# CS 61A Fall 2019 — Lists, Mutability, ADTs, and Trees

Guerrilla Section 2: October 18, 2019

# 1 Sequences

## Questions

1.1 What would Python display?

```
lst = [1, 2, 3, 4, 5]
lst[1:3]

lst[0:len(lst)]

lst[-4:]

lst[3:]

lst[1:4:2]

lst[:4:2]

lst[1::2]

lst[::-1]

lst + 100

lst3 = [[1], [2], [3]]
lst + lst3
```

1.2 Draw the environment diagram that results from running the code below

```
def reverse(lst):
    if len(lst) <= 1:
        return lst
    return reverse(lst[1:]) + [lst[0]]

lst = [1, [2, 3], 4]
rev = reverse(lst)
```

1.3 Implement a function *map_mut* that takes a list as an argument and maps a function f onto each element of the list. You should mutate the original lists, without creating any new lists. Do NOT return anything.

```
def map_mut(f, L):
    >>> L = [1, 2, 3, 4]
    >>> map_mut(lambda x: x**2, L)
    >>> L
    [1, 4, 9, 16]
```

1.4 Check your understanding

**1** When copying the list, when are you copying a pointer of the list vs. copying the actual value inside of a list?

**2** How would you make a deep copy of a list?

# 2 Mutability

## Questions

2.1 Name two data types that are mutable. What does it mean to be mutable?

2.2 Name at least two data types at are not mutable.

2.3 Will the following code error? If so, why?

```
a = 1
b = 2
dt = {a: 1, b: 2}
```

```
a = [1]
b = [2]
dt = {a: 1, b: 2}
```

2.4 Fill in the output and draw a box-and-pointer diagram for the following code. If an error occurs, write Error, but include all output displayed before the error.

```
a = [1, [2, 3], 4]
c = a[1]
c
```

```
a.append(c)
a
```

```
c[0] = 0
c
```

```
a
```

```
a.extend(c)
c[1] = 9
a
```

```
list1 = [1, 2, 3]
list2 = [1, 2, 3]
list1 == list2
```

```
list1 is list2
```

2.5 Check your understanding:

**1** What is the difference between the append function, extend function, and the '+' operator?

**2** Given the below code, answer the following questions: a = [1, 2, [3, 4], 5]
b = a[:]
b[1] = 6
b[2][0] = 7

What does b evaluate to?

What does a evaluate to? Are a and b the same? Please explain your reasoning.

# 3 Data Abstraction

## Questions

3.1 What are the two types of functions necessary to make an Abstract Data Type? What do they do?

3.2 Assume that **rational**, **numer**, **denom**, and **gcd** run without error and behave as described below. Can you identify where the abstraction barrier is broken? Come up with a scenario where this code runs without error and a scenario where this code would stop working.

```
def rational(num, den): # Returns a rational number ADT
    #implementation not shown
def numer(x): # Returns the numerator of the given rational
    #implementation not shown
def denom(x): # Returns the denominator of the given rational
    #implementation not shown
def gcd(a, b): # Returns the GCD of two numbers
    #implementation not shown

def simplify(f1): #Simplifies a rational number
    g = gcd(f1[0], f1[1])
    return rational(numer(f1) // g, denom(f1) // g)

def multiply(f1, f2): # Multiples and simplifies two rational numbers
    r = rational(numer(f1) * numer(f2), denom(f1) * denom(f2))
    return simplify(r)

x = rational(1, 2)
y = rational(2, 3)
multiply(x, y)
```

3.3 Check your understanding

**1** How do we know what we are breaking an abstraction barrier?

**2** What are the benefits to Data Abstraction?

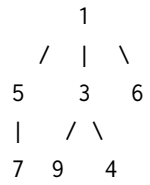
# 4 Trees

## Questions

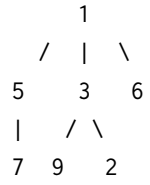
4.1 Fill in this implementation of the Tree ADT.

```
def tree(label, branches = []):
    for b in branches:
        assert is_tree(b), 'branches must be trees'
    return [label] + list(branches)

def is_tree(tree):
    if type(tree) != list or len(tree) < 1:
        return False
    for b in branches(tree):
        if not is_tree(b):
            return False
    return True

def label(tree):


def branches(tree):


def is_leaf(tree):
```

4.2 A min-heap is a tree with the special property that every nodes value is less than or equal to the values of all of its children. For example, the following tree is a min-heap:



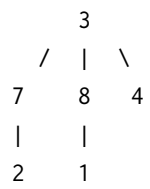

However, the following tree is not a min-heap because the node with value 3 has a value greater than one of its children:



Write a function **is_min_heap** that takes a tree and returns True if the tree is a min-heap and False otherwise.

```
def is_min_heap(t):
```

4.3 Write a function **largest_product_path** that finds the largest product path possible. A product path is defined as the product of all nodes between the root and a leaf. The function takes a tree as its parameter. Assume all nodes have a non-negative value.




For example, calling **largest_product_path** on the above tree would return 42, since 3 * 7 * 2 is the largest product path.

```
def largest_product_path(tree):
    """
    >>> largest_product_path(None)
    0
    >>> largest_product_path(tree(3))
    3
    >>> t = tree(3, [tree(7, [tree(2)]), tree(8, [tree(1)]), tree(4)])
    >>> largest_product_path(t)
    42
    """
```

4.4 Check your understanding:

**1** Given the first tree in 4.2, write the corresponding python call to create the tree

**2** What is the benefit of using a tree as a data structure, rather than a list or linked list?

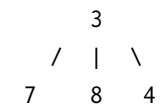
**3** Below is the function contains, which takes in an input of a tree, t and a value, e. The function returns true if e exists as a label inside t. However, the function does not work properly, debug this code and find the error(s).

```
def contains(t, e):
     if is_leaf(t):
        return False
     elif e == label(t):
        return True
     else:
        for b in branches(t):
            return contains(b, e)
        return True
```

**4** Implement a function max_tree, which takes a tree t. It returns a new tree with the exact same structure as t; at each node in the new tree, the entry is the largest number that is contained in that node's subtrees or the corresponding node in t.

```
def max_tree(t):
>>> max_tree(tree(1, [tree(5, [tree(7)]),tree(3,[tree(9),tree(4)]),tree(6)]))
    tree(9, [tree(7, [tree(7)]),tree(9,[tree(9),tree(4)]),tree(6)])
    if ___________:
        return ________________
    else:
        new_branches= _______________________________
        new_label = ___________________________________
        return ________________________
```

4.5 Challenge Question: The level-order traversal of a tree is defined as visiting the nodes in each level of a tree before moving onto the nodes in the next level. For example, the level order of the following tree is: 3 7 8 4




Write a function **level_order** that takes in a tree as the parameter and returns a list of the values of the nodes in level order.

```
def level_order(tree):
```

4.6 Challenge Question: Write a function **all_paths** which will return a list of lists of all the possible paths of an input tree, t. When the function is called on the same tree as the problem above, the function would return: $[[3, 7], [3, 8], [3, 4]]$

```
def all_paths(t):
    if _________________:
        ____________________
    else:
        ____________________
        ____________________
            ________________________
                ______________________
        ___________________
```

# 5 Nonlocal

## Questions

5.1 Draw an environment diagram for the following code:

```
spiderman = 'peter parker'
def spider(man):
    def myster(io):
        nonlocal man
        man = spiderman
        spider = lambda stark: stark(man) + ' ' +  io
        return spider
    return myster
truth = spider('quentin is')('the greatest superhero')(lambda x: x)
```

5.2 Draw an environment diagram for the following code:

```
fa = 0

def fi(fa):
    def world(cup):
        nonlocal fa
        fa = lambda fi: world or fa or fi
        world = 0
        if (not cup) or fa:
            fa(2022)
            fa, cup = world + 2, fa
            return cup(fa)
        return fa(cup)
    return world

won = lambda opponent, x: opponent(x)
us = won(fi(fa), 2019)
```

5.3 Write **make_max_finder**, which takes in no arguments but returns a function which takes in a list. The function it returns should return the maximum value it's been called on so far, including the current list and any previous list. You can assume that any list this function takes in will be nonempty and contain only non-negative values.

```
def make_max_finder():
    """
        >>> m = make_max_finder()
        >>> m([5, 6, 7])
        7
        >>> m([1, 2, 3])
        7
        >>> m([9])
        9
        >>> m2 = make_max_finder()
        >>> m2([1])
        1
        """
```

5.4 Check your understanding:

```
x = 5
def f(x):
    def g(s):
        def h(h):
            nonlocal x
            x = x + h
            return x
        nonlocal x
        x = x + x
        return h
print(x)
return g
t = f(7)(8)(9)
```

a. What is t after the code is executed?

b. In the h frame, which x is being referenced? Which frame?

c. In the g frame, is a new variable x being created?

# 6 OOP

## Questions

6.1 What is the relationship between a class and an ADT?

6.2 What is the definition of a Class? What is the definition of an Instance?

6.3 What is a Class Attribute? What is an Instance Attribute?

6.4 What Would Python Display?

```
class Foo():
    x = 'bam'
    def __init__(self, x):
        self.x = x
    def baz(self):
        return self.x

class Bar(Foo):
        x = 'boom'
        def __init__(self, x):
                Foo.__init__(self, 'er' + x)
        def baz(self):
                return Bar.x + Foo.baz(self)

foo = Foo('boo')

Foo.x

foo.x

foo.baz()

Foo.baz()

Foo.baz(foo)

bar = Bar('ang')
Bar.x

bar.x

bar.baz()
```

6.5 What Would Python Display?

```
class Student:
        def __init__(self, subjects):
                self.current_units = 16
                self.subjects_to_take = subjects
                self.subjects_learned = {}
                self.partner = None

        def learn(self, subject, units):
                print('I just learned about ' + subject)
                self.subjects_learned[subject] = units
                self.current_units -= units

        def make_friends(self):
                if len(self.subjects_to_take) > 3:
                        print('Whoa! I need more help!')
                        self.partner = Student(self.subjects_to_take[1:])
                else:
                        print("I'm on my own now!")
                        self.partner = None

        def take_course(self):
                course = self.subjects_to_take.pop()
                self.learn(course, 4)
                if self.partner:
                        print('I need to switch this up!')
                        self.partner = self.partner.partner
                        if not self.partner:
                                print('I have failed to make a friend :(')

tim = Student(['Chem1A', 'Bio1B', 'CS61A', 'CS70', 'CogSci1'])
tim.make_friends()

print(tim.subjects_to_take)

tim.partner.make_friends()

tim.take_course()

tim.partner.take_course()

tim.take_course()

tim.make_friends()
```

6.6 Fill in the implementation for the Cat and Kitten classes. When a cat meows, it should say "Meow, (name) is hungry" if it is hungry, and "Meow, my name is (name)" if not. Kittens do the same thing as cats, except they say "i'm baby" instead of "meow", and they say "I want mama (parents name)" after every call to meow().

```
>>>cat = Cat('Tuna')
>>>kitten = kitten('Fish', cat)
>>>cat.meow()
meow, Tuna is hungry
>>>kitten.meow()
i'm baby, Fish is hungry
I want mama Tuna
>>>cat.eat()
meow
>>>cat.meow()
meow, my name is Tuna
>>>kitten.eat()
i'm baby
>>>kitten.meow()
meow, my name is Fish
I want mama Tuna

class Cat():
     noise = 'meow'
     def __init__(self, name):









     def meow(self):









     def eat(self):
          print(self.noise)
          self.hungry = False

class Kitten(Cat):
```

# 7 Object Oriented Trees

## Questions

7.1 Define **filter_tree**, which takes in a tree **t** and one argument predicate function **fn**. It should mutate the tree by removing all branches of any node where calling **fn** on its label returns **False**. In addition, if this node is not the root of the tree, it should remove that node from the tree as well.

```
def filter_tree(t, fn):
    """
    >>> t = Tree(1, [Tree(2), Tree(3, [Tree(4)]), Tree(6, [Tree(7)])])
    >>> filter_tree(t, lambda x: x % 2 != 0)
    >>> t
    tree(1, [Tree(3)])
    >>> t2 = Tree(2, [Tree(3), Tree(4), Tree(5)])
    >>> filter_tree(t2, lambda x: x != 2)
    >>> t2
    Tree(2)
    """
```

7.2 Fill in the definition for **nth_level_tree_map**, which also takes in a function and a tree, but mutates the tree by applying the function to every nth level in the tree, where the root is the 0th level.

```
def nth_level_tree_map(fn, tree, n):
   """Mutates a tree by mapping a function all the elements of a tree.
   >>> tree = Tree(1, [Tree(7, [Tree(3), Tree(4), Tree(5)]),
                Tree(2, [Tree(6), Tree(4)])])
   >>> nth_level_tree_map(lambda x: x + 1, tree, 2)
   >>> tree
   Tree(2, [Tree(7, [Tree(4), Tree(5), Tree(6)]),
            Tree(2, [Tree(7), Tree(5)])])
   """
```

# Check Your Understanding

7.1 Why can we mutate trees using the Tree class? How does the Tree class differ from the Tree ADT?

7.2 How do you guarantee that your code does not recurse forever? Do we need an explicit base case?

# 8 Linked Lists

## Questions

8.1 What is a linked list? Why do we consider it a naturally recursive structure?

8.2 Draw a box and pointer diagram for the following:

```
Link('c', Link(Link(6, Link(1, Link('a'))), Link('s')))
```

8.3 The Link class can represent lists with cycles. That is, a list may contain itself as a sublist. Implement **has_cycle** that returns whether its argument, a Link instance, contains a cycle. There are two ways to do this: iteratively with two pointers, or keeping track of Link objects we've seen already. Try to come up with both!

```
def has_cycle(link):
    """
    >>> s = Link(1, Link(2, Link(3)))
    >>> s.rest.rest.rest = s
    >>> has_cycle(s)
    True
    """
```

8.4 Fill in the following function, which checks to see if **sub_link**, a particular sequence of items in one linked list, can be found in another linked list (the items have to be in order, but not necessarily consecutive).

```
def seq_in_link(link, sub_link):
    """
    >>> lnk1 = Link(1, Link(2, Link(3, Link(4))))
    >>> lnk2 = Link(1, Link(3))
    >>> lnk3 = Link(4, Link(3, Link(2, Link(1))))
    >>> seq_in_link(lnk1, lnk2)
    True
    >>> seq_in_link(lnk1, lnk3)
    False
    """
```

## Check Your Understanding

8.1 What can go in the first box of a linked list? What can go in the second?

8.2 For question 2, why do we need to store the linked list first in our code? Why can't we just iterate through it? Why can we iterate through the linked list without storing it in question 3?

# 9 Iterators and Generators

## Questions

9.1 What is the definition of an iterable? What is the definition of an iterator? What is the definition of a generator? What built-in functions or keywords are associated with each. Give an example of each.

9.2 Evaluate if each line is valid? If not, state the error and how you would fix it.

```
>>> new_list = [2, 3, 6, 8, 8, 3]
>>> next(new_list)
```

```
>>> iter(new_list)[1]
```

```
>>> [x for x in iter(new_list)]
```

```
>>> for i in range(len(iter(new_list))):
...             new_list.append(2)
```

9.3 What is the difference between these two statements?

a.
```
def infinity1(start):
        while True:
                start = start + 1
                return start
```

b.
```
def infinity2(start):
        while True:
                start = start + 1
                yield start
```

What would python display?

```
>>> infinity1

>>> infinity2

>>> infinity1(2)

>>> infinity2(2)

>>> x = infinity1(2)

>>> next(x)

>>> y = infinity2(2)

>>> next(y)

>>> next(y)

>>> next(infinity2(2))
```

9.4 They can't stop all of us!!! Write a function **generate_constant** which, a generator function that repeatedly yields the same value forever.

```
def generate_constant(x):
        """A generator function that repeats the same value x forever.
        >>> area = generate_constant(51)
        >>> next(area)
        51
        >>> next(area)
        51
        >>> sum([next(area) for _ in range(100)])
        5100
        """
```

9.5 4.2 Now implement **black_hole** , a generator that yields items in seq until one of them matches trap, in which case that value should be repeated yielded forever. You may assume that **generate_constant** works. You may not index into or slice seq.

```
def black_hole(seq, trap):
        """A generator that yields items in SEQ until one of them matches TRAP, in which case that
    value        should be repeatedly yielded forever.
        >>> trapped = black_hole([1, 2, 3], 2)
        >>> [next(trapped) for _ in range(6)]
        [1, 2, 2, 2, 2, 2]
        >>> list(black_hole(range(5), 7))
        [0, 1, 2, 3, 4]
        """
```

9.6 What Would Python Display?

```
>>> def weird_gen(x):
...     if x % 2 == 0:
...       yield x * 2
>>> wg = weird_gen(2)
>>> next(wg)
>>> next(weird_gen(2))
```

```
>>> next(wg)
```

```
>>> def greeter(x):
...   while x % 2 != 0:
...     print('hi')
...     yield x
...     print('bye')
>>> greeter(5)
```

```
>>> gen = greeter(5)
>>> g = next(gen)

>>> g = (g, next(gen))
>>> g
```

```
>>> next(gen)
```

```
>>> next(g)
```

An iterator _____ a generator

A generator **is** a(n) _____ iterator

9.7 Write a generator function **gen_inf** that returns a generator which yields all the numbers in the provided list one by one in an infinite loop.

```
>>> t = gen_inf([3, 4, 5])
>>> next(t)
3
>>> next(t)
4
>>> next(t)
5
>>> next(t)
3
>>> next(t)
4
def gen_inf(lst):
```

9.8 Implement a generator function called `filter(iterable, fn)` that only yields elements of iterable for which fn returns True.

```
def naturals():
        i = 1
        while True:
                yield i
                i += 1


def filter(iterable, fn):
    """
    >>> is_even = lambda x: x % 2 == 0
    >>> list(filter(range(5), is_even))
    [0 , 2 , 4]
    >>> all_odd = (2*y-1 for y in range (5))
    >>> list(filter(all_odd, is_even))
    []
    >>> s = filter(naturals(), is_even)
    >>> next(s)
    2
    >>> next(s)
    4
    """
```

9.9 What could you use a generator for that you could not use a standard iterator paired with a function for?

9.10 Define **tree_sequence**, a generator that iterates through a tree by first yielding the root value and then yielding the values from each branch.

```
def tree_sequence(t):
        """
        >>> t = tree(1, [tree(2, [tree(5)]), tree(3, [tree(4)])])
        >>> print(list(tree_sequence(t)))
        [1, 2, 5, 3, 4]
        """
```

9.11 Write a function **make_digit_getter** that, given a positive integer n, returns a new function that returns the digits in the integer one by one, starting from the rightmost digit.

Once all digits have been removed, subsequent calls to the function should return the sum of all the digits in the original integer.

```
def make_digit_getter(n):
        """ Returns a function that returns the next digit in n
        each time it is called, and the total value of all the integers
        once all the digits have been returned.
        >>> year = 8102
        >>> get_year_digit = make_digit_getter(year)
        >>> for _ in range(4):
        ... print(get_year_digit())
        2
        0
        1
        8
        >>> get_year_digit()
        11
        """
```

9.12 Sorry another environment diagram, but it's the last one I promise.

```
def iter(iterable):
    def iterator(msg):
        nonlocal iterable
        if msg == 'next':
            next = iterable[0]
            iterable = iterable[1:]
            return next
        elif msg == 'stop':
            raise StopIteration
    return iterator
def next(iterator):
    return iterator('next')
def stop(iterator):
    iterator('stop')

lst = [1, 2, 3]
iterator = iter(lst)
elem = next(iterator)
```