# SICP

## God's Programming Book

# Environments

Slides Adapted from cs61a of UC Berkeley

# Environments for Higher-Order Functions

# Environments Enable Higher-Order Functions

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

**Higher-order function:**

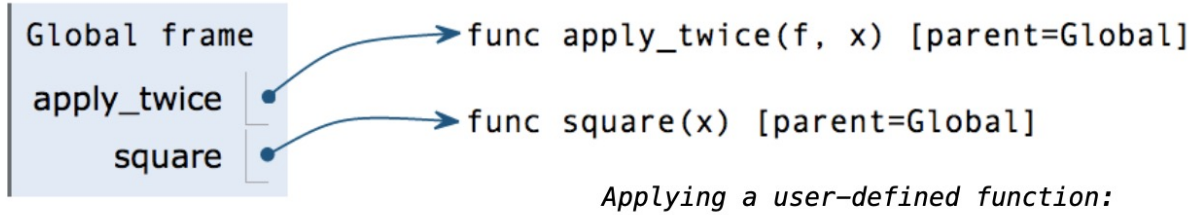
- A function that takes a function as an argument value **or**
- A function that returns a function as a return value

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

(Demo)

# Names can be Bound to Functional Arguments

```
1  def apply_twice(f, x):
2      return f(f(x))
3
4  def square(x):
5      return x * x
6
7  result = apply_twice(square, 2)
```




*Applying a user-defined function:*

- Create a new frame
- Bind formal parameters (f & x) to arguments
- Execute the body: return f(f(x))

```
1  def apply_twice(f, x):
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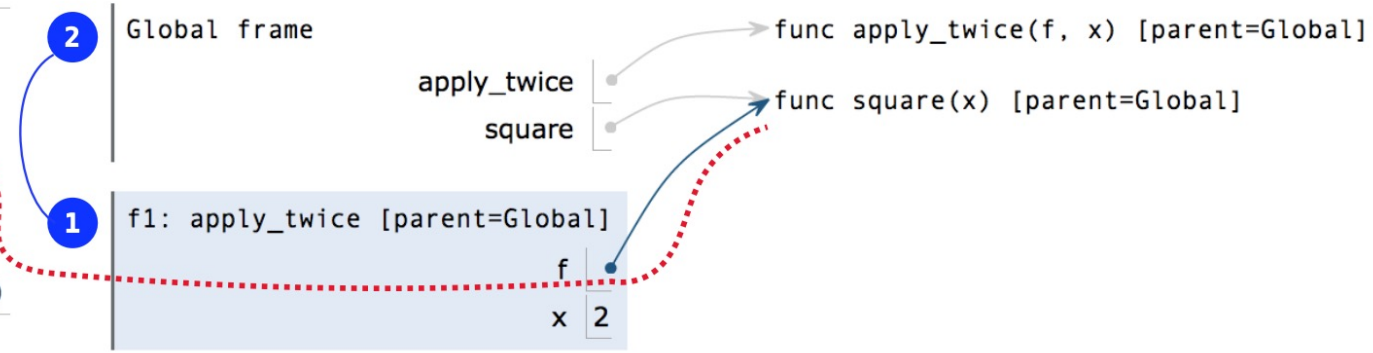
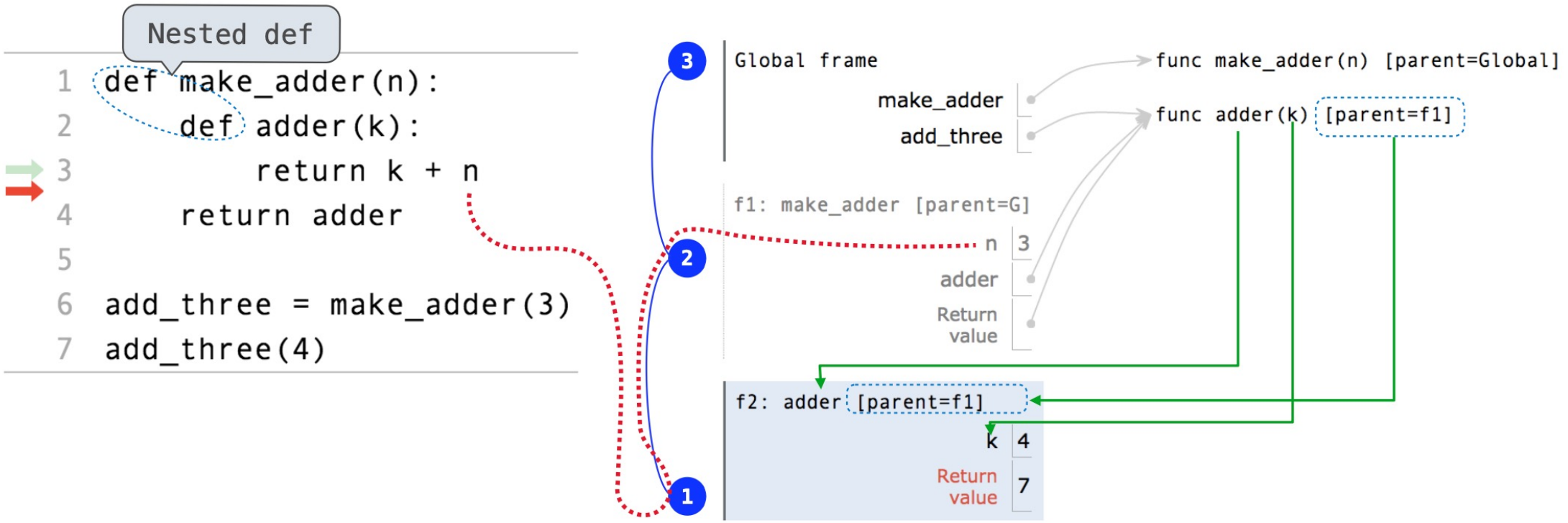


# Environments for Nested Definitions

(Demo)

# Environment Diagrams for Nested Def Statements



# Environment Diagrams for Nested Def Statements

- Every user-defined function has a parent frame (often global)
- The parent of a function is the frame in which it was defined
- Every local frame has a parent frame (often global)
- The parent of a frame is the parent of the function called

# How to Draw an Environment Diagram

---

**When a function is defined:**

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

Its parent is the current frame.


Bind <name> to the function value in the current frame

# How to Draw an Environment Diagram

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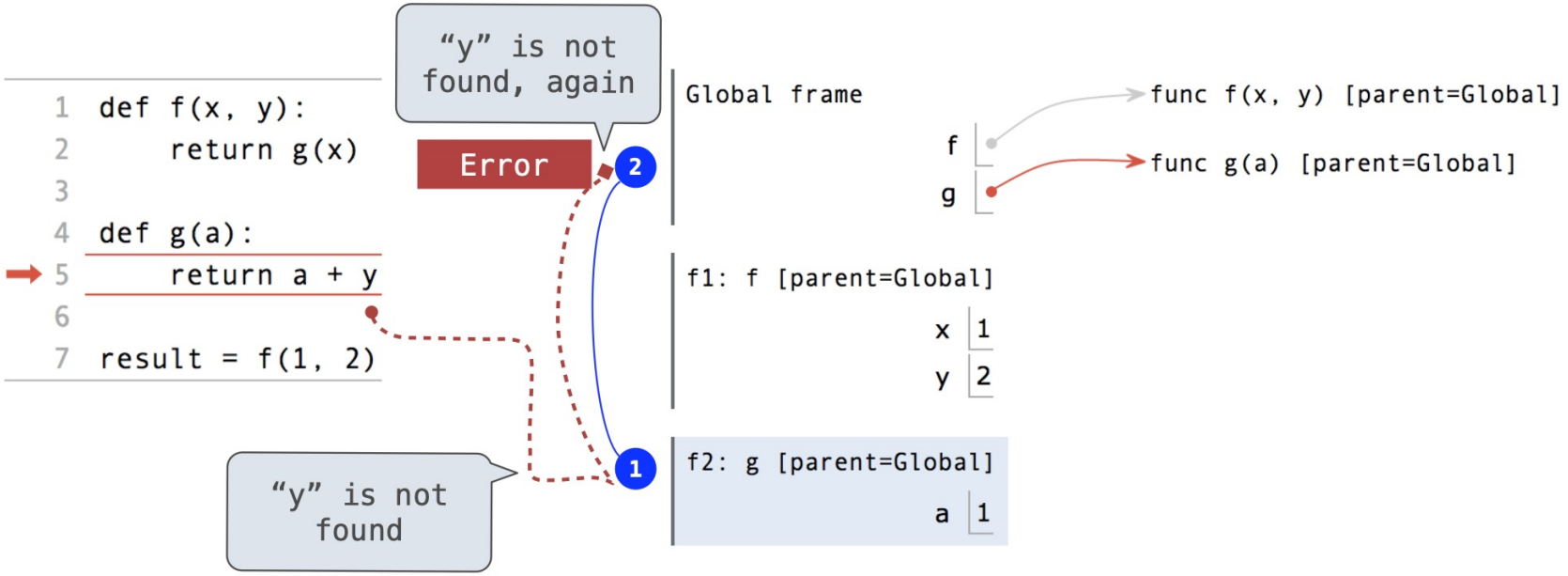
**When a function is called:**

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.

# Local Names

(Demo)

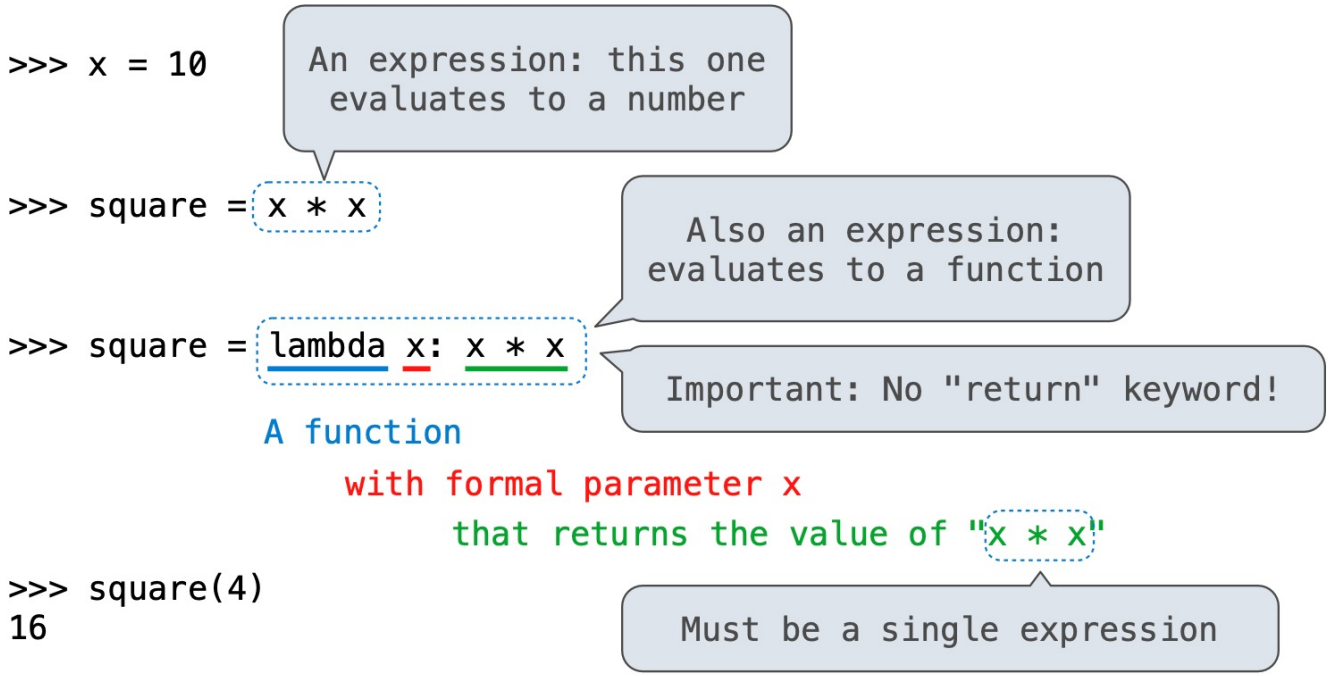
# Local Names are not Visible to Other (Non-Nested) Functions




- An environment is a sequence of frames.
- The environment created by calling a top-level function (no def within def) consists of one local frame, followed by the global frame.

# Lambda Expressions

# Lambda Expressions




- Lambda expressions are not common in Python, but important in general
- Lambda expressions in Python cannot contain statements at all!

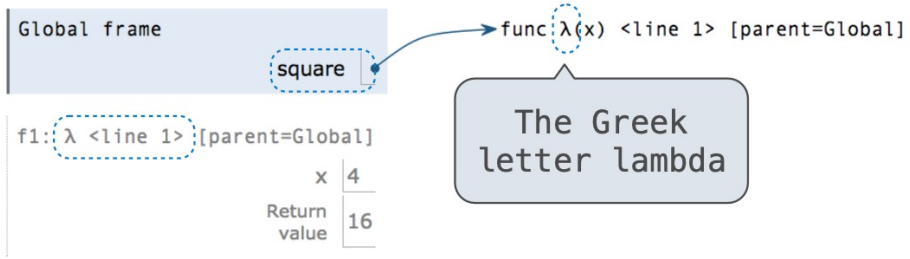
# Lambda Expressions Versus Def Statements

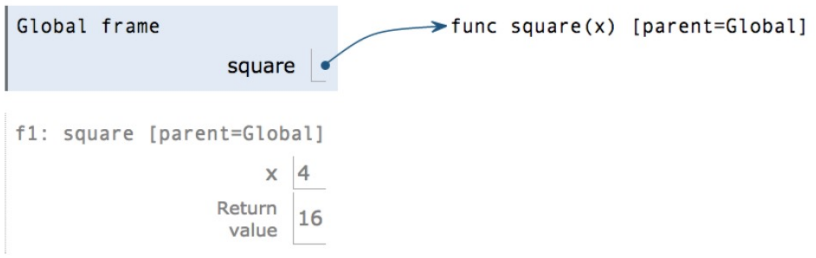
```
square = lambda x: x * x
```

**VS**

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

- Both create a function with the same domain, range, and behavior.
- Both bind that function to the name square.
- Only the def statement gives the function an intrinsic name, which shows up in environment diagrams but doesn't affect execution (unless the function is printed).



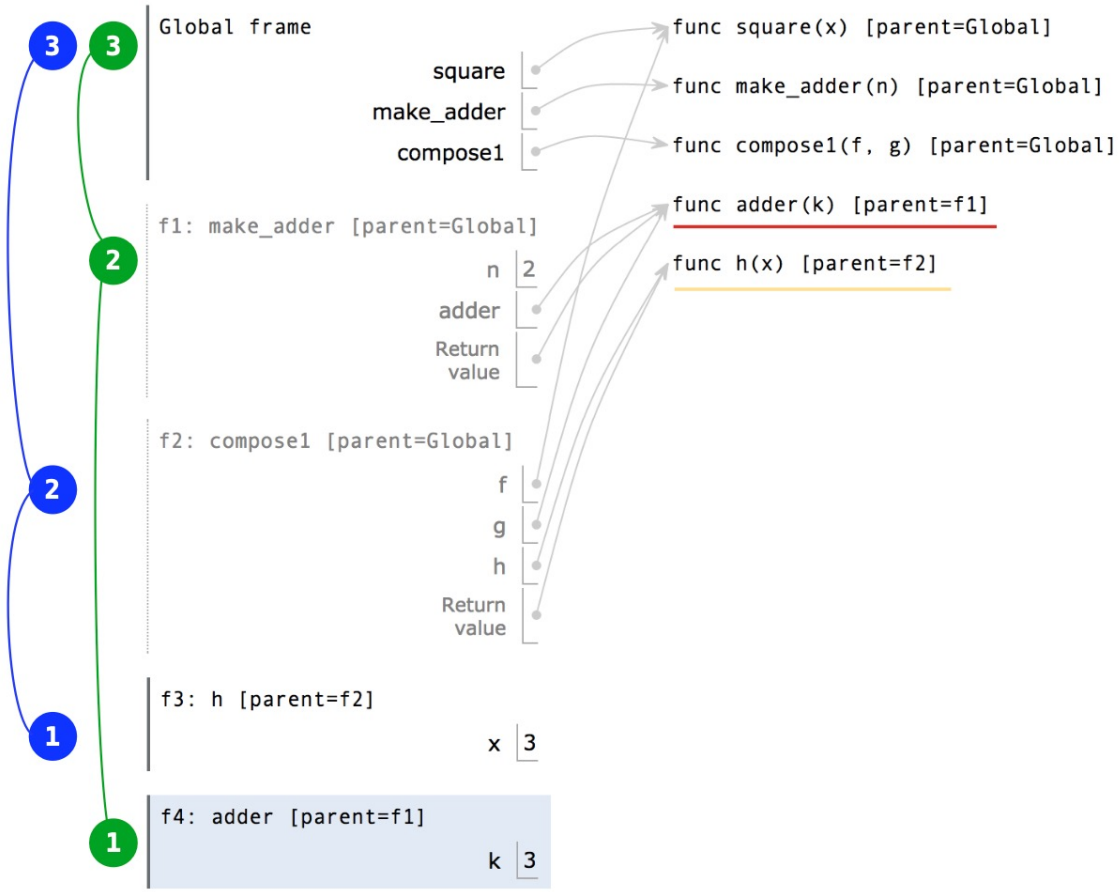
# Function Composition

(Demo)

# The Environment Diagram for Function Composition

```
1  def square(x):
2      return x * x
3
4  def make_adder(n):
5      def adder(k):
6          return k + n
7      return adder
8
9  def compose1(f, g):
10     def h(x):
11         return f(g(x))
12     return h
13
14 compose1(square, make_adder(2))(3)
```

Return value of make_adder is an argument to compose1

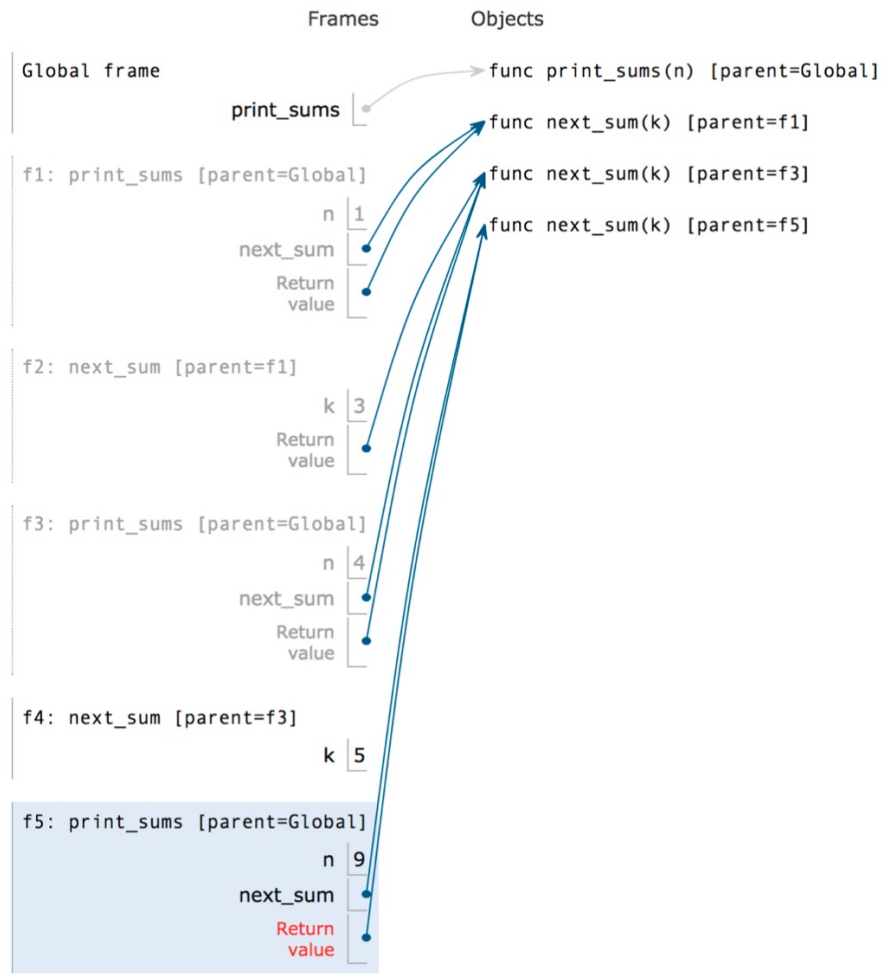


# Self-Reference

(Demo)

# Returning a Function Using Its Own Name

```
1  def print_sums(n):
2      print(n)
3      def next_sum(k):
4          return print_sums(n+k)
5      return next_sum
6
7  print_sums(1)(3)(5)
```



# Currying

# Function Currying

```
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

# Thanks for Listening