61A Lecture 8

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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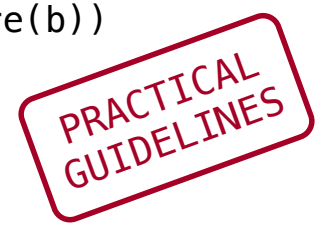

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(Demo)

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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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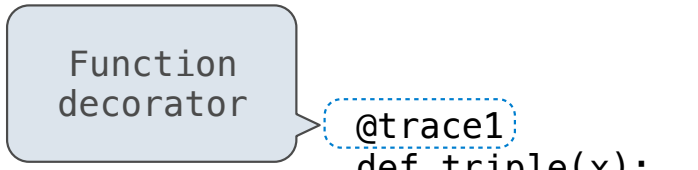
Function Decorators

(Demo)

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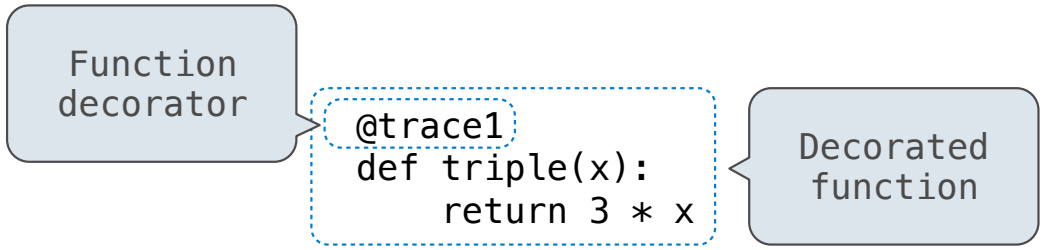

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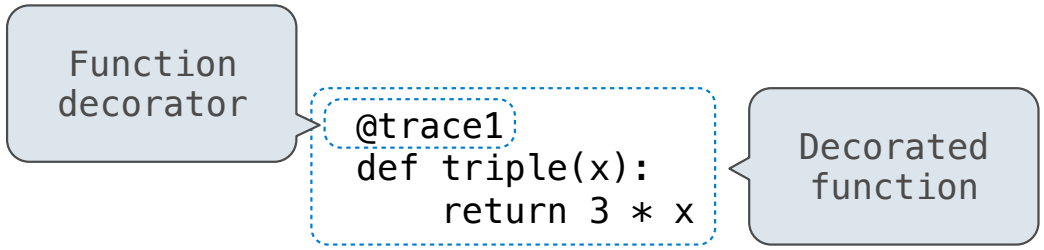

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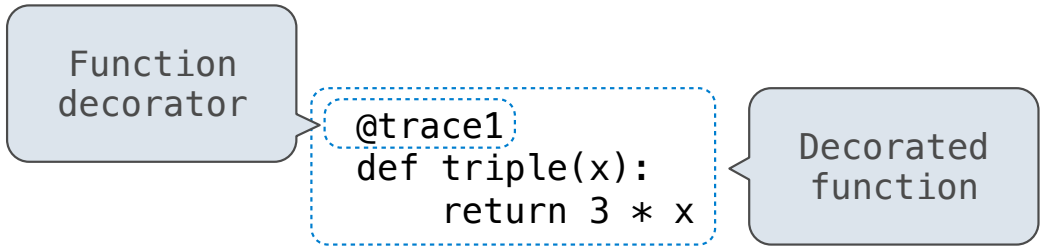

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Function Decorators

(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 g():
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A function that takes any argument and returns a function that returns that arg

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

`print(print(5))` — None

What Would Python Display?

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

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`print(5)` → `None`

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

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`print(print(5))`	`None`	`5` `None`

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

None

What Would Python Display?

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

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

None

What Would Python Display?

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

What Would Python Display?

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 Display?

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

What Would Python Display?

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 Display?

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():
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    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`

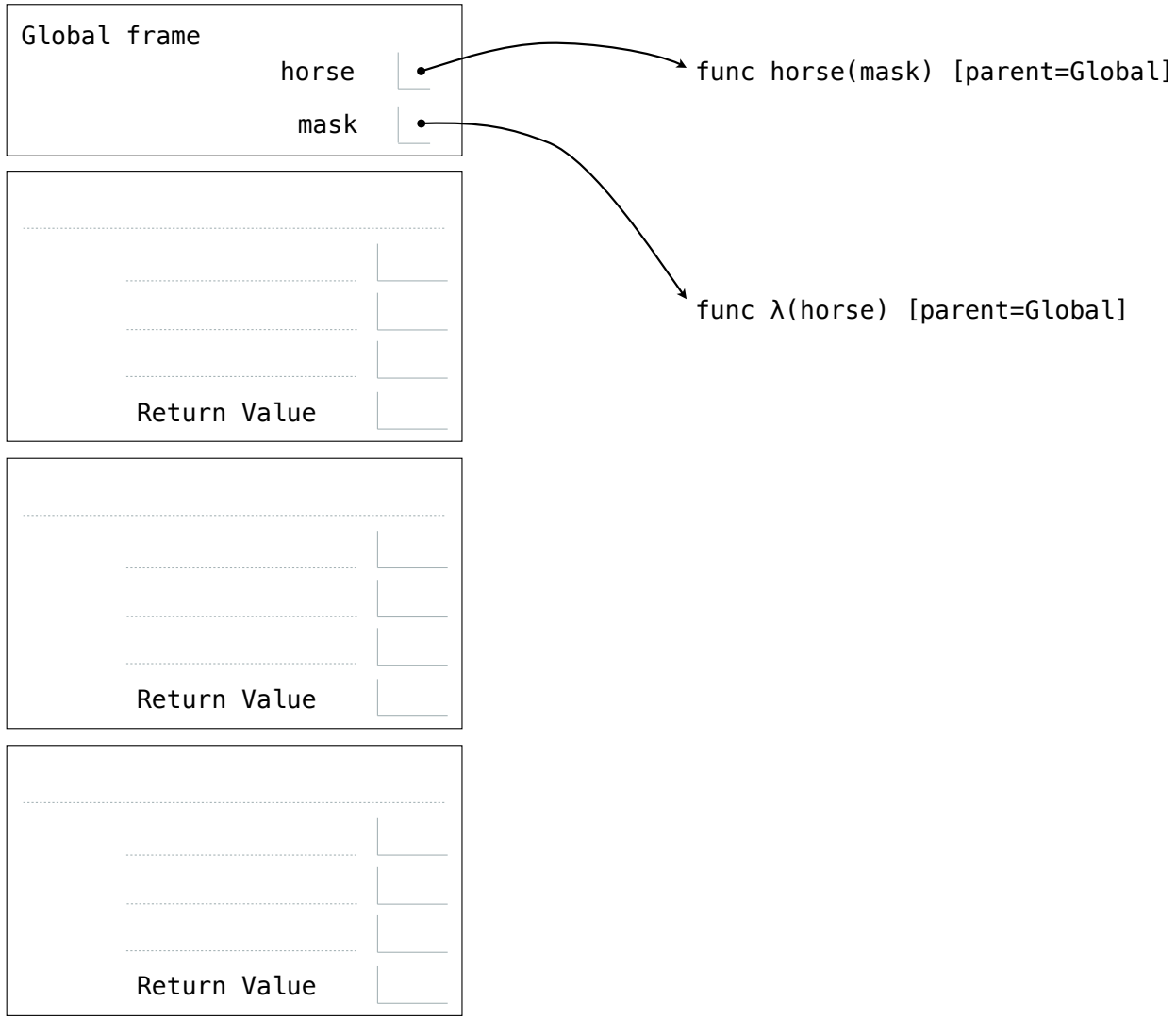
`delay(delay)()(6)()`	`6`	`delayed`
		`delayed`
		`6`

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

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

mask = lambda horse: horse(2)

horse(mask)
```



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def horse(mask):
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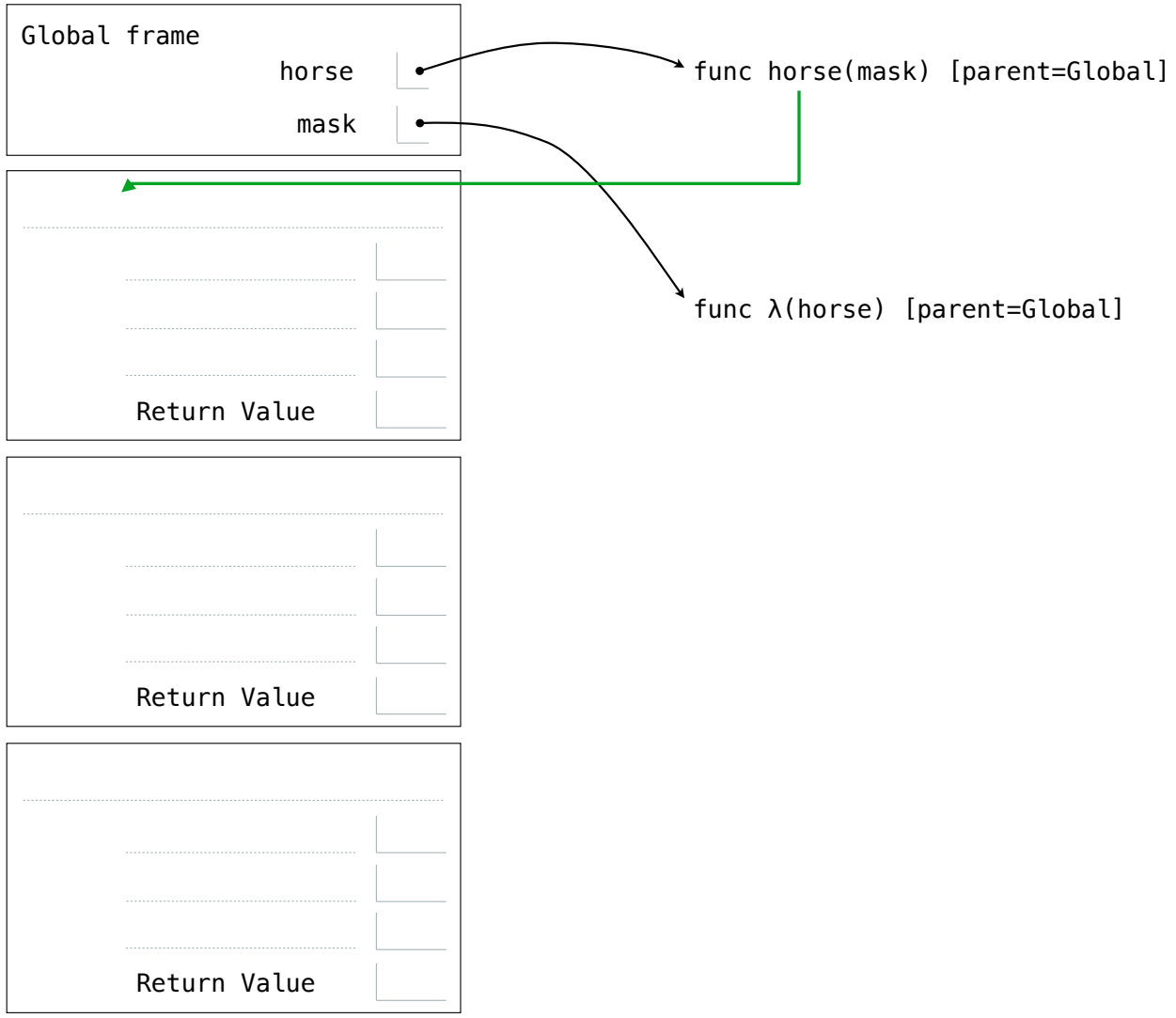

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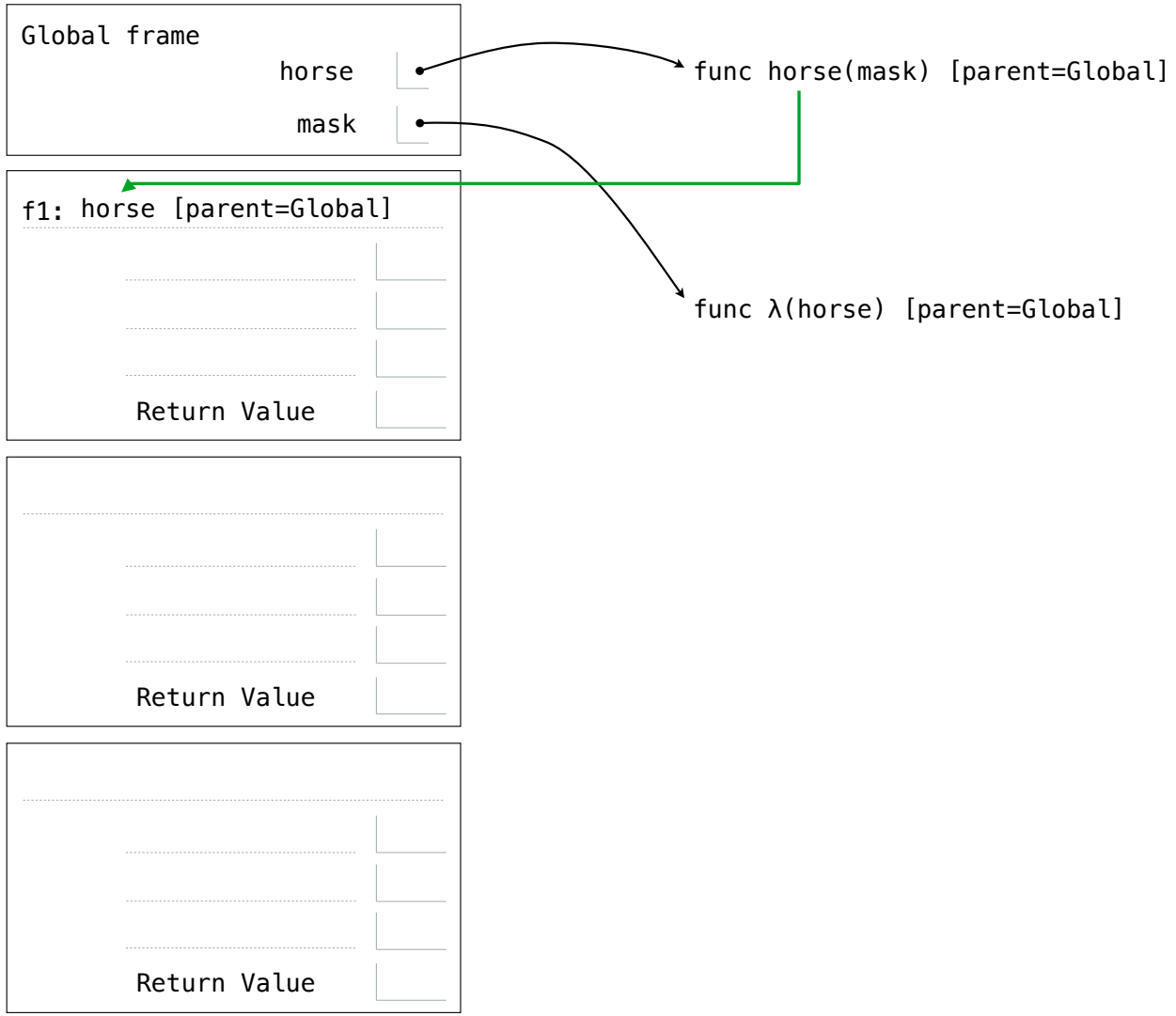

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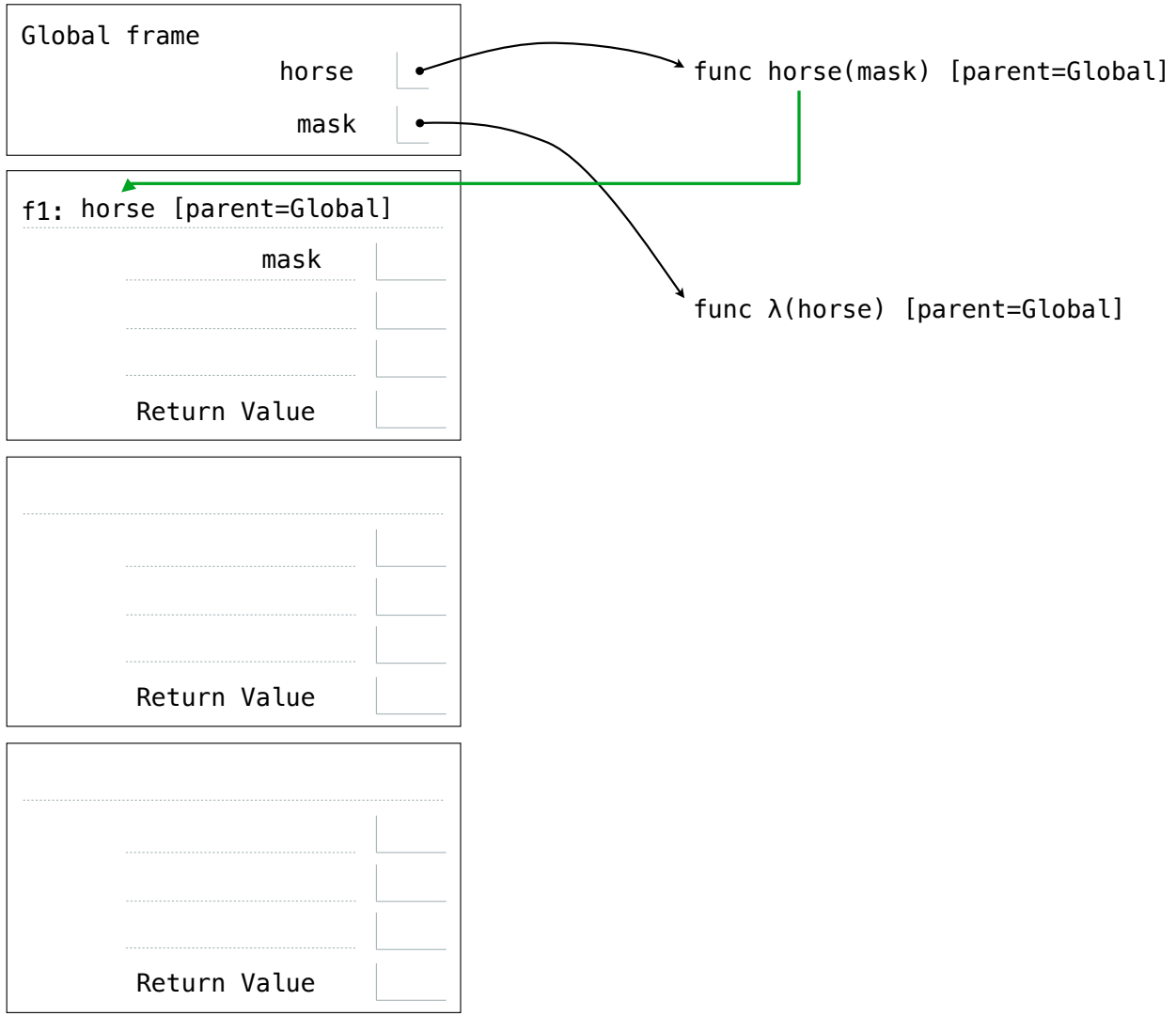

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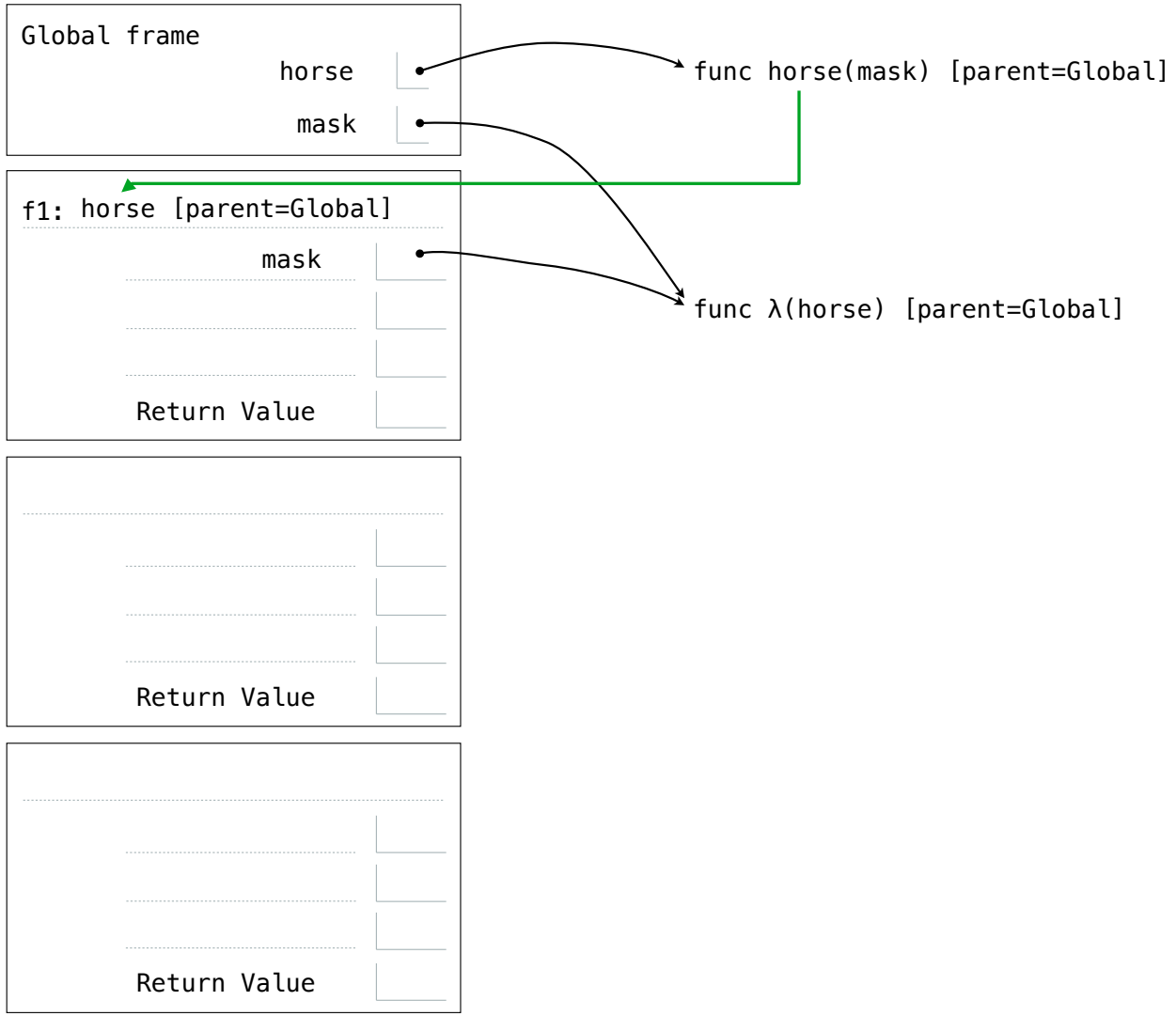

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def horse(mask):
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mask = lambda horse: horse(2)

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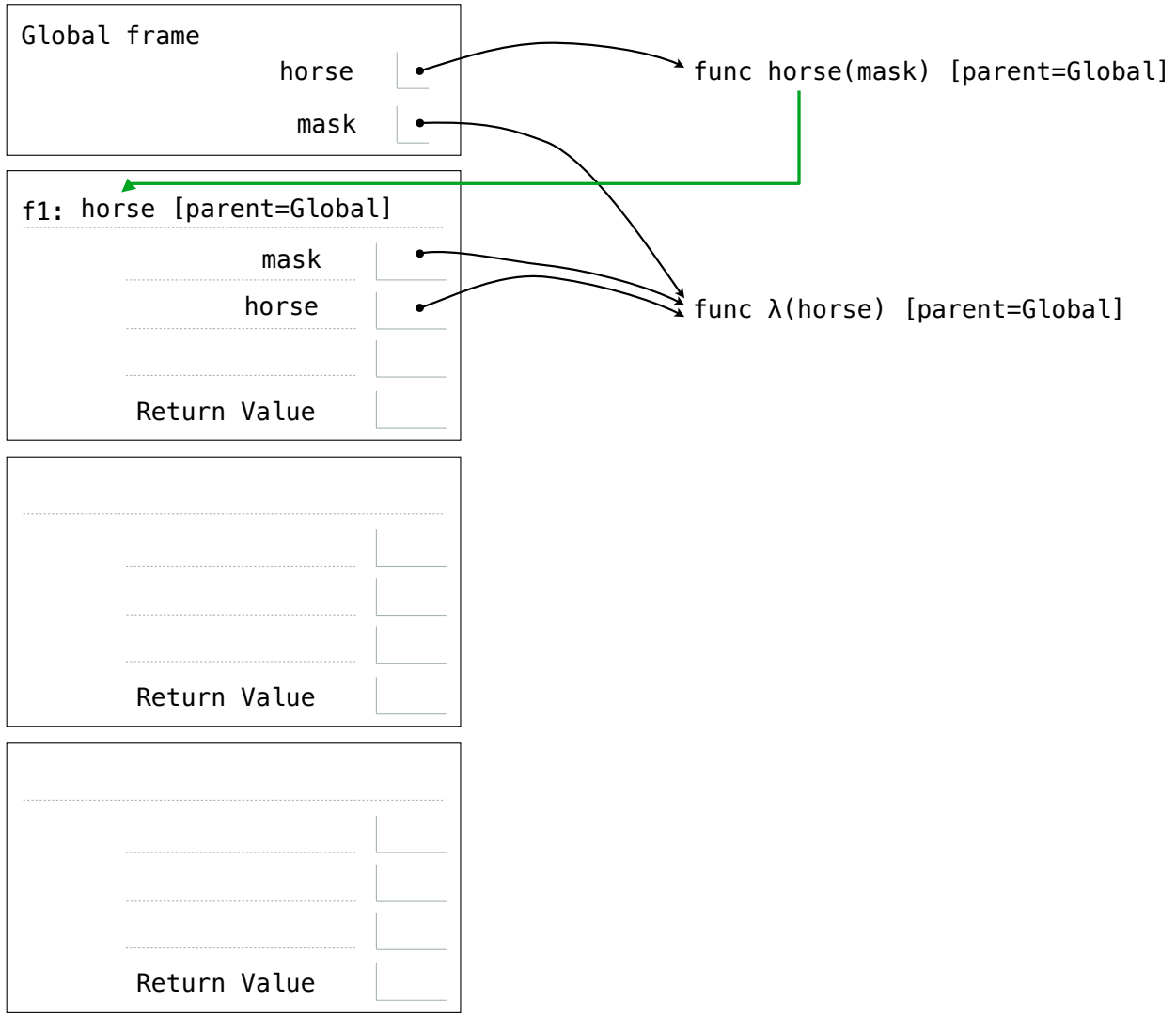

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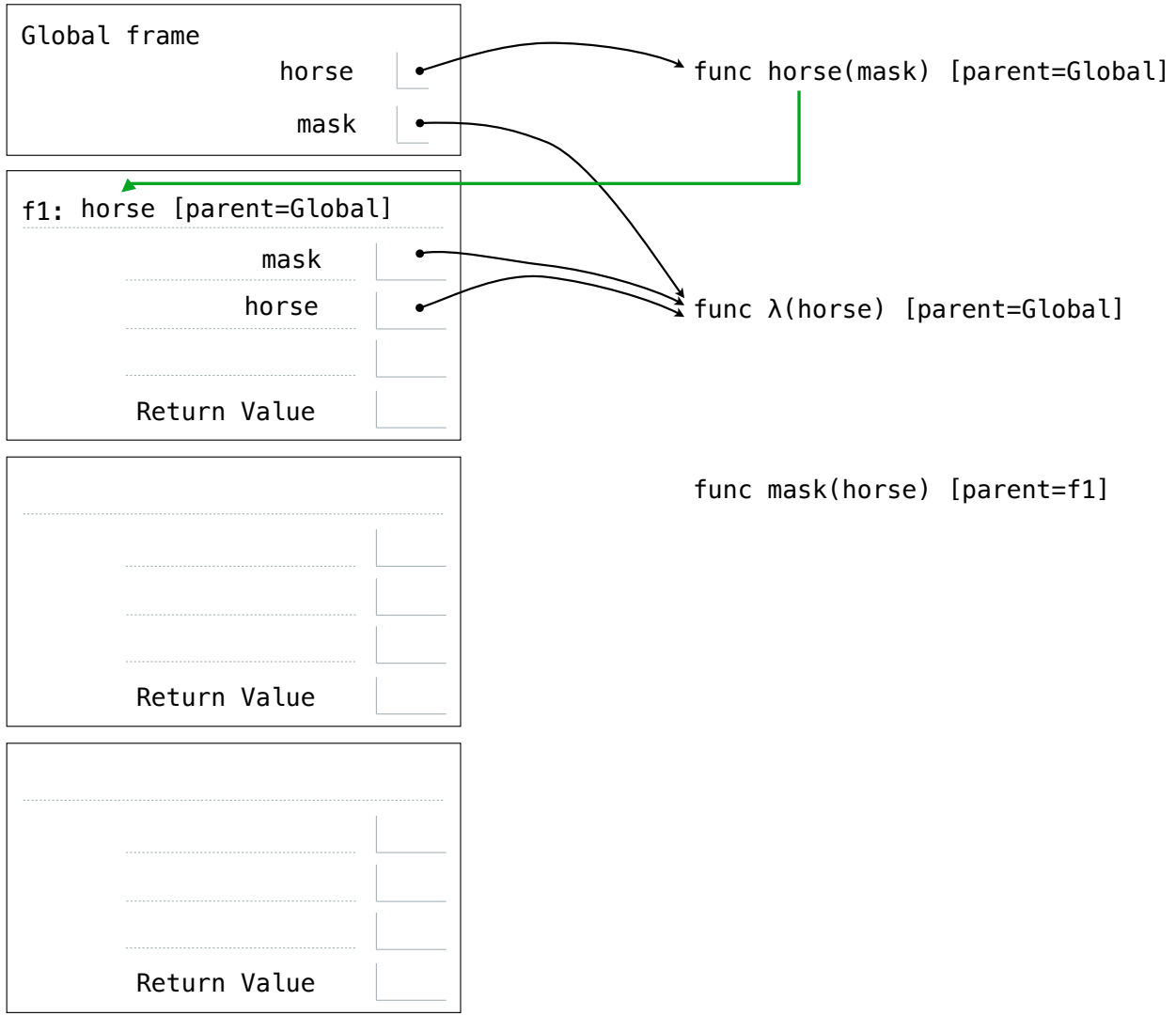

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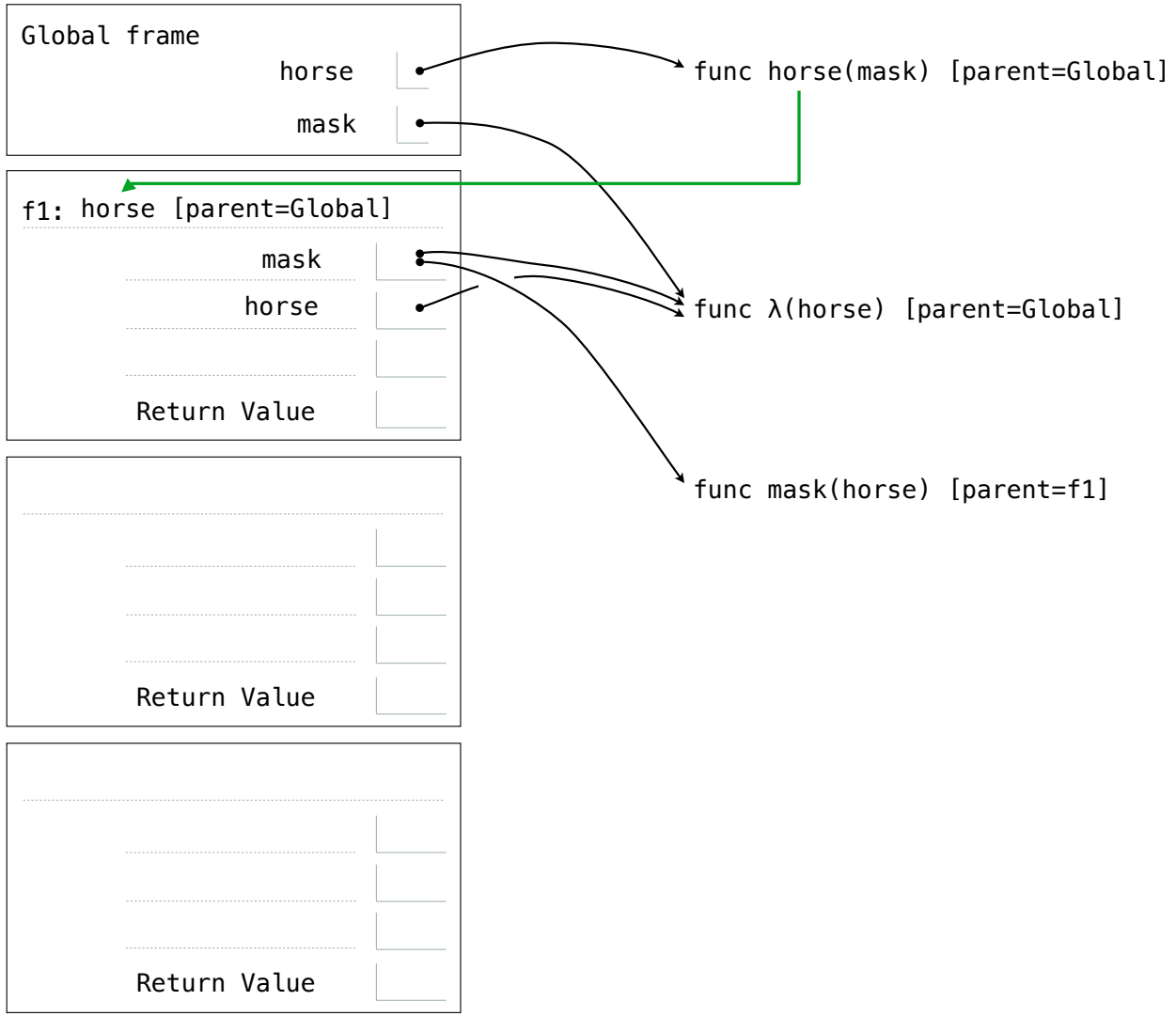

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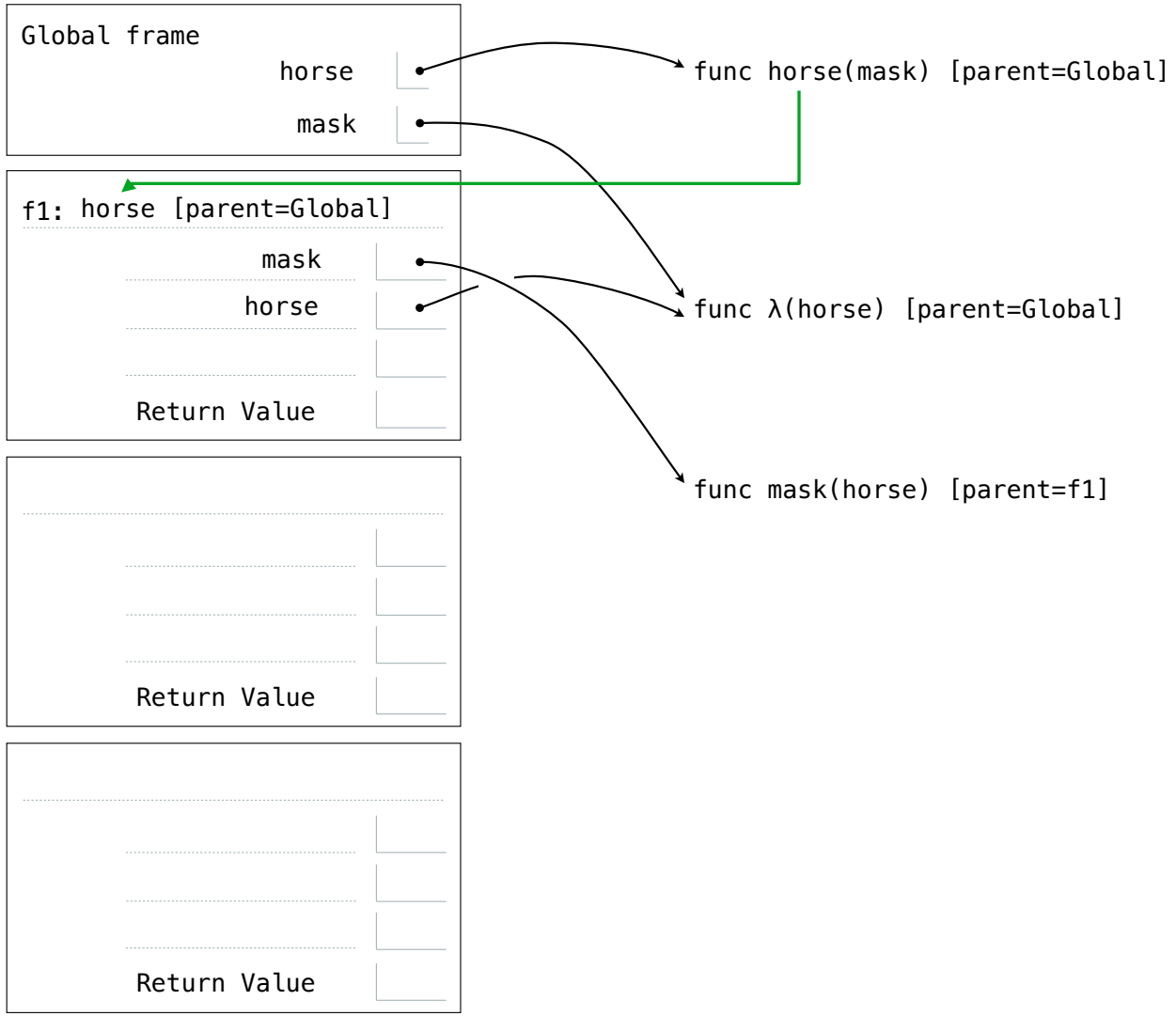

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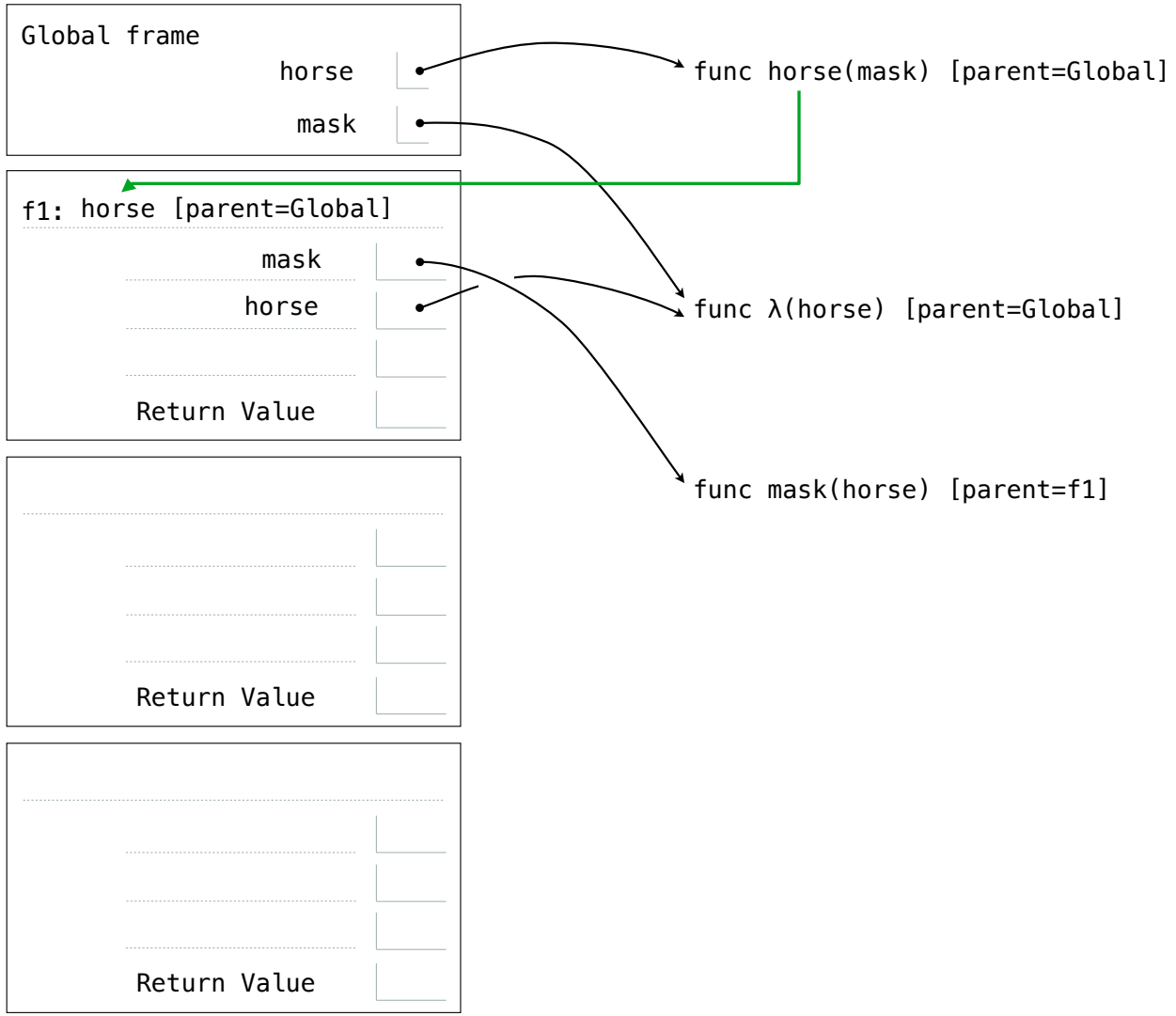
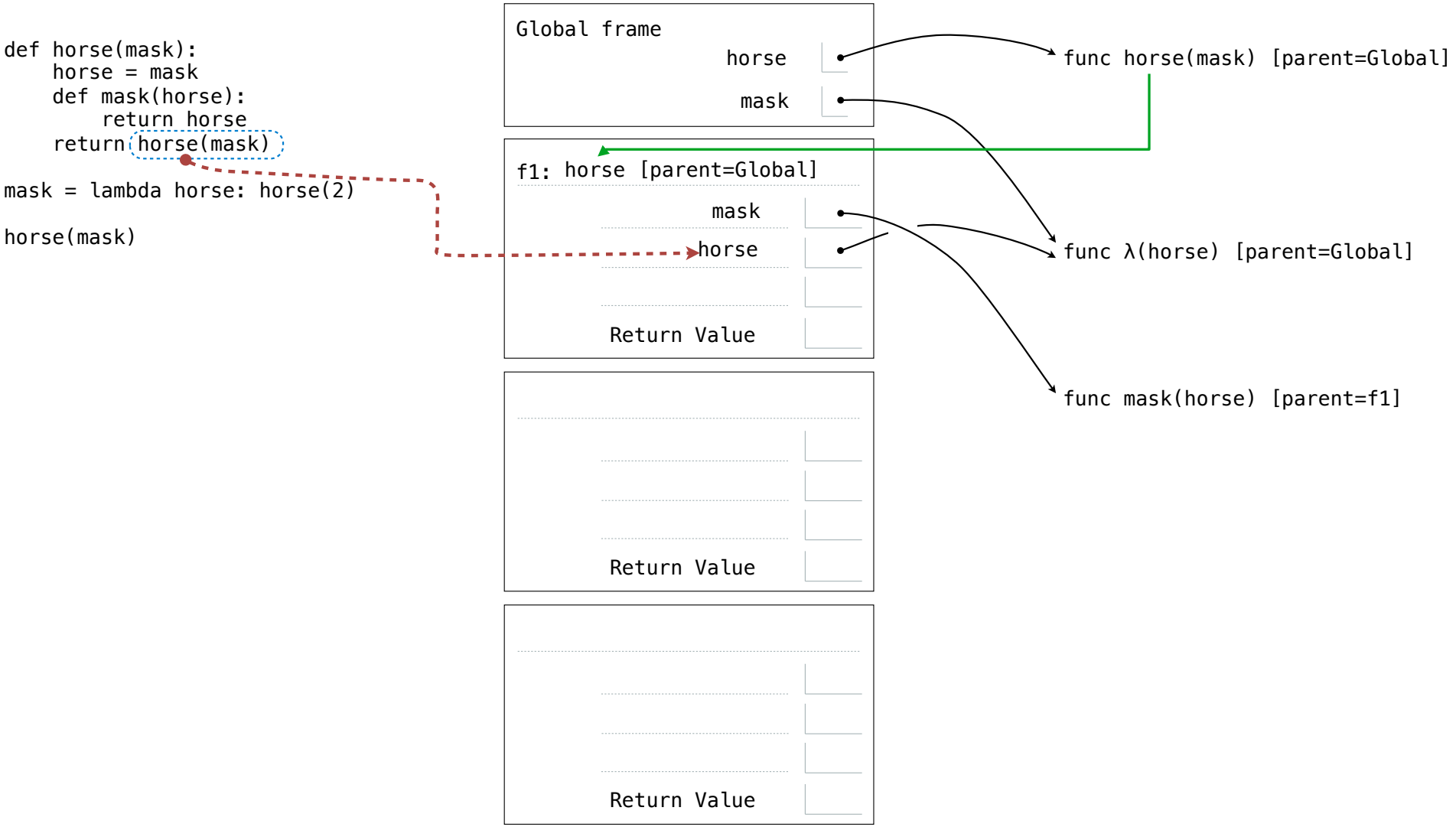
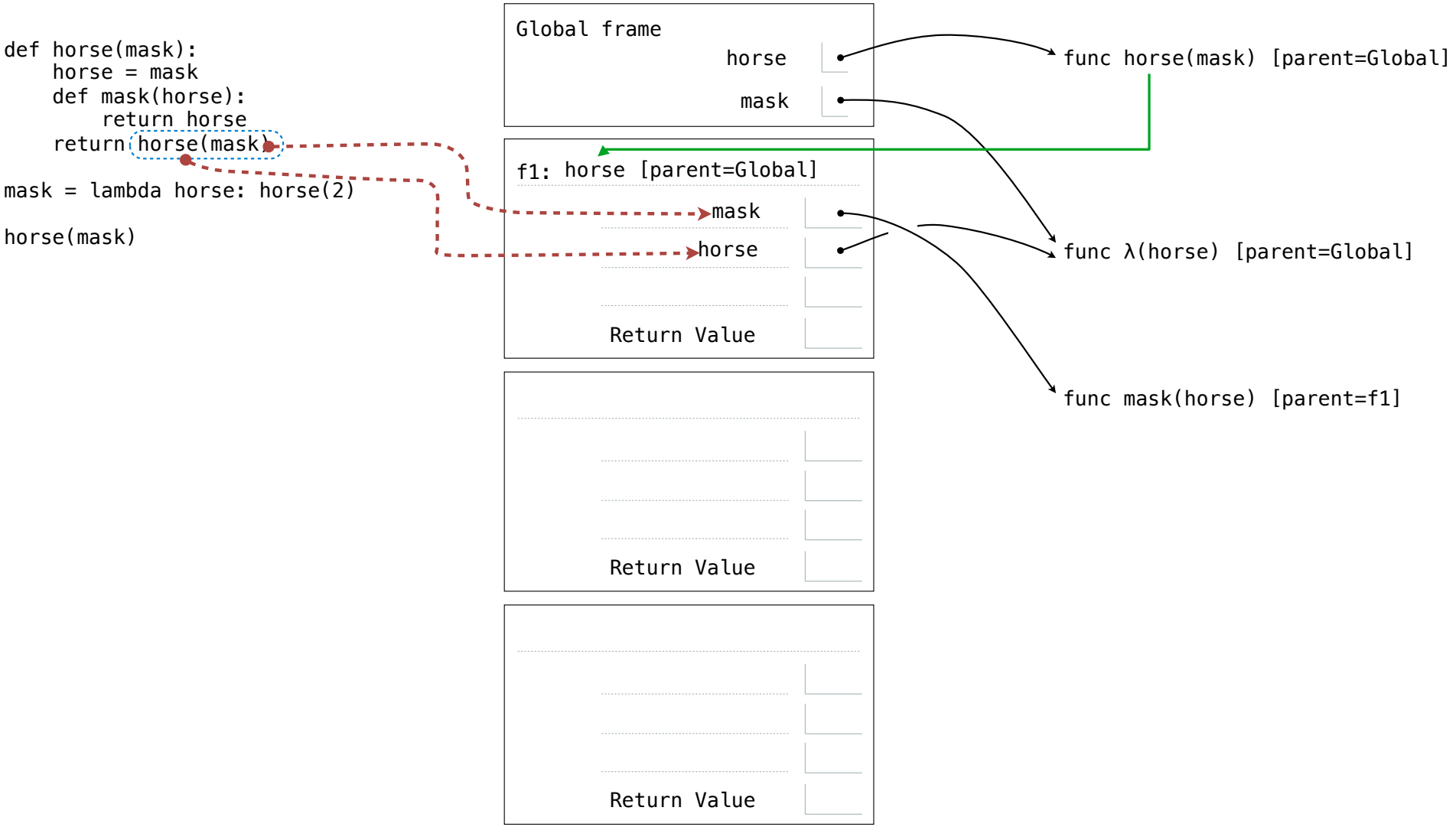



def horse(mask):
horse = mask
def mask(horse):
return horse
return horse(mask)
mask = lambda horse: horse(2)
horse(mask)
Global frame
horse
mask
func horse(mask) [parent=Global]
f1: horse [parent=Global]
mask
horse
Return Value
func λ(horse) [parent=Global]
func mask(horse) [parent=f1]
Return Value
Return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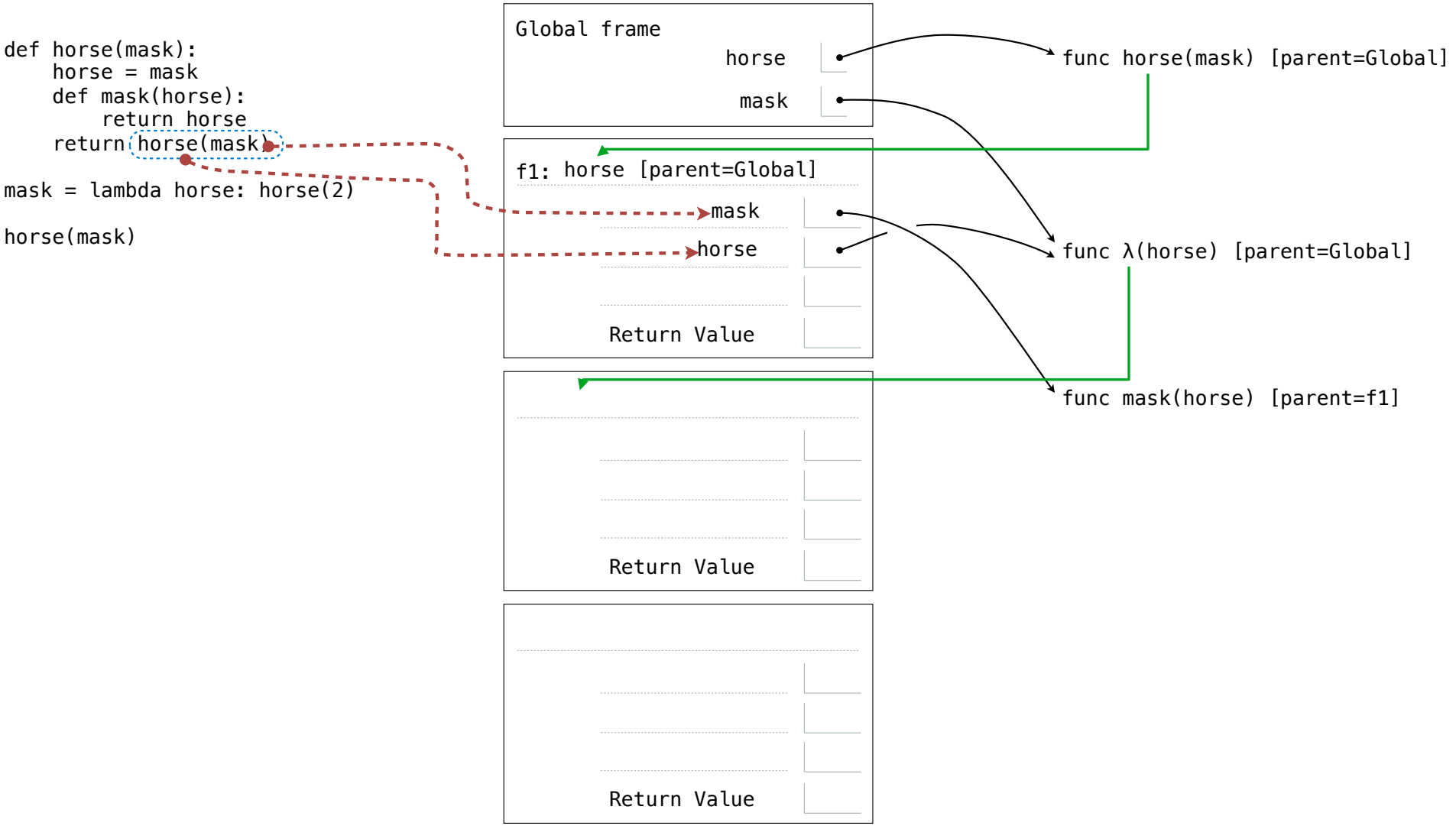
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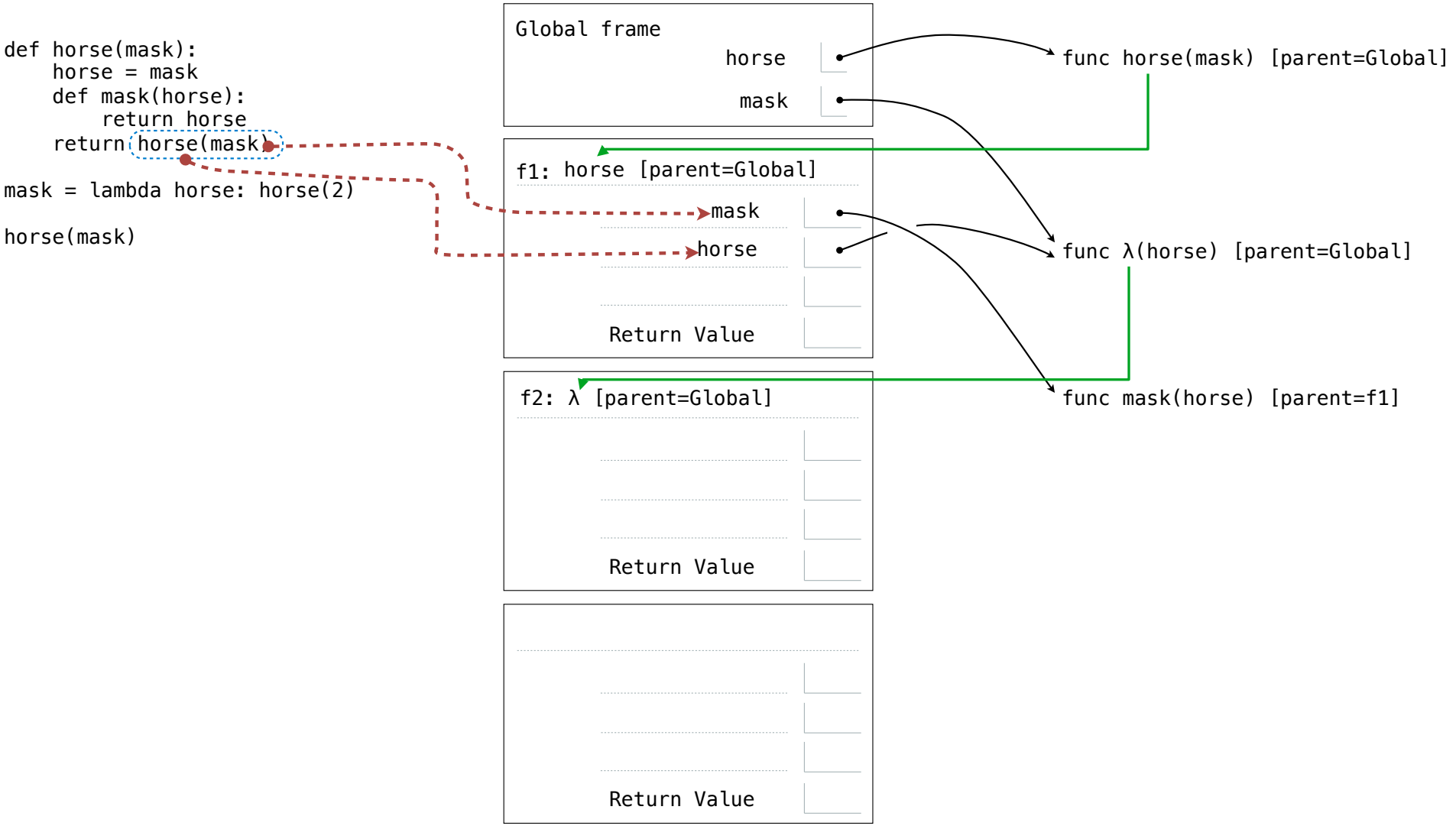
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mask
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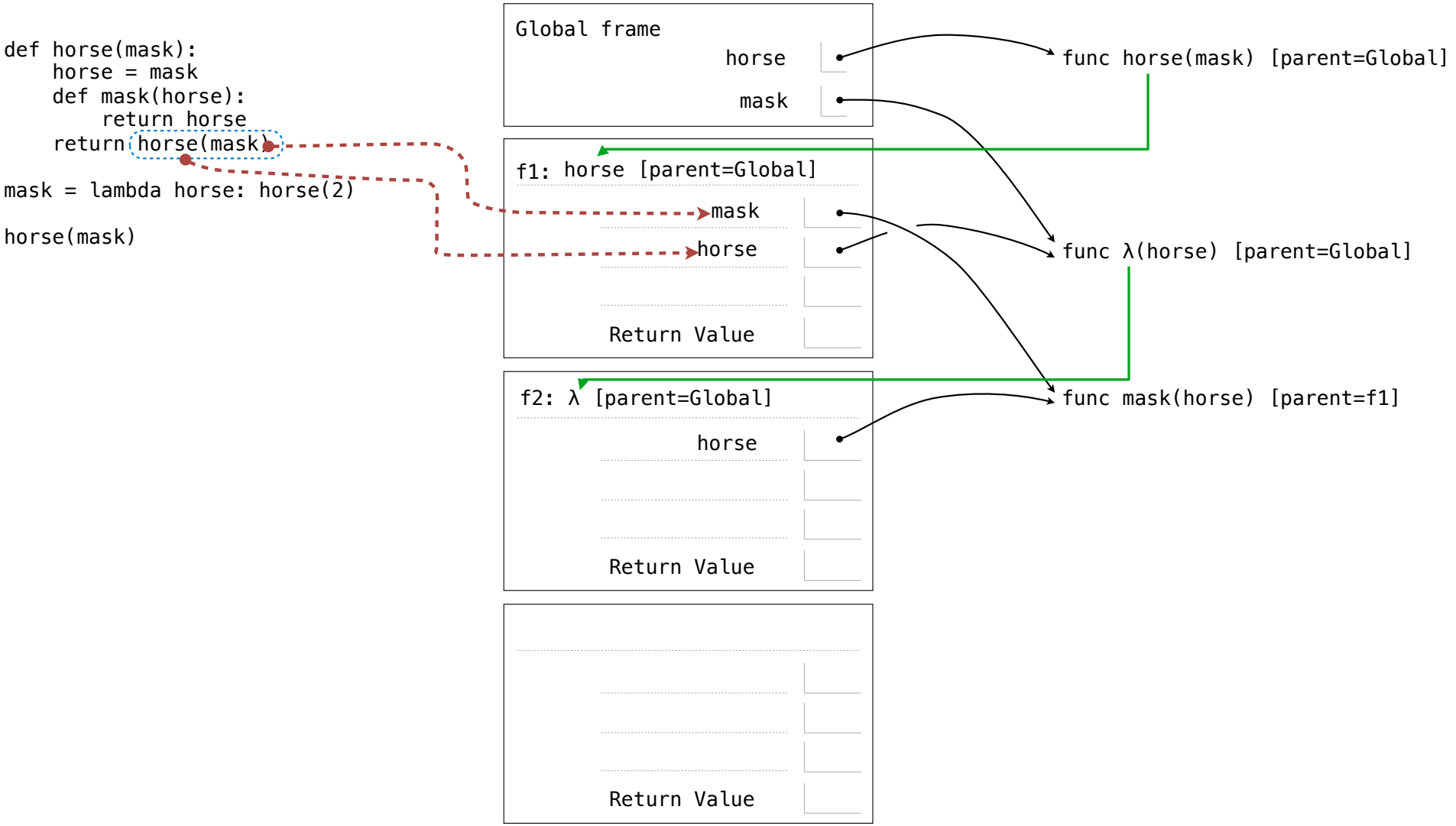
func λ(horse) [parent=Global]
f2: λ [parent=Global]
Return Value
func mask(horse) [parent=f1]
Return Value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def mask(horse):
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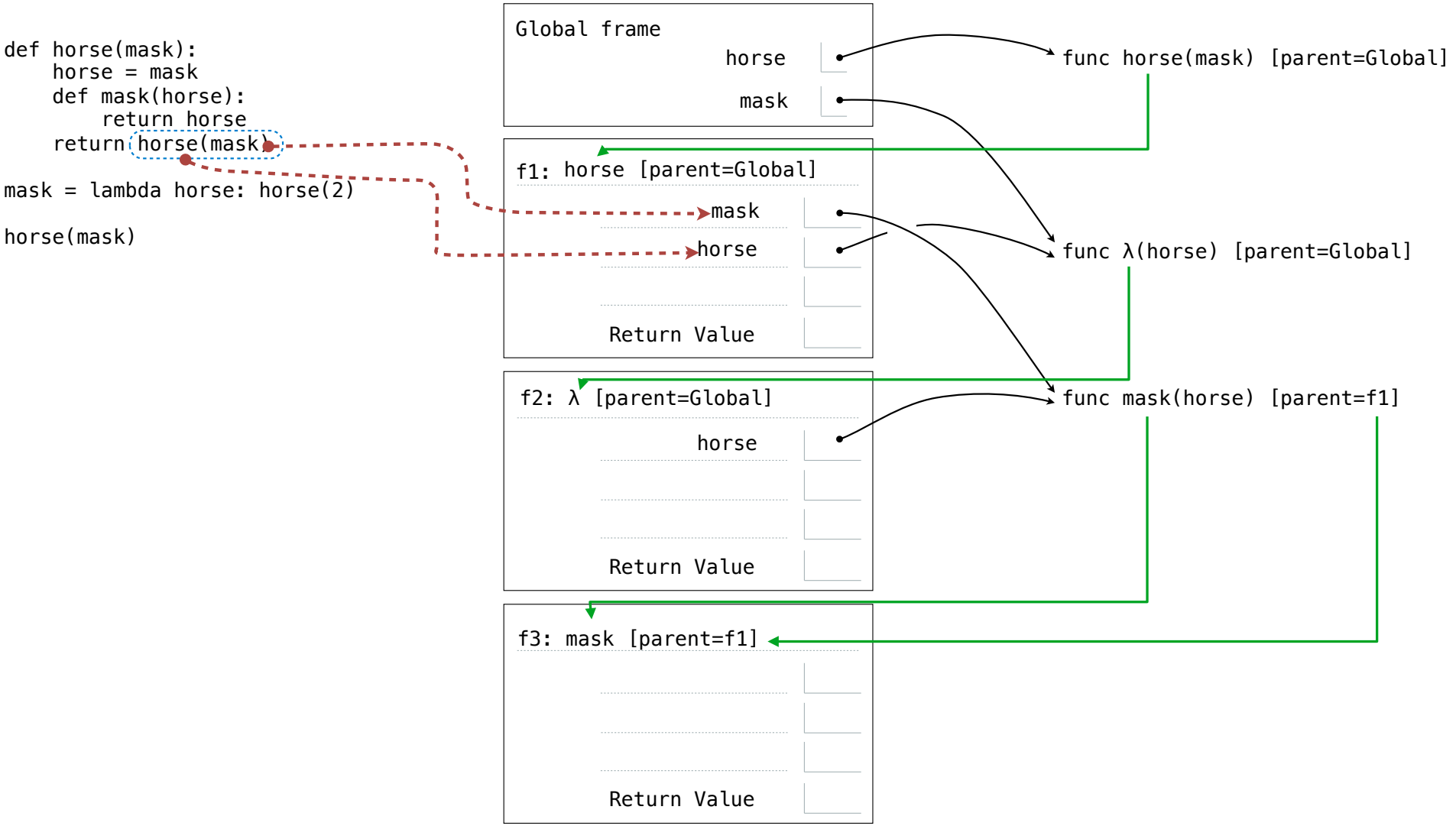
return horse(mask)
mask = lambda horse: horse(2)
horse(mask)
Global frame
horse
mask
func horse(mask) [parent=Global]
f1: horse [parent=Global]
mask
horse
Return Value
func λ(horse) [parent=Global]
f2: λ [parent=Global]
horse
Return Value
func mask(horse) [parent=f1]
Return Value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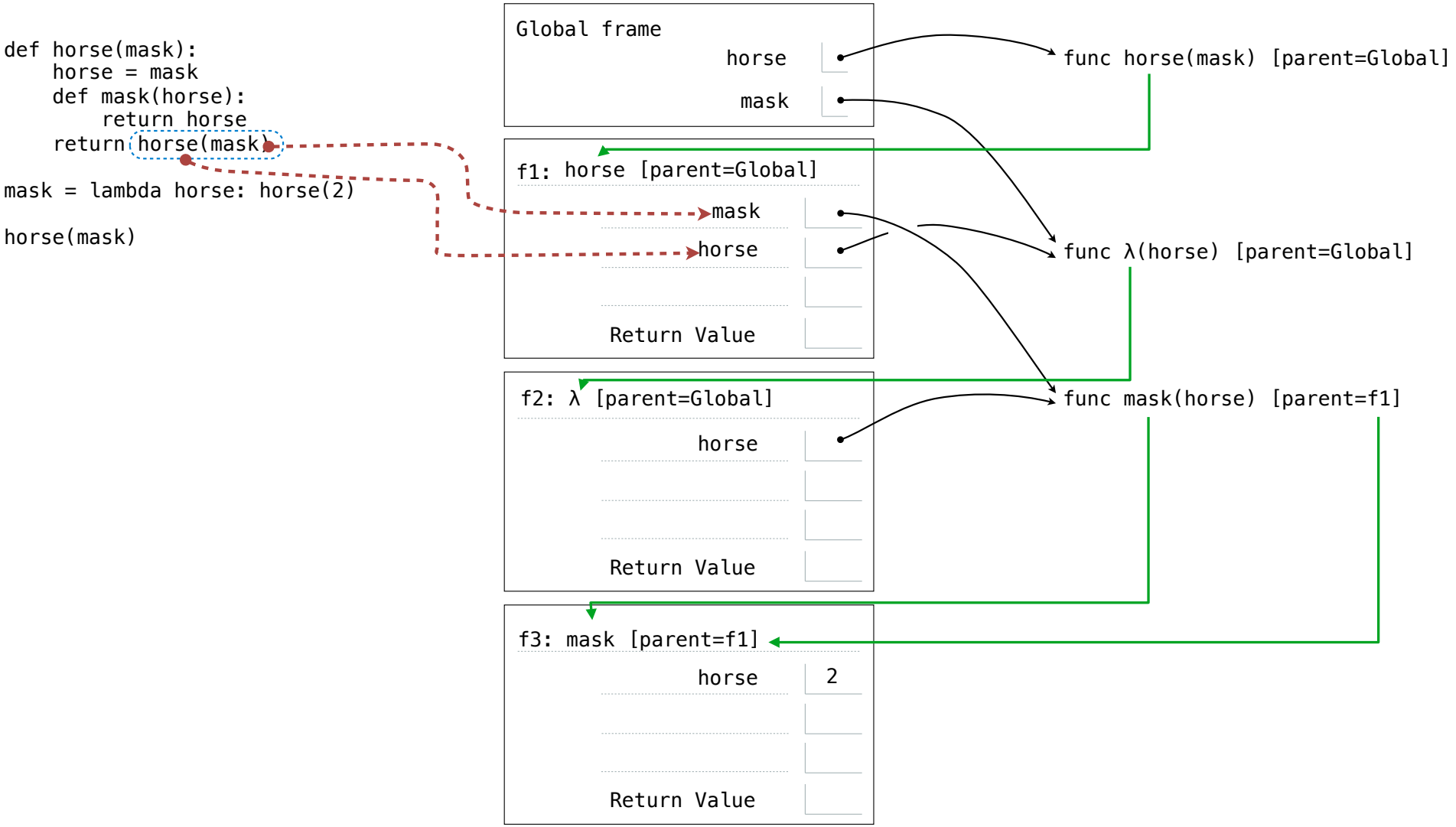
mask = lambda horse: horse(2)
horse(mask)
Global frame
horse
mask
func horse(mask) [parent=Global]
f1: horse [parent=Global]
mask
horse
Return Value
func λ(horse) [parent=Global]
f2: λ [parent=Global]
horse
Return Value
func mask(horse) [parent=f1]
f3: mask [parent=f1]
Return Value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horse(mask)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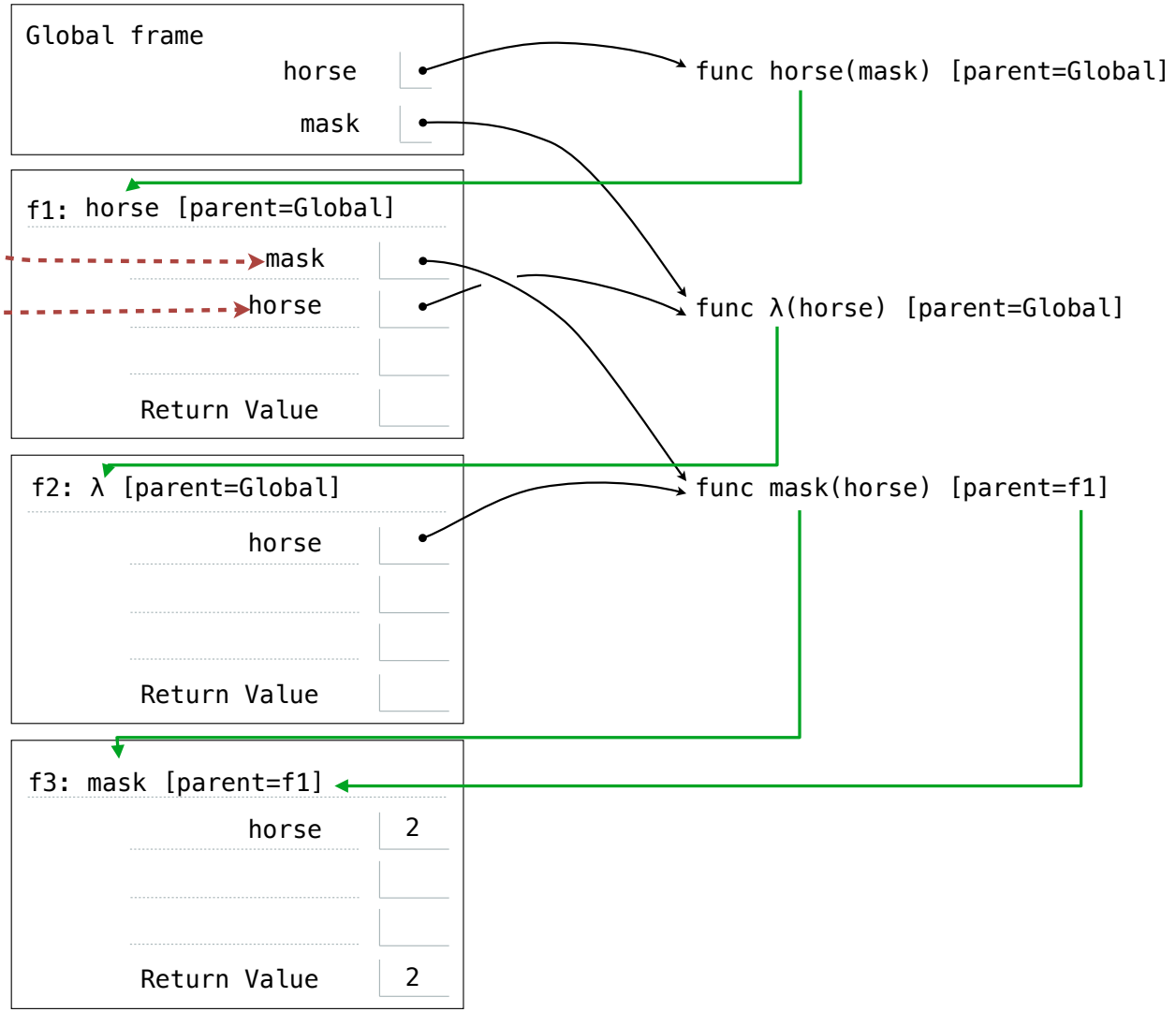
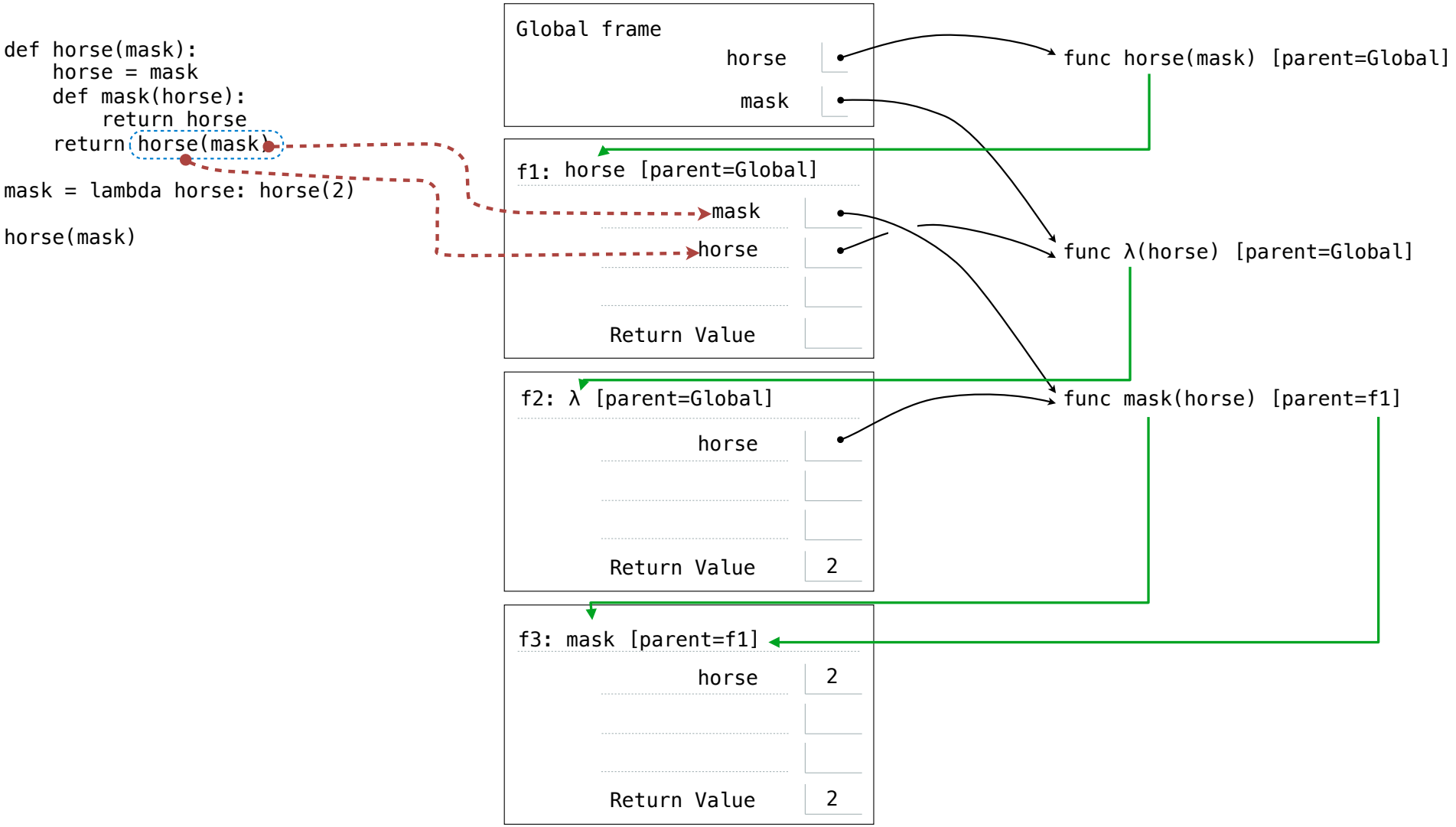
func horse(mask) [parent=Global]
f1: horse [parent=Global]
mask
horse
Return Value
func λ(horse) [parent=Global]
f2: λ [parent=Global]
horse
Return Value
func mask(horse) [parent=f1]
f3: mask [parent=f1]
horse
2
Return Value

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

mask = lambda horse: horse(2)

horse(mask)
```

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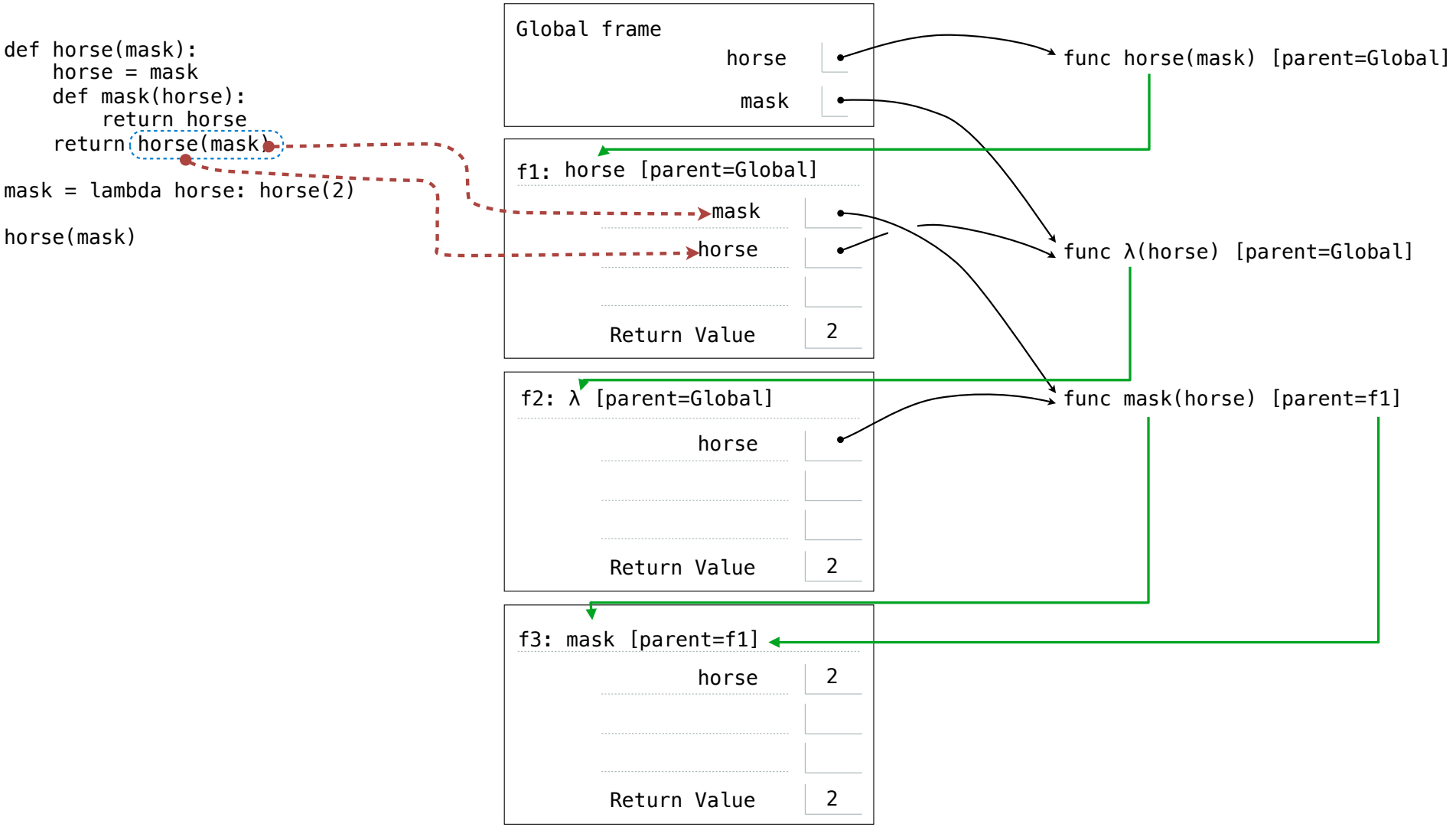
mask
horse
Return Value
func λ(horse) [parent=Global]
f2: λ [parent=Global]
horse
Return Value
2
func mask(horse) [parent=f1]
f3: mask [parent=f1]
horse
2
Return Value
2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return horse(mask)
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horse(mask)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