Abstract Data Types

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CS8 – Computational Structures in Data Science

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Lecture 7

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Computational Concepts Toolbox

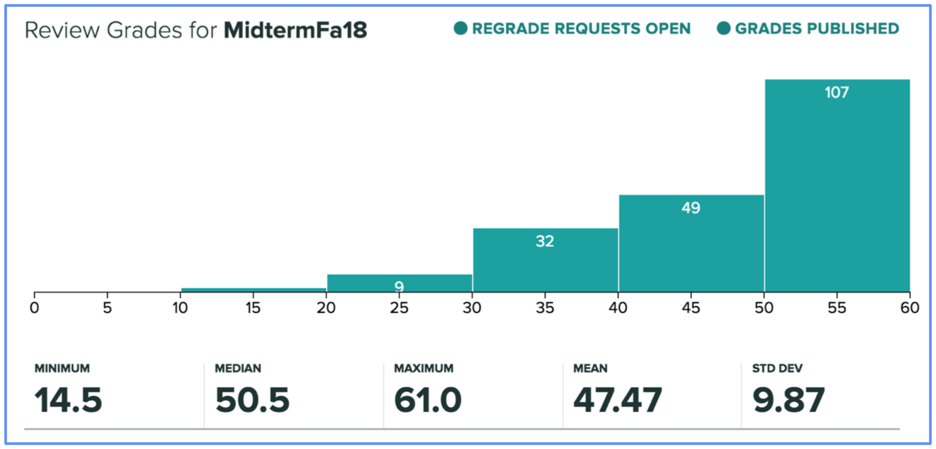
- Data type: values, literals, operations,
  - e.g., int, float, string
- Expressions, Call expression
- Variables
- Assignment Statement
- Sequences: tuple, list
  - indexing
- Data structures
- Tuple assignment
- Call Expressions
- Function Definition Statement
- Conditional Statement

- Iteration:
  - data-driven (list comprehension)
  - control-driven (for statement)
  - while statement
- Higher Order Functions
  - Functions as Values
  - Functions with functions as argument
  - Assignment of function values
- Recursion
- Lambda - function valued expressions

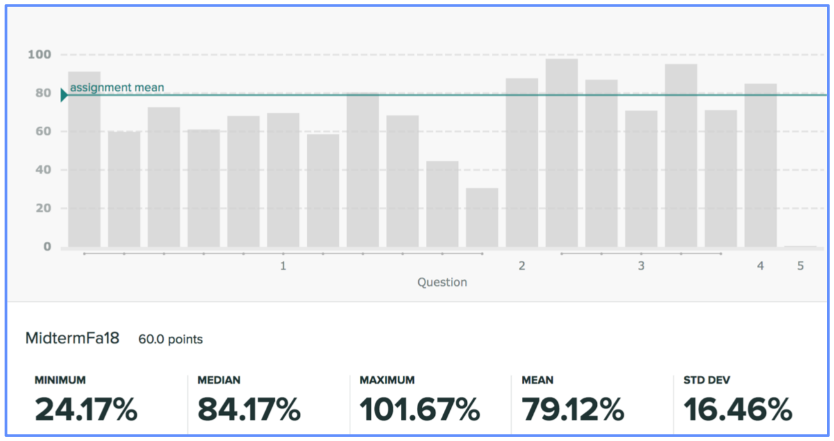
Environments and Closures

Administrative Issues

- Midterm went very well


Review Grades for **MidtermFa18** ● REGRADE REQUESTS OPEN ● GRADES PUBLISHED

MINIMUM	MEDIAN	MAXIMUM	MEAN	STD DEV
14.5	50.5	61.0	47.47	9.87

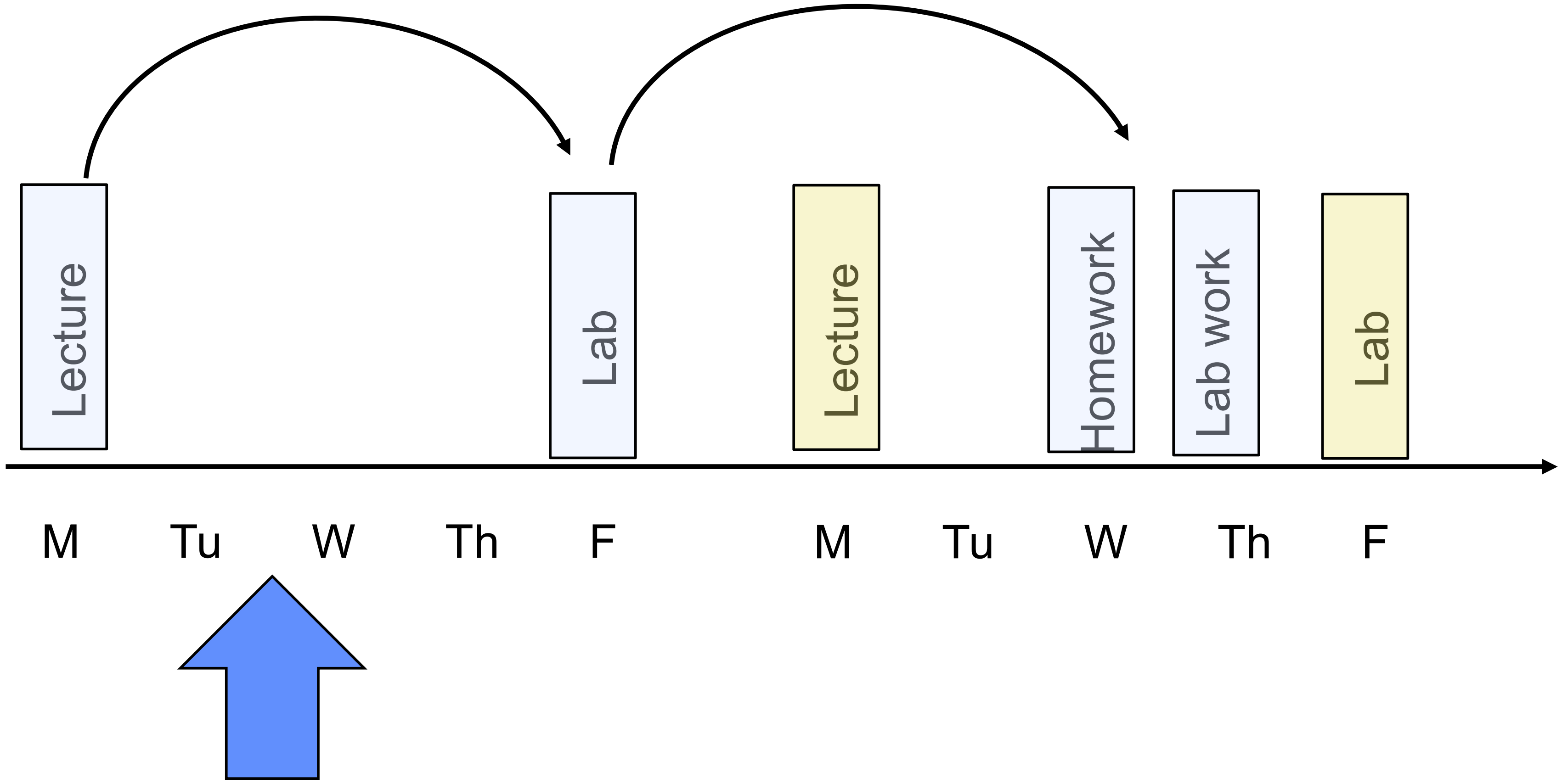


MidtermFa18 60.0 points

MINIMUM	MEDIAN	MAXIMUM	MEAN	STD DEV
24.17%	84.17%	101.67%	79.12%	16.46%

- Project 1 is out
- Mid Term Survey Thanks

Weekly “Pipeline”



Optional Exercises

Universality

- Everything that can be computed, can be computed with what you know now.
- Well
- or poorly

Today's Lecture

http://bit.ly/cs88-fa18-L07

- Administrative Issues
- Review: lambda
- New Concept: Abstract Data Type
- Example Illustration: key-value store
  - Internal representation 1: list of pair
  - Internal representation 2: pair of lists (including zip intro)
- A simple application over the KV interface
- New language construct: dict
- Key-Value store 3: dict
- Optional Exercises

http://datahub.berkeley.edu/user-redirect/interact?account=data-8&repo=cs-connector&branch=gh-pages&path=ADT

lambda

- **Function expression**
  - **"anonymous" function creation**
  - **Expression, not a statement, no return or any other statement**

lambda <arg or arg_tuple> **:** <expression w/ args>

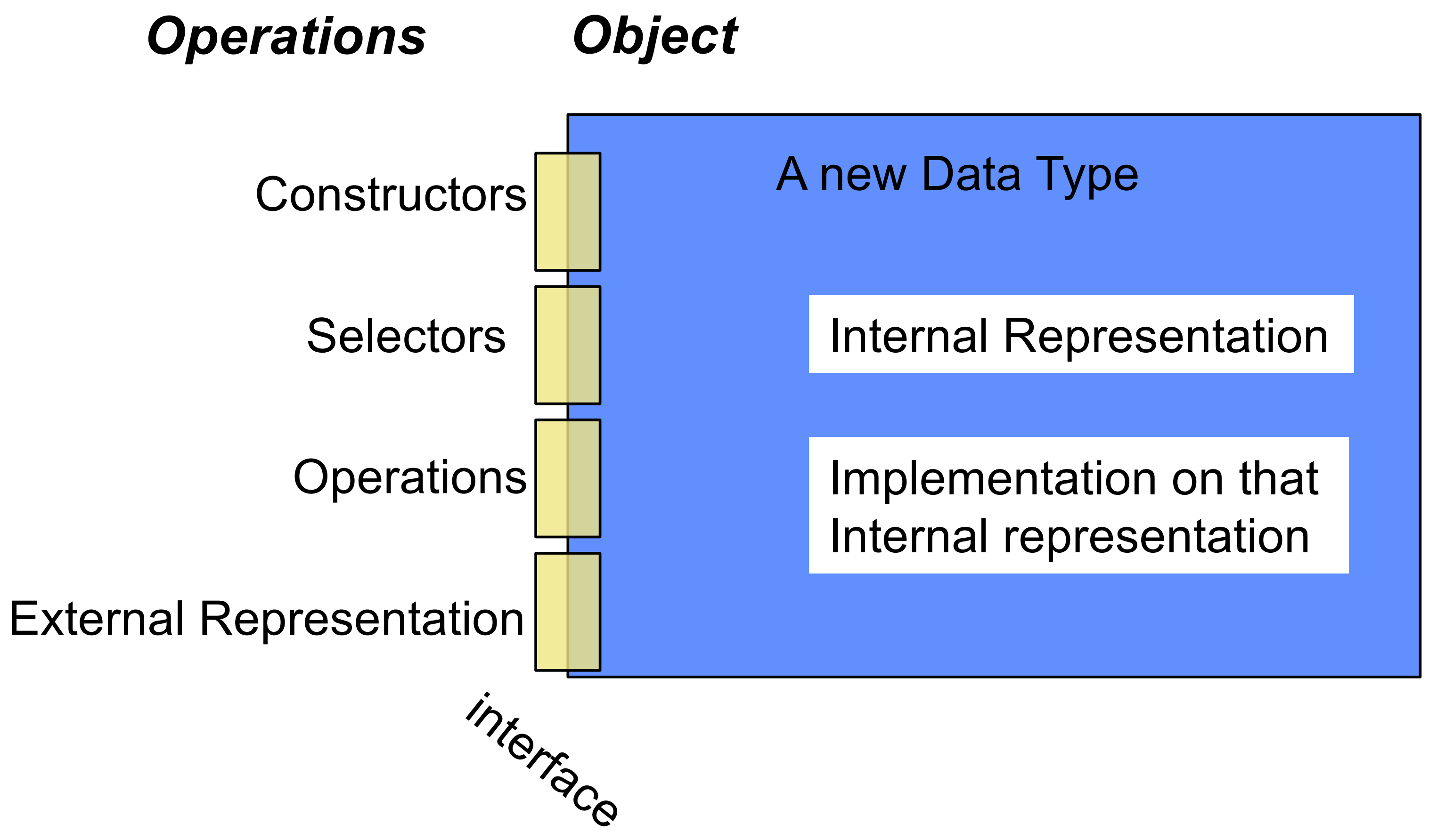
```
inc = lambda v : v + 1
```

```
def inc(v):
    return v + 1
```

Lambda Examples

```
>>> sort([1,2,3,4,5], lambda x: x)
    [1, 2, 3, 4, 5]

>>> sort([1,2,3,4,5], lambda x: -x)
    [5, 4, 3, 2, 1]

>>> sort([(2, "hi"), (1, "how"), (5, "goes"), (7, "I")],
              lambda x:x[0])
[(1, 'how'), (2, 'hi'), (5, 'goes'), (7, 'I')]

>>> sort([(2, "hi"), (1, "how"), (5, "goes"), (7, "I")],
             lambda x:x[1])
    [(7, 'I'), (5, 'goes'), (2, 'hi'), (1, 'how')]

>>> sort([(2,"hi"),(1,"how"),(5,"goes"),(7,"I")],
             lambda x: len(x[1]))
    [(7, 'I'), (2, 'hi'), (1, 'how'), (5, 'goes')]
```

Abstract Data Type



Examples Data Types You have seen

- **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**
  - Constructors:
    - » `tuple( … )`
    - » `( <exps>,…  )`
  - Selectors: `<tuple> [ <index or slice> ]`
  - Operations: `in, not in, +, *, len, min, max`

More “Built-in” Examples

- Lists
- Tuples
- Strings
  - Constructors:
    - » `str( … )`
    - » `“<chars>”, ‘<chars>’`
  - Selectors: `<str> [ <index or slice> ]`
  - Operations: `in, not in, +, *, len, min, max`
- Range
  - Constructors:
    - » `range(<end>), range(<start>,<end>), range(<start>,<end>,<step>)`
  - Selectors: `<range> [ <index or slice> ]`
  - Operations: `in, not in, len, min, max`

A New Abstract Data Type: Key-Value

- **Collection of key-Value bindings**
  - **Key : Value**
- **Many real-world examples**
  - **Dictionary, Directory, Phone book, Course Schedule, Facebook Friends, Movie listings, …**

Given some Key, What is the value associated with it?

Key-Value ADT

- Constructors
  - kv_empty: create an empty KV
  - kv_add: add a key:value binding to a KV
  - kv_create: create a KV from a list of key,value tuples
- Selectors
  - kv_items: list of (key,value) tuple in KV
  - kv_keys: list of keys in KV
  - kv_values: list of values in KV
- Operations
  - kv_len: number of bindings
  - kv_in: presence of a binding with a key
  - kv_display: external representation of KV

A little application

```
from kv_pairs import *

phone_book_data = [
    ("Christine Strauch", "510-842-9235"),
    ("Frances Catal Buloan", "932-567-3241"),
    ("Jack Chow", "617-547-0923"),
    ("Joy De Rosario", "310-912-6483"),
    ("Casey Casem", "415-432-9292"),
    ("Lydia Lu", "707-341-1254")]


phone_book = kv_create(phone_book_data)

print("Jack Chows's Number: ", kv_get(phone_book, "Jack Chow"))

print("Area codes")
area_codes = list(map(lambda x:x[0:3], kv_values(phone_book)))
print(area_codes)
```

A Layered Design Process

- Build the application based entirely on the ADT interface
  - Operations, Constructors and Selectors
- Build the operations in ADT on Constructors and Selectors
  - Not the implementation representation
- Build the constructors and selectors on some concrete representation

Example 1

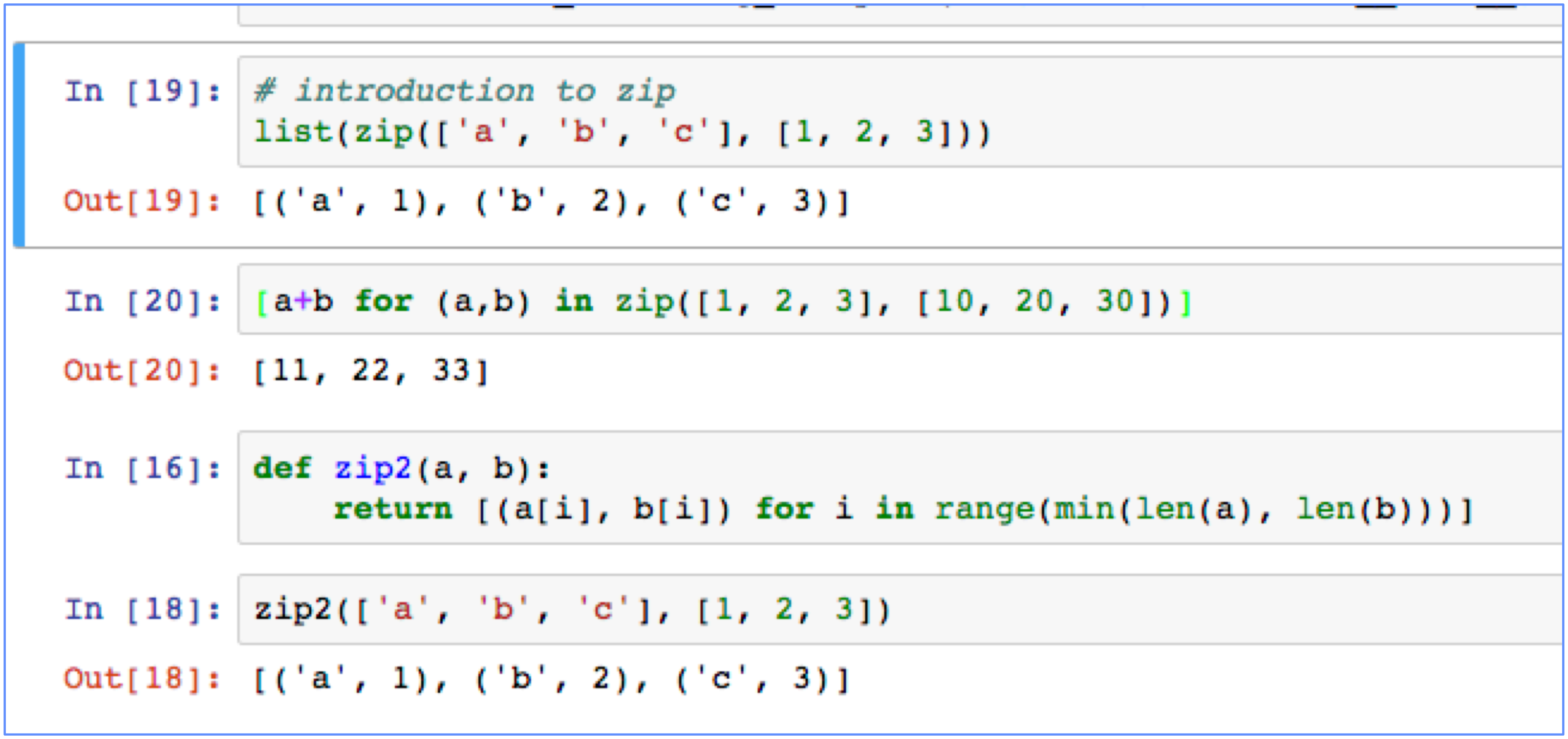
- KV represented as list of (key, value) pairs

Example 2

- KV represented as pair of lists – (keys, values)

zip

- **Zip (like a zipper) together k lists to form a list of k-tuples**



```
In [19]:  # introduction to zip
          list(zip(['a', 'b', 'c'], [1, 2, 3]))

Out[19]:  [('a', 1), ('b', 2), ('c', 3)]

In [20]:  [a+b for (a,b) in zip([1, 2, 3], [10, 20, 30])]

Out[20]:  [11, 22, 33]

In [16]:  def zip2(a, b):
              return [(a[i], b[i]) for i in range(min(len(a), len(b)))]

In [18]:  zip2(['a', 'b', 'c'], [1, 2, 3])

Out[18]:  [('a', 1), ('b', 2), ('c', 3)]
```

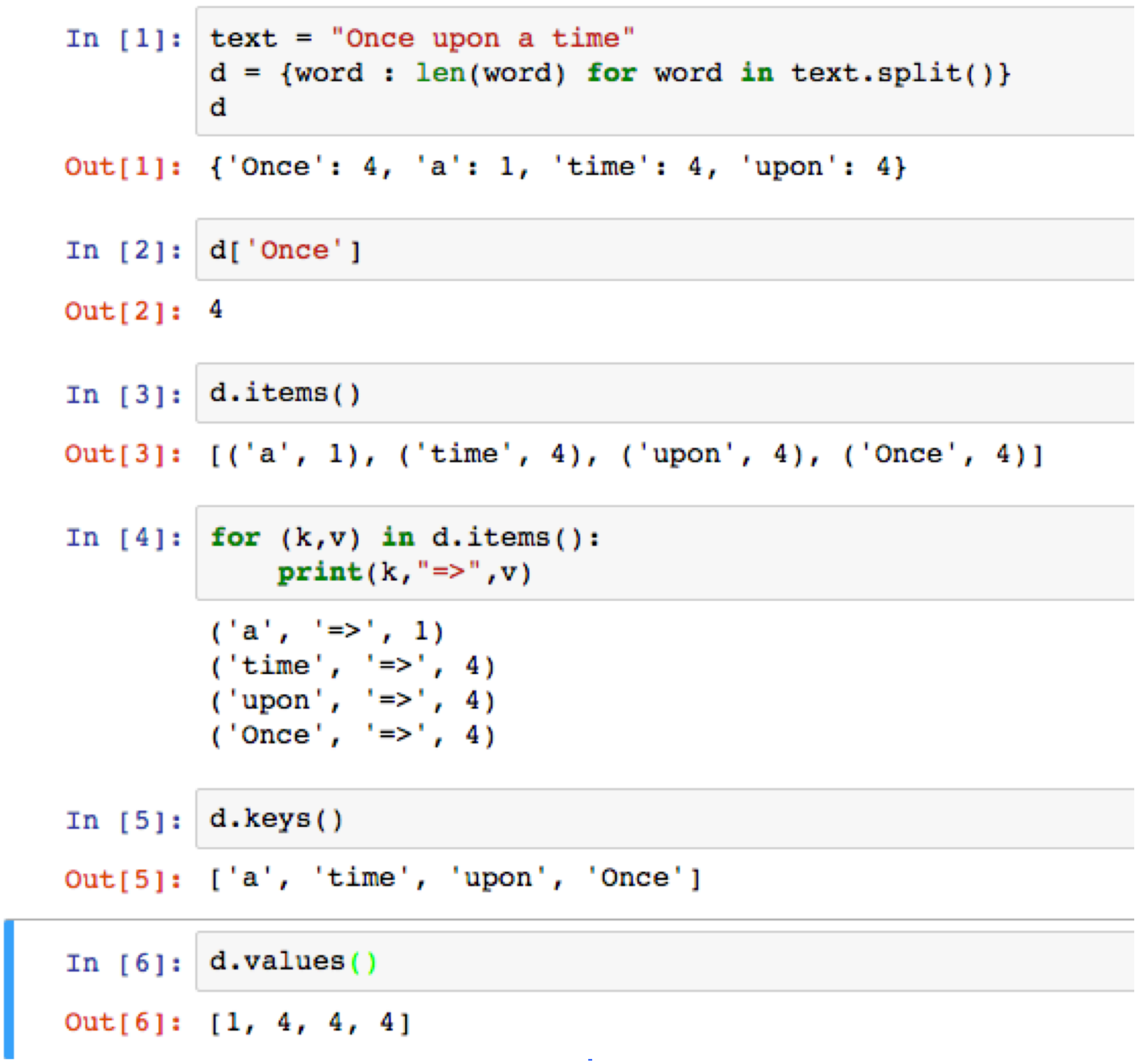
Dictionaries

- Lists, Tuples, Strings, Range
- Dictionaries
  - Constructors:
    - » `dict( <list of 2-tuples> )`
    - » `dict( <key>=<val>, ...) # like kwargs`
    - » `{ <key exp>:<val exp>, … }`
    - » `{ <key>:<val> for <iteration expression> }`

```
>>> {x:y for x,y in zip(["a","b"],[1,2])}
{'a': 1, 'b': 2}
```

  - Selectors: `<dict> [ <key> ]`
    - » `<dict>.keys(), .items(), .values()`
    - » `<dict>.get(key [, default] )`
  - Operations:
    - » `Key in, not in, len, min, max`
    - » <dict>[<key>] = <val>

Dictionary Example



```
In [1]: text = "Once upon a time"
        d = {word : len(word) for word in text.split()}
        d

Out[1]: {'Once': 4, 'a': 1, 'time': 4, 'upon': 4}

In [2]: d['Once']

Out[2]: 4

In [3]: d.items()

Out[3]: [('a', 1), ('time', 4), ('upon', 4), ('Once', 4)]

In [4]: for (k,v) in d.items():
            print(k,"=>",v)

        ('a', '=>', 1)
        ('time', '=>', 4)
        ('upon', '=>', 4)
        ('Once', '=>', 4)

In [5]: d.keys()

Out[5]: ['a', 'time', 'upon', 'Once']

In [6]: d.values()

Out[6]: [1, 4, 4, 4]
```

Beware

- Built-in data type `dict` relies on mutation
  - Clobbers the object, rather than "functional" – creating a new one
- Throws an errors of key is not present
- We will learn about mutation shortly

Example 3

- KV represented as dict

Building Apps over KV ADT

```
friend_data = [
    ("Christine Strauch", "Jack Chow"),
    ("Christine Strauch", "Lydia Lu"),
    ("Jack Chow", "Christine Strauch"),
    ("Casey Casem", "Christine Strauch"),
    ("Casey Casem", "Jack Chow"),
    ("Casey Casem", "Frances Catal Buloan"),
    ("Casey Casem", "Joy De Rosario"),
    ("Casey Casem", "Casey Casem"),
    ("Frances Catal Buloan", "Jack Chow"),
    ("Jack Chow", "Frances Catal Buloan"),
    ("Joy De Rosario", "Lydia Lu"),
    ("Joy De Lydia", "Jack Chow")
    ]
```

- **Construct a table of the friend list for each person**

Example: make_friends

```
def make_friends(friendships):
    friends = kv_empty()
    for (der, dee) in friendships:
        if not kv_in(friends, der):
            friends = kv_add(friends, der, [dee])
        else:
            der_friends = kv_get(friends, der)
            friends = kv_add(kv_delete(friends, der),
                                 der, [dee] + der_friends)
    return friends
```

C.O.R.E concepts

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

Abstract Data Type

Abstraction Barrier

Creating an Abtract 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

- 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
- Abstraction barriers make programs easier to get right, maintain, and modify
  - Few changes when representation changes

Exercises

- Read 2.2, reread 2.3, esp 2.3.6
- Modify all three KV ADTs to avoid ever adding duplicate keys
- Create and ADT for a shopping cart containing a collection of products and their order count
  - `cart()` – creates an empty cart
  - `cart_add(ct, product)` – returns a new cart that includes an additional order of product, or the first one
  - `cart_print(ct)` – prints the contents of the cart
  - `cart_products(ct)` – returns the list of products ordered
  - `cart_items(ct)` – returns list of (product, count)
  - `cart_remove(ct, product)` - returns a new cart with product removed
- Create an 1D array abstraction (like np.array) using lists as representation