61A Lecture 13

Wednesday, September 26

A Function with Behavior That Varies Over Time

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

Return value: remaining balance

Argument: amount to withdraw

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

Different return value!

Second withdrawal of the same amount

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

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

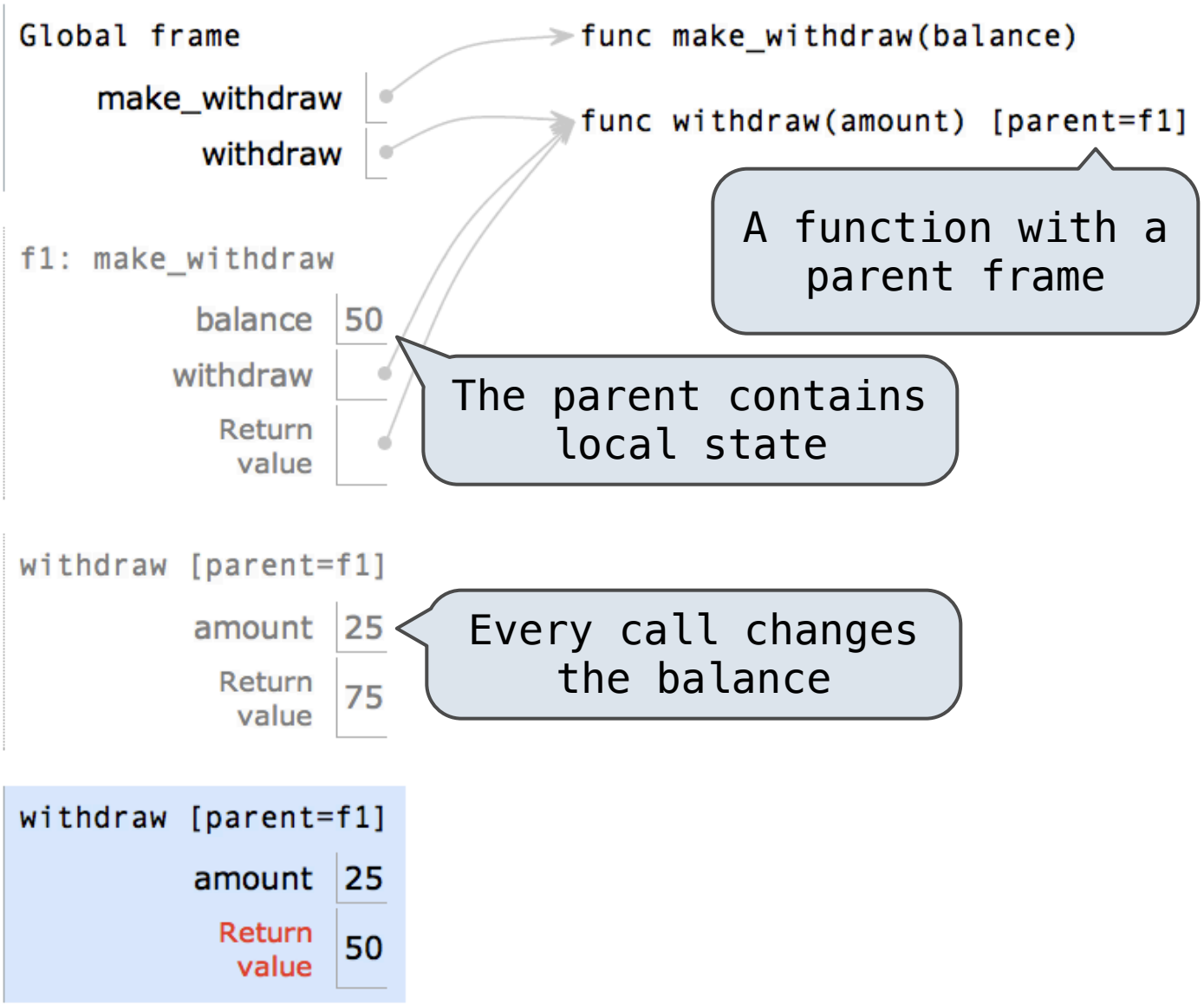
```
>>> withdraw(15)
35
```

Where's this balance stored?

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

Within the function!

Persistent Local State

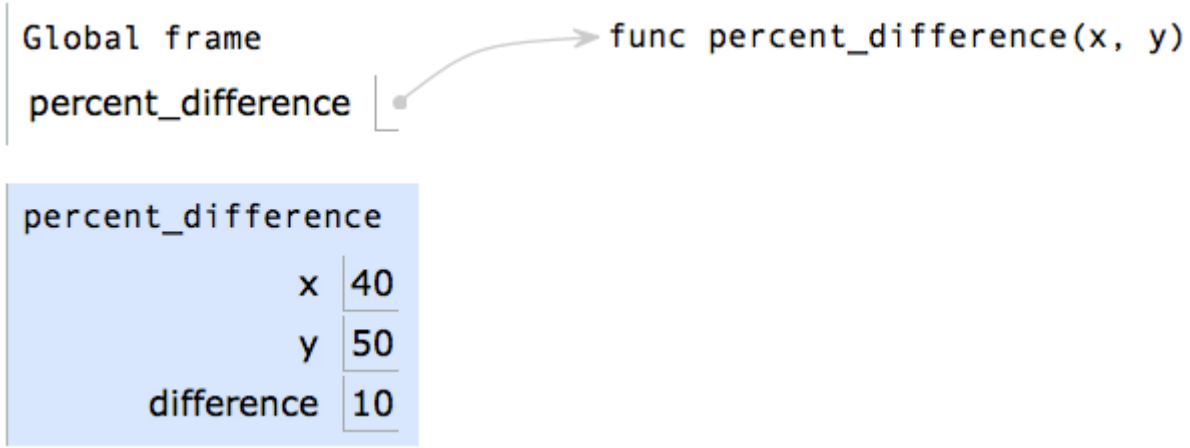


http://goo.gl/StRZP

Reminder: Local Assignment

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

Assignment binds names to values in the current local frame



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.

Example: http://goo.gl/wcF71

Non-Local Assignment & Persistent Local State

```
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

Demo

The Effect of Nonlocal Statements

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

Effect: Future references to that name refer to 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/

The Many Meanings of Assignment Statements

`x = 2`

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 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

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.

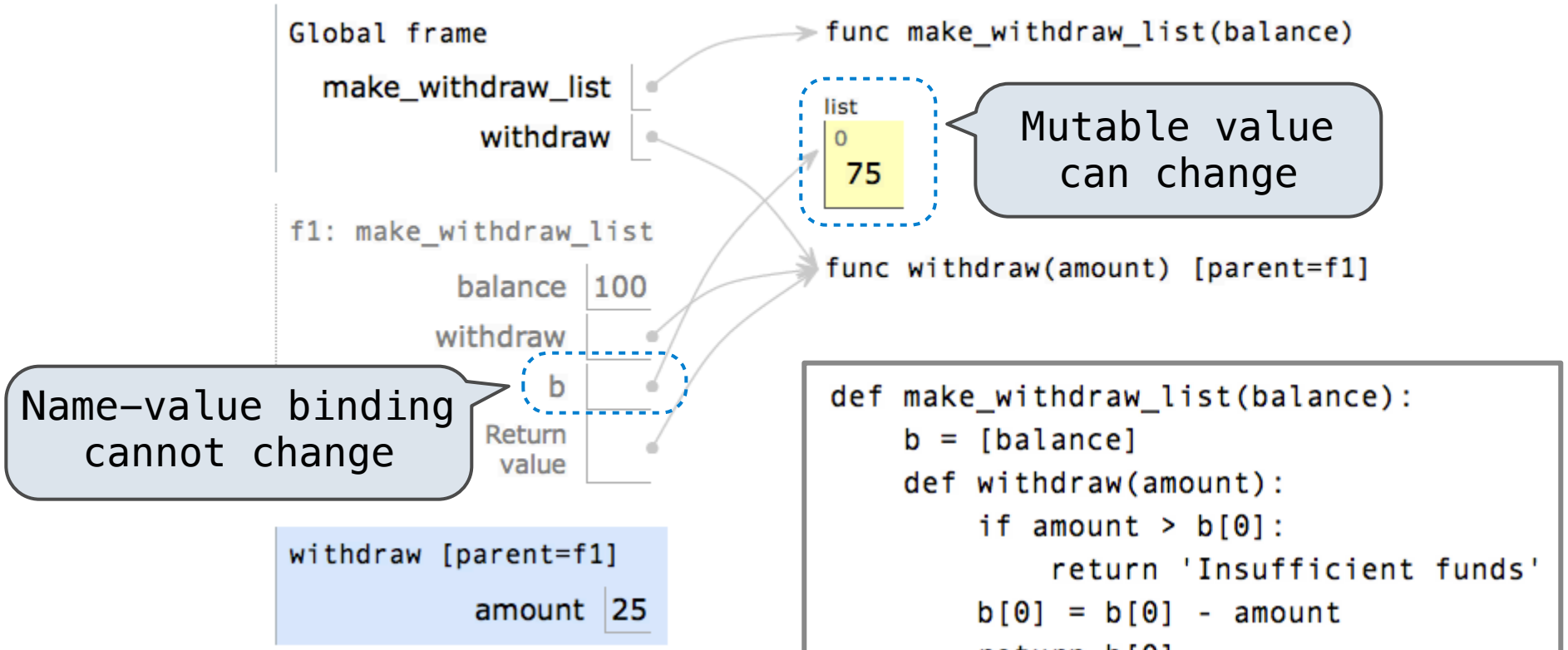
```
def make_withdraw(balance):
    def withdraw(amount):
        if amount > balance:
            return 'Insufficient funds'
        balance = balance - amount
        return balance
    return withdraw

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

Local assignment

UnboundLocalError: local variable 'balance' referenced before assignment

Mutable Values & Persistent Local State

Mutable values can be changed *without* a nonlocal statement.




```
def make_withdraw_list(balance):
    b = [balance]
    def withdraw(amount):
        if amount > b[0]:
            return 'Insufficient funds'
        b[0] = b[0] - amount
        return b[0]
    return withdraw

withdraw = make_withdraw_list(100)
withdraw(25)
```

Creating Two Different Withdraw Functions

Demo

The Benefit of Non-Local Assignment

- Ability to **maintain some state** that is **local** to a function, but **evolves** over successive calls to that function.
- The binding for balance in the first non-local frame of the environment associated with an instance of withdraw is **inaccessible to the rest of the program.**
- An abstraction of a bank account that **manages its own internal state.**

Multiple References to a Single Withdraw Function

Demo

Sameness and Change

- As long as we **never modify** objects, we can regard a compound object to be precisely the **totality of its pieces.**
- A **rational number** is just its numerator and denominator.
- This view is no longer valid **in the presence of change.**
- Now, a compound data **object has an "identity"** that is something more than the pieces of which it is composed.
- A bank account is **still "the same" bank account even if we change the balance** by making a withdrawal.
- Conversely, we could have two bank accounts that happen to have the **same balance, but are different objects.**

Referential Transparency, Lost

- Expressions are **referentially transparent** if substituting an expression with its value does not change the meaning of a program.

```
mul(add(2, mul(4, 6)), add(3, 5))

mul(add(2,    24    ), add(3, 5))

mul(       26         , add(3, 5))
```

- Re-binding operations violate the condition of referential transparency because they let us define functions that do more than just return a value; **we can change the environment**, causing values to mutate.

Demo