Homework 5: Linked Lists, Trees, and Generators **hw05.zip (hw05.zip)**

Due by 11:59pm on Tuesday, March 17

Instructions

Submission: When you are done, submit with `python3 ok --submit`. You may submit more than once before the deadline; only the final submission will be scored. Check that you have successfully submitted your code on okpy.org (https://okpy.org/). See Lab 0 (/~cs61a/sp20/lab/lab00#submitting-the-assignment) for more instructions on submitting assignments.

Using Ok: If you have any questions about using Ok, please refer to this guide. (/~cs61a/sp20/articles/using-ok.html)

Readings: You might find the following references useful:

- Section 2.4 (http://composingprograms.com/pages/24-mutable-data.html)
- Section 2.5 (http://composingprograms.com/pages/25-object-oriented-programming.html)
- Section 4.2 (http://composingprograms.com/pages/42-implicit-sequences.html)

Grading: Homework is graded based on correctness. Each incorrect problem will decrease the total score by one point. There is a homework recovery policy as stated in the syllabus. **This homework is out of 2 points.**

Required Questions

OOP

Q1: Vending Machine

Create a class called `VendingMachine` that represents a vending machine for some product. A `VendingMachine` object returns strings describing its interactions.
Fill in the `VendingMachine` class, adding attributes and methods as appropriate, such that its behavior matches the following doctests:

```
class VendingMachine:
    """A vending machine that vends some product for some price.

    >>> v = VendingMachine('candy', 10)
    >>> v.vend()
    'Machine is out of stock.'
    >>> v.add_funds(15)
    'Machine is out of stock. Here is your $15.'
    >>> v.restock(2)
    'Current candy stock: 2'
    >>> v.vend()
    'You must add $10 more funds.'
    >>> v.add_funds(7)
    'Current balance: $7'
    >>> v.vend()
    'You must add $3 more funds.'
    >>> v.add_funds(5)
    'Current balance: $12'
    >>> v.vend()
    'Here is your candy and $2 change.'
    >>> v.add_funds(10)
    'Current balance: $10'
    >>> v.vend()
    'Here is your candy.'
    >>> v.add_funds(15)
    'Machine is out of stock. Here is your $15.'

    >>> w = VendingMachine('soda', 2)
    >>> w.restock(3)
    'Current soda stock: 3'
    >>> w.restock(3)
    'Current soda stock: 6'
    >>> w.add_funds(2)
    'Current balance: $2'
    >>> w.vend()
    'Here is your soda.'
    """
    "*** YOUR CODE HERE ***"
```

> You may find Python string formatting syntax (https://docs.python.org/2/library/stdtypes.html#str.format) useful. A quick example:

```
>>> ten, twenty, thirty = 10, 'twenty', [30]
>>> '{0} plus {1} is {2}'.format(ten, twenty, thirty)
'10 plus twenty is [30]'
```

Use Ok to test your code:

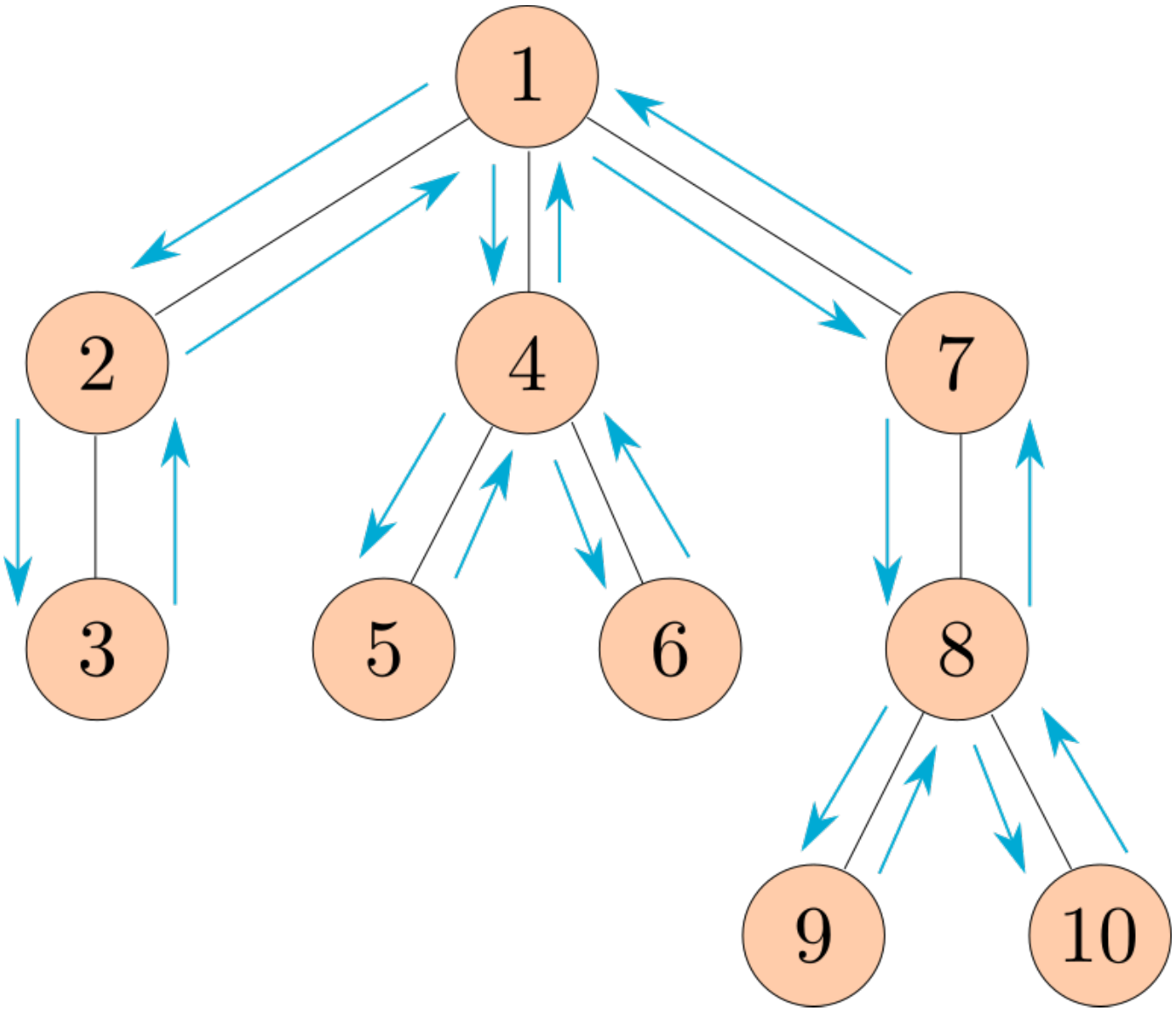
```
python3 ok -q VendingMachine
```

Trees

Q2: Preorder

Define the function `preorder`, which takes in a tree as an argument and returns a list of all the entries in the tree in the order that `print_tree` would print them.

The following diagram shows the order that the nodes would get printed, with the arrows representing function calls.



> *Note*: This ordering of the nodes in a tree is called a preorder traversal.

```
def preorder(t):
    """Return a list of the entries in this tree in the order that they
    would be visited by a preorder traversal (see problem description).

    >>> numbers = Tree(1, [Tree(2), Tree(3, [Tree(4), Tree(5)]), Tree(6, [Tree(7)])])
    >>> preorder(numbers)
    [1, 2, 3, 4, 5, 6, 7]
    >>> preorder(Tree(2, [Tree(4, [Tree(6)])]))
    [2, 4, 6]
    """
    "*** YOUR CODE HERE ***"
```

Use Ok to test your code:

```
python3 ok -q preorder
```

Linked Lists

Q3: Store Digits

Write a function `store_digits` that takes in an integer `n` and returns a linked list where each element of the list is a digit of `n`.

```
def store_digits(n):
    """Stores the digits of a positive number n in a linked list.

    >>> s = store_digits(1)
    >>> s
    Link(1)
    >>> store_digits(2345)
    Link(2, Link(3, Link(4, Link(5))))
    >>> store_digits(876)
    Link(8, Link(7, Link(6)))
    """
    "*** YOUR CODE HERE ***"
```

Use Ok to test your code:

```
python3 ok -q store_digits
```

Generators/Trees

Q4: Generate Paths

Define a generator function `generate_paths` which takes in a Tree `t`, a value `value`, and

returns a generator object which yields each path from the root of `t` to a node that has label `value`.

`t` is implemented with a class, not as the function-based ADT.

Each path should be represented as a list of the labels along that path in the tree. You may yield the paths in any order.

We have provided a (partial) skeleton for you. You do not need to use this skeleton, but if your implementation diverges significantly from it, you might want to think about how you can get it to fit the skeleton.

```
def generate_paths(t, value):
    """Yields all possible paths from the root of t to a node with the label value
    as a list.

    >>> t1 = Tree(1, [Tree(2, [Tree(3), Tree(4, [Tree(6)]), Tree(5)]), Tree(5)])
    >>> print(t1)
    1
      2
        3
        4
          6
        5
      5
    >>> next(generate_paths(t1, 6))
    [1, 2, 4, 6]
    >>> path_to_5 = generate_paths(t1, 5)
    >>> sorted(list(path_to_5))
    [[1, 2, 5], [1, 5]]

    >>> t2 = Tree(0, [Tree(2, [t1])])
    >>> print(t2)
    0
      2
        1
          2
            3
            4
              6
            5
          5
    >>> path_to_2 = generate_paths(t2, 2)
    >>> sorted(list(path_to_2))
    [[0, 2], [0, 2, 1, 2]]
    """

    "*** YOUR CODE HERE ***"

    for _________________ in _________________:
        for _________________ in _________________:

            "*** YOUR CODE HERE ***"
```

Hint: If you're having trouble getting started, think about how you'd approach this problem if it wasn't a generator function. What would your recursive calls be? With a generator function, what happens if you make a "recurisve call" within its body?

Use Ok to test your code:

```
python3 ok -q generate_paths
```

Submit

Make sure to submit this assignment by running:

```
python3 ok --submit
```

Optional Questions

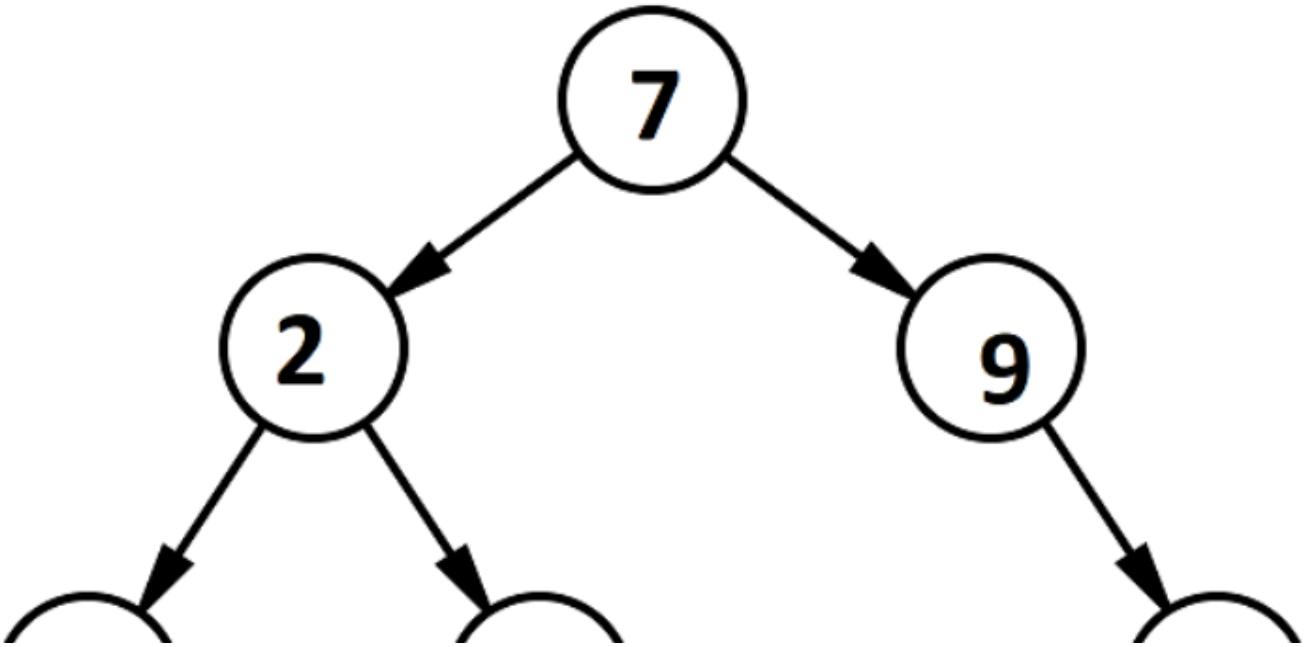
> These are recommended as review for the exam!

Q5: Is BST

Write a function `is_bst`, which takes a Tree `t` and returns `True` if, and only if, `t` is a valid binary search tree, which means that:

- Each node has at most two children (a leaf is automatically a valid binary search tree)
- The children are valid binary search trees
- For every node, the entries in that node's left child are less than or equal to the label of the node
- For every node, the entries in that node's right child are greater than the label of the node

An example of a BST is:



Note that, if a node has only one child, that child could be considered either the left or right child. You should take this into consideration.

Hint: It may be helpful to write helper functions `bst_min` and `bst_max` that return the minimum and maximum, respectively, of a Tree if it is a valid binary search tree.

```
def is_bst(t):
    """Returns True if the Tree t has the structure of a valid BST.

    >>> t1 = Tree(6, [Tree(2, [Tree(1), Tree(4)]), Tree(7, [Tree(7), Tree(8)])])
    >>> is_bst(t1)
    True
    >>> t2 = Tree(8, [Tree(2, [Tree(9), Tree(1)]), Tree(3, [Tree(6)]), Tree(5)])
    >>> is_bst(t2)
    False
    >>> t3 = Tree(6, [Tree(2, [Tree(4), Tree(1)]), Tree(7, [Tree(7), Tree(8)])])
    >>> is_bst(t3)
    False
    >>> t4 = Tree(1, [Tree(2, [Tree(3, [Tree(4)])])])
    >>> is_bst(t4)
    True
    >>> t5 = Tree(1, [Tree(0, [Tree(-1, [Tree(-2)])])])
    >>> is_bst(t5)
    True
    >>> t6 = Tree(1, [Tree(4, [Tree(2, [Tree(3)])])])
    >>> is_bst(t6)
    True
    >>> t7 = Tree(2, [Tree(1, [Tree(5)]), Tree(4)])
    >>> is_bst(t7)
    False
    """
    "*** YOUR CODE HERE ***"
```

Use Ok to test your code:

```
python3 ok -q is_bst
```

Q6: Mint

Complete the `Mint` and `Coin` classes so that the coins created by a mint have the correct year and worth.

- Each `Mint` instance has a `year` stamp. The `update` method sets the `year` stamp to the `current_year` class attribute of the `Mint` class.
- The `create` method takes a subclass of `Coin` and returns an instance of that class

stamped with the `mint`'s year (which may be different from `Mint.current_year` if it has not been updated.)

- A `Coin`'s `worth` method returns the `cents` value of the coin plus one extra cent for each year of age beyond 50. A coin's age can be determined by subtracting the coin's year from the `current_year` class attribute of the `Mint` class.

```
class Mint:
    """A mint creates coins by stamping on years.

    The update method sets the mint's stamp to Mint.current_year.

    >>> mint = Mint()
    >>> mint.year
    2020
    >>> dime = mint.create(Dime)
    >>> dime.year
    2020
    >>> Mint.current_year = 2100  # Time passes
    >>> nickel = mint.create(Nickel)
    >>> nickel.year     # The mint has not updated its stamp yet
    2020
    >>> nickel.worth()  # 5 cents + (80 - 50 years)
    35
    >>> mint.update()   # The mint's year is updated to 2100
    >>> Mint.current_year = 2175     # More time passes
    >>> mint.create(Dime).worth()    # 10 cents + (75 - 50 years)
    35
    >>> Mint().create(Dime).worth()  # A new mint has the current year
    10
    >>> dime.worth()     # 10 cents + (155 - 50 years)
    115
    >>> Dime.cents = 20  # Upgrade all dimes!
    >>> dime.worth()     # 20 cents + (155 - 50 years)
    125

    """
    current_year = 2020

    def __init__(self):
        self.update()

    def create(self, kind):
        "*** YOUR CODE HERE ***"

    def update(self):
        "*** YOUR CODE HERE ***"

class Coin:
    def __init__(self, year):
        self.year = year

    def worth(self):
        "*** YOUR CODE HERE ***"
```

```
class Nickel(Coin):
    cents = 5

class Dime(Coin):
    cents = 10
```

Use Ok to test your code:

```
python3 ok -q Mint
```

Q7: Remove All

Implement a function `remove_all` that takes a `Link`, and a `value`, and remove any linked list node containing that value. You can assume the list already has at least one node containing `value` and the first element is never removed. Notice that you are not returning anything, so you should mutate the list.

```
def remove_all(link , value):
    """Remove all the nodes containing value in link. Assume that the
    first element is never removed.

    >>> l1 = Link(0, Link(2, Link(2, Link(3, Link(1, Link(2, Link(3)))))))
    >>> print(l1)
    <0 2 2 3 1 2 3>
    >>> remove_all(l1, 2)
    >>> print(l1)
    <0 3 1 3>
    >>> remove_all(l1, 3)
    >>> print(l1)
    <0 1>
    >>> remove_all(l1, 3)
    >>> print(l1)
    <0 1>
    """
    "*** YOUR CODE HERE ***"
```

Use Ok to test your code:

```
python3 ok -q remove_all
```

Q8: Deep Map

Implement `deep_map`, which takes a function `f` and a `link`. It returns a *new* linked list with the same structure as `link`, but with `f` applied to any element within `link` or any `Link` instance contained in `link`.

The `deep_map` function should recursively apply `fn` to each of that `Link`'s elements

rather than to that `Link` itself.

Hint: You may find the built-in `isinstance` function useful. You can also use the `type(link) == Link` to check whether an object is a linked list (like you did in homework 3 question 1).

```
def deep_map(f, link):
    """Return a Link with the same structure as link but with fn mapped over
    its elements. If an element is an instance of a linked list, recursively
    apply f inside that linked list as well.

    >>> s = Link(1, Link(Link(2, Link(3)), Link(4)))
    >>> print(deep_map(lambda x: x * x, s))
    <1 <4 9> 16>
    >>> print(s) # unchanged
    <1 <2 3> 4>
    >>> print(deep_map(lambda x: 2 * x, Link(s, Link(Link(Link(5))))))
    <<2 <4 6> 8> <<10>>>
    """
    "*** YOUR CODE HERE ***"
```

Use Ok to test your code:

```
python3 ok -q deep_map
```

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