Announcements

- Maps project out!
  - Remember to test locally!
  - `python3 ok -u … # to unlock tests`
  - `python3 ok -i … # open interactive Python when tests fail.`
  - Use `print("DEBUG: ", …)` or `print(f"DEBUG: {…}")`
    - These **will not cause the** autograder to **fail.**
- Today:
  - Wrap up 1 mutable data example, then ADTs

Computational Structures in Data Science

Mutable Functions

Learning Objectives

- Remember: Each function gets its own new frame
- Inner functions can access data in the parent environment
- Use an inner function along with a mutable data type to capture changes

Making Functions that Capture and change state

- We want to make a function, which returns a function that can change the state.
- Python Tutor Link

```
def make_counter():
    counter = [0]
    def count_up():
            counter[0] += 1
            return counter
    return count_up

c = make_counter()
print(c)
c()
c()
c()
```


Functions with Changing State

- Goal: Use a function to repeatedly withdraw from a bank account that starts with $100.
- Build our account: `withdraw = make_withdraw_account(100)`
- First call to the function:

```
withdraw(25)        # 75
```

- Second call to the function:

```
withdraw(25)        # 50
```

- Third call to the function:

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

How Do We Implement Bank Accounts?

- A mutable value in the parent frame can maintain the local state for a function.
- View in PythonTutor

```
def make_withdraw_account(initial):
    balance = [initial]

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

Implementing Bank Accounts

- A mutable value in the parent frame can maintain the local state for a function.

```
def make_withdraw_account(initial):
    balance = [initial]

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

[View in PythonTutor]

Computational Structures in Data Science

Abstract Data Types

Berkeley
UNIVERSITY OF CALIFORNIA

Abstract Data Type

- Uses pure functions to encapsulate some logic as part of a program.
- We rely of built-in types (int, str, list, etc) to build ADTs
- This is a contrast to object-oriented programming
  - Which is coming soon!

Creating Abstractions

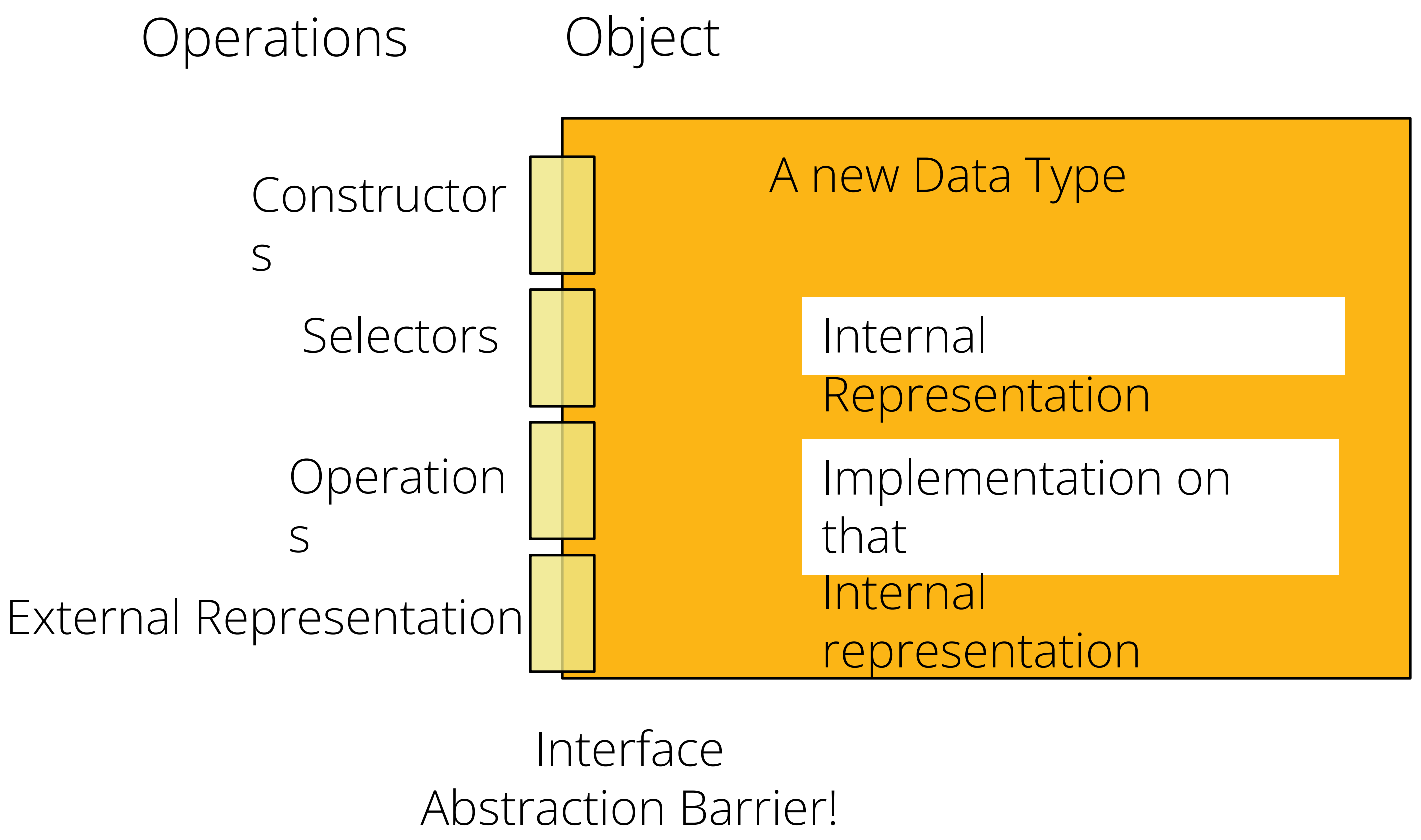
- Compound values combine other values together
  - date: a year, a month, and a day
  - geographic position: latitude and longitude
  - a game board

- Data abstraction lets us manipulate compound values as units
- Isolate two parts of any program that uses data:
  - How data are represented (as parts)
  - How data are manipulated (as units)
- **Data abstraction**: A methodology by which functions enforce an abstraction barrier between *representation* and *use*

Why Abstract Data Types?

- How do you represent the *idea* of a game board, a "course", a person, a student, anything?
  - Programming languages allow you to do just about anything!
- “Self-Documenting”
  - contact_name(contact)
    - vs contact[0]
  - “0” may seem clear now, but what about in a week? 3 months?
- Change your implementation
  - Maybe today it’s just a Python List
  - Tomorrow: It could be a file on your computer; a database in web

Abstract Data Type



C.O.R.E concepts

Abstract Data Type

Compute	Perform useful computations treating objects abstractly as whole values and operating on them.
Operations	Provide operations on the abstract components that allow ease of use – independent of concrete representation.
Representation	Constructors and selectors that provide an abstract interface to a concrete representation
Evaluation	Execution on a computing machine

Abstraction Barrier

Reminder: Lists

- Lists
  - Constructors:
    - list(…)
    - [<exps>,…]
    - [<exp> for <var> in <list> [if <exp>]]
  - Selectors: <list> [<index or slice>]
  - Operations: in, not in, +, *, len, min, max
    - Mutable ones too (but not yet
- Tuples
  - A lot like lists, but you cannot edit them. We'll revisit on Monday.

A Small ADT

```
def point(x, y): # constructor
     return [x, y]

x = lambda point: point[0] # selector
y = lambda point: point[1]

def distance(p1, p2): # Operator
     return ((x(p2) - x(p1)**2 + (y(p2) -
y(p1))**2) ** 0.5

origin = point(0, 0)
my_house = point(5, 5)
campus = point(25, 25)
distance_to_campus = distance(my_house, campus)
```

Creating an Abstract Data Type

- Constructors & Selectors
- Operations
  - Express the behavior of objects, invariants, etc
  - Implemented (abstractly) in terms of Constructors and Selectors for the object
- Representation
  - Implement the structure of the object

Defining The Abstraction Barrier

- An abstraction barrier violation occurs when a part of the program that can use the "higher level" functions uses "lower level" ones instead
  - At either layer of abstraction
  - e.g. Should your function be aware of the implementation?
    - Be consistent!
- Abstraction barriers make programs easier to get right, maintain, and modify
  - Fewer changes when representation changes

A Layered Design Process – Button Up

- Start with "What do you want to do?"
- Build the application based entirely on the ADT interface
  - Focus first on Operations, then Constructors and Selectors
  - Do not implement them! Your program won't work.
  - You want to capture the "user's" point of view
- Build the operations in ADT on Constructors and Selectors
  - Not the implementation representation
  - This is the end of the abstraction barrier.
- Build the constructors and selectors on some concrete representation

Example: Tic Tac Toe and Phone Book

- See the companion notebook.
- Download the file "ipynb"
  - Go to datahub.berkeley.edu
  - Log in, then select "Upload"

Question: The Abstraction Barrier

Which of these *violates* a board ADT?

- A) `diag_left = diagonal(board, 0)`
- B) `board[0][2] = 'x'`
- C) `all_rows = rows(board)`
- D) `board = empty_board()`
- E) None of the above