61A LECTURE 9 – LISTS, DICTIONARIES, OBJECTS, MUTABLE DATA

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July 9, 2013

Announcements

- Hw6 is released, due next Monday
- Hog Contest!
  - Turn in a strategy that will be played against other students' strategies
  - Can work in partnership (optional)
  - Win eternal 61A glory
  - See details up on the course web page!
- Trends project
  - Everything you need to complete the project will be covered by the end of this lecture
  - Recommended you find a partner

Midterm

- Midterm is Thursday, 7pm
  - Info page up: http://inst.eecs.berkeley.edu/~cs61a/su13/exams/midterm1.html
  - Staff cheat sheet is up on the mt1 page
  - Two exam rooms:
    - 2050 VLSB for logins cs61a-aa through cs61a-hz
    - 10 Evans for everyone else
  - Lists are on the midterm.
    - Need to know how to create one, how to select elements, and how to use list comprehensions
    - Mutation and assignment of lists are NOT covered
  - Objects, dictionaries, and mutable data will NOT be covered on midterm 1

Sequence arithmetic

Some Python sequences support arithmetic operations

```
>>> city = 'Berkeley'
>>> city + ', CA'
'Berkeley, CA'
```

Concatenate

```
>>> "Don't repeat yourself! " * 2
"Don't repeat yourself! Don’t repeat yourself! "
```

Repeat twice

```
>>> (1, 2, 3) * 3
(1, 2, 3, 1, 2, 3, 1, 2, 3)

>>> (1, 2, 3) + (4, 5, 6, 7)
(1, 2, 3, 4, 5, 6, 7)
```

Sequences as conventional interfaces

We can apply a function to every element in a sequence

This is called *mapping* the function over the sequence

```
>>> fibs = tuple(map(fib, range(8)))
>>> fibs
(0, 1, 1, 2, 3, 5, 8, 13)
```

We can extract elements that satisfy a given condition

```
>>> even_fibs = tuple(filter(is_even, fibs))
>>> even_fibs
(0, 2, 8)
```

We can compute the sum of all elements

```
>>> sum(even_fibs)
10
```

Both **`map`** and **`filter`** produce an iterable, not a sequence

Iterables

Iterables provide access to some elements in order but do not provide length or element selection

Python-specific construct; more general than a sequence

Many built-in functions take iterables as argument

`tuple`	Construct a tuple containing the elements
`map`	Construct a map that results from applying the given function to each element
`filter`	Construct a filter with elements that satisfy the given condition
`sum`	Return the sum of the elements
`min`	Return the minimum of the elements
`max`	Return the maximum of the elements

For statements also operate on iterable values.

Sequences and Iterables

- Iterables work in many built-in functions
  - `for element in iterable_object:` ...
- However, iterables do not necessarily have element selection or length capabilities
  - `x = map(lambda num: num * 3, (5, 6, 7, 8))`
  - `len(x)` is an error
  - `x[2]` is an error
- Sequences are iterables. Thus, also work in many built-in functions
  - `for element in (1, 2, 3, 4, 5): ...`
  - `x = tuple(map(lambda num: num * 3, (5, 6, 7, 8)))`
  - `len(x)`
  - `x[2]`

Generator expressions

One large expression that combines mapping and filtering to produce an iterable

`(<map exp> for <name> in <iter exp> if <filter exp>)`

- Evaluates to an iterable.
- <iter exp> is evaluated when the generator expression is evaluated.
- Remaining expressions are evaluated when elements are accessed.

No-filter version: `(<map exp> for <name> in <iter exp>)`

Precise evaluation rule introduced in Chapter 4.

Reducing a Sequence

Reduce is a higher-order generalization of max, min, and sum.

```
>>> from operator import mul
>>> from functools import reduce
>>> reduce(mul, (1, 2, 3, 4, 5), 1)
120
```

Optional initial value as third argument

First argument: A two-argument function

Second argument: an iterable object

Like accumulate from Homework 2, but with iterables

```
def accumulate(combiner, start, n, term):
    return reduce(combiner,
                  map(term, range(1, n + 1)),
                  start)
```

More Functions on Iterables (Bonus)

Create an iterable of fixed-length sequences

```
>>> a, b = (1, 2, 3), (4, 5, 6, 7)
>>> for x, y in zip(a, b):
...     print(x + y)
...
5
7
9
```

Produces tuples with one element from each argument, up to length of smallest argument

The **`itertools`** module contains many useful functions for working with iterables

```
>>> from itertools import product, combinations
>>> tuple(product(a, b[:2]))
((1, 4), (1, 5), (2, 4), (2, 5), (3, 4), (3, 5))
>>> tuple(combinations(a, 2))
((1, 2), (1, 3), (2, 3))
```

Lists

```
>>> a = [3, 1, 2]
>>> a
[3, 1, 2]
>>> len(a)
3
>>> a[1]
1
>>> c, d = a, a[:]
>>> a, c, d
([3, 1, 2], [3, 1, 2], [3, 1, 2])
>>> c[0] = 4
>>> a, c, d
([4, 1, 2], [4, 1, 2], [3, 1, 2])
>>> d[0] = 5
>>> a, c, d
([4, 1, 2], [4, 1, 2], [5, 1, 2])
>>> a[1:2] = [7, 8, 9]
>>> a, c, d
([4, 7, 8, 9, 2], [4, 7, 8, 9, 2], [5, 1, 2])
```

Create a list using square brackets

Lists are sequences

Bind another name to a list or a slice of a list

Modify contents of a list

`wut()`?

Objects

An *object* is a representation of information

All data in Python are objects

But an object is not just data; it also bundles behavior together with that data

An object's *type* determines what data it stores and what behavior it provides

```
>>> type(4)
<class 'int'>

>>> type([4])
<class 'list'>
```

Object Attributes

All objects have attributes

We use dot notation to access an attribute

```
>>> (4).real, (4).imag
(4, 0)
```

An attribute may be a *method*, which is a type of function, so it may be called

```
>>> [1, 2, 1, 4].count(1)
2
```

Notice that we did not have to pass in the list as an argument; the method already knows the object on which it is operating

Creating and Distinguishing Objects

Calling the constructor of a built-in type creates a new object of that type

Objects can be distinct even if they hold the same data

The is and not is operators check if two objects are the same

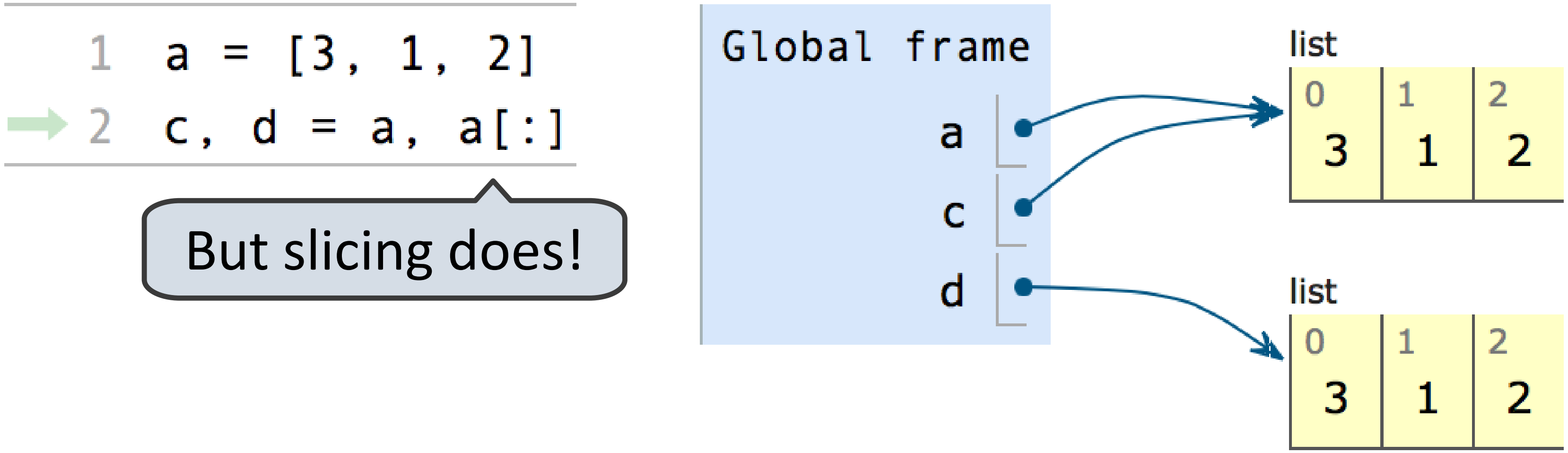
```
>>> [1, 2, 1, 4] is [1, 2, 1, 4]
False
```

Compare to ==, which checks for equality, not sameness

```
>>> [1, 2, 1, 4] == [1, 2, 1, 4]
True
```

Objects and Assignment

Assignment does not create a new object



```
a = [3, 1, 2]
c, d = a, a[:]
```

But slicing does!

In our environment diagrams, assignment copies the arrow

The “arrow” is called a *pointer* or *reference*

Multiple names can *point to* or *reference* the same object

Break

Immutable Types

An object may be *immutable*, which means that its data cannot be changed

Most of the types we have seen so far are immutable

- ints, floats, booleans, tuples, ranges, strings

For an immutable type, it doesn't matter whether or not two equal objects are the same

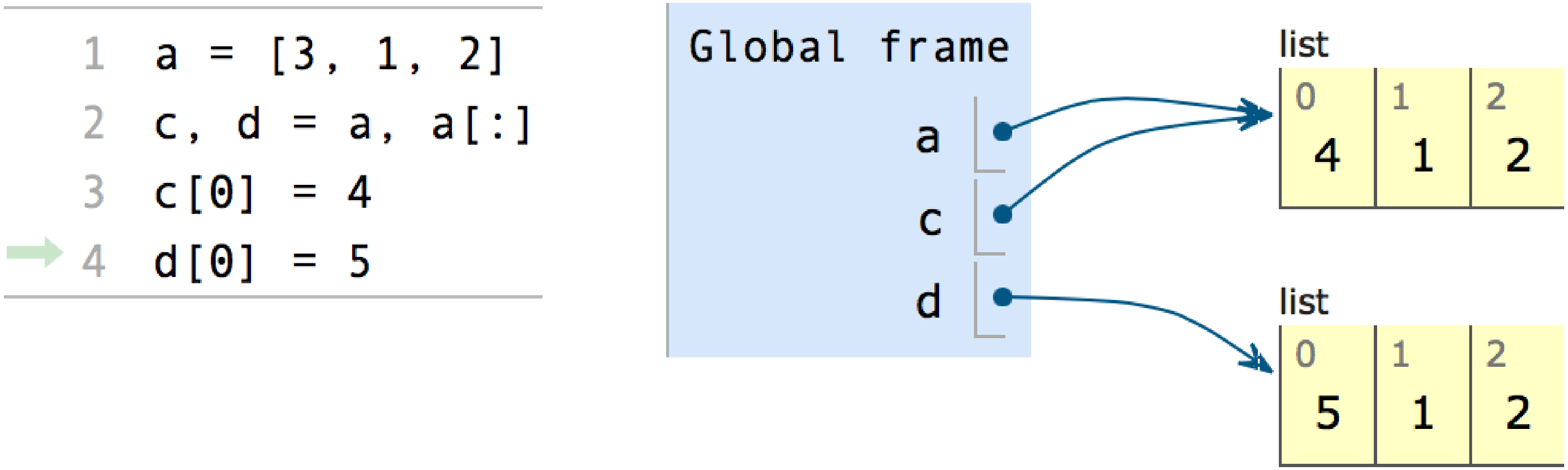
Neither can change, so one is as good as the other

```
>>> e, f = 300, 300
>>> e is f
True
>>> e = 300
>>> f = 300
>>> e is f
False
```

Mutable Types

Mutable objects, on the other hand, can change, and any change affects all references to that object

So we need to be careful with mutation



```
a = [3, 1, 2]
c, d = a, a[:]
c[0] = 4
d[0] = 5
```

List Methods

Lists have many useful methods

- **`append`**: add an element to the end of a list
- **`extend`**: add all elements from an iterable to the end of the list
- **`count`**: count the number of occurrences of a value
- **`pop`**: remove an element from the end of a list
- **`sort`**: sort the elements of a list

These methods (except **`count`**) mutate the list

Compare to **`sorted(x)`**, which returns a new list

Call **`dir(list)`** to see a full list of attributes

List Comprehensions

We can construct a list using a *list comprehension*, which is similar to a generator expression

`[<map exp> for <name> in <iter exp> if <filter exp>]`

- Evaluates to a list.
- <iter exp> is evaluated once.
- <name> is bound to an element, and <filter exp> is evaluated. If it evaluates to a true value, then <map exp> is evaluated, and its value is added to the resulting list.

```
>>> [3 / x for x in range(4) if x != 0]
[3.0, 1.5, 1.0]
```

Dictionaries

Sequences map integers to values

```
>>> a = [3, 1, 2]
```

```
-3 -> 3     0 -> 3
-2 -> 1     1 -> 1
-1 -> 2     2 -> 2
```

What if we wanted arbitrary values in the domain?

We use a dictionary

```
>>> colors = {'eric':    'blue',
            'steven':     'red',
            'mark':     'green',
            'albert':    'gold'}
>>> colors['eric']
'blue'
```

```
'eric'   -> 'blue'
'steven' -> 'red'
'mark'   -> 'green'
'albert' -> 'gold'
```

Dictionary Features

Dictionaries are not sequences, but they do have a length and are iterable

- Iterating provides each of the keys in some arbitrary order

```
>>> for person in colors:
...     print colors[person]
...
### prints colors in unspecified order
```

Dictionaries are mutable

```
>>> colors['eric'] = 'fuchsia'
```

There are dictionary comprehensions, which are similar to list comprehensions

```
>>> {p: colors[p] + 'ish' for p in colors}
{'steven': 'redish', 'mark': 'greenish',
'albert': 'goldish', 'eric': 'blueish'}
```

Limitations on Dictionaries

Dictionaries are unordered collections of key-value pairs.

Dictionary keys do have two restrictions:

- A key of a dictionary cannot be an object of a mutable built-in type.
- Two keys cannot be equal. There can be at most one value for a given key.

This first restriction is tied to Python's underlying implementation of dictionaries.

The second restriction is an intentional consequence of the dictionary abstraction.

A Function with Evolving Behavior

Let's model a bank account that has a balance of $100

Return value: remaining balance

```
>>> withdraw(25)
75
```

Argument: amount to withdraw

Different return value!

```
>>> withdraw(25)
50
```

Second withdrawal of the same amount

```
>>> withdraw(60)
'Insufficient funds'
```

Where's this balance stored?

```
>>> withdraw(15)
35
```

```
>>> withdraw = make_withdraw(100)
```

Within the function!

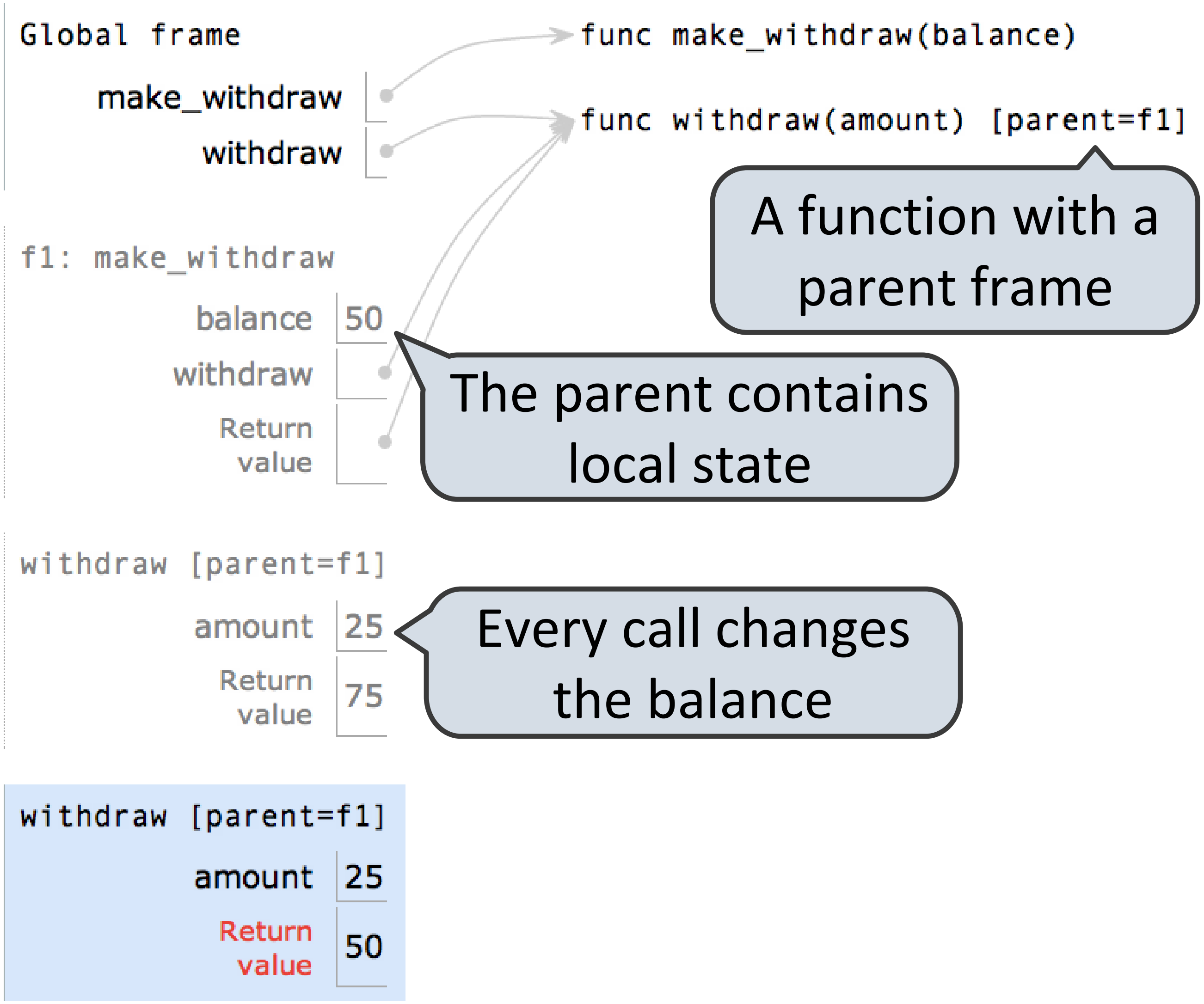
Persistent Local State

```
#initialize a
withdraw...

...

>>> withdraw(25)
75

>>> withdraw(25)
50
```



Global frame

make_withdraw

withdraw

func make_withdraw(balance)

func withdraw(amount) [parent=f1]

f1: make_withdraw

balance 50

withdraw

Return value

withdraw [parent=f1]

amount 25

Return value 75

withdraw [parent=f1]

amount 25

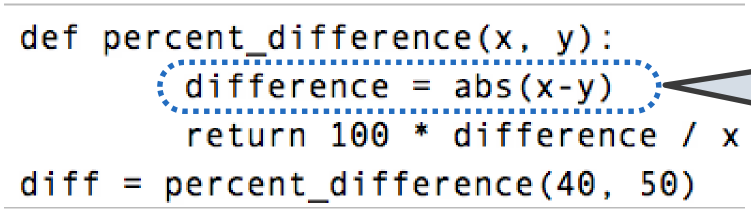
Return value 50

A function with a parent frame

The parent contains local state

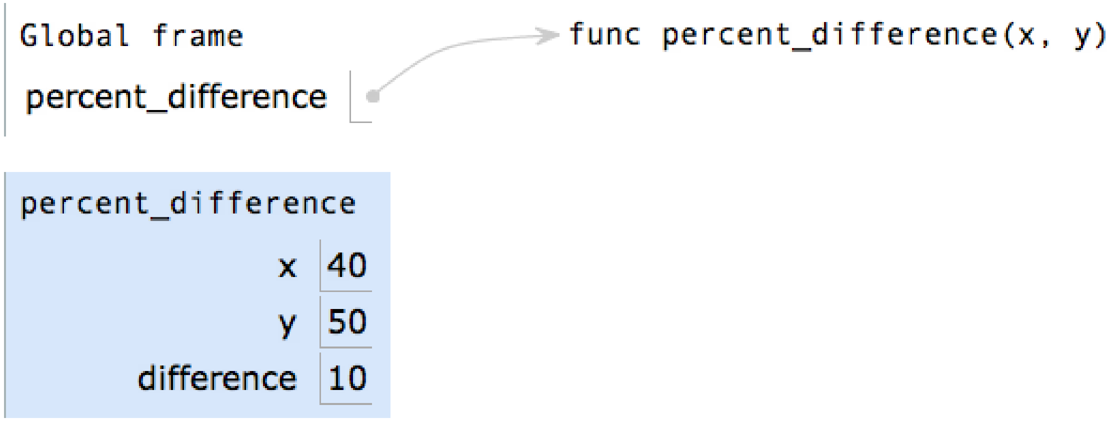
Every call changes the balance

Reminder: Local Assignment



```
def percent_difference(x, y):
    difference = abs(x-y)
    return 100 * difference / x
diff = percent_difference(40, 50)
```

Assignment binds name(s) to value(s) in the first frame of the current environment



Execution rule for assignment statements:

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

Non-Local Assignment

```
def make_withdraw(balance):
    """Return a withdraw function with a starting balance."""
    def withdraw(amount):
        nonlocal balance
        if amount > balance:
            return 'Insufficient funds'
        balance = balance - amount
        return balance
    return withdraw
```

Declare the name "balance" nonlocal

Re-bind balance where it was bound previously

The Effect of Nonlocal Statements

`nonlocal <name>, <name 2>, ...`

Effect: Future assignments to that name change its pre-existing binding in the **first non-local frame** of the current environment in which that name is bound.

Python Docs: an "enclosing scope"

From the Python 3 language reference:

Names listed in a [nonlocal](#) statement must refer to pre-existing bindings in an enclosing scope. Names listed in a nonlocal [statement](#) must not collide with pre-existing bindings in the local scope.

http://docs.python.org/release/3.1.3/reference/simple_stmts.html#the-nonlocal-statement

http://www.python.org/dev/peps/pep-3104/

Effects of Assignment Statements

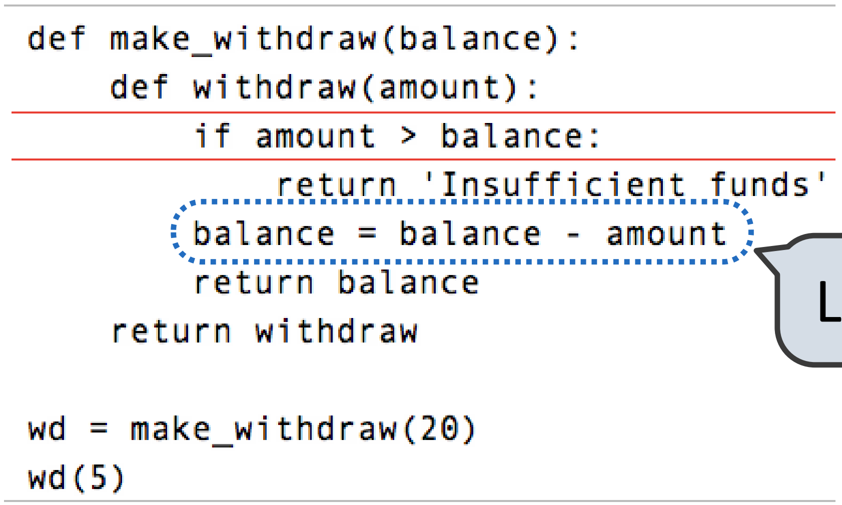
Status	Effect
• No nonlocal statement • "x" is not bound locally	Create a new binding from name "x" to object 2 in the first frame of the current environment.
• No nonlocal statement • "x" is bound locally	Re-bind name "x" to object 2 in the first frame of the current env.
• nonlocal x • "x" is bound in a non-local frame	Re-bind "x" to 2 in the first non-local frame of the current environment in which it is bound.
• nonlocal x • "x" is not bound in a non-local frame	SyntaxError: no binding for nonlocal 'x' found
• nonlocal x • "x" is bound in a non-local frame • "x" also bound locally	SyntaxError: name 'x' is parameter and nonlocal

```
x = 2
```

Python Particulars

Python pre-computes which frame contains each name before executing the body of a function.

Therefore, within the body of a function, all instances of a name must refer to the same frame.



```
def make_withdraw(balance):
    def withdraw(amount):
        if amount > balance:
            return 'Insufficient funds'
        balance = balance - amount
        return balance
    return withdraw

wd = make_withdraw(20)
wd(5)
```

Local assignment

```
UnboundLocalError: local variable 'balance' referenced before assignment
```