Mutable Functions

Functions with behavior that changes over time

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

```
>>> square(5)
25
>>> square(5)
25
>>> square(5)
25
```

Returns the same value when called with the same input

```
def f(x):
    ...
```

```
>>> f(5)
25
>>> f(5)
26
>>> f(5)
27
```

Return value is different when called with the same input

Example - Withdraw

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

```
>>> withdraw(25)
75
>>> withdraw(25)
50
>>> withdraw(60)
'Insufficient funds'
>>> withdraw(15)
35
>>> withdraw = make_withdraw(100)
```

Return value: remaining balance

Argument: amount to withdraw

Different return value!

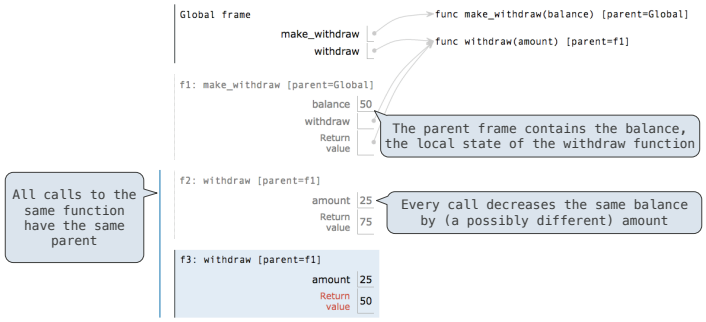
Second withdrawal of the same amount

Where's this balance stored?

Within the parent frame of the function!

A function has a body and a parent environment

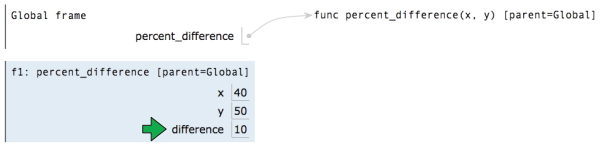
Persistent Local State Using Environments



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 to the resulting values in the **current frame**

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 at the top of the body of the function in which it is re-assigned

Re-bind balance in the first non-local frame in which it was bound previously

(Demo)

Non-Local Assignment

The Effect of Nonlocal Statements

nonlocal <name>, <name>, ...

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.

Current frame

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 environment
•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 "x" 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.

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

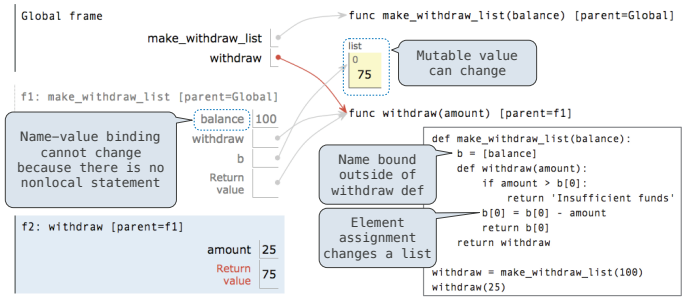
```
def make_withdraw(balance):
    def withdraw(amount):
        if amount > balance:
            return 'Insufficient funds'
        balance = balance - amount
        return balance
    return withdraw

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.



goo.gl/y4TyFZ

Multiple Mutable Functions

(Demo)

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))
```

- Mutation operations violate the condition of referential transparency because they do more than just return a value; **they change the environment.**

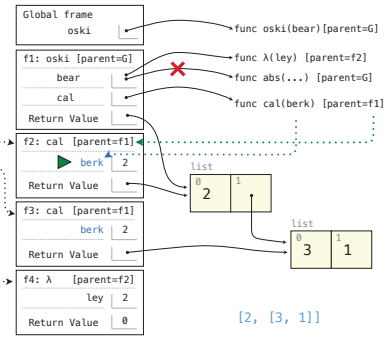
Referential Transperency in Environment Diagrams

```
def f(x):
    x = 4
    def g(y):
        def h(z):
            nonlocal x
            x = x + 1
            return x + y + z
        return h
    return g
```

```
a = f(1)
b = a(2)
total = b(3) + b(4)
```

Go Bears!

```
def oski(bear):
    def cal(berk):
        nonlocal bear
        if bear(berk) == 0:
            return [berk+1, berk-1]
        bear = lambda ley: berk-ley
        return [berk, cal(berk)]
    return cal(2)
oski(abs)
```



Summary

- Nonlocal allows for functions whose behavior changes over time
- When declaring a variable nonlocal, we move part of the function's local state to its parent
- There are various rules for which variables may be declared nonlocal
- Nonlocal gives us a new type of assignment, where we change the binding in a parent instead
- Next time, we'll see more examples of functions which change state outside their local frame!