Environment Diagrams

Slides adapted from Berkeley CS61a

What are Environment Diagrams?

- A visual tool to keep track of bindings & state of a computer program

- In this class, we use Python as our primary language
  - The diagrams we teach can be applied to similar languages

Why do we use Environment Diagrams?

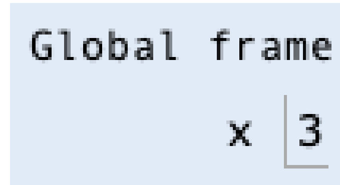
- Environment Diagrams are conceptual
  - understand *why* programs work the way they do
  - confidently predict how a program will behave
- Environment Diagrams are helpful for debugging
  - When you're really stuck,

    diagramming code > staring at lines of code
- Environment Diagrams will be used in future courses
  - CS 61C (Machine Structures)
  - CS 164 (Programming Languages and Compilers)

What do we've seen so far

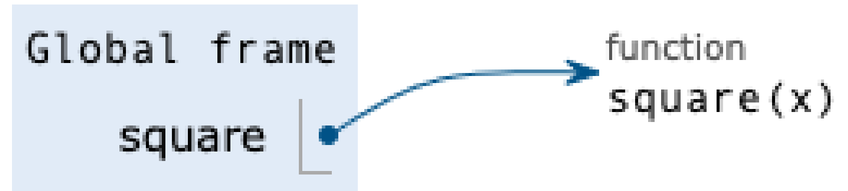
Assignment Statements

```
x = 1
x = x + x + x
```



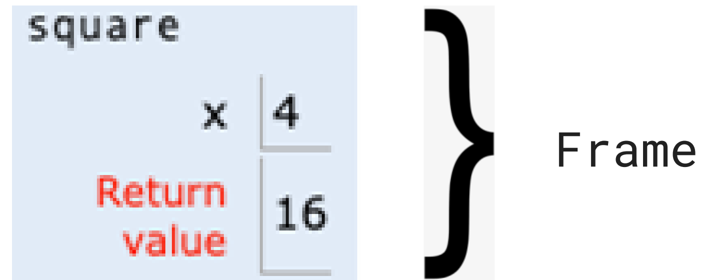
Def Statements

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



Call Expressions

```
square(4)
```



Frame

Terminology: Frames

A **frame** keeps track of variable-to-value bindings.

- Every call expression has a corresponding frame.

Global, a.k.a. the global frame, is the starting frame.

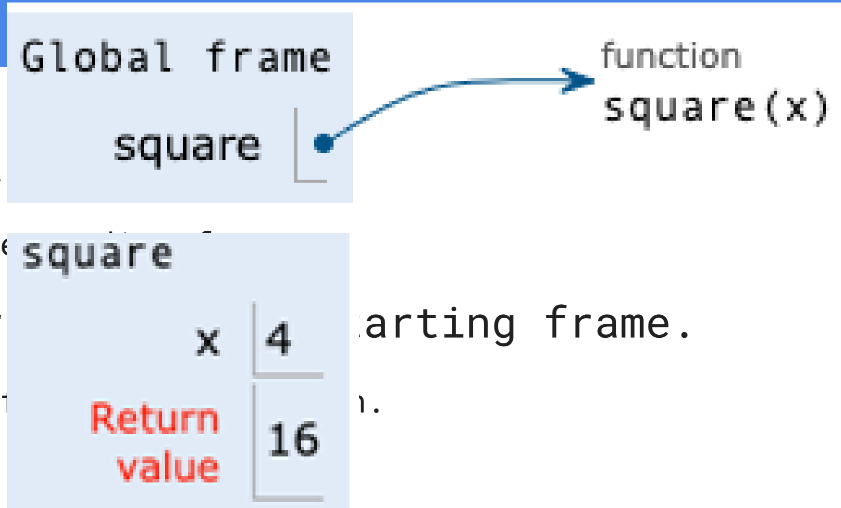
- It doesn't correspond to a specific call expression.

Parent frames

- The parent of a function is the frame in which it was defined.
- If you can't find a variable in the current frame, you check it's parent, and so on. If you can't find the variable, NameError

Demo

Terminology: Frames



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Demo

Check Your Understanding

Draw the environment diagram

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

def sum_of_squares(x, y):
    return square(x) + square(y)

sum_of_squares(3, 4)
```

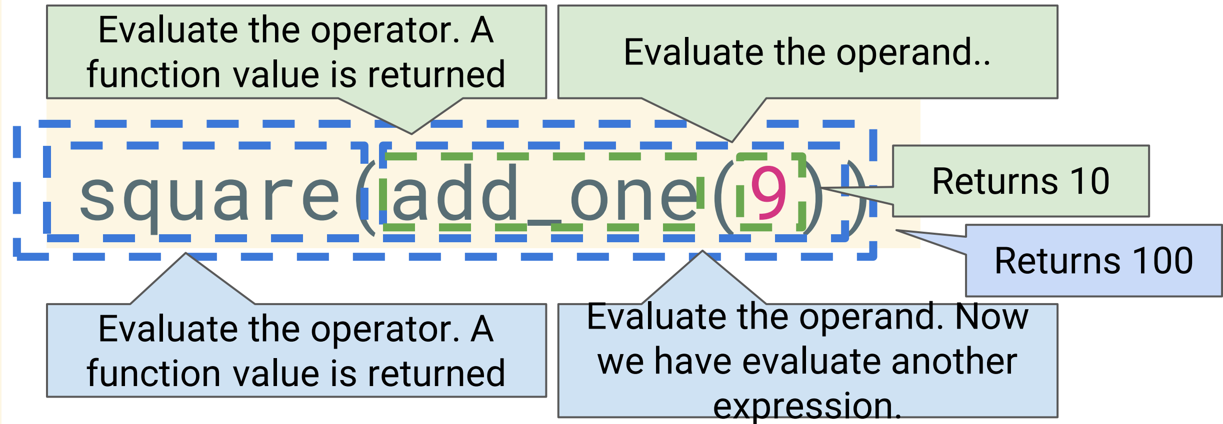
Review: Evaluation Order

Demo

Remember to evaluate the **operator**, then the **operand(s)**, then apply the **operator** onto the **operand(s)**.

```
def add_one(x):
    y = x + 1
    return y

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



What will the environment diagram look like? (**When are frames created?**)

The environment diagram should reflect Python's evaluation.

Variable Lookup

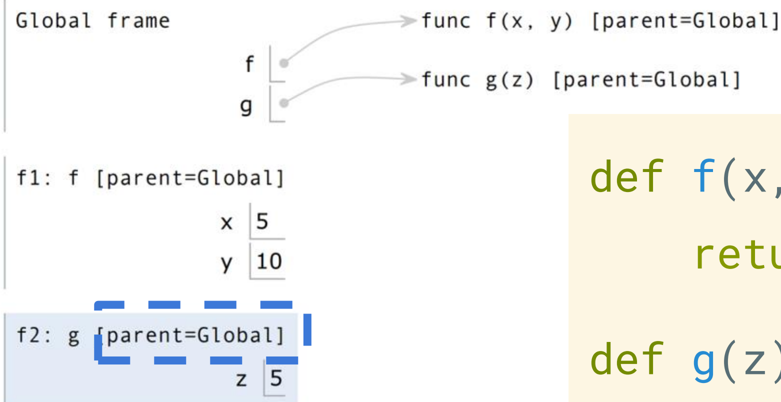
Local Names

Variable Lookup:

- Lookup name in the current frame
- Lookup name in parent frame, its parent frame, etc..
- Stop at the global frame
- If not found, an error is thrown

Where do we look next?

Name “x” is not found




```python
def f(x, y):
    return g(x)

def g(z):
    return z + x

result = f(5, 10)
```

What happens here?

Important: There was no lookup done in f1 since the parent of f2 was Global

Local Names

Variable Lookup:

- Lookup name in the current frame
- Lookup name in parent frame, its parent frame, etc..
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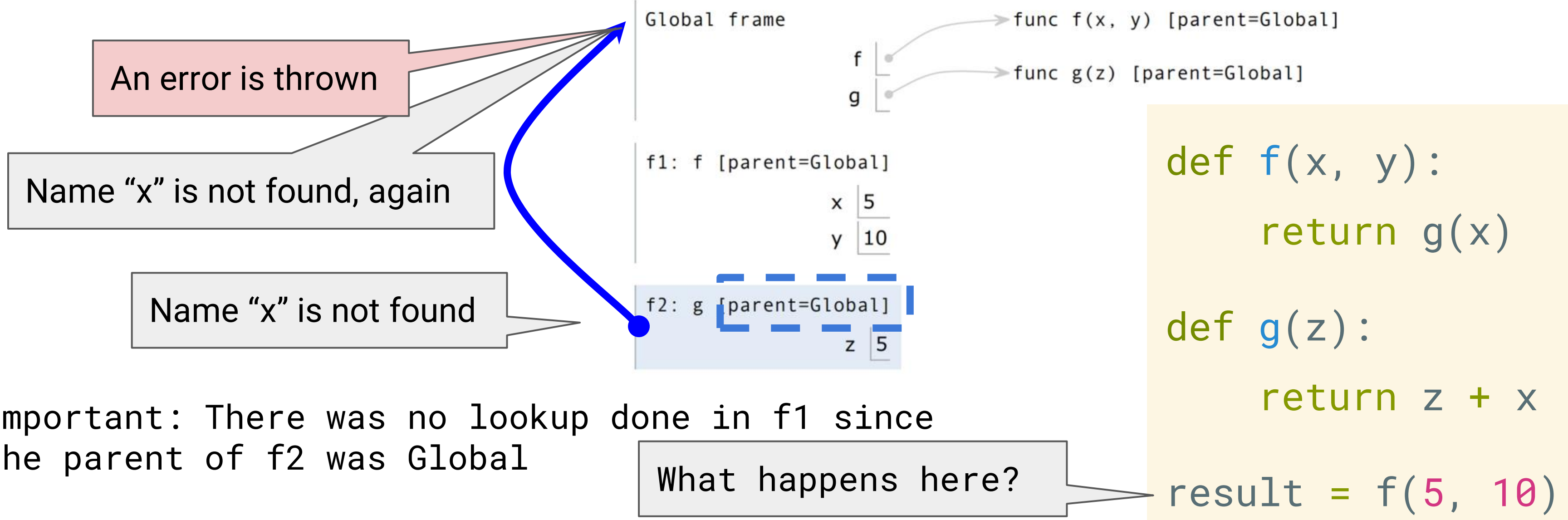


Important: There was no lookup done in f1 since the parent of f2 was Global

Evaluation vs Apply

Demo

```
def a_plus_bc(a, b, c):
    """
    >>> a_plus_bc(2, 3, 4) # 2 + 3 * 4
    14
    """
    bc = b * c
    return a + bc
```

Evaluation vs Apply

Demo

```
def a_plus_bc(a, b, c):
    """
    >>> a_plus_bc(2, 3, 4) # 2 + 3 * 4
    14
    """
```

```
a_plus_bc(square(2), 3, square(square(3)))
```

Apply operator a_plus_bc function to operand 4, 3, 81.

How many frames are created?
In what order?

Apply operator square function to operand 2.

Apply operator square function to operand 9.

Apply operator square function to operand 3.

Break/Q&A

Lambda Expressions

Lambda Expressions

Expressions that evaluate to functions!

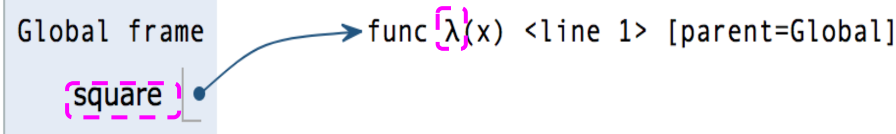
A function with parameter x that returns the value of x * x

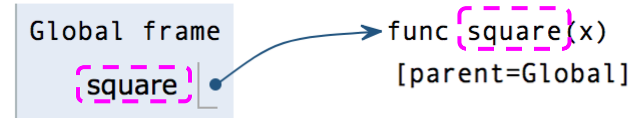
```
>>> square = lambda x: x * x
>>> square
<function <lambda> ... >
>>> square(4)
16
>>> x = square(5)
>>> x
25
```

Lambda Expressions vs def Statements

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

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





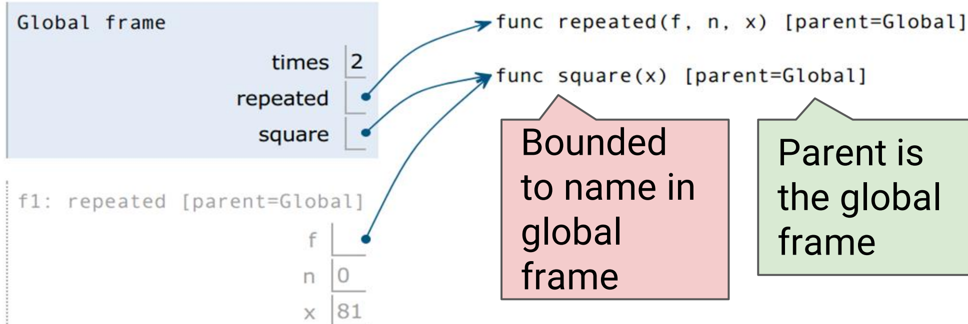
- Both create a function with the same behavior
- The parent frame of each function is the frame in which they were defined
- Both bind the function to the same name
- Only the def statement gives the function an intrinsic name

Environment Diagram

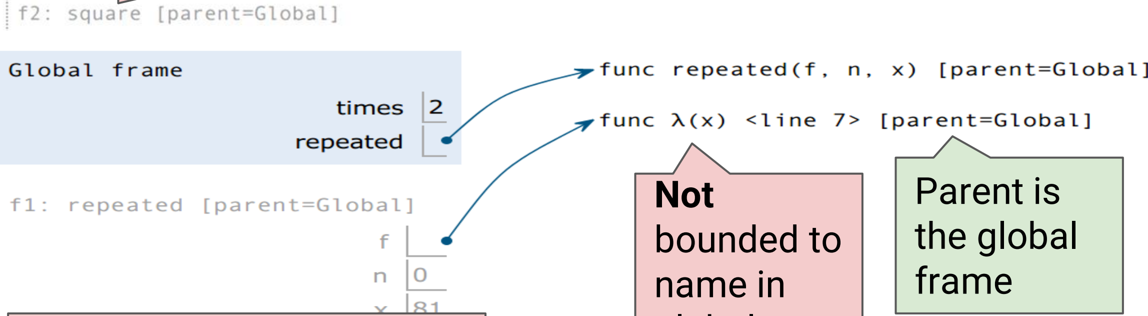
```
times = 2

def repeated(f, n, x):
        while n > 0:
                x = f(x)
                n -= 1
        return x

repeated(lambda x: x*x, times, 3)
```

```
repeated(square, times, 3)
```

Comparisons




```
times = 2
def repeated(f, n, x):
    while n > 0:
        x = f(x)
        n -= 1
    return x
def square(x):
    return x * x
repeated(square, times, 3)
```




```
times = 2
def repeated(f, n, x):
    while n > 0:
        x = f(x)
        n -= 1
    return x
repeated(lambda x: x * x, times, 3)
```

Higher Order Functions

Higher Order Functions

A function that ...

- takes a function as an argument value, and/or
- returns a function as a return value

You just saw this in

the previous example!

```
times = 2

def repeated(f, n, x):
        while n > 0:
                x = f(x)
        n -= 1
        return x
```

```
repeated(lambda x: x*x, times, 3)
```

Locally Defined Functions

```
>>> def make_greeter(name):
...                         return lambda greeting: print(greeting, name)
>>> greeter_function = make_greeter("Tiffany")
>>> greeter_function("Hey what's up, ")
```

Currying

```
>>> make_greeter("Tiffany")("Where's the party at, ")
```

Summary

- **Environment Diagrams** formalize the evaluation procedure for Python
  - Understanding them will help you think deeply about how the code that you are writing actually works
- **Lambda** functions are similar to functions defined with `def`, but are nameless
- A **Higher Order Function** is a function that either takes in functions as an argument (shown earlier) and/or returns a function as a return value (will see soon)