61A Lecture 9

Friday, September 20

Announcements

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- Optional Hog strategy contest ends Thursday 10/3 @ 11:59pm

Abstraction

Functional Abstractions

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Functional Abstractions

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- Square has the **intrinsic** name square.

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- Square computes the square of a number.

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def square(x):
    return mul(x, x-1) + x
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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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l, I, O	k, i, m

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- Names can be long if they help document your code:

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  is preferable to

  ```
  # Compute average age of students
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PRACTICAL GUIDELINES

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Testing

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(Demo)

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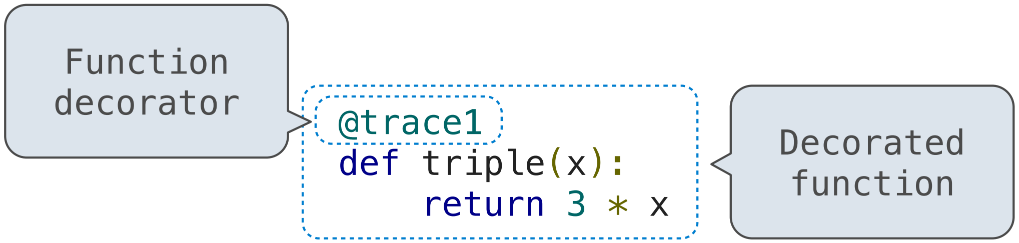

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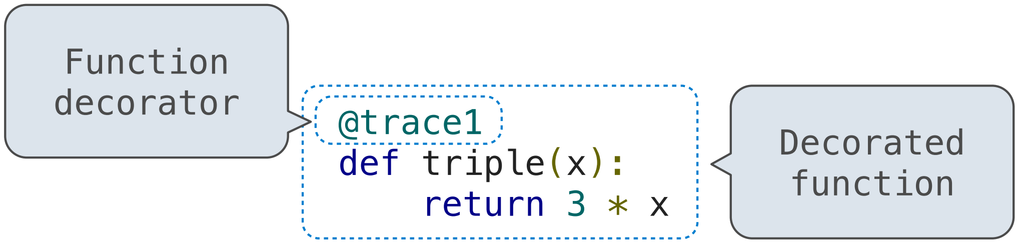

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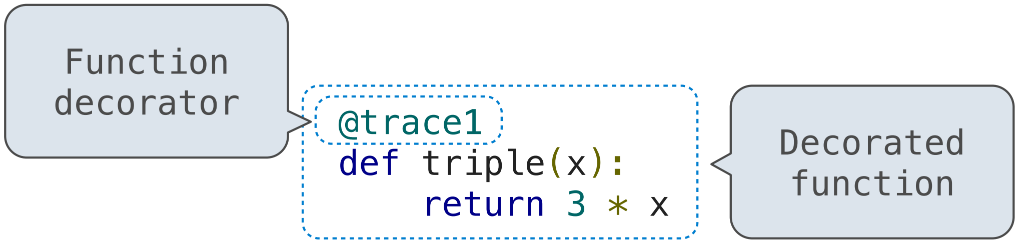

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def triple(x):
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triple = trace1(triple)
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Function Decorators

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Why not just use this?

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Review

What Would Python Print?

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```
The print function returns None.  It also displays its arguments
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    def g():
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    return g
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delay(delay)()(6)()		

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    return g
```

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	And prints
5	5	
print(5)	None	5
$\texttt{print(}\underbrace{\texttt{add(3, 4)}}_{7}\texttt{, }\underbrace{\texttt{print(5)}}_{\texttt{None}}\texttt{)}$	None	5 7 None
delay(delay)()(6)()		

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

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	And prints
5	5	
print(5)	None	5
$\texttt{print(}\underbrace{\texttt{add(3, 4)}}_{\texttt{7}}\texttt{, }\underbrace{\texttt{print(5)}}_{\texttt{None}}\texttt{)}$	None	5 7 None
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print(5)	None	5
$\texttt{print(}\underbrace{\texttt{add(3, 4)}}_{7}\texttt{, }\underbrace{\texttt{print(5)}}_{\texttt{None}}\texttt{)}$	None	5 7 None
$\underline{\texttt{delay(delay)()(6)}}\texttt{()}$		

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This expression	Evaluates to	And prints
5	5	
print(5)	None	5
print($\underbrace{\texttt{add(3, 4)}}_{7}$, $\underbrace{\texttt{print(5)}}_{\texttt{None}}$)	None	5 7 None
$\underline{\underline{\texttt{delay(delay)()}}\texttt{(6)}}\texttt{()}$		

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```

Names in nested def statements can refer to their enclosing scope

This expression	Evaluates to	And prints
5	5	
print(5)	None	5
print(add(3, 4), print(5)) 7 None	None	5 7 None
delay(delay)()(6)()		delayed

What Would Python Print?

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5	5	
print(5)	None	5
$\texttt{print(}\underbrace{\texttt{add(3, 4)}}_{7}\texttt{, }\underbrace{\texttt{print(5)}}_{\text{None}}\texttt{)}$	None	5 7 None
delay(delay)()(6)()		delayed delayed

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    return g
```

Names in nested def statements can refer to their enclosing scope

This expression	Evaluates to	And prints
`5`	5	
`print(5)`	None	5
$\texttt{print(}\underbrace{\texttt{add(3, 4)}}_{7}\texttt{, }\underbrace{\texttt{print(5)}}_{\texttt{None}}\texttt{)}$	None	5 7 None
`delay(delay)()(6)()`	6	delayed 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)
```

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        return arg
    return g
```

Names in nested def statements can refer to their enclosing scope

This expression	Evaluates to	And prints
`5`	5	
`print(5)`	None	5
`print(add(3, 4), print(5))` 7 None	None	5 7 None
`delay(delay)()(6)()`	6	delayed delayed
`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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```
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	And prints
5	5	
print(5)	None	5
print(add(3, 4), print(5)) 7 None	None	5 7 None
delay(delay)()(6)()	6	delayed delayed
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):
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```

Names in nested def statements can refer to their enclosing scope

This expression	Evaluates to	And prints
5	5	
print(5)	None	5
$\texttt{print(}\underbrace{\texttt{add(3, 4)}}_{7}\texttt{, }\underbrace{\texttt{print(5)}}_{\texttt{None}}\texttt{)}$	None	5 7 None
delay(delay)()(6)()	6	delayed delayed
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	And prints
`5`	5	
`print(5)`	None	5
$\texttt{print(}\underbrace{\texttt{add(3, 4)}}_{7}\texttt{, }\underbrace{\texttt{print(5)}}_{\text{None}}\texttt{)}$	None	5 7 None
`delay(delay)()(6)()`	6	delayed delayed
`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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    def g():
        return arg
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```

Names in nested def statements can refer to their enclosing scope

This expression	Evaluates to	And prints
5	5	
print(5)	None	5
print(add(3, 4), print(5)) 7 None	None	5 7 None
delay(delay)()(6)()	6	delayed delayed
print(delay(print)()(4))	None	delayed 4 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):
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```

This expression	Evaluates to	And prints

Example: http://goo.gl/NdrVqr

What Would Python Print?

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The print function returns None.  It also displays its arguments
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```
from operator import add, mul
def square(x):
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```

This expression	Evaluates to	And prints

```
def pirate(arggg):
    print('matey')
    def plunder(arggg):
        return arggg
    return plunder
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Example: http://goo.gl/NdrVqr

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	And prints
add(pirate(3)(square)(4), 1)		

```
def pirate(arggg):
    print('matey')
    def plunder(arggg):
        return arggg
    return plunder
```

Example: http://goo.gl/NdrVqr

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from operator import add, mul
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```

This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1)		

```
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    print('matey')
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```

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

Example: http://goo.gl/NdrVqr

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 always returns the identity function

```
def pirate(arggg):
    print('matey')
    def plunder(arggg):
        return arggg
    return plunder
```

This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1)		

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def pirate(arggg):
    print('matey')
    def plunder(arggg):
        return arggg
    return plunder
```

This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1)		Matey

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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```

This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1)		Matey

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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    return plunder
```

This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1) *func square(x)*		Matey

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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        return arggg
    return plunder
```

This expression	**Evaluates to**	**And prints**
add(pirate(3)(square)(4), 1)		Matey
func square(x)		

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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```

This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1)		Matey
func square(x)		
16		

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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```
def pirate(arggg):
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    def plunder(arggg):
        return arggg
    return plunder
```

This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1)	17	Matey
func square(x)		
16		

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

Example: http://goo.gl/NdrVqr

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    return plunder
```

This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1)	17	Matey
func square(x)		
16		
pirate(pirate(pirate))(5)(7)		

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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This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1) *func square(x)* *16*	17	Matey
pirate(pirate(pirate))(5)(7)		

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    return plunder
```

This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1) *func square(x)* *16*	17	Matey
pirate(pirate(pirate))(5)(7) *Identity function*		

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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    return plunder
```

This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1) *func square(x)* *16*	17	Matey
pirate(pirate(pirate))(5)(7) *Identity function*		Matey Matey

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

Example: http://goo.gl/NdrVqr

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    def plunder(arggg):
        return arggg
    return plunder
```

This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1) *func square(x)* *16*	17	Matey
pirate(pirate(pirate))(5)(7) *Identity function*		Matey Matey

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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```

This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1)	17	Matey
func square(x)		
16		
pirate(pirate(pirate))(5)(7)		Matey Matey
Identity function		
5		

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

Example: http://goo.gl/NdrVqr

What Would Python Print?

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    def plunder(arggg):
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    return plunder
```

This expression	Evaluates to	And prints
add(pirate(3)(square)(4), 1) *func square(x)* *16*	17	Matey
pirate(pirate(pirate))(5)(7) *Identity function* *5*	Error	Matey Matey

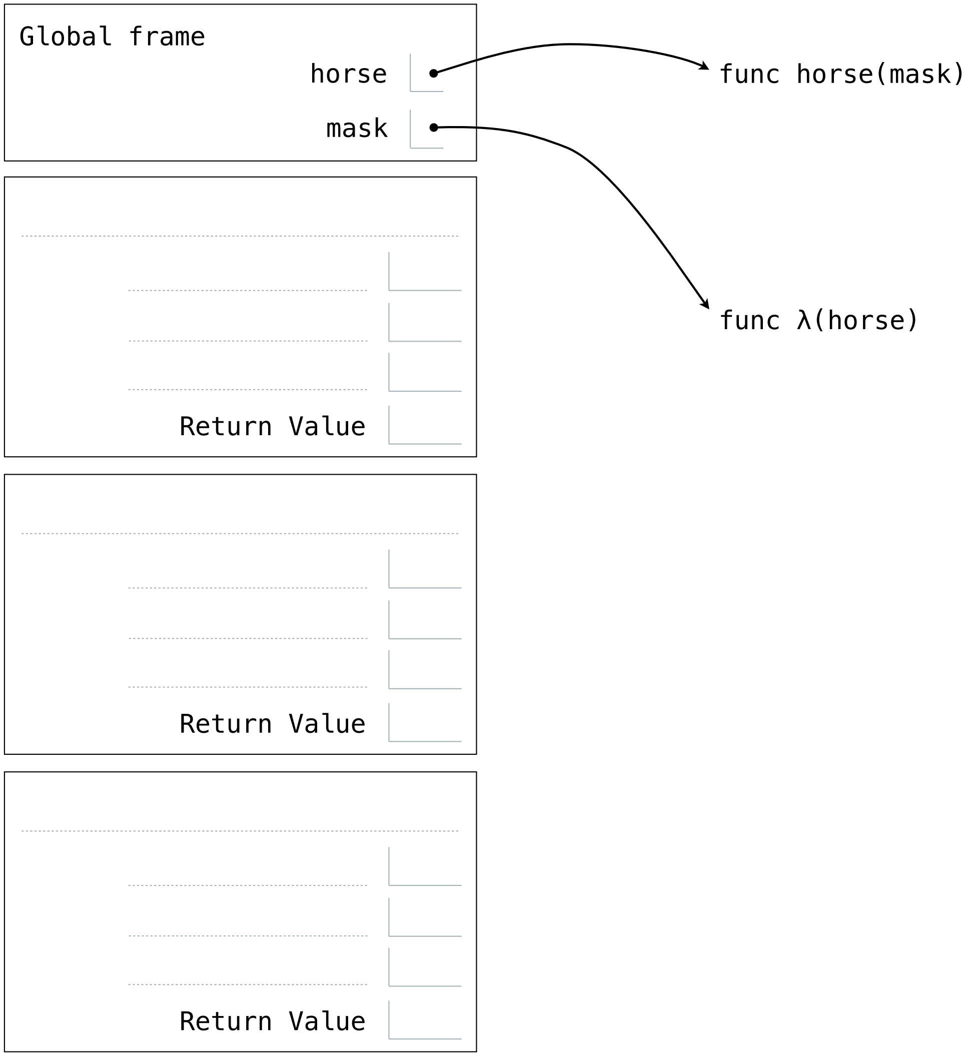
A name evaluates to the value bound to that name in the earliest frame of the current environment in which that name is found.

Example: http://goo.gl/NdrVqr

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

mask = lambda horse: horse(2)

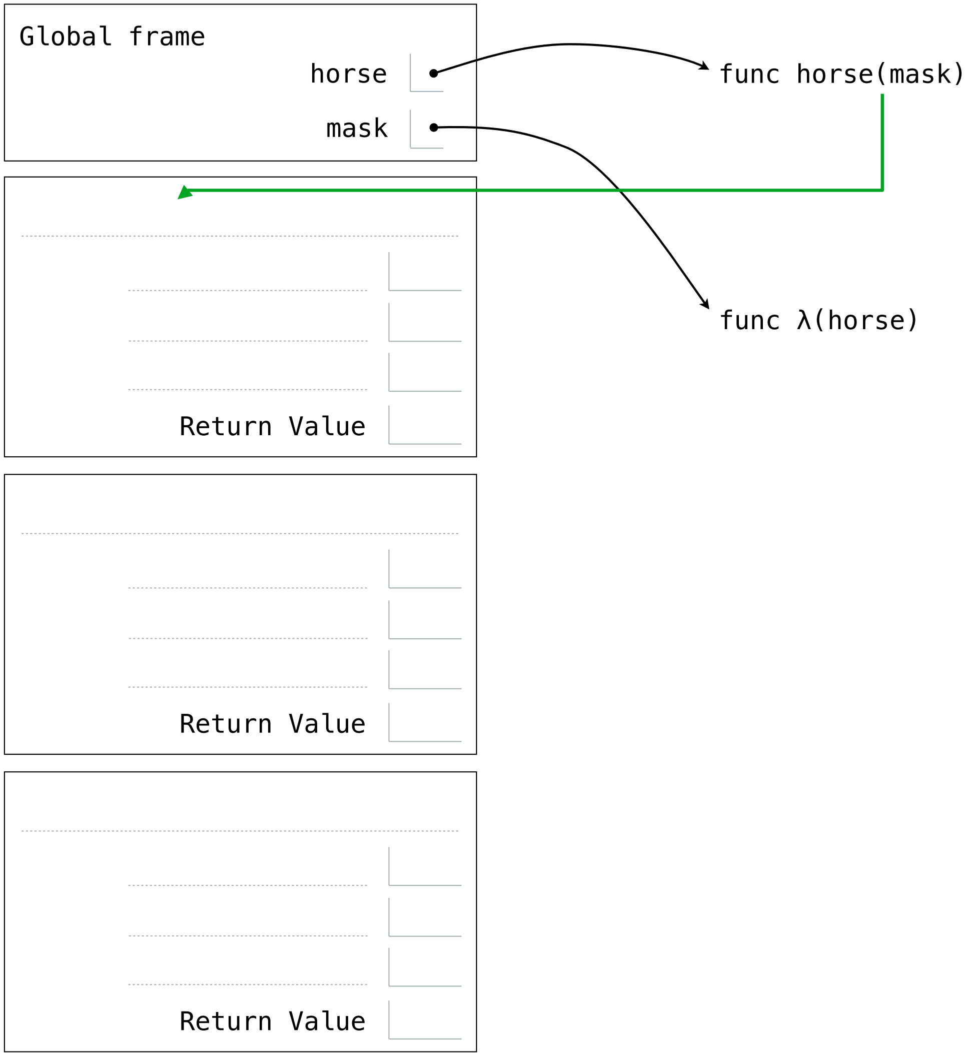
horse(mask)
```



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

mask = lambda horse: horse(2)

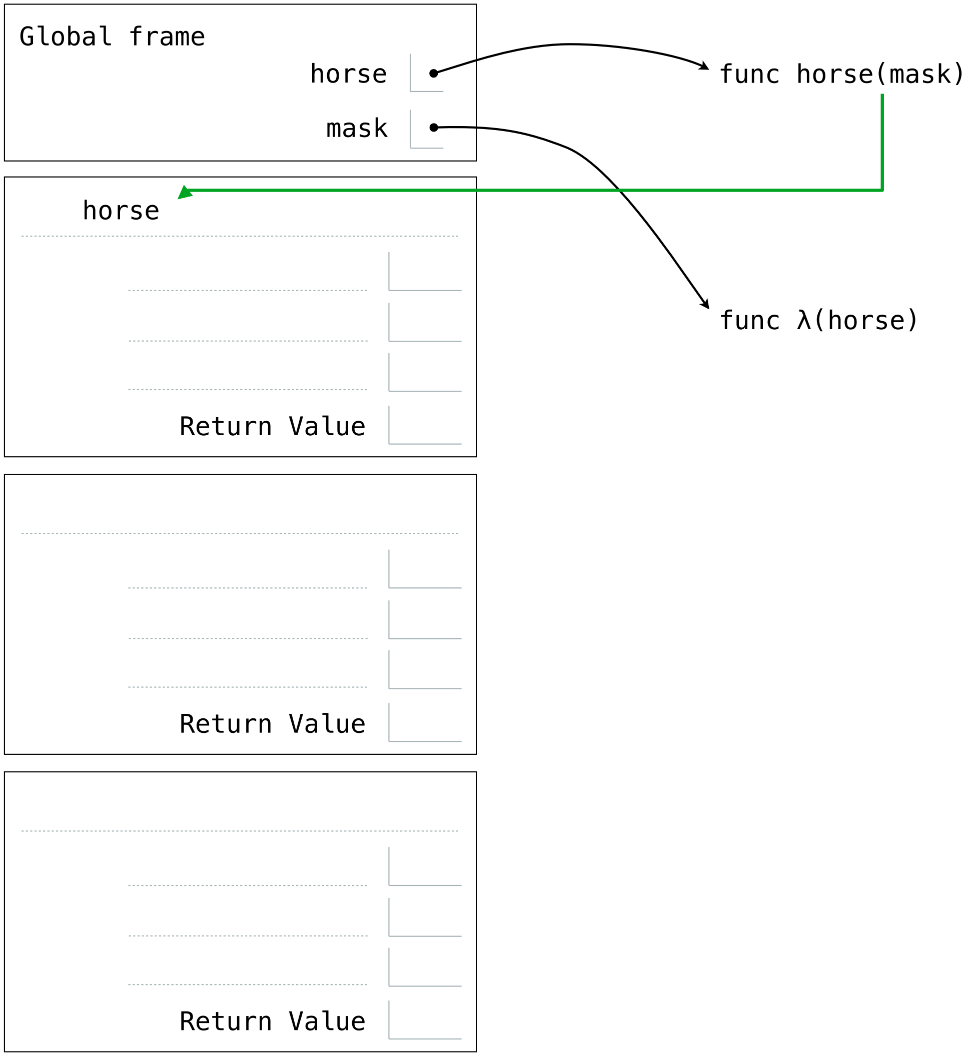
horse(mask)
```



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

mask = lambda horse: horse(2)

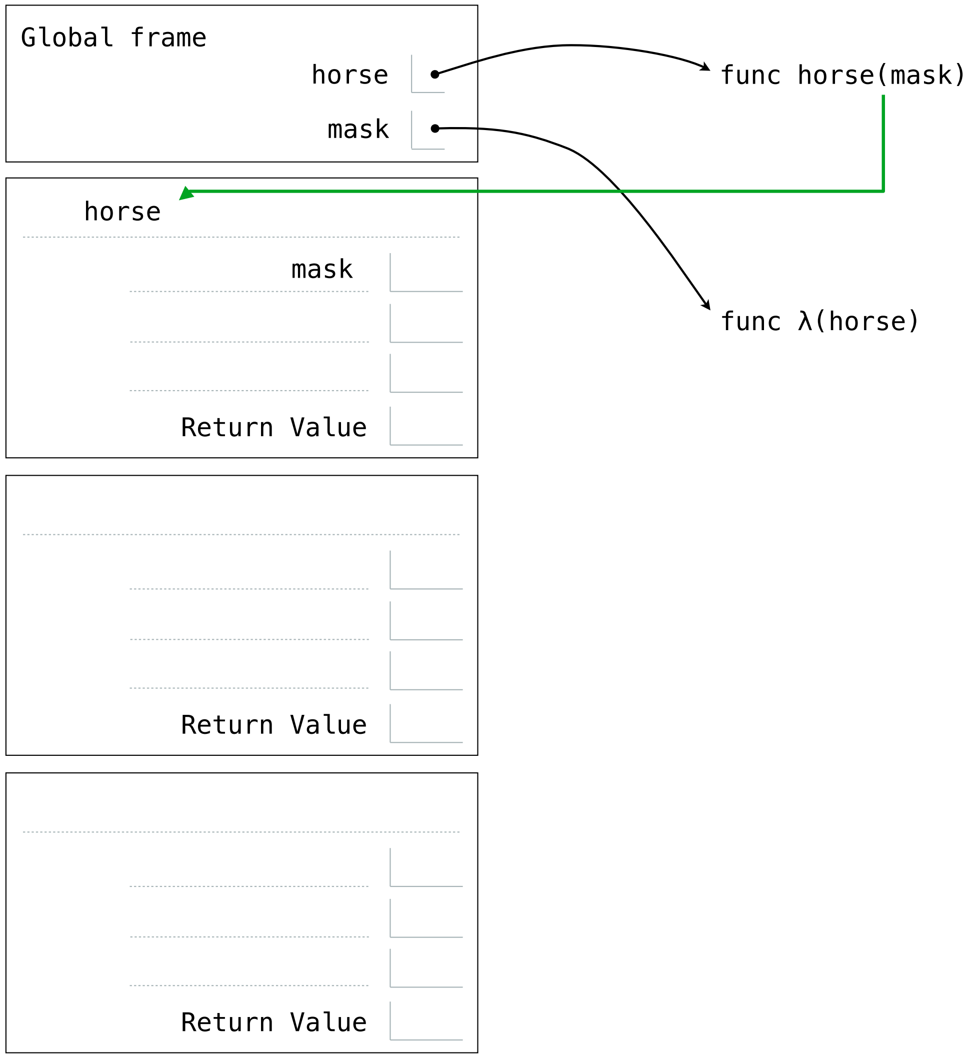
horse(mask)
```



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

mask = lambda horse: horse(2)

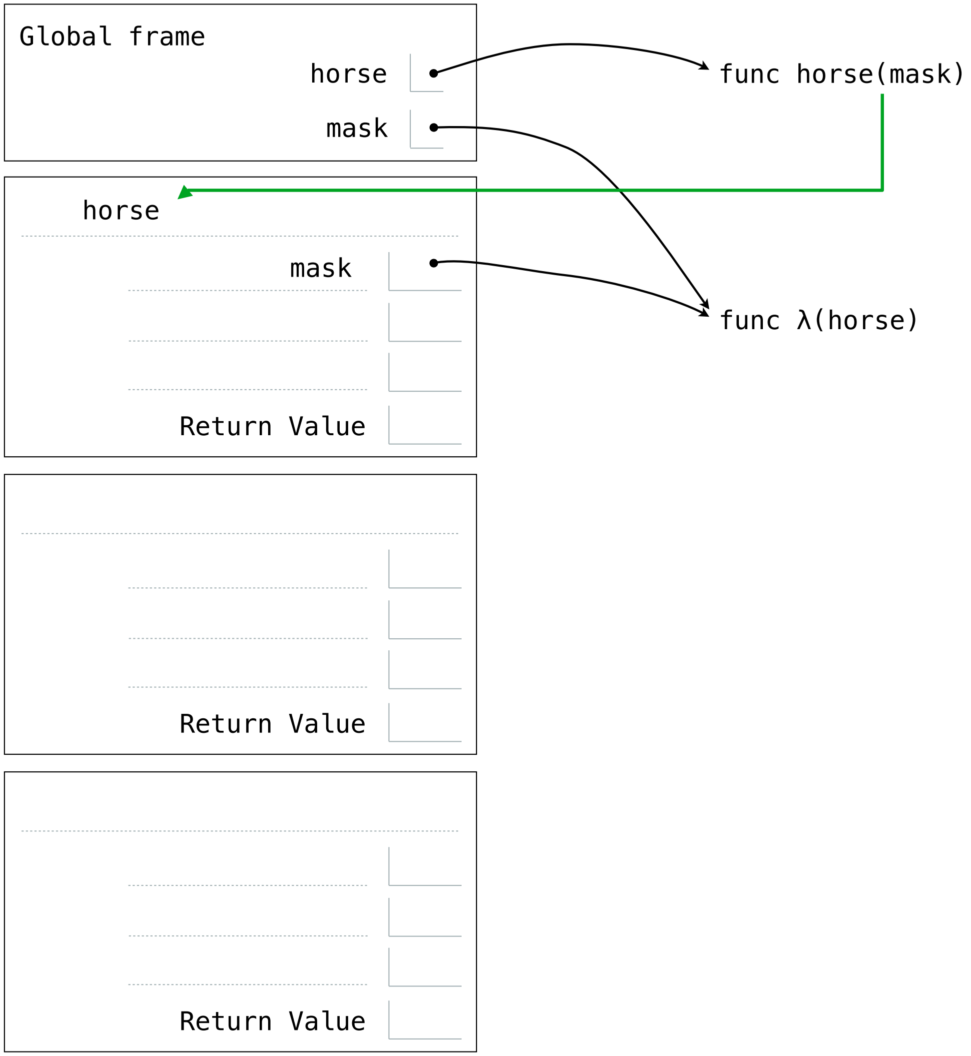
horse(mask)
```



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

mask = lambda horse: horse(2)

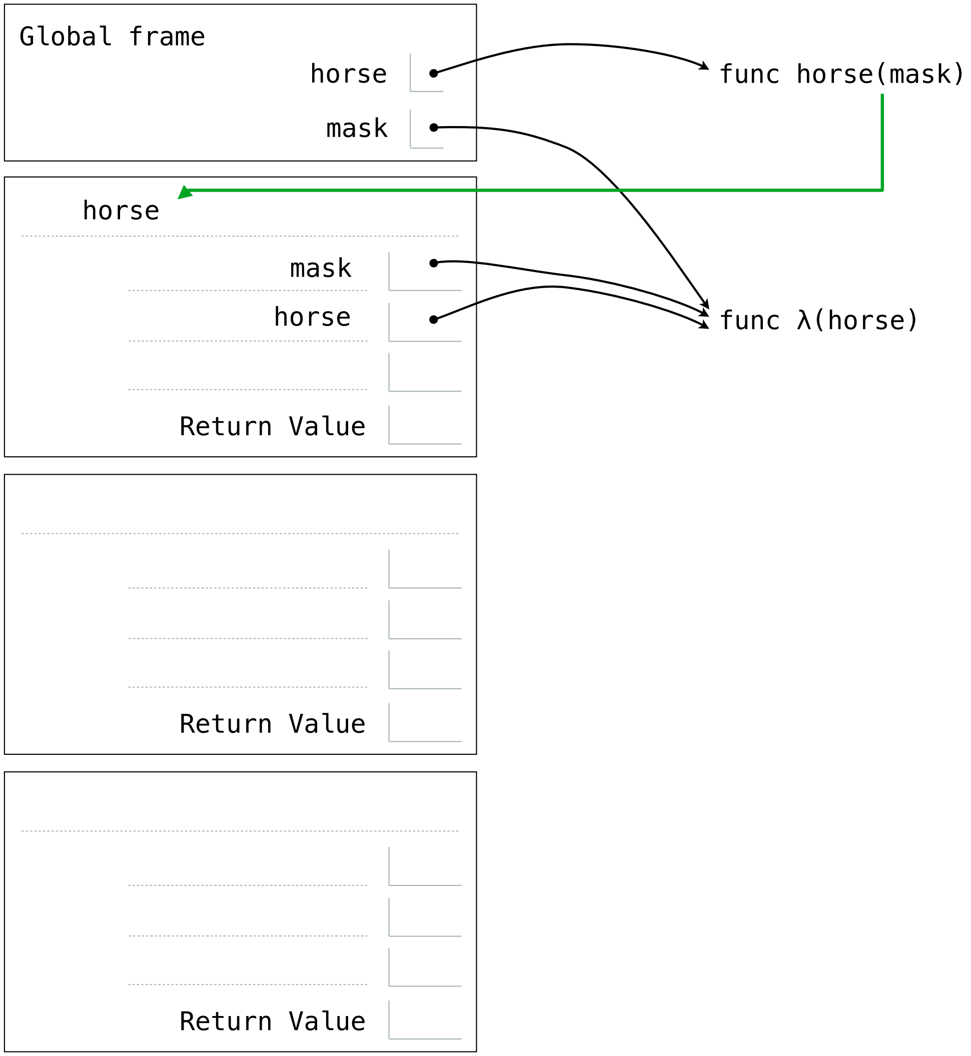
horse(mask)
```



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

mask = lambda horse: horse(2)

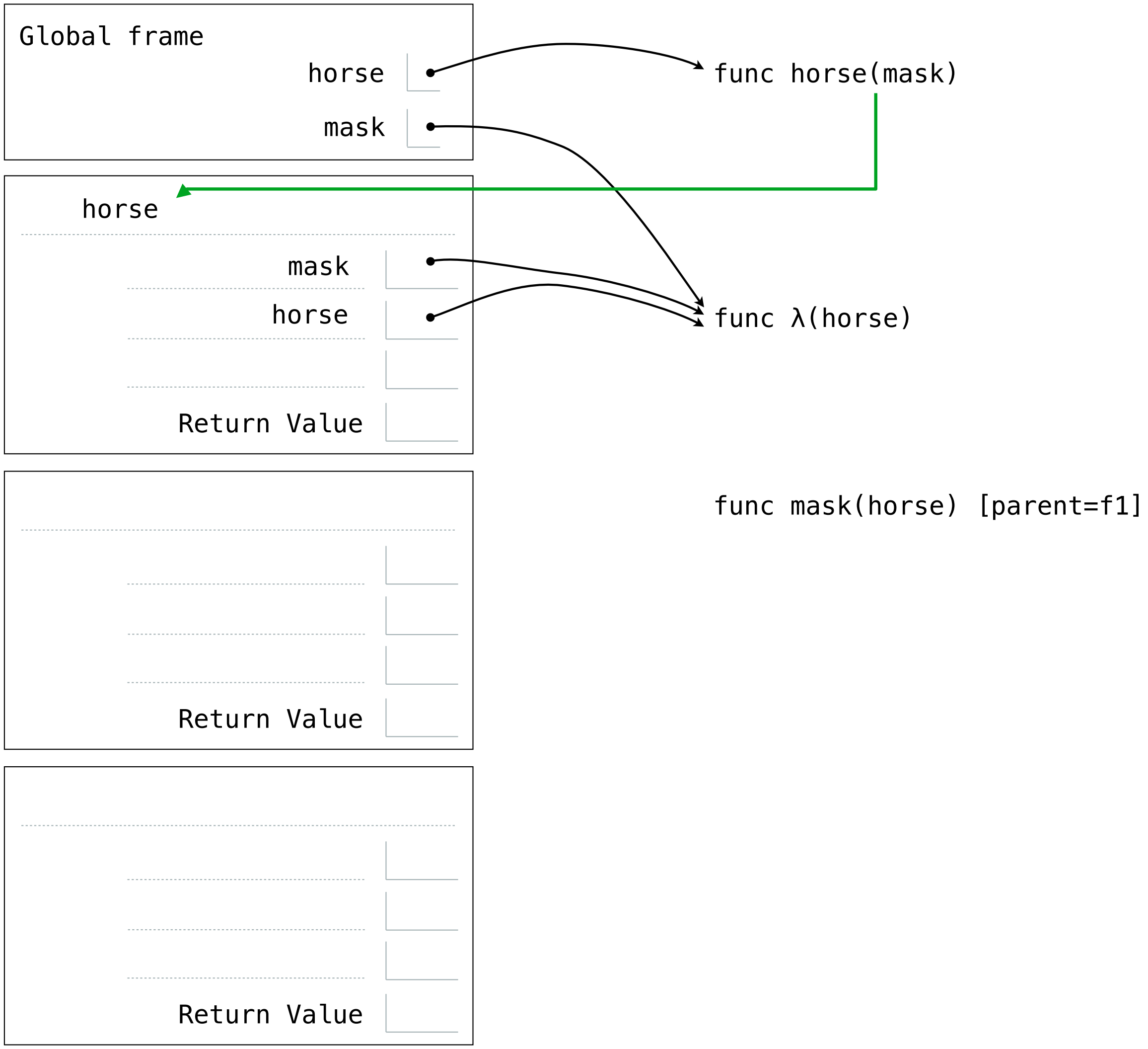
horse(mask)
```



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

mask = lambda horse: horse(2)

horse(mask)
```



Global frame

horse

mask

horse

mask

horse

Return Value

Return Value

Return Value

func horse(mask)

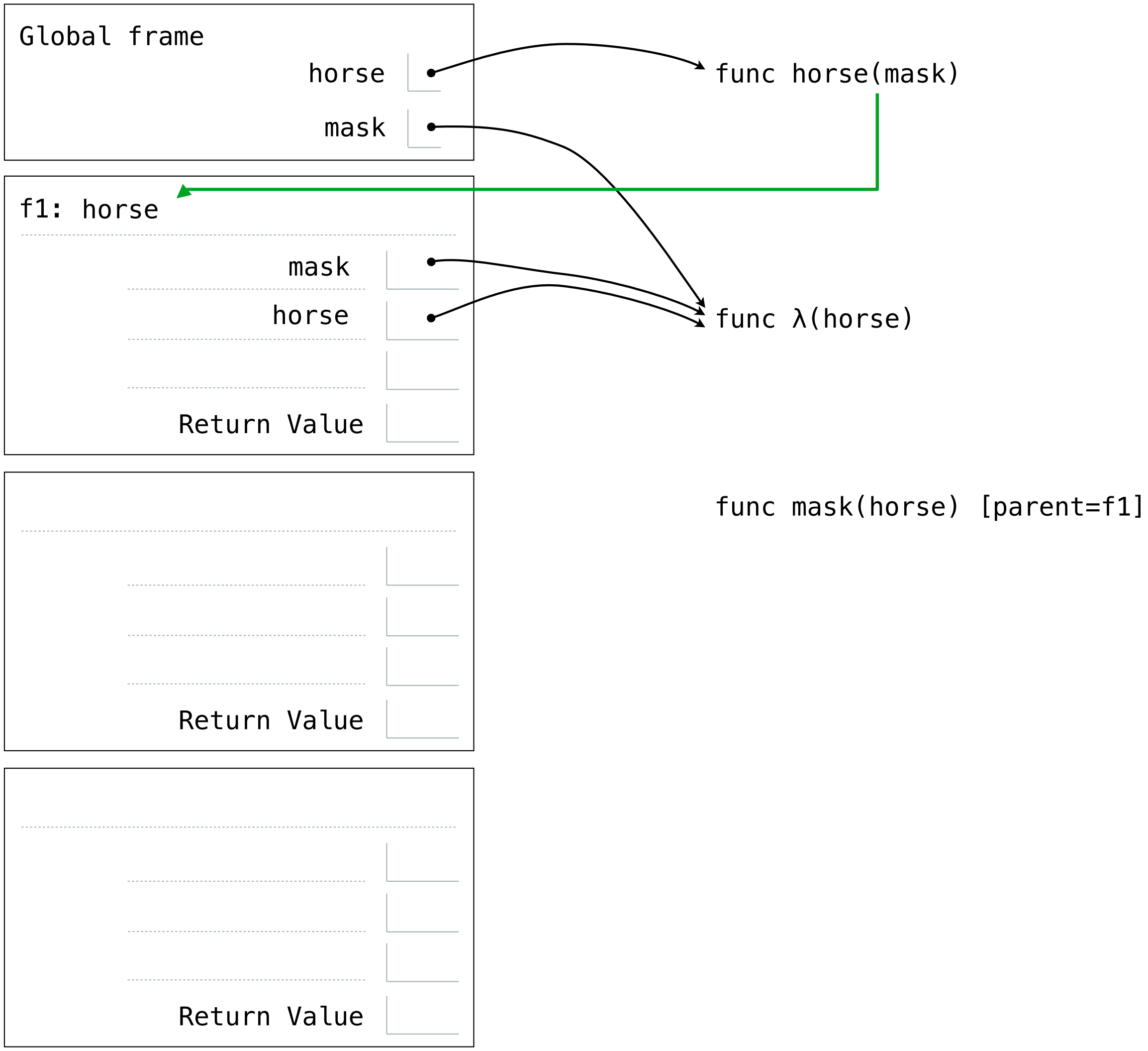
func λ(horse)

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)
```



Global frame

horse

mask

func horse(mask)

f1: horse

mask

horse

Return Value

func λ(horse)

Return Value

func mask(horse) [parent=f1]

Return Value

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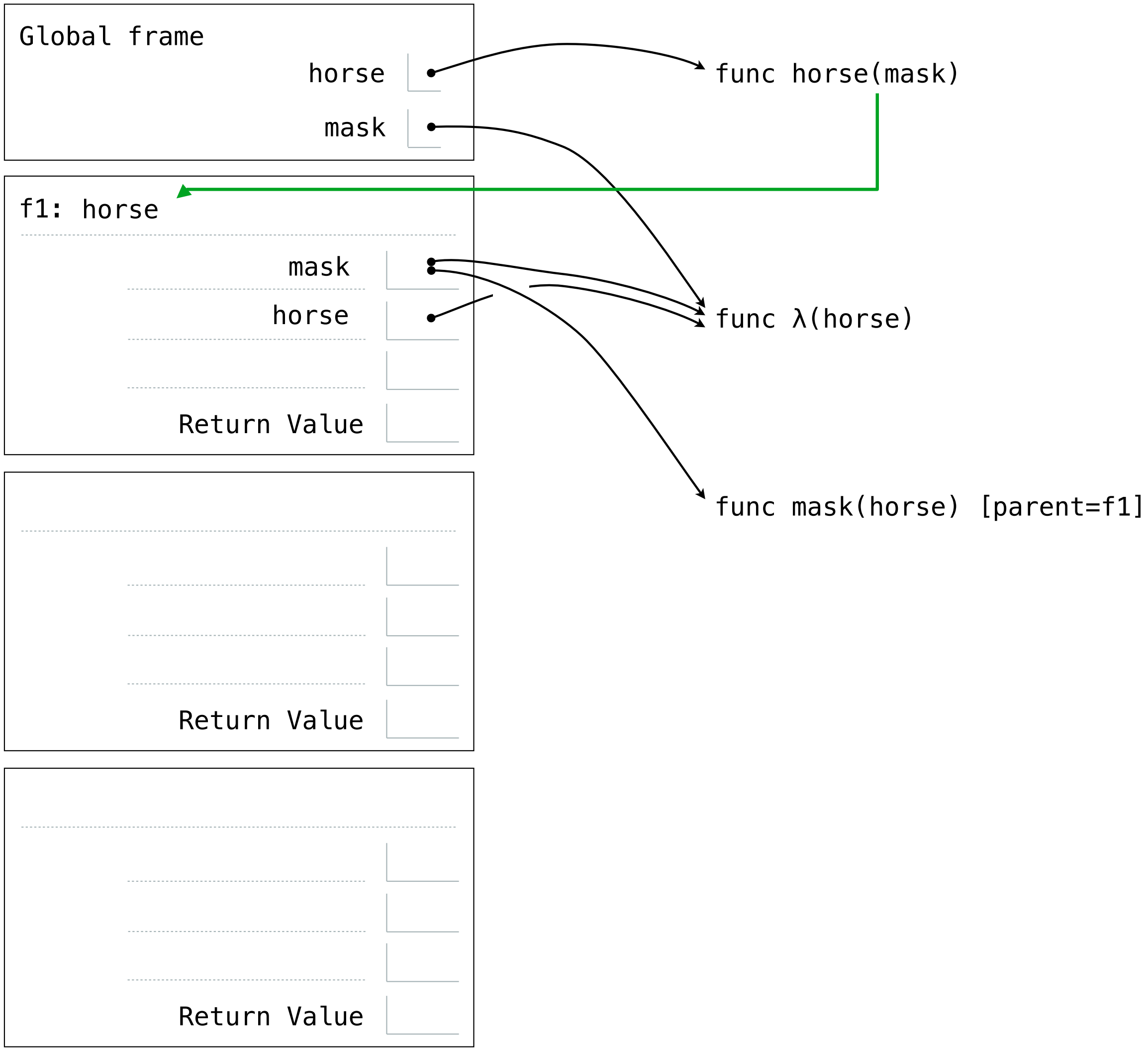
    return horse(mask)

mask = lambda horse: horse(2)

horse(mask)
```



Global frame

horse

mask

func horse(mask)

f1: horse

mask

horse

Return Value

func λ(horse)

func mask(horse) [parent=f1]

Return Value

Return Value

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def horse(mask):
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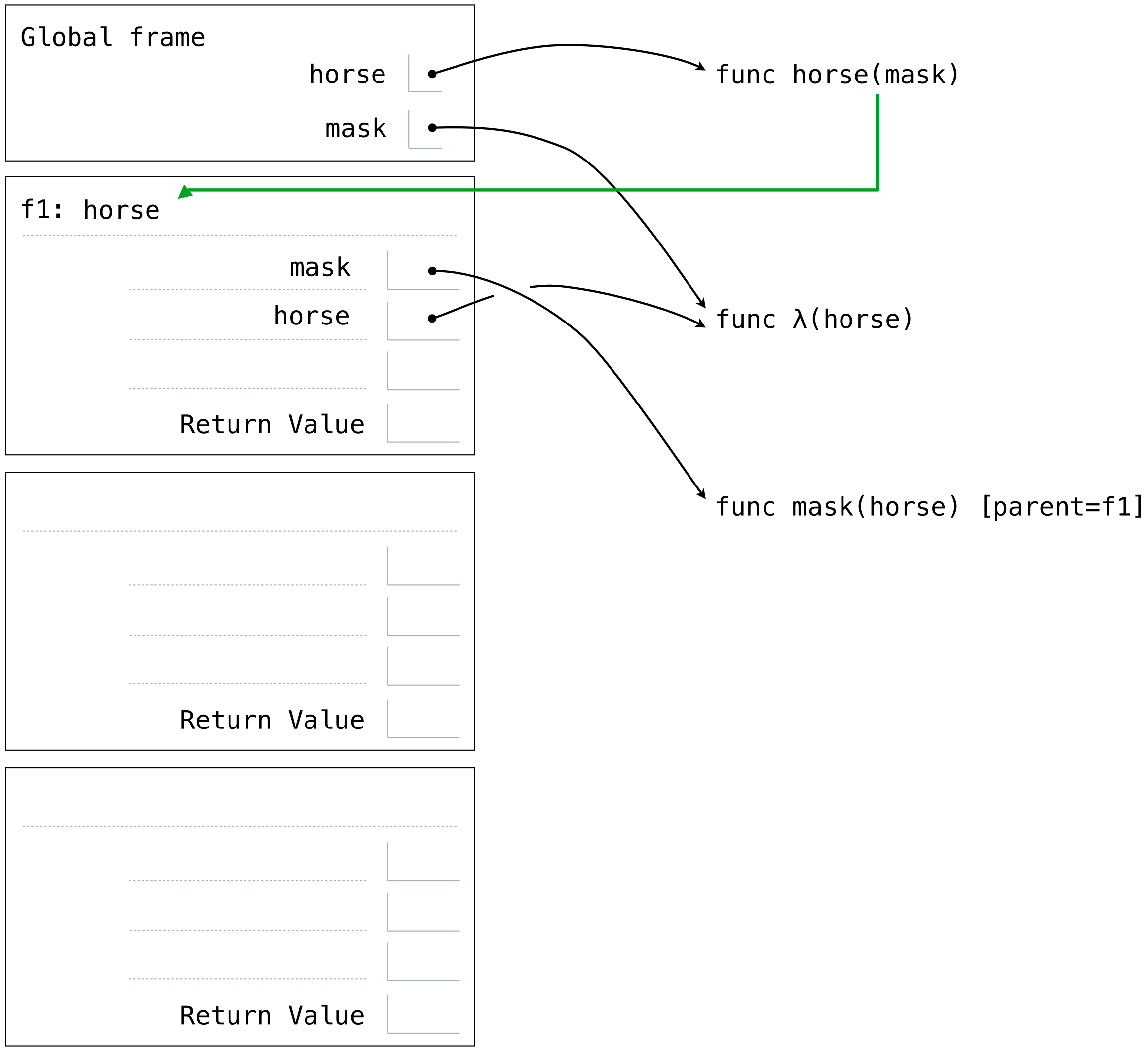

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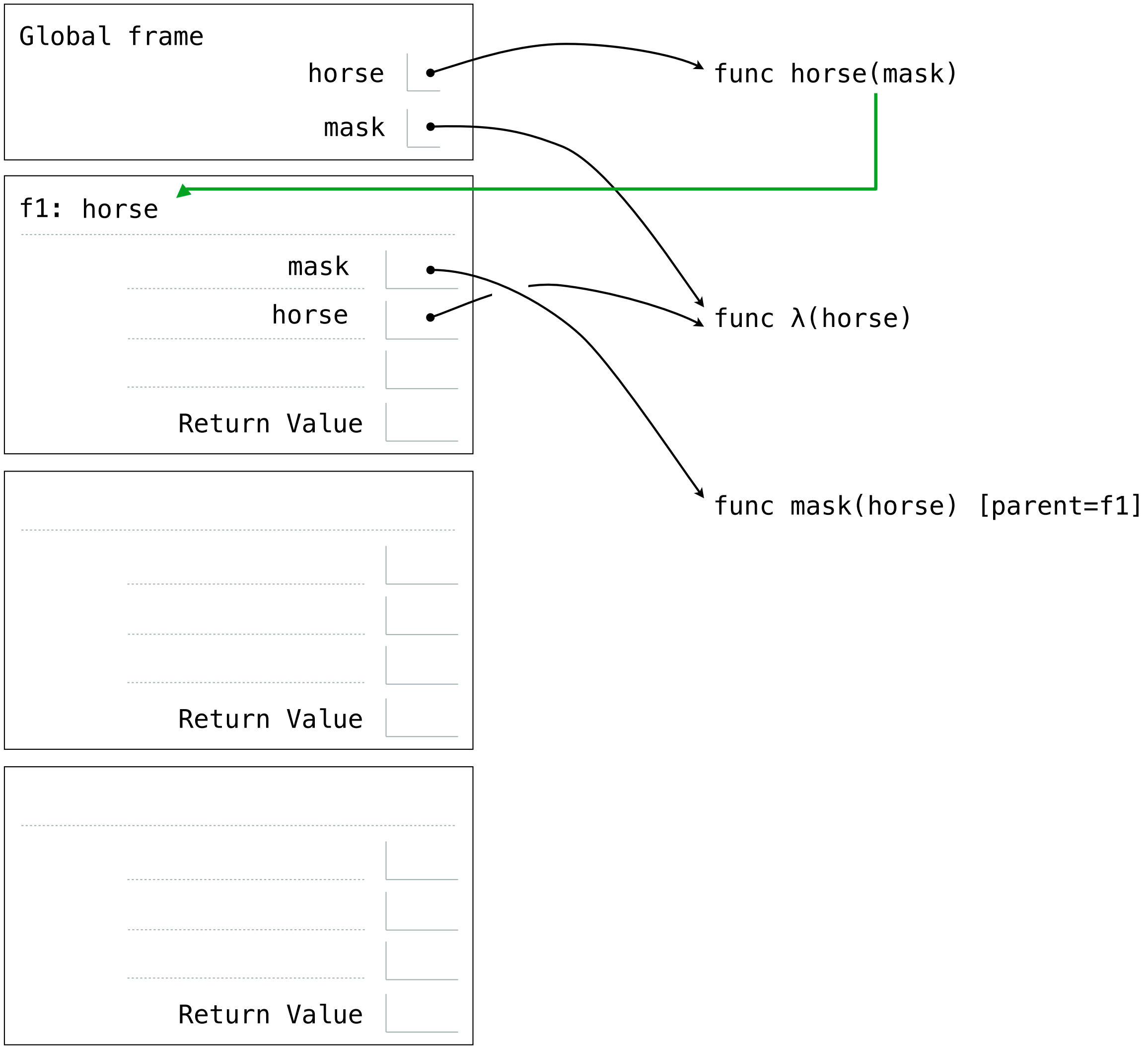

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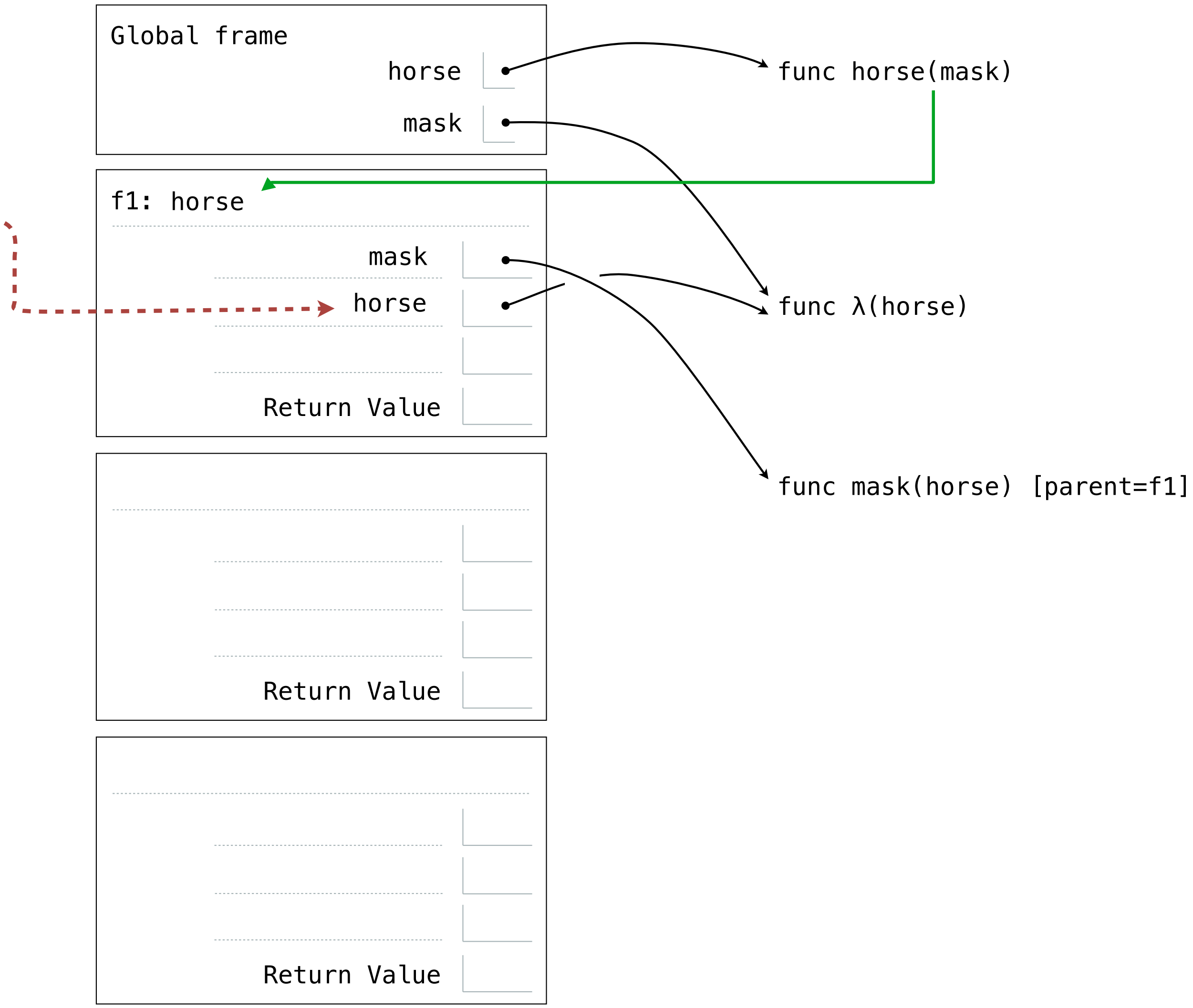

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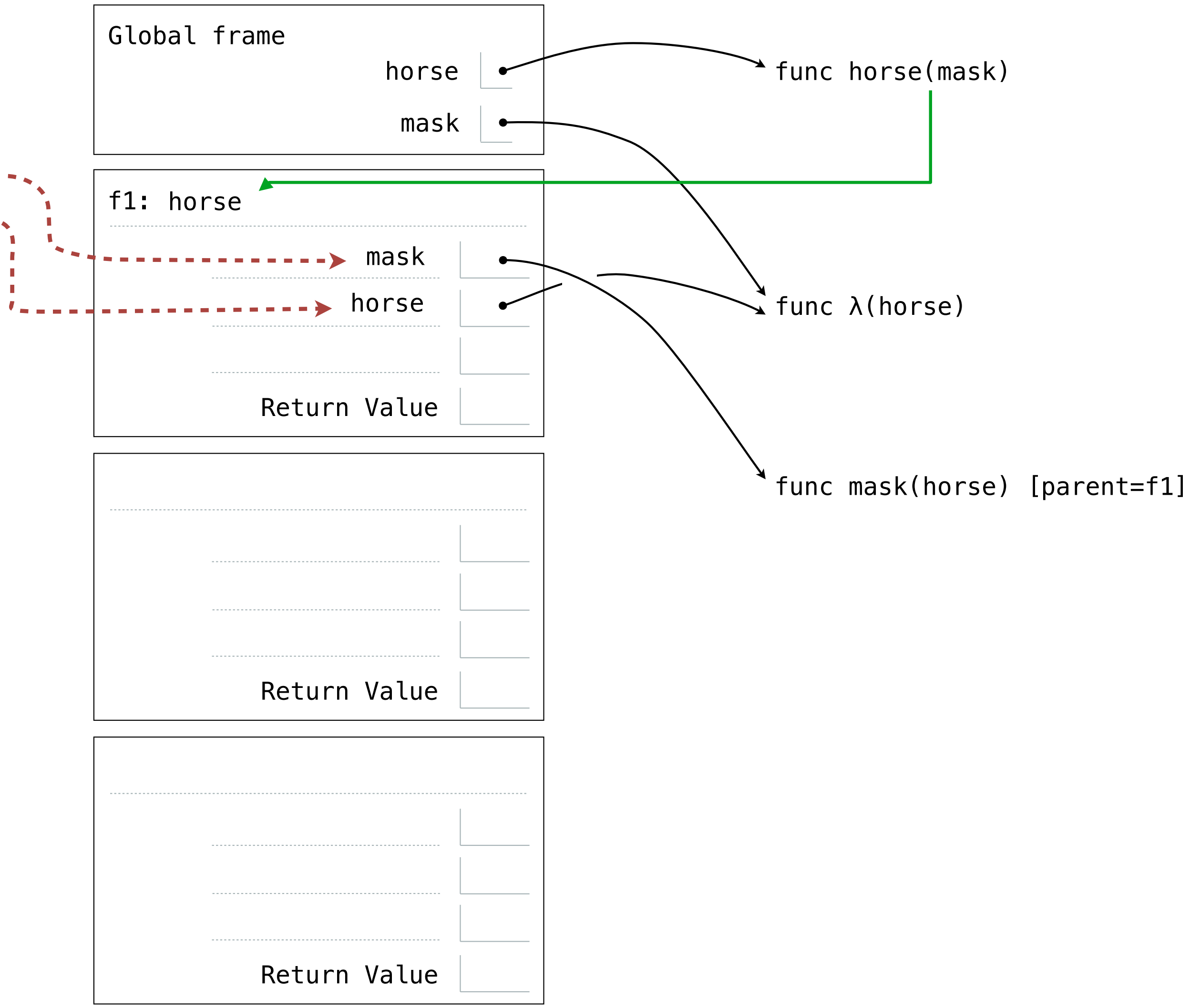

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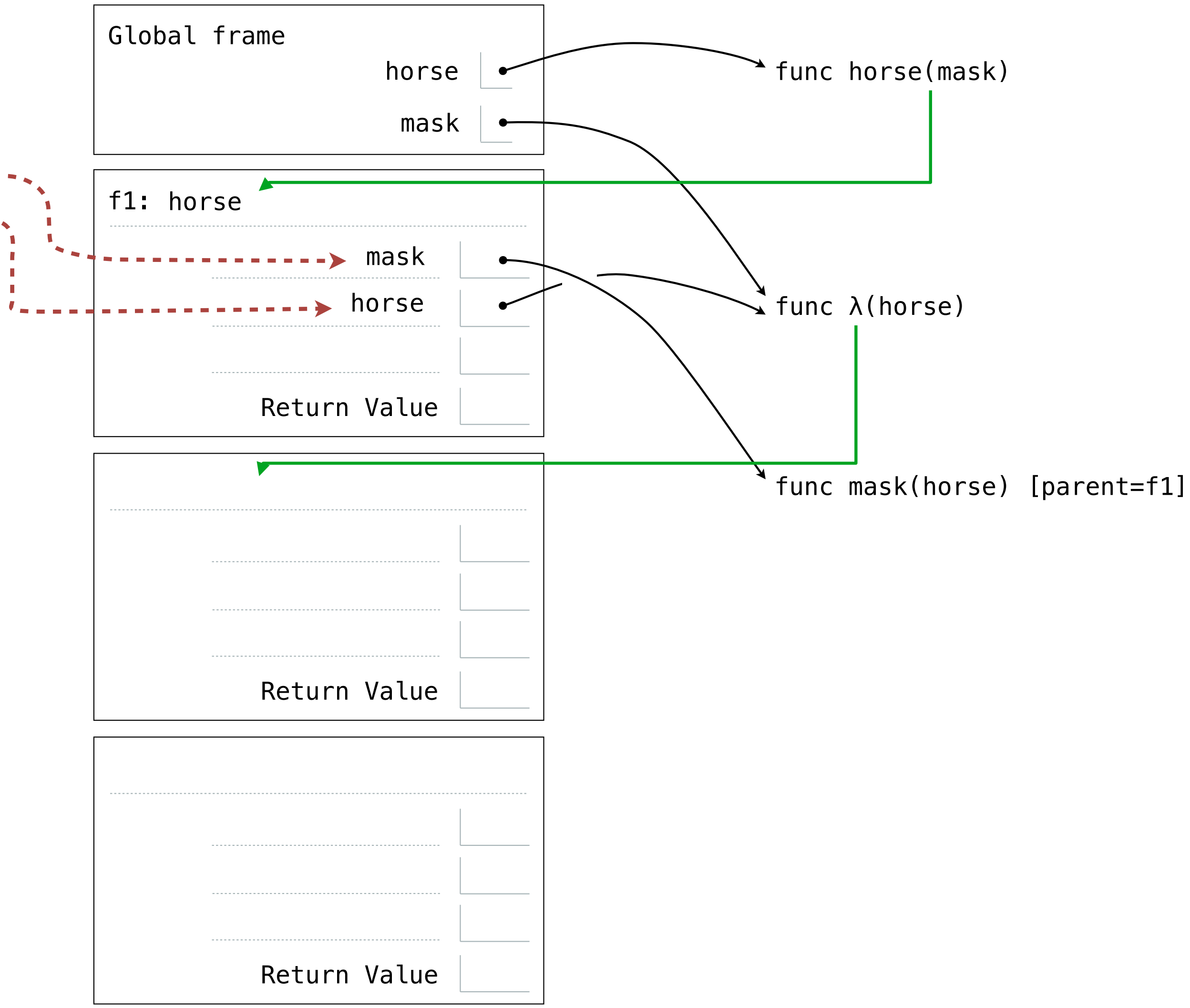

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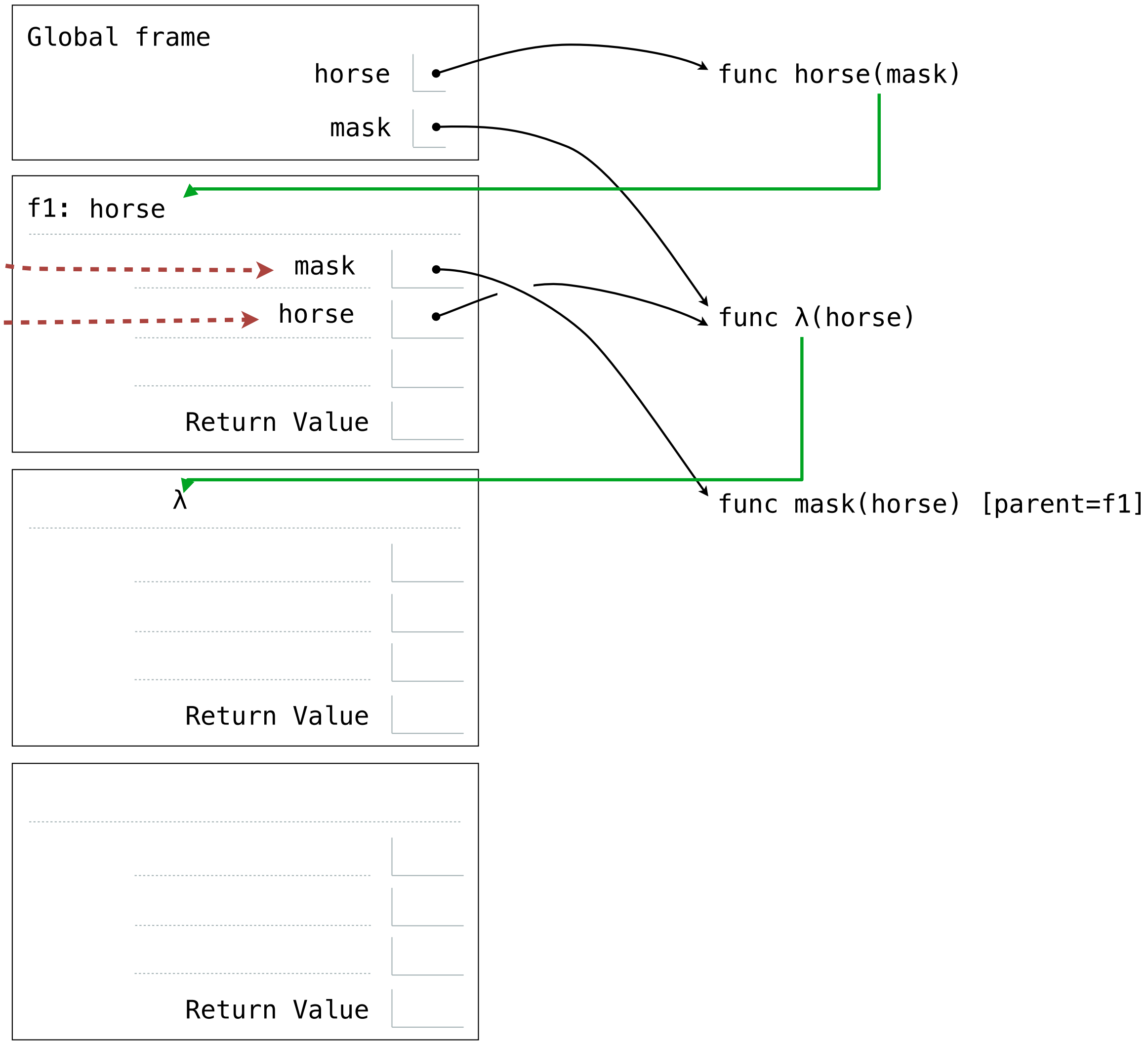

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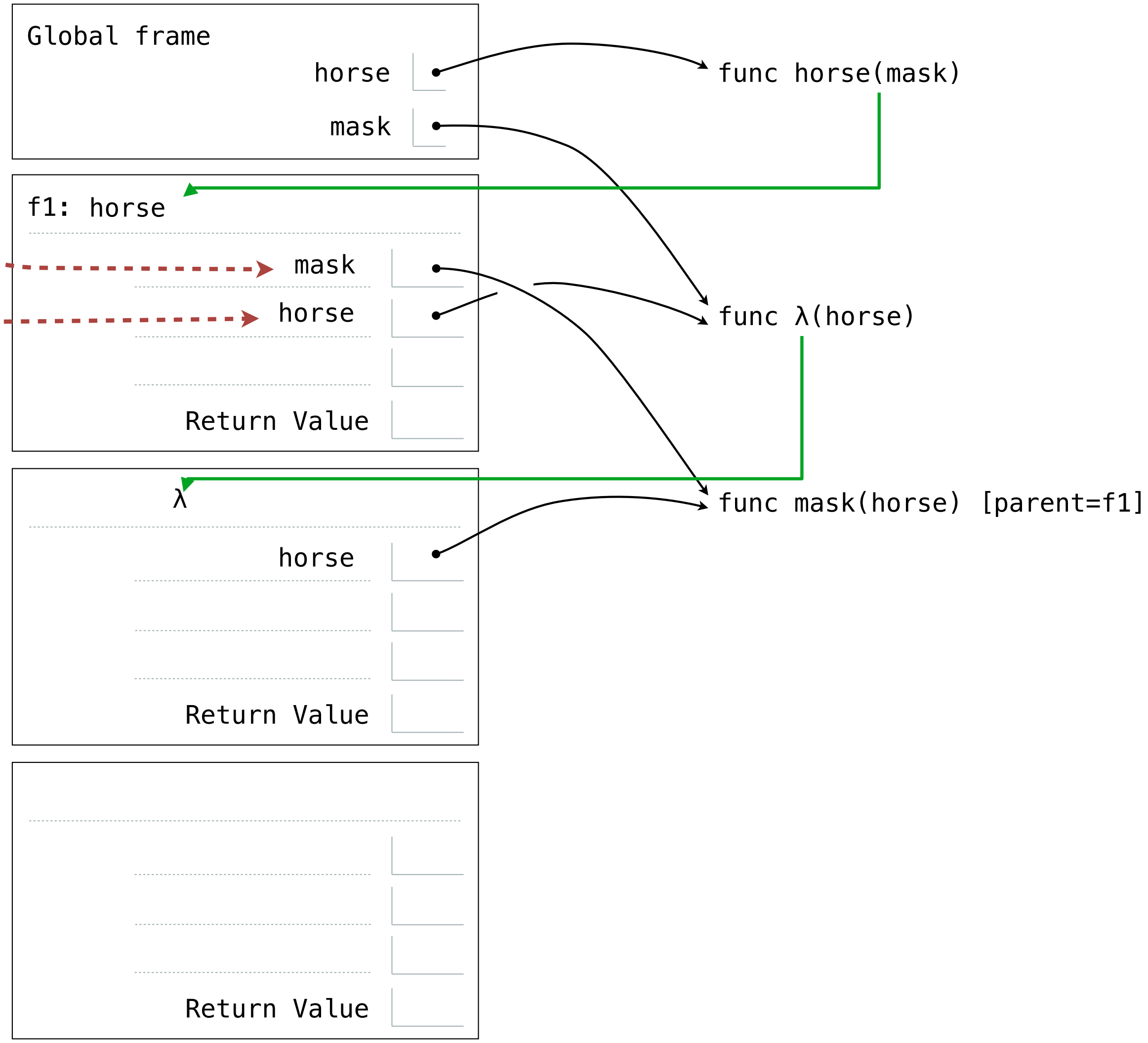

Global frame

horse

mask

f1: horse

mask

horse

Return Value

λ

horse

Return Value

Return Value

func horse(mask)

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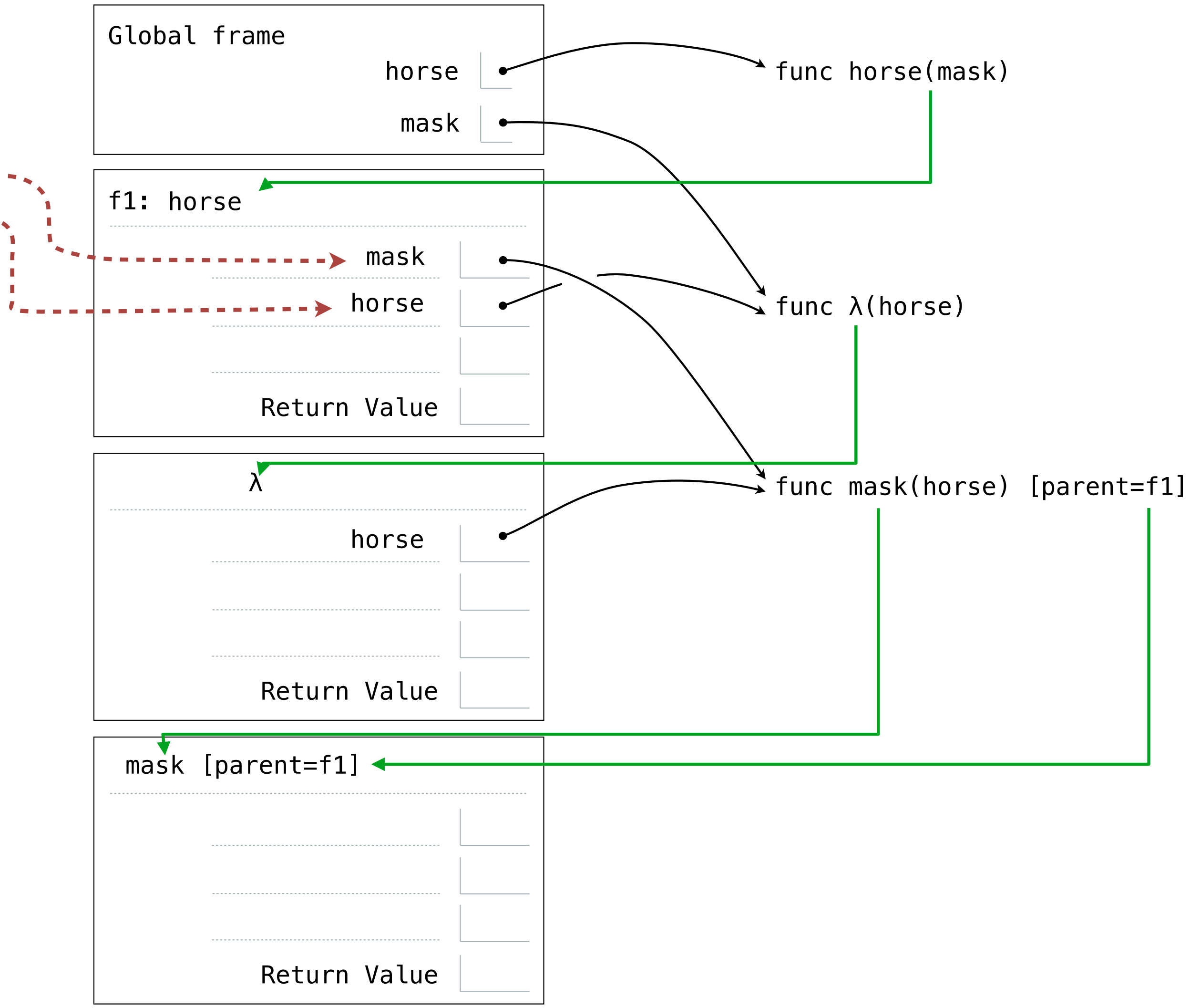

Global frame

horse

mask

f1: horse

mask

horse

Return Value

λ

horse

Return Value

mask [parent=f1]

Return Value

func horse(mask)

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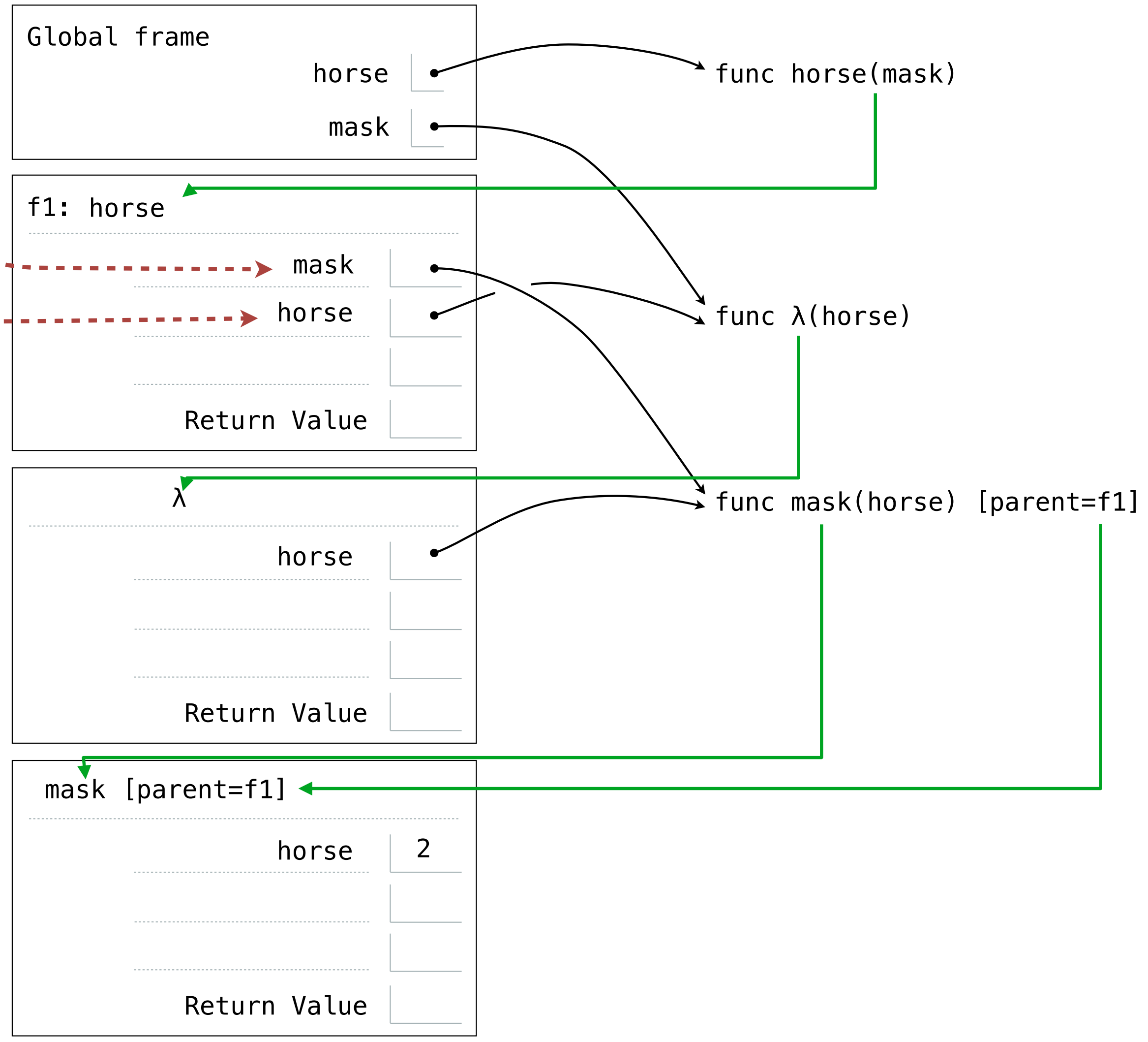

Global frame

horse

mask

func horse(mask)

f1: horse

mask

horse

Return Value

func λ(horse)

λ

horse

Return Value

func mask(horse) [parent=f1]

mask [parent=f1]

horse 2

Return Value

```
def horse(mask):
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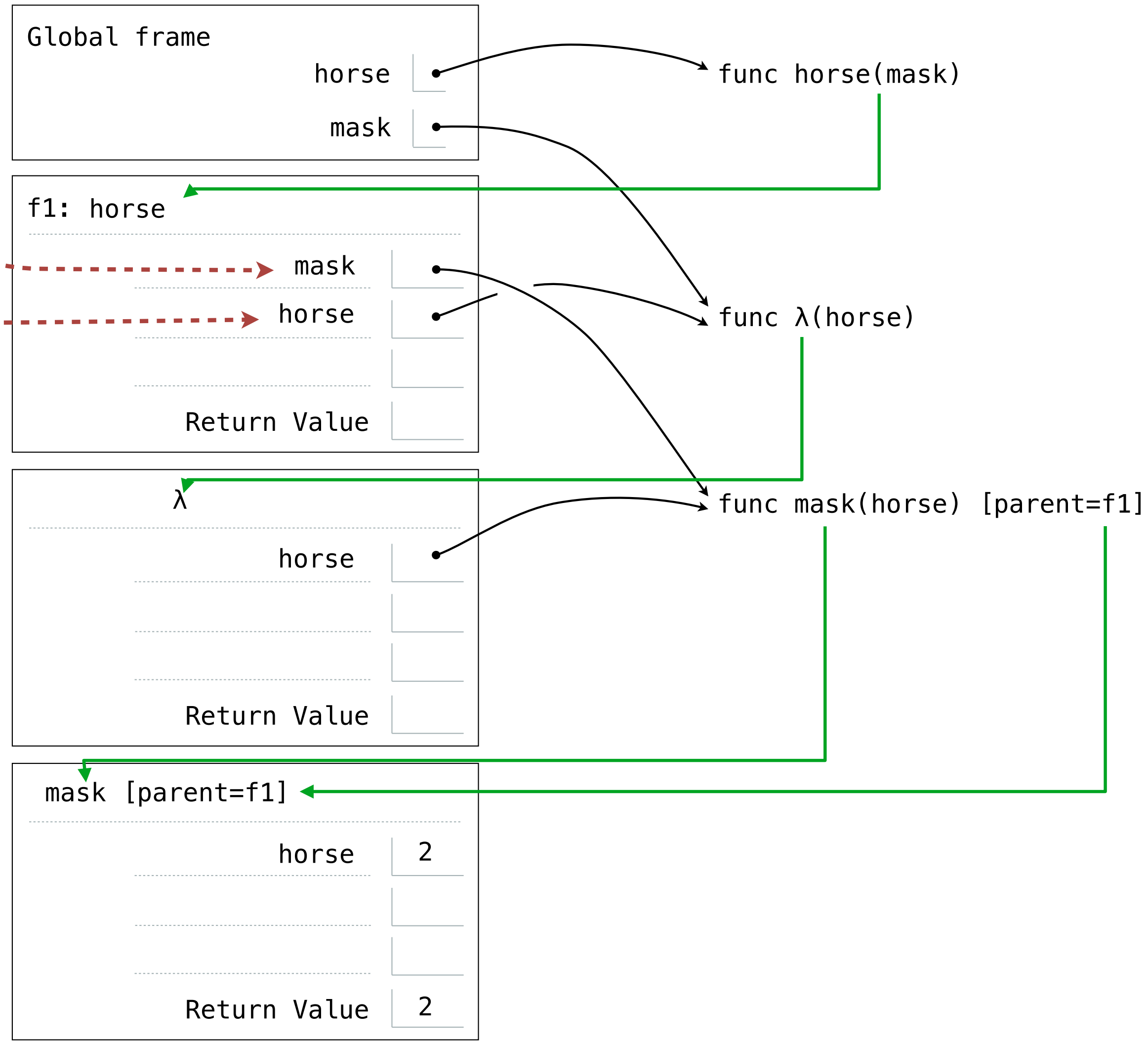
horse(mask)
```



Global frame

horse

mask

func horse(mask)

f1: horse

mask

horse

Return Value

func λ(horse)

λ

horse

Return Value

func mask(horse) [parent=f1]

mask [parent=f1]

horse 2

Return Value 2

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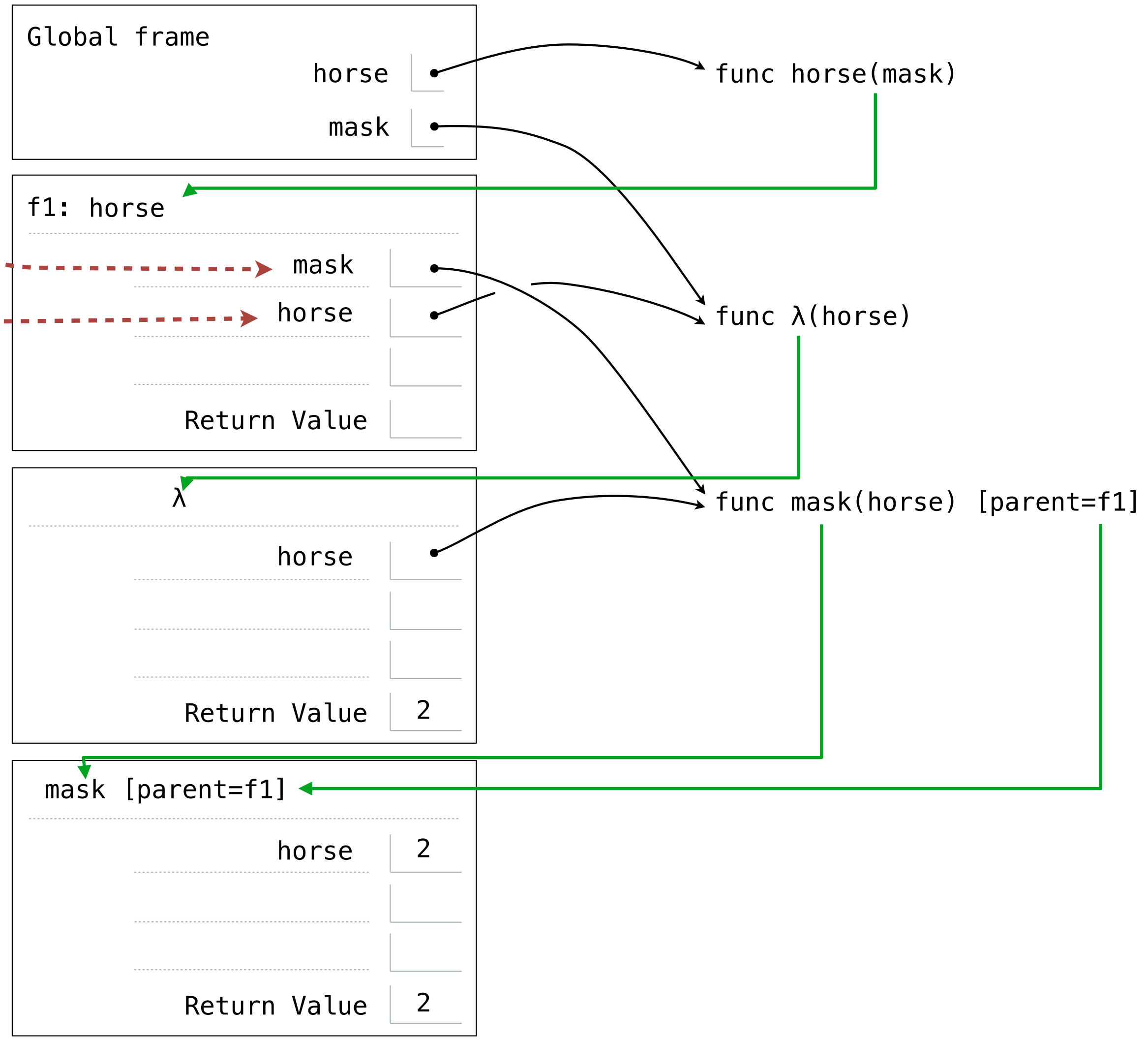

Global frame

horse

mask

func horse(mask)

f1: horse

mask

horse

Return Value

func λ(horse)

λ

horse

Return Value 2

func mask(horse) [parent=f1]

mask [parent=f1]

horse 2

Return Value 2

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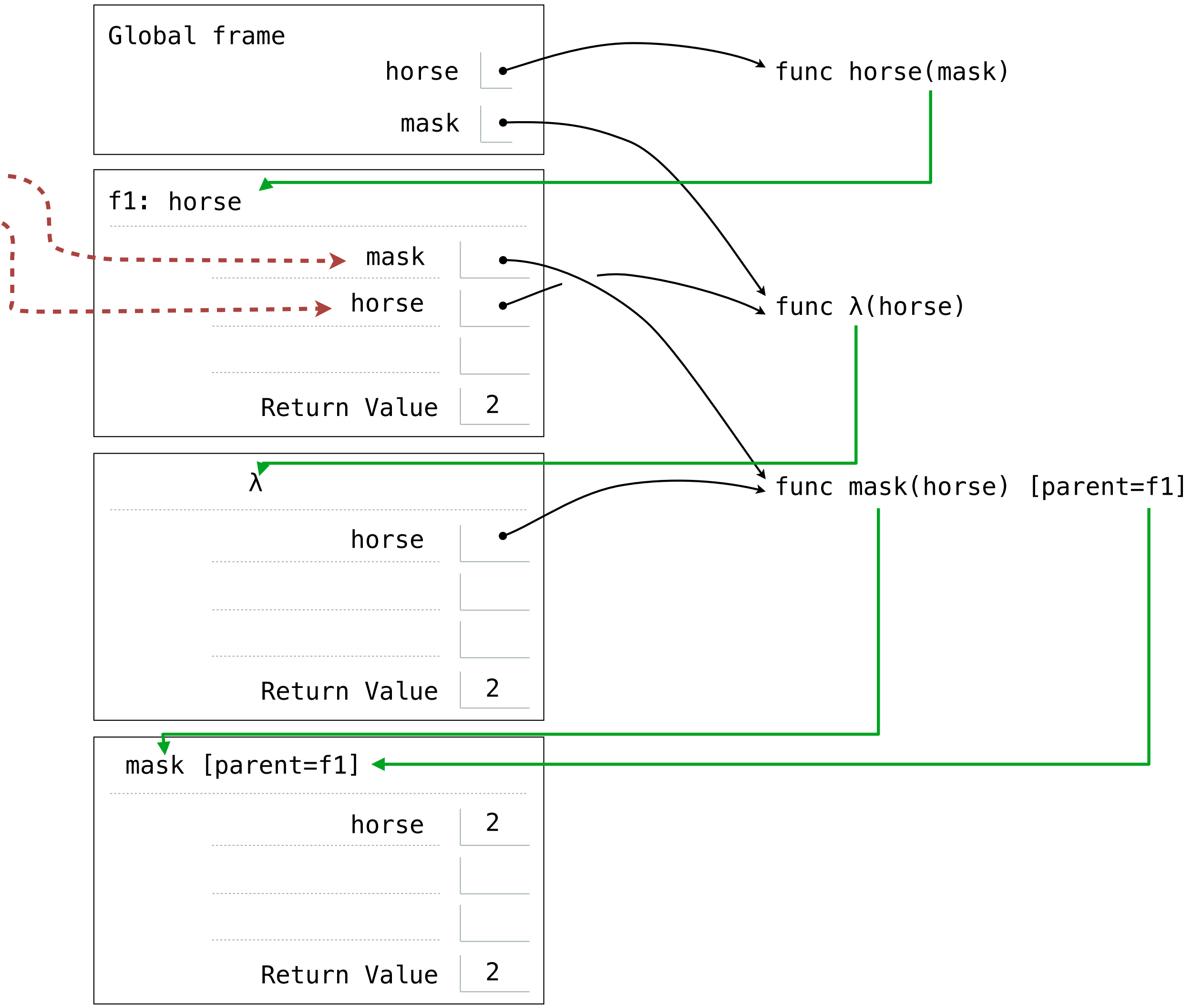

Global frame

horse

mask

func horse(mask)

f1: horse

mask

horse

Return Value 2

func λ(horse)

λ

horse

Return Value 2

func mask(horse) [parent=f1]

mask [parent=f1]

horse 2

Return Value 2