Environments

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Class outline:

- Multiple environments
- Environments for HOFs
- Local names
- Function composition
- Self-referencing functions
- Currying

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Multiple Environments

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Life cycle of a function

		What happens?
Def statement	`def square( x ):` `  return x * x`	• A new function is created! • Name bound to that function in the current frame
Call expression	`square( 2 + 2 )`	• Operator & operands evaluated • Function (value of operator) called on arguments (values of operands)
Calling/applying	4 ▶ `def square( x )` ▶ 16	• A new frame is created! • Parameters bound to arguments • Body is executed in that new environment

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A nested call expression

1.
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```
def square(x):
    return x * x
square(square(3))
```

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```

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```
def square(x):
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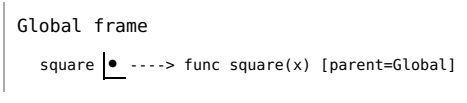
square(square(3))
```



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square(square(3))
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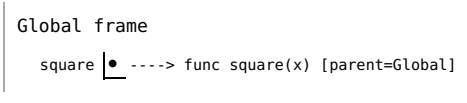

```
square( square(3) )
```

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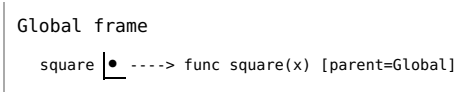

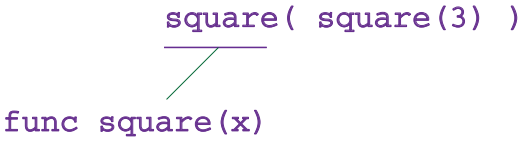

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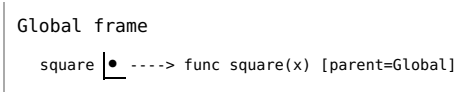

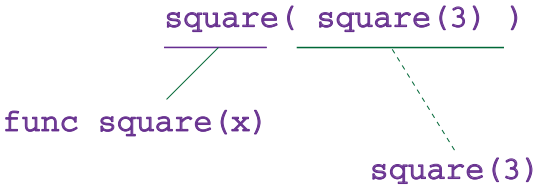

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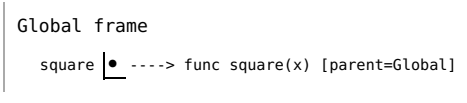

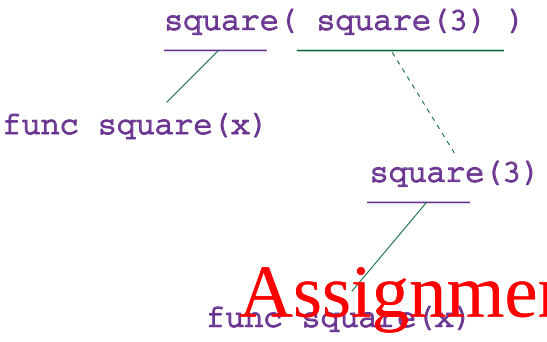

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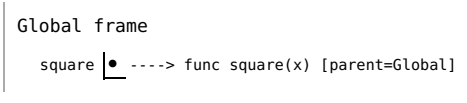
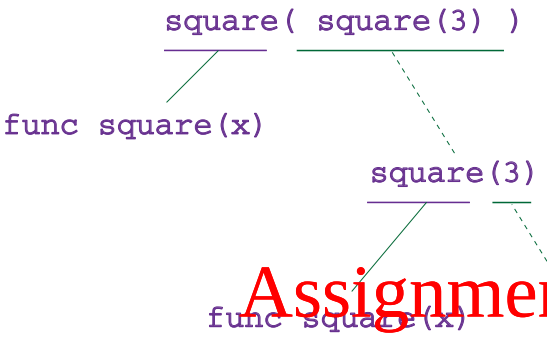
```





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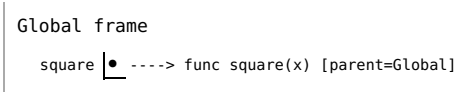

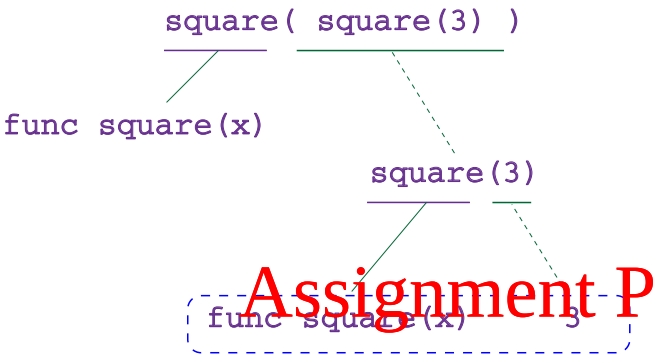

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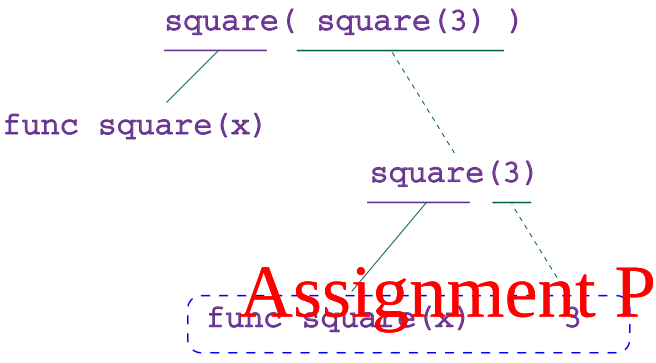

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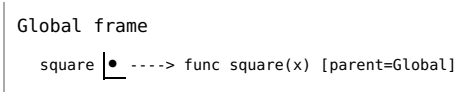

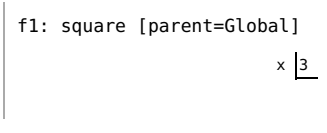

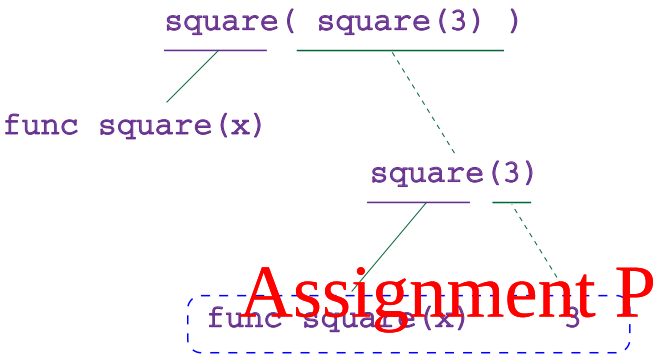

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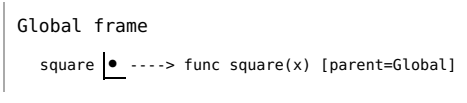

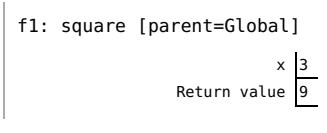

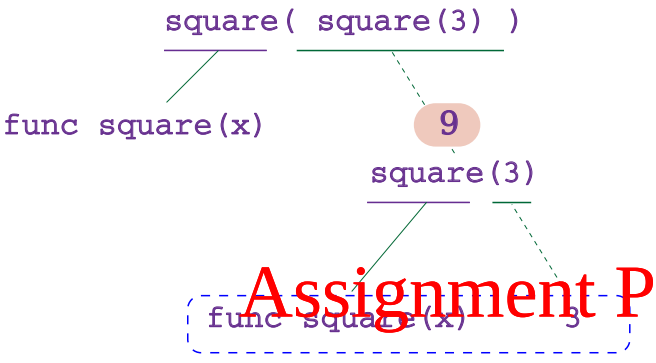

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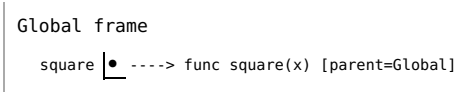

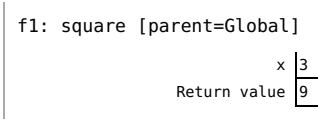

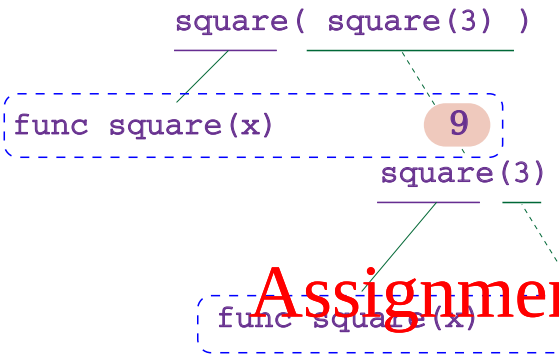

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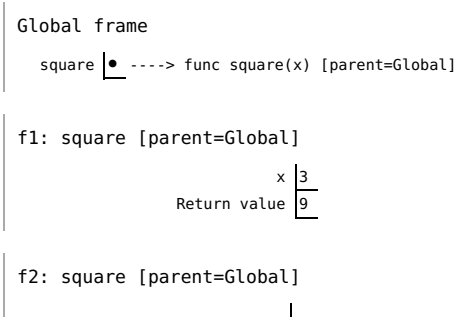

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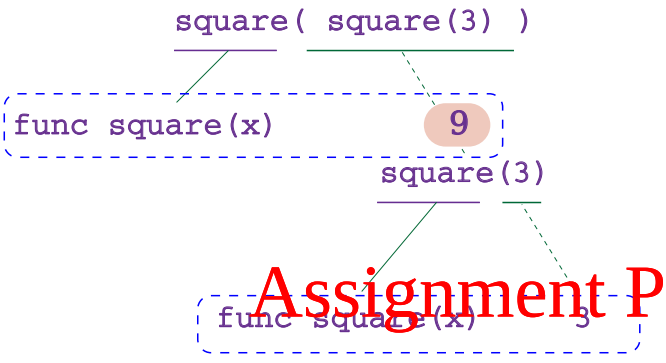

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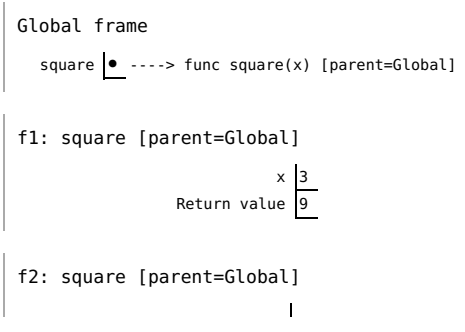

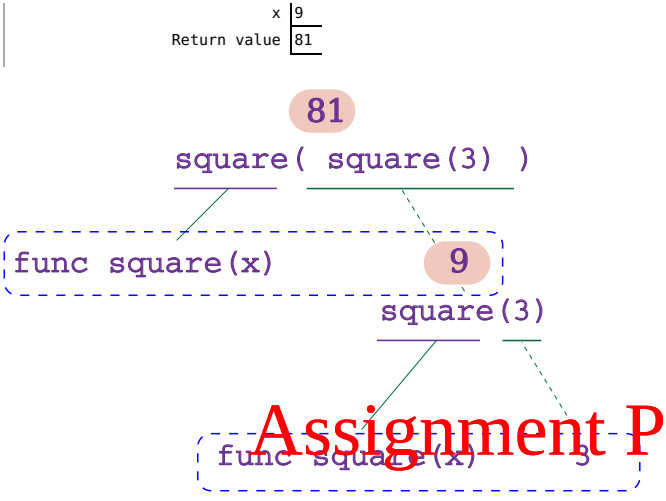

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Multiple environments in one diagram!

```
def square(x):
    return x * x
square(square(3))
```

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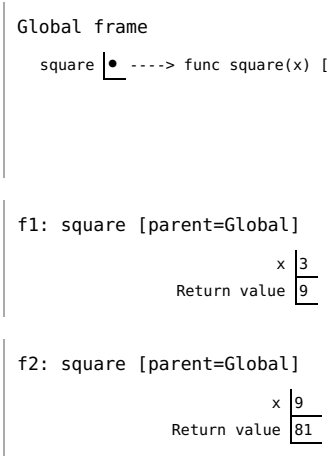

An environment is a sequence of frames.

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Multiple environments in one diagram!

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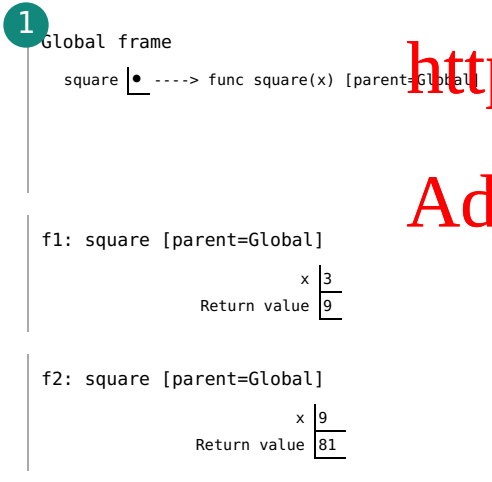

An environment is a sequence of frames.

- Environment: Global frame

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Multiple environments in one diagram!

```
def square(x):
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square(square(3))
```

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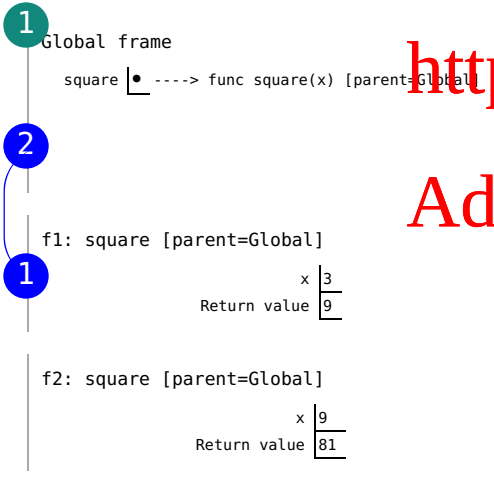

An environment is a sequence of frames.

- Environment: Global frame
- Environment: Local frame (f1), then global frame

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Multiple environments in one diagram!

```
def square(x):
    return x * x
square(square(3))
```

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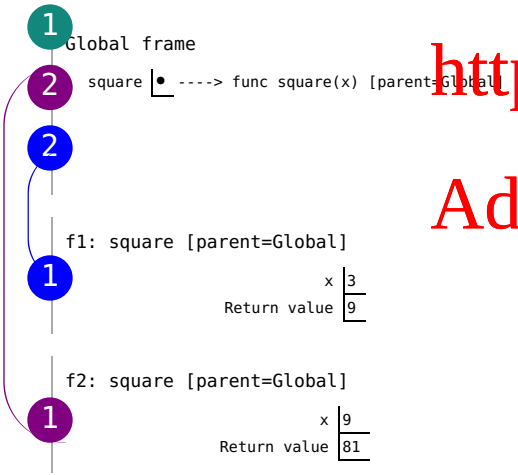

An environment is a sequence of frames.

- Environment: Global frame
- Environment: Local frame (f1), then global frame
- Environment: Local frame (f2), then global frame

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Names have no meanings without environments

```
def square(x):
    return x * x
square(square(3))
```

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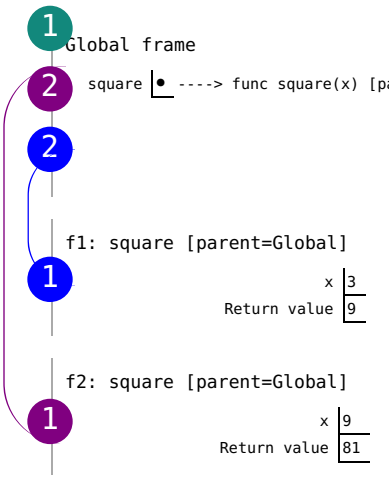

Every expression is evaluated in the context of an environment.

A name evaluates to the value bound to that name in the earliest frame of the current environment in which that name is found.

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Names have different meanings in different environments

```
def square(square):
    return square * square
square(4)
```

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Every expression is evaluated in the context of an environment.

A name evaluates to the value bound to that name in the earliest frame of the current environment in which that

Names have different meanings in different environments

```
def square(square):
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square(4)
```

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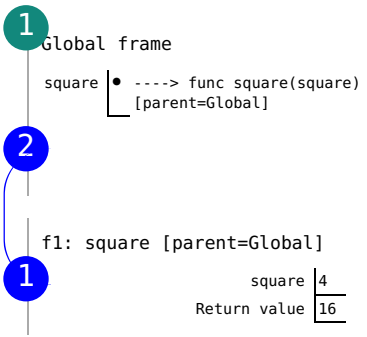

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Every expression is evaluated in the context of an environment.

A name evaluates to the value bound to that name in the earliest frame of the current environment in which that

Environments for higher-order functions

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Review: Higher-order functions

A higher-order function is either...

- A function that takes a function as an argument value
  `summation(5, lambda x: x**2)`
- A function that returns a function as a return value
  `make_adder(3)(1)`

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Functions are first class: Functions are values in Python.

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Example: Apply twice

```
def apply_twice(f, x):
    return f(f(x))

def square(x):
    return x ** 2

apply_twice(square, 3)
```

View in Pythontutor

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Arguments bound to functions

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Arguments bound to functions

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Arguments bound to functions

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Environments for nested definitions

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Example: Make texter

```
def make_texter(emoji):
    def texter(text):
        return emoji + text + emoji
    return texter

happy_text = make_texter("😁")
result = happy_text("lets go to the beach!")
```

View in Pythontutor

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Environments for nested def statements

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Environments for nested def statements

- Every user-defined **function** has a parent frame
- The parent of a **function** is the **frame in which it was defined**

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Environments for nested def statements

- Every user-defined **function** has a parent frame
- The parent of a **function** is the **frame in which it was defined**
- Every local **frame** has a parent frame
- The parent of a **frame** is the **parent of the called function**

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Environments for nested def statements

- Every user-defined **function** has a parent frame
- The parent of a **function** is the **frame in which it was defined**
- Every local **frame** has a parent frame
- The parent of a **frame** is the **parent of the called function**
- An environment is a **sequence of frames**.

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How to draw an environment diagram

When a function is defined:

1. Create a function value:
   `func <name>(<formal parameters>) [parent=<label>]`
2. Its parent is the current frame.
3. Bind `<name>` to the function value in the current frame

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When a function is called:

1. Add a local frame titled with the `<name>` of the function being called.
2. Copy the parent of the function to the local frame:
   `[parent=>label<]`
3. Bind the `<formal parameters>` to the arguments in the local frame.
4. Execute the body of the function in the environment that starts with the local frame.

Local names

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Example: Thingy Bobber

```
def thingy(x, y):
    return bobber(y)

def bobber(a):
    return a + y

result = thingy("ma", "jig")
```

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What do you think will happen?

Example: Thingy Bobber

```
def thingy(x, y):
    return bobber(y)

def bobber(a):
    return a + y

result = thingy("ma", "jig")
```

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What do you think will happen?

View in PythonTutor

Local name visibility

Local names are not visible to other (non-nested) functions.

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- An environment is a sequence of frames.
- The environment created by calling a top-level function consists of one local frame followed by the global frame.

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Function Composition

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Example: Composer

```
def happy(text):
    return "☻" + text + "☻"

def sad(text):
    return "☹" + text + "☹"

def composer(f, g):
    def composed(x):
        return f(g(x))
    return composed

msg1 = composer(sad, happy)("cs61a!")
msg2 = composer(happy, sad)("eecs16a!")
```

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What do you think will happen?

Example: Composer (Part 2)

One of the composed functions could itself be an HOF...

```
def happy(text):
    return "☻" + text + "☻"

def sad(text):
    return "☹" + text + "☹"

def make_texter(emoji):
    def texter(text):
        return emoji + text + emoji
    return texter

def composer(f, g):
    def composed(x):
        return f(g(x))
    return composed

composer(happy, make_texter("☃"))('snow day!')
```

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Composer 2 expression tree

```
composer(happy, make_texter("☃"))("snow day!")
```

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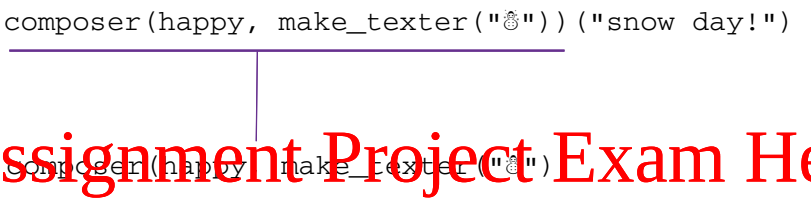

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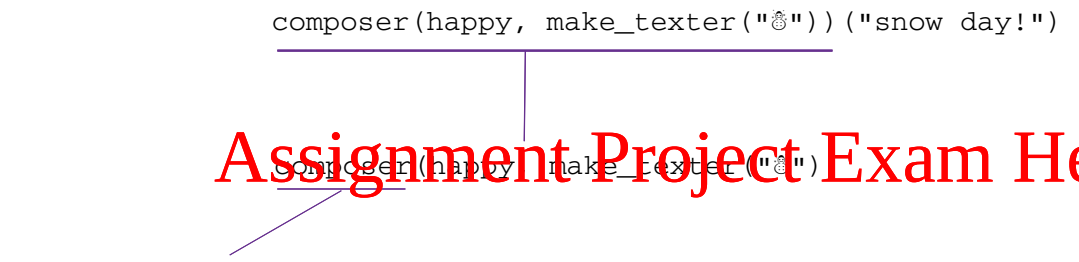

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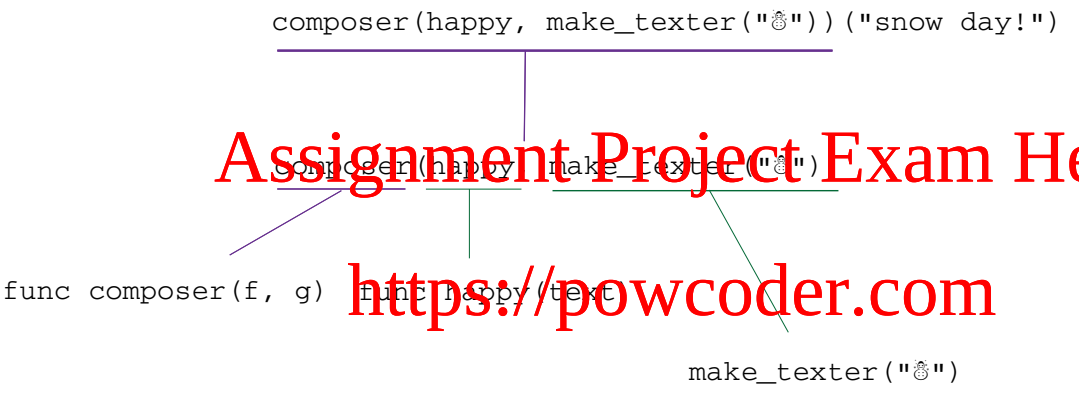

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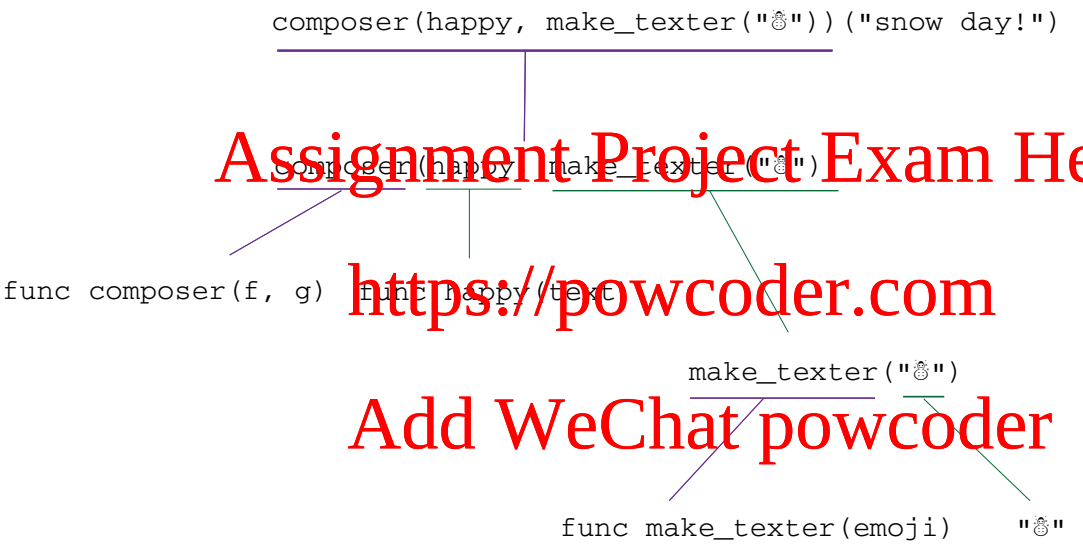

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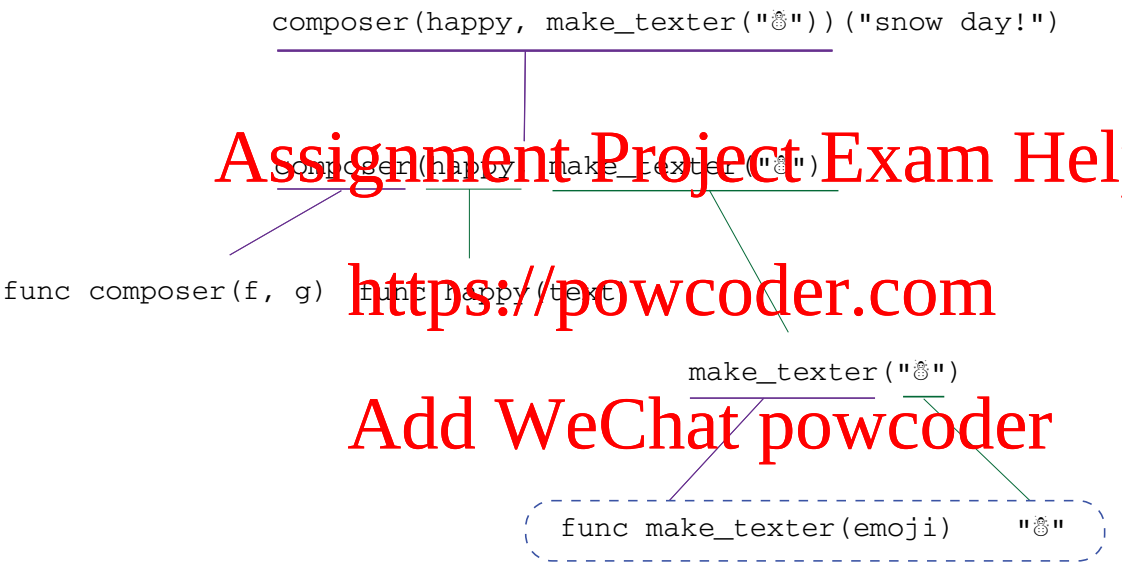

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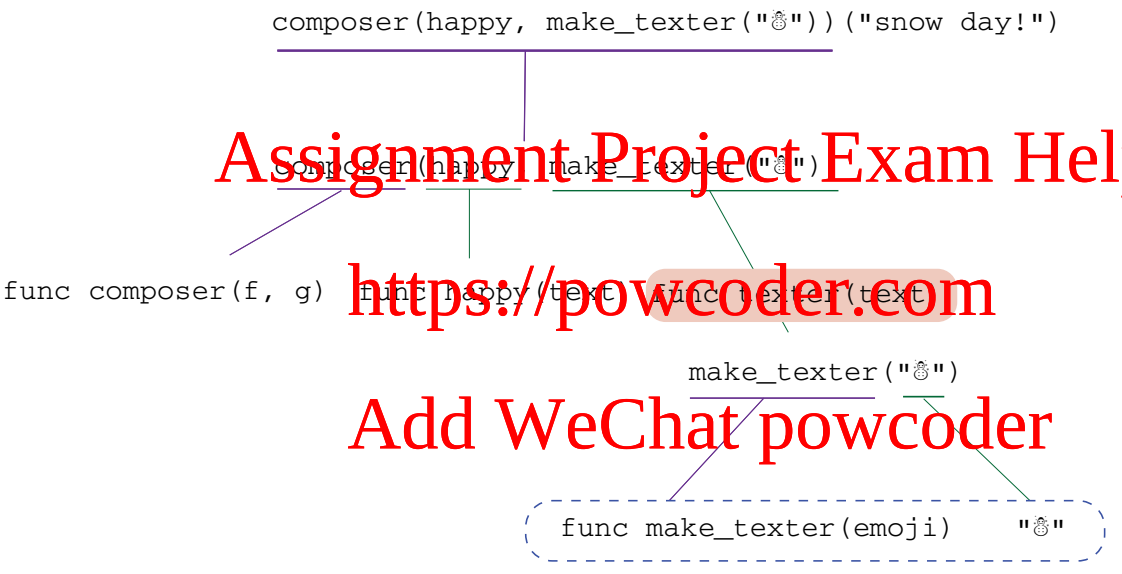

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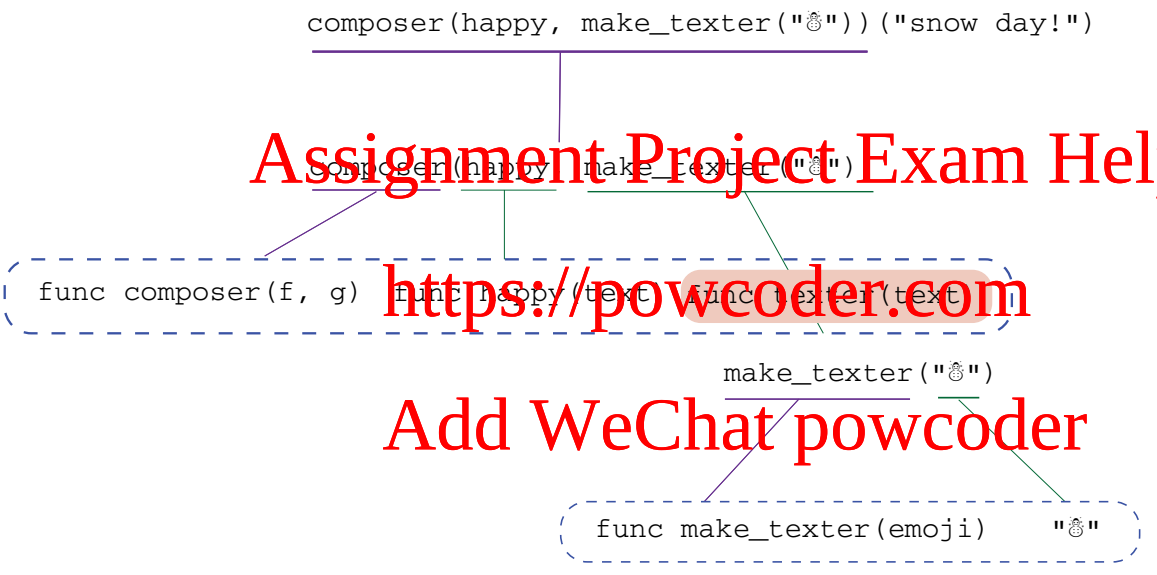

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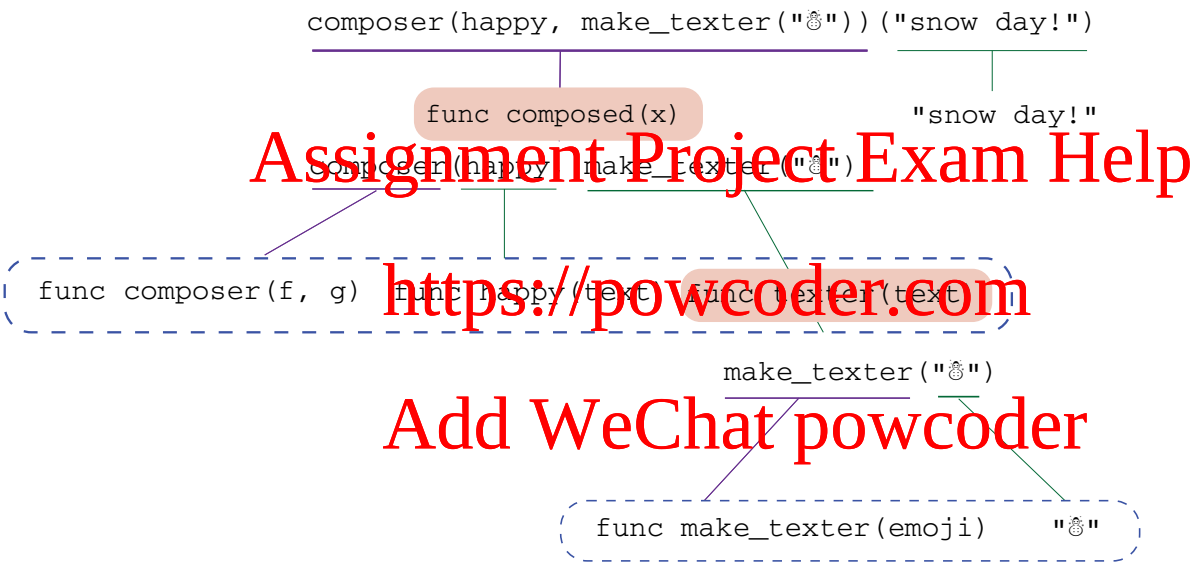

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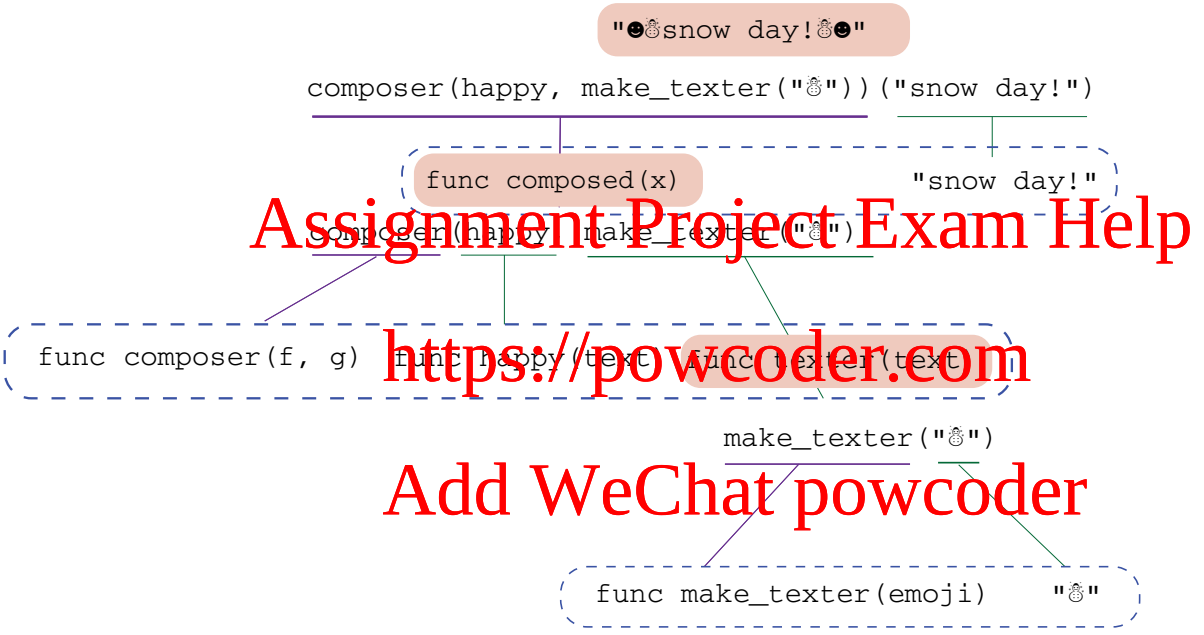

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Self-reference

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A self-referencing function

A higher-order function could return a function that references its own name.

```
def print_sums(n):
    print(n)
    def next_sum(k):
        return print_sums(n + k)
    return next_sum

print_sums(1)(3)(5)
```

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Environment for print_sums

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Understanding print_sums

The call:

```
print sums(1)(3)(5)
```

produces the same result as:

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```
g1 = print sums(1)
g2 = g1(3)
g2(5)
```

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A call to `print sums(x)` returns a function that:

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- Prints `x` as a side-effect, and
- Returns a function that, when called with argument `y`, will do the same thing, but with `x+y` instead of `x`.

So these calls will...

- First print 1 and return `g1`,
- which when called with 3, will print 4 (= 1+3) and return `g2`,
- which when called with 5, will print 9 (= 4+5), and return. . . .

Currying

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add vs. make_adder

Compare...

```
from operator import add

add(2, 3)
```

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```
def make_adder(n):
    return lambda x: n + x

make_adder(2)(3)
```

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What's the relationship between `add(2, 3)` and `make_adder(2)(3)`?

Function currying

Currying: Converting a function that takes multiple arguments into a single-argument higher-order function.

A function that currys any two-argument function:

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

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```
make_adder = curry2(add)
make_adder(2)(3)
```

Function currying

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            return f(x, y)
        return h
    return g
```

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```
make_adder = curry2(add)
make_adder(2)(3)
```

```
curry2 = lambda f: lambda x: lambda y: f(x, y)
```

Why "currying"?

It's not food! ✖ ✖

Named after American logician Haskell Curry, but actually published first by Russian Moses Schönfinkel, based on principles by German Gottlob Frege.

See also: Stigler's law of eponymy.

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