Containers
Announcements
Pairs

(Demo)
Pairs Implemented as Functions

```python
def pair(x, y):
    def dispatch(m):
        if m == 'first':
            return x
        elif m == 'second':
            return y
    return dispatch

>>> p = pair(3, pair(4, 5))
>>> p('first')
3
>>> p('second')('first')
4
>>> p('second')('second')
5
```

Constructor is a higher-order function

This function represents the pair \((x, y)\)

(Demo)
Linked Lists (Sneak Preview)

- An empty list is called "nil" and represented as None
- A non-empty list is represented as a pair
  - The first element of the pair is the first element of the list
  - The second element of the pair is the rest of the list

```
nil = None
def list_len(s):
    if s == nil:
        return 0
    else:
        return 1 + list_len(s('second'))
```

(Demo)
Mutable Functions
A Function with Behavior That Varies Over Time

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

>>> withdraw = make_withdraw(100)

Return value: remaining balance

>>> withdraw(25)
75

Argument: amount to withdraw

>>> withdraw(25)
50

Different return value!

>>> withdraw(60)
'Insufficient funds'

Second withdrawal of the same amount

>>> withdraw(15)
35

Where's this balance stored?

Within the parent frame of the function!
Persistent Local State Using Environments

All calls to the same function have the same parent.

The parent frame contains the balance, the local state of the withdraw function.

Every call decreases the same balance by (a possibly different) amount.
Reminder: Local Assignment

**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

```python
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
```

(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.

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

<table>
<thead>
<tr>
<th>Status</th>
<th>Effect</th>
</tr>
</thead>
</table>
| • 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.

```python
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)
```

*UnboundLocalError: local variable 'balance' referenced before assignment*
Mutable Data
Functions with Shared Local State

def box(contents):
    def get():
        return contents
    def put(value):
        nonlocal contents
        contents = value
        return get, put
    get, put = box('Hello')
before = get()
put('Goodbye')
after = get()