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 in 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)
```

```python
>>> negate(double, -19)
```

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

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:

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`.

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

def inner(y):
    ...

def outer(x):
    return inner
```
Questions

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

\begin{verbatim}
def outer(n):
    def inner(m):
        return n - m
    return inner

>>> outer(61)

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

>>> outer(5)(4)
\end{verbatim}

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

\begin{verbatim}
def and_add(f, n):
    """Return a new function. This new function takes an argument \texttt{x} and returns \texttt{f(x) + n}."
    return lambda x: f(x) + n

>>> def square(x):
...     return x * x
...     return square
>>> new_square = and_add(square, 3)
>>> new_square(4) # 4 * 4 + 3
19
"""
\end{verbatim}
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
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)
```

4  Higher-Order Functions
1.3 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)
```

```