Announcements

- Maps Autograder is (kind of) broken!
  - It's no skipping "locked" tests.
  - You should run `python3 ok -u` on your computer.
  - If your tests pass locally, you're all set.

Computational Structures in Data Science

Mutable Functions

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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

Taking This One Step Further

- We can make an account which allows more than just withdraws
- What should our inner function return?
  - Could be many things… but what about a function which takes multiple arguments?

```
def new_account(initial_balance):
    ## Some code omitted…
    data = { 'balance': initial_balance }
    def do_action(action, value=None):
        if action == 'balance':
            return data['balance']
        elif action == 'withdraw':
            return withdraw(value)
        elif action == 'deposit':
            return deposit(value)
return do_action
```

Computational Structures in Data Science

Abstract Data Types

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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

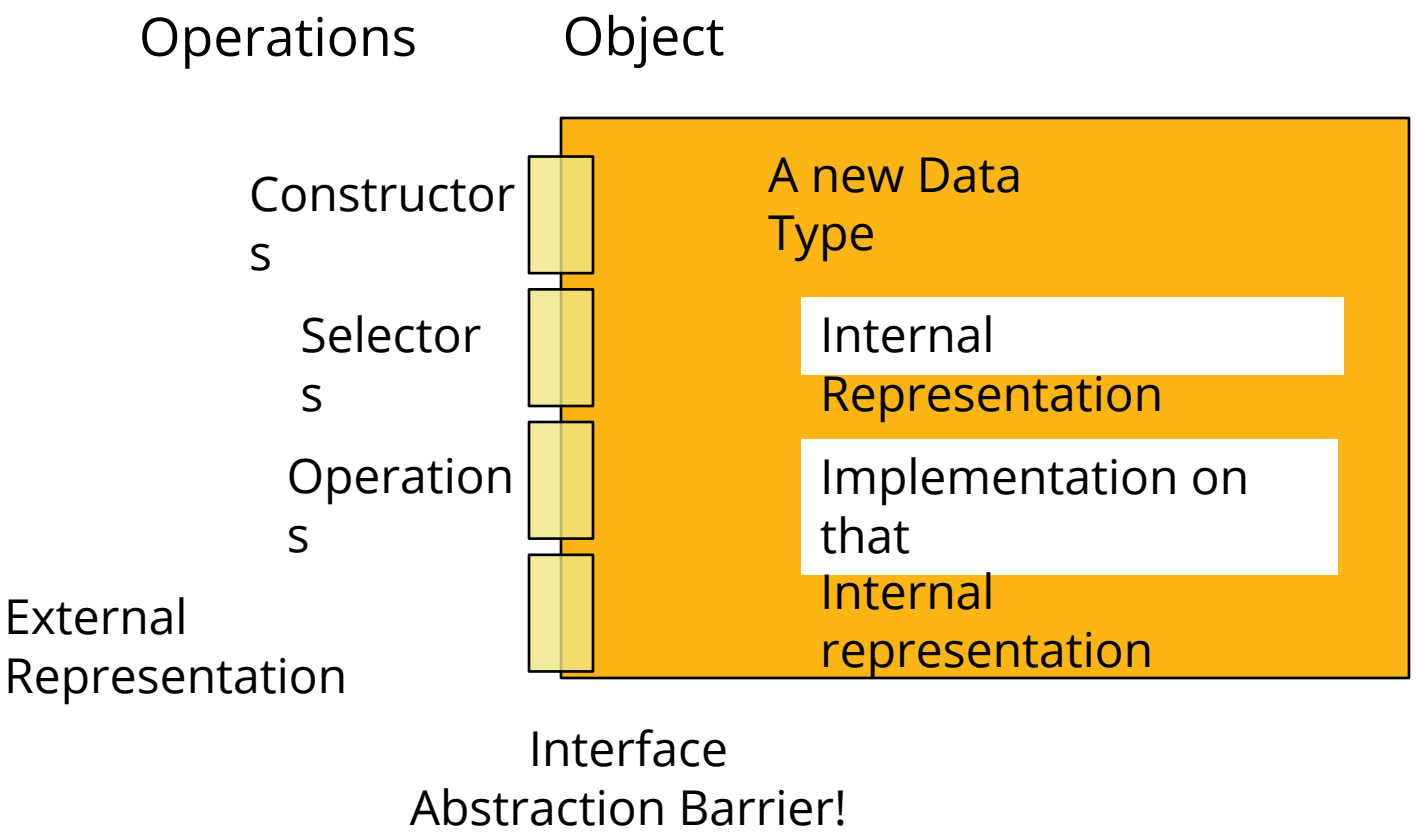
- Compound values combine other values together
  - date: a year, a month, and a day
  - geographic position: latitude and longitude
  - a game board

- 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*

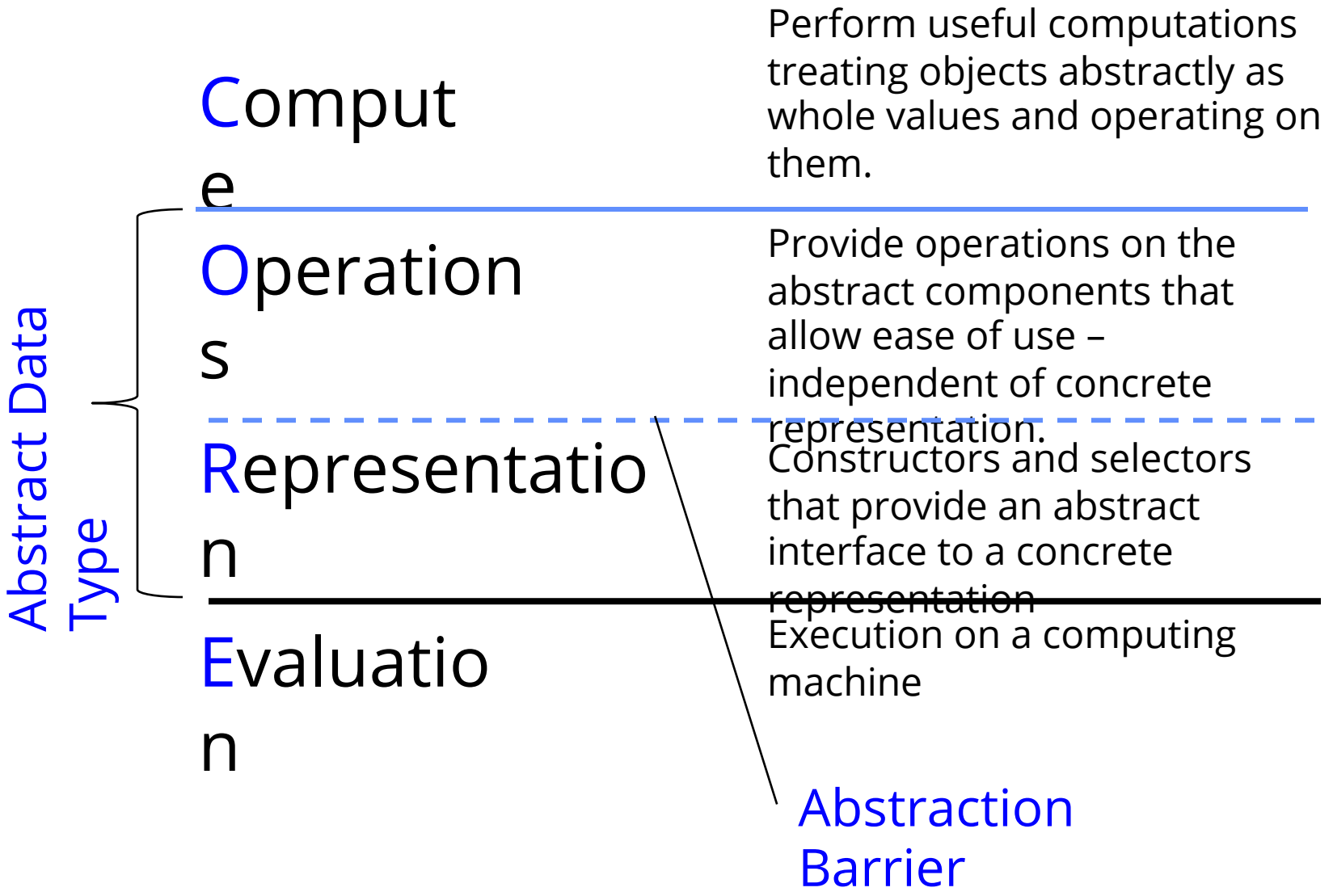
Why Abstract Data Types?

- 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



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

Question: Changing Representations? http://go.c88c.org/10

- Question 1.1
- Assuming we update our selectors, what are valid representations for our point(x, y) ADT?

- Currently point(1, 2) is represented as [1, 2]

- A) [y, x] # [2, 1]
- B) “X: ” + str(x) + “ Y: ” + str(y)
  # “X: 1 Y: 2”
- C) str(x) + ' ' + str(y) # '1 2'
- D) All of the above
- E) None of the above

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