Linked Lists and Midterm Review

Computer Science Mentors 61A

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Linked Lists

For each of the following problems, assume linked lists are defined as follows:

```
class Link:
    empty = ()
    def __init__(self, first, rest=empty):
        assert rest is Link.empty or isinstance(rest, Link)
        self.first = first
        self.rest = rest
```

To check if a `Link` is empty, compare it against the class attribute `Link.empty`:

```
if link is Link.empty:
    print('This linked list is empty!')
```

1. What will Python output? Draw box-and-pointer diagrams to help determine this.

```
>>> a = Link(1, Link(2, Link(3)))
```

Solution:

```
+---+---+  +---+---+  +---+---+
| 1 | --|->| 2 | --|->| 3 | / |
+---+---+  +---+---+  +---+---+
```

```
>>> a.first
```

Solution:

```
1
```

```
>>> a.first = 5
```

Solution:

```
+---+---+  +---+---+  +---+---+
| 5 | --|->| 2 | --|->| 3 | / |
+---+---+  +---+---+  +---+---+
```

```
>>> a.first
```

Solution: 5

```
>>> a.rest.first
```

Solution: 2

```
>>> a.rest.rest.rest.rest.first
```

Solution: Error: tuple object has no attribute rest (Link.empty has no rest)

```
>>> a.rest.rest.rest = a
```

Solution:

```
   +---+---+  +---+---+  +---+---+
+->| 5 | --|->| 2 | --|->| 3 | --|--+
|  +---+---+  +---+---+  +---+---+  |
|                                   |
+-----------------------------------+
```

```
>>> a.rest.rest.rest.rest.first
```

Solution:
2

2. Write a function `skip`, which takes in a `Link` and returns a new `Link` with every other element skipped.

```
def skip(lst):
    """
    >>> a = Link(1, Link(2, Link(3, Link(4))))
    >>> a
    Link(1, Link(2, Link(3, Link(4))))
    >>> b = skip(a)
    >>> b
    Link(1, Link(3))
    >>> a
    Link(1, Link(2, Link(3, Link(4)))) # Original is unchanged
    """
    if ________________________________________:
        ________________________________________:
    elif ______________________________________:
        ________________________________________
    ____________________________________________
```

Solution:

```
    if lst is Link.empty
        return Link.empty
     elif lst.rest is Link.empty:
        return Link(lst.first)
    return Link(lst.first, skip(lst.rest.rest))
```

3. Now write function `skip` by mutating the original list, instead of returning a new list. Do NOT call the `Link` constructor.

```
def skip(lst):
    """
    >>> a = Link(1, Link(2, Link(3, Link(4))))
    >>> b = skip(a)
    >>> b
    None
    >>> a
    Link(1, Link(3))
    """
```

Solution:

```
def skip(lst): # Recursively
    if lst is Link.empty or lst.rest is Link.empty:
        return
    lst.rest = lst.rest.rest
    skip(lst.rest)

def skip(lst): # Iteratively
    if lst is Link.empty:
        return
    while lst is not Link.empty and lst.rest is not Link.
       empty:
        lst.rest = lst.rest.rest
        lst = lst.rest
```

4. Write a function `reverse`, which takes in a `Link` and returns a new `Link` that has the order of the contents reversed.
   Hint: You may want to use a helper function if you're solving this recursively.

```
def reverse(lst):
    """
    >>> a = Link(1, Link(2, Link(3)))
    >>> b = reverse(a)
    >>> b
    Link(3, Link(2, Link(1)))
    >>> a
    Link(1, Link(2, Link(3)))
    """
```

Solution: There are quite a few different methods. We have listed some here – can you think of any others?

```
# Recursive w/ Helper
def reverse(lst):
    def helper(so_far, rest):
        if rest is Link.empty:
            return so_far
        else:
            return helper(Link(rest.first, so_far), rest.
               rest)
    return helper(Link.empty, lst)

# Iterative
def reverse(lst):
    rev = Link.empty
    while lst is not Link.empty:
        rev = Link(lst.first, rev)
        lst = lst.rest
    return rev
```

Midterm Review

For each of the following problems, assume the Tree class is defined as follows:

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

```
        self.label = label
        self.branches = branches

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

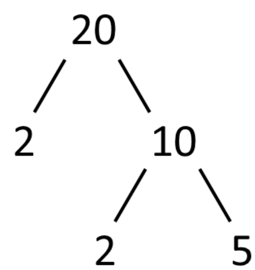
1. Write a function that returns true only if there exists a path from root to leaf that contains at least `n` instances of `elem` in a tree `t`.

```
def contains_n(elem, n, t):
    """
    >>> t1 = Tree(1, [Tree(1, [Tree(2)])])
    >>> contains(1, 2, t1)
    True
    >>> contains(2, 2, t1)
    False
    >>> contains(2, 1, t1)
    True
    >>> t2 = Tree(1, [Tree(2), Tree(1, [Tree(1), Tree(2)])])
    >>> contains(1, 3, t2)
    True
    >>> contains(2, 2, t2) # Not on a path
    False
    """
    if n == 0:
        return True
    elif ______________________________________________:
        return ______________________________________
    elif t.label == elem:
        return ______________________________________
    else:
        return ______________________________________
```

Solution:

```
    if n == 0:
        return True
    elif t.is_leaf():
        return n == 1 and t.label == elem
    elif t.label == elem:
        return True in [contains_n(elem, n - 1, b) for b in
          t.branches]
    else:
        return True in [contains_n(elem, n, b) for b in
          t.branches]
```

2. Define the function `factor_tree` which returns a *factor tree*. Recall that in a factor tree, multiplying the leaves together is the prime factorization of the root, n. See below for an example of a factor tree for $n = 20$.



```
def factor_tree(n):
    for i in ____________________________:
        if ___________________________________:
            return Tree(______, ____________________________________)
    ______________________________________
```

Solution:

```
    for i in range(2, n):
        if n % i == 0:
            return Tree(n, [factor_tree(i), factor_tree(n
              // i)])
    return Tree(n)
```

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3. Draw the environment diagram that results from running the following code. If the code errors, draw the environment diagram up to the point that the error occurs.

```
earth = [0]
earth.append([earth])

def wind(fire, groove):
    fire[1][0][0] = groove
    def fire():
        nonlocal fire
        fire = lambda fantasy: earth.pop(1).extend(fantasy)
        return fire(groove)
    return fire()

sep = earth[1]
wind(earth, [earth[0]] + [earth.append(0)])
```

Solution: https://goo.gl/JYwrSH

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