Linked Lists

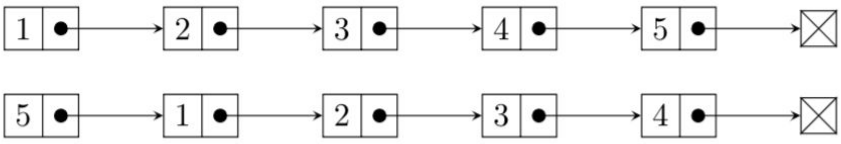
Remove All

Given a linked list, and a list of values, return a new linked list where all the links whose value exists in the list of values are removed.

```
def remove_all(lnk, vals):
    """
    >>> link = Link(1, Link(2, Link(3, Link(4, Link(5, Link(6))))))
    >>> print(link)
    <1, 2, 3, 4, 5, 6>
    >>> print(remove_all(link, [2, 4]))
    <1, 3, 5, 6>
    >>> print(remove_all(link, []))
    <1, 2, 3, 4, 5, 6>
    """
    if _____________________________________________________:
        _____________________________________________________________________
    elif _____________________________________________________:
        _____________________________________________________________________
    else:
        _____________________________________________________________________
```

Reorder

Write a function `reorder` that takes in a linked list `lst` and mutates the linked list so that the last node is now the first node. Return the head of the linked list.




```
def reorder(lst):
    prev, last = Link.empty, lst
    while last.rest is not Link.empty:
        prev = ____________________________________________________
        last = ____________________________________________________
    ____________________________________________________________
    ____________________________________________________________
    ____________________________________________________________
    return lst
```

The Giraffe of Linked-lists

Given a linked-list, lst, of positive integers, mutate the linked-list such that each link is repeated the amount of times as the number in its first attribute.

```
def elongate(lst):
      >>> list = Link(2, Link(3, Link(1)))
      >>> print(list)
      <2 3 1>
      >>> elongate(list)
      >>> print(list)
      <2 2 3 3 3 1>
      if ____________________________________________________________________________:

          ____________________________________________________________________

          for ___ in range(_____________________________________________________________):

              ________________ = ____________________________________________________
```

Trees

Remove Nodes

Implement `remove_nodes` which removes all nodes (excluding the root node) of a tree if the label of that root node returns True when the predicate `pred` is called on it. If a node is removed, all of its children are transfered to be its parents.

```
def remove_nodes(t, pred):
    """
    >>> t = Tree(1, [Tree(2), Tree(3), Tree(4, [Tree(6)]), Tree(5, [Tree(7)])])
    >>> remove_nodes(t, lambda x: x % 2 == 1)
    >>> t
    Tree(1, [Tree(2), Tree(4, [Tree(6)])])
    >>> t = Tree(6, [Tree(3, [Tree(5, [Tree(9), Tree(2, [Tree(7)])]), Tree(1)])])
    >>> remove_nodes(t, lambda x: x % 2 == 0)
    >>> t
    Tree(6, [Tree(3, [Tree(5, [Tree(9), Tree(7)]), Tree(1)])])
    """
    for ____________________________________________________________________________:

        ____________________________________________________________________

        if ____________________________________________________________________:

            t.branches.____________________________________________________________

            t.branches.____________________________________________________________
```

A Function for a Tree of Functions

Given a tree, t, that has one-parameter functions in its label attributes, a starting value n, and an ending value k, return a python list of linked-lists that contains all the paths from the root of the tree to it's leaves such that evaluating each level starting with the starting value n, results in k at the leaf.

```
def func_paths(t, n, k):
    >>> t = Tree(add_one , [Tree(square), Tree(cube)] )
    >>> func_paths(t, 3, 16)
    [Link(<function add_one>, Link(<function square>))]
    >>> func_paths(t, 0, 1)
    [Link(<function add_one>, Link(<function square>)), Link(<function add_one>, Link(<function cube>))]
    if t.is_leaf():
        if ____________________________________________________________ :
            ____________________________________________________________
        else:
            ____________________________________________________________
    paths = []
    for ____________________________________________________________:
        paths += ____________________________________________________
    return ____________________________________________________________
```

Lowest Hanging Fruit

Return the label at the lowest (greatest depth) leaf. If tie, return the leftmost one.
Calling lowest on the tree on the right would return 5.

```
def lowest(t):
    def lowest_pair(t):
        if ____________________________________________________________:
            return ____________________________________________________
        max_pair = ____________________________________________________
        ____________________________________________________________
        return ____________________________________________________
    return ____________________________________________________________
```

Fa12 Final (Adapted)

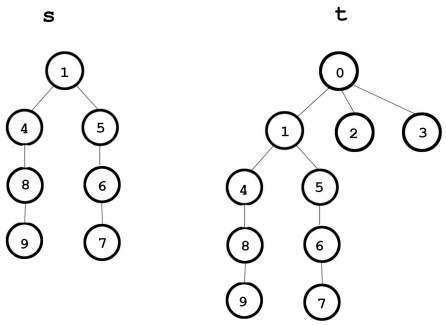
Various Longest Paths

A path through a tree is a sequence of connected nodes in which each node appears at most once. We will be solving three problems that deal with various longest paths. Below are the tree ADT functions that you'll

need. Their implementations are abstracted away. We will also be using tree `s` and tree `t`. Make sure you understand their structures before you start on the questions.

```
s = tree(1, [tree(4, [tree(8, [tree(9)])]),
             tree(5, [tree(6, [tree(7)])])])
t = tree(0, [s,
             tree(2),
             tree(3)])
>>> print_tree(s)
1
 4
  8
   9
 5
  6
   7
>>> print_tree(t)
0
 1
  4
   8
    9
  5
   6
    7
 2
 3
```

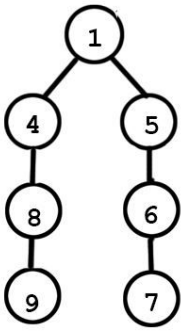
```
def tree(label, branches=[]):
    ...

def label(tree):
    ...

def branches(tree):
    ...

def is_leaf(tree):
    ...

def print_tree(tree):
    ...
```



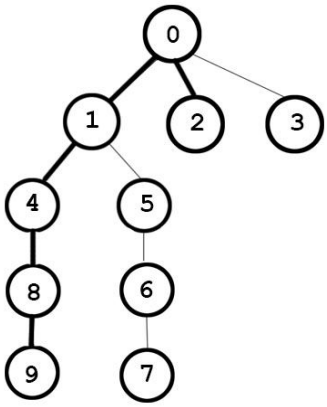
(a) Let's start with `longest_path_root_leaf`. Given a tree, return the number of nodes along the longest path from the root to a leaf. If there are multiple paths, pick the one that goes through the leftmost branch first.

```
def longest_path_root_leaf(tree):
      """ Given a tree, returns the number of nodes along the longest path from
      the root to a leaf. If there are multiple, pick the one that goes
      through the leftmost branch first.
      >>> longest_path_root_leaf(tree(1))
      1
      >>> longest_path_root_leaf(s)
      4
      >>> longest_path_root_leaf(t)
      5
      """

      if _____:

          return _____

      return _____
```

(b) We will now implement `longest_path_root`. Given a tree, return the number of nodes along the longest path between two nodes, where the longest path must go through the root. You may assume `longest_path_root_leaf` works when implementing `longest_path_root`.




```
>>> longest_path_root(s)
7
```

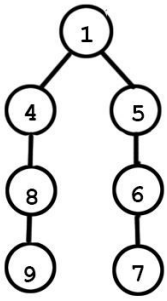



```
>>> longest_path_root(t)
6
```

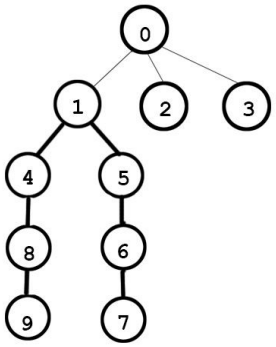
The function `second_largest` takes in a list and returns the second largest element. If the list has less than two elements, `second_largest` returns 0. Assume `second_largest` is implemented correctly and you can call `second_largest` in `longest_path_root`.
Hint: The longest path through the root can be composed of the two longest paths from the root to the leaf.

```
def second_largest(lst):
      """ Return the second largest item in a list, otherwise returns 0.
      Assume this function is already implemented and works correctly.
      >>> second_largest([3])
      0
      >>> second_largest([2, 2])
      2
      >>> second_largest([2,1,8,9,4])
      8
      """
      ...

def longest_path_root(tree):
      """ Given a tree, return the number of nodes along the longest path between
      any two nodes through the root.
      >>> longest_path_root(tree(1))
      1
      >>> longest_path_root(s)
      7
      >>> longest_path_root(t)
      6
      """

      if _____:

          return _____

      longest_paths = _____

      return _____
```

(c) Finally, let's implement `longest_path_tree`. Given a tree, return the total number of nodes along the longest path between any two nodes. The longest path does not necessarily have to go through the root. You may assume `longest_path_root` works when implementing `longest_path_tree`. If there are multiple longest paths, pick any of them.




```
>>> longest_path_root(s)
7
```




```
>>> longest_path_tree(t)
7
```

```
def longest_path_tree(tree):
    """ Given a tree, return the number of nodes along the longest path between
    any two nodes in the tree.
    >>> longest_path_tree(tree(1))
    1
    >>> longest_path_tree(s)
    7
    >>> longest_path_tree(t)
    7
    """
    if _____:

        return _____

    longest_paths_without_root = _____

    longest_path_with_root = _____

    return max(_____, _____)
```

(d) Challenge Problem: Implement `list_nodes_root_leaf`, which is exactly the same as part a, except it returns a list with the labels of the nodes themselves instead of the total number of nodes in the path.

```
def list_nodes_root_leaf(tree):
    """ Given a tree, return a list with the labels of the nodes along the longest path
    from the root to a leaf. If there are multiple, pick the one that goes
    through the left most branch first.
    >>> list_nodes_root_leaf(tree(1))
    [1]
    >>> list_nodes_root_leaf(s)
    [1, 4, 8, 9]
    >>> list_nodes_root_leaf(t)
    [0, 1, 4, 8, 9]
    """
    if _____:

        return _____

    return _____
```