1 Higher-Order Functions

A higher order function (HOF) is a function that manipulates other functions by taking in functions as arguments, returning a function, or both.

Functions as Arguments

One way a higher order function can manipulate other functions is by taking functions as input (an argument). Consider this higher order function called `negate`.

`negate` takes a function `f` and a number `x`. It doesn’t care what exactly `f` does, as long as `f` is a function, takes in a number and returns a number. Its job is simple: call `f` on `x` and return the negation of that value.

Questions

1.1 Here are some possible functions that can be passed through as `f`.

```python
def square(n):
    return n * n

def double(n):
    return 2 * n
```

What will the following Python statements display?

```python
>>> negate(square, 5)
-25

>>> negate(double, -19)
38

>>> negate(double, negate(square, -4))
32
```

Functions as Return Values

Often, we will need to write a function that returns another function. One way to do this is to define a function inside of a function:

```python
def outer(x):
    def inner(y):
        ...
        return inner
```

```python
def inner(y):
    ...
    return inner
```
Higher-Order Functions

The return value of `outer` is the function `inner`. This is a case of a function returning a function. In this example, `inner` is defined inside of `outer`. Although this is a common pattern, we can also define `inner` outside of `outer` and still use the same `return` statement. However, note that in this second example (unlike the first example), `inner` doesn't have access to variables defined within the `outer` function, like `x`.

Questions

1.1 Use this definition of `outer` to fill in what Python would display when the following lines are evaluated.

```python
def outer(n):
    def inner(m):
        return n - m
    return inner

>>> outer(61)
<function outer.inner ...>

>>> f = outer(10)
>>> f(4)
6

>>> outer(5)(4)
1
```

1.2 Write a function `and_add` that takes a one-argument function `f` and a number `n` as arguments. It should return a function that takes one argument, and does the same thing as the function `f`, except also adds `n` to the result.

```python
def and_add(f, n):
    """Return a new function. This new function takes an argument x and returns f(x) + n."

    >>> def square(x):
    ...     return x * x
    ...     return x
    >>> new_square = and_add(square, 3)
    >>> new_square(4)  # 4 * 4 + 3
    19
    """

def g(x):
    return f(x) + n
return g
```
Environment Diagrams

1.1 Draw the environment diagram for the following code:

```python
def curry2(h):
    def f(x):
        def g(y):
            return h(x, y)
        return g
    return f

make_adder = curry2(lambda x, y: x + y)
add_three = make_adder(3)
five = add_three(2)
```
1.2 Draw the environment diagram that results from running the following code:

```python
n = 7

def f(x):
    n = 8
    return x + 1

def g(x):
    n = 9
    def h():
        return x + 1
    return h

def f(f, x):
    return f(x + n)

f = f(g, n)
g = (lambda y: y())(f)
```

![Environment Diagram](image)
The following question is extremely difficult. Something like this would not appear on the exam. Nonetheless, it’s a fun problem to try.

Draw the environment diagram for the following code: (Note that using the + operator with two strings results in the second string being appended to the first. For example "C" + "S" concatenates the two strings into one string "CS")

```python
y = "y"
h = y
def y(y):
    h = "h"
    if y == h:
        return y + "i"
    y = lambda y: y(h)
    return lambda h: y(h)
y = y(y)(y)
```