Lecture #3: Environments

- Substitution is not as simple as it might seem.
- For example:

```
def f(x):
    def g(x):
        return x + 10
    return g(5)
f(3)
```

- When we call f(3), we should not substitute 3 for the xs in g!
- And there are other difficulties...

Names

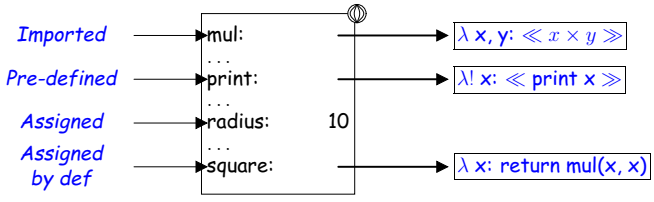
- Evaluating expressions that are literals is easy: the literal's text gives all the information needed.
- But how did I evaluate names like add, mul, or print?
- How do I explain *assignment*? Substitution inadequate.

```
x = 3
print(x)
x = 4
print(x)    # After x = 3, does this x change to 3??!
```

- Deduction: there must be another source of information.
- We'll use the concept of an *environment* to explain it.

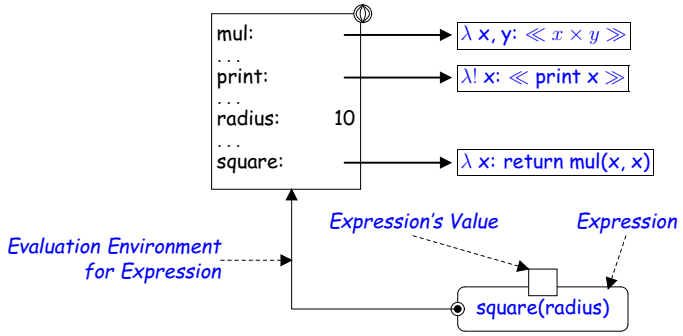
Environments

- An environment is a mapping from names to values.
- We say that a name is *bound to* a value in this environment.
- Every expression is evaluated *in an environment,* which supplies the meanings of any names in it.
- Simplest environment consists of a single *global environment frame*:



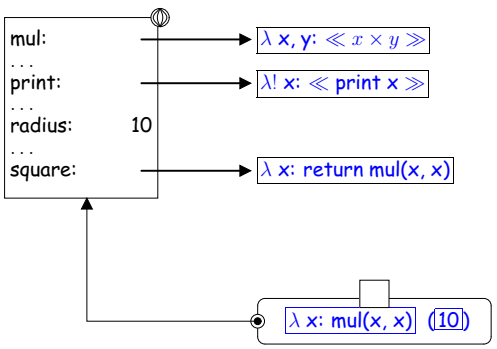
Evaluation of Names

- To evaluate a name (identifier) in an environment, look for what that name "*is bound to*" in that environment.
- For example, in this situation...



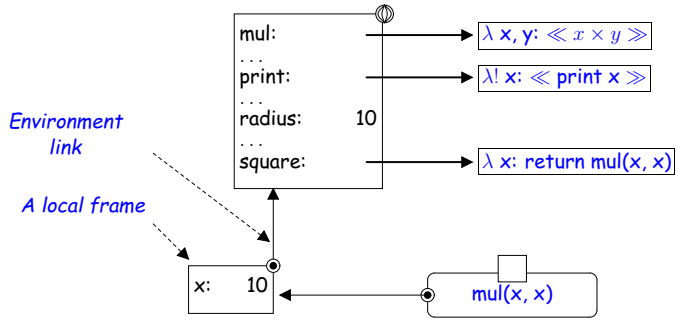
Evaluation of Names (II)

...We find the values for square and radius in the global frame (the big box with the globe on its upper right).

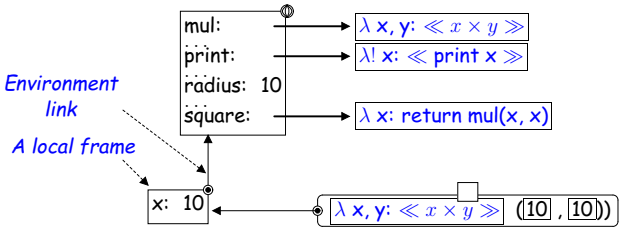


Evaluation of Names: More Complicated Environments

- In general, as we'll see, environments consist of *chains* of frames.
- Here, we find the value of x in the small, "*local frame*"
- We don't find mul, there, so we must follow the "*environment link*" looking for it.



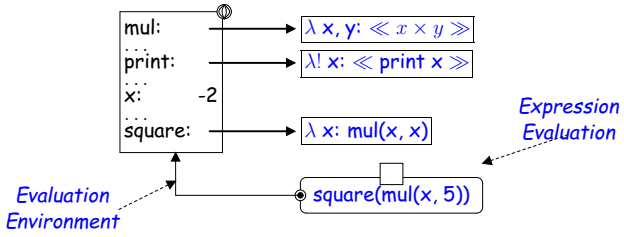
More Complicated Environments (II)



Evaluating User-Defined Function Calls

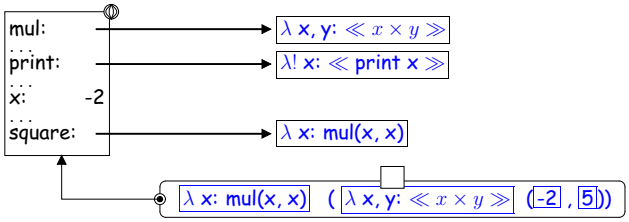
- Consider the expression square(mul(x, x)) in

```
from operator import mul
def square(x):
   return mul(x, x)
x = -2
print(square(mul(x, 5)))
```



Evaluating User-Defined Function Calls (II)

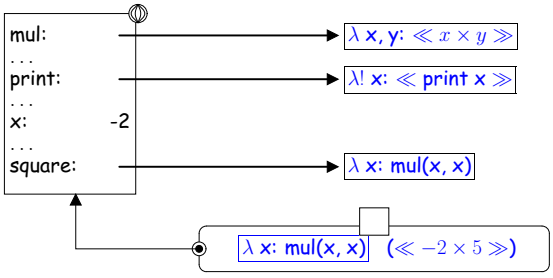
- First evaluate the subexpressions of square(mul(x, x)) in the global environment:



- Evaluating subexpressions x, mul, and square takes values from the expression's environment.

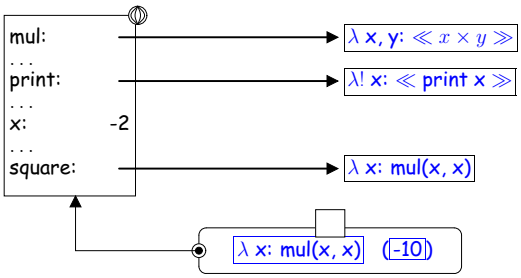
Evaluating User-Defined Functions Calls (III)

- Then call the multiply function. Since this is primitive, let's just use the substitution model:



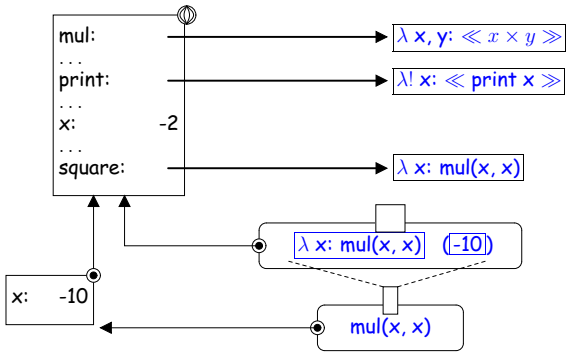
Evaluating User-Defined Functions Calls (IV)

- Execute the primitive operation:



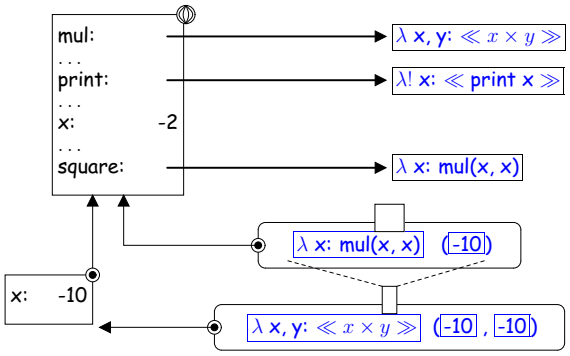
Evaluating User-Defined Functions Calls (V)

- To evaluate the call to the user-defined function (square), start a new evaluation in a new *local environment frame*, attached to the frame where square was defined (the global frame here), and giving x the operand value.



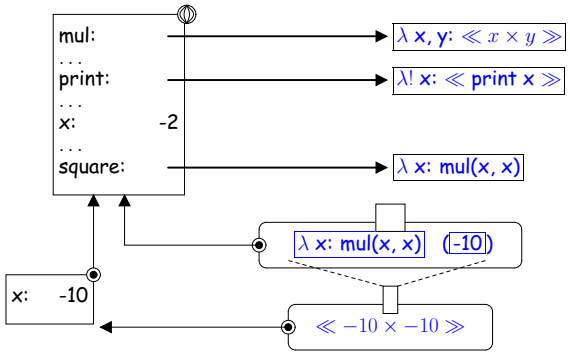
Evaluating User-Defined Functions Calls (VI)

- When we evaluate mul(x, x) in this new environment, we get the same value as before for mul, but the local value for x.



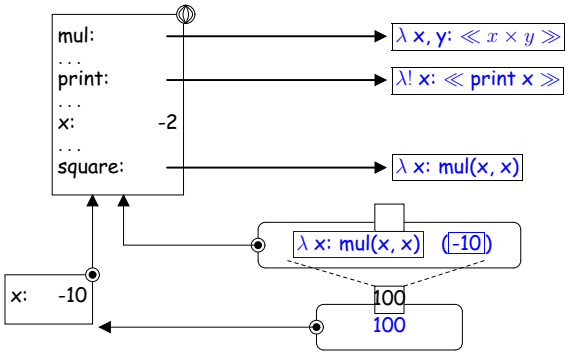
Evaluating User-Defined Functions Calls (VII)

- Evaluate the primitive multiplication as before:



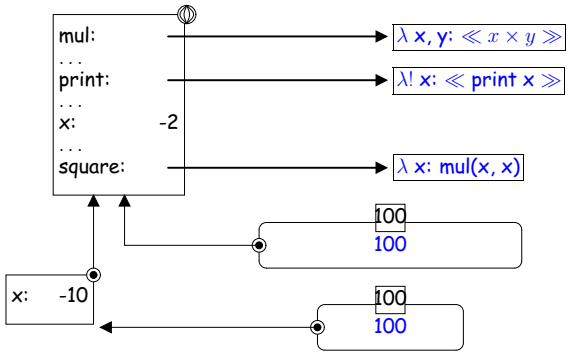
Evaluating User-Defined Functions Calls (VIII)

- And return the finished value...



Evaluating User-Defined Functions Calls (IX)

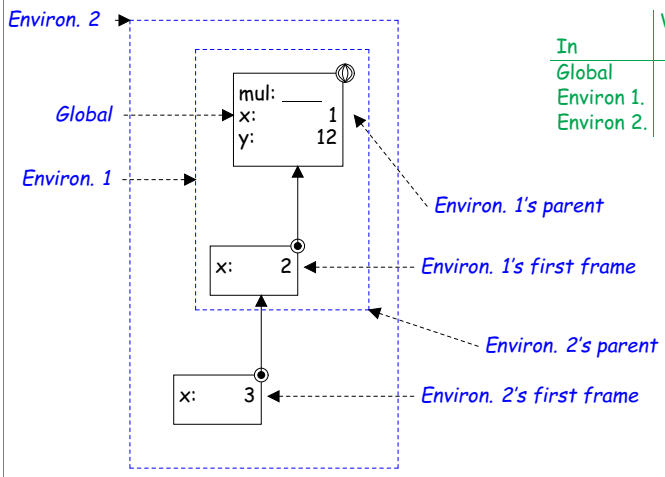
- ...replacing the call to the user-defined function and yielding the final value:



Summary: Environments

- *Environments* map names to values.
- They consist of chains of *environment frames.*
- An environment is either a *global frame* or a first (local) frame chained to a *parent environment* (which is itself either a global frame or ...).
- We say that a name is *bound to* a value in a frame.
- The *value (or meaning) of a name* in an environment is the value it is bound to in the first frame, if there is one, ...
- ...or if not, the meaning of the name in the parent environment

A Sample Environment Chain



In	Value of x	y
Global	1	12
Environ 1.	2	12
Environ 2.	3	12

Environments: Binding and Evaluation

- Every expression and statement is evaluated (executed) in an environment, which determines the meaning of its names.
- Subexpressions (pieces) of an expression are evaluated in the same environment as the expression
- *Assigning* to a variable binds a value to it in (for now) the first frame of the environment in which the assignment is executed.
- *Def statements* bind a name to a function value in the first frame of the environment in which the def statement is executed.
- *Calling* a user-defined function creates a new local environment and binds the operand values in the call to the parameter names in that environment.

Example: Evaluation of a Call: sum_square(3,4)