1 Recursion

1.1 (Adapted from Fall 2013) Fill in the blanks in the implementation of paths, which takes as input two positive integers x and y. It returns a list of paths, where each path is a list containing steps to reach y from x by repeated incrementing or doubling. For instance, we can reach 9 from 3 by incrementing to 4, doubling to 8, then incrementing again to 9, so one path is [3, 4, 8, 9]

```python
def paths(x, y):
    """Return a list of ways to reach y from x by repeated incrementing or doubling."""
    >>> paths(3, 5)
    [[3, 4, 5]]
    >>> sorted(paths(3, 6))
    [[3, 4, 5, 6], [3, 6]]
    >>> sorted(paths(3, 9))
    [[3, 4, 5, 6, 7, 8, 9], [3, 4, 8, 9], [3, 6, 7, 8, 9]]
    >>> paths(3, 3) # No calls is a valid path
    [[3]]
    ""
    if _________________:
        return ____________________________________________
    elif ________________:
        return ____________________________________________
    else:
        a = _______________________________________________
        b = _______________________________________________
        return _____________________________________________
```
1.2 We will now write one of the faster sorting algorithms commonly used, known as *merge sort*. Merge sort works like this:

1. If there is only one (or zero) item(s) in the sequence, it is already sorted!

2. If there are more than one item, then we can split the sequence in half, sort each half recursively, then merge the results, using the *merge* procedure described below. The result will be a sorted sequence.

Using the algorithm described, write a function `mergesort(seq)` that takes an unsorted sequence and sorts it.

Recall the *merge* procedure is as follows:

```python
def merge(s1, s2):
    """ Merges two sorted lists """
    if len(s1) == 0:
        return s2
    elif len(s2) == 0:
        return s1
    elif s1[0] < s2[0]:
        return [s1[0]] + merge(s1[1:], s2)
    else:
        return [s2[0]] + merge(s1, s2[1:])

def mergesort(seq):
```

*Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.*
2 Trees

2.1 Implement `long_paths`, which returns a list of all `paths` in a tree with length at least `n`. A path in a tree is a linked list of node values that starts with the root and ends at a leaf. Each subsequent element must be from a child of the previous value’s node. The `length` of a path is the number of edges in the path (i.e. one less than the number of nodes in the path). Paths are listed in order from left to right. See the doctests for some examples.

```python
def long_paths(tree, n):
    """Return a list of all paths in tree with length at least n."
    
    >>> t = Tree(3, [Tree(4), Tree(4), Tree(5)]
    >>> left = Tree(1, [Tree(2), t]
    >>> mid = Tree(6, [Tree(7, [Tree(8]]), Tree(9))
    >>> right = Tree(11, [Tree(12, [Tree(13, [Tree(14)])])]
    >>> whole = Tree(0, [left, Tree(13), mid, right])
    >>> for path in long_paths(whole, 2):
    ...     print(path)
    ...
    <0 1 2>
    <0 1 3 4>
    <0 1 3 4>
    <0 1 3 5>
    <0 6 7 8>
    <0 6 9>
    <0 11 12 13 14>
    >>> for path in long_paths(whole, 3):
    ...     print(path)
    ...
    <0 1 3 4>
    <0 1 3 4>
    <0 1 3 5>
    <0 6 7 8>
    <0 11 12 13 14>
    >>> long_paths(whole, 4)
    [Link(0, Link(11, Link(12, Link(13, Link(14))))))]
    """
```

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
Write a function that takes a Tree object and returns the elements at the depth with the most elements.

In this problem, you may find it helpful to use the second optional argument to `sum`, which provides a starting value. All items in the sequence to be summed will be concatenated to the starting value. By default, start will default to 0, which allows you to sum a sequence of numbers. We provide an example of sum starting with a list, which allows you to concatenate items in a list.

```python
def widest_level(t):
    
    >>> sum([[1], [2]], [])
    [1, 2]
    >>> t = Tree(3, [Tree(1, [Tree(1), Tree(5)]),
        ... Tree(4, [Tree(9, [Tree(2)])])])
    >>> widest_level(t)
    [1, 5, 9]
    
    levels = []
x = [t]

    while ____________________________:
        ________________________________
        ________________________________
        __________ = sum(_________________________, [])

    return max(levels, key=___________________________)
```
3 Mutation

3.1 For each row below, fill in the blanks in the output displayed by the interactive Python interpreter when the expression is evaluated. Expressions are evaluated in order, and expressions may affect later expressions.

```python
>>> cats = [1, 2]
>>> dogs = [cats, cats.append(23), list(cats)]
>>> cats

>>> dogs[1] = list(dogs)
>>> dogs[1]

>>> dogs[0].append(2)
>>> cats

>>> cats[1::2]

>>> cats[:3]

>>> dogs[2].extend([list(cats).pop(0), 3])
>>> dogs[3]

>>> dogs
```
4 OOP

4.1 (Summer 2015 Final) The TAs are building a social networking website called CS61A+. The TAs plan to represent the network in a class called Network that supports the following method:

- **add_friend(user1, user2)** adds user1 and user2 to each other’s friends lists.

  If user1 or user2 are not in the Network, add them to the dictionary of friends.

Help the TAs implement these two methods to make their social networking website popular!

class Network:

```
>>> cs61a_plus = Network()
>>> cs61a_plus.add_friend('Robert', 'Jeffrey')
>>> cs61a_plus.friends['Robert']
['Jeffrey']
>>> cs61a_plus.friends['Jeffrey']
['Robert']
>>> cs61a_plus.add_friend('Jessica', 'Robert')
>>> cs61a_plus.friends['Robert']
['Jeffrey', 'Jessica']
```

def __init__(self):
    self.friends = {}  # Maps users to a list of their friends

def add_friend(self, user1, user2):

    if ________________________________:

        ________________________________

    if ________________________________:

        ________________________________

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
CS61A+ turns out to be unpopular. To attract more users, the TAs want to implement a feature that checks if two users have at most $n$ degrees of separation. Consider the following CS61A+ Network:

```python
self.friends = {
    'Robert': ['Jeffrey', 'Jessica'],
    'Jeffrey': ['Robert', 'Jessica', 'Yulin'],
    'Jessica': ['Robert', 'Jeffrey', 'Yulin'],
    'Yulin': ['Jeffrey', 'Jessica'],
    'Albert': []
}
```

- There is 1 degree of separation between Robert and Jeffrey, because they are direct friends.
- There are 2 degrees of separation between Robert and Yulin ($Robert \rightarrow Jessica \rightarrow Yulin$)
- The degree of separation between Albert and anyone else is undefined, since Albert has no friends.

```python
class Network:
    # Code from previous question

def degrees(self, user1, user2, n):
    """In these doctests, assume cs61a_plus is a Network with the dictionary of friends described in the example."

    >>> cs61a_plus.degrees('Robert', 'Yulin', 2)  # Exactly 2 degrees
    True
    >>> cs61a_plus.degrees('Robert', 'Jessica', 2)  # Less than 2 degrees
    True
    >>> cs61a_plus.degrees('Yulin', 'Robert', 1)  # More than 1 degree
    False
    >>> cs61a_plus.degrees('Albert', 'Jessica', 10)  # No friends!
    False
    """

    if ______________________________________:
        return True

    elif ______________________________________:
        return False

    for friend in ____________________________:
        if ______________________________________:
            return True

    return ________________________________
```

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
5 Mutable Linked Lists and Trees

5.1 Write a recursive function `flip_two` that takes as input a linked list `lnk` and mutates `lnk` so that every pair is flipped.

```python
def flip_two(lnk):
    """
    >>> one_lnk = Link(1)
    >>> flip_two(one_lnk)
    >>> one_lnk
    Link(1)
    >>> lnk = Link(1, Link(2, Link(3, Link(4, Link(5)))))
    >>> flip_two(lnk)
    >>> lnk
    Link(2, Link(1, Link(4, Link(3, Link(5)))))
    """
```
6 Generators

6.1 Write a generator function that yields functions that are repeated applications of a one-argument function \( f \). The first function yielded should apply \( f \) 0 times (the identity function), the second function yielded should apply \( f \) once, etc.

```python
def repeated(f):
    ""
    >>> double = lambda x: 2 * x
    >>> funcs = repeated(double)
    >>> identity = next(funcs)
    >>> double = next(funcs)
    >>> quad = next(funcs)
    >>> oct = next(funcs)
    >>> quad(1)
    4
    >>> oct(1)
    8
    >>> [g(1) for _, g in
    ...     zip(range(5), repeated(lambda x: 2 * x))]
    [1, 2, 4, 8, 16]
    ""

    g = ________________________________________________________________________

    while True:

    __________________________________________________________________________

    __________________________________________________________________________

    __________________________________________________________________________
```

6.2 Ben Bitdiddle proposes the following alternate solution. Does it work?

```python
def ben_repeated(f):
    g = lambda x: x
    while True:
        yield g
        g = lambda x: f(g(x))
```

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
6.3 Implement `accumulate`, which takes in an `iterable` and a function `f` and yields each accumulated value from applying `f` to the running total and the next element.

```python
from operator import add, mul

def accumulate(iterable, f):
    
    >>> list(accumulate([1, 2, 3, 4, 5], add))
    [1, 3, 6, 10, 15]
    >>> list(accumulate([1, 2, 3, 4, 5], mul))
    [1, 2, 6, 24, 120]
    
    it = iter(iterable)
```

Note: This worksheet is a problem bank—most TAs will not cover all the problems in discussion section.
7 Scheme

7.1 Write a function that takes a procedure and applies to every element in a given nested list.

The result should be a nested list with the same structure as the input list, but with each element replaced by the result of applying the procedure to that element.

Use the built-in list? procedure to detect whether a value is a list.

(define (deep-map fn lst)

scm> (deep-map (lambda (x) (* x x)) '(1 2 3))
(1 4 9)
scm> (deep-map (lambda (x) (* x x)) '((4) 5) 9))
(1 ((16) 25) 81)

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