

## 61A Lecture 8

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## Announcements

Abstraction

## Functional Abstractions

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- Square computes the square of a number.

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```

If the name “`square`” were bound to a built-in function, `sum_squares` would still work identically.

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Function names typically convey their effect (**print**), their behavior (**triple**), or the value returned (**abs**).

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n, k, i - Usually integers

x, y, z - Usually real numbers

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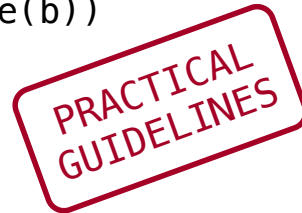
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Testing

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(Demo)

Currying

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>>> add(2, 3)  
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There's a general relationship between these functions

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```

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(Demo)

**Curry:** Transform a multi-argument function into a single-argument, higher-order function

# Decorators

# Function Decorators

---

(Demo)

## Function Decorators

---

(Demo)

```
@trace1
def triple(x):
    return 3 * x
```

## Function Decorators

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(Demo)

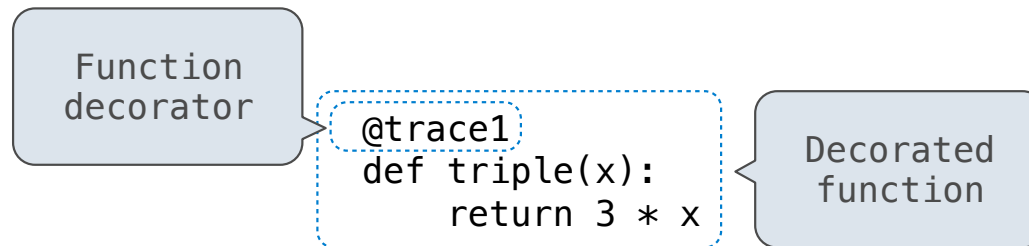
Function  
decorator

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(Demo)

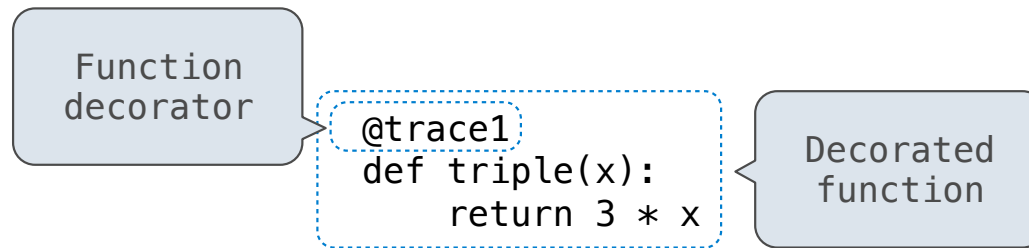




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(Demo)

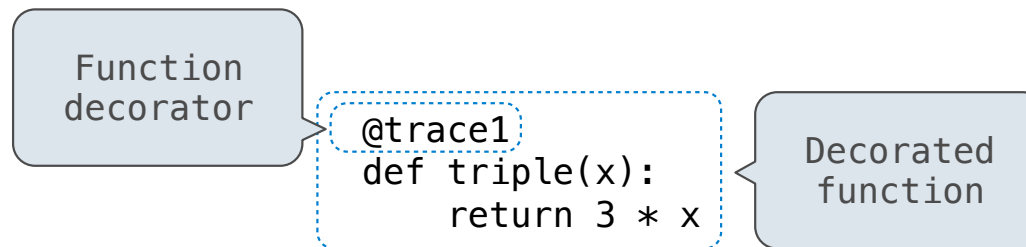


*is identical to*

## Function Decorators

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(Demo)



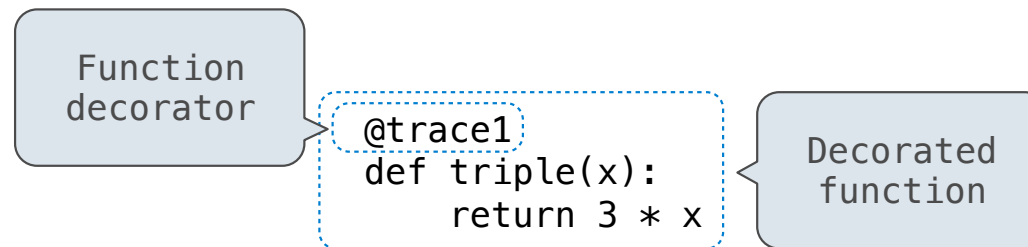
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```
def triple(x):
    return 3 * x
triple = trace1(triple)
```

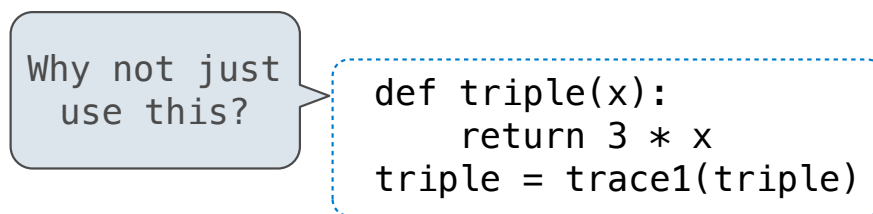
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Review

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<code>5</code>	<code>5</code>	<code>5</code>
<code>print(5)</code>	<code>None</code>	<code>5</code>
<code>print(print(5))</code>		

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def delay(arg):
    print('delayed')
    def g():
        return arg
    return g
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print(5)	None	5
print( <u>print(5)</u> ) None	None	5 None
def delay(arg): print('delayed') def g(): return arg return g	delay(delay)()(6)()	

## What Would Python Print?

The print function returns None. It also displays its arguments (separated by spaces) when it is called.

```
from operator import add, mul
def square(x):
    return mul(x, x)
```

```
def delay(arg):
    print('delayed')
    def g():
        return arg
    return g
```

Names in nested def statements can refer to their enclosing scope

<u>This expression</u>	<u>Evaluates to</u>	<u>Interactive Output</u>
5	5	5
print(5)	None	5
print( <u>print(5)</u> ) None	None	5 None
delay(delay)()(6)()		

## What Would Python Print?

The print function returns None. It also displays its arguments (separated by spaces) when it is called.

```
from operator import add, mul
def square(x):
    return mul(x, x)
```

A function that takes any argument and returns a function that returns that arg

```
def delay(arg):
    print('delayed')
    def g():
        return arg
    return g
```

Names in nested def statements can refer to their enclosing scope

<u>This expression</u>	<u>Evaluates to</u>	<u>Interactive Output</u>
5	5	5
print(5)	None	5
print( <u>print(5)</u> ) None	None	5 None
delay(delay)()(6)()		

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5	5	5
print(5)	None	5
print( <u>print(5)</u> )	None	5 None
<u>delay(delay)()(6)()</u>		

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<u>delay(delay)</u> (6)()		

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<u>This expression</u>	<u>Evaluates to</u>	<u>Interactive Output</u>
5	5	5
print(5)	None	5
print( <u>print(5)</u> )	None	5 None
<u>delay(delay)</u> (6)()		delayed

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print(5)	None	5
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<u>delay(delay)()(6)()</u>		delayed delayed

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```

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5	5	5
print(5)	None	5
print( <u>print(5)</u> )	None	5 None
<u>delay(delay)()(6)()</u>		delayed delayed 6

## What Would Python Print?

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<u>This expression</u>	<u>Evaluates to</u>	<u>Interactive Output</u>
5	5	5
print(5)	None	5
print( <u>print(5)</u> )	None	5 None
<u>delay(delay)()(6)()</u>	6	delayed delayed 6

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    def g():
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Names in nested def statements can refer to their enclosing scope

<u>This expression</u>	<u>Evaluates to</u>	<u>Interactive Output</u>
5	5	5
print(5)	None	5
print( <u>print(5)</u> )	None	5 None
<u>delay(delay)</u> (6)()	6	delayed delayed 6
print(delay(print)()(4))		

## What Would Python Print?

The print function returns None. It also displays its arguments (separated by spaces) when it is called.

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```

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```
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    print('delayed')
    def g():
        return arg
    return g
```

Names in nested def statements can refer to their enclosing scope

<u>This expression</u>	<u>Evaluates to</u>	<u>Interactive Output</u>
5	5	5
print(5)	None	5
print( <u>print(5)</u> )	None	5 None
<u>delay(delay)()(6)()</u>	6	delayed delayed 6
print(delay(print)()(4))		delayed

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The print function returns None. It also displays its arguments (separated by spaces) when it is called.

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```

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<u>This expression</u>	<u>Evaluates to</u>	<u>Interactive Output</u>
5	5	5
print(5)	None	5
print( <u>print(5)</u> )	None	5 None
<u>delay(delay)()(6)()</u>	6	delayed delayed 6
print(delay(print)()(4))		delayed 4



## What Would Python Print?

The print function returns None. It also displays its arguments (separated by spaces) when it is called.

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from operator import add, mul
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    return g
```

Names in nested def statements can refer to their enclosing scope

<u>This expression</u>	<u>Evaluates to</u>	<u>Interactive Output</u>
5	5	5
print(5)	None	5
print( <u>print(5)</u> )	None	5 None
<u>delay(delay)</u> (6)(6)	6	delayed delayed 6
print(delay(print)()(4))		delayed 4 None

## What Would Python Print?

The print function returns None. It also displays its arguments (separated by spaces) when it is called.

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from operator import add, mul
def square(x):
    return mul(x, x)
```

A function that takes any argument and returns a function that returns that arg

```
def delay(arg):
    print('delayed')
    def g():
        return arg
    return g
```

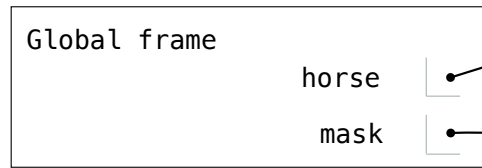
Names in nested def statements can refer to their enclosing scope

<u>This expression</u>	<u>Evaluates to</u>	<u>Interactive Output</u>
5	5	5
print(5)	None	5
print( <u>print(5)</u> )	None	5 None
<u>delay(delay)</u> (6)	6	delayed delayed 6
print(delay(print)) (4)	None	delayed 4 None

```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)
```

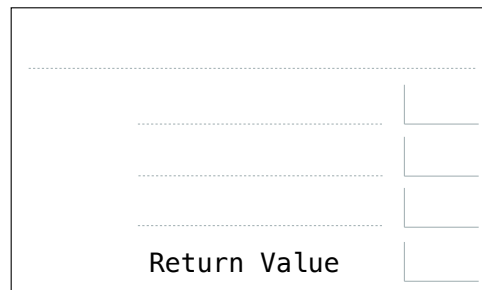
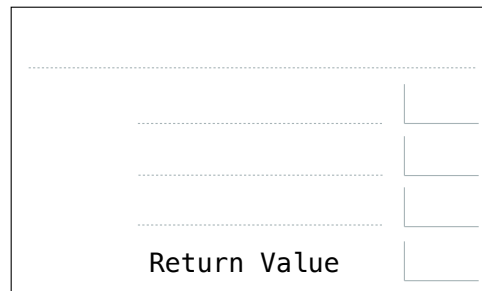
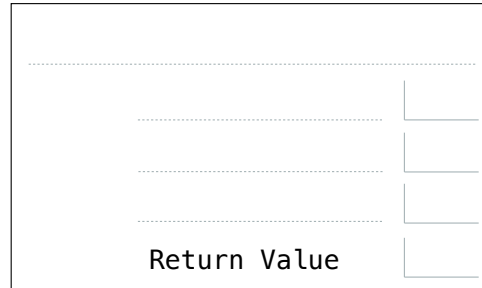
```
mask = lambda horse: horse(2)
```

```
horse(mask)
```



func horse(mask) [parent=Global]

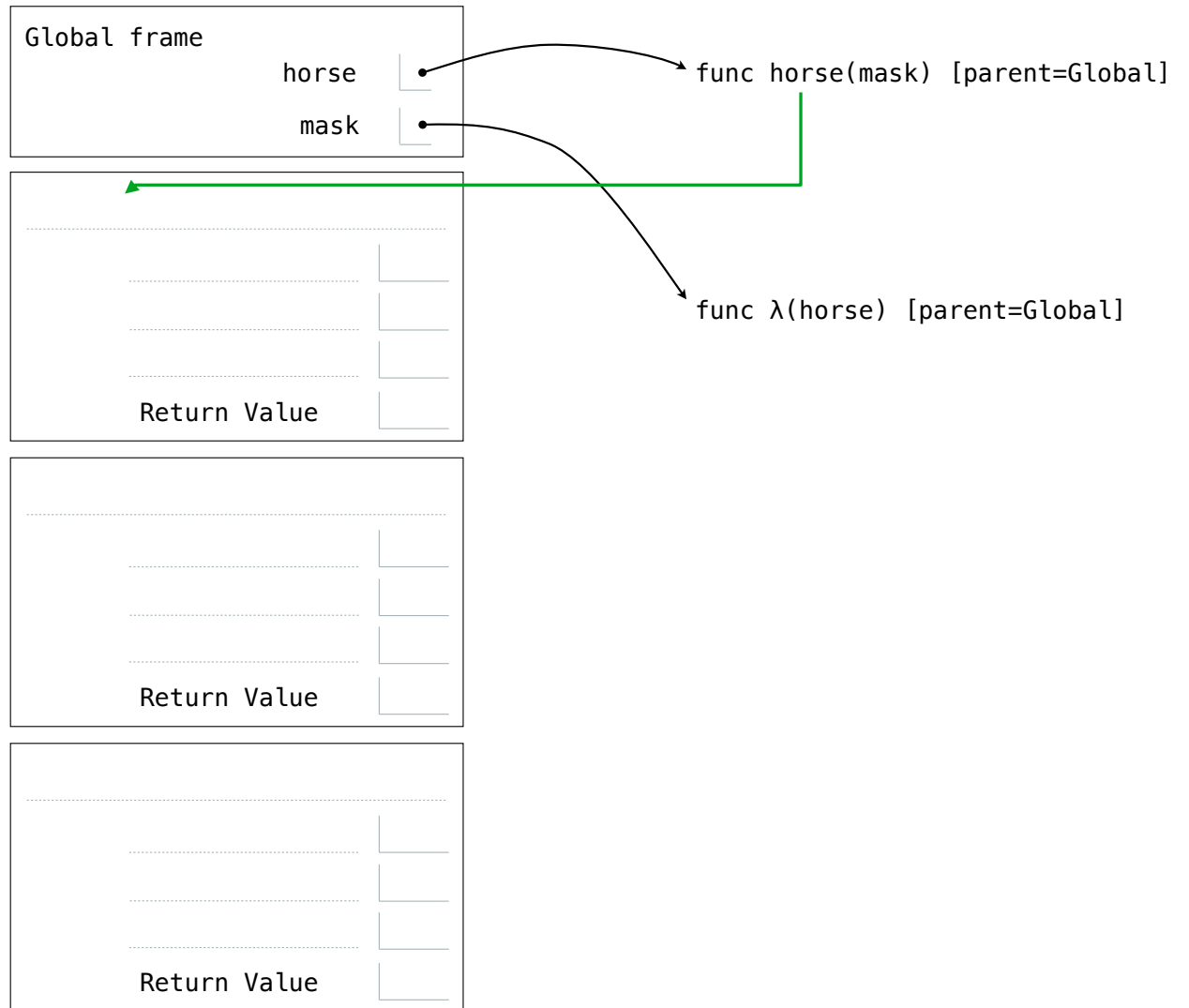
func  $\lambda$ (horse) [parent=Global]



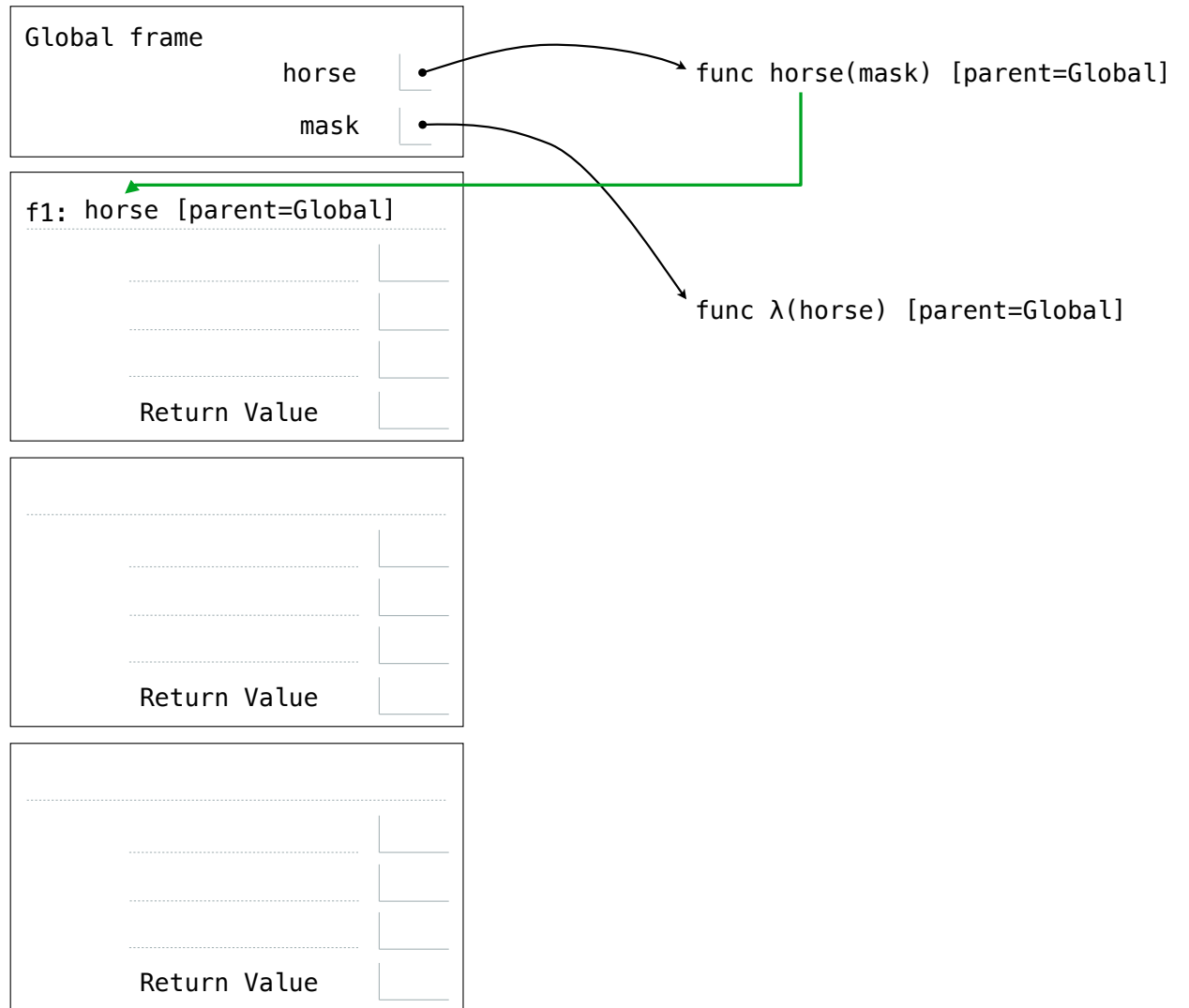
```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)
```

```
mask = lambda horse: horse(2)
```

```
horse(mask)
```

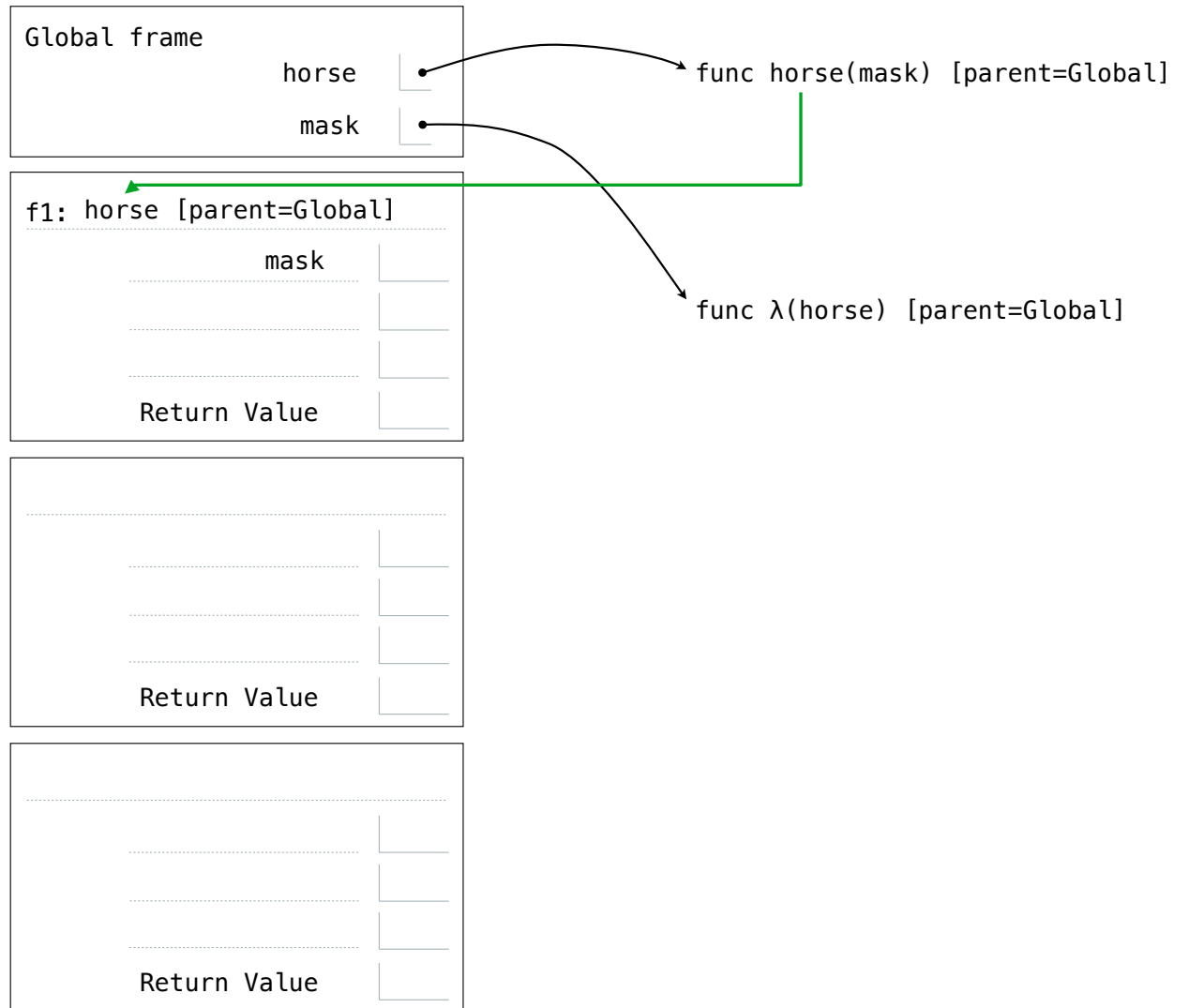


```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)  
  
mask = lambda horse: horse(2)  
horse(mask)
```



```
def horse(mask):
    horse = mask
    def mask(horse):
        return horse
    return horse(mask)

mask = lambda horse: horse(2)
horse(mask)
```

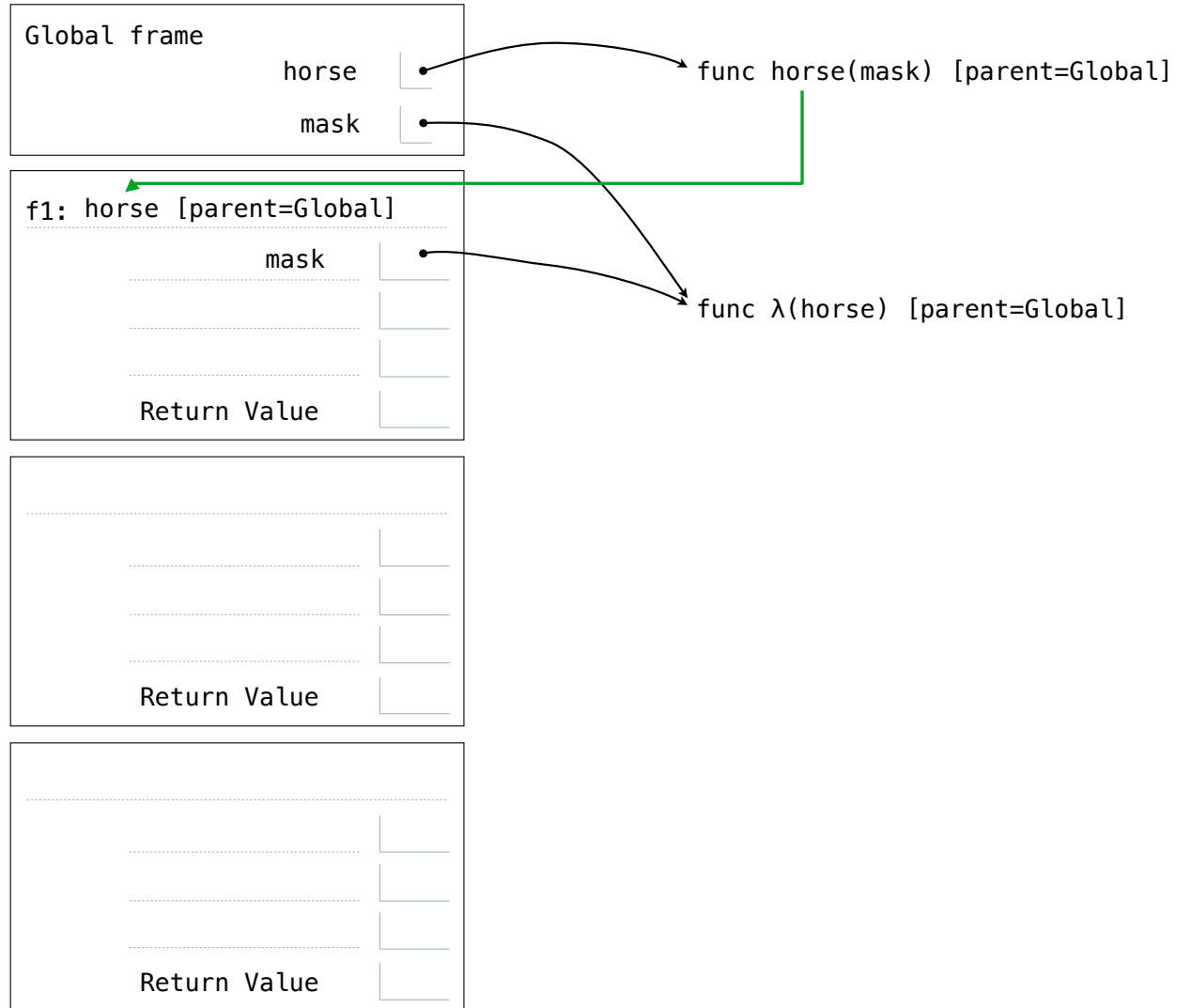


```

def horse(mask):
    horse = mask
    def mask(horse):
        return horse
    return horse(mask)

mask = lambda horse: horse(2)
horse(mask)

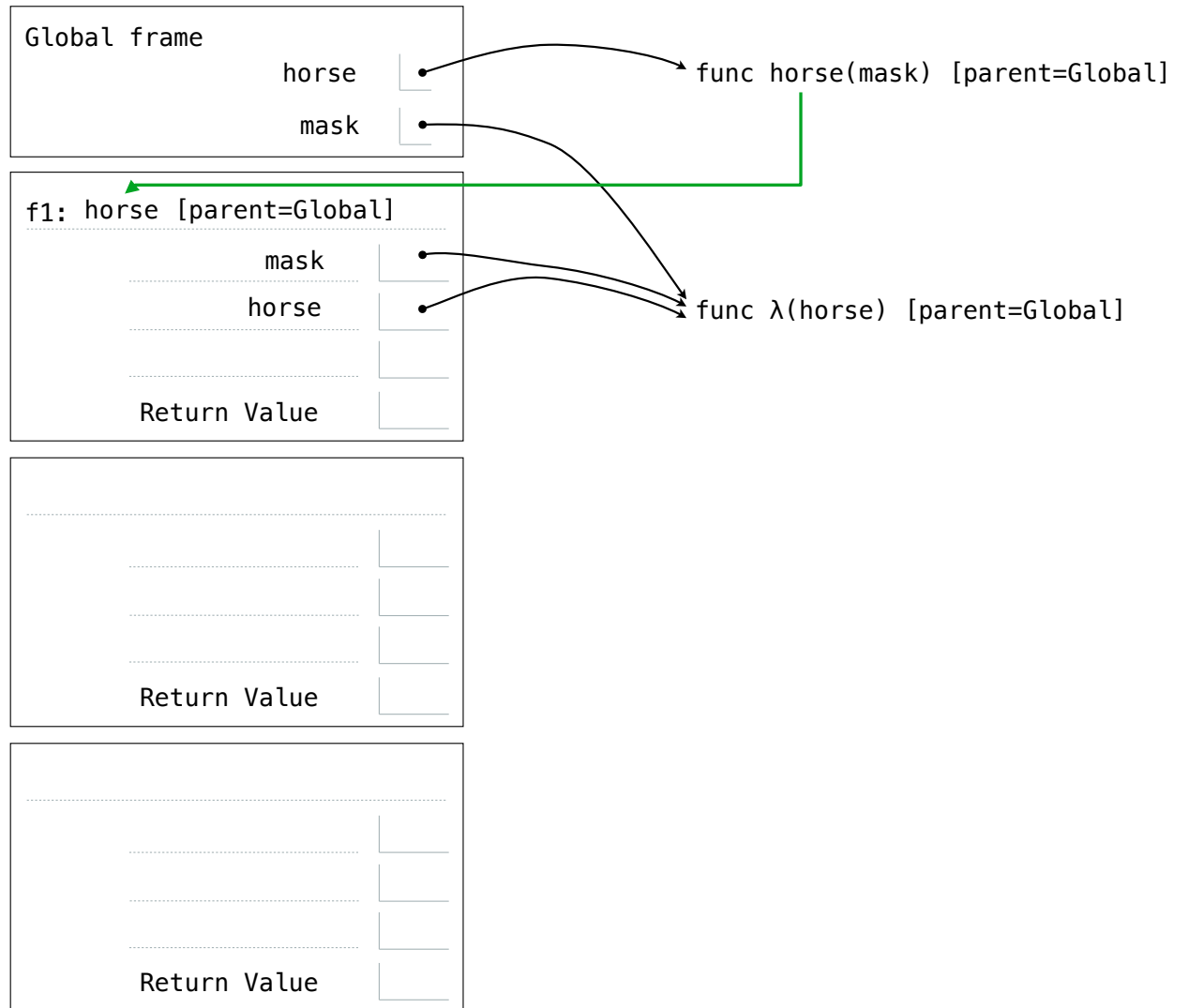
```



```
def horse(mask):
    horse = mask
    def mask(horse):
        return horse
    return horse(mask)

mask = lambda horse: horse(2)

horse(mask)
```



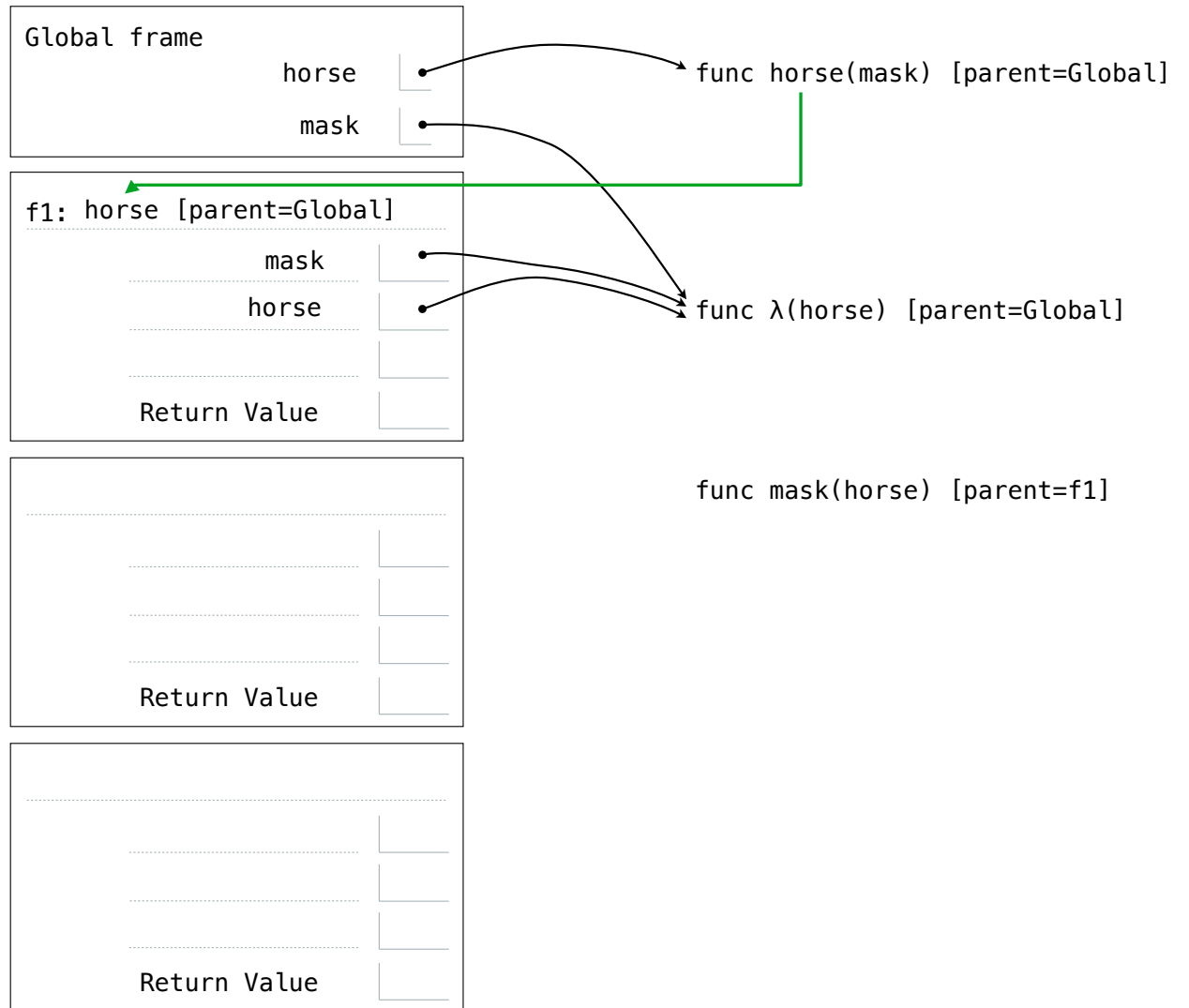


```

def horse(mask):
    horse = mask
    def mask(horse):
        return horse
    return horse(mask)

mask = lambda horse: horse(2)
horse(mask)

```

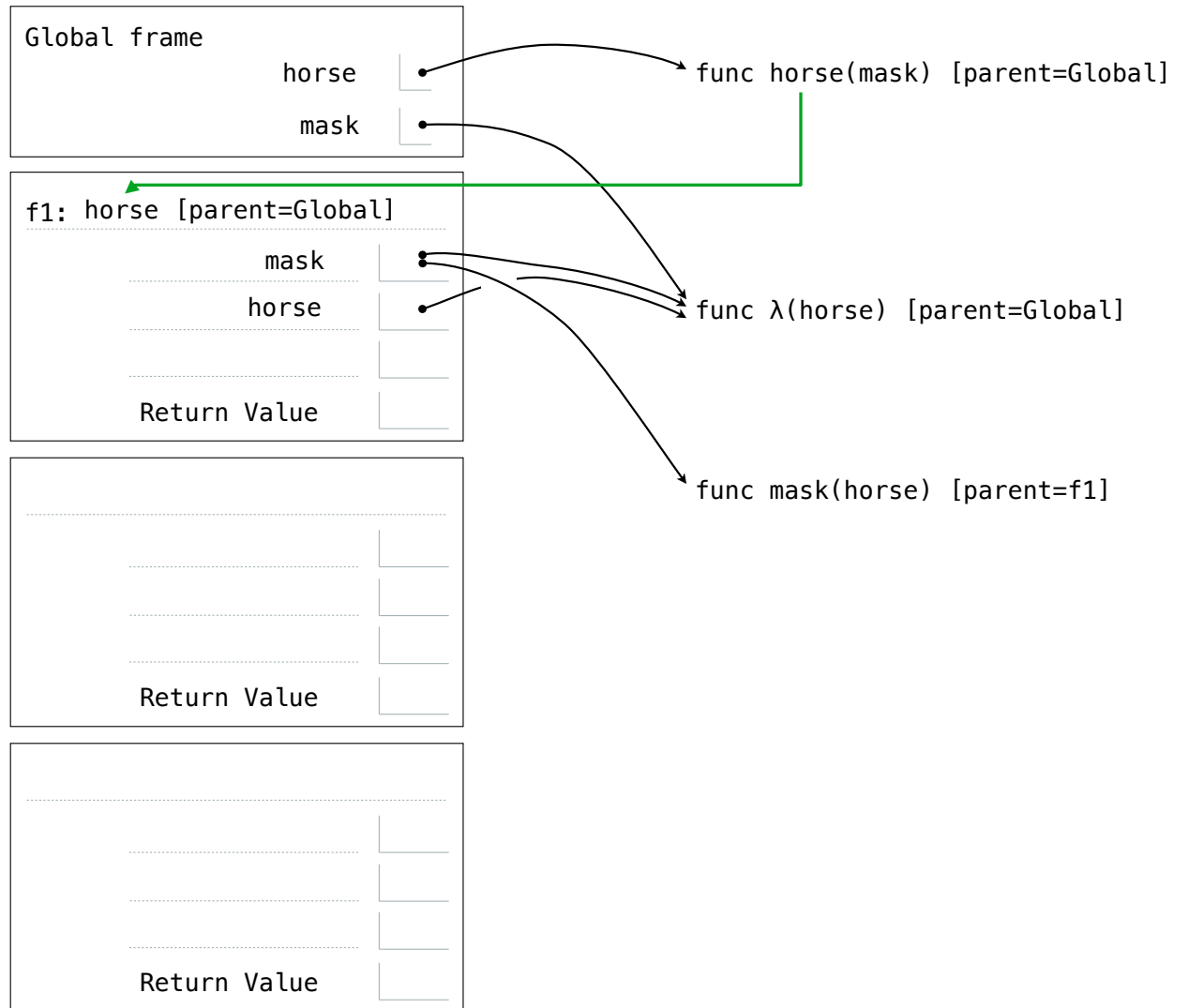


```

def horse(mask):
    horse = mask
    def mask(horse):
        return horse
    return horse(mask)

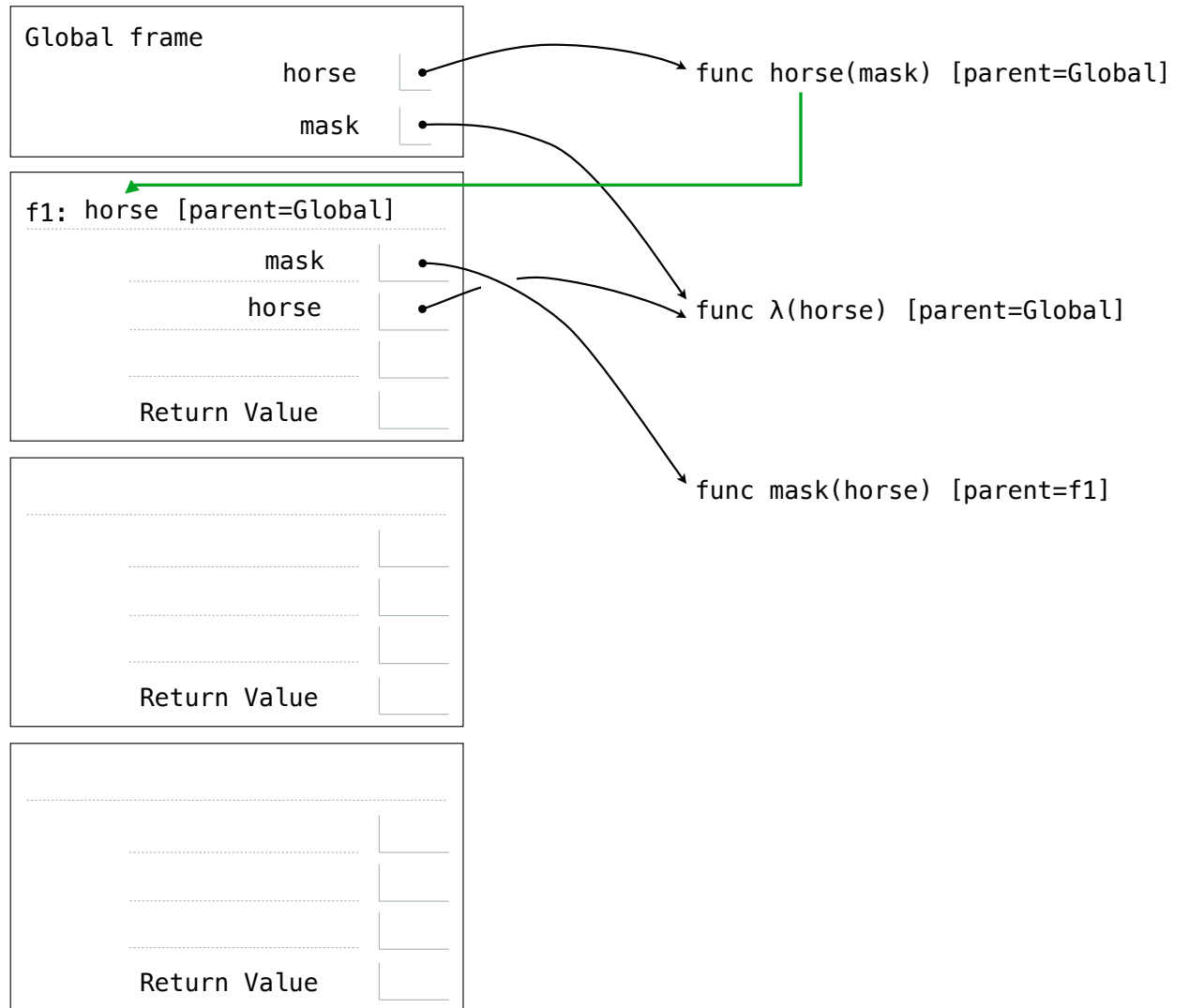
mask = lambda horse: horse(2)
horse(mask)

```

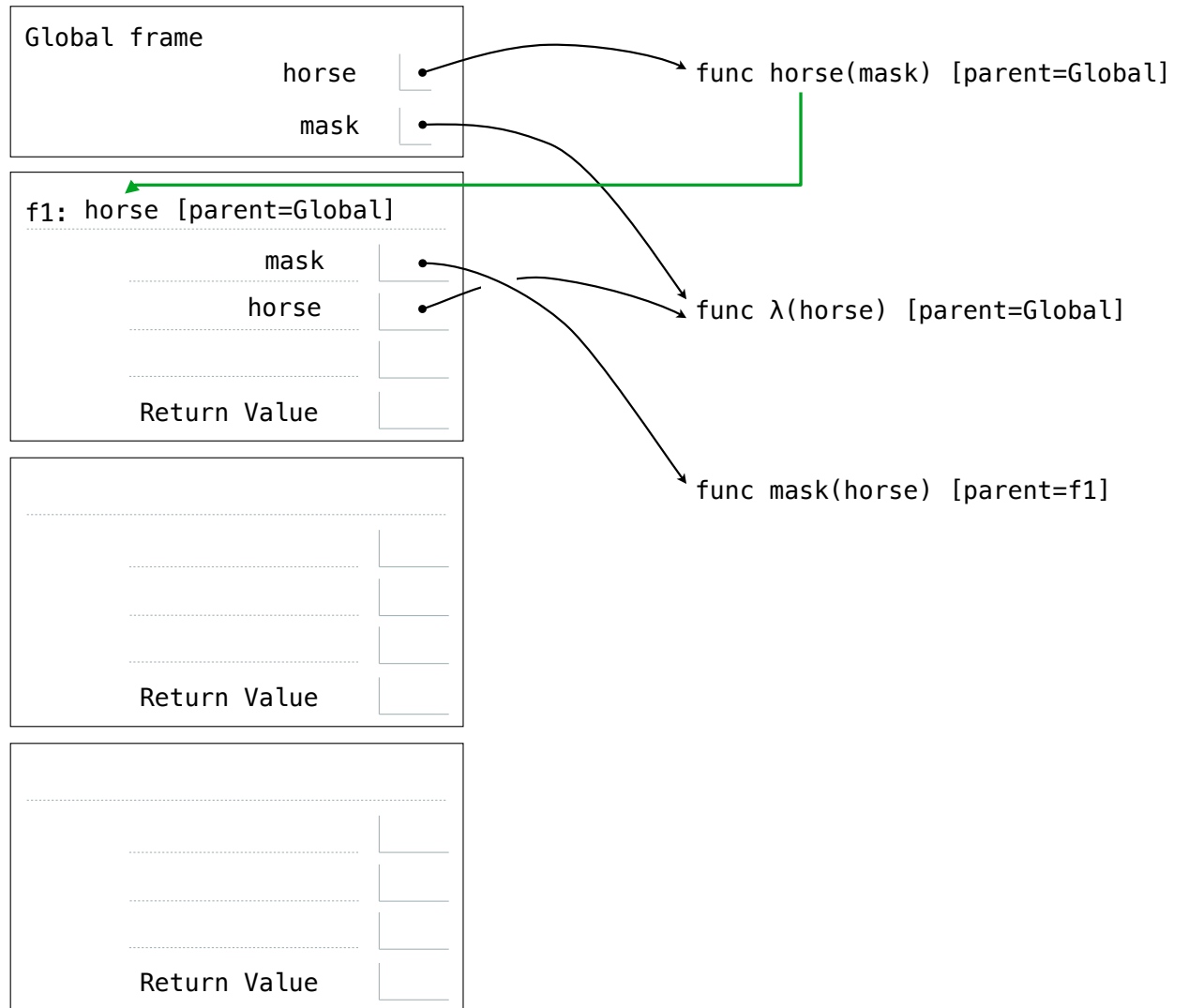


```
def horse(mask):
    horse = mask
    def mask(horse):
        return horse
    return horse(mask)

mask = lambda horse: horse(2)
horse(mask)
```



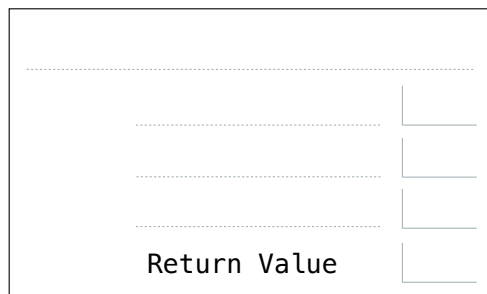
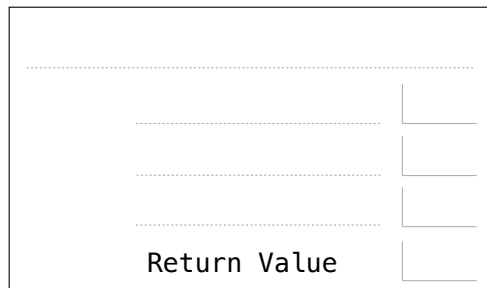
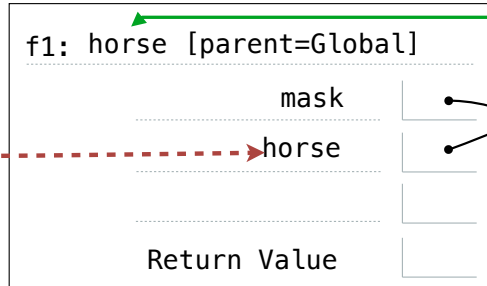
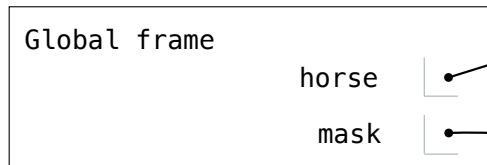
```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)  
  
mask = lambda horse: horse(2)  
horse(mask)
```



```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)
```

```
mask = lambda horse: horse(2)
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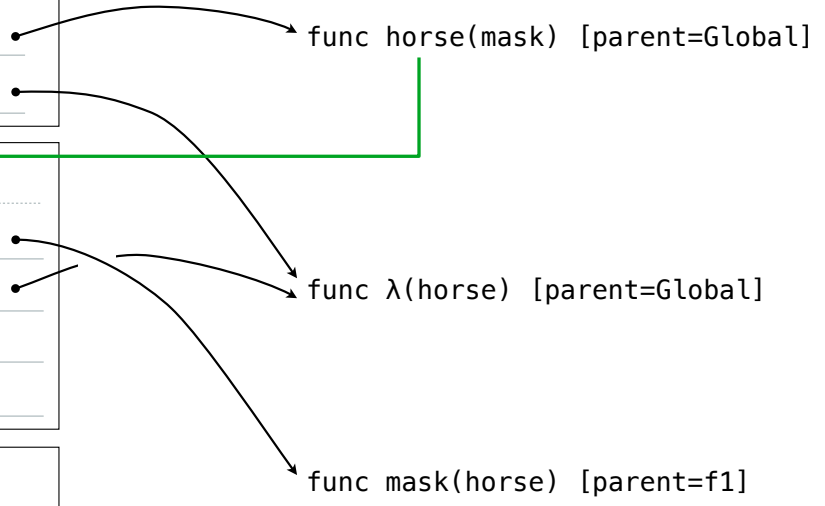
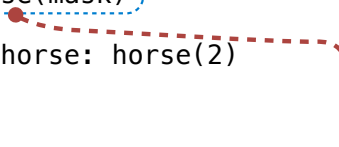
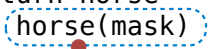
```
horse(mask)
```



func horse(mask) [parent=Global]

func λ(horse) [parent=Global]

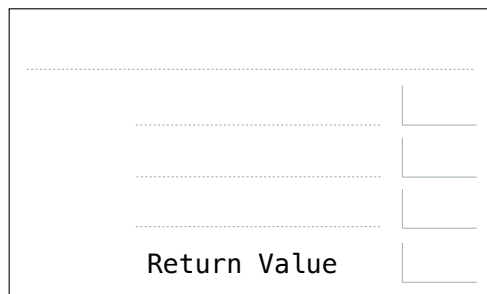
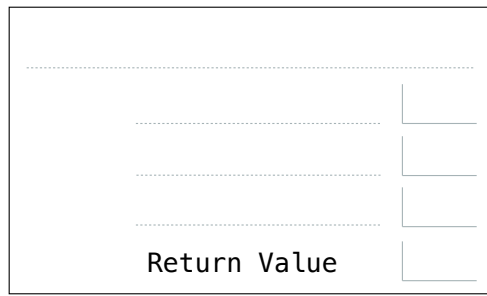
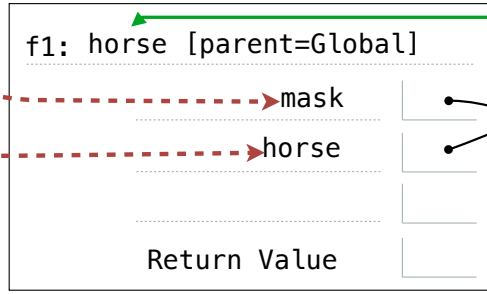
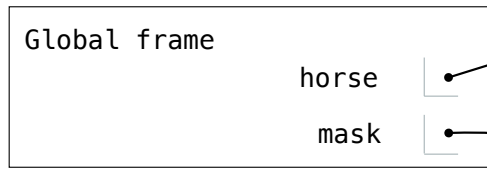
func mask(horse) [parent=f1]



```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)
```

```
mask = lambda horse: horse(2)
```

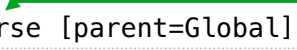
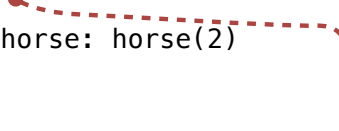
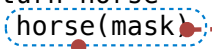
```
horse(mask)
```



func horse(mask) [parent=Global]

func λ(horse) [parent=Global]

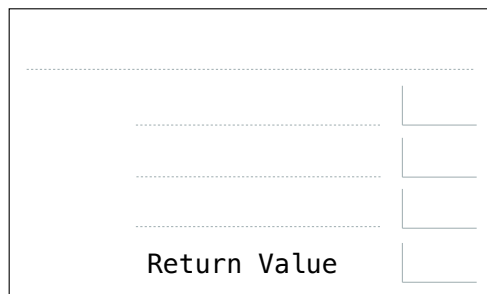
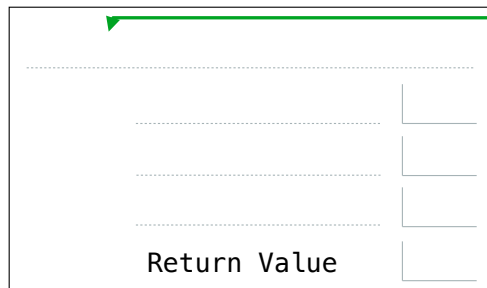
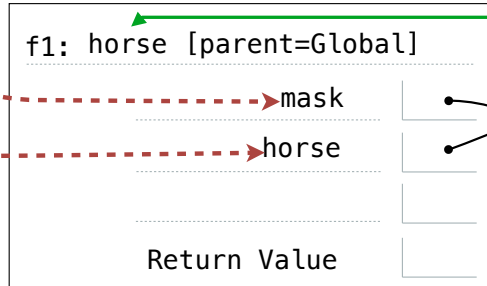
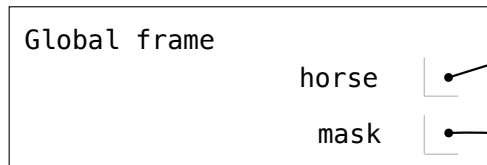
func mask(horse) [parent=f1]



```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)
```

```
mask = lambda horse: horse(2)
```

```
horse(mask)
```



func horse(mask) [parent=Global]

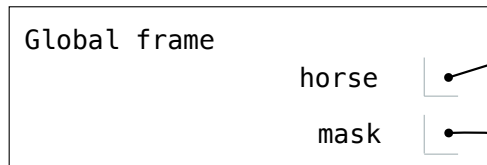
func λ(horse) [parent=Global]

func mask(horse) [parent=f1]

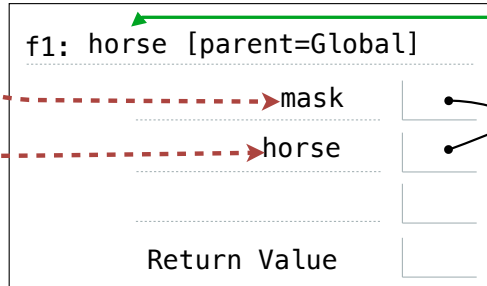
```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)
```

```
mask = lambda horse: horse(2)
```

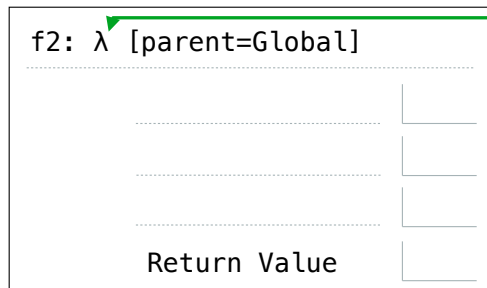
```
horse(mask)
```



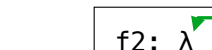
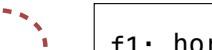
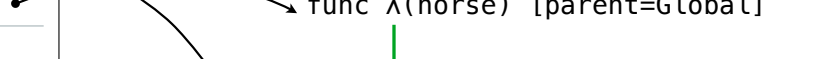
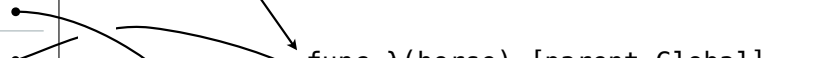
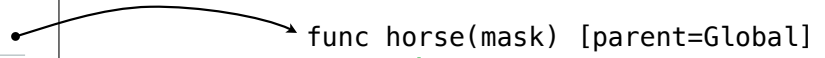
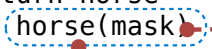
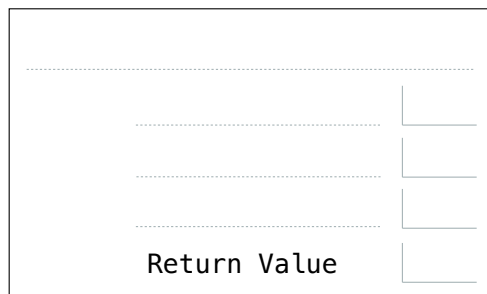
func horse(mask) [parent=Global]



func λ(horse) [parent=Global]



func mask(horse) [parent=f1]

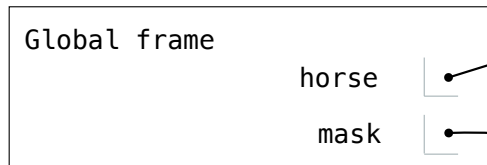




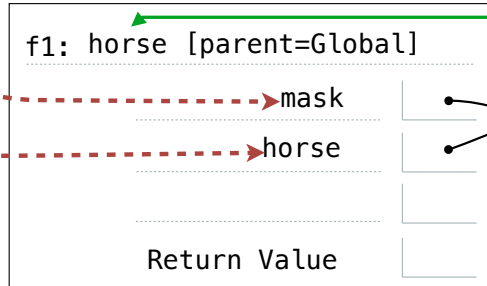
```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)
```

```
mask = lambda horse: horse(2)
```

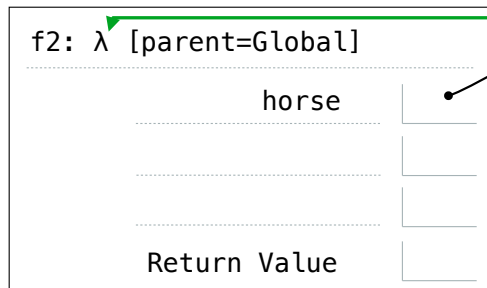
```
horse(mask)
```



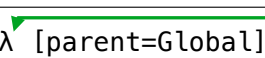
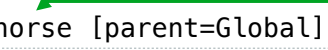
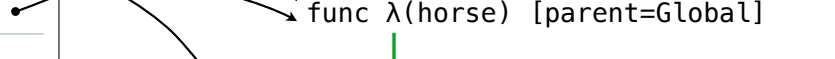
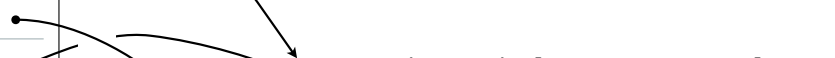
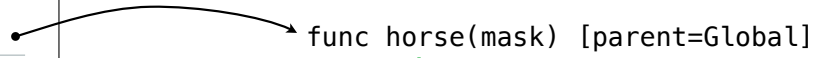
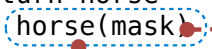
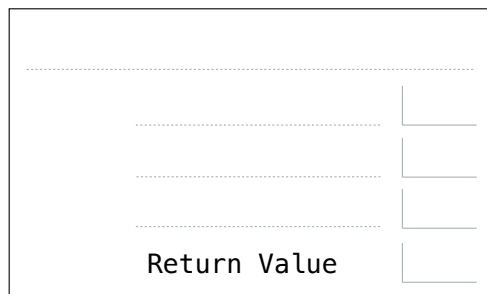
func horse(mask) [parent=Global]



func λ(horse) [parent=Global]



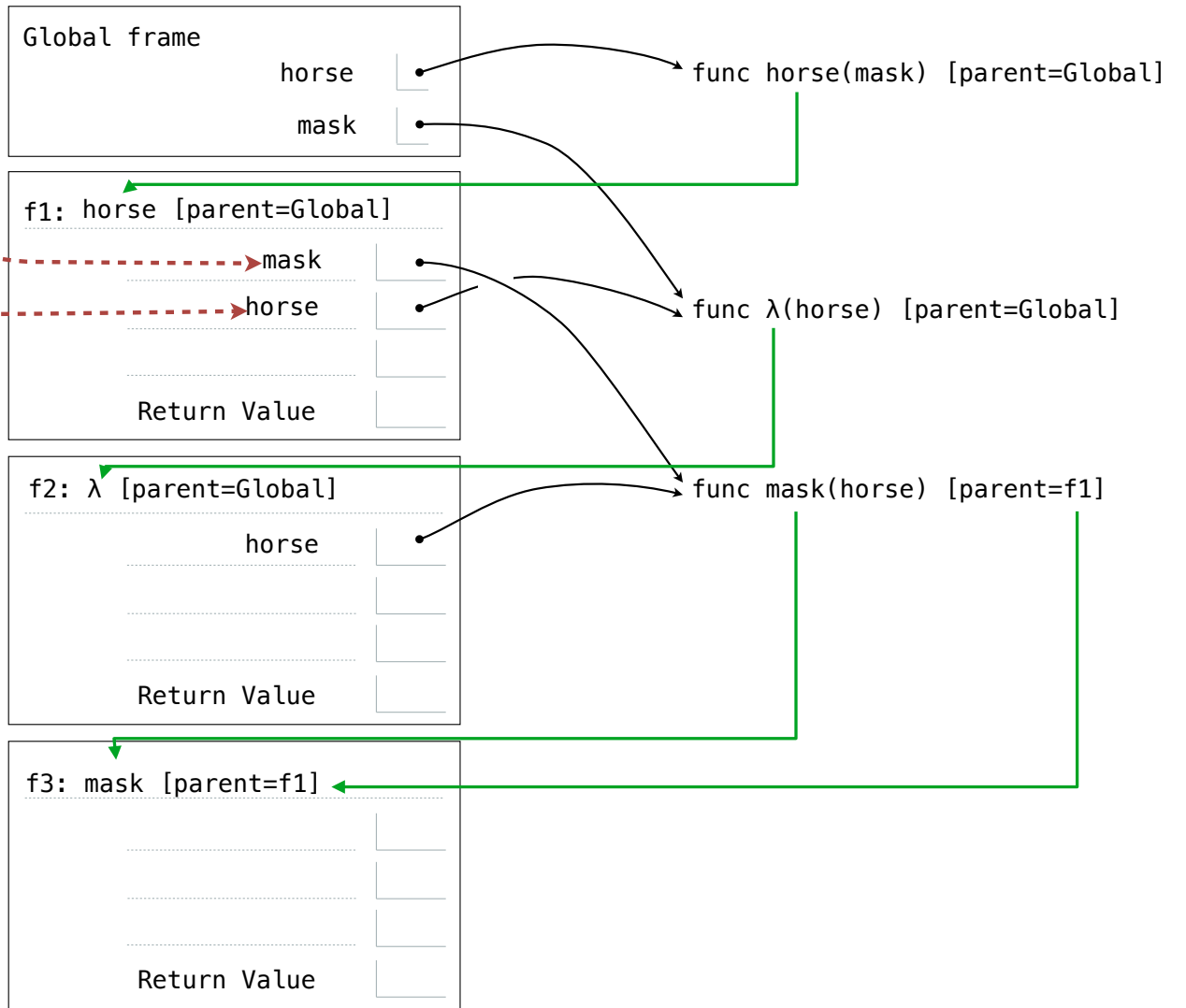
func mask(horse) [parent=f1]



```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)
```

```
mask = lambda horse: horse(2)
```

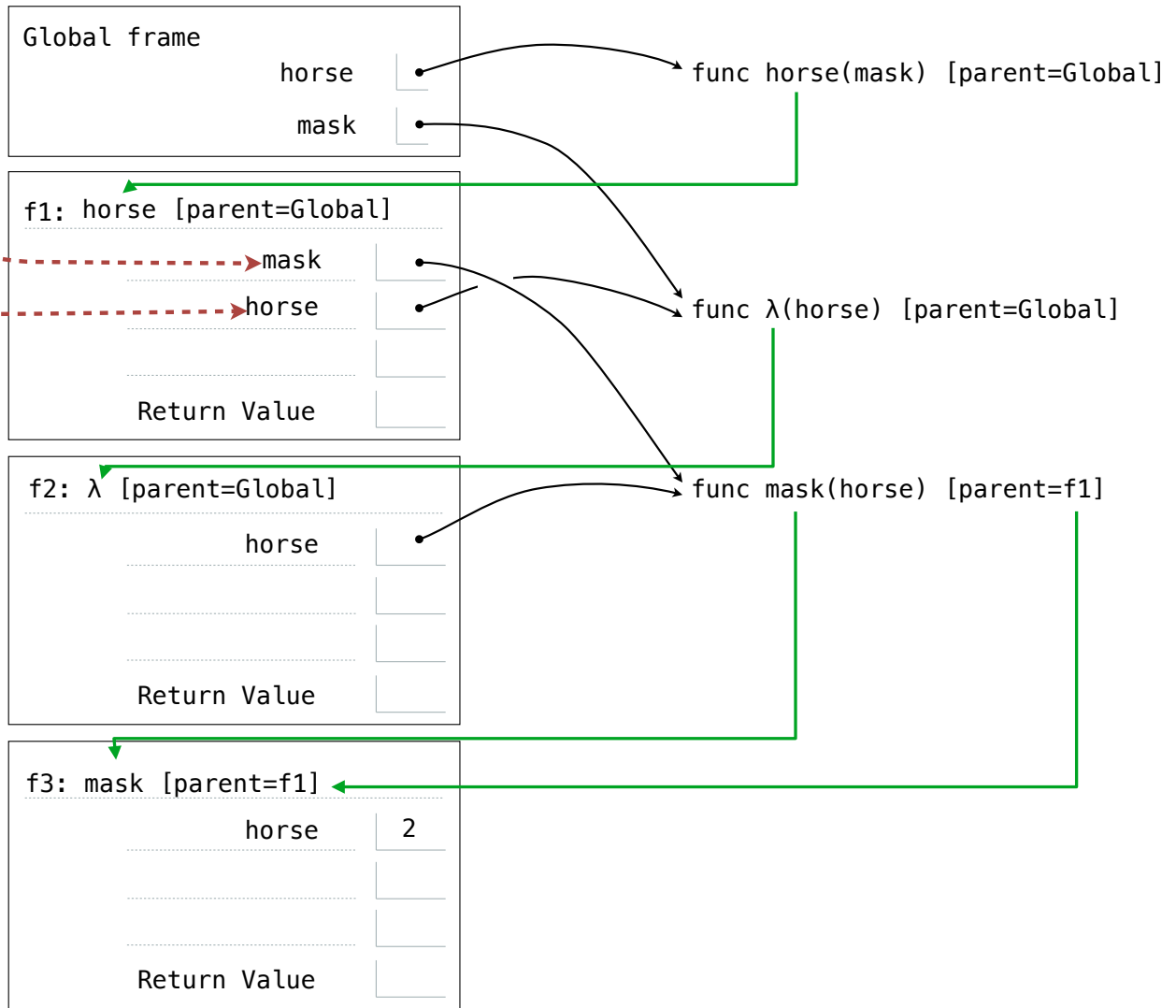
```
horse(mask)
```



```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)
```

```
mask = lambda horse: horse(2)
```

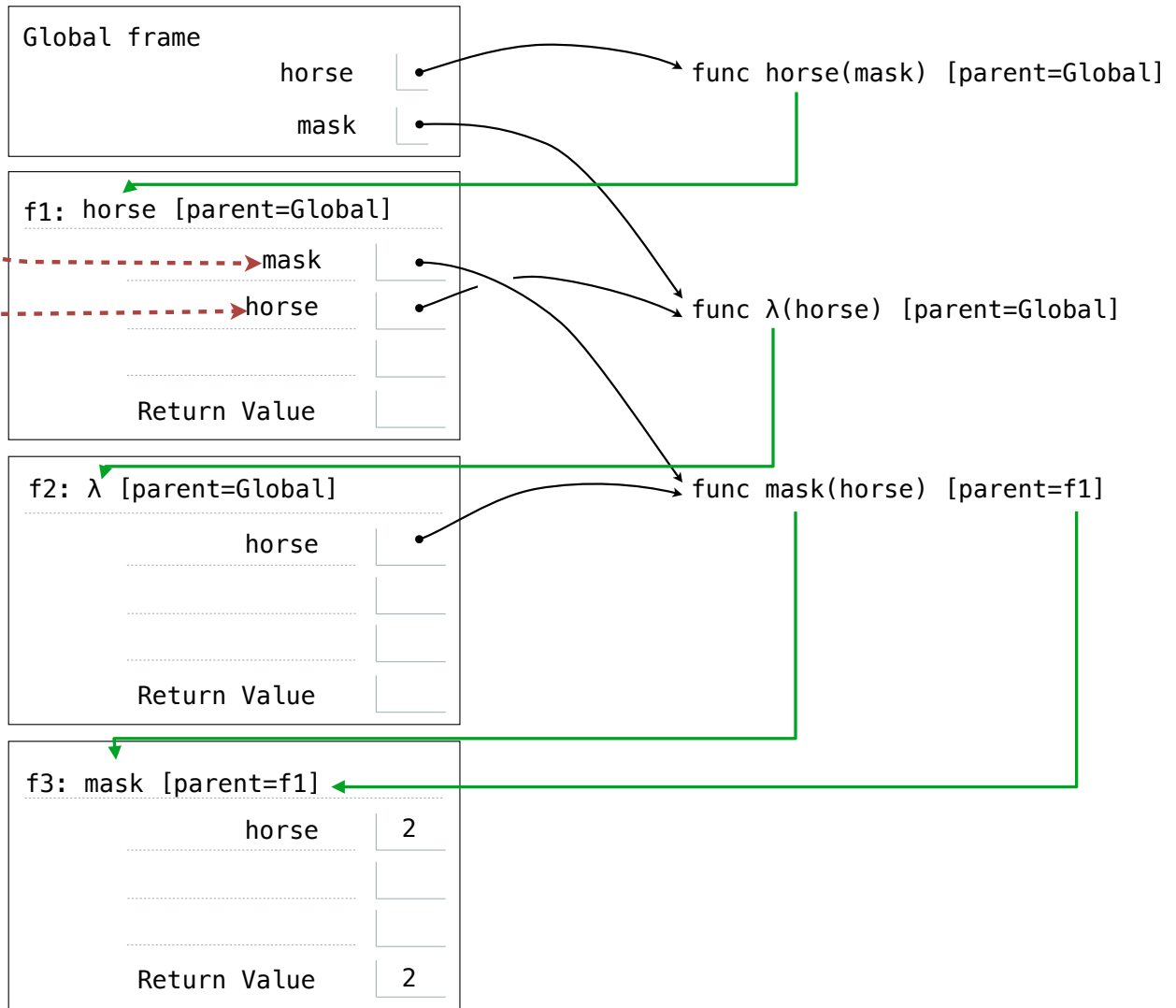
```
horse(mask)
```



```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)
```

```
mask = lambda horse: horse(2)
```

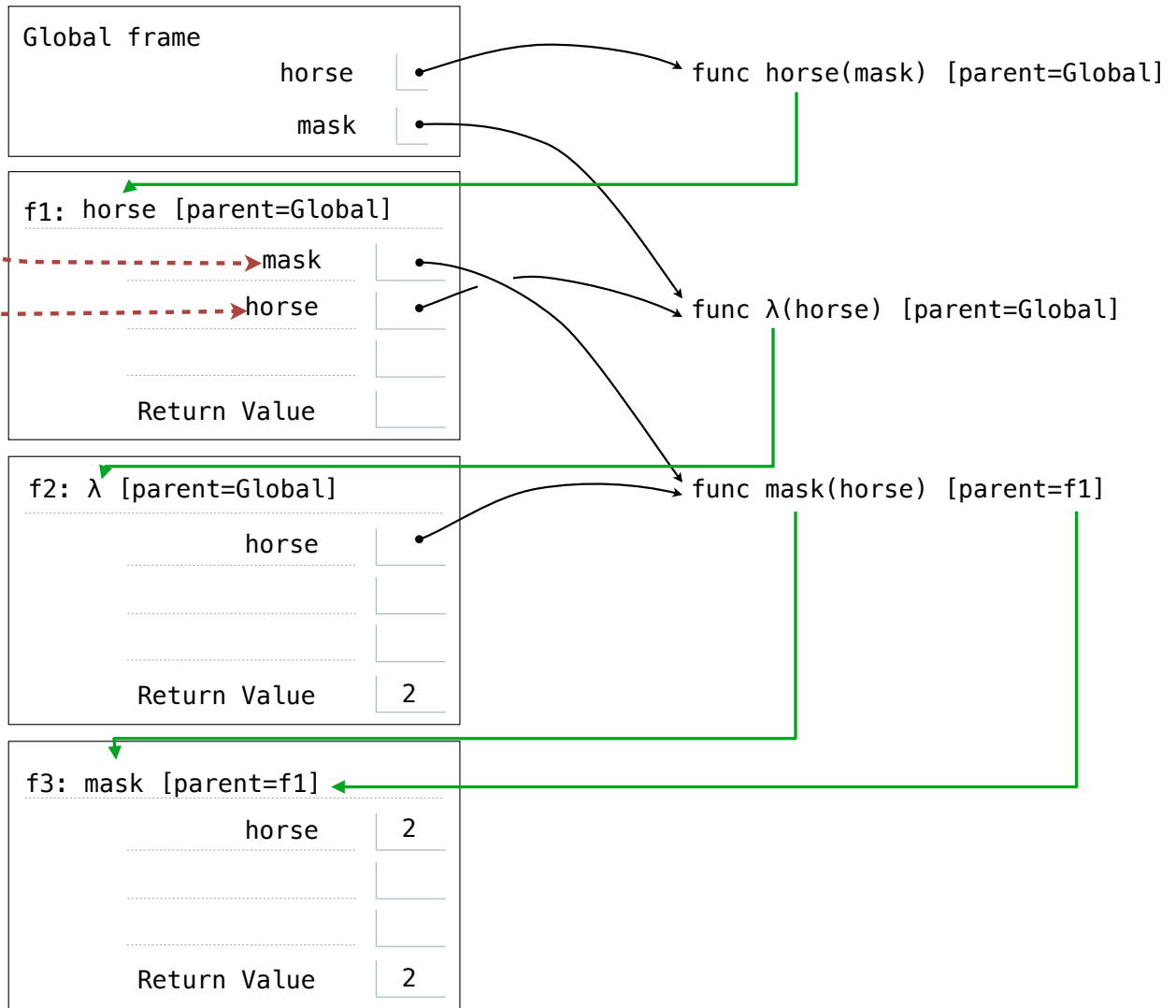
```
horse(mask)
```



```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)
```

```
mask = lambda horse: horse(2)
```

```
horse(mask)
```



```
def horse(mask):  
    horse = mask  
    def mask(horse):  
        return horse  
    return horse(mask)
```

```
mask = lambda horse: horse(2)
```

```
horse(mask)
```

