61A Lecture 8

Friday, February 6

Announcements

Abstraction

Functional Abstractions

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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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x, y, z - Usually real numbers
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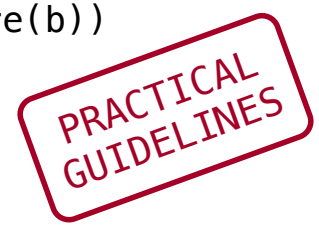

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(Demo)

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(Demo)

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

Decorators

Function Decorators

(Demo)

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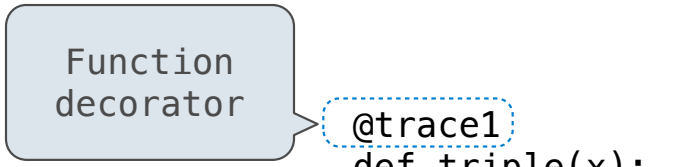
Function Decorators

(Demo)

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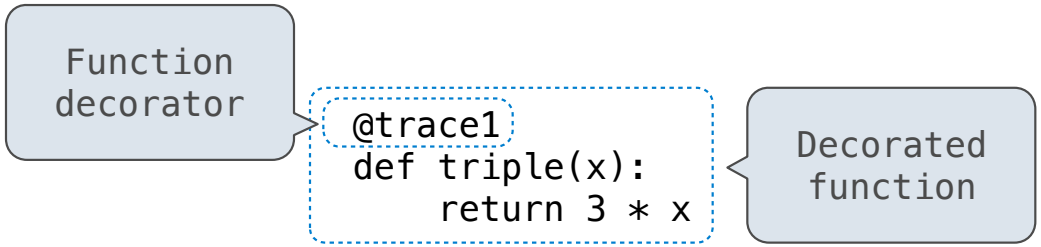

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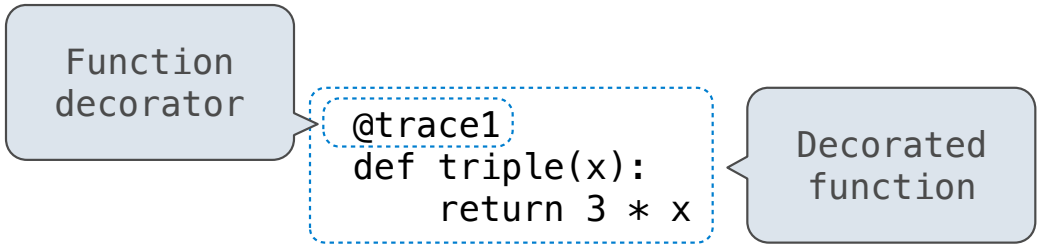

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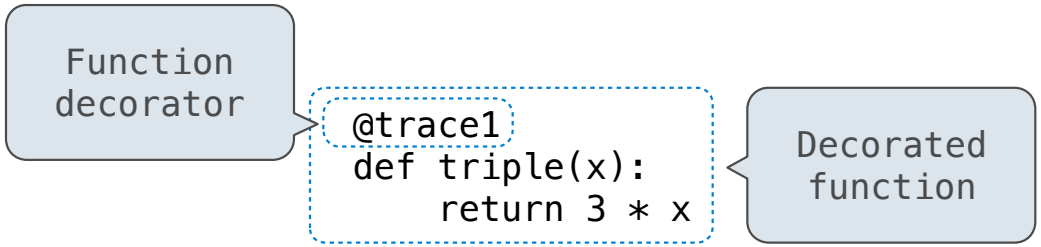

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Function Decorators

(Demo)

Function decorator

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Decorated function

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Why not just use this?

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Review

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def delay(arg):
    print('delayed')
    def g():
        return arg
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`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`

`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)
```

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`

`print(print(5))` → `None`

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

`delay(delay)()(6)()`

Names in nested def statements can refer to their enclosing scope

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

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`
`delay(delay)()(6)()`		

`print(5)` → None

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

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`
`delay(delay)()(6)()`		

What Would Python Print?

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Names in nested def statements can refer to their enclosing scope

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`
`delay(delay)()(6)()`		

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```
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    def g():
        return arg
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```

Names in nested def statements can refer to their enclosing scope

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`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`
`delay(delay)()(6)()`		

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Names in nested def statements can refer to their enclosing scope

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`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

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`
`delay(delay)()(6)()`		`delayed`

None

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

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`
`delay(delay)()(6)()`		`delayed` `delayed`

None

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

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`

`delay(delay)()(6)()`		`delayed`
		`delayed`
		`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

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`

`delay(delay)()(6)()`	`6`	`delayed`
		`delayed`
		`6`

None

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

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`

`delay(delay)()(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.

```
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

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`

`delay(delay)()(6)()`	`6`	`delayed`
		`delayed`
		`6`

`print(delay(print)()(4))`		`delayed`

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

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`

`delay(delay)()(6)()`	`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.

```
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

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`

`delay(delay)()(6)()`	`6`	`delayed`
		`delayed`
		`6`

`print(delay(print)()(4))`		`delayed`
		`4`
		`None`

None

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

This expression	Evaluates to	Interactive Output
`5`	`5`	`5`
`print(5)`	`None`	`5`
`print(print(5))`	`None`	`5` `None`

`delay(delay)()(6)()`	`6`	`delayed`
		`delayed`
		`6`

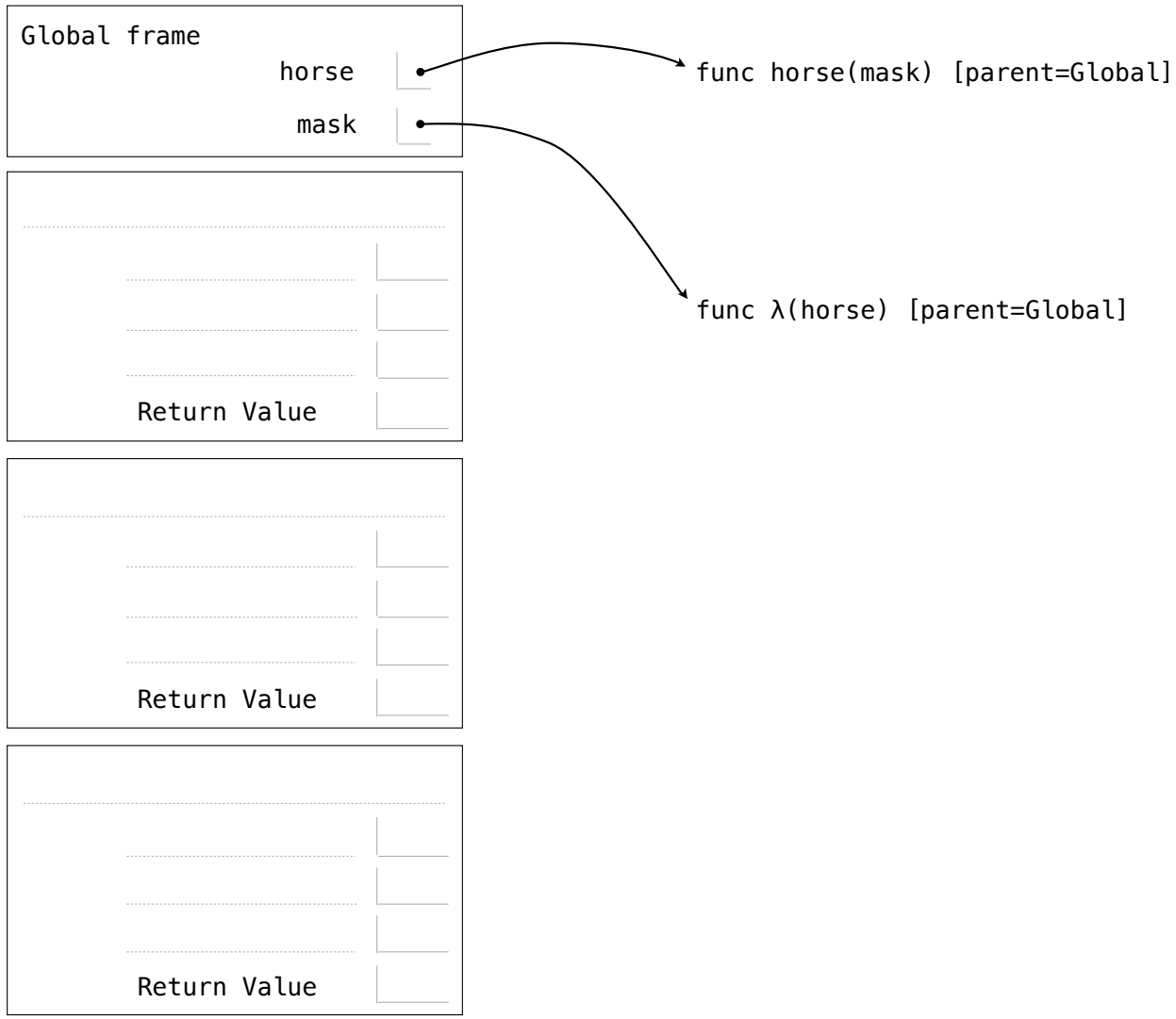
`print(delay(print)()(4))`	`None`	`delayed`
		`4`
		`None`

None

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

mask = lambda horse: horse(2)

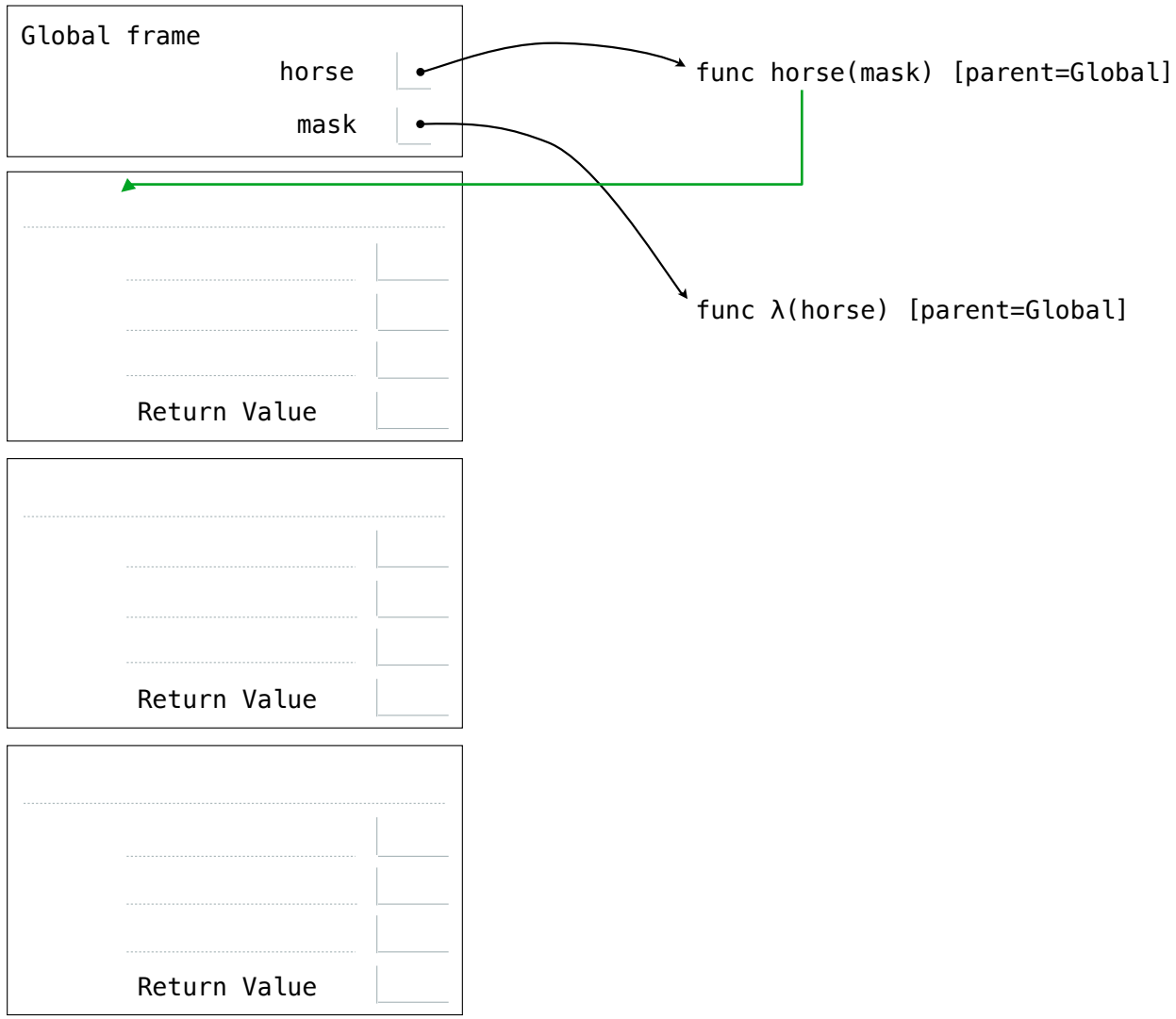
horse(mask)
```



```
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
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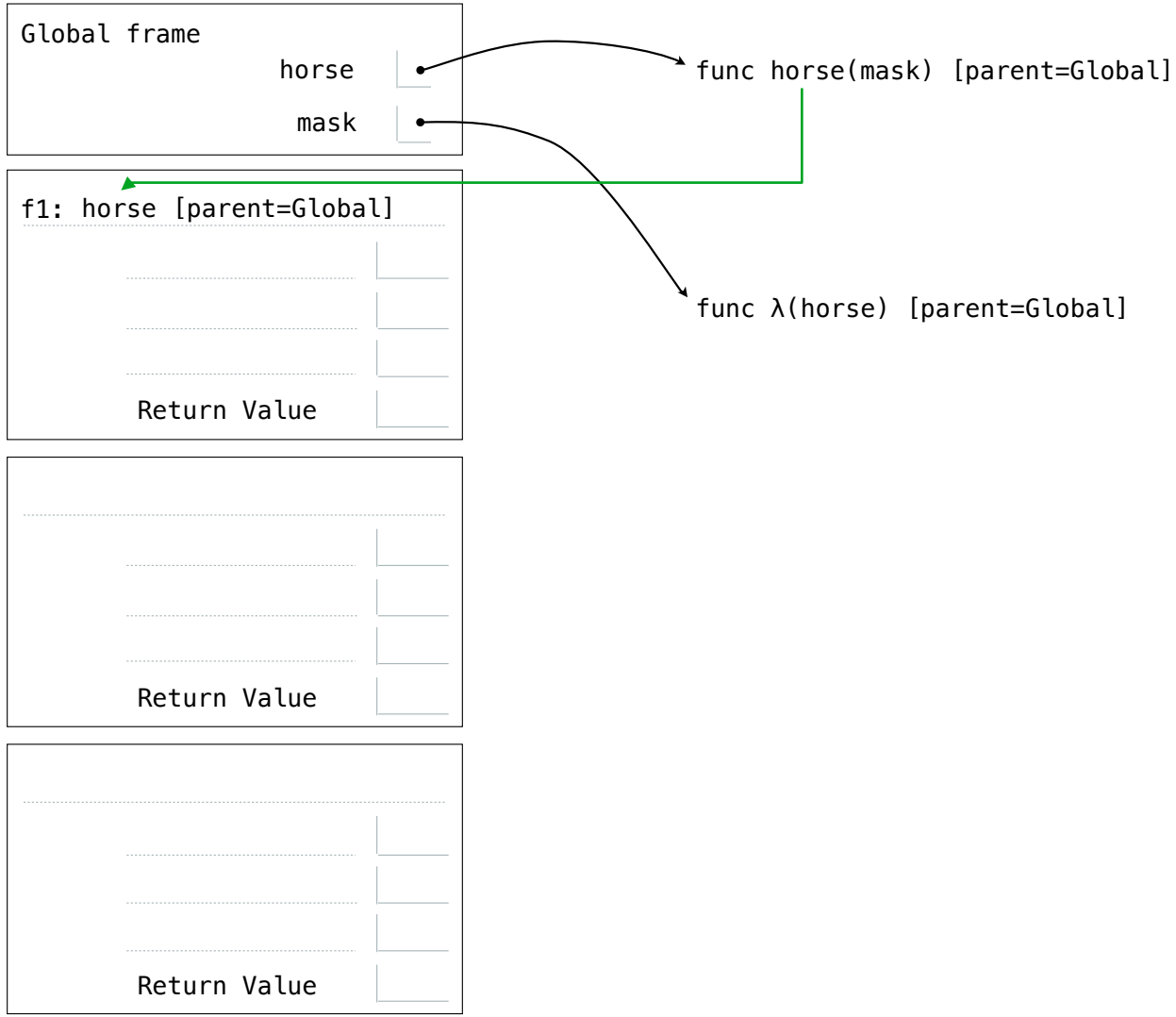
        return horse
    return horse(mask)

mask = lambda horse: horse(2)

horse(mask)
```



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def horse(mask):
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    return horse(mask)

mask = lambda horse: horse(2)

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```
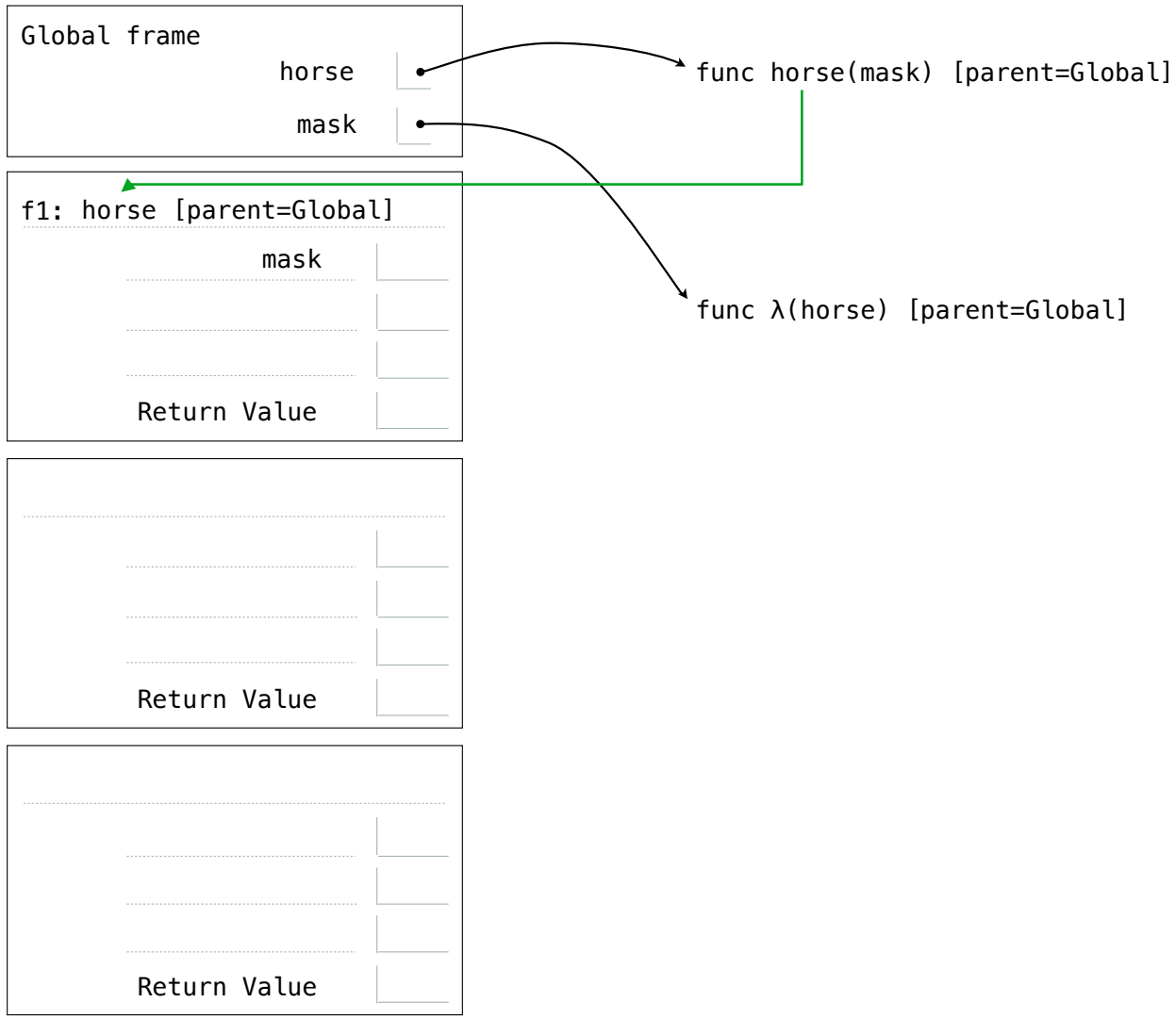
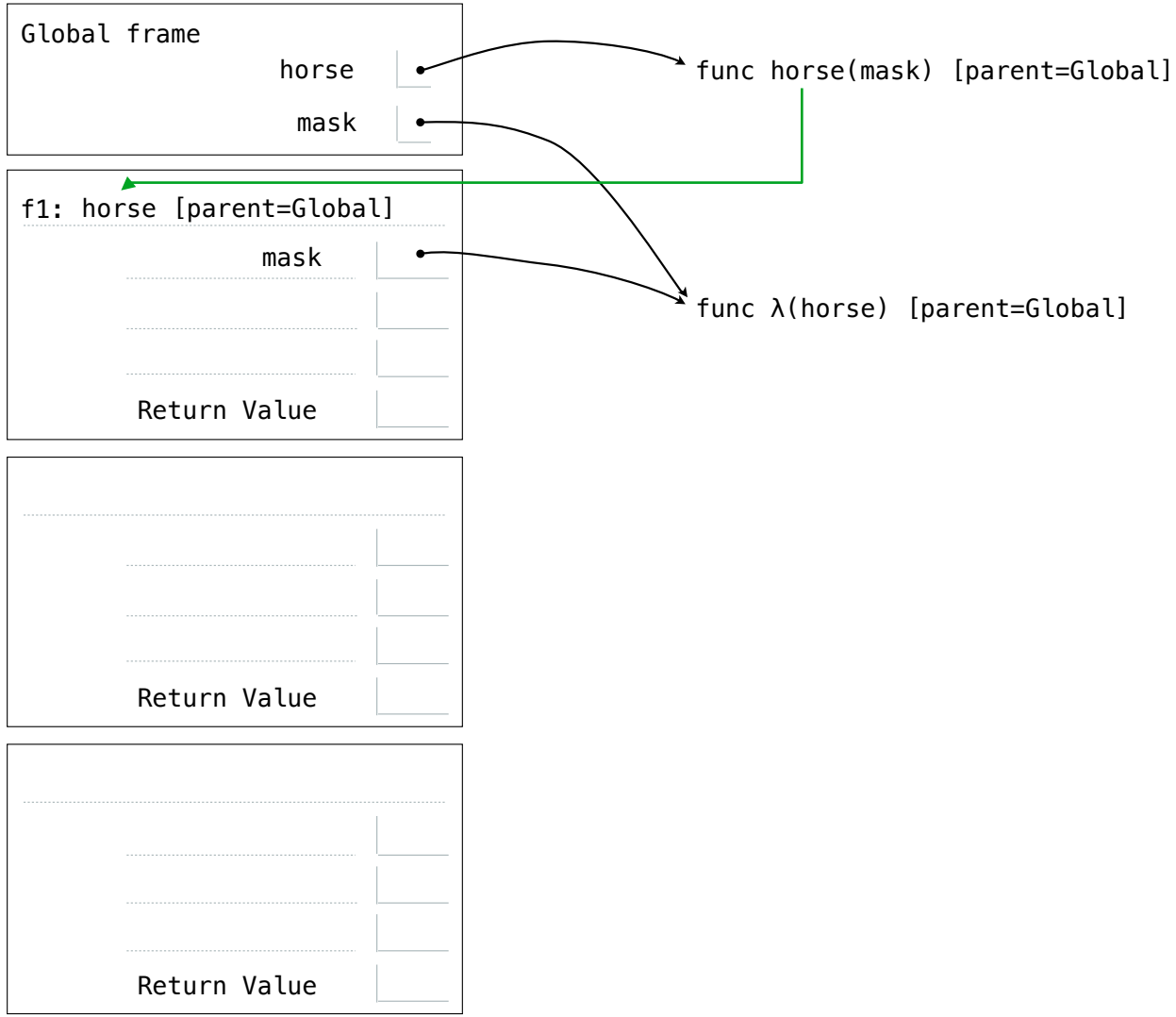
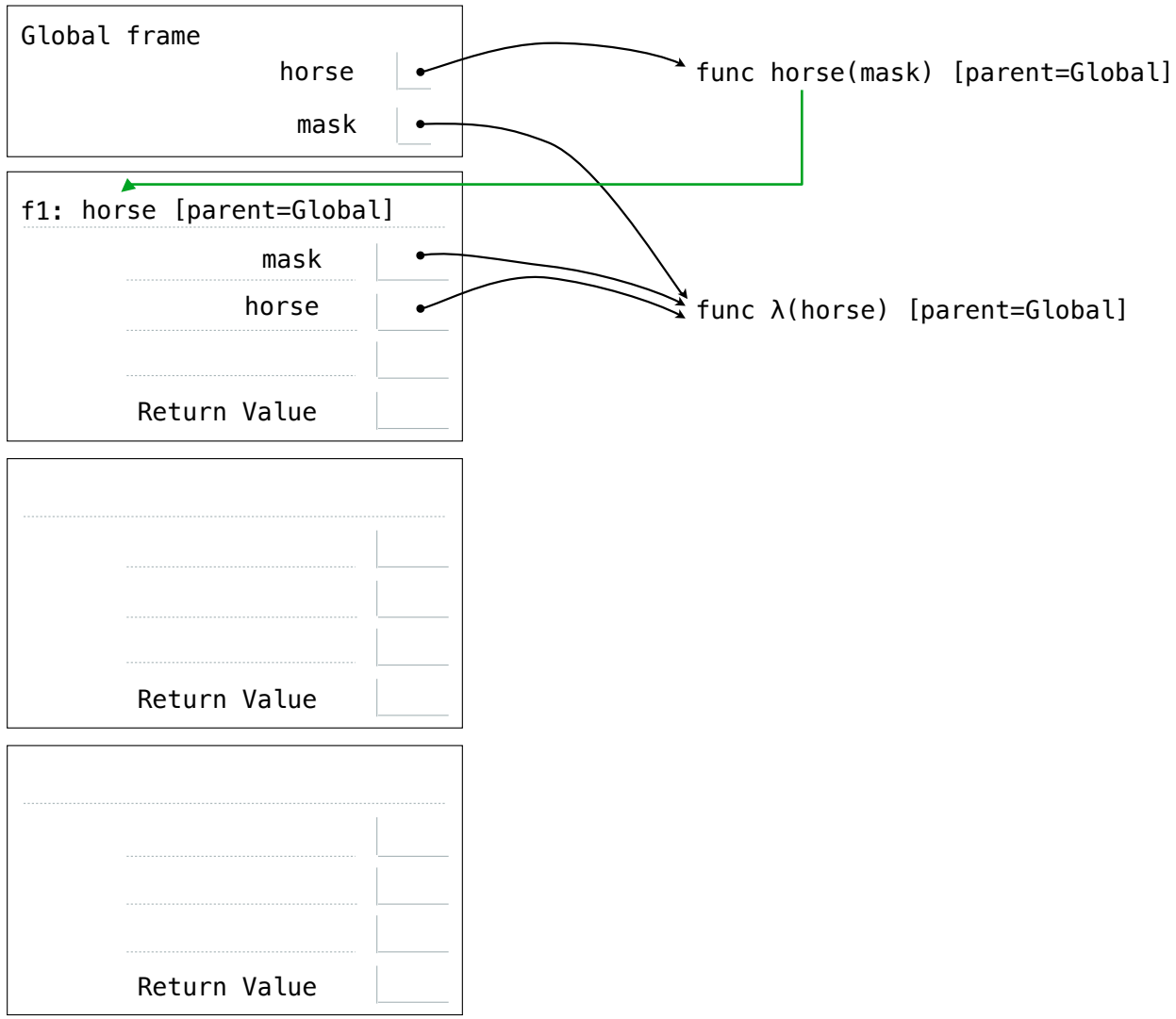



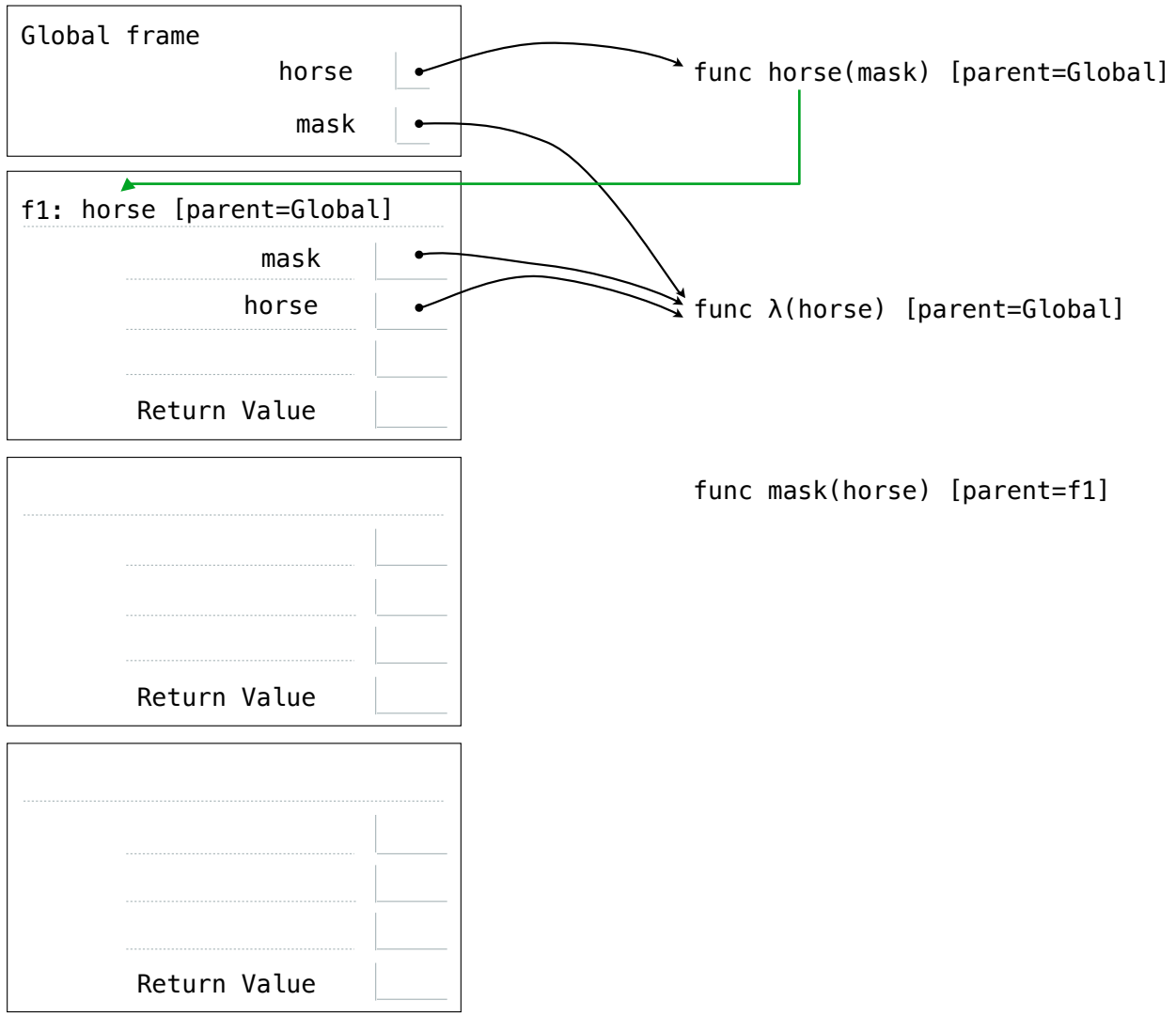
```
def horse(mask):
    horse = mask
    def mask(horse):
        return horse
    return horse(mask)

mask = lambda horse: horse(2)

horse(mask)
```



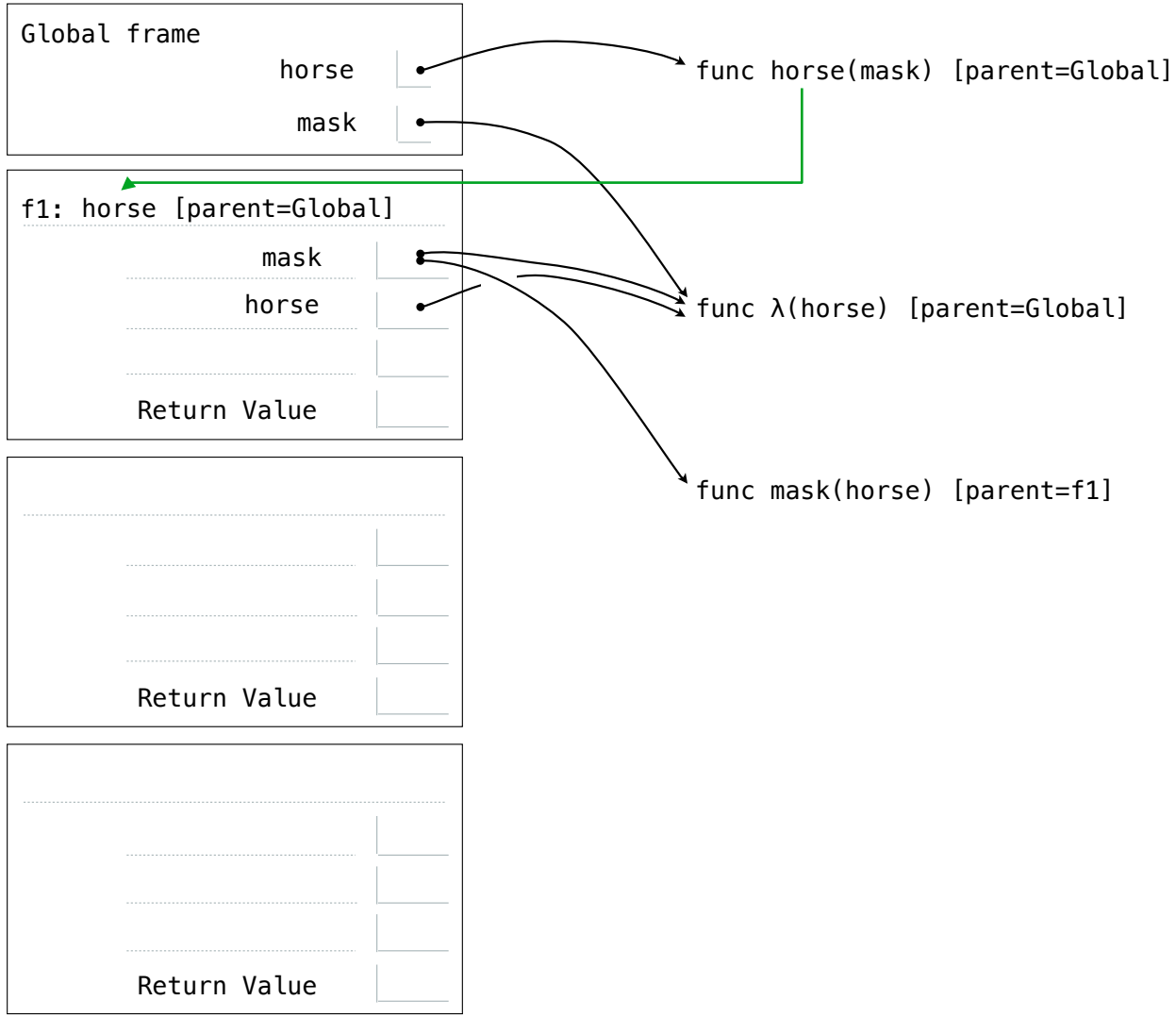
```
def horse(mask):
    horse = mask
    def mask(horse):
        return horse
    return horse(mask)

mask = lambda horse: horse(2)

horse(mask)
```



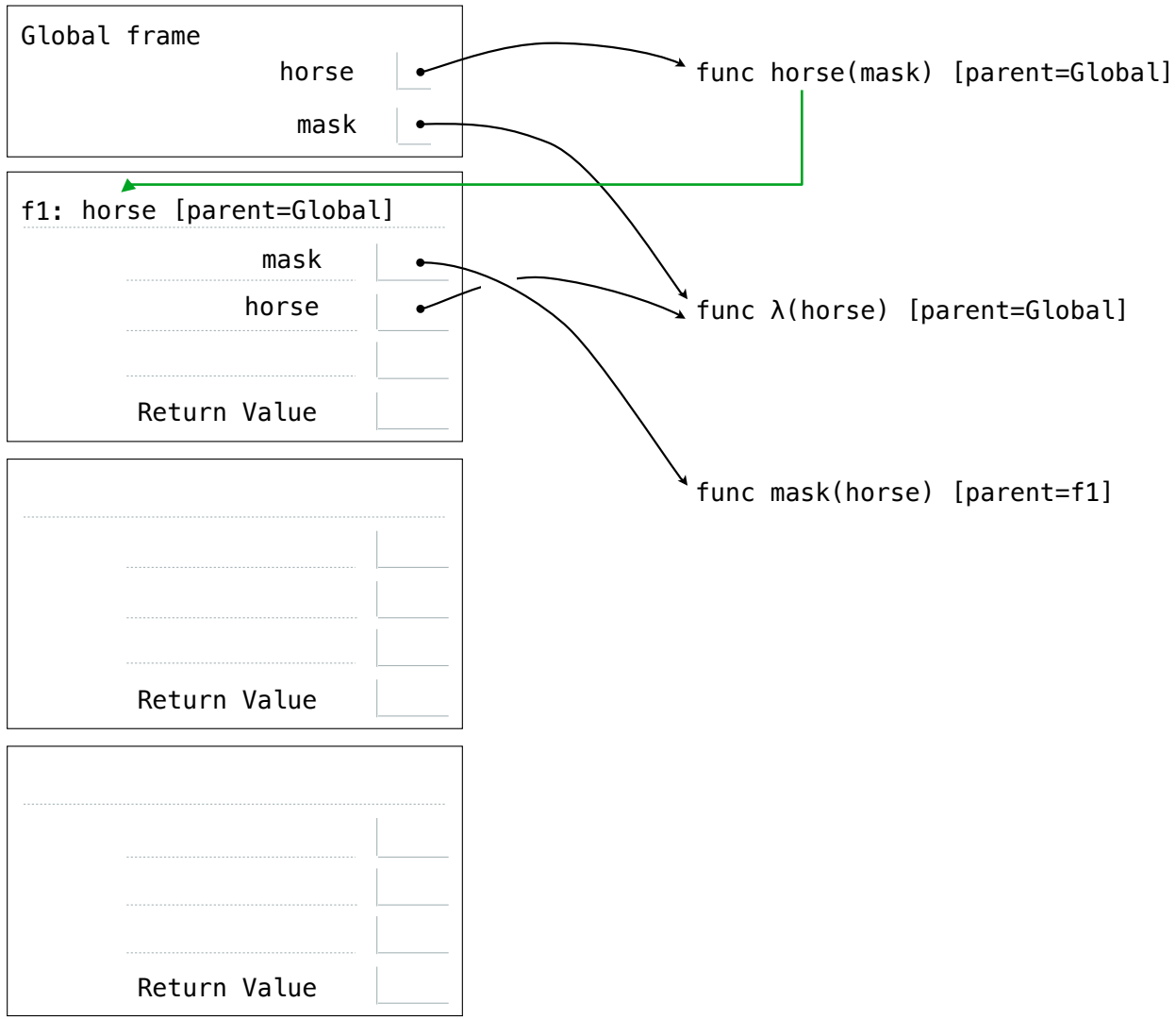
```
def horse(mask):
    horse = mask
    def mask(horse):
        return horse
    return horse(mask)

mask = lambda horse: horse(2)

horse(mask)
```



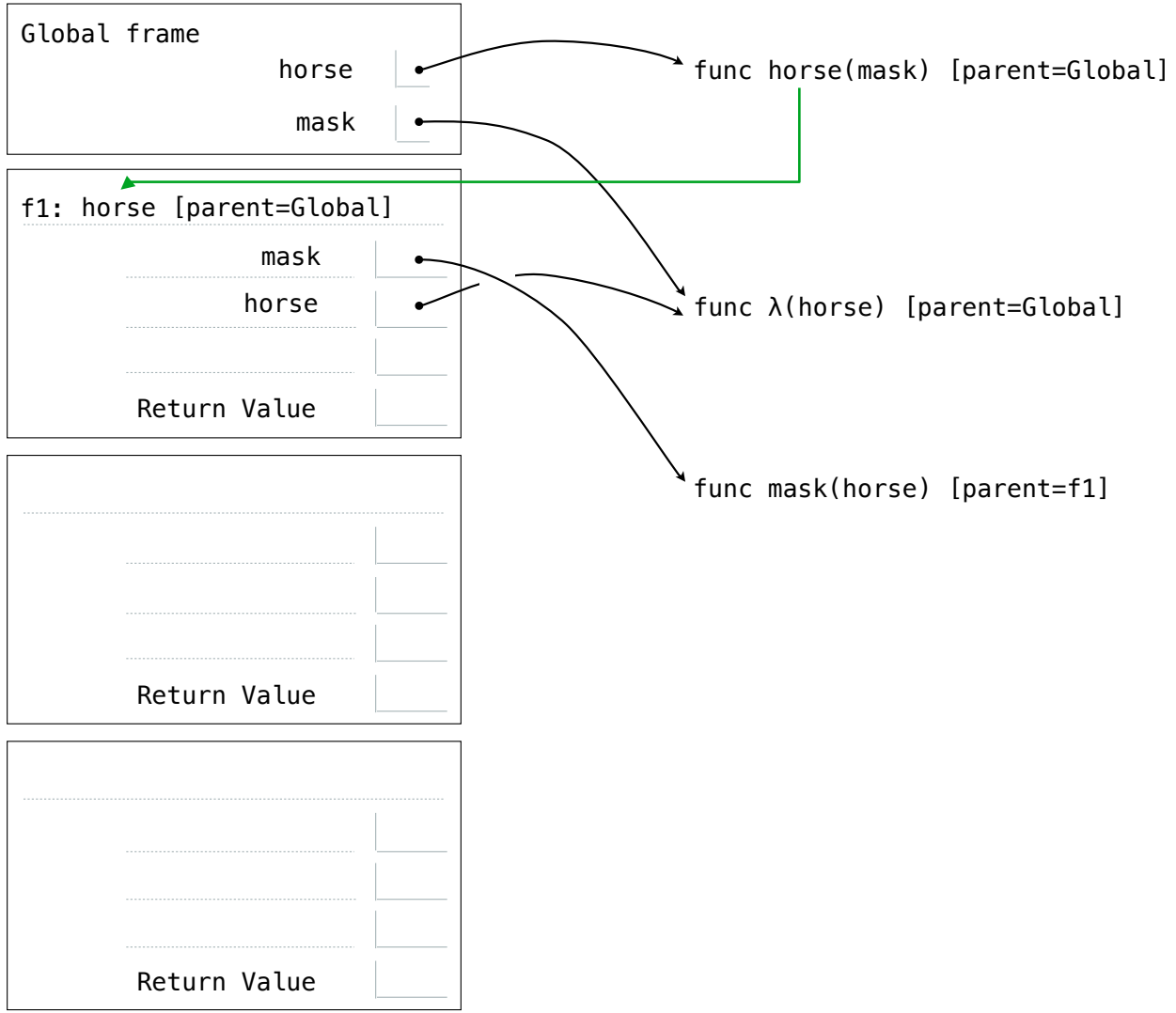
```
def horse(mask):
    horse = mask
    def mask(horse):
        return horse
    return horse(mask)

mask = lambda horse: horse(2)

horse(mask)
```



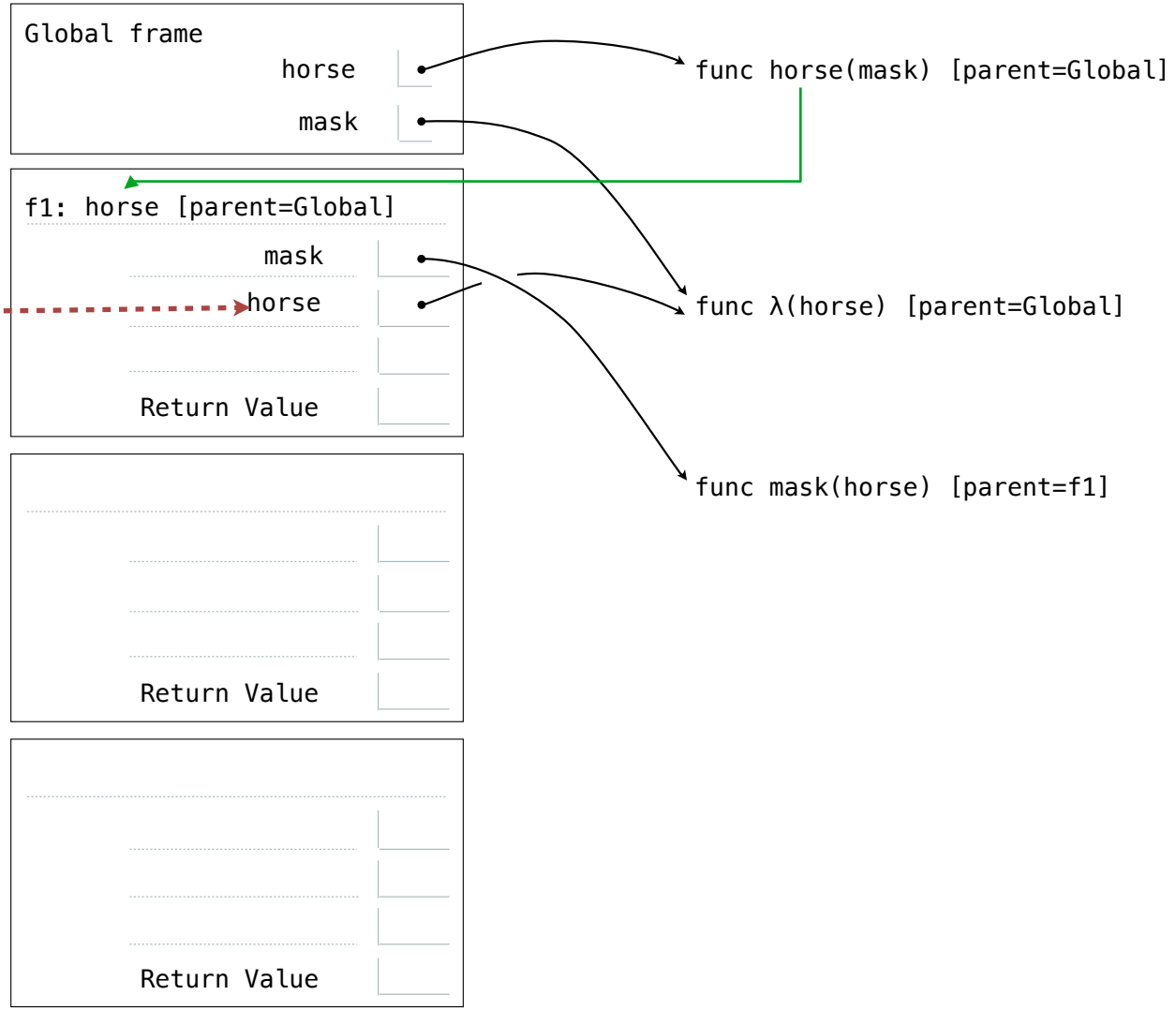
```
def horse(mask):
    horse = mask
    def mask(horse):
        return horse
    return horse(mask)

mask = lambda horse: horse(2)

horse(mask)
```

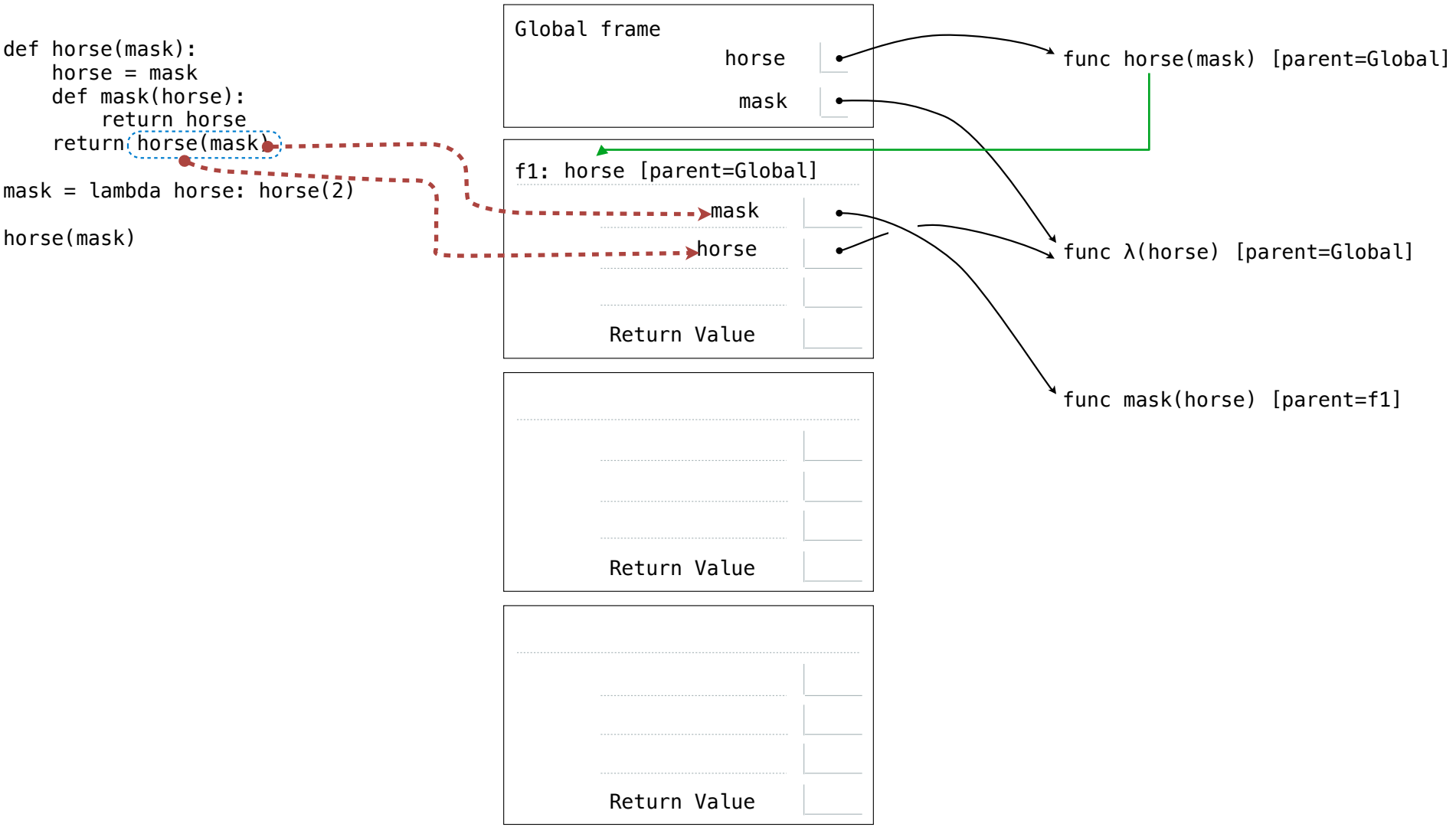


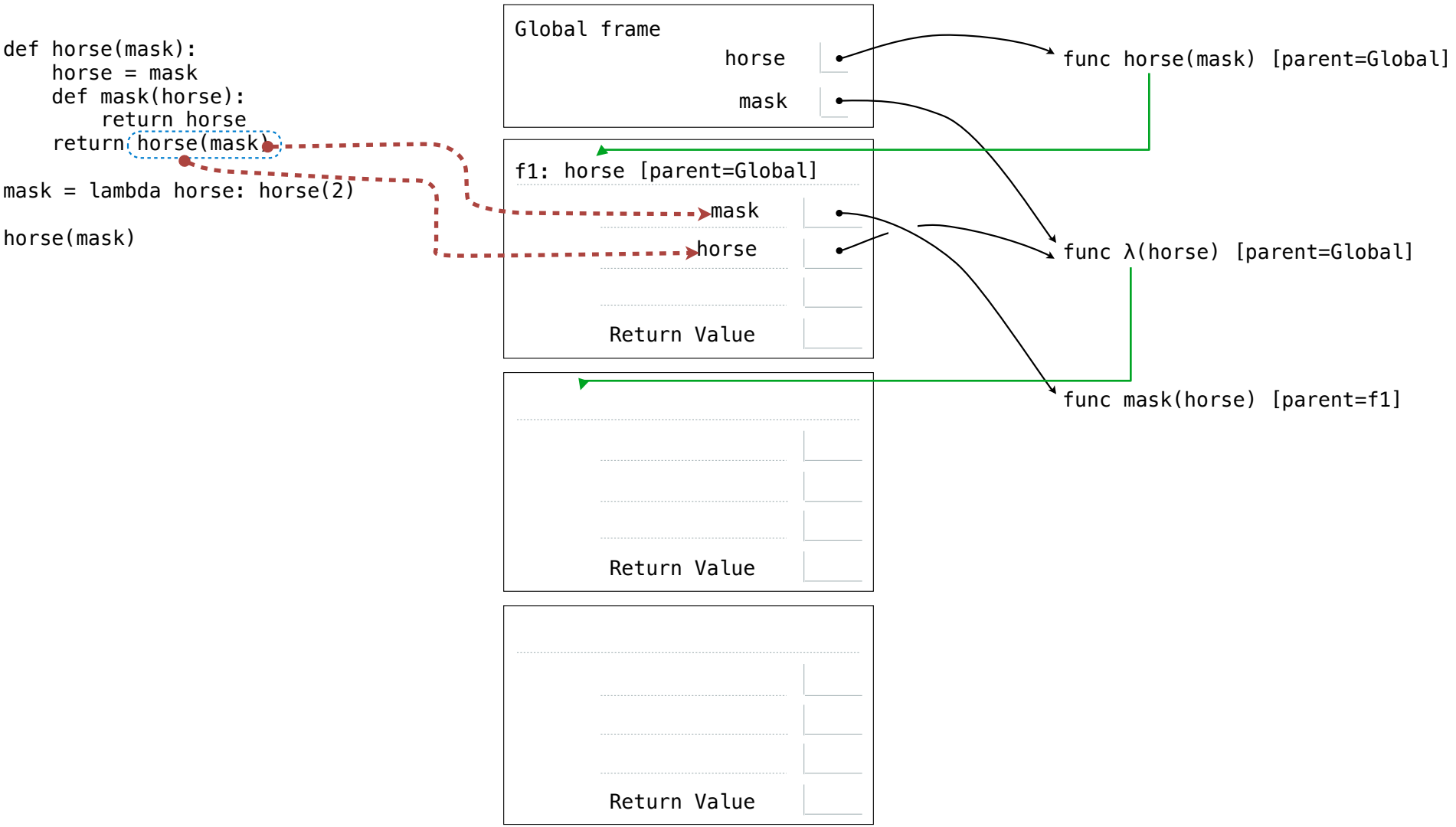
```
def horse(mask):
    horse = mask
    def mask(horse):
        return horse
    return horse(mask)

mask = lambda horse: horse(2)

horse(mask)
```

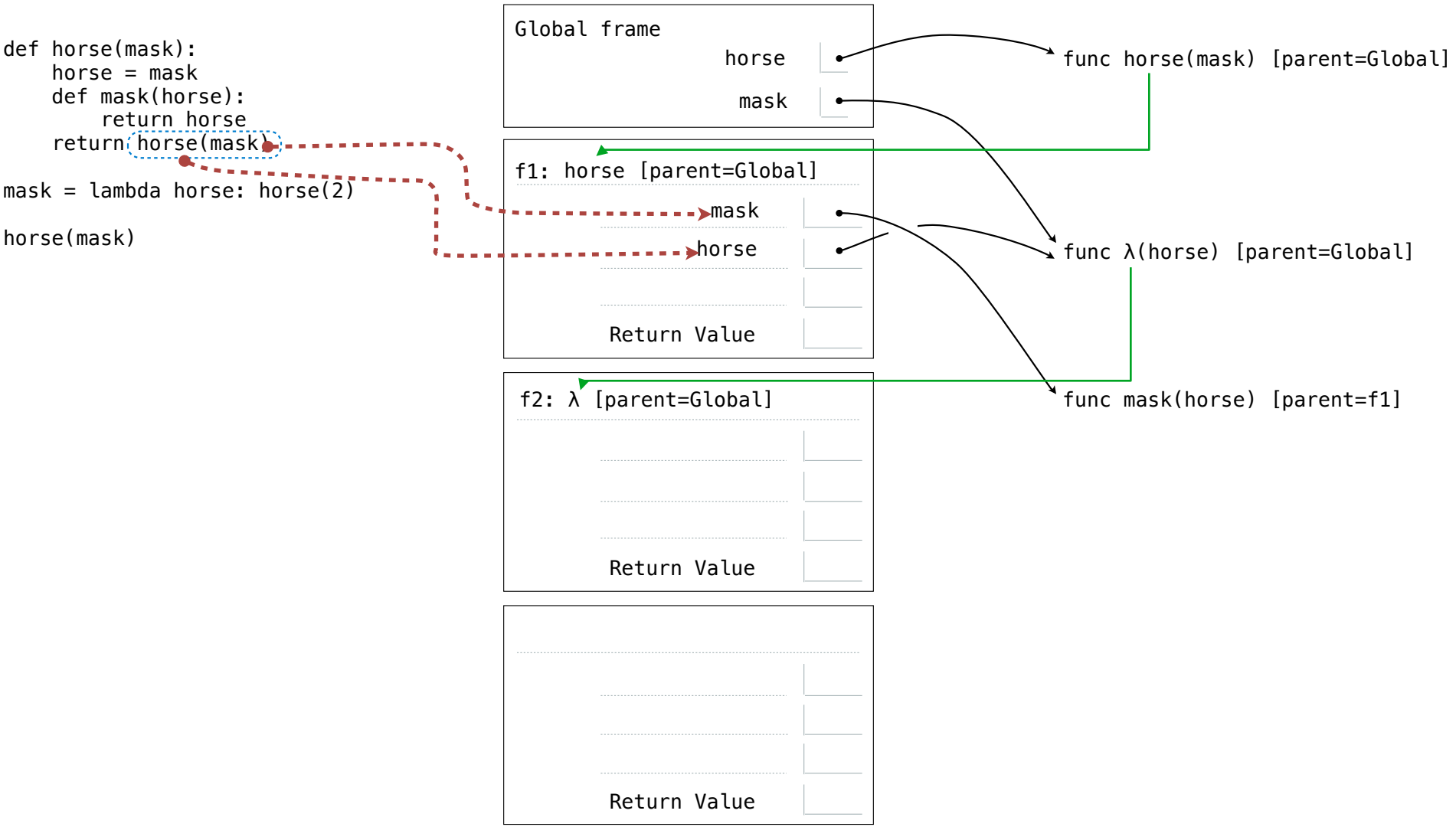


```
def horse(mask):
    horse = mask
    def mask(horse):
        return horse
    return horse(mask)

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)
Global frame
horse
mask
func horse(mask) [parent=Global]
f1: horse [parent=Global]
mask
horse
Return Value
func λ(horse) [parent=Global]
func mask(horse) [parent=f1]
Return Value
Return Value


def horse(mask):
horse = mask
def mask(horse):
return horse
return horse(mask)
mask = lambda horse: horse(2)
horse(mask)
Global frame
horse
mask
func horse(mask) [parent=Global]
f1: horse [parent=Global]
mask
horse
Return Value
func λ(horse) [parent=Global]
func mask(horse) [parent=f1]
Return Value
Return Value


def horse(mask):
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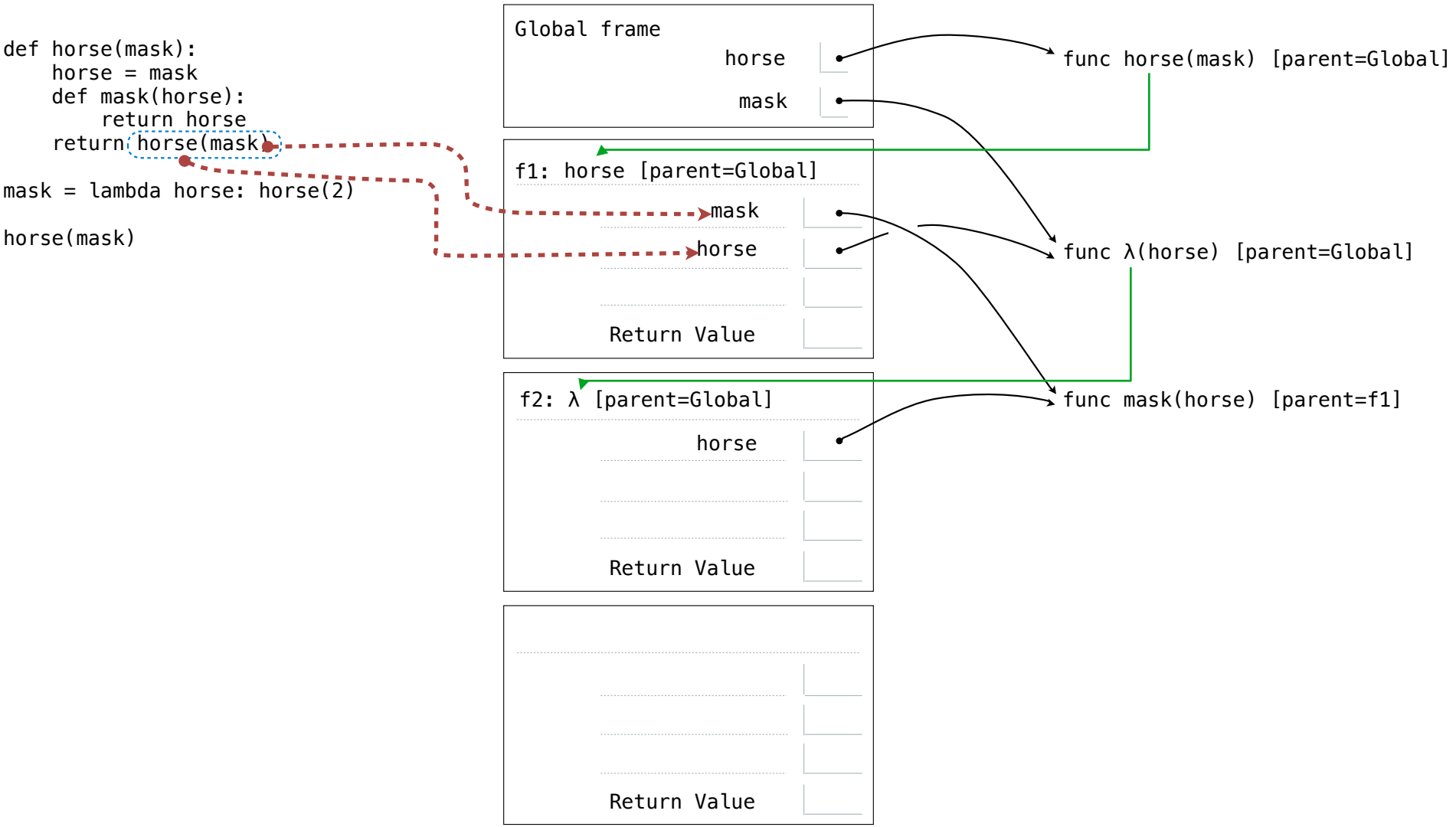
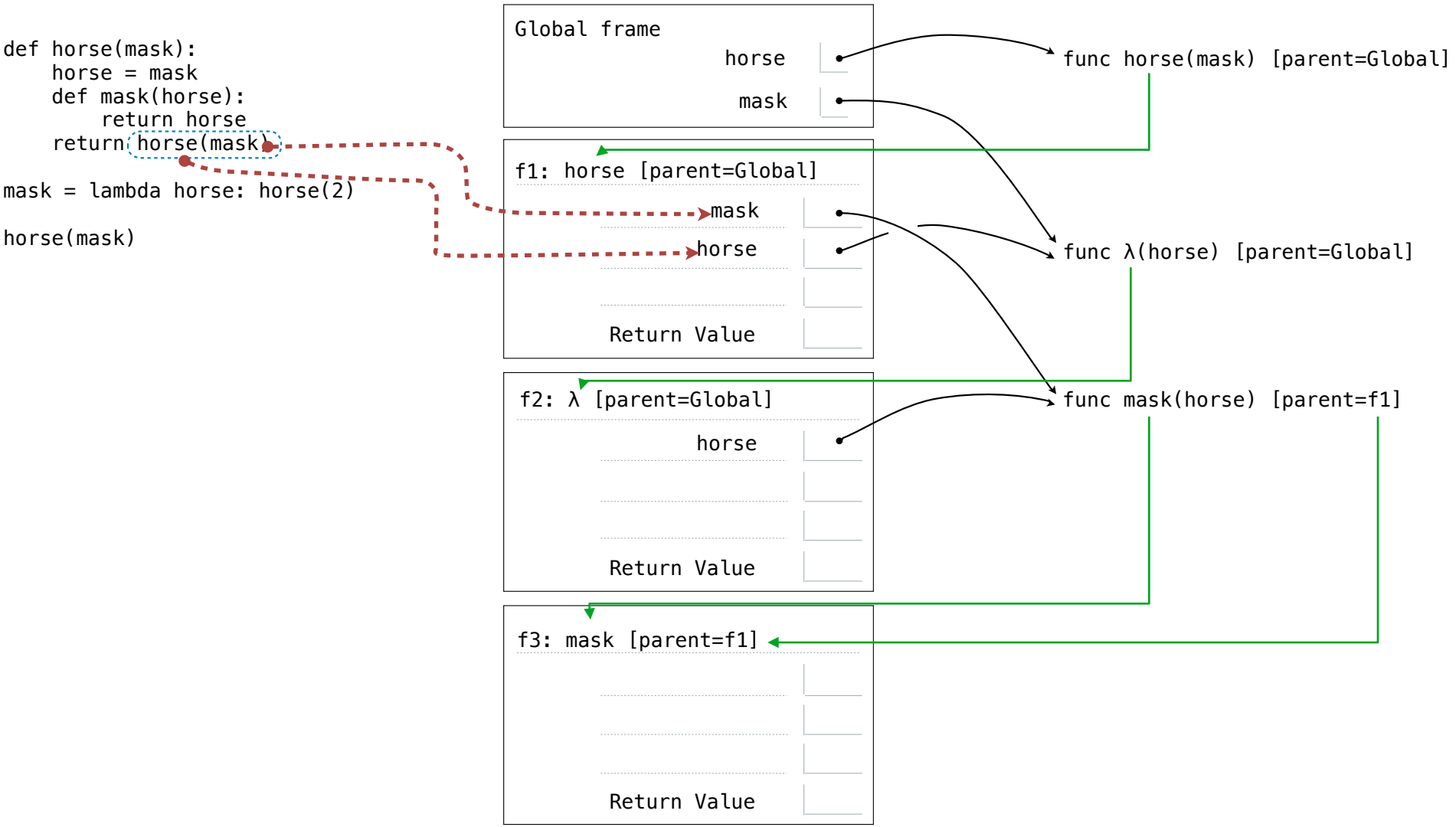
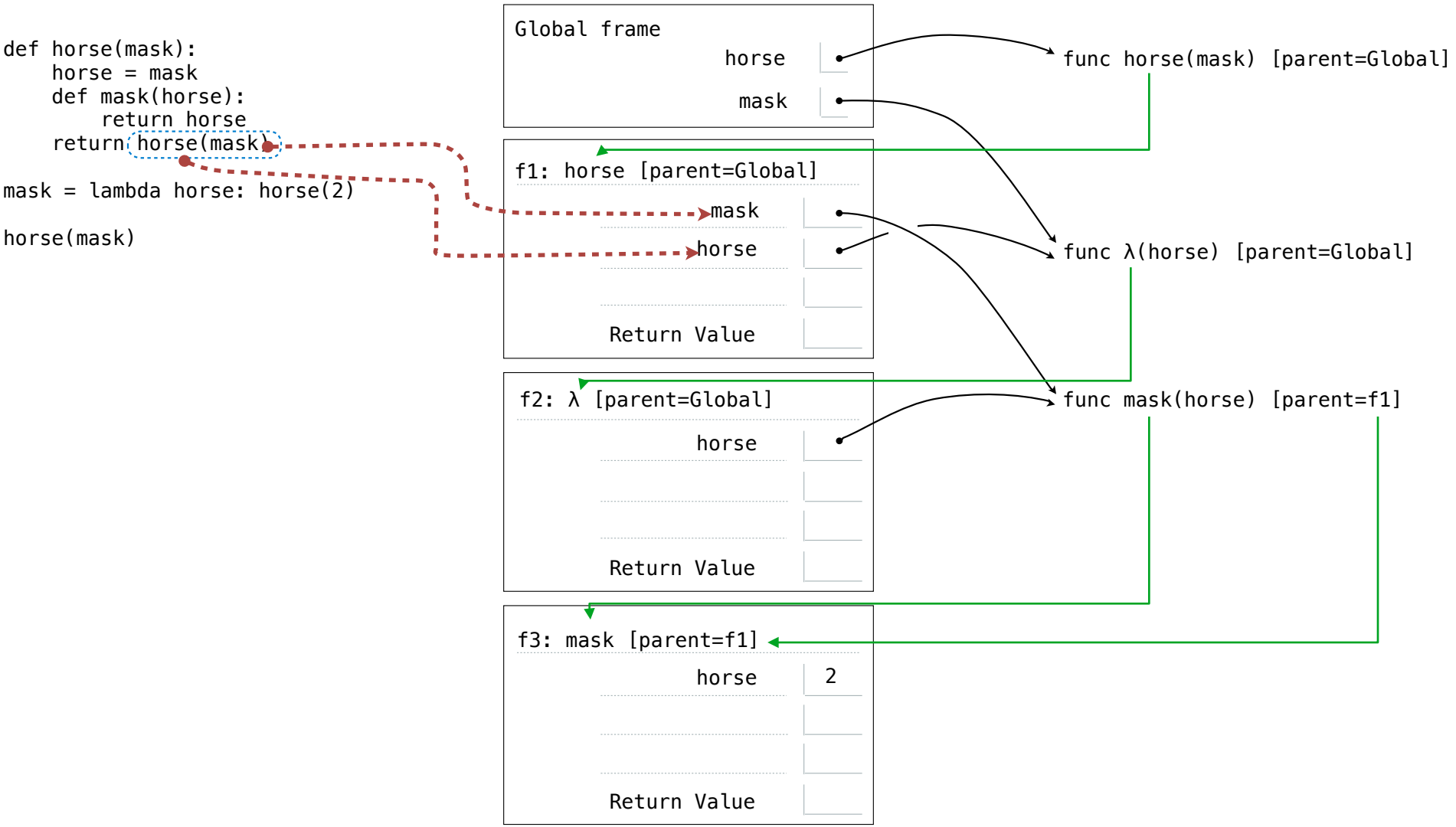
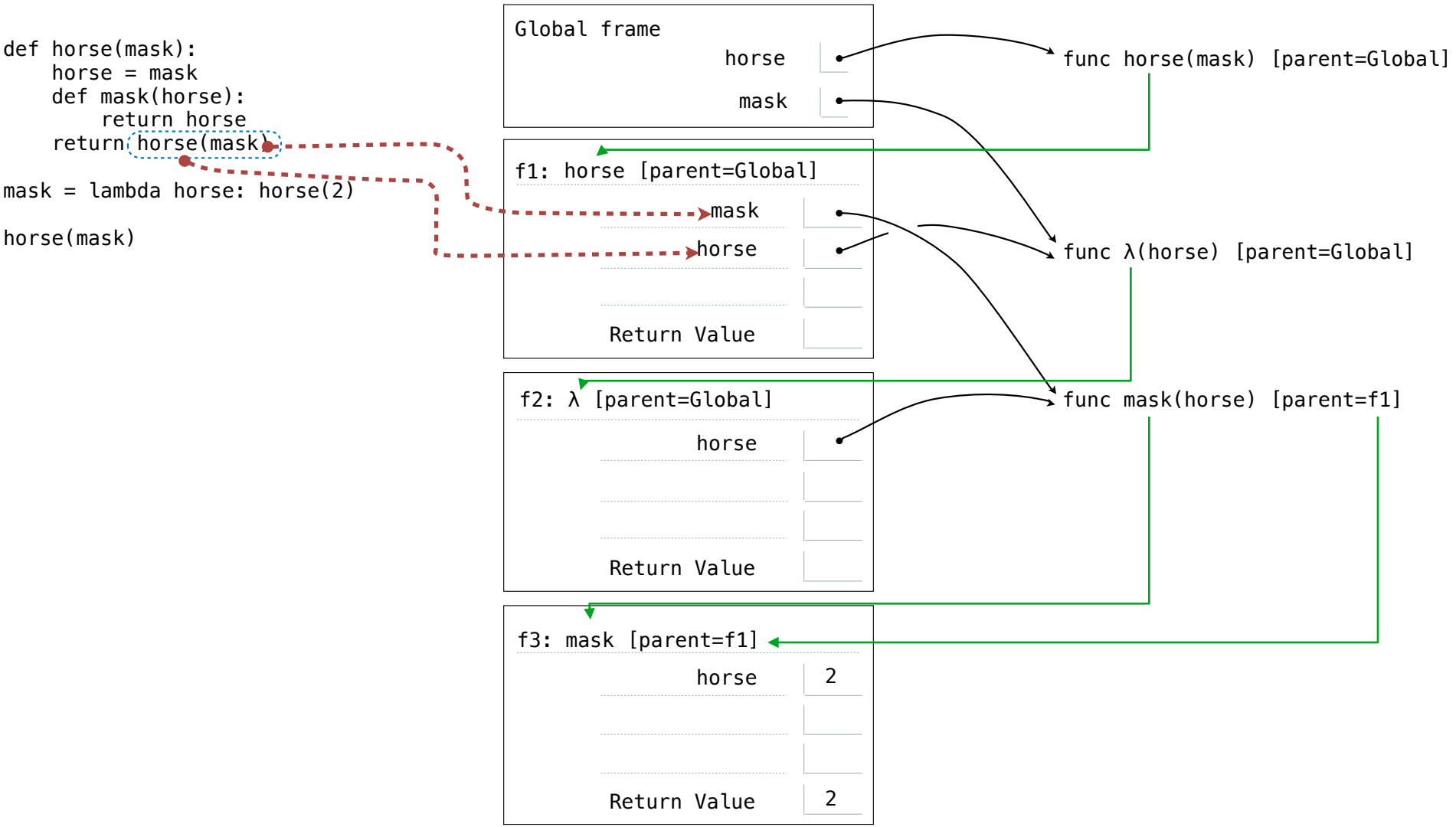
horse(mask)
Global frame
horse
mask
func horse(mask) [parent=Global]
f1: horse [parent=Global]
mask
horse
Return Value
func λ(horse) [parent=Global]
f2: λ [parent=Global]
Return Value
func mask(horse) [parent=f1]
Return Value


def horse(mask):
horse = mask
def mask(horse):
return horse
return horse(mask)
mask = lambda horse: horse(2)
horse(mask)
Global frame
horse
mask
func horse(mask) [parent=Global]
f1: horse [parent=Global]
mask
horse
Return Value
func λ(horse) [parent=Global]
f2: λ [parent=Global]
horse
Return Value
func mask(horse) [parent=f1]
Return Value


def horse(mask):
horse = mask
def mask(horse):
return horse
return horse(mask)
mask = lambda horse: horse(2)
horse(mask)
Global frame
horse
mask
func horse(mask) [parent=Global]
f1: horse [parent=Global]
mask
horse
Return Value
func λ(horse) [parent=Global]
f2: λ [parent=Global]
horse
Return Value
func mask(horse) [parent=f1]
f3: mask [parent=f1]
Return Value


def horse(mask):
horse = mask
def mask(horse):
return horse
return horse(mask)
mask = lambda horse: horse(2)
horse(mask)
Global frame
horse
mask
func horse(mask) [parent=Global]
f1: horse [parent=Global]
mask
horse
Return Value
func λ(horse) [parent=Global]
f2: λ [parent=Global]
horse
Return Value
func mask(horse) [parent=f1]
f3: mask [parent=f1]
horse
2
Return Value


def horse(mask):
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def mask(horse):
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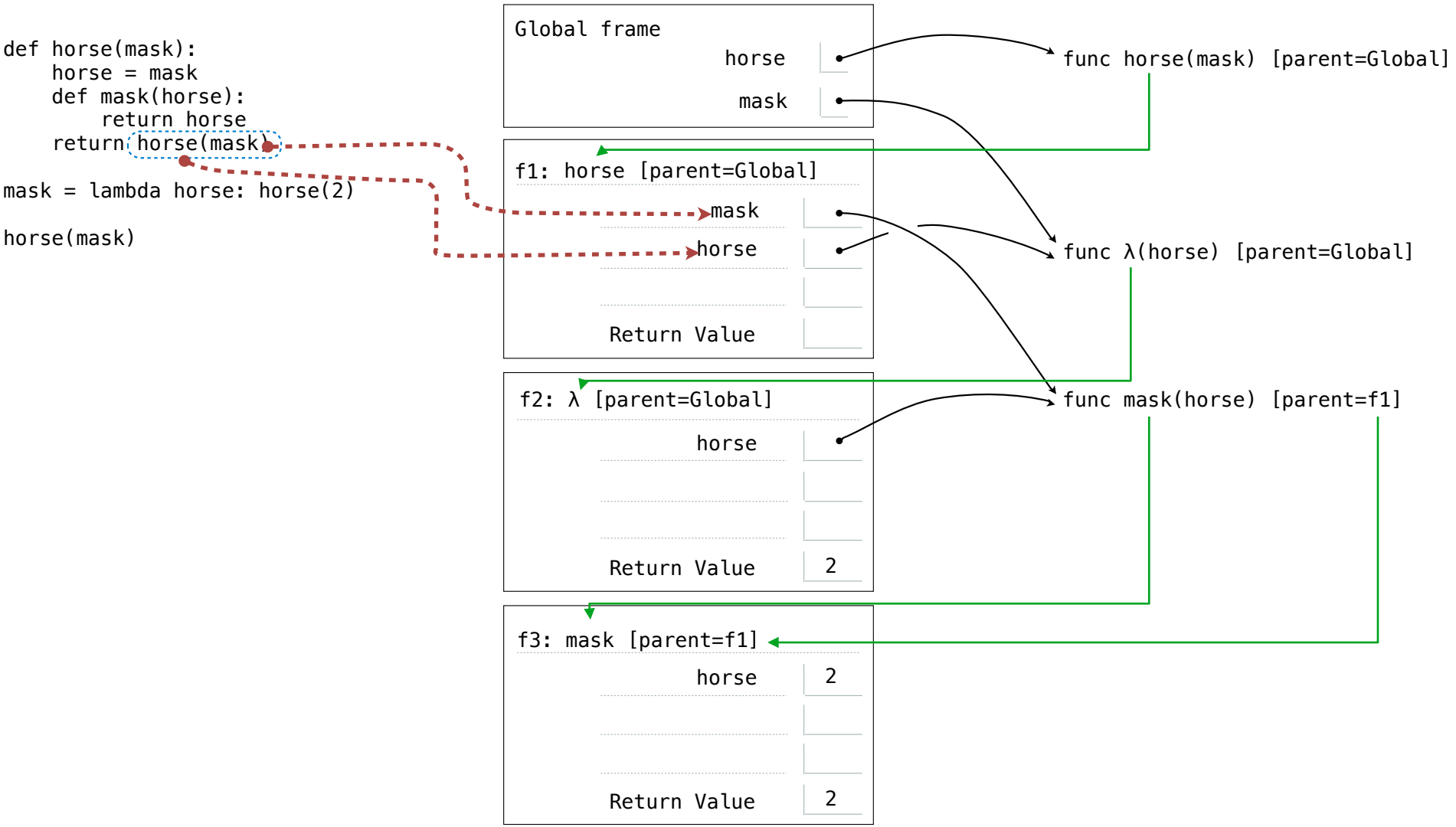
return horse(mask)
mask = lambda horse: horse(2)
horse(mask)
Global frame
horse
mask
func horse(mask) [parent=Global]
f1: horse [parent=Global]
mask
horse
Return Value
func λ(horse) [parent=Global]
f2: λ [parent=Global]
horse
Return Value
func mask(horse) [parent=f1]
f3: mask [parent=f1]
horse
2
Return Value
2


def horse(mask):
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return horse(mask)
mask = lambda horse: horse(2)
horse(mask)
Global frame
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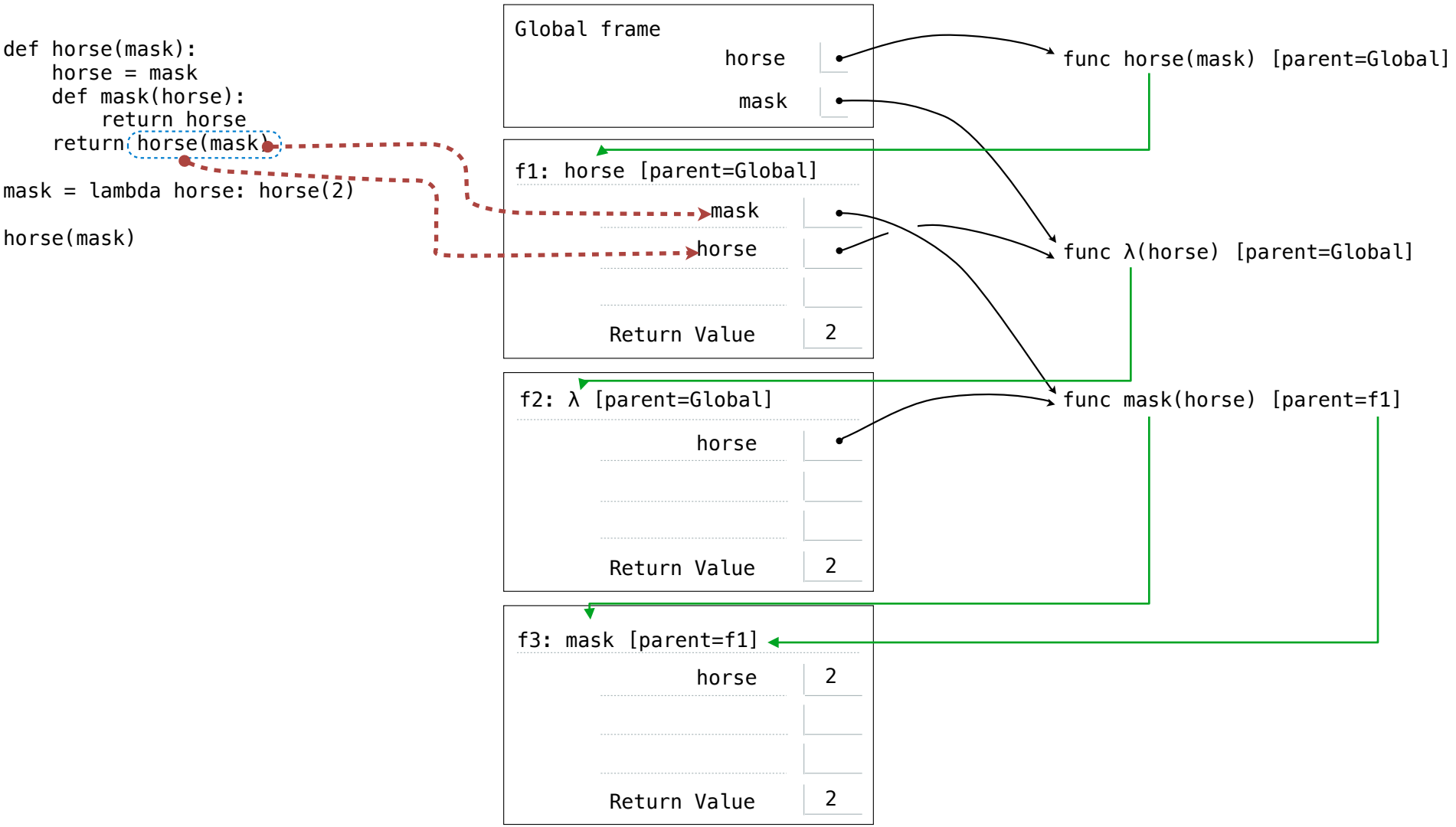
mask
func horse(mask) [parent=Global]
f1: horse [parent=Global]
mask
horse
Return Value
func λ(horse) [parent=Global]
f2: λ [parent=Global]
horse
Return Value
2
func mask(horse) [parent=f1]
f3: mask [parent=f1]
horse
2
Return Value
2


def horse(mask):
horse = mask
def mask(horse):
return horse
return horse(mask)
mask = lambda horse: horse(2)
horse(mask)
Global frame
horse
mask
func horse(mask) [parent=Global]
f1: horse [parent=Global]
mask
horse
Return Value
2
func λ(horse) [parent=Global]
f2: λ [parent=Global]
horse
Return Value
2
func mask(horse) [parent=f1]
f3: mask [parent=f1]
horse
2
Return Value
2