Final Examples

Announcements

Trees

Tree-Structured Data

Tree-Structured Data

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

def label(t):
    return t[0]

def branches(t):
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def is_leaf(t):
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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 all labels of their ancestor nodes.

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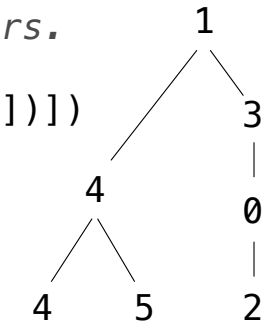

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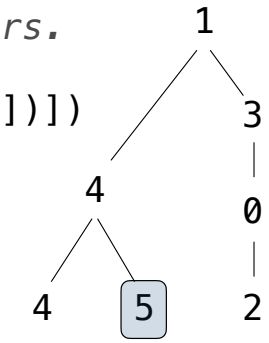

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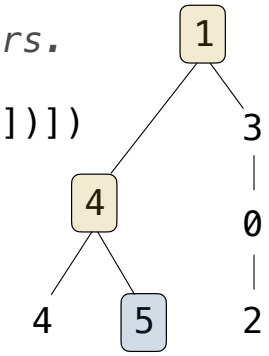

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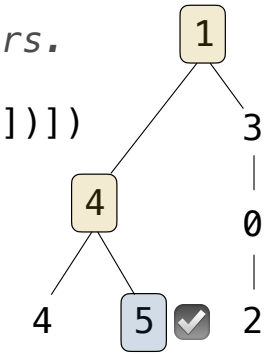

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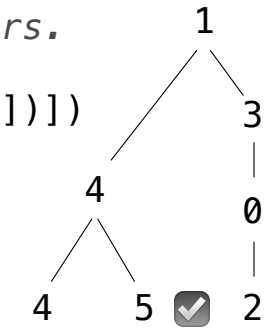

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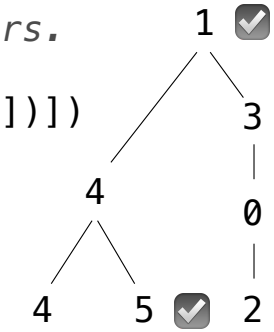

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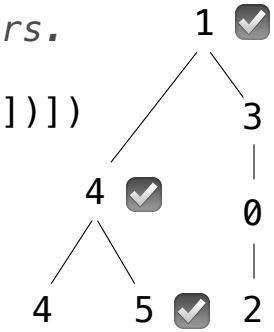

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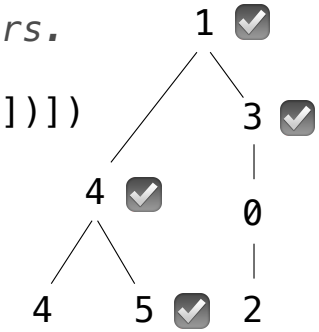

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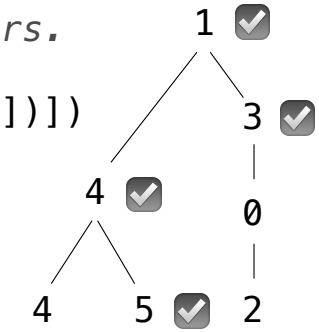

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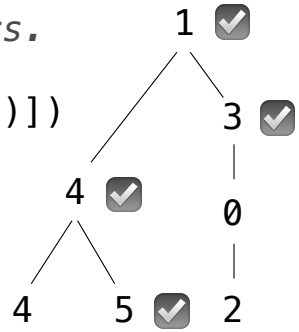

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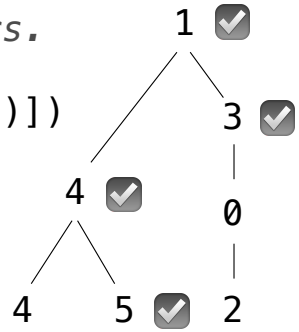

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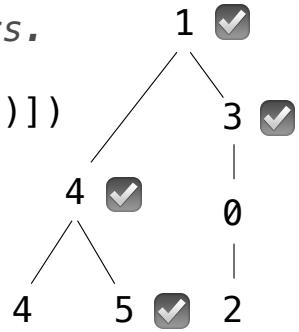

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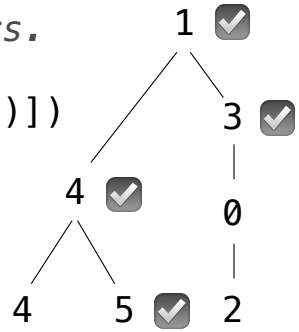

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if node.label > max(ancestors):
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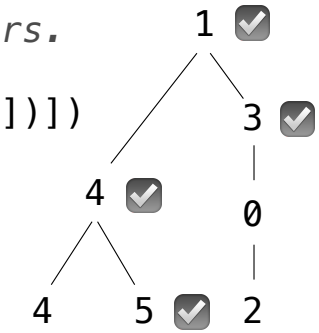

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Somehow track a list of ancestors

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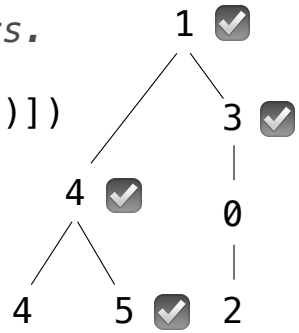

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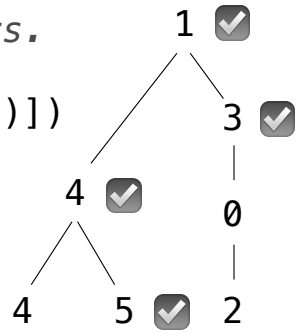

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Somehow track the largest ancestor

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            return 1 + ____________________________________________

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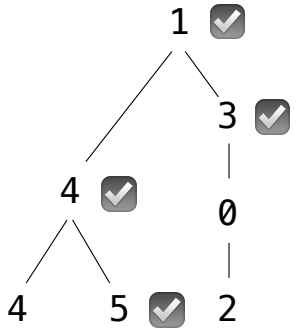

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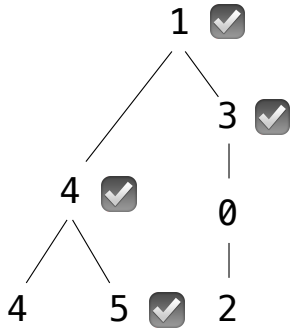

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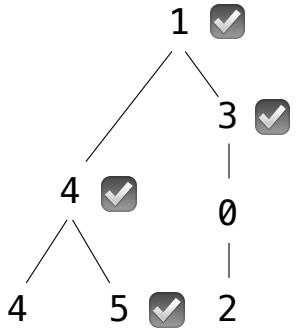

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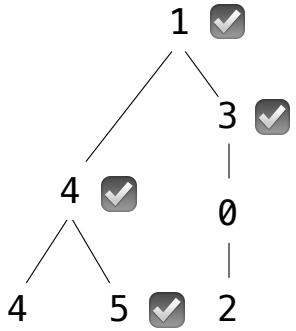

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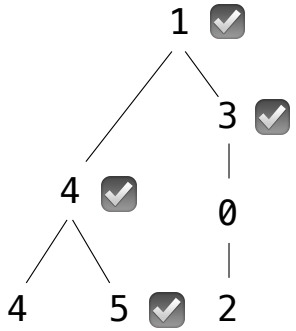
Somehow track the largest ancestor

A node

max_ancestor

a.label > x

node.label > max_ancestors



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    >>> bigs(a)
    4
    """
    def f(a, x):
        if _____________________________________________________:
            return 1 + _____________________________________________
        else:
            return _____________________________________________
    return f(t,            )
```

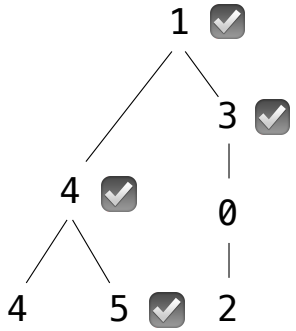
Somehow track the largest ancestor

A node

max_ancestor

a.label > x

node.label > max_ancestors



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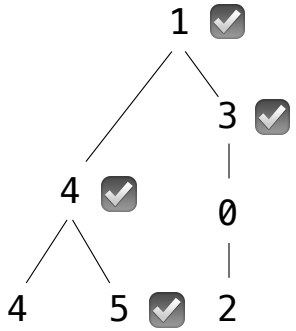

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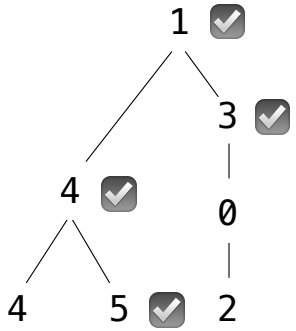
Somehow increment the total count

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



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Somehow increment the total count

f(t,)

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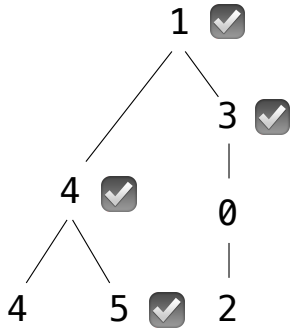

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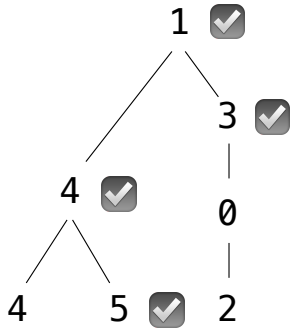

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Root label is always larger than its ancestors

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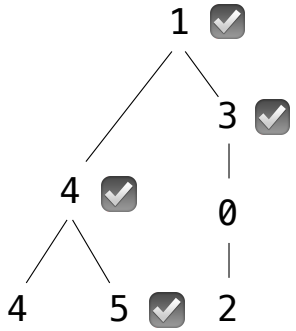

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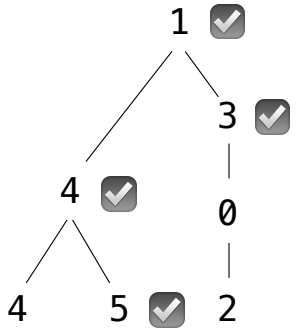

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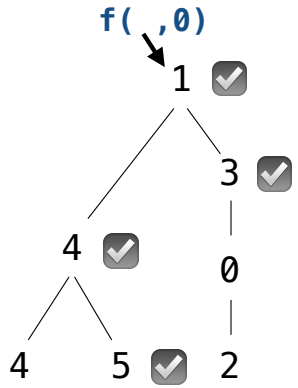

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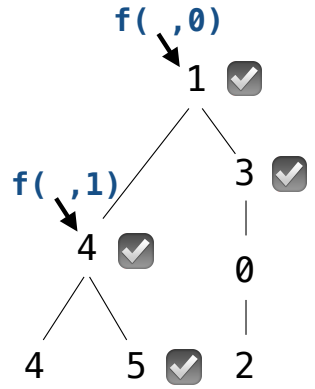

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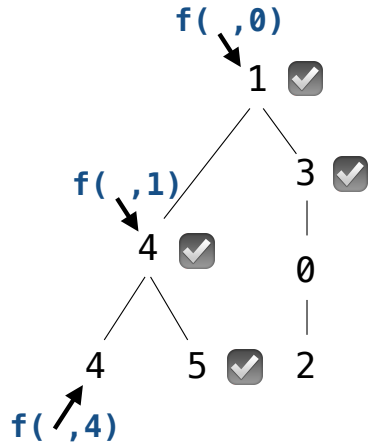

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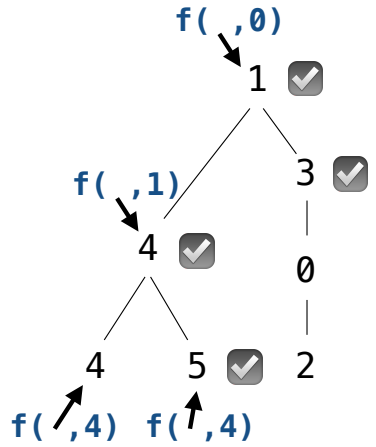

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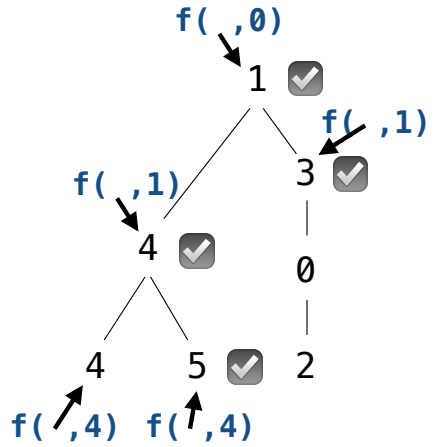

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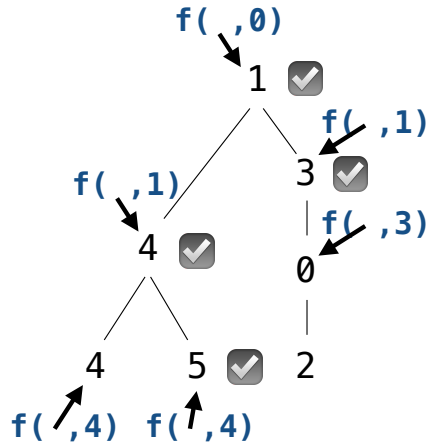

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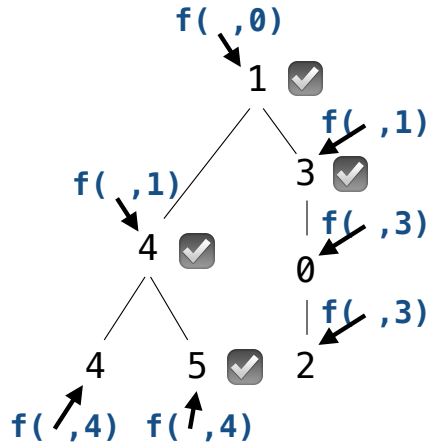

Recursive Accumulation

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 _____________________:

           _____________________

        _____________________:

            f(_____________________)

    _____________________________

    return n[0]
```

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Somehow track the largest ancestor

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Somehow track the largest ancestor

node.label > max_ancestors

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Somehow increment the total count

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Somehow increment the total count

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            _____________________
        _____________________

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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):
        if a.label > x:
            n[0] += 1

        f(_____)

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    return n[0]
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        for b in a.branches:
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    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):                    # Somehow track the largest ancestor
        if a.label > x:             # node.label > max_ancestors
            n[0] += 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[0]
```

Designing Functions

How to Design Programs

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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.

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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.

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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)])
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    """
    result = []
    def process(t):









    process(t)
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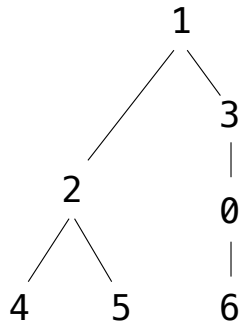

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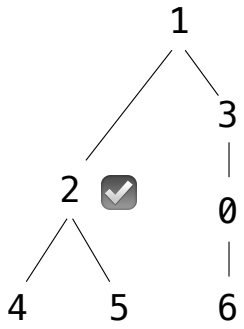

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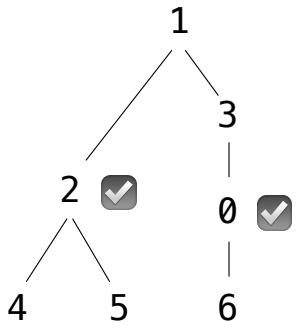

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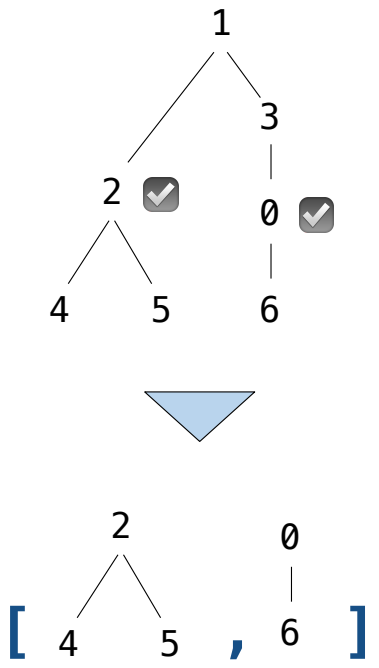

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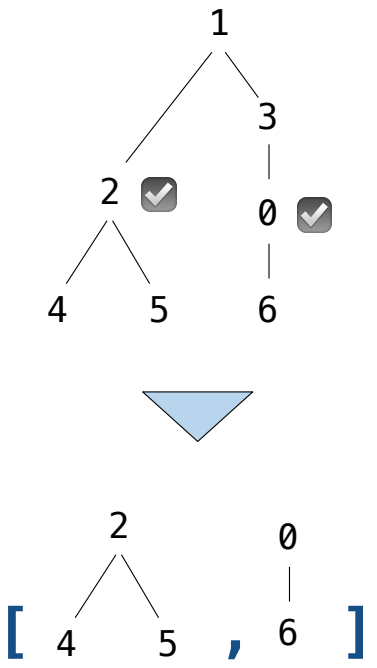
Signature: Tree -> number



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Signature: Tree -> List of Trees

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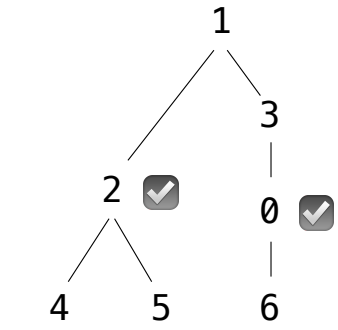
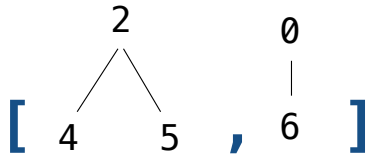
"Find smallest label in t & maybe add t to result"





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

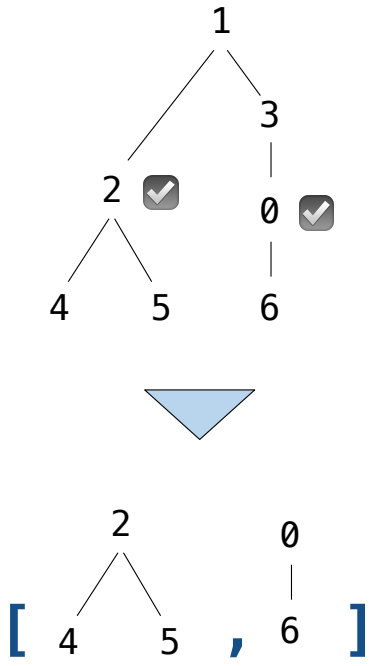


            return min(...)
    process(t)
    return result
```

Signature: Tree -> List of Trees

Signature: Tree -> number

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



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            if ____________________________________________:
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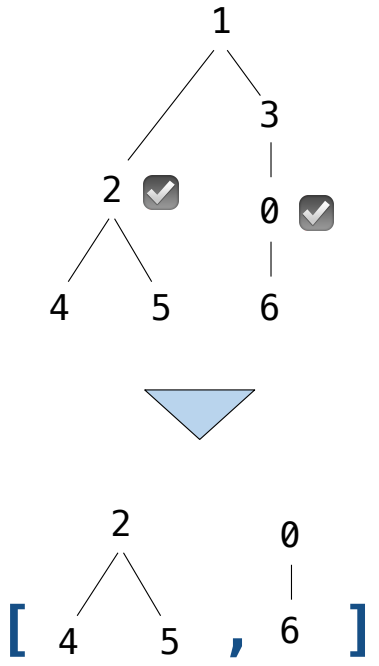

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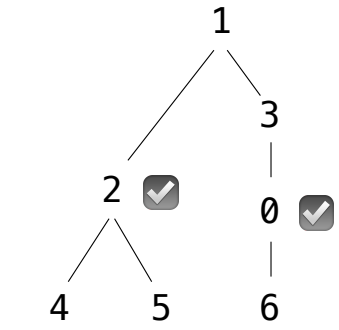

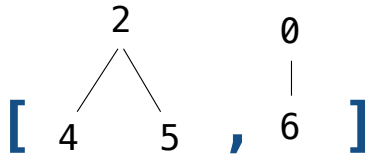

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Signature: Tree -> List of Trees

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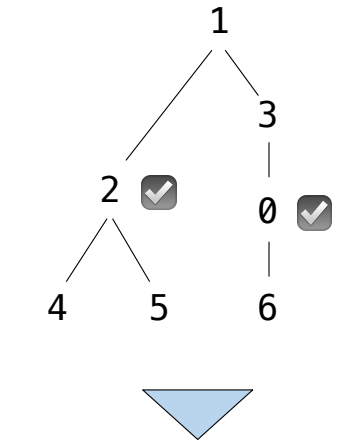
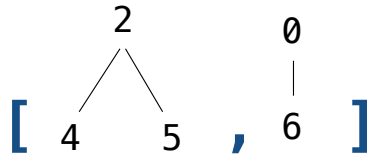
t.label

smallest label in a branch of t





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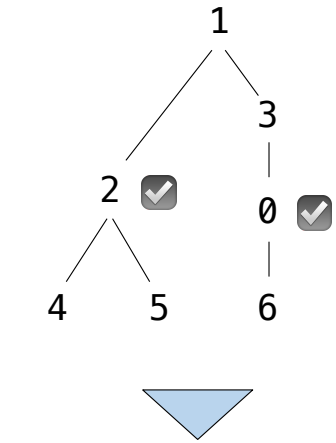
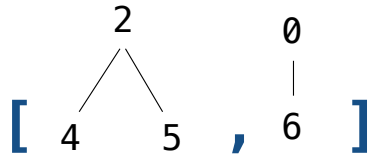
t.label

smallest label in a branch of t

t.label < smallest





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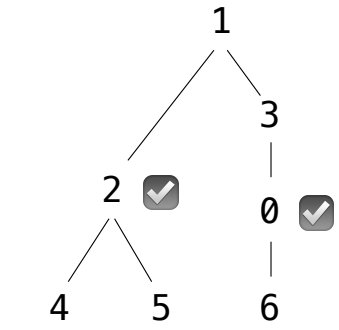
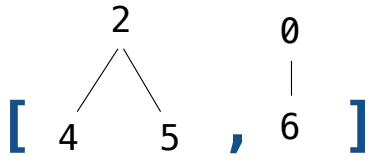
t.label

t.label < smallest

result.append( )

smallest label in a branch of t





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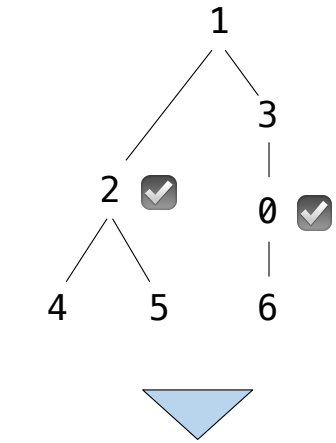

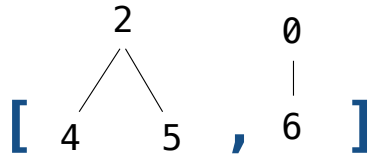

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smallest label in a branch of t

t.label

min([process(b) for b in t.branches])

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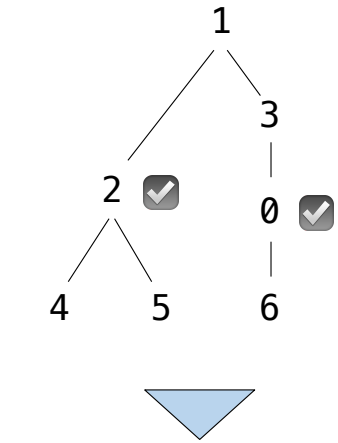

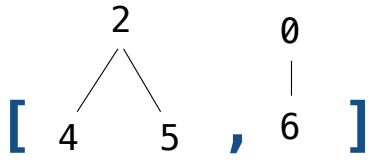

Interpreters

Interpreter Analysis

What expressions are passed to scheme_eval when evaluating the following expressions?

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(define x (+ 1 2))
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(define (f y) (+ x y))
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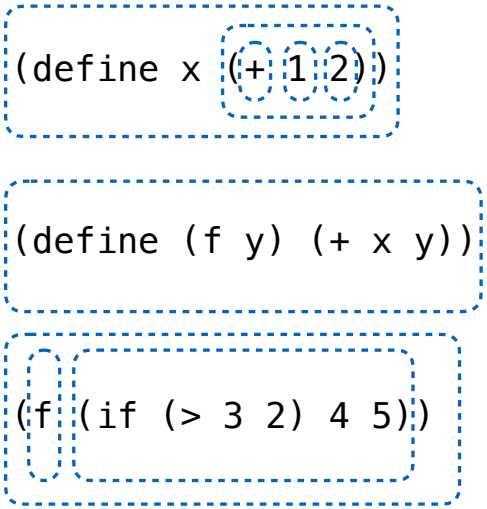

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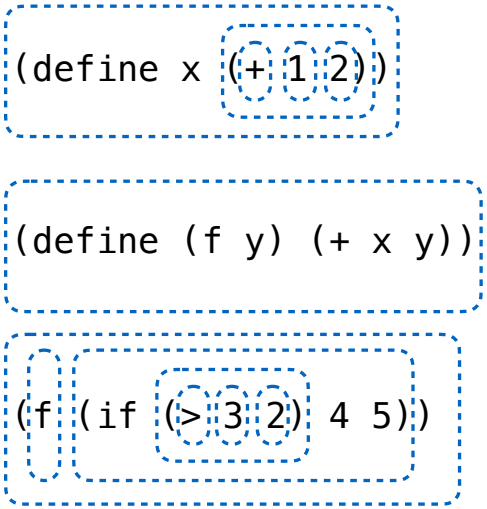

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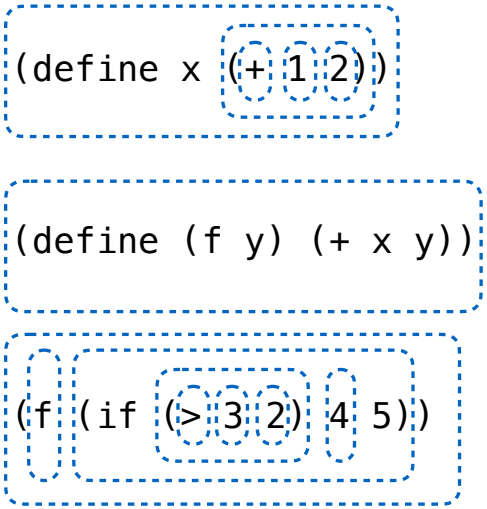

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