Final Examples

Class outline:

- Trees
- Recursive accumulation
- Regular expressions
- Interpreters

Trees

Tree abstractions

In Python, using a class:

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

    def is_leaf(self):
        return not self.branches
```

In Scheme, using procedures to build a data abstraction:

```
(define (tree label branches)
    (cons label branches))

(define (label t) (car t))

(define (branches t) (cdr t))

(define (is-leaf t) (null? (branches t)))
```

Tree-structured data

A tree is a recursive structure, where each branch may itself be a tree.

```
[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 <strong>1</strong></li>
    <li>Midterm <strong>2</strong></li>
</ul>
```

Tree processing often involves recursive calls on subtrees.

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.

```
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
    """
```

1. Understand the question and function signature.

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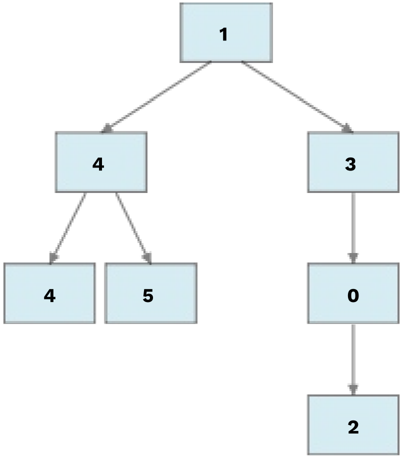
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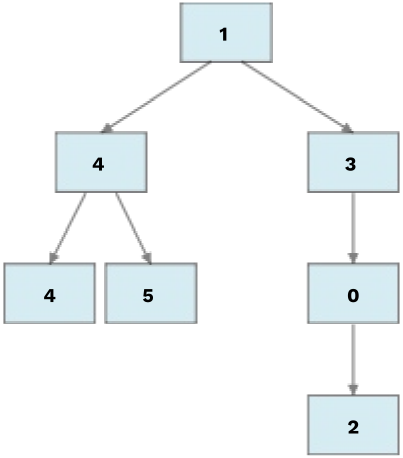
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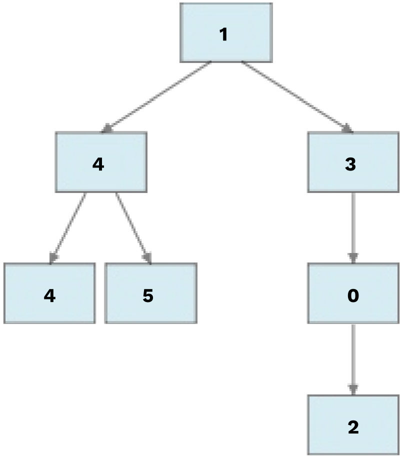
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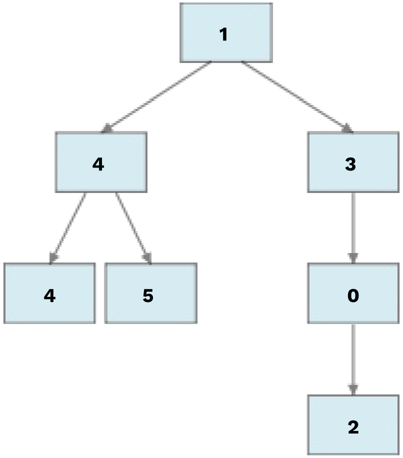
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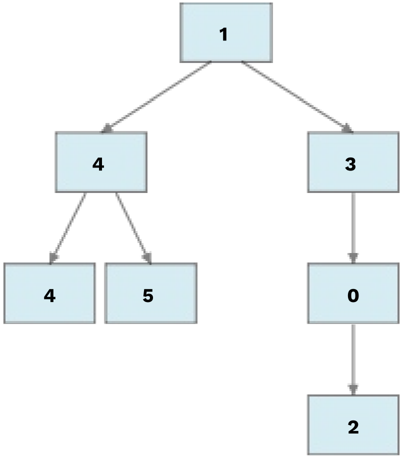
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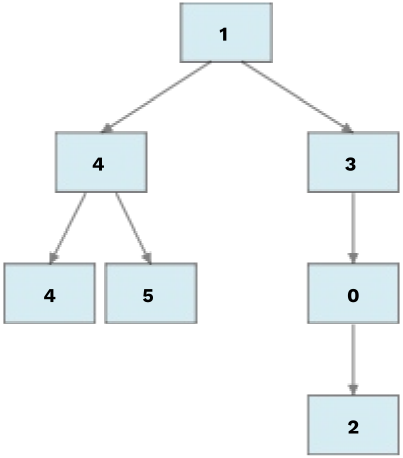
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```

4. Consider what you expect to see in the solution.

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    """
```

4. Consider what you expect to see in the solution.

Typical tree processing structure?

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

Solving bigs #2

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def bigs(t):
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Typical tree processing structure?

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

✗ That won't work, since we need to know about ancestors.

Solving bigs #3

```
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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    """
```

4. Consider what you expect to see in the solution.

Solving bigs #3

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    """
```

4. Consider what you expect to see in the solution.

Some code that increments the total count

```
1 + ______
```

Solving bigs #3

```python
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
    """
```

4. Consider what you expect to see in the solution.

Some code that increments the total count

```
1 + ______
```

Some way of tracking ancestor labels or max of ancestors seen so far.

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

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

Solving bigs #4

```
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
    """
```

5. Check out the provided template.

```
def f(a, x):
    if ______________________:
        return 1 + __________
    else:
        return ______________
return ______________________
```

Solving bigs #4

```
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)])])])
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    4
    """
```

5. Check out the provided template.
6. Figure out where what you expected fits into the template.

```

def f(a, x):
    if ______________________:
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    >>> bigs(a)
    4
    """
```

5. Check out the provided template.
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```

def f(a, x):
    if ______________________:
        return 1 + __________ # Increment total
    else:
        return ______________
return ______________________
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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)])])])
    >>> bigs(a)
    4
    """
```

5. Check out the provided template.
6. Figure out where what you expected fits into the template.

```

def f(a, x):
    if ______________________: # Track the largest ancestor
        return 1 + __________ # Increment total
    else:
        return ______________
return ______________________
```

Solving bigs #4

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def bigs(t):
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    """
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5. Check out the provided template.
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7. Label any ambiguously named variables if its helpful.

```
def f(a, x):
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5. Check out the provided template.
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```
# a is the current subtree, x is the largest ancestor
def f(a, x):
    if ______________________: # Track the largest ancestor
        return 1 + __________ # Increment total
    else:
        return ______________
return ______________________
```

Solving bigs #5

```
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
    """
```

8. Finish filling in the skeleton.

```
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)
```

Solving bigs #6

```
def bigs(t):
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    """
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            return sum([f(b, x) for b in a.branches])
    return f(t, t.label - 1)
```

Recursive accumulation

Initialize some data structure to an empty/zero value, and populate it as you go.

Solving smalls

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)])
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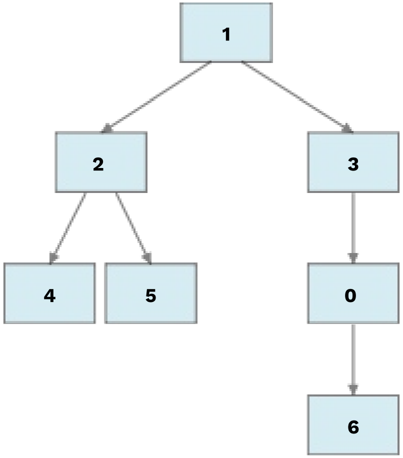
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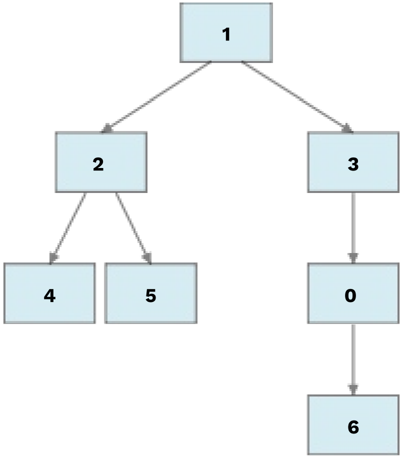
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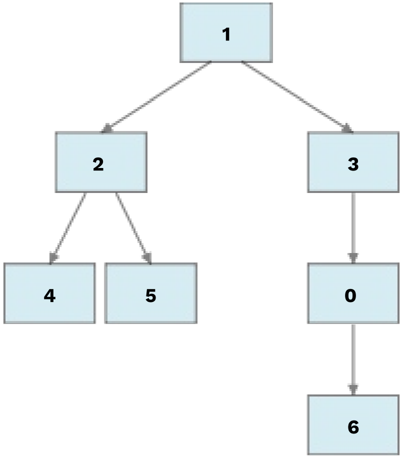
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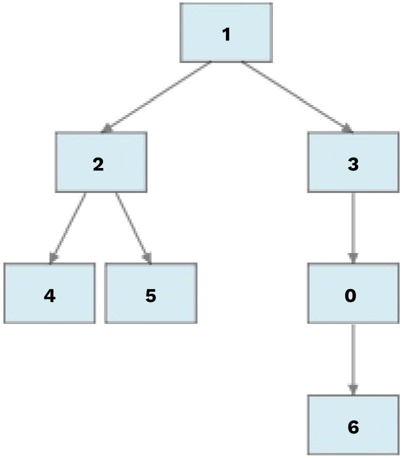
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Solving smalls #2

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```

4. Consider what you expect to see in the solution.

Solving smalls #2

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4. Consider what you expect to see in the solution.

Something which finds the smallest value in a subtree

```
min(____)
```

Solving smalls #2

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Something which compares smallest to current

```
t.label < smallest
```

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    >>> sorted([t.label for t in smalls(a)])
    [0, 2]
    """
```

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Something which finds the smallest value in a subtree

```
min(____)
```

Something which compares smallest to current

```
t.label < smallest
```

Something which adds a subtree to a list

```
___.append(t)
```

Solving smalls #3

```
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]
    """
```

5. Check out the provided template.

```
result = []
def process(t):
    if t.is_leaf():
        return ______________________
    else:
        smallest = __________________
        if _________________________:
            _________________________
        return min(smallest, t.label)
process(t)
return result
```

Solving smalls #3

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

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result = []
def process(t):
    if t.is_leaf():
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        smallest = __________________  # Finds smallest
        if _________________________:
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```
result = []
def process(t):
    if t.is_leaf():
        return ______________________
    else:
        smallest = __________________ # Finds smallest
        if _________________________: # Compares smallest
         _________________________
        return min(smallest, t.label)
process(t)
return result
```

Solving smalls #3

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def smalls(t):
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    >>> 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]
    """
```

5. Check out the provided template.
6. Figure out where what you expected fits into the template.

```
result = [] # The result list
def process(t):
    if t.is_leaf():
        return ______________________
    else:
        smallest = __________________ # Finds smallest
        if ________________________: # Compares smallest
           ________________________ # Appends subtree to list
        return min(smallest, t.label)
process(t)
return result
```

Solving smalls #3

```
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)])])])
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        smallest = __________________ # Finds smallest
        if _________________________: # Compares smallest
           _________________________ # Appends subtree to list
        return min(smallest, t.label)
process(t)
return result
```

Solving smalls #3

```
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]
    """
```

5. Check out the provided template.
6. Figure out where what you expected fits into the template.
7. Label any ambiguously named variables if its helpful.

```
result = [] # The result list
def process(t): # t is a Tree
    if t.is_leaf():
        return ______________________
    else:
        smallest = __________________ # Finds smallest
        if _________________________: # Compares smallest
         ____________________________ # Appends subtree to list
        return min(smallest, t.label)
process(t)
return result
```

Solving smalls #4

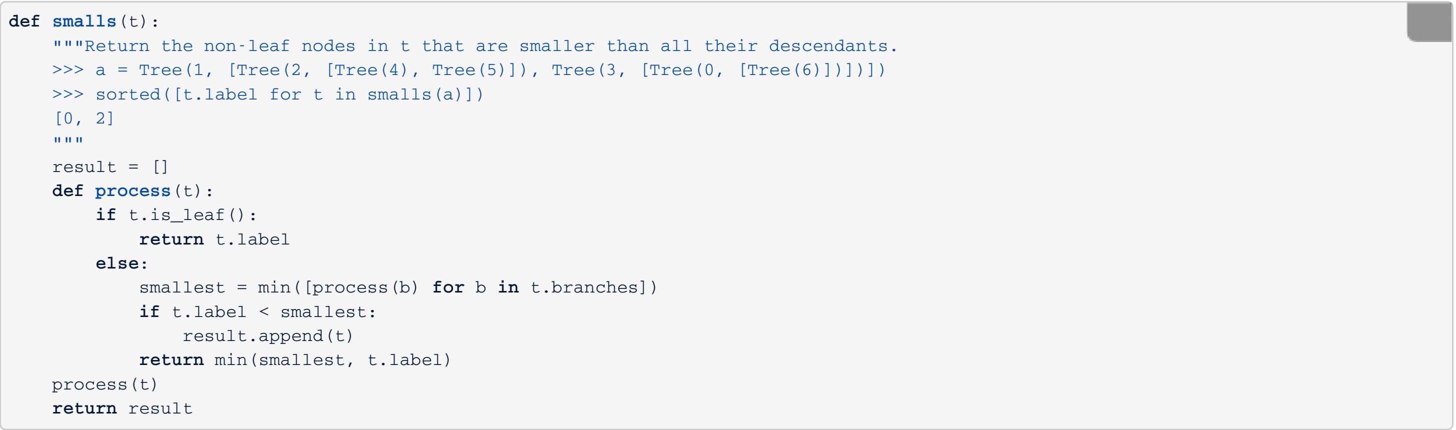
```
def smalls(t):
    """Return the non-leaf nodes in t that are smaller than all their descendants.

    >>> 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]
    """
```

8. Finish filling in the skeleton.

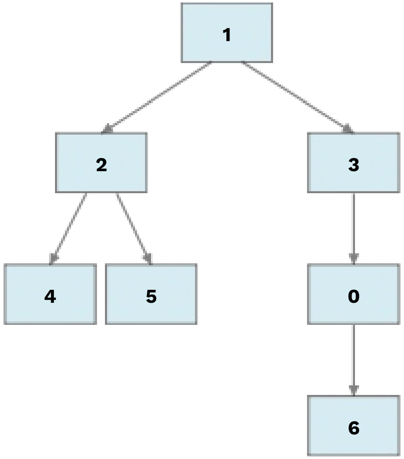
```
result = []
def process(t):
    if t.is_leaf():
        return t.label
    else:
        smallest = min([process(b) for b in t.branches])
        if t.label < smallest:
            result.append(t)
        return min(smallest, t.label)
process(t)
return result
```

Solving smalls #5



```python
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
```

8. Check your work!



Regular expressions

Matching patterns

Which strings are matched by each regular expression?

<table>
<tr><th>Expressions:</th><th>abc</th><th>cab</th><th>bac</th><th>baba</th><th>ababca</th><th>aabcc</th><th>abbal</th></tr>
<tr><td><code>[abc]*</code></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td><code>a*b*c*</code></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td><code>ab|[bc]*</code></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td><code>(a[bc]+)+a?</code></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td><code>(ab|ba)+(ab|[bc])?</code></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Matching patterns

Which strings are matched by each regular expression?

Expressions:	abc	cab	bac	baba	ababca	aabcc	abba
`[abc]*`	✓	✓	✓	✓	✓	✓	✓
`a*b*c*`	✓	✗	✗	✗	✗	✓	✗
`ab|[bc]*`	✗	✗	✗	✗	✗	✗	✗
`(a[bc]+)+a?`	✓	✗	✗	✗	✓	✗	✓
`(ab|ba)+(ab|[bc])?`	✓	✗	✓	✓	✗	✗	✓

Interpreters

Interpreter analysis

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

```scheme
(define x (+ 1 2))

(define (f y) (+ x y))

(f (if (> 3 2) 4 5))
```

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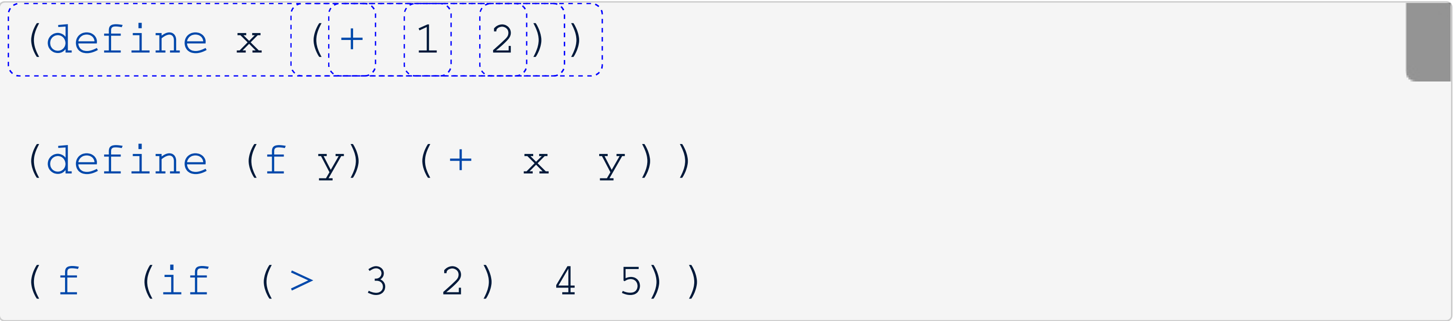

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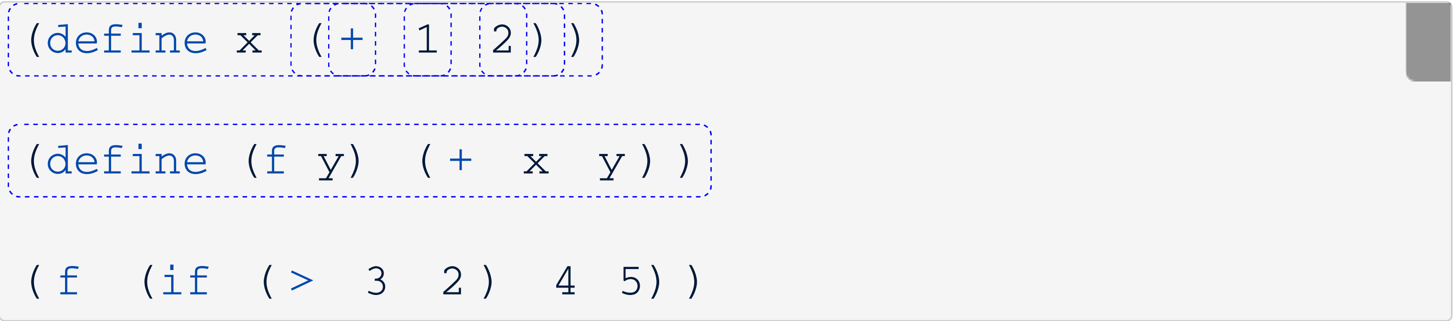

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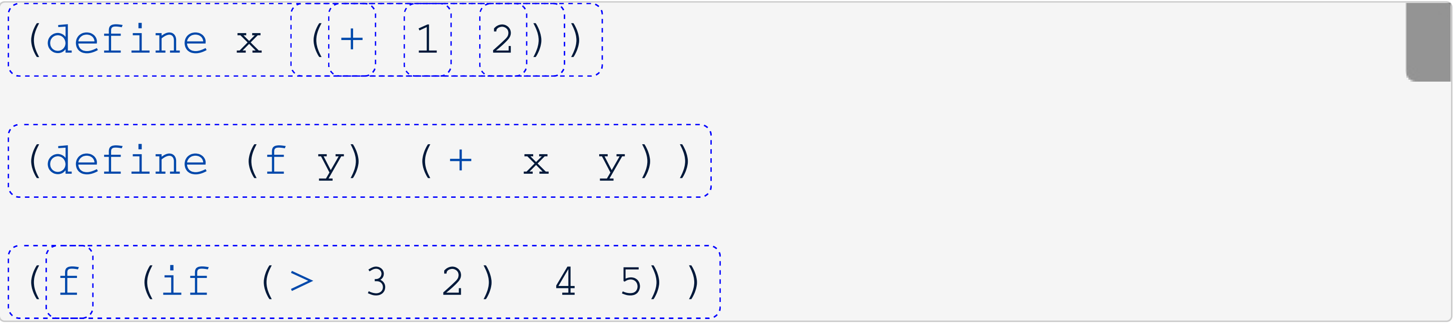

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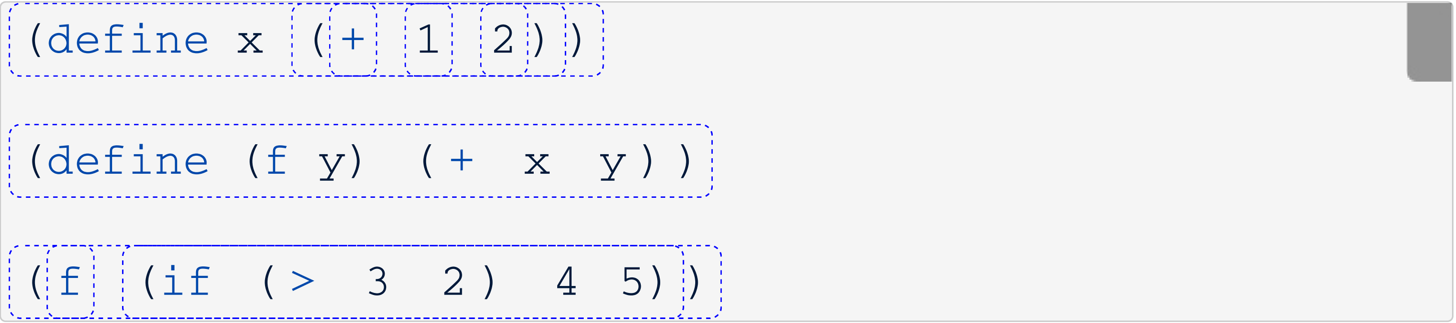

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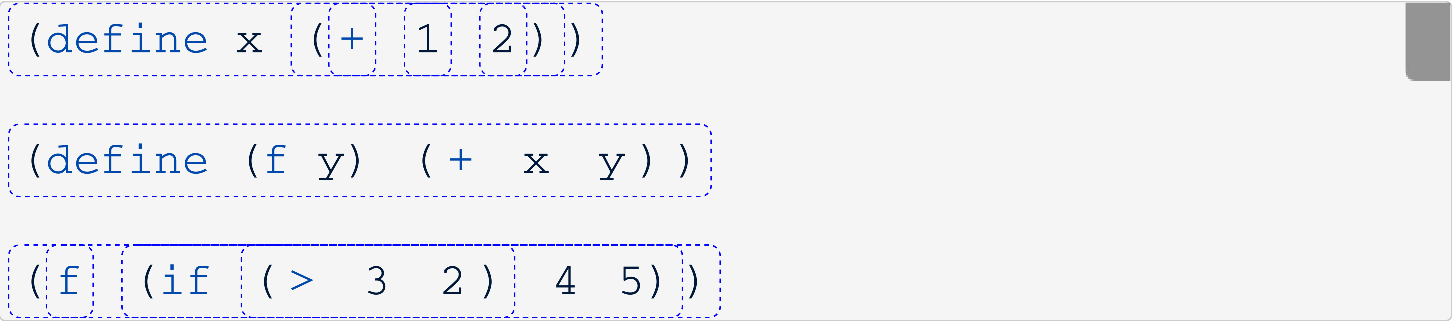

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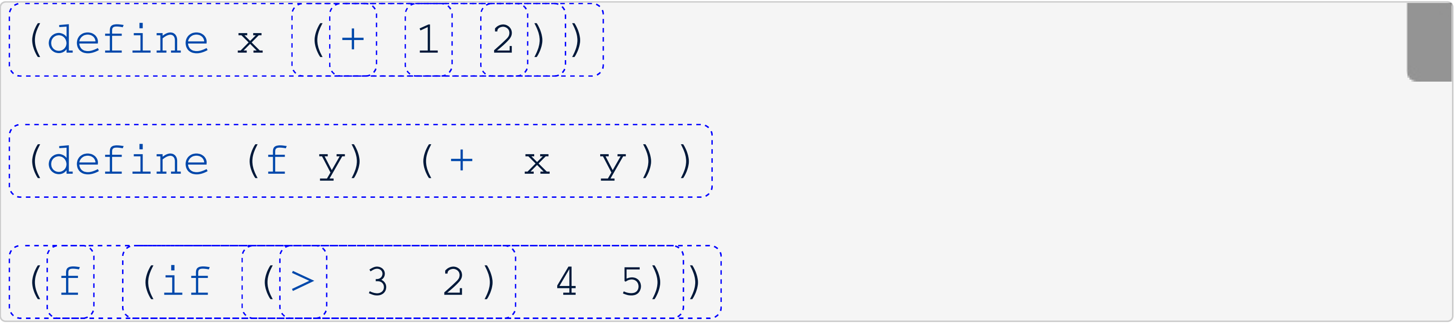

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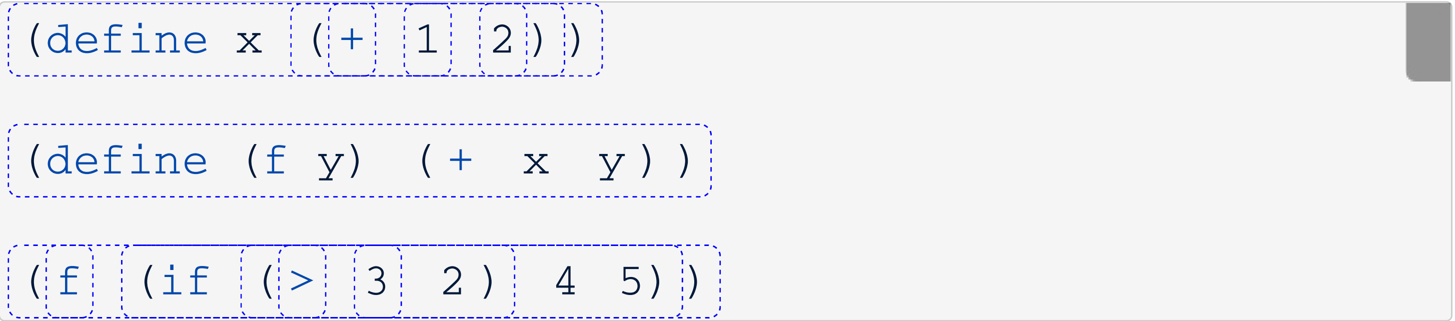

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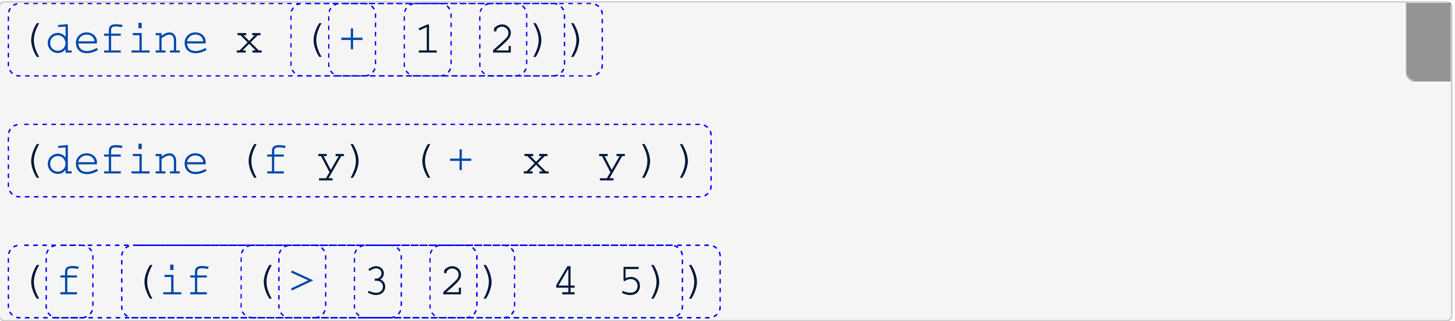

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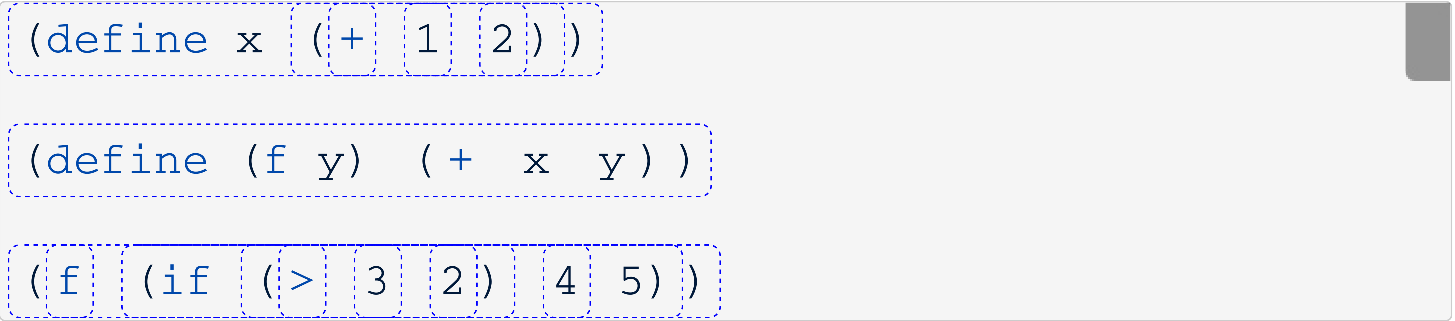

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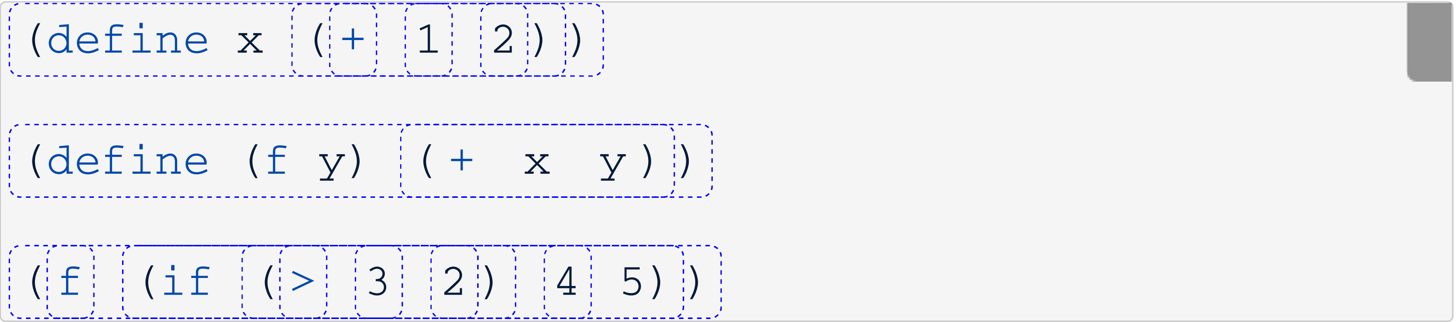

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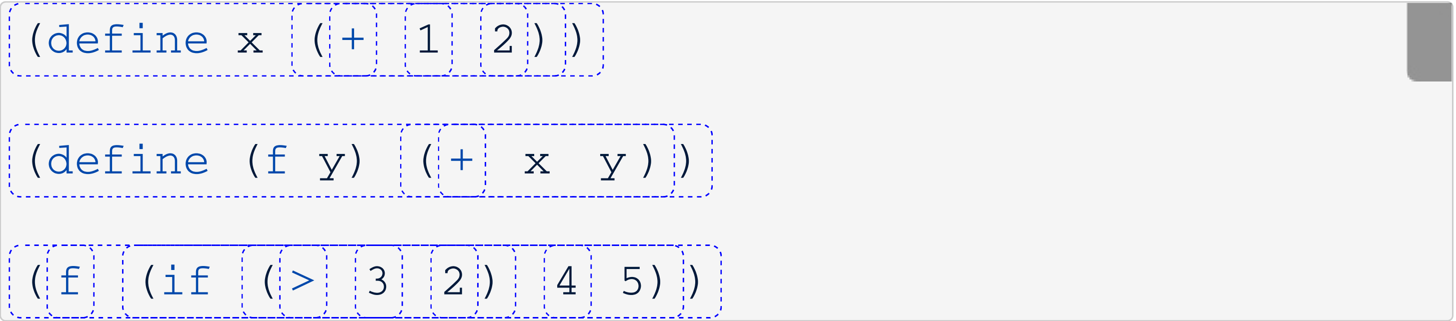

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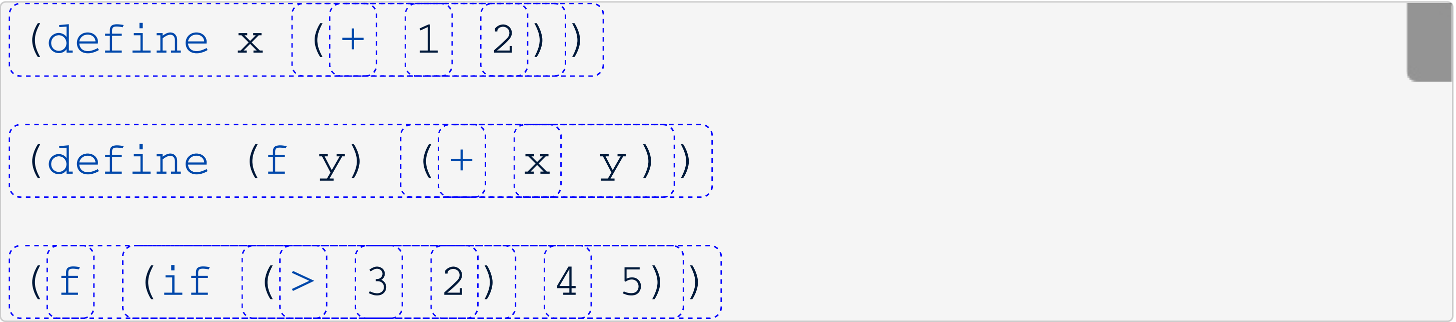

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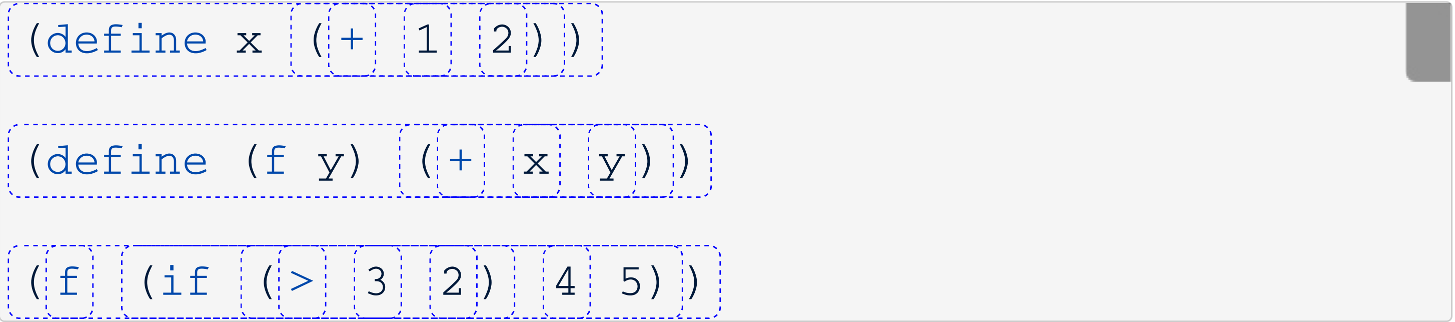

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