

# Environments

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# Announcements

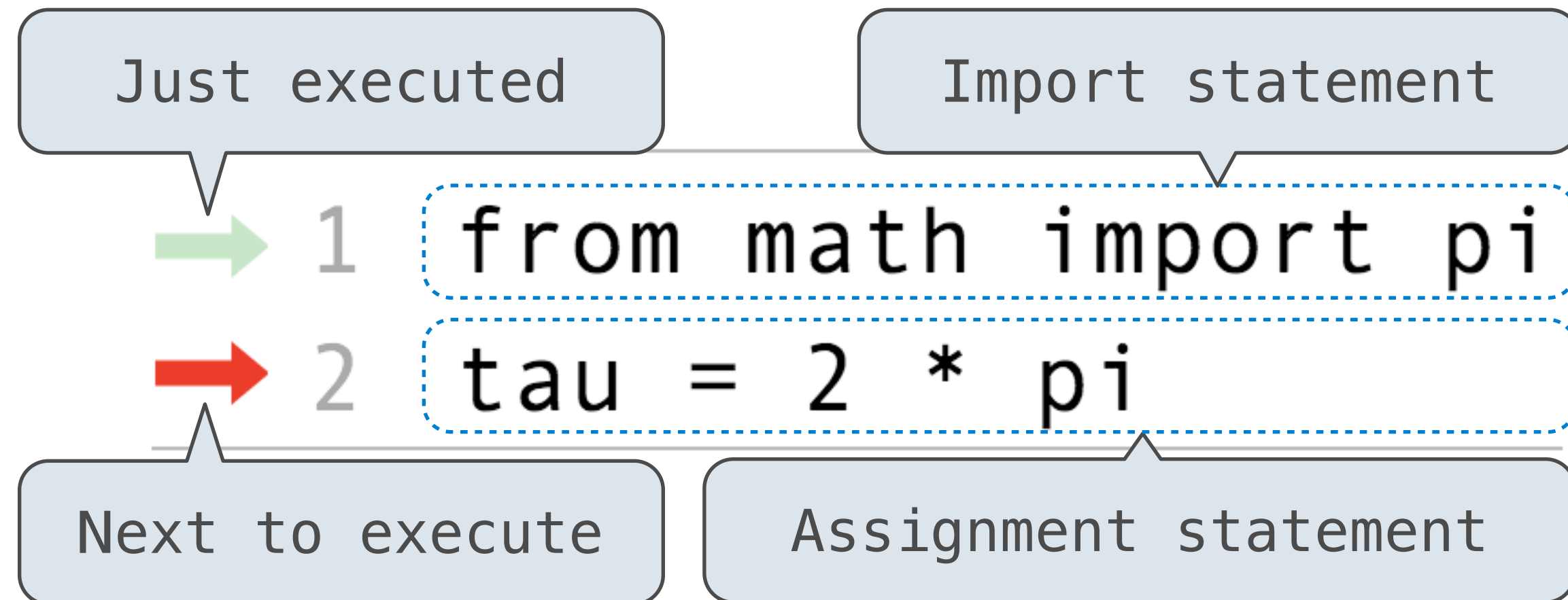
- Hog, HW1, and Lab 1 have been released!
  - Lab 1 is due tomorrow
  - HW 1 is due Thursday
  - Hog Checkpoint is due Friday
- Tutoring section sign ups released!
  - [tutorials.cs61a.org](http://tutorials.cs61a.org)
- Regular OH this week!
  - Calendar: <https://cs61a.org/office-hours/>
- Instructor OH Schedule in Soda 781
  - Jordan: Mondays, 12:45 – 1:45 pm
  - Noor: Tuesdays, 9:30 – 10:30 am
  - Tim: Thursdays, 12:45 – 1:45 pm
- Sections will be finalized 6/30
  - [sections.cs61a.org](http://sections.cs61a.org)

# Environment Diagrams

# Environment Diagrams

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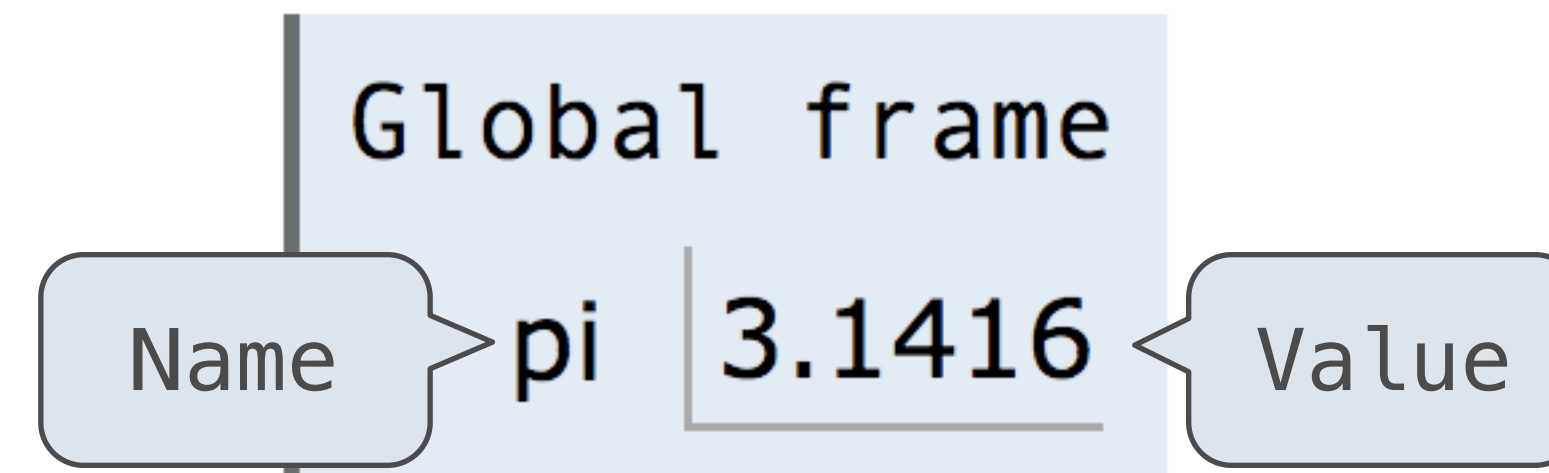
Environment diagrams visualize the interpreter's process.



## Code (left):

Statements and expressions

Arrows indicate evaluation order



## Frames (right):

Each name is bound to a value

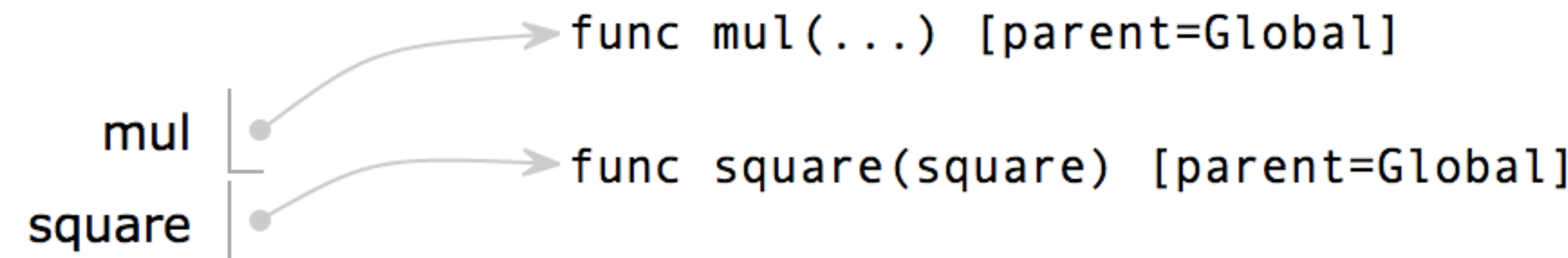
Within a frame, a name cannot be repeated

# Why Use Environment Diagrams?

- They help us understand why the programs we design work the way they do!
  - Predict how a program will behave

```
1 from operator import mul
2 def square(square):
3     return mul(square, square)
4 square(4)
```

Global frame



f1: square [parent=Global]

square	4
Return value	16

- They can also be useful in debugging!
  - When we run into an unexpected error, we can trace back our steps!



staring at lines of codes

diagramming code

# What We Have Seen So Far

- **Assignment Statements**

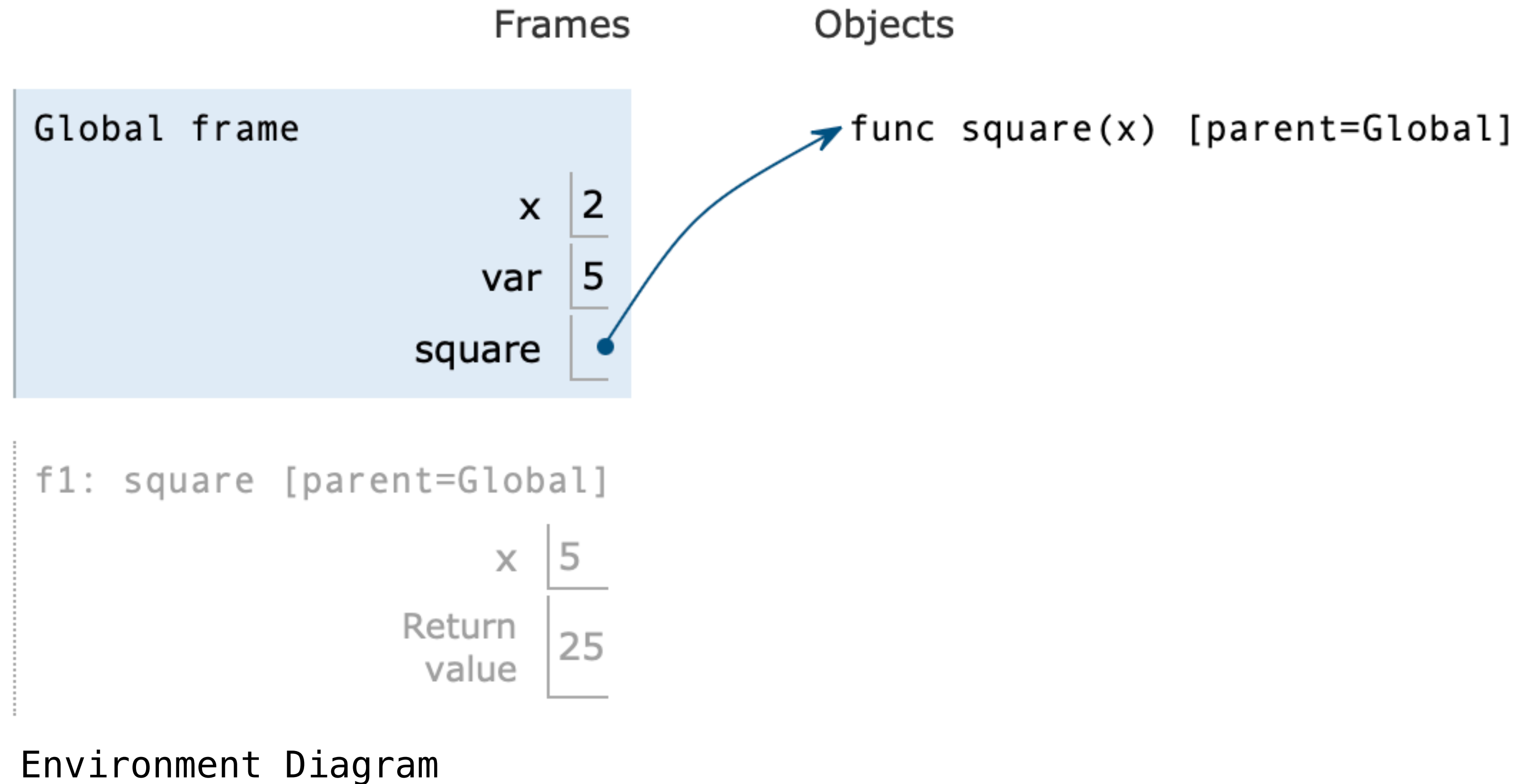
- `x = 2`
- `var = 5`

- **Def Statements**

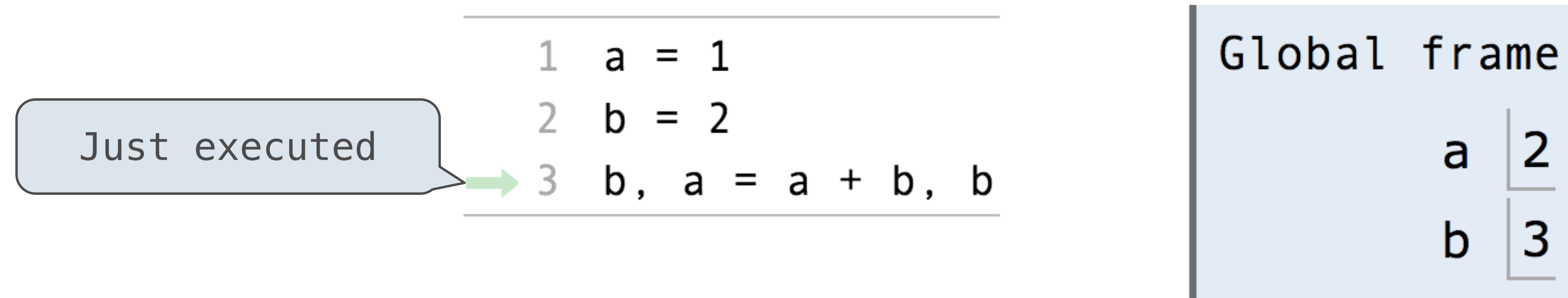
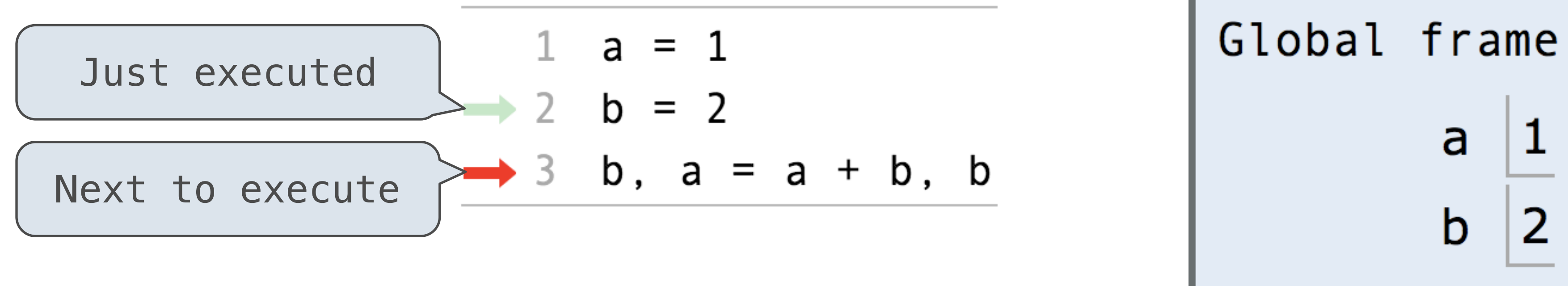
- `def square(x):`  
    `return x * x`

- **Call Expressions**

- `square(var)`



# Assignment Statements



## Execution rule for assignment statements:

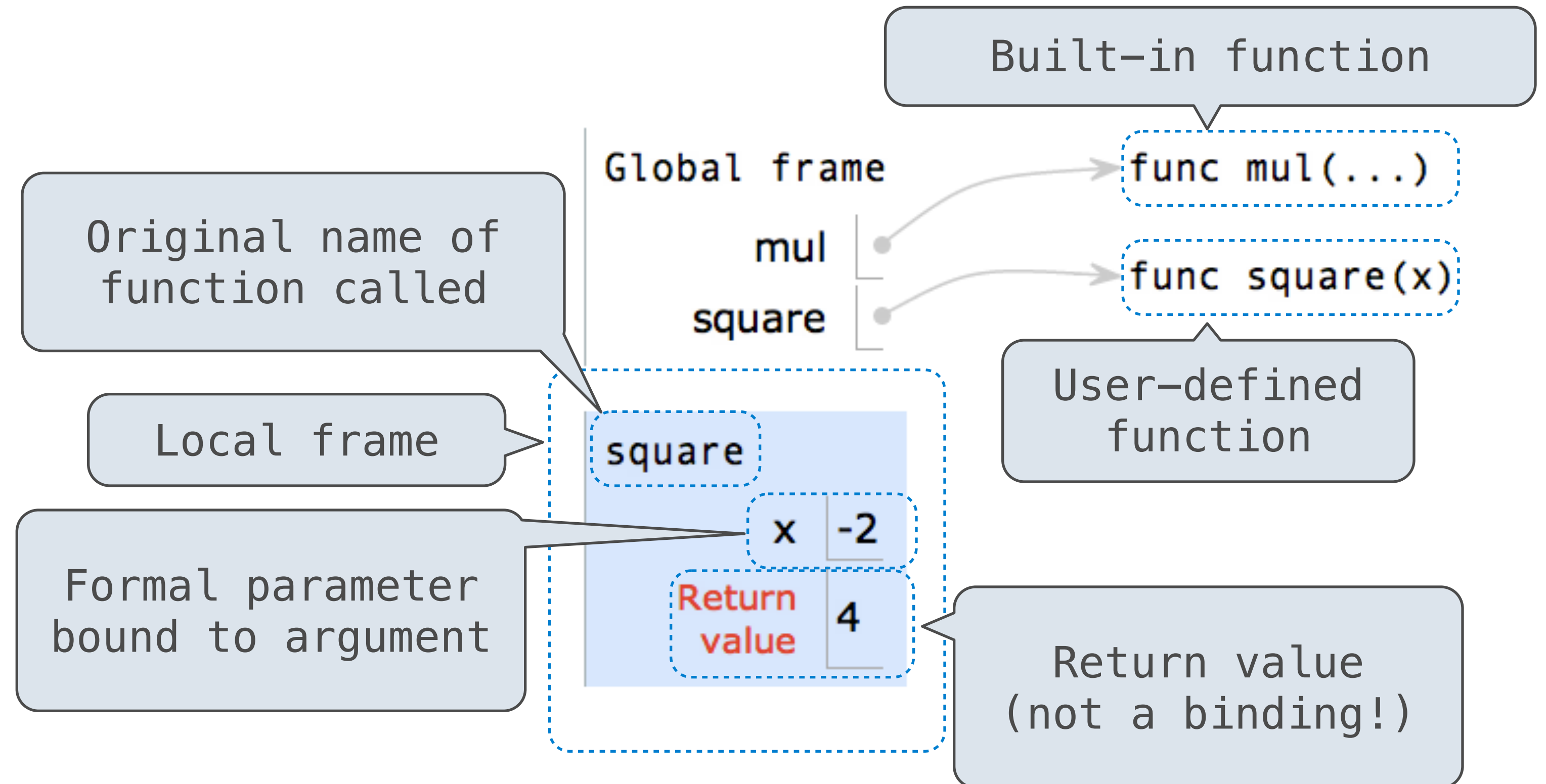
1. Evaluate all expressions to the right of = from left to right.
2. Bind all names to the left of = to those resulting values in the current frame.

# Calling User-Defined Functions

## Procedure for calling/applying user-defined functions:

1. Add a local frame
2. Bind the function's formal parameters to its arguments in that frame
3. Execute the body of the function in that new environment

```
1 from operator import mul
2 def square(x):
3     return mul(x, x)
4 square(-2)
```





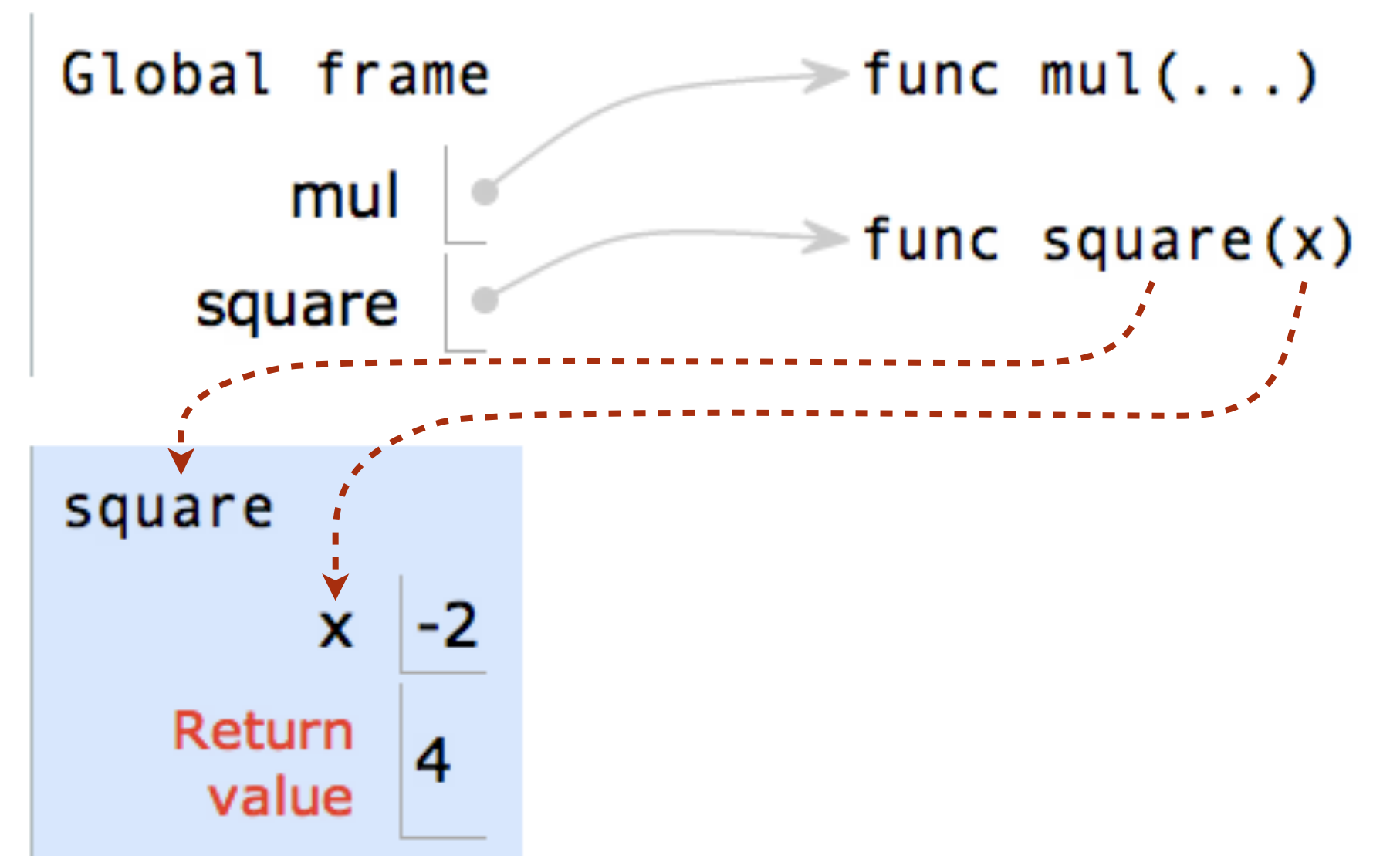
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3     return mul(x, x)
4 square(-2)
```

A function's signature has all the information needed to create a local frame



# Frames

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- A frame keeps track of variable-to-value bindings
- By default, the global frame is the starting frame
  - It doesn't correspond to a specific call expression
- Every call expression has a corresponding frame
- The parent of a function is the frame in which it was **defined** *not called*
  - *Important for variable lookup!*
  - If you cannot find a name in the current frame, you can go up to its parent until you reach the global frame
    - If it is not found, you get a **NameError: name 'x' is not defined**

Global frame	
a	1
b	2

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## Demo

# How to Draw an Environment Diagram

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When a function is defined:

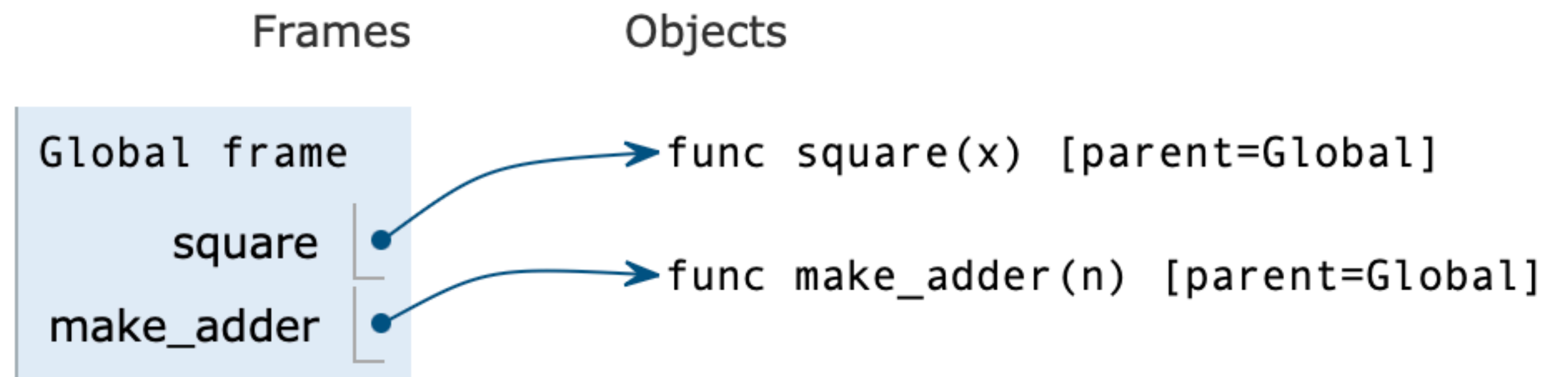
Create a function value: `func <name>(<formal parameters>) [parent=<label>]`

Its parent is the current frame.

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```
1 def square(x):
2     return x * x
3
4 def make_adder(n):
5     def adder(k):
6         return n + k
7     return adder
```

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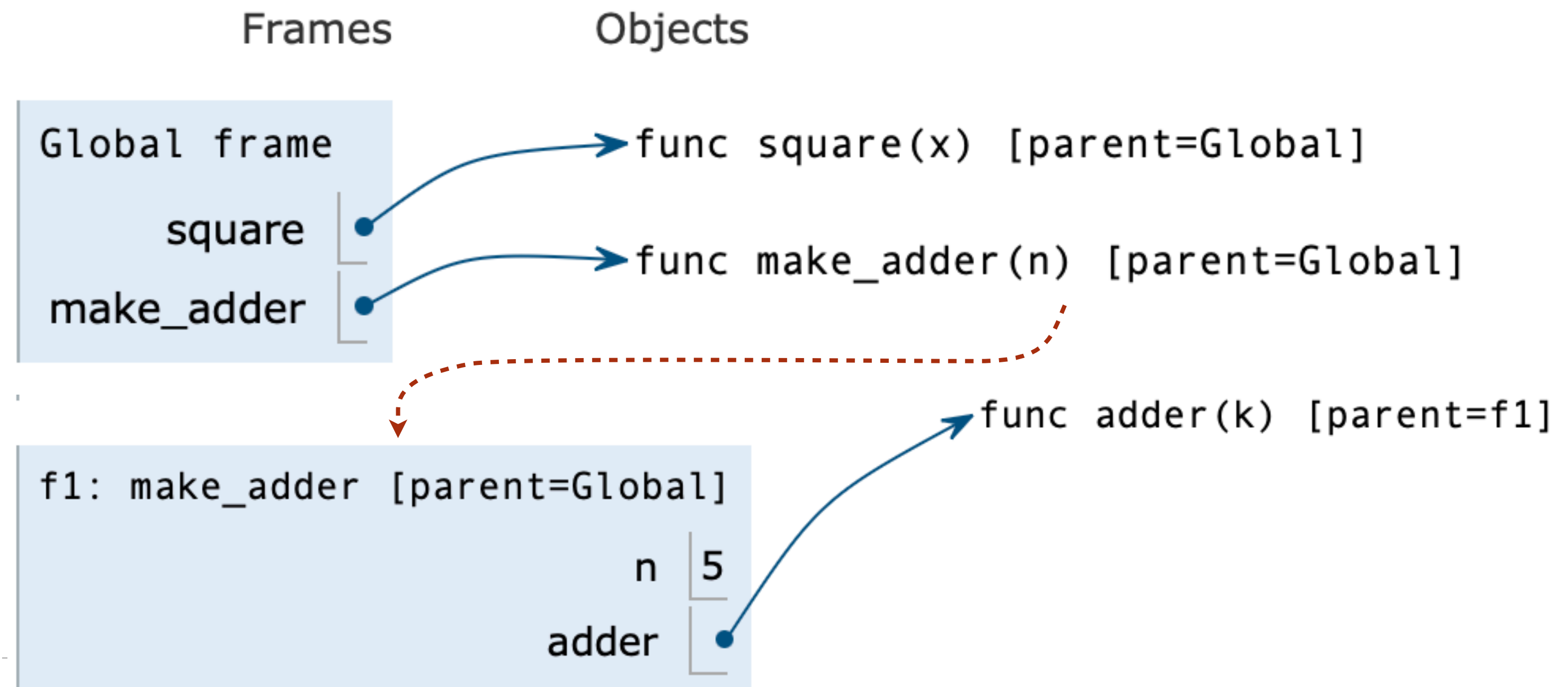
# How to Draw an Environment Diagram

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.

```
1 def square(x):  
2     return x * x  
3  
→ 4 def make_adder(n):  
5     def adder(k):  
6         return n + k  
7     return adder
```

`make_adder(5)`



## Check Your Understanding: Calling Functions

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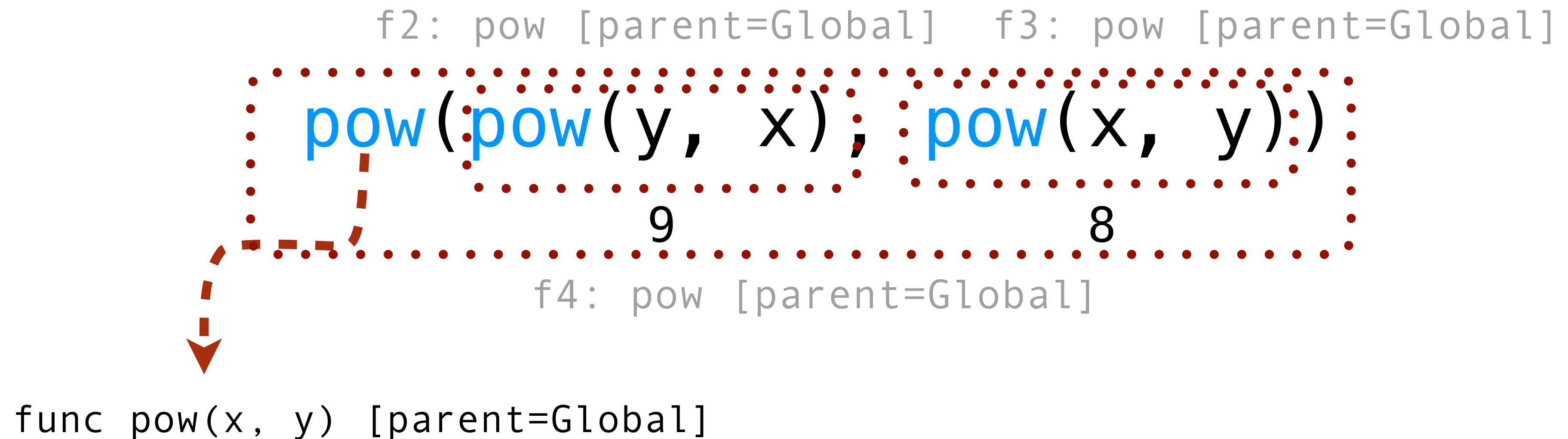
```
→ 1 from operator import pow
   2
   3 def pow(x, y):
   4     return x ** y
   5
   6 def power_of_pow(x, y):
   7     return pow(pow(y, x), pow(x, y))
   8
   9 power_of_pow(2, 3)
```

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# Evaluation Order

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- An environment diagram reflects Python evaluation order
  - Evaluate the operator, then the operands, finally apply the operator to the operands



# Lambda Expressions

# Lambda Expressions

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```
>>> x = 10
```

An expression: this one evaluates to a number

```
>>> square = x * x
```

Also an expression: evaluates to a function

```
>>> square = lambda x: x * x
```

Important: No "return" keyword!

A function

with formal parameter `x`

that returns the value of `"x * x"`

```
>>> square(4)
16
```

Must be a single expression

Lambda expressions are not common in Python, but important in general

Lambda expressions in Python cannot contain statements at all!



## Check Your Understanding: Calling Lambda

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```
→ 1 y = 6
   2
   3 def apply_func(f, x):
   4     return f(x)(y)
   5
   6
   7 apply_func(lambda x: lambda y: x + y + 1, 5)
```

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# Environments for Higher-Order Functions

## Environments Enable Higher-Order Functions

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**Functions are first-class:** Functions are values in our programming language

**Higher-order function:** A function that takes a function as an argument value **or**  
A function that returns a function as a return value

*Environment diagrams describe how higher-order functions work!*

# Revisiting Evaluation Order

- Even with higher-order function, the rules remain the same and the environment diagram reflects Python evaluation order!
  - Evaluate the operator, then the operands, finally apply the operator to the operands

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```
def make_adder(n):  
    def adder(k):  
        return n + k  
    return adder
```

---

```
make_adder(3)(5)
```

---

```
f2: adder [parent=f1]  
f1: make_adder [parent=Global]
```

```
func adder(k) [p=f1] (5)
```

8

```
func make_adder(n) [parent=Global]  
func adder(k) [parent=f1]
```

(Demo)

# Currying

# Function Currying

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

```
>>> make_adder(2)(3)  
5  
>>> add(2, 3)  
5
```

There's a general  
relationship between  
these functions

(Demo)

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

## Summary

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- Using **environment diagrams** to visualize and understand programming
  - Diagramming follow the evaluation procedure for Python
  - Think deeply about how the code you write actually works
- **Lambda expressions**
  - Similar to user-defined functions but are anonymous
  - They are simple and can be created for one-time use or stored by assigning it to a variable
- The same rules of diagramming apply to **HOFs**, which take in a function as an input to return a function as an output
- To **curry** a multi-argument function is to transform it into a single-argument, multi-nested HOF