

INTRODUCTION TO DATA SCIENCE

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Lecture #2 – 08/29/2019

CMSC320
Tuesdays & Thursdays
5:00pm – 6:15pm



COMPUTER SCIENCE
UNIVERSITY OF MARYLAND

ANNOUNCEMENTS

Register on Piazza: piazza.com/umd/fall2019/cmsc320

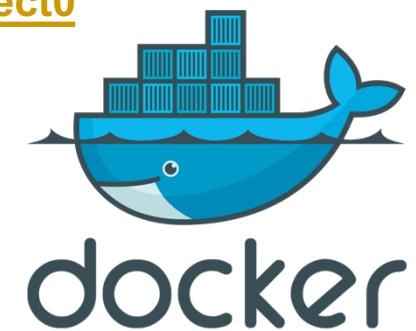
- 187 have registered already ❤️
- 111 have not registered yet 💔

If you were on Piazza, you'd know ...

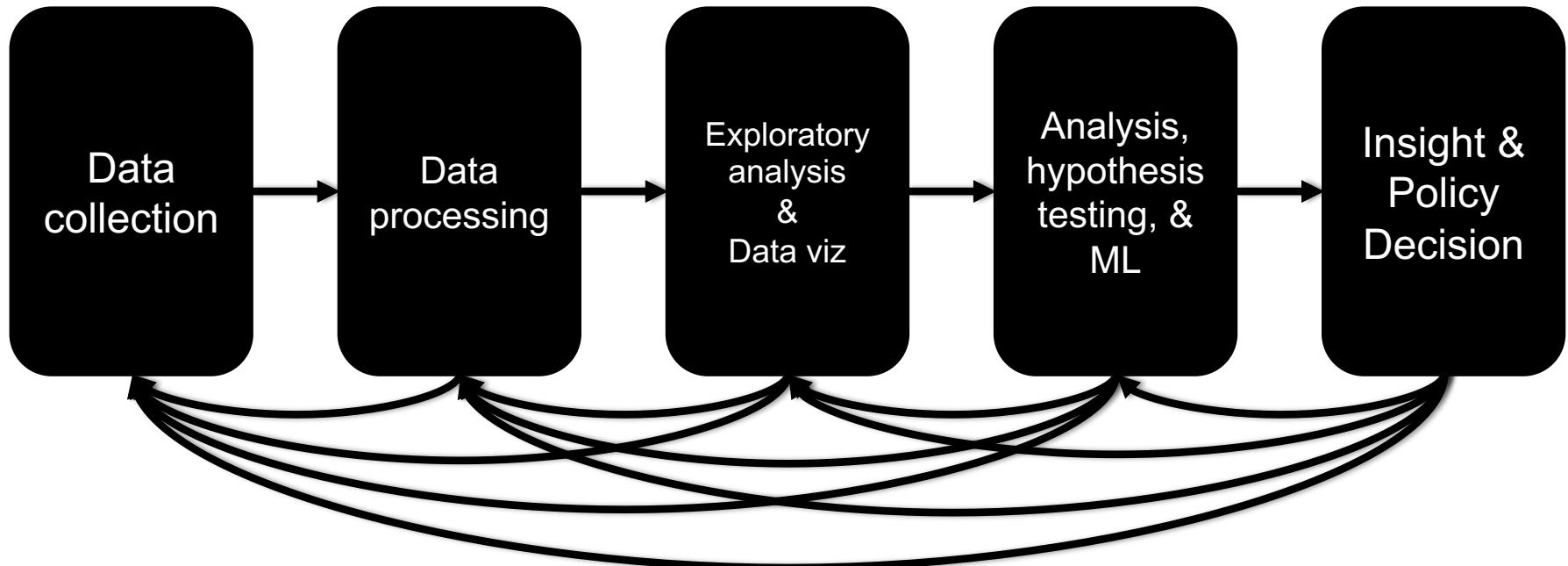
- Project 0 is out! It is due next Wednesday evening.
- Link: <https://github.com/cmsc320/fall2019/tree/master/project0>

We'll also link some reading for the week soon!

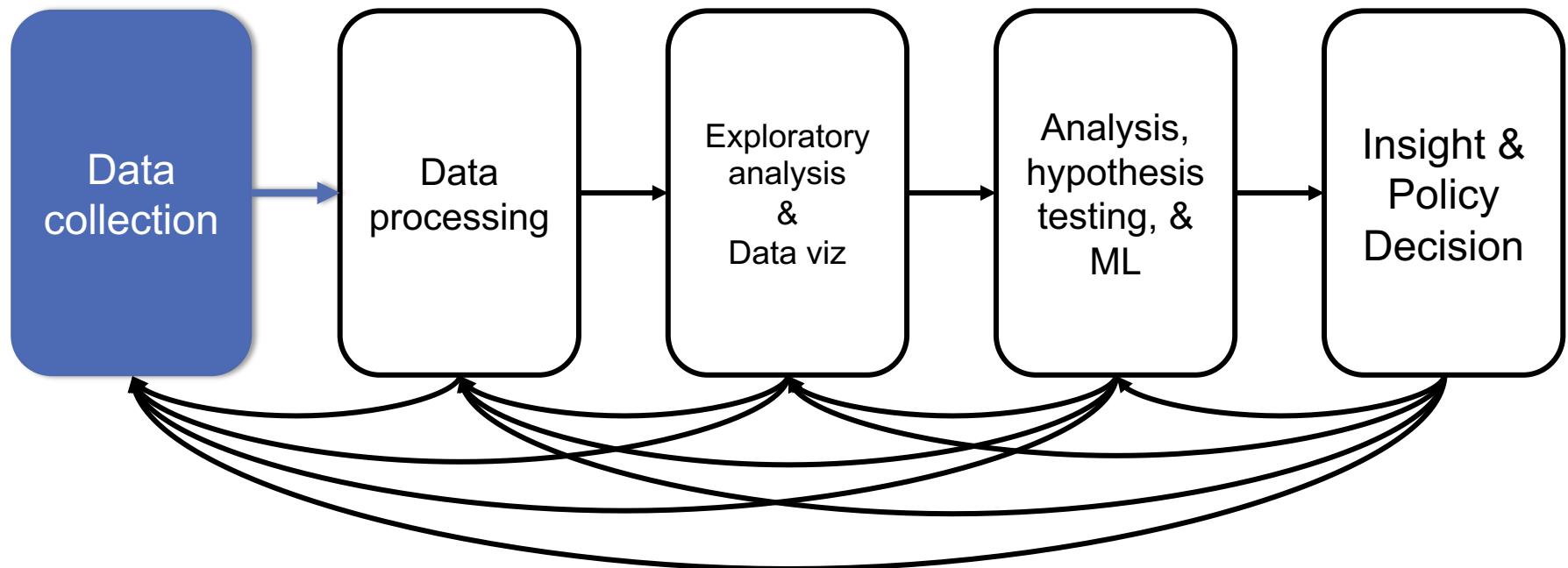
- First quiz will be due Thursday at 4:45PM.



THE DATA LIFECYCLE



TODAY'S LECTURE





BUT FIRST, SNAKES!

Python is an interpreted, dynamically-typed, high-level, garbage-collected, object-oriented-functional-imperative, and widely used scripting language.

- **Interpreted:** instructions executed without being compiled into (virtual) machine instructions*
- **Dynamically-typed:** verifies type safety at runtime
- **High-level:** abstracted away from the raw metal and kernel
- **Garbage-collected:** memory management is automated
- **OOFI:** you can do bits of OO, F, and I programming

Not the point of this class!

- Python is **fast** (developer time), **intuitive**, and **used in industry!**

*you can compile Python source, but it's not required

THE ZEN OF PYTHON

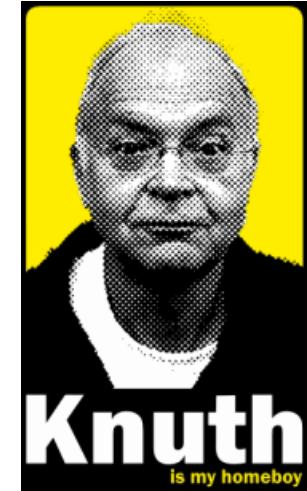
- Beautiful is better than ugly.
- Explicit is better than implicit.
- Simple is better than complex.
- Complex is better than complicated.
- Flat is better than nested.
- Sparse is better than dense.
- Readability counts.
- Special cases aren't special enough to break the rules ...
 - ... although practicality beats purity.
- Errors should never pass silently ...
 - ... unless explicitly silenced.



LITERATE PROGRAMMING

Literate code contains in **one document**:

- the **source** code;
- text **explanation** of the code; and
- the **end result** of running the code.



Basic idea: present code in the order that logic and flow of human thoughts demand, not the machine-needed ordering

- Necessary for data science!
- Many choices made need textual explanation, ditto results.

Stuff you'll be using in Project 0 (and beyond)!

IP[y]: IPython
Interactive Computing

jupyter

JUPYTER PROJECT

Started as iPython Notebooks, a web-based frontend to the iPython Shell

- Notebook functionality separated out a few years ago
- Now supports over 40 languages/kernels
- Notebooks can be shared easily
- Can leverage big data tools like Spark

Apache Zeppelin:

- <https://www.linkedin.com/pulse/comprehensive-comparison-jupyter-vs-zeppelin-hoc-q-phan-mba->

Several others including RStudio (specific to R)

10-MINUTE PYTHON PRIMER

Define a function:

```
def my_func(x, y):  
    if x > y:  
        return x  
    else:  
        return y
```

Python is whitespace-delimited

Define a function that returns a tuple:

```
def my_func(x, y):  
    return (x-1, y+2)  
  
(a, b) = my_func(1, 2)
```

a = 0; b = 4

USEFUL BUILT-IN FUNCTIONS: COUNTING AND ITERATING

len: returns the number of items of an enumerable object

```
len( [ 'c', 'm', 's', 'c', 3, 2, 0] )
```

```
7
```

range: returns an iterable object

```
list( range(10) )
```

```
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

enumerate: returns iterable tuple (index, element) of a list

```
enumerate( ["311", "320", "330"] )
```

```
[(0, "311"), (1, "320"), (2, "330")]
```

<https://docs.python.org/3/library/functions.html>

USEFUL BUILT-IN FUNCTIONS: MAP AND FILTER

map: apply a function to a sequence or iterable

```
arr = [1, 2, 3, 4, 5]
map(lambda x: x**2, arr)
```

```
[1, 4, 9, 16, 25]
```

filter: returns a list of elements for which a predicate is true

```
arr = [1, 2, 3, 4, 5, 6, 7]
filter(lambda x: x % 2 == 0, arr)
```

```
[2, 4, 6]
```

We'll go over in much greater depth with pandas/numpy.

PYTHONIC PROGRAMMING

Basic iteration over an array in Java:

```
int[] arr = new int[10];
for(int idx=0; idx<arr.length; ++idx) {
    System.out.println( arr[idx] );
}
```

Direct translation into Python:

```
idx = 0
while idx < len(arr):
    print( arr[idx] ); idx += 1
```

A more “Pythonic” way of iterating:

```
for element in arr:
    print( element )
```

LIST COMPREHENSIONS

Construct sets like a mathematician!

- $P = \{ 1, 2, 4, 8, 16, \dots, 2^{16} \}$
- $E = \{ x \mid x \text{ in } \mathbb{N} \text{ and } x \text{ is odd and } x < 1000 \}$

Construct lists like a mathematician **who codes!**

```
P = [ 2**x for x in range(17) ]
```

```
E = [ x for x in range(1000) if x % 2 != 0 ]
```

Very similar to `map`, but:

- You'll see these way more than `map` in the wild
- Many people consider `map/filter` not "pythonic"
- They can perform differently (`map` is "lazier")

follow
your



EXCEPTIONS

Syntactically correct statement throws an exception:

- tweepy (Python Twitter API) returns “Rate limit exceeded”
- sqlite (a file-based database) returns IntegrityError

```
print('Python', python_version())  
  
try:  
    cause_a_NameError  
except NameError as err:  
    print(err, '-> some extra text')
```

PYTHON 2 VS 3

Python 3 is intentionally backwards incompatible

- (But not *that* incompatible)

Biggest changes that matter for us:

- `print "statement"` → `print("function")`
- `1/2 = 0` → `1/2 = 0.5` and `1//2 = 0`
- ASCII `str` default → default Unicode

Namespace ambiguity fixed:

```
i = 1  
[i for i in range(5)]  
print(i) # ????????
```

TO ANY CURMUDGEONS ...

If you're going to use Python 2 anyway, use the `_future_` module:

- Python 3 introduces features that will throw runtime errors in Python 2 (e.g., `with` statements)
- `_future_` module incrementally brings 3 functionality into 2
- https://docs.python.org/2/library/_future_.html

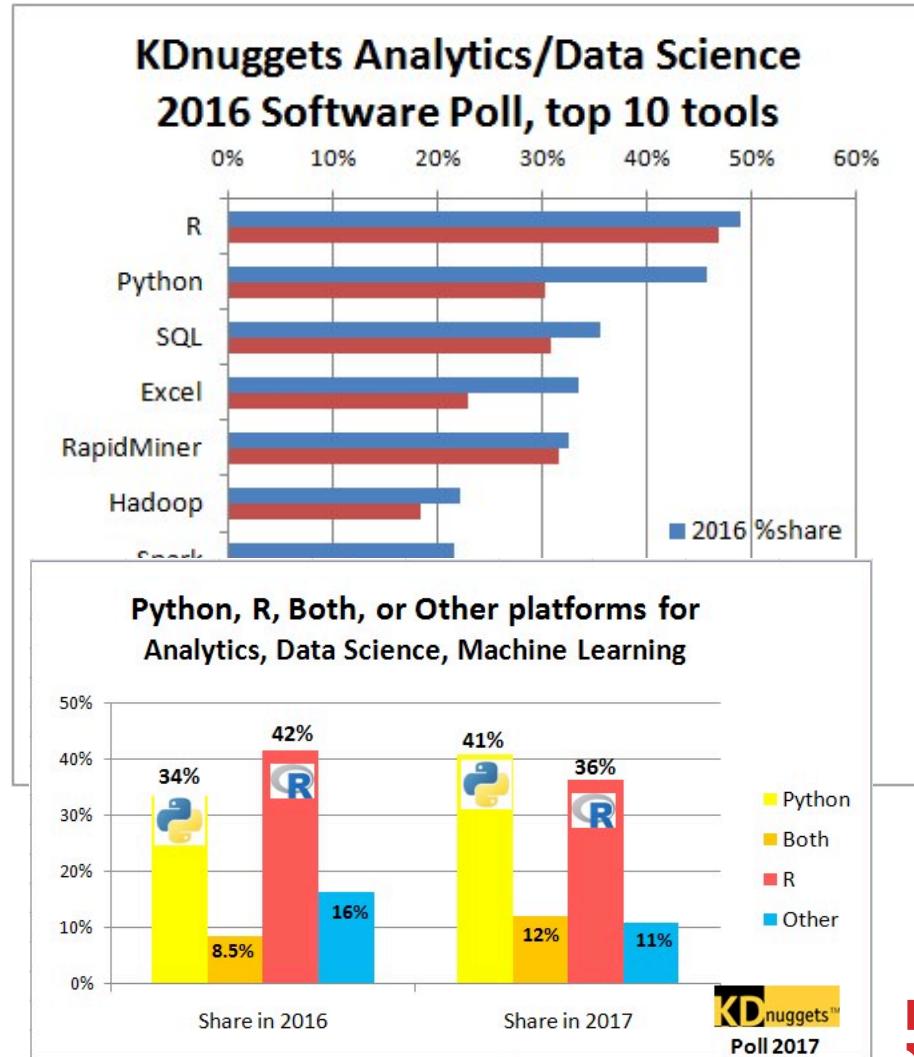
```
from __future__ import division  
from __future__ import print_function  
from __future__ import please_just_use_python_3
```

PYTHON VS R (FOR DATA SCIENTISTS)

There is no right answer here!

- Python is a “full” programming language – easier to integrate with systems in the field
- R has a more mature set of pure stats libraries ...
- ... but Python is catching up quickly ...
- ... and is already ahead specifically for ML.

You will see Python more in the tech industry.



EXTRA RESOURCES

Plenty of tutorials on the web:

- <https://www.learnpython.org/>

Work through Project 0, which will take you through some baby steps with Python and the Pandas library:

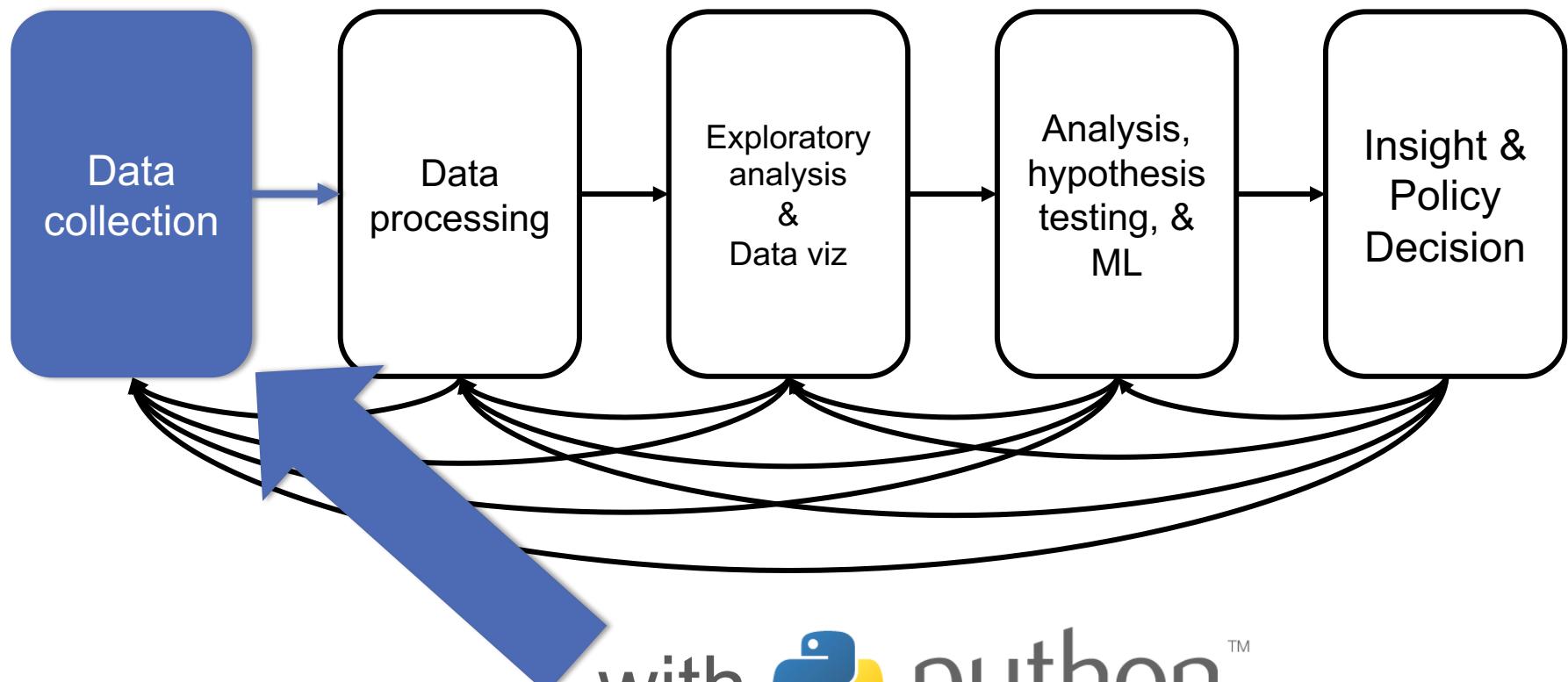
- (We'll also post some readings soon.)

Come hang out at office hours (or chat with me privately)

- All office hours will be on the website/Piazza by tomorrow.
- Will have coverage MTWThF.



TODAY'S LECTURE



with  python™

GOTTA CATCH 'EM ALL



Five ways to get data:

- Direct download and load from local storage
- Generate locally via downloaded code (e.g., simulation)
- Query data from a database (covered in a few lectures)
- Query an API from the intra/internet
- Scrape data from a webpage

} Covered today.

WHEREFORE ART THOU, API?

A web-based Application Programming Interface (API) like we'll be using in this class is a contract between a server and a user stating:

“If you send me a specific request, I will return some information in a structured and documented format.”

(More generally, APIs can also perform actions, may not be web-based, be a set of protocols for communicating between processes, between an application and an OS, etc.)

“SEND ME A SPECIFIC REQUEST”

Most web API queries we'll be doing will use HTTP requests:

- conda install -c anaconda requests=2.12.4

```
r = requests.get('https://api.github.com/user',
                  auth=('user', 'pass'))
```

```
r.status_code
```

```
200
```

```
r.headers['content-type']
```

```
'application/json; charset=utf8'
```

```
r.json()
```

```
{u'private_gists': 419, u'total_private_repos': 77, ...}
```

HTTP REQUESTS

`https://www.google.com/?q=cmsc320&tbs=qdr:m`



???????????

HTTP GET Request:

GET /?q=cmsc320&tbs=qdr:m HTTP/1.1

Host: www.google.com

User-Agent: Mozilla/5.0 (X11; Linux x86_64; rv:10.0.1) Gecko/20100101 Firefox/10.0.1

```
params = { "q": "cmsc320", "tbs": "qdr:m" }
r = requests.get(    "https://www.google.com",
                    params = params )
```

*be careful with https:// calls; requests will not verify SSL by default

RESTFUL APIs

This class will just **query** web APIs, but full web APIs typically allow more.

Representational **S**tate **T**ransfer (**R****E****S****T**ful) APIs:

- **GET**: perform query, return data
- **POST**: create a new entry or object
- **PUT**: update an existing entry or object
- **DELETE**: delete an existing entry or object

Can be more intricate, but verbs (“put”) align with actions



QUERYING A RESTFUL API

Stateless: with every request, you send along a token/authentication of who you are

```
token = "super_secret_token"
r = requests.get("https://github.com/user",
                  params={"access_token": token})
print( r.content )
```

```
{"login":"JohnDickerson","id":472985,"avatar_url":"ht...
```

GitHub is more than a GETHub:

- PUT/POST/DELETE can edit your repositories, etc.
- Try it out: <https://github.com/settings/tokens/new>

AUTHENTICATION AND OAUTH

Old and busted:

```
r = requests.get("https://api.github.com/user",
                  auth=("JohnDickerson", "ILoveKittens"))
```

New hotness:

- What if I wanted to grant an app access to, e.g., my Facebook account **without** giving that app my password?
- OAuth: grants **access tokens** that give (possibly incomplete) access to a user or app without exposing a password

“... I WILL RETURN INFORMATION IN A STRUCTURED FORMAT.”

So we've queried a server using a well-formed GET request via the `requests` Python module. What comes back?

General structured data:

- Comma-Separated Value (CSV) files & strings
- Javascript Object Notation (JSON) files & strings
- HTML, XHTML, XML files & strings

Domain-specific structured data:

- Shapefiles: geospatial vector data (OpenStreetMap)
- RVT files: architectural planning (Autodesk Revit)
- You can make up your own! **Always document it.**

GRAPHQL?

An alternative to REST and ad-hoc webservice architectures

- Developed internally by Facebook and released publicly

Unlike REST, the requester specifies the format of the response

```
GET /books/1

{
  "title": "Black Hole Blues",
  "author": {
    "firstName": "Janna",
    "lastName": "Levin"
  }
  // ... more fields here
}
```

```
GET /graphql?query={ book(id: "1") { title, author { firstName } } }

{
  "title": "Black Hole Blues",
  "author": {
    "firstName": "Janna",
  }
}
```

CSV FILES IN PYTHON

Any CSV reader worth anything can parse files with any delimiter, not just a comma (e.g., “TSV” for tab-separated)

1,26-Jan,Introduction,—,"pdf, pptx",Dickerson,
2,31-Jan,Scraping Data with Python,Anaconda's Test Drive.,,Dickerson,
3,2-Feb,"Vectors, Matrices, and Dataframes",Introduction to pandas.,,Dickerson,
4,7-Feb,Jupyter notebook lab,,,,"Denis, Anant, & Neil",
5,9-Feb,Best Practices for Data Science Projects,,,Dickerson,

Don't write your own CSV or JSON parser

```
import csv
with open("schedule.csv", "rb") as f:
    reader = csv.reader(f, delimiter=",", quotechar='''')
    for row in reader:
        print(row)
```

(We'll use pandas to do this much more easily and efficiently)

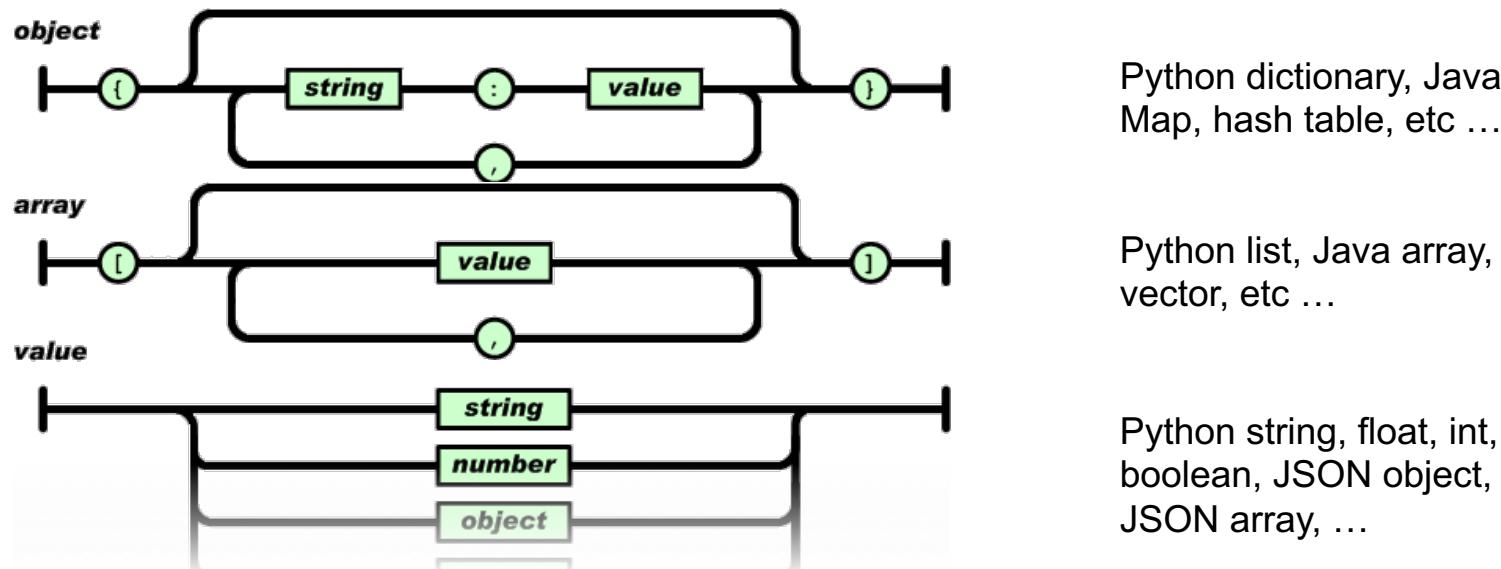
JSON FILES & STRINGS

JSON is a method for **serializing** objects:

- Convert an object into a string (done in Java in 131/132?)
- **Deserialization** converts a string back to an object

Easy for humans to read (and sanity check, edit)

Defined by three universal data structures



Python dictionary, Java Map, hash table, etc ...

Python list, Java array, vector, etc ...

Python string, float, int, boolean, JSON object, JSON array, ...

JSON IN PYTHON

Some built-in types: “Strings”, 1.0, True, False, None

Lists: [“Goodbye”, “Cruel”, “World”]

Dictionaries: {“hello”: “bonjour”, “goodbye”, “au revoir”}

Dictionaries within lists within dictionaries within lists:

```
[1, 2, {"Help": [  
    "I'm", {"trapped": "in"},  
    "CMSC320"  
]}]
```



JSON FROM TWITTER

```
GET https://api.twitter.com/1.1/friends/list.json?cursor=-1&screen_name=twitterapi&skip_status=true&include_user_entities=false
```

```
{
  "previous_cursor": 0,
  "previous_cursor_str": "0",
  "next_cursor": 1333504313713126852,
  "users": [
    {
      "profile_sidebar_fill_color": "252429",
      "profile_sidebar_border_color": "181A1E",
      "profile_background_tile": false,
      "name": "Sylvain Carle",
      "profile_image_url":
      "http://a0.twimg.com/profile_images/2838630046/4b82e286a659fae310012520f4f756bb_normal.png",
      "created_at": "Thu Jan 18 00:10:45 +0000 2007", ...
    }
  ]
}
```

PARSING JSON IN PYTHON

Repeat: don't write your own CSV or JSON parser

- <https://news.ycombinator.com/item?id=7796268>
- rsdy.github.io/posts/dont_write_your_json_parser_plz.html

Python comes with a fine JSON parser

```
import json

r = requests.get(
    "https://api.twitter.com/1.1/statuses/user_timeline.json?screen_name=JohnPDickerson&count=100", auth=auth )

data = json.loads(r.content)
```

```
json.load(some_file) # loads JSON from a file
json.dump(json_obj, some_file) # writes JSON to file
json.dumps(json_obj) # returns JSON string
```

XML, XHTML, HTML FILES AND STRINGS

Still hugely popular online, but JSON has essentially replaced XML for:

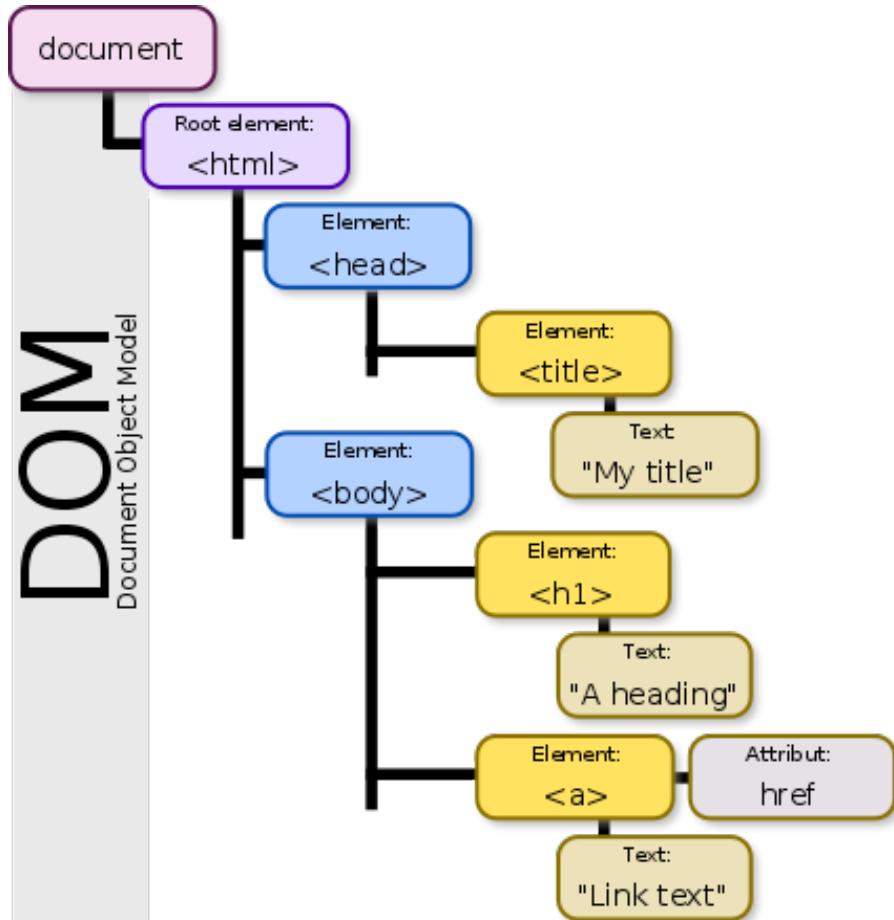
- Asynchronous browser ↔ server calls
- Many (most?) newer web APIs

XML is a hierarchical markup language:

```
<tag attribute="value1">
    <subtag>
        Some content goes here
    </subtag>
    <openclosetag attribute="value2" />
</tag>
```

You probably won't see much XML, but you will see plenty of HTML, its substantially less well-behaved cousin ...

DOCUMENT OBJECT MODEL (DOM)



XML encodes Document-Object Models (“the DOM”)

The DOM is tree-structured.

Easy to work with!
Everything is encoded via links.

Can be **huge**, & mostly full of stuff you don't need ...

SAX

SAX (Simple API for XML) is an alternative “lightweight” way to process XML.

A SAX parser generates a stream of events as it parses the XML file. The programmer registers handlers for each one.

It allows a programmer to handle only parts of the data structure.

SCRAPING HTML IN PYTHON

HTML – the specification – is fairly pure

HTML – what you find on the web – is horrifying

We'll use BeautifulSoup:

- conda install -c asmeurer beautiful-soup=4.3.2



```
import requests
from bs4 import BeautifulSoup

r = requests.get(
    "https://cs.umd.edu/class/fall2019/cmsc320/" )

root = BeautifulSoup( r.content )
root.find("div", id="schedule")\
    .find("table")           # find all schedule
    .find("tbody").findAll("a") # links for CMSC320
```

BUILDING A WEB SCRAPER IN PYTHON

Totally not hypothetical situation:

- You really want to learn about data science, so you choose to download all of last semester's CMSC320 lecture slides to wallpaper your room ...
- ... but you now have carpal tunnel syndrome from clicking refresh on Piazza last night, and can no longer click on the PDF and PPTX links.

Hopeless? No! Earlier, you built a scraper to do this!

```
lnks = root.find("div", id="schedule")\
    .find("table")\                      # find all schedule
    .find("tbody").findAll("a") # links for CMSC320
```

Sort of. You only want PDF and PPTX files, not links to other websites or files.

REGULAR EXPRESSIONS

Given a list of URLs (strings), how do I find only those strings that end in *.pdf or *.pptx?

- Regular expressions!
- (Actually Python strings come with a built-in `endswith` function.)

```
"this_is_a_filename.pdf".endswith((".pdf", ".pptx"))
```

What about .pDf or .pPTx, still legal extensions for PDF/PPTX?

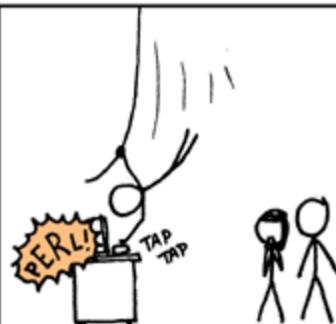
- Regular expressions!
- (Or cheat the system again: built-in string `lower` function.)

```
"tHiS_IS_a_FileNAme.pDF".lower().endswith(  
    (".pdf", ".pptx"))
```

EVERYBODY STAND BACK.



I KNOW REGULAR EXPRESSIONS.



IF YOU'RE HAVIN' PERL
PROBLEMS I FEEL
BAD FOR YOU, SON-



I GOT 99
PROBLEMS,



SO I USED
REGULAR
EXPRESSIONS.



NOW I HAVE
100 PROBLEMS.



REGULAR EXPRESSIONS

Used to **search** for specific elements, or groups of elements, that match a pattern

```
import re

# Find the index of the 1st occurrence of "cmsc320"
match = re.search(r"cmsc320", text)
print( match.start() )
```

```
# Does start of text match "cmsc320"?
match = re.match(r"cmsc320", text)
```

```
# Iterate over all matches for "cmsc320" in text
for match in re.finditer(r"cmsc320", text):
    print( match.start() )
```

```
# Return all matches of "cmsc320" in the text
match = re.findall(r"cmsc320", text)
```

MATCHING MULTIPLE CHARACTERS

Can match sets of characters, or multiple and more elaborate sets and sequences of characters:

- Match the character 'a': a
- Match the character 'a', 'b', or 'c': [abc]
- Match any character except 'a', 'b', or 'c': [^abc]
- Match any digit: \d (= [0123456789] or [0-9])
- Match any alphanumeric: \w (= [a-zA-Z0-9_])
- Match any whitespace: \s (= [\t\n\r\f\v])
- Match any character: .

Special characters must be escaped: . ^ \$ * + ? { } \ [] | ()

MATCHING SEQUENCES AND REPEATED CHARACTERS

A few common modifiers (available in Python and most other high-level languages; +, {n}, {n,} may not):

- Match character ‘a’ exactly once: a
- Match character ‘a’ zero or once: a?
- Match character ‘a’ zero or more times: a*
- Match character ‘a’ one or more times: a+
- Match character ‘a’ exactly n times: a{ n }
- Match character ‘a’ at least n times: a{ n , }

Example: match all instances of “University of <somewhere>” where <somewhere> is an alphanumeric string with at least 3 characters:

- \s*University\sof\s\w{3,}

COMPILED REGEXES

If you're going to reuse the same regex many times, or if you aren't but things are going slowly for some reason, try **compiling** the regular expression.

- <https://blog.codinghorror.com/to-compile-or-not-to-compile/>

```
# Compile the regular expression "cmsc320"
regex = re.compile(r"cmsc320")

# Use it repeatedly to search for matches in text
regex.match( text )      # does start of text match?
regex.search( text )     # find the first match or None
regex.findall( text )    # find all matches
```

Interested? CMSC330, CMSC430, CMSC452, talk to me.

DOWNLOADING A BUNCH OF FILES

Import the modules

```
import re
import requests
from bs4 import BeautifulSoup
try:
    from urllib.parse import urlparse
except ImportError:
    from urlparse import urlparse
```

Get some HTML via HTTP

```
# HTTP GET request sent to the URL url
r = requests.get( url )

# Use BeautifulSoup to parse the GET response
root = BeautifulSoup( r.content )
lnks = root.find("div", id="schedule") \
    .find("table") \
    .find("tbody").findAll("a")
```

DOWNLOADING A BUNCH OF FILES

Parse exactly what you want

```
# Cycle through the href for each anchor, checking
# to see if it's a PDF/PPTX link or not
for lnk in lnks:
    href = lnk['href']

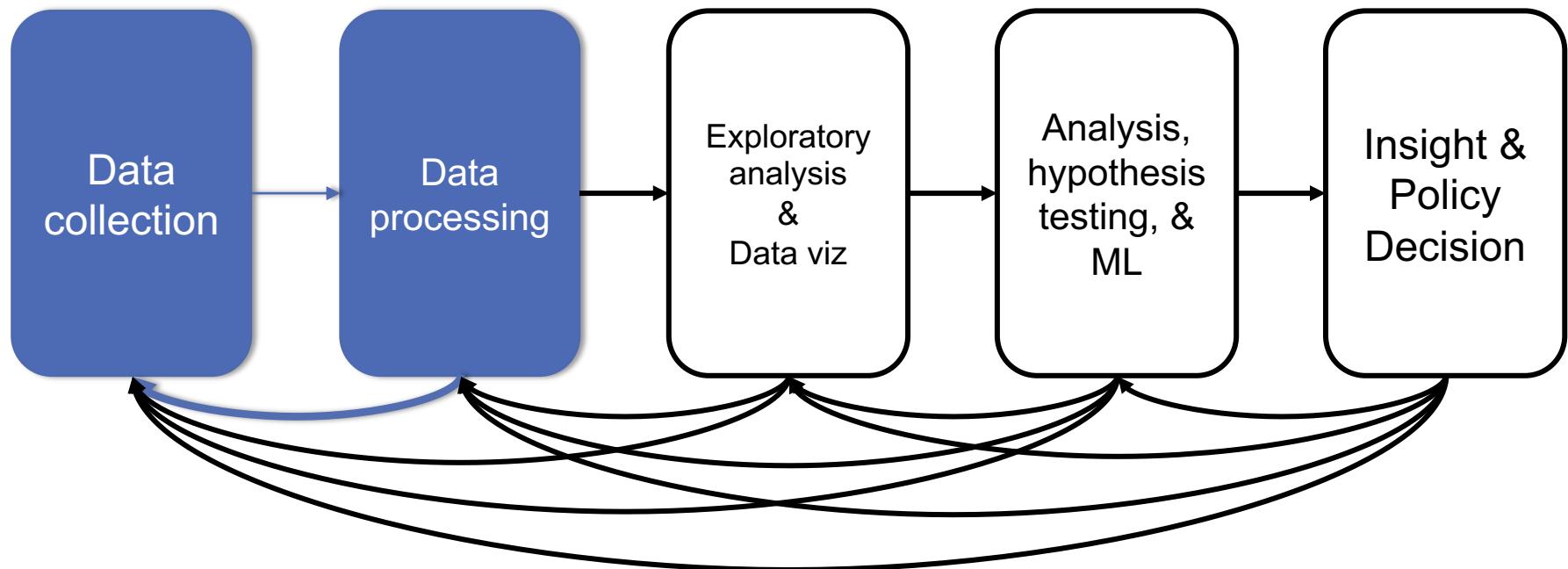
    # If it's a PDF/PPTX link, queue a download
    if href.lower().endswith('.pdf', '.pptx'):
```

Get some more data?!

```
urld = urlparse.urljoin(url, href)
rd = requests.get(urld, stream=True)

# Write the downloaded PDF to a file
outfile = path.join(outbase, href)
with open(outfile, 'wb') as f:
    f.write(rd.content)
```

NEXT LECTURE





NEXT CLASS:

NUMPY, SCIPY, AND DATAFRAMES

pandas

$$y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$$

