1 Recursion and Tree Recursion

Questions

1.1 What are three things you find in every recursive function?

1) Base Case(s)
2) Way(s) to reduce the problem into a smaller problem of the same type
3) Recursive case(s) that uses the solution of the smaller problem to solve the original (large) problem

1.2 When you write a Recursive function, you seem to call it before it has been fully defined. Why doesn’t this break the Python interpreter?

When you define a function, Python does not evaluate the body of the function.

1.3 The domain is the type of data that a function takes in as argument. The range is the type of data that a function returns. For example, the domain of the function square is numbers. The range is numbers. Below is a Python function that computes the nth Fibonacci number. What’s its domain and range? Also identify the three things it contains as a recursive function (from 1.1).

```python
def fib(n):
    if n == 0:
        return 0
    elif n == 1:
        return 1
    else:
        return fib(n-1) + fib(n-2)
```

Domain is integers, range is integers.
Base Cases: if n == 0: ..., elif n == 1: ...
Finding Smaller Problems: finding fib(n - 1), fib(n - 2)
Recursive Case: when n is neither 0 nor 1, add together the fib(n - 1) and fib(n - 2) to find fib(n)

1.4 With the definition of the Fibonacci function above, draw out a diagram of the recursive calls made when fib(4) is called.

```
         fib(4)
        /   \
       fib(3) fib(2)
      /    |    \ 
     fib(2) fib(1) fib(0) 
    /     |     |
   /     fib(1) fib(1) fib(0)
```

1.5 What does the following function \texttt{cascade2} do? What is its domain and range?

\begin{verbatim}
def cascade2(n):
    print(n)
    if n >= 10:
        cascade2(n//10)
    print(n)
\end{verbatim}

Domain is integers, range is None. It takes in a number \( n \) and prints out \( n \), then prints out \( n \) excluding the ones digit, then prints \( n \) excluding the hundreds digit, and so on, then back up to the full number.

1.6 What does each of the following functions do?

\begin{verbatim}
def mystery(n):
    if n == 0:
        return 0
    else:
        return n + mystery(n - 1)
def foo(n):
    if n <= 1:
        return n
    return foo(n - 2) + foo(n - 1)
def fooply(n):
    if n < 0:
        return 0
    return foo(n) + fooply(n - 1)
\end{verbatim}

sums positive integers up to \( n \) \((1 + 2 + \ldots + n)\)

returns the \( n \)th Fibonacci number

returns the sum of the first \( n \) Fibonacci numbers.
2 Higher Order Functions

Questions

2.1 What do lambda expressions do? Can we write all functions as lambda expressions? In what cases are lambda expressions useful?

Lambda expressions create functions. When a lambda expression is evaluated, it produces a function. We often use lambdas to create short anonymous functions that we won’t need for too long.

We can’t write all functions as lambda expressions because lambda functions all have to have `return` statements and they can’t contain very complex multi-line expressions.

2.2 Determine if each of the following will error:

```python
>>> 1/0
Error

>>> boom = lambda: 1/0
No error, since we don’t evaluate the body of the lambda when we define it.

>>> boom()
Error
```

2.3 Express the following lambda expression using a `def` statement, and the `def` statement using a lambda expression.

```python
pow = lambda x, y: x**y

def pow(x, y):
    return x**y

def foo(x):
    def f(y):
        def g(z):
            return x + y * z
        return g
    return f

foo = lambda x: lambda y: lambda z: x + y * z
```
2.4 Draw Environment Diagrams for the following lines of code

```python
square = lambda x: x * x
higher = lambda f: lambda y: f(f(y))
higher(square)(5)
```

Solution: https://goo.gl/LATqV9

```python
a = (lambda f, a: f(a))(lambda b: b * b, 2)
```

Solution: https://goo.gl/TyriuP
2.5 Write `make_skipper` which takes in a number `n` and outputs a function. When this function takes in a number `x`, it prints out all the numbers between 0 and `x`, skipping every `n`th number (meaning skip any value that is a multiple of `n`).

```python
def make_skipper(n):
    """
    >>> a = make_skipper(2)
    >>> a(5)
    1
    3
    5
    ""

    def skipper(x):
        for i in range(x + 1):
            if i % n != 0:
                print(i)
    return skipper
```

2.6 Write `make_alternator` which takes in two functions, `f` and `g`, and outputs a function. When this function takes in a number `x`, it prints out all the numbers between 1 and `x`, applying the function `f` to every odd-indexed number and `g` to every even-indexed number before printing.

```python
def make_alternator(f, g):
    """
    >>> a = make_alternator(lambda x: x * x, lambda x: x + 4)
    >>> a(5)
    1
    6
    9
    8
    25
    >>> b = make_alternator(lambda x: x * 2, lambda x: x + 2)
    >>> b(4)
    2
    4
    6
    6
    ""

    def alternator(n):
        i = 1
        while i <= n:
            if i % 2 == 1:
                print(f(i))
            else:
                print(g(i))
```
\[ i \leftarrow i + 1 \]

return alternator