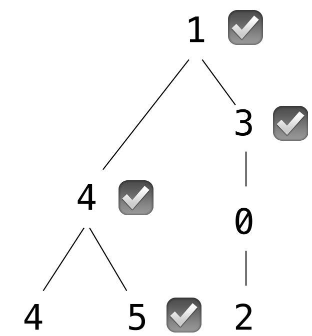
```
        if ________________________________________:

            return 1 + ______________________________

        else:

            return _________________________________

    return _________________________________________
```



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.

    >>> 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          node.label > max_ancestors
           _____________________________________________________:

            return 1 + ____________________________________________

        else:

            return ________________________________________________

    return ________________________________________________________
```



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.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
    def f(a, x):
```

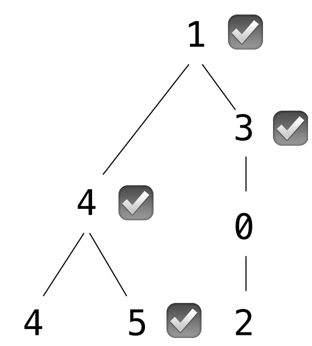
Somehow track the largest ancestor

A node in t

max_ancestor

node.label > max_ancestors

```
        if a.label > x_____________________________________________:

            return 1 + _________________________________________

        else:

            return _____________________________________________

    return _____________________________________________________
```



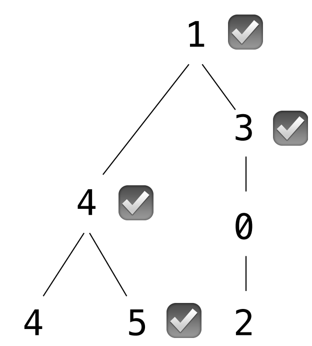
Solving Tree Problems

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.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
    def f(a, x):
A node in t  max_ancestor
        if  a.label > x  ____________________________:

            return 1 + ______________________________

        else:

            return ________________________________

    return f(t,              )___________________
```

Somehow track the largest ancestor

node.label > max_ancestors



Solving Tree Problems

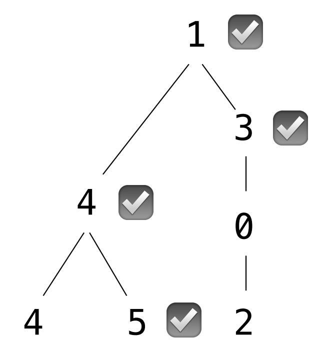
Implement **bigs**, which takes a Tree instance t containing integer labels. It returns the number of nodes in t whose labels are larger than any labels of their ancestor nodes.

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

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
    def f(a, x):
A node in t  max_ancestor
        if a.label > x ______________________:

            return 1 + ______________________

        else:

            return ______________________

    return f(t,          ) ______________________
```

Somehow track the largest ancestor

node.label > max_ancestors

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



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.

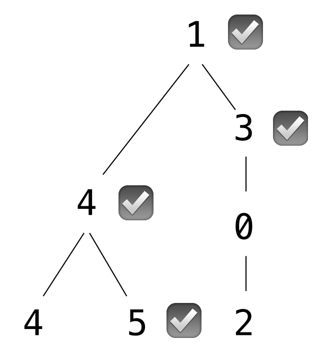
```
def bigs(t):
    """Return the number of nodes in t that are larger than all their ancestors.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
    def f(a, x):
A node in t  max_ancestor
        if a.label > x ____________________________________:

            return 1 + ____________________________________

        else:

            return ________________________________________

    return f(t,                )________________________________
```

Somehow track the largest ancestor

node.label > max_ancestors

Somehow increment the total count

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



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.

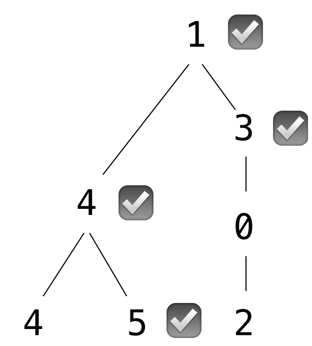
```
def bigs(t):
    """Return the number of nodes in t that are larger than all their ancestors.

    >>> a = Tree(1, [Tree(4, [Tree(4), Tree(5)]), Tree(3, [Tree(0, [Tree(2)])])])
    >>> bigs(a)
    4
    """
    def f(a, x):
A node in t   max_ancestor
        if a.label > x                                             :

            return 1 + sum([f(b, a.label) for b in a.branches])

        else:

            return ______________________________________________

    return f(t,              )
```

Somehow track the largest ancestor

node.label > max_ancestors

Somehow increment the total count

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



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.

    >>> 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 + sum([f(b, a.label) for b in a.branches])
        else:
            return sum([f(b, x) for b in a.branches])
    return f(t,          )
```

Somehow track the largest ancestor

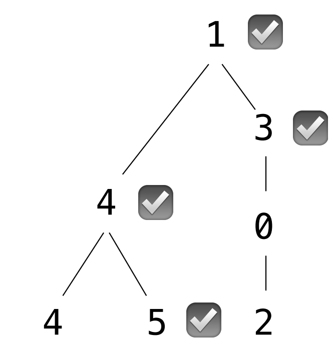
A node in t

max_ancestor

node.label > max_ancestors

Somehow increment the total count

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



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.

    >>> 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 + sum([f(b, a.label) for b in a.branches])

        else:

            return    sum([f(b, x) for b in a.branches])

    return f(t,           )
```

A node in t — *max_ancestor*

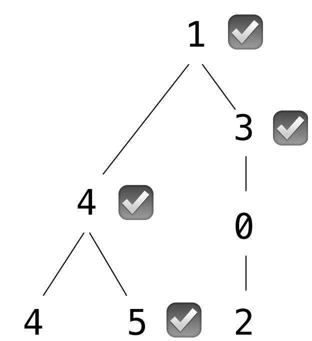
Somehow track the largest ancestor

node.label > max_ancestors

Somehow increment the total count

Root label is always larger than its ancestors

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



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.

    >>> 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 + 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)
```

A node in t

max_ancestor

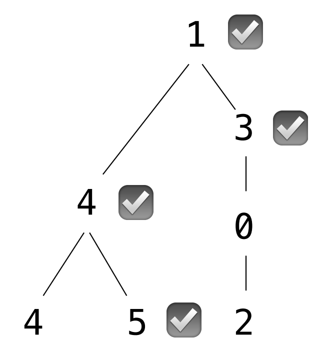
Somehow track the largest ancestor

node.label > max_ancestors

Somehow increment the total count

Root label is always larger than its ancestors

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



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.

    >>> 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 + 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)
```

A node in t

max_ancestor

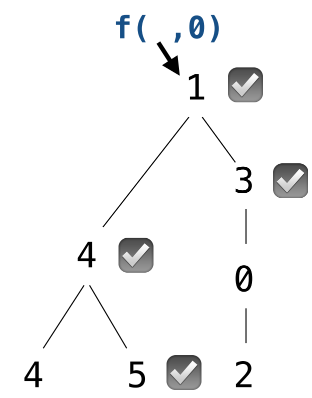
Somehow track the largest ancestor

node.label > max_ancestors

Somehow increment the total count

Root label is always larger than its ancestors

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



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.

    >>> 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 + 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

A node in t

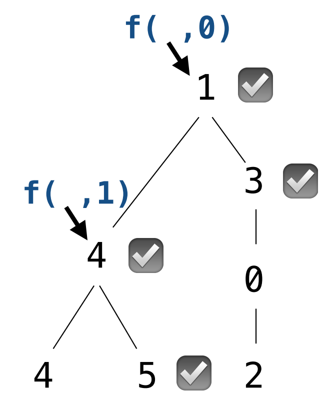
max_ancestor

node.label > max_ancestors

Somehow increment the total count

Root label is always larger than its ancestors

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



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.

    >>> 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 + 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

A node in t

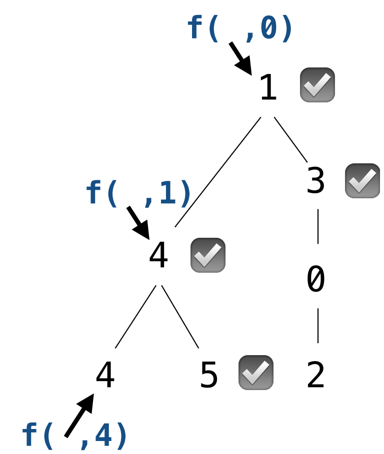
max_ancestor

node.label > max_ancestors

Somehow increment the total count

Root label is always larger than its ancestors

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



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.

    >>> 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 + 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)
```

A node in t (a) — *max_ancestor* (x)

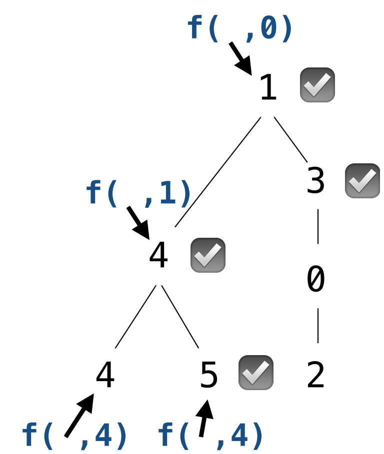
Somehow track the largest ancestor

node.label > max_ancestors

Somehow increment the total count

Root label is always larger than its ancestors

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



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.

    >>> 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 + 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

A node in t

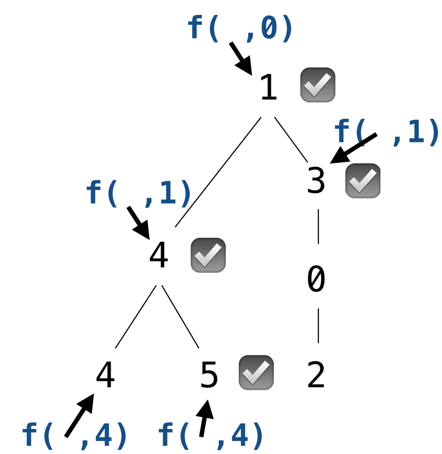
max_ancestor

node.label > max_ancestors

Somehow increment the total count

Root label is always larger than its ancestors

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



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.

    >>> 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 + 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

A node in t

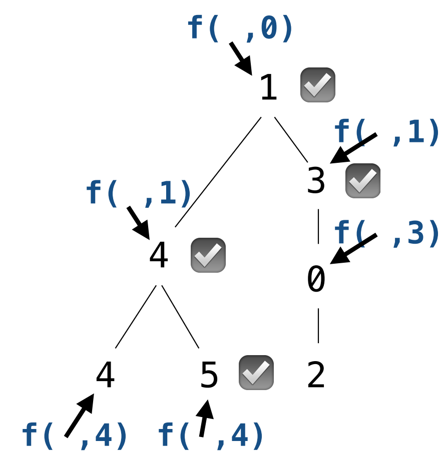
max_ancestor

node.label > max_ancestors

Somehow increment the total count

Root label is always larger than its ancestors

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



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.

    >>> 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 + 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

A node in t

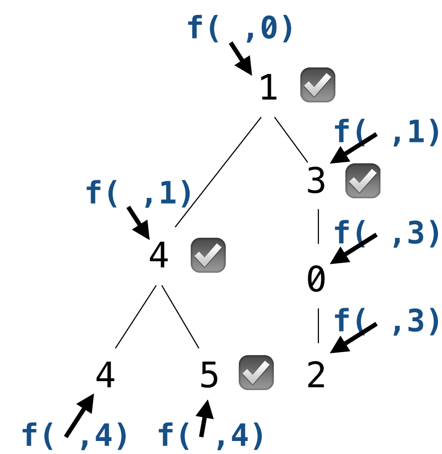
max_ancestor

node.label > max_ancestors

Somehow increment the total count

Root label is always larger than its ancestors

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



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.

    >>> 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 + 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)
```

A node in t

max_ancestor

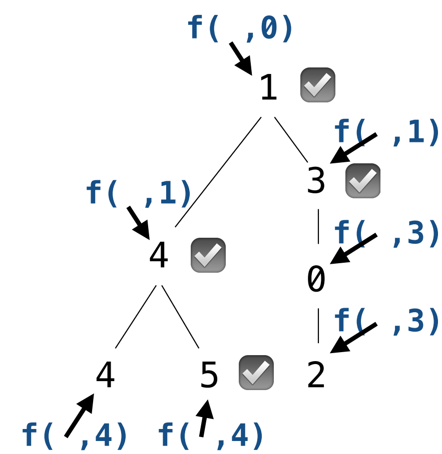
Somehow track the largest ancestor

node.label > max_ancestors

Somehow increment the total count

Root label is always larger than its ancestors

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



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
```

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):    Somehow track the largest ancestor

        ___________________________

        if ________________________:

            n += 1

        ___________________________:

            f(_____________________)

    _______________________________

    return n
```

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):    Somehow track the
                    largest ancestor

        ___________________________

        if ________________________:    node.label > max_ancestors

            n += 1

        ___________________________:

            f(_____________________)

    _______________________________

    return n
```

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):    Somehow track the
                    largest ancestor

        ___________________________

        if ________________________:    node.label > max_ancestors

            n += 1                      Somehow increment
                                        the total count
        ___________________________:

            f(_____________________)

    _______________________________

    return n
```

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):          Somehow track the
                          largest ancestor

        ___________________________

        if ________________________:     node.label > max_ancestors

            n += 1                       Somehow increment
                                         the total count
        ___________________________:

            f(_____________________)
                              Root label is always larger than its ancestors
    _______________________________

    return n
```

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):    Somehow track the
                    largest ancestor

        ____________________

        if a.label > x_________:    node.label > max_ancestors

            n += 1                  Somehow increment
                                    the total count
        ______________________:

            f(__________________)
                     Root label is always larger than its ancestors
    ______________________

    return n
```

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):                      Somehow track the
                                      largest ancestor
        ____________________________

        if a.label > x_______________:    node.label > max_ancestors

            n += 1                        Somehow increment
                                          the total count
        ____________________________:

            f(______________________)
    f(t, t.label - 1)                 Root label is always larger than its ancestors
    ________________________________

    return n
```

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 a.label > x                :
            n += 1
        for b in a.branches           :
            f(________________________)
    f(t, t.label - 1)
    ______________________________
    return n
```

Somehow track the largest ancestor

node.label > max_ancestors

Somehow increment the total count

Root label is always larger than its ancestors

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 a.label > x______________:
            n += 1
        for b in a.branches_________:
            f(b, max(a.label, x)_)
    f(t, t.label - 1)_______________
    return n
```

Somehow track the largest ancestor

node.label > max_ancestors

Somehow increment the total count

Root label is always larger than its ancestors

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):          Somehow track the
                          largest ancestor
        nonlocal n
        ______________________

        if  a.label > x     :    node.label > max_ancestors
            ____________________

            n += 1               Somehow increment
                                 the total count
        for b in a.branches  :
        ______________________

            f( b, max(a.label, x) )
               ____________________
    f(t, t.label - 1)     Root label is always larger than its ancestors
    ______________________

    return n
```

Designing Functions

How to Design Programs

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

From Problem Analysis to Data Definitions
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.

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

How to Design Programs

From Problem Analysis to Data Definitions
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.

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

How to Design Programs

From Problem Analysis to Data Definitions
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.

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

How to Design Programs

From Problem Analysis to Data Definitions
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.

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

How to Design Programs

From Problem Analysis to Data Definitions
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.

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

How to Design Programs

From Problem Analysis to Data Definitions
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/

How to Design Programs

From Problem Analysis to Data Definitions
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/

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)
    return result
```

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.

Signature: Tree -> List of Trees

```
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)
    return result
```

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.

Signature: Tree -> List of Trees

```
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)
    return result
```

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.

Signature: Tree -> List of Trees

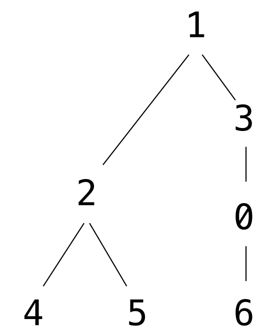
```
def smalls(t):
    """Return the non-leaf nodes in t that are smaller than all their descendants.

    >>> 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)
    return result
```

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.

Signature: Tree -> List of Trees

```
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)
    return result
```

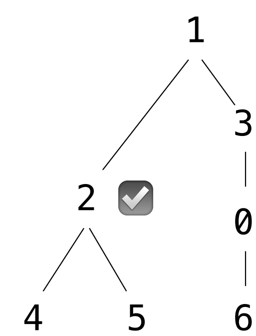


Designing a Function

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.

Signature: Tree -> List of Trees

```
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)
    return result
```

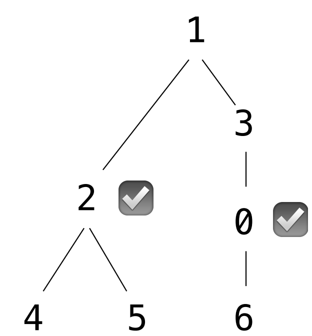


Designing a Function

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.

Signature: Tree -> List of Trees

```
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)
    return result
```

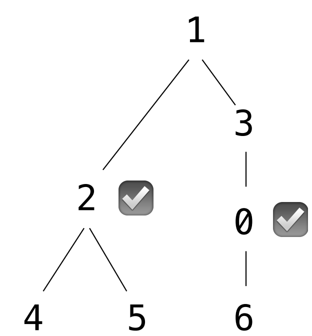


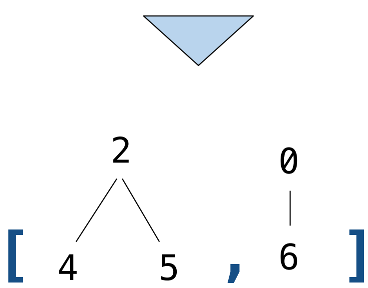
Designing a Function

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.

Signature: Tree -> List of Trees

```
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)
    return result
```





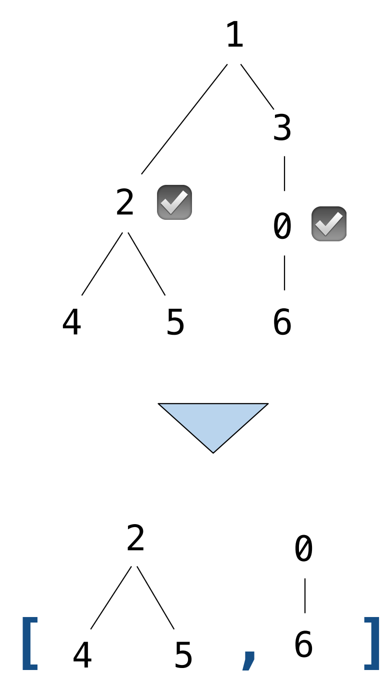
Designing a Function

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.

Signature: Tree -> List of Trees

```
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)
    return result
```

Signature: Tree -> number



Designing a Function

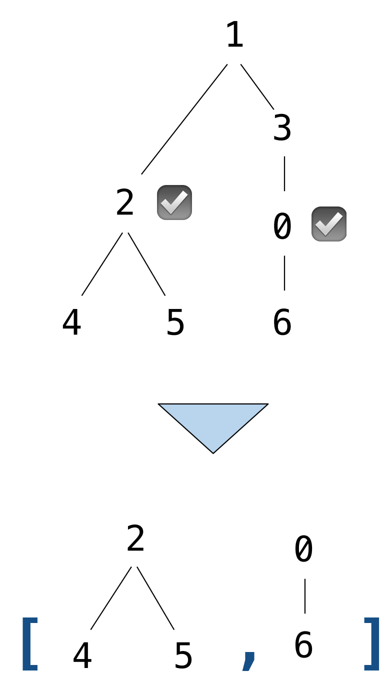
Implement **smalls**, which takes a Tree instance t containing integer labels. It returns the non-leaf nodes in t whose labels are smaller than any labels of their descendant nodes.

Signature: Tree -> List of Trees

```
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)
    return result
```

Signature: Tree -> number

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



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.

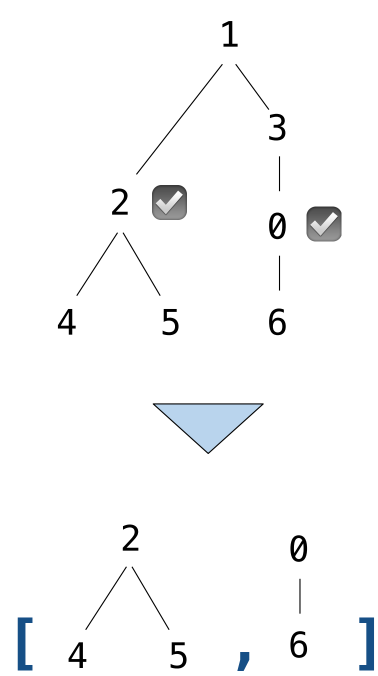
Signature: Tree -> List of Trees

```
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]
    """
```

Signature: Tree -> number

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

```
    result = []
    def process(t):
        if t.is_leaf():
            return t.label
        else:



            return min(...)
    process(t)
    return result
```



Designing a Function

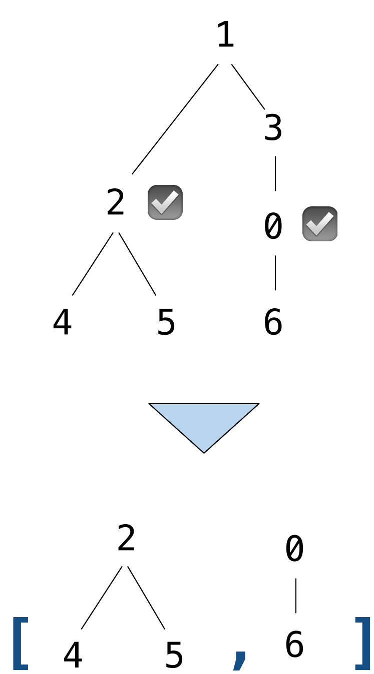
Implement **smalls**, which takes a Tree instance t containing integer labels. It returns the non-leaf nodes in t whose labels are smaller than any labels of their descendant nodes.

Signature: Tree -> List of Trees

```
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):
        if t.is_leaf():
            return ____________________________________________
        else:
            smallest = ________________________________________
            if ____________________________________________:
                ____________________________________________
            return min(smallest, t.label)
    process(t)
    return result
```

Signature: Tree -> number

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



Designing a Function

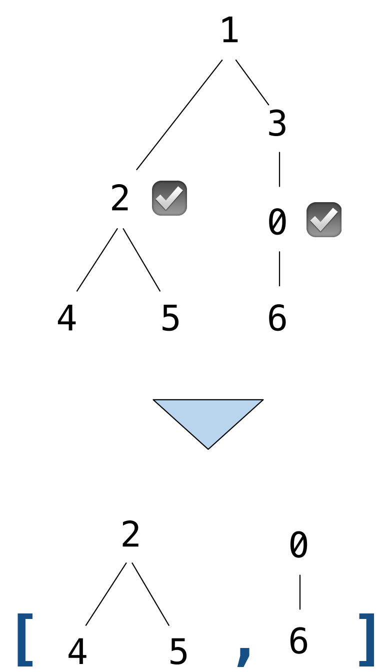
Implement **smalls**, which takes a Tree instance t containing integer labels. It returns the non-leaf nodes in t whose labels are smaller than any labels of their descendant nodes.

Signature: Tree -> List of Trees

```
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):
        if t.is_leaf():
            return ______________t.label______________
        else:
            smallest = ______________________________
            if ______________________________________:
                _____________________________________
            return min(smallest, t.label)
    process(t)
    return result
```

Signature: Tree -> number

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



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.

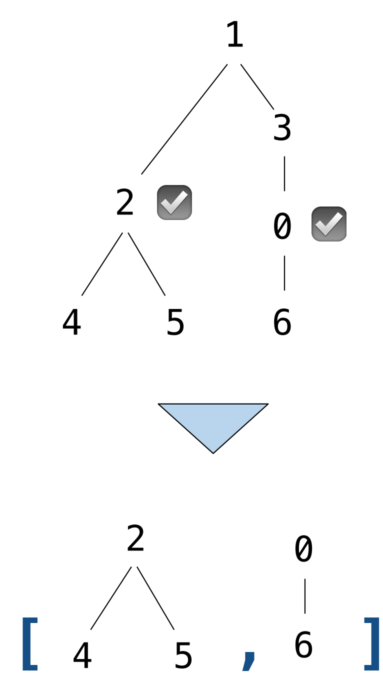
Signature: Tree -> List of Trees

```
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):
        if t.is_leaf():
            return ______________t.label______________
        else:
            smallest = ______________________________
            if ______________________________________:
                _____________________________________
            return min(smallest, t.label)
    process(t)
    return result
```

Signature: Tree -> number

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

smallest label in a branch of t



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.

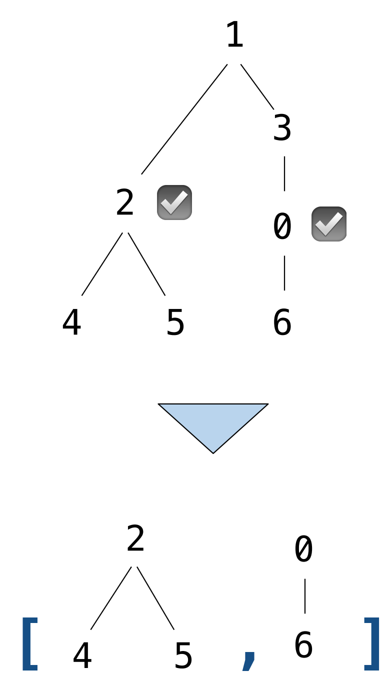
Signature: Tree -> List of Trees

```
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):
        if t.is_leaf():
            return ______________t.label______________
        else:
            smallest = ______________________________
            if ____t.label < smallest________________:
                _____________________________________
            return min(smallest, t.label)
    process(t)
    return result
```

Signature: Tree -> number

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

smallest label in a branch of t



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.

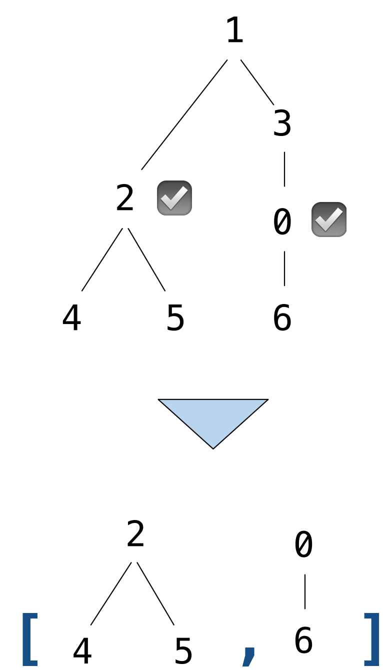
Signature: Tree -> List of Trees

```
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):
        if t.is_leaf():
            return ___________t.label___________
        else:
            smallest = ____________________________
            if ____t.label < smallest______________:
                ___result.append(    )_____________
            return min(smallest, t.label)
    process(t)
    return result
```

Signature: Tree -> number

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

smallest label in a branch of t



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.

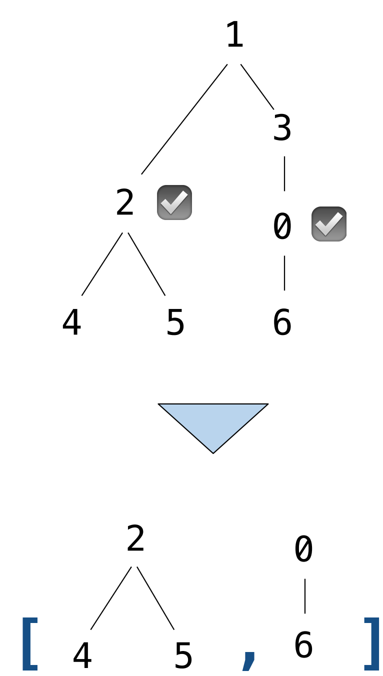
Signature: Tree -> List of Trees

```
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):
        if t.is_leaf():
            return ______________t.label______________
        else:
            smallest = ________________________________
            if _____t.label < smallest_________________:
                ___result.append( t )__________________
            return min(smallest, t.label)
    process(t)
    return result
```

Signature: Tree -> number

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

smallest label in a branch of t



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.

Signature: Tree -> List of Trees

```
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):
        if t.is_leaf():
            return ______________t.label______________
        else:
            smallest = __min([process(b) for b in t.branches])__
            if ____t.label < smallest______________________:
                ___result.append( t )__________________________
            return min(smallest, t.label)
    process(t)
    return result
```

Signature: Tree -> number

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

smallest label in a branch of t