# Data Science: Principles and Practice

## Lecture 1: Introduction

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UNIVERSITY OF CAMBRIDGE

# Data Science: Principles and Practice

01 Introduction and motivation

02 Practical basics

03 Course logistics

# What is Data Science?

### Data Processing

crawling
cleaning
connecting

### Statistics

measuring
analyzing
exploring

### Machine Learning

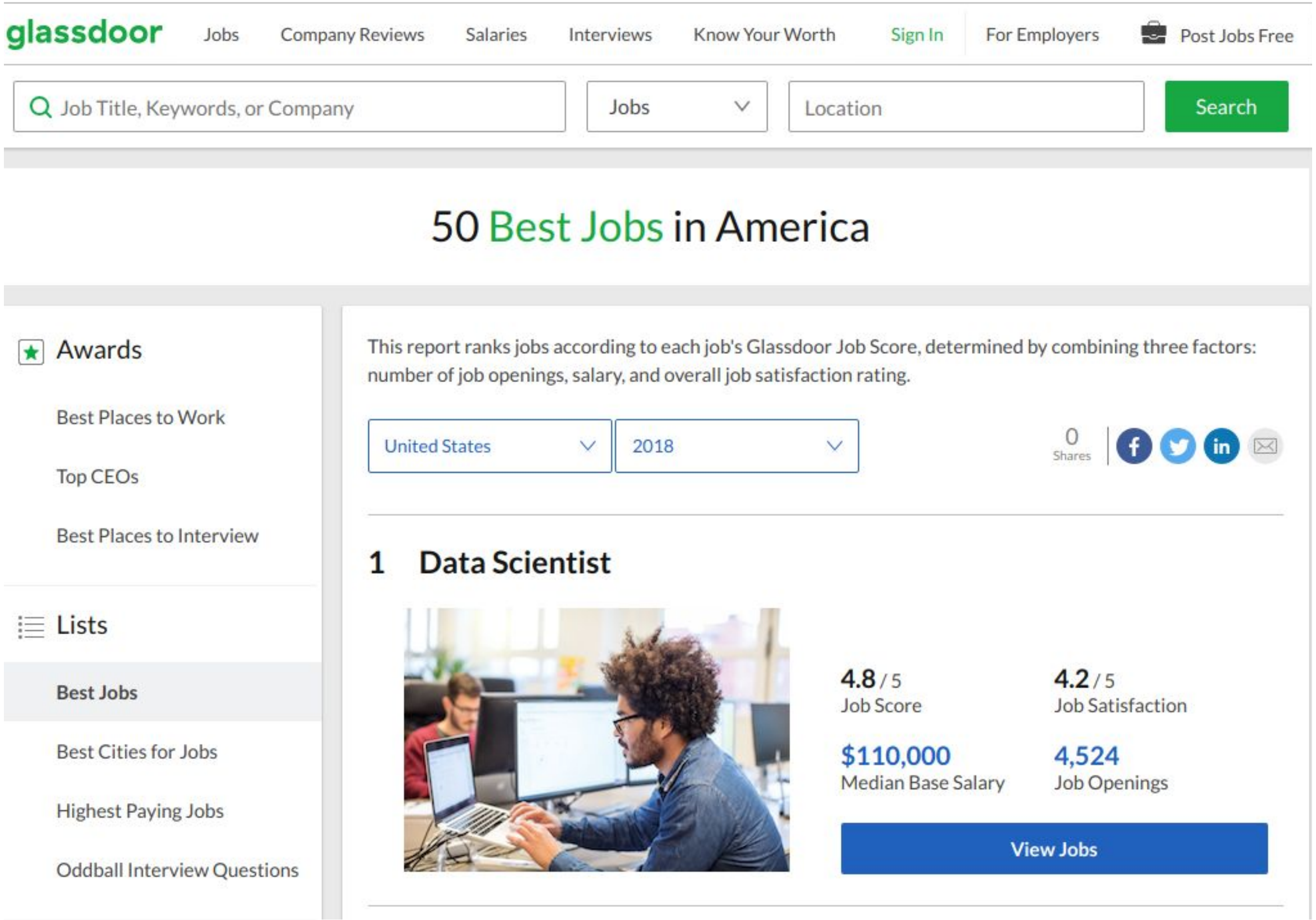
modeling
predicting
simulating

### Visualization

investigating
structuring
presenting

### Big Data

processing
parallelizing
optimizing



# 50 Best Jobs in America

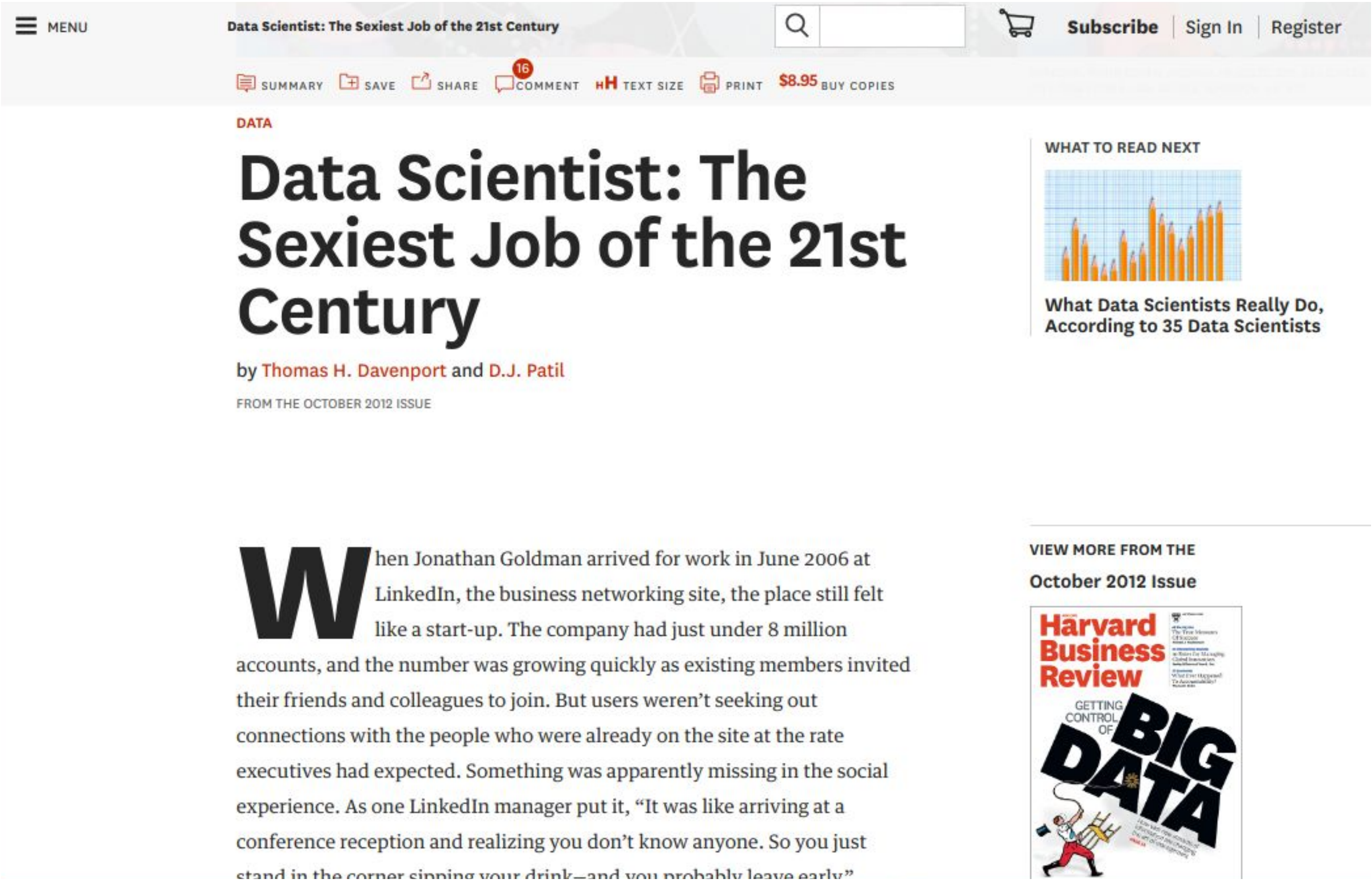
This report ranks jobs according to each job's Glassdoor Job Score, determined by combining three factors: number of job openings, salary, and overall job satisfaction rating.

United States | 2018

## 1 Data Scientist

| | |
|---|---|
| 4.8 / 5<br>Job Score | 4.2 / 5<br>Job Satisfaction |
| $110,000<br>Median Base Salary | 4,524<br>Job Openings |

https://www.glassdoor.com/List/Best-Jobs-in-America-LST_KQ0,20.htm



DATA

# Data Scientist: The Sexiest Job of the 21st Century

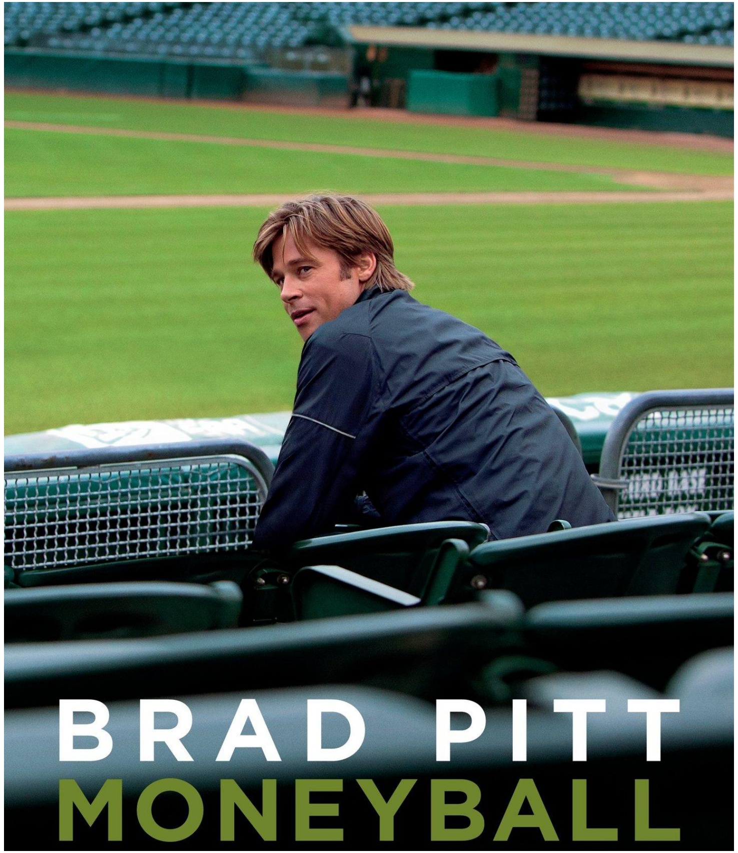
by Thomas H. Davenport and D.J. Patil

FROM THE OCTOBER 2012 ISSUE

When Jonathan Goldman arrived for work in June 2006 at LinkedIn, the business networking site, the place still felt like a start-up. The company had just under 8 million accounts, and the number was growing quickly as existing members invited their friends and colleagues to join. But users weren't seeking out connections with the people who were already on the site at the rate executives had expected. Something was apparently missing in the social experience. As one LinkedIn manager put it, "It was like arriving at a conference reception and realizing you don't know anyone. So you just stand in the corner sipping your drink—and you probably leave early."

https://hbr.org/2012/10/data-scientist-the-sexiest-job-of-the-21st-century

# Data Science in Sports

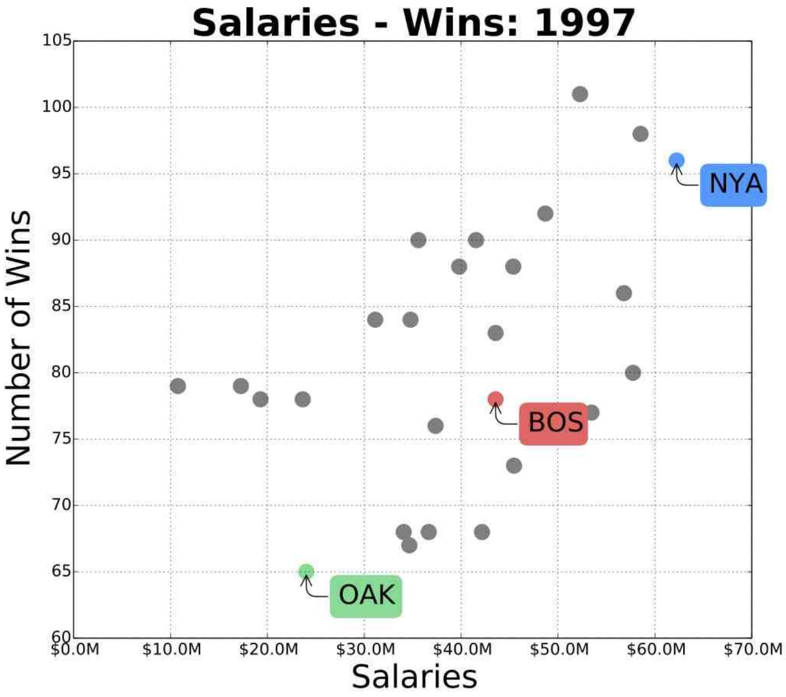


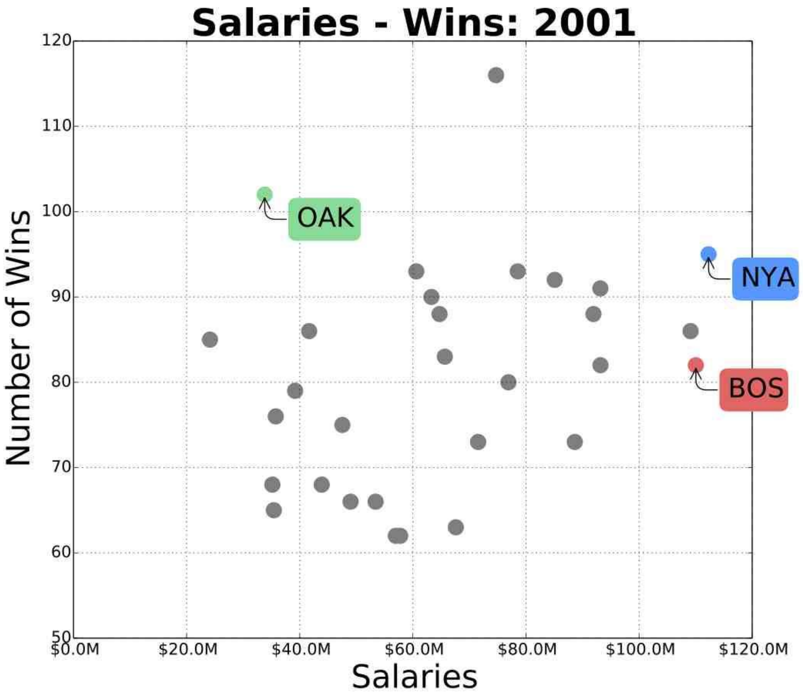
> *The market for baseball players was so inefficient...*
> *that superior management could run circles around taller piles of cash.*
> *- Michael Lewis*

Legendary 2002 season for Oakland Athletics.

Manager Billy Beane put together an unexpected team using data science.

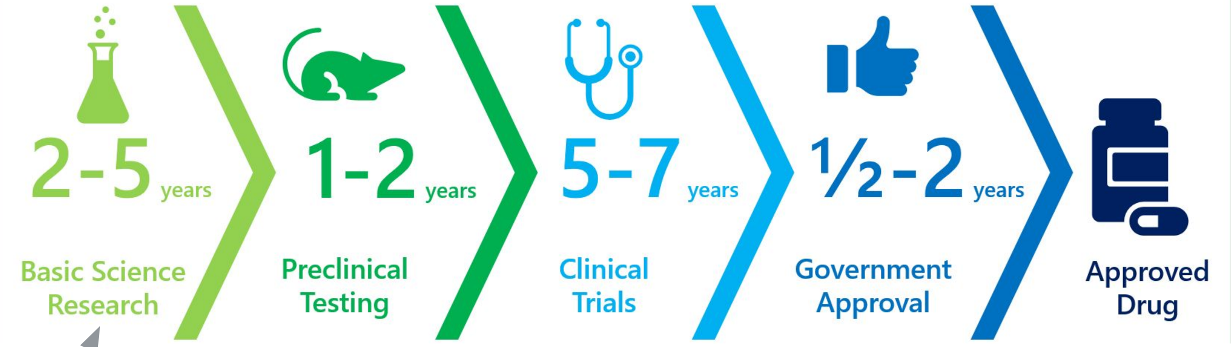
# Data Science in Sports





http://adilmoujahid.com/posts/2014/07/baseball-analytics/

# Data Science in Drug Discovery



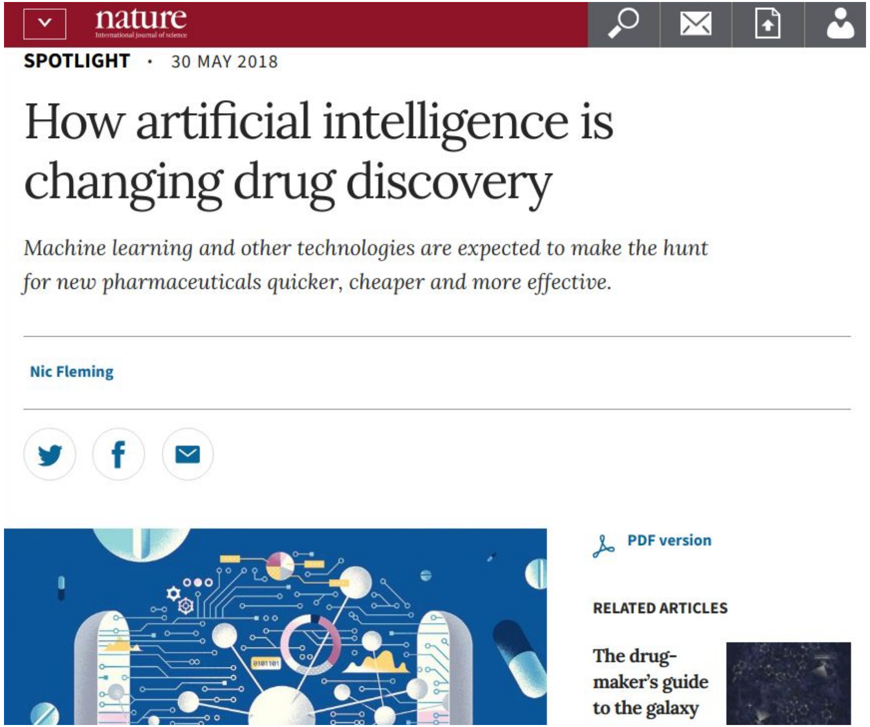
1:10,000 success rate

1:10 success rate

$350M to $5.5B cost

http://sitn.hms.harvard.edu/flash/2017/make-fda-great-trump-future-drug-approval-process/
https://en.wikipedia.org/wiki/Cost_of_drug_development

# Data Science in Drug Discovery



SPOTLIGHT · 30 MAY 2018

## How artificial intelligence is changing drug discovery

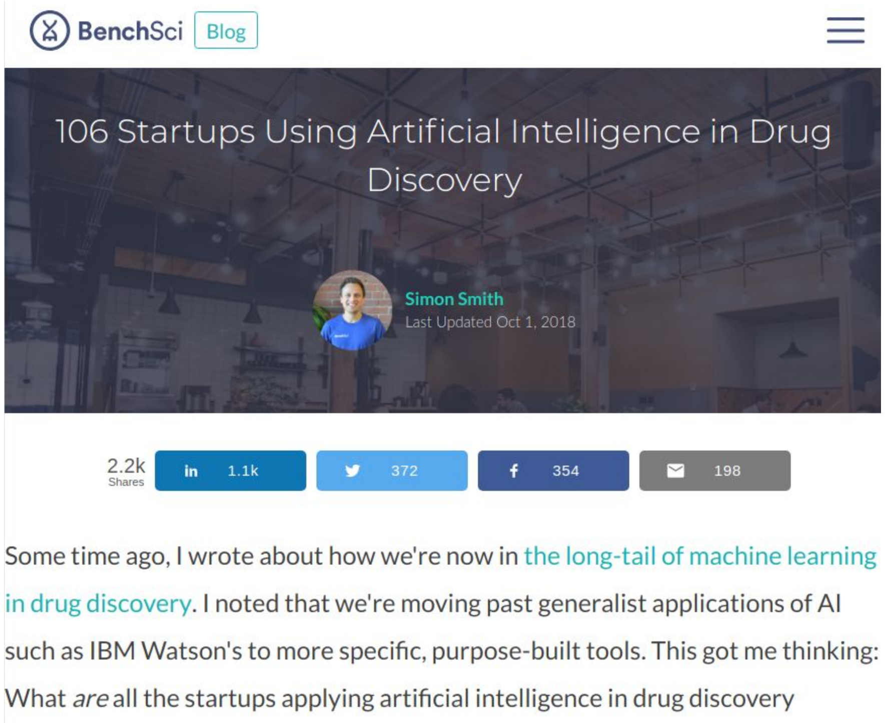
*Machine learning and other technologies are expected to make the hunt for new pharmaceuticals quicker, cheaper and more effective.*

Nic Fleming

PDF version

RELATED ARTICLES

The drug-maker's guide to the galaxy

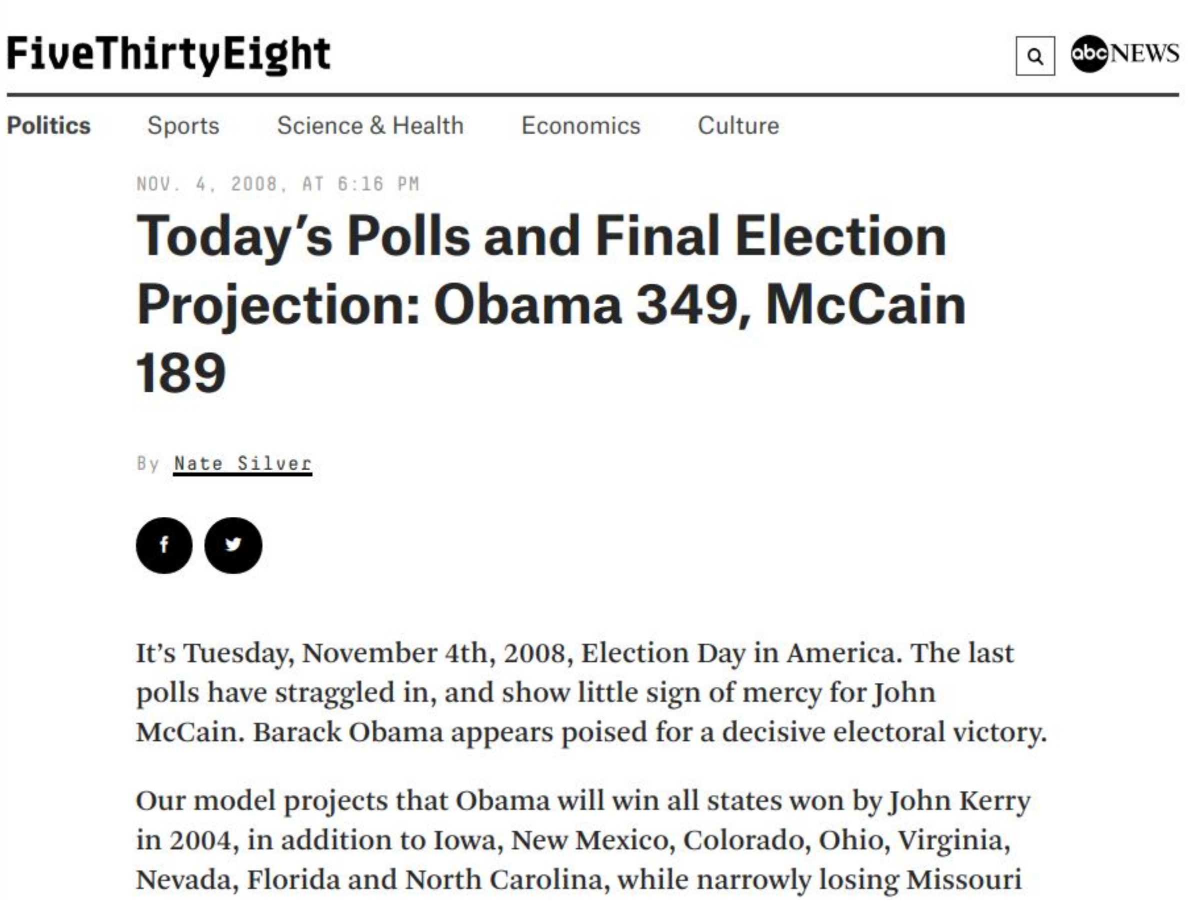


## 106 Startups Using Artificial Intelligence in Drug Discovery

Simon Smith
Last Updated Oct 1, 2018

Some time ago, I wrote about how we're now in the long-tail of machine learning in drug discovery. I noted that we're moving past generalist applications of AI such as IBM Watson's to more specific, purpose-built tools. This got me thinking: What *are* all the startups applying artificial intelligence in drug discovery

https://www.nature.com/articles/d41586-018-05267-x
https://blog.benchsci.com/startups-using-artificial-intelligence-in-drug-discovery



NOV. 4, 2008, AT 6:16 PM

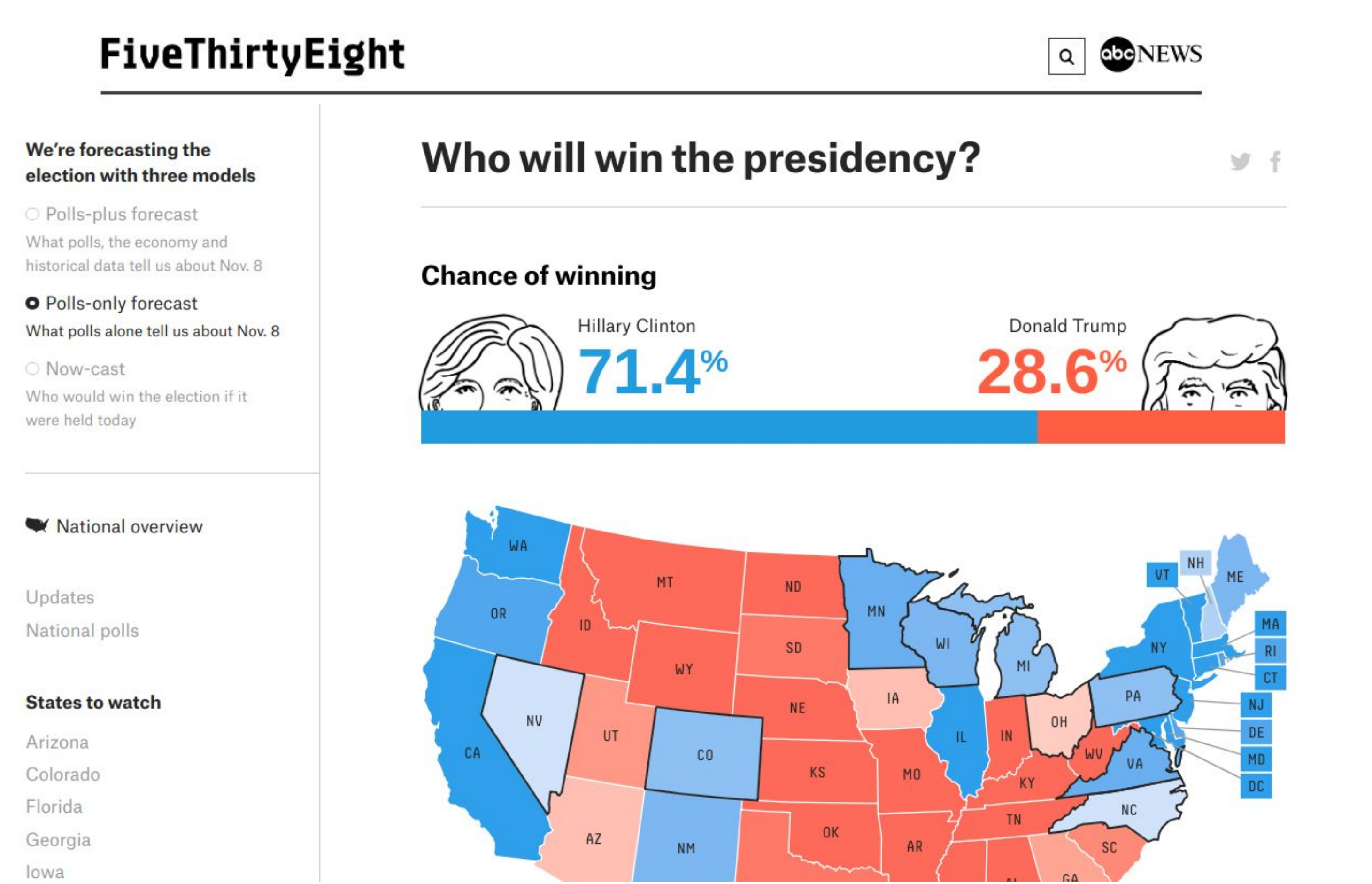
# Today’s Polls and Final Election Projection: Obama 349, McCain 189

By Nate Silver

It’s Tuesday, November 4th, 2008, Election Day in America. The last polls have straggled in, and show little sign of mercy for John McCain. Barack Obama appears poised for a decisive electoral victory.

Our model projects that Obama will win all states won by John Kerry in 2004, in addition to Iowa, New Mexico, Colorado, Ohio, Virginia, Nevada, Florida and North Carolina, while narrowly losing Missouri

https://fivethirtyeight.com/features/todays-polls-and-final-election/



FiveThirtyEight

abcNEWS

We're forecasting the election with three models

○ Polls-plus forecast

What polls, the economy and historical data tell us about Nov. 8

● Polls-only forecast

What polls alone tell us about Nov. 8

○ Now-cast

Who would win the election if it were held today

National overview

Updates

National polls

States to watch

Arizona

Colorado

Florida

Georgia

Iowa

## Who will win the presidency?

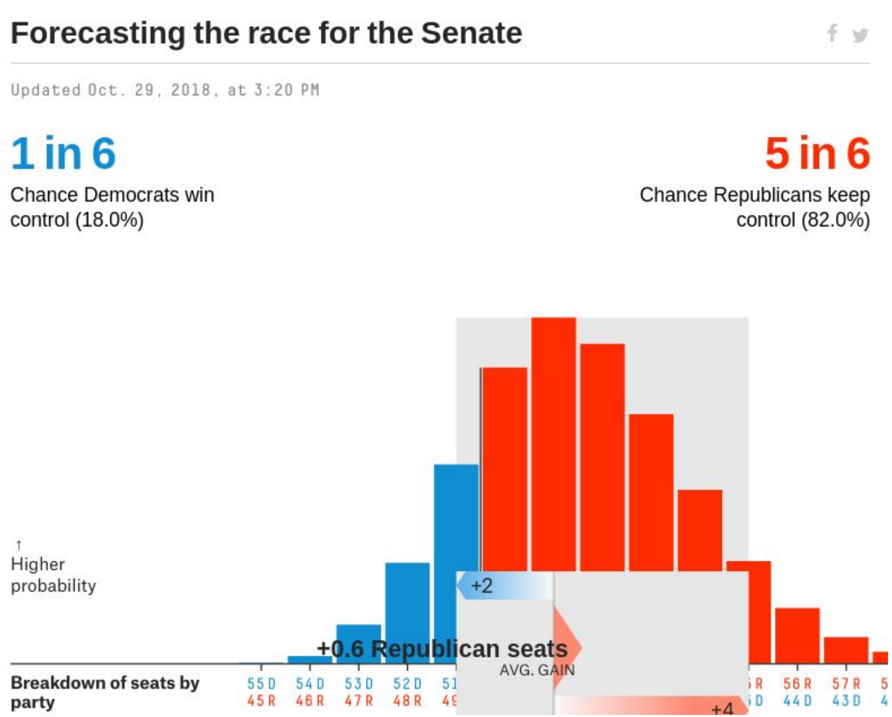
### Chance of winning

Hillary Clinton 71.4%

Donald Trump 28.6%

https://projects.fivethirtyeight.com/2016-election-forecast/

# Data Science in Politics



## Forecasting the race for the Senate

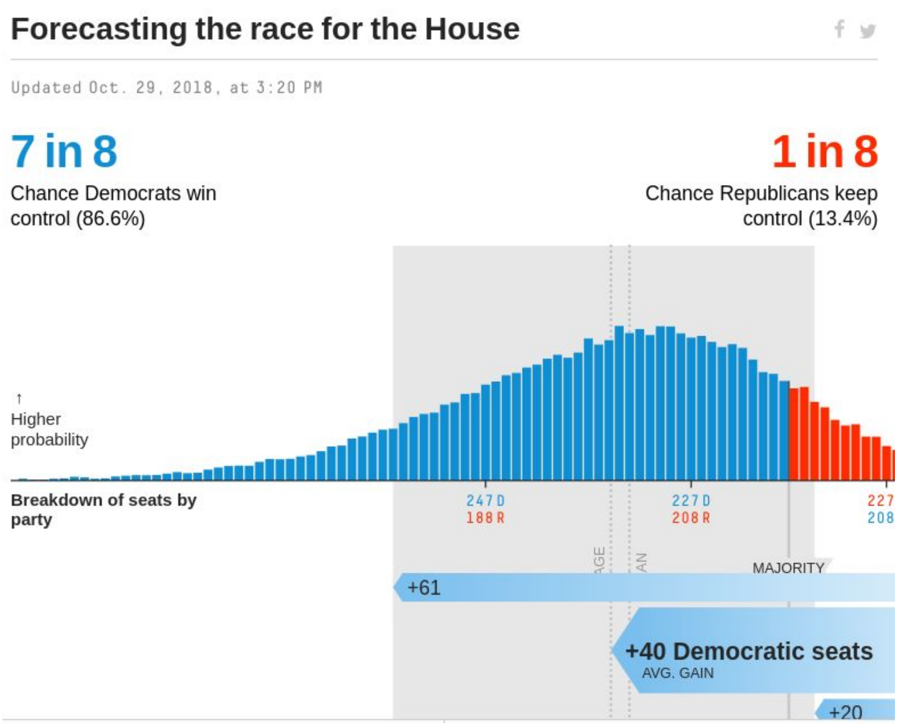
Updated Oct. 29, 2018, at 3:20 PM

**1 in 6**

Chance Democrats win control (18.0%)

**5 in 6**

Chance Republicans keep control (82.0%)



## Forecasting the race for the House

Updated Oct. 29, 2018, at 3:20 PM

**7 in 8**

Chance Democrats win control (86.6%)

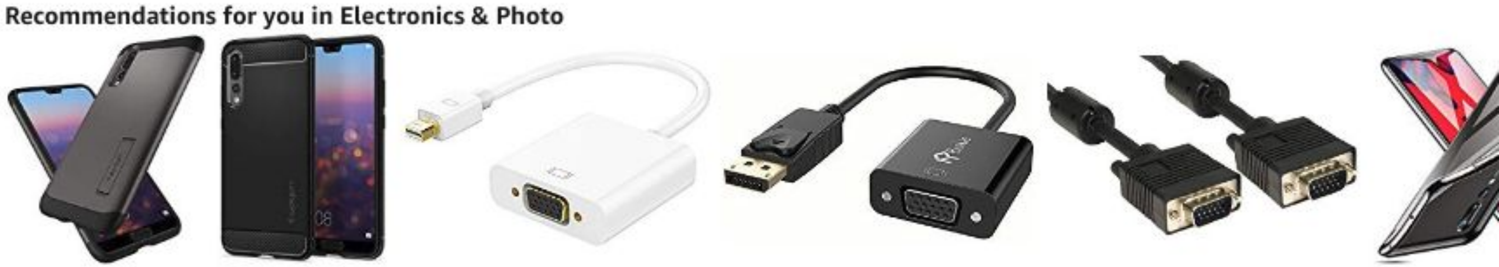
**1 in 8**

Chance Republicans keep control (13.4%)

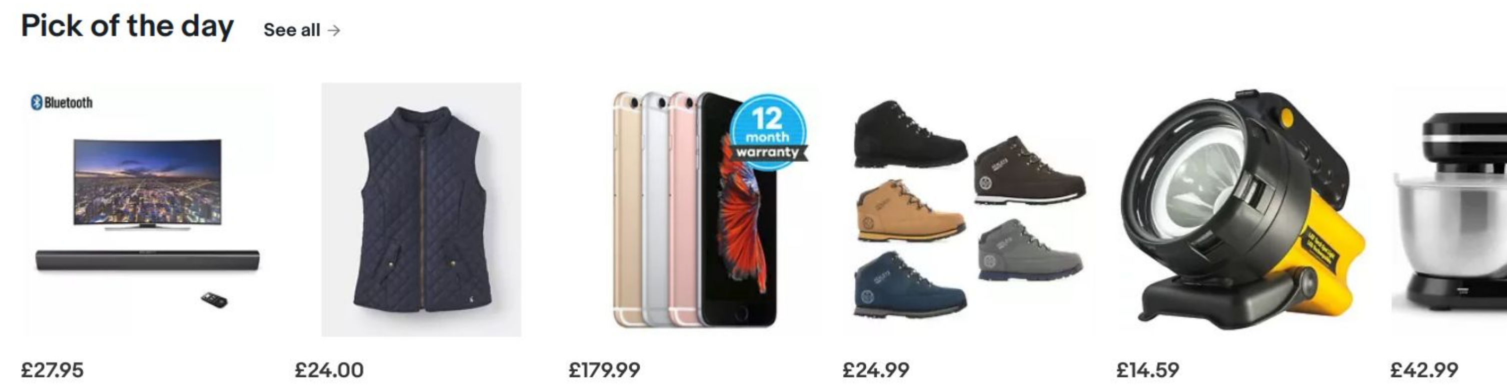
https://fivethirtyeight.com/tag/2018-election/

# Data Science in Commerce

amazon


Recommendations for you in Electronics & Photo

ebay


Pick of the day

See all →

£27.95

£24.00

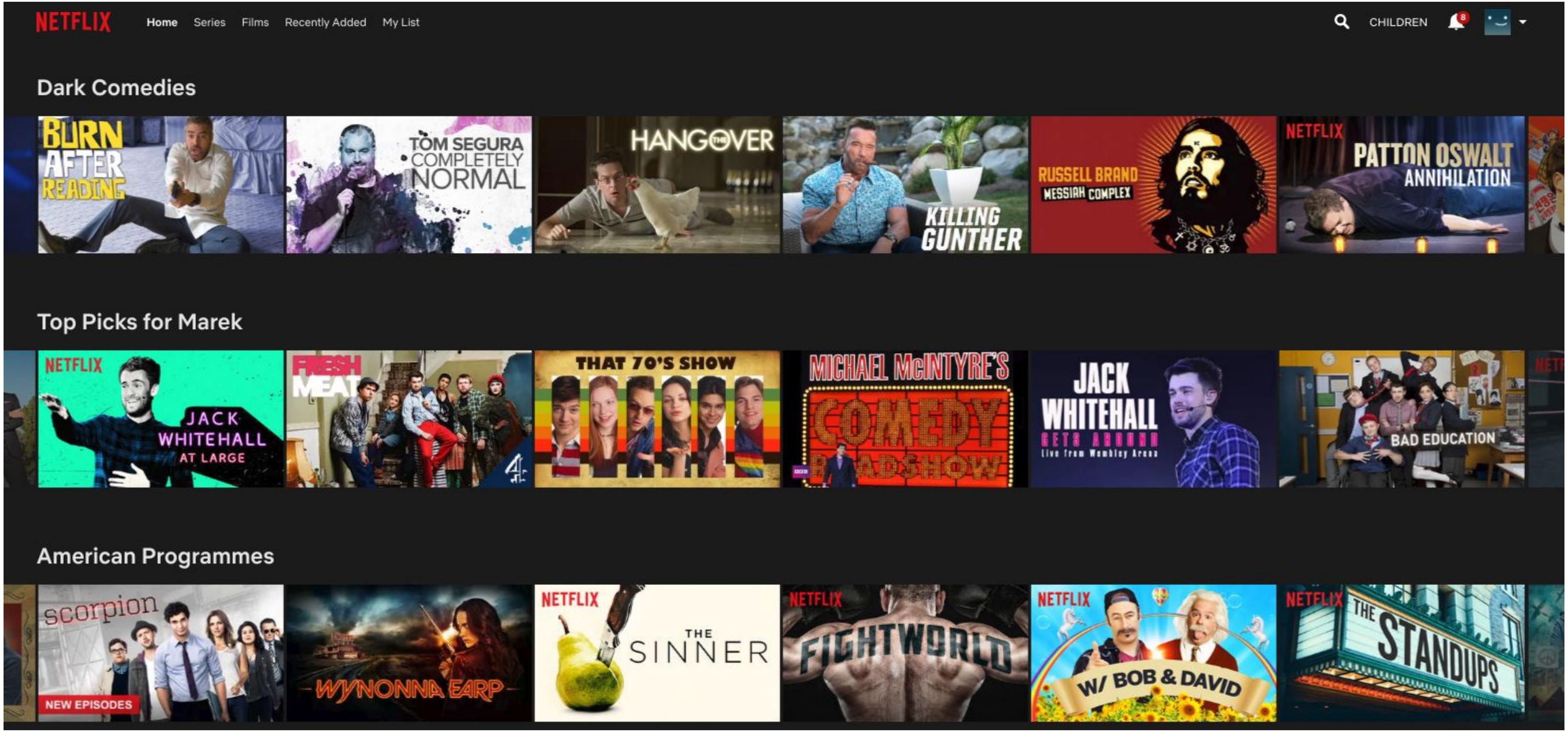
£179.99

£24.99

£14.59

£42.99

# Data Science in Commerce



# Netflix Challenge

In 2006, Netflix offered 1 million dollars for an improved movie recommendation algorithm.

Provided 100M movie ratings for training.

**The goal:** Improve over Netflix's own algorithm by 10% to get the prize.

Several teams joined up and claimed the prize on in 2009.

| movie | user | date | score |
|---|---|---|---|
| 1 | 56 | 2004-02-14 | 5 |
| 1 | 25363 | 2004-03-01 | 3 |
| 2 | 855321 | 2004-07-29 | 3 |
| 2 | 44562 | 2004-07-30 | 4 |
| 3 | 42357 | 2004-12-10 | 1 |
| 3 | 1345 | 2005-01-08 | 2 |

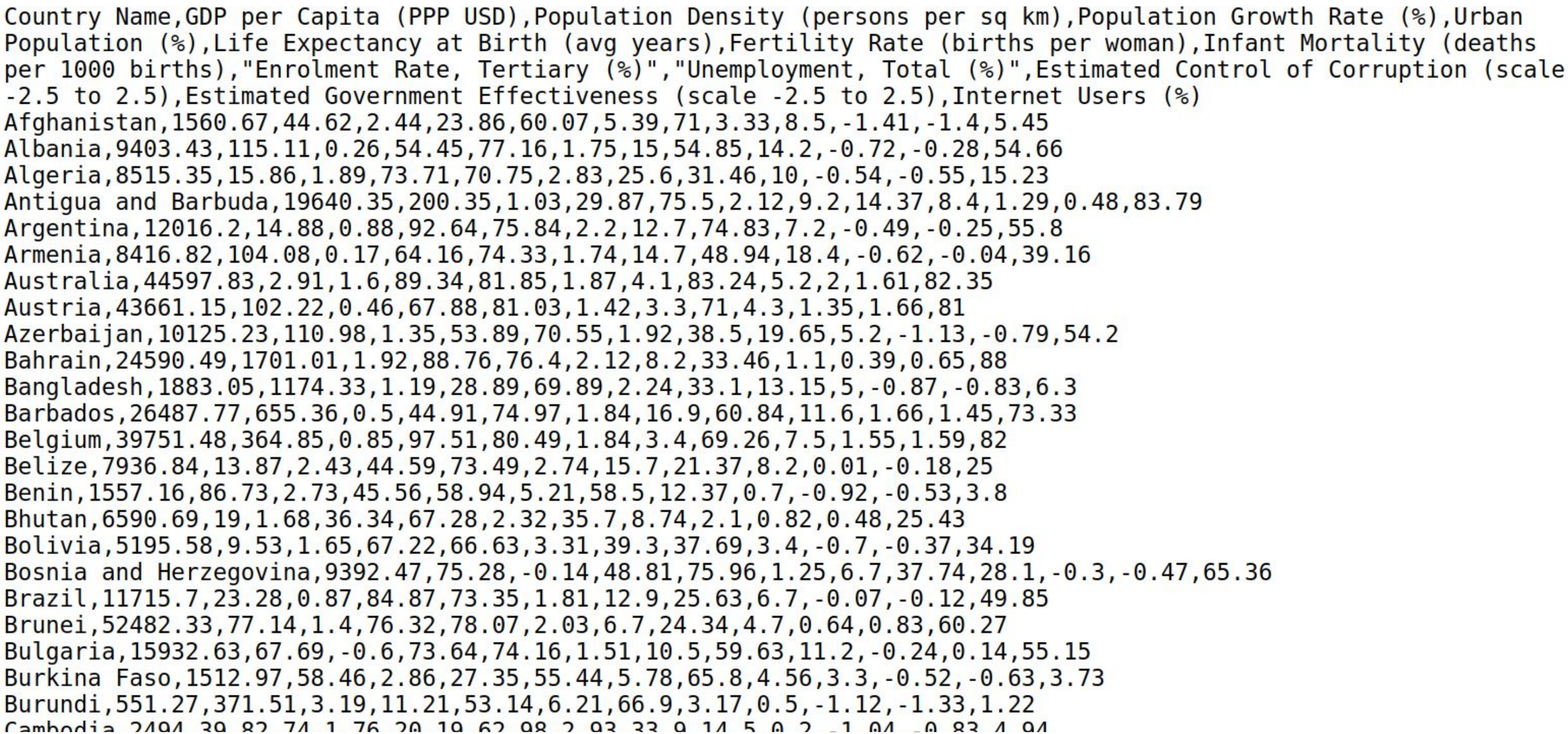
# Getting Practical

# Dataset: Country Statistics

World Bank data about 161 countries

- Country Name
- GDP per Capita (PPP USD)
- Population Density (persons per sq km)
- Population Growth Rate (%)
- Urban Population (%)
- Life Expectancy at Birth (avg years)
- Fertility Rate (births per woman)
- Infant Mortality (deaths per 1000 births)
- Enrolment Rate, Tertiary (%)
- Unemployment, Total (%)
- Estimated Control of Corruption (scale -2.5 to 2.5)
- Estimated Government Effectiveness (scale -2.5 to 2.5)
- Internet Users (%)

# Dataset: Country Statistics



```
Country Name,GDP per Capita (PPP USD),Population Density (persons per sq km),Population Growth Rate (%),Urban
Population (%),Life Expectancy at Birth (avg years),Fertility Rate (births per woman),Infant Mortality (deaths
per 1000 births),"Enrolment Rate, Tertiary (%)","Unemployment, Total (%)",Estimated Control of Corruption (scale
-2.5 to 2.5),Estimated Government Effectiveness (scale -2.5 to 2.5),Internet Users (%)
Afghanistan,1560.67,44.62,2.44,23.86,60.07,5.39,71,3.33,8.5,-1.41,-1.4,5.45
Albania,9403.43,115.11,0.26,54.45,77.16,1.75,15,54.85,14.2,-0.72,-0.28,54.66
Algeria,8515.35,15.86,1.89,73.71,70.75,2.83,25.6,31.46,10,-0.54,-0.55,15.23
Antigua and Barbuda,19640.35,200.35,1.03,29.87,75.5,2.12,9.2,14.37,8.4,1.29,0.48,83.79
Argentina,12016.2,14.88,0.88,92.64,75.84,2.2,12.7,74.83,7.2,-0.49,-0.25,55.8
Armenia,8416.82,104.08,0.17,64.16,74.33,1.74,14.7,48.94,18.4,-0.62,-0.04,39.16
Australia,44597.83,2.91,1.6,89.34,81.85,1.87,4.1,83.24,5.2,2,1.61,82.35
Austria,43661.15,102.22,0.46,67.88,81.03,1.42,3.3,71,4.3,1.35,1.66,81
Azerbaijan,10125.23,110.98,1.35,53.89,70.55,1.92,38.5,19.65,5.2,-1.13,-0.79,54.2
Bahrain,24590.49,1701.01,1.92,88.76,76.4,2.12,8.2,33.46,1.1,0.39,0.65,88
Bangladesh,1883.05,1174.33,1.19,28.89,69.89,2.24,33.1,13.15,5,-0.87,-0.83,6.3
Barbados,26487.77,655.36,0.5,44.91,74.97,1.84,16.9,60.84,11.6,1.66,1.45,73.33
Belgium,39751.48,364.85,0.85,97.51,80.49,1.84,3.4,69.26,7.5,1.55,1.59,82
Belize,7936.84,13.87,2.43,44.59,73.49,2.74,15.7,21.37,8.2,0.01,-0.18,25
Benin,1557.16,86.73,2.73,45.56,58.94,5.21,58.5,12.37,0.7,-0.92,-0.53,3.8
Bhutan,6590.69,19,1.68,36.34,67.28,2.32,35.7,8.74,2.1,0.82,0.48,25.43
Bolivia,5195.58,9.53,1.65,67.22,66.63,3.31,39.3,37.69,3.4,-0.7,-0.37,34.19
Bosnia and Herzegovina,9392.47,75.28,-0.14,48.81,75.96,1.25,6.7,37.74,28.1,-0.3,-0.47,65.36
Brazil,11715.7,23.28,0.87,84.87,73.35,1.81,12.9,25.63,6.7,-0.07,-0.12,49.85
Brunei,52482.33,77.14,1.4,76.32,78.07,2.03,6.7,24.34,4.7,0.64,0.83,60.27
Bulgaria,15932.63,67.69,-0.6,73.64,74.16,1.51,10.5,59.63,11.2,-0.24,0.14,55.15
Burkina Faso,1512.97,58.46,2.86,27.35,55.44,5.78,65.8,4.56,3.3,-0.52,-0.63,3.73
Burundi,551.27,371.51,3.19,11.21,53.14,6.21,66.9,3.17,0.5,-1.12,-1.33,1.22
Cambodia,2494.39,82.74,1.76,20.19,62.98,2.93,33.9,14.5,0.2,-1.04,-0.83,4.94
```

# Using Python. Why Python?

✓

Fast to write and modify

Great for working with datasets

Portable

Most machine learning research happens in python

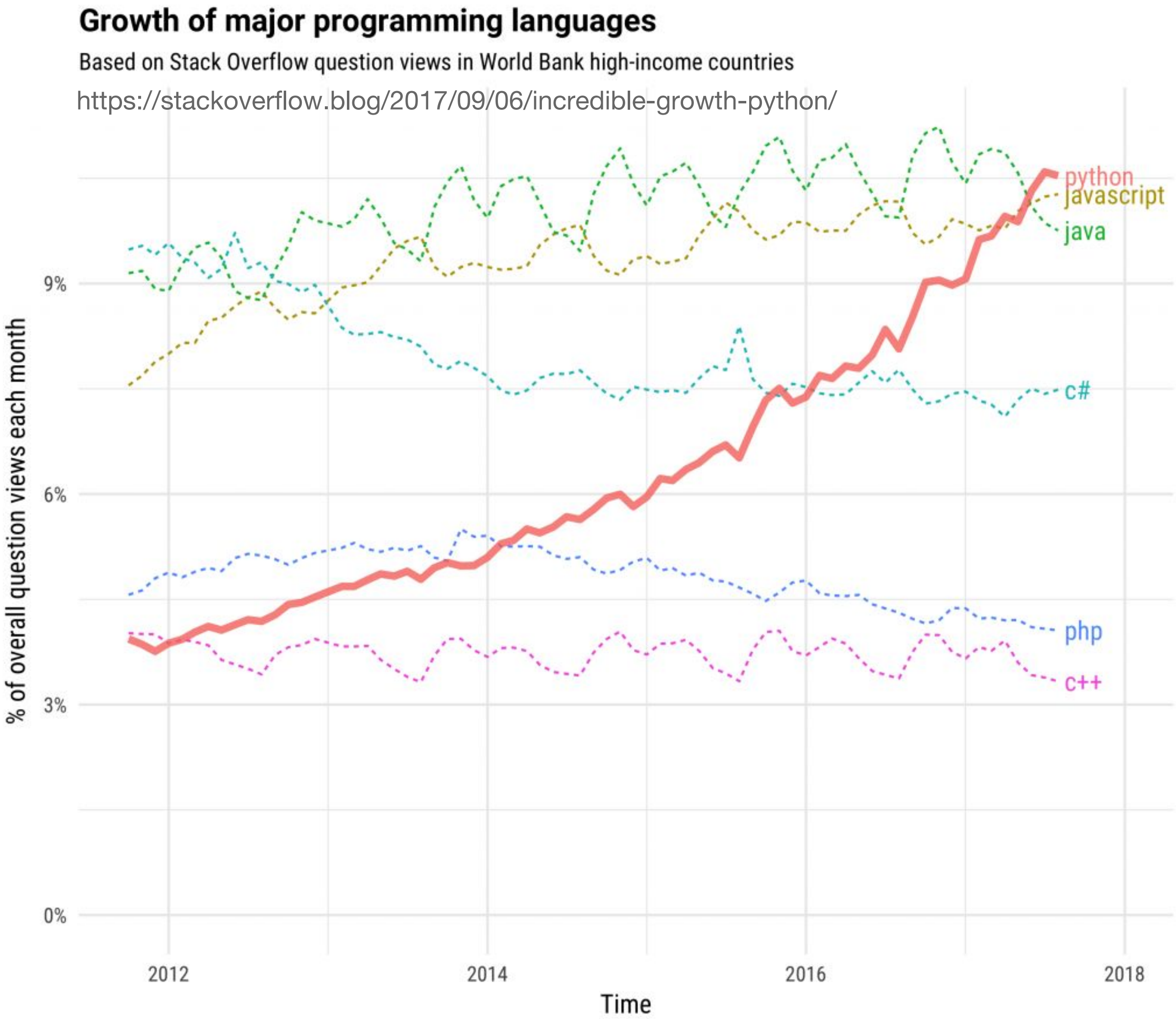
Actually useful for other things besides data science

✗

Dynamically typed (can cause run-time errors)

Not as fast as lower-level languages (sometimes)

Not good for unusual platforms

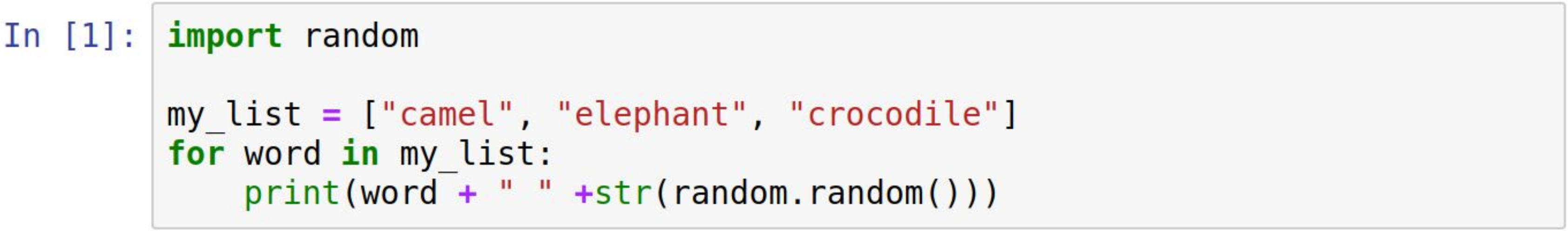


Growth of major programming languages

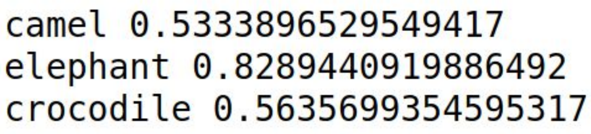
Based on Stack Overflow question views in World Bank high-income countries

https://stackoverflow.blog/2017/09/06/incredible-growth-python/

# Python Refresher



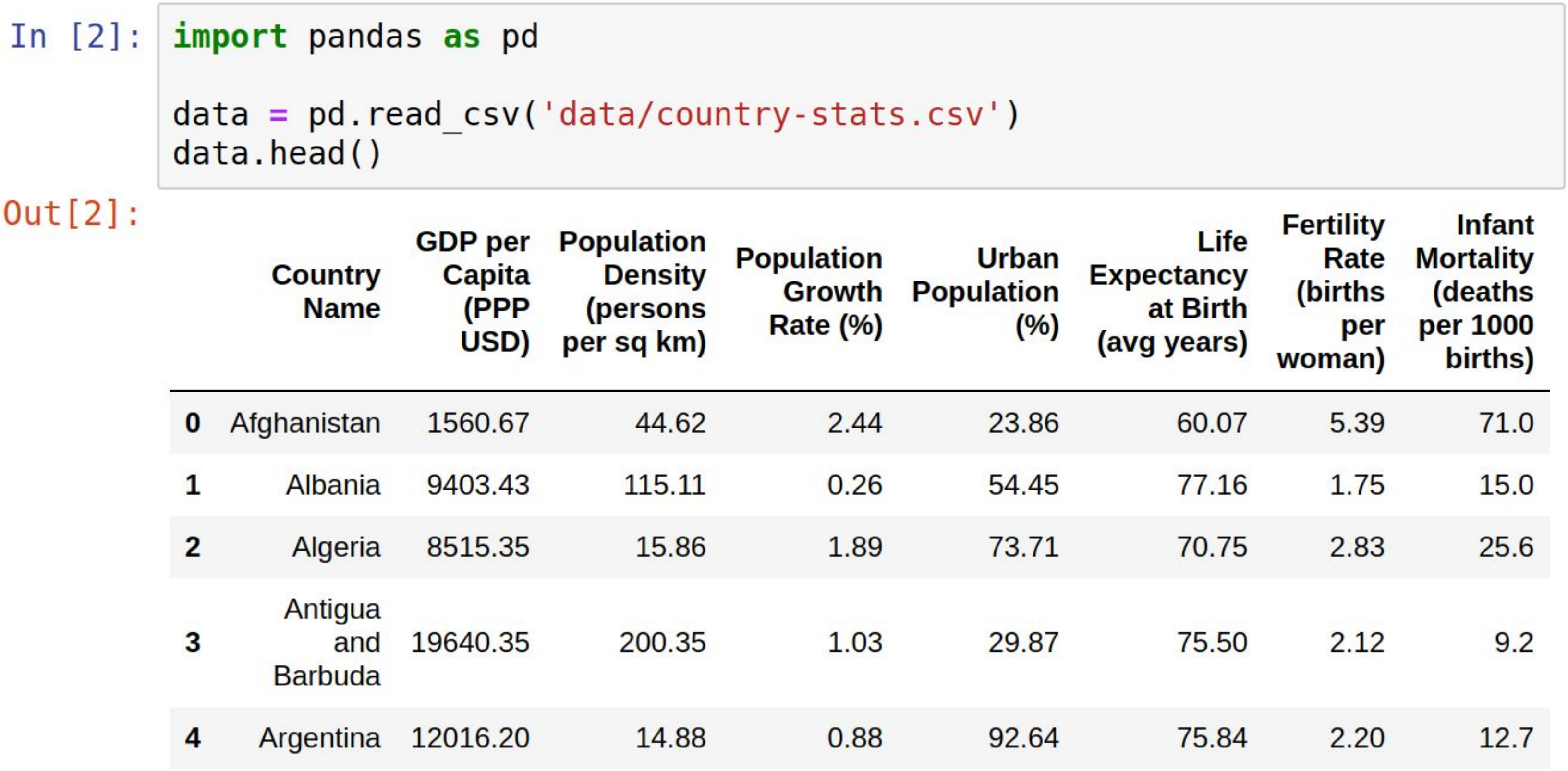
```
In [1]: import random

        my_list = ["camel", "elephant", "crocodile"]
        for word in my_list:
            print(word + " " +str(random.random()))
```



```
camel 0.5333896529549417
elephant 0.8289440919886492
crocodile 0.5635699354595317
```

Python tutorial: https://www.tutorialspoint.com/python/index.htm

# Loading CSV files



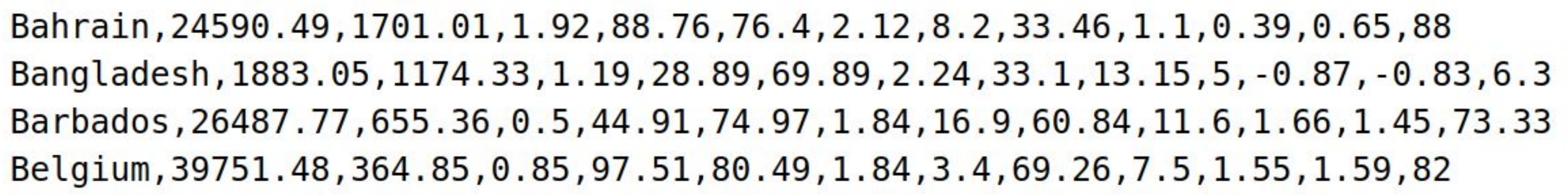
```
In [2]: import pandas as pd

        data = pd.read_csv('data/country-stats.csv')
        data.head()
```

Out[2]:

| | Country Name | GDP per Capita (PPP USD) | Population Density (persons per sq km) | Population Growth Rate (%) | Urban Population (%) | Life Expectancy at Birth (avg years) | Fertility Rate (births per woman) | Infant Mortality (deaths per 1000 births) |
|---|---|---|---|---|---|---|---|---|
| **0** | Afghanistan | 1560.67 | 44.62 | 2.44 | 23.86 | 60.07 | 5.39 | 71.0 |
| **1** | Albania | 9403.43 | 115.11 | 0.26 | 54.45 | 77.16 | 1.75 | 15.0 |
| **2** | Algeria | 8515.35 | 15.86 | 1.89 | 73.71 | 70.75 | 2.83 | 25.6 |
| **3** | Antigua and Barbuda | 19640.35 | 200.35 | 1.03 | 29.87 | 75.50 | 2.12 | 9.2 |
| **4** | Argentina | 12016.20 | 14.88 | 0.88 | 92.64 | 75.84 | 2.20 | 12.7 |

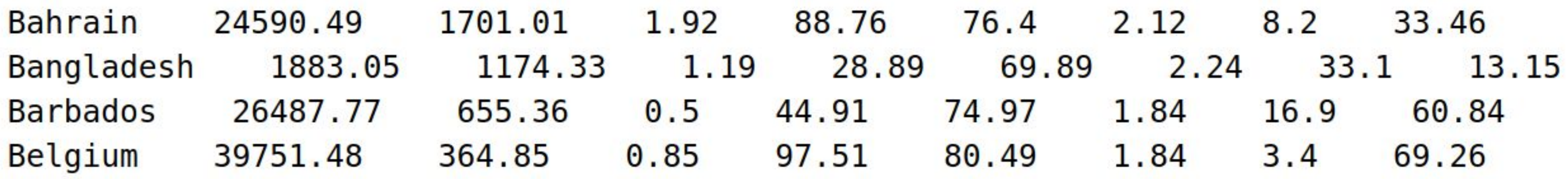
# Common File Formats

## CSV - comma-separated values



```
Bahrain,24590.49,1701.01,1.92,88.76,76.4,2.12,8.2,33.46,1.1,0.39,0.65,88
Bangladesh,1883.05,1174.33,1.19,28.89,69.89,2.24,33.1,13.15,5,-0.87,-0.83,6.3
Barbados,26487.77,655.36,0.5,44.91,74.97,1.84,16.9,60.84,11.6,1.66,1.45,73.33
Belgium,39751.48,364.85,0.85,97.51,80.49,1.84,3.4,69.26,7.5,1.55,1.59,82
```

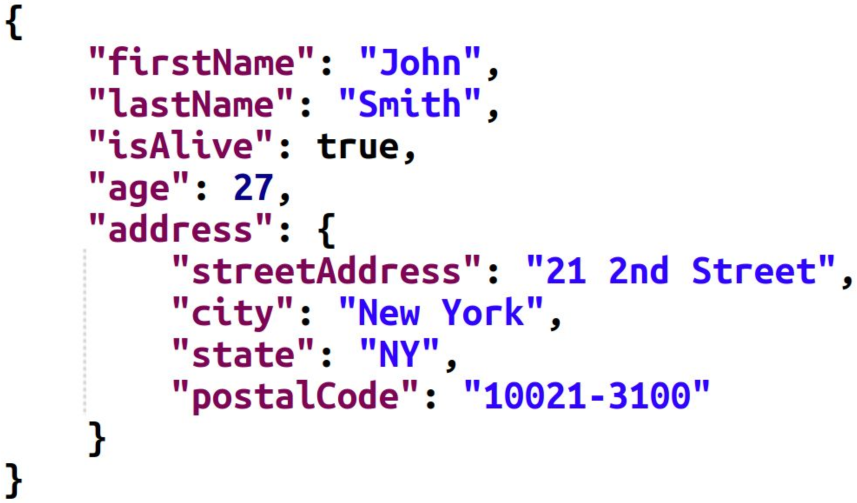
## TSV - tab-separated values



```
Bahrain    24590.49    1701.01    1.92    88.76    76.4    2.12    8.2     33.46
Bangladesh    1883.05    1174.33    1.19    28.89    69.89    2.24    33.1    13.15
Barbados    26487.77    655.36    0.5    44.91    74.97    1.84    16.9    60.84
Belgium    39751.48    364.85    0.85    97.51    80.49    1.84    3.4     69.26
```

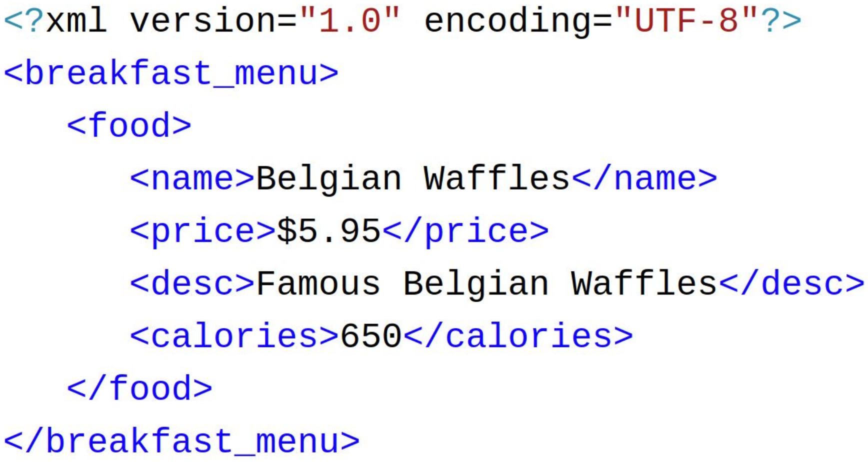
# Common File Formats

## JSON:
## JavaScript Object Notation



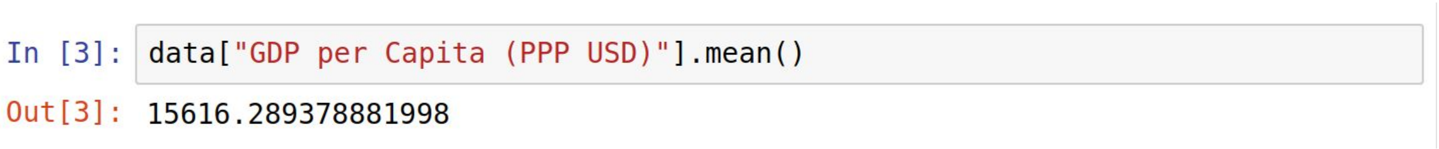
```
{
    "firstName": "John",
    "lastName": "Smith",
    "isAlive": true,
    "age": 27,
    "address": {
        "streetAddress": "21 2nd Street",
        "city": "New York",
        "state": "NY",
        "postalCode": "10021-3100"
    }
}
```

## XML:
## Extensible Markup Language

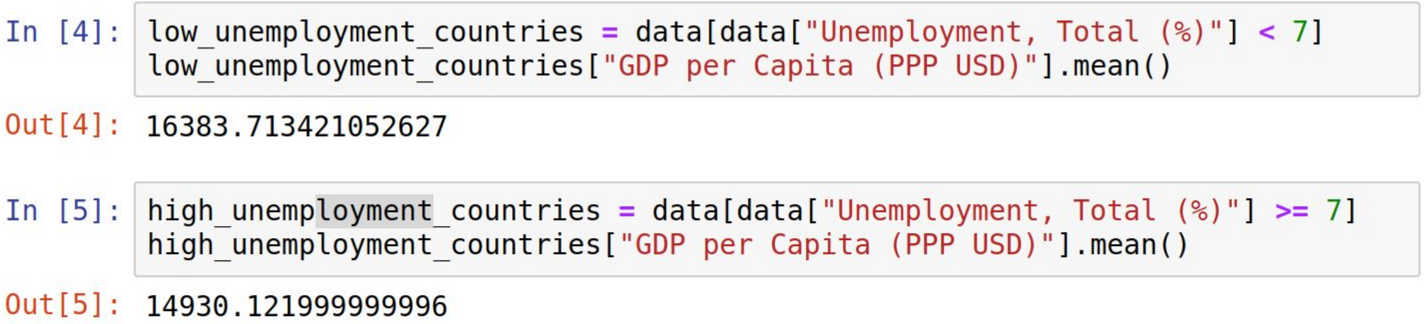


```
<?xml version="1.0" encoding="UTF-8"?>
<breakfast_menu>
   <food>
      <name>Belgian Waffles</name>
      <price>$5.95</price>
      <desc>Famous Belgian Waffles</desc>
      <calories>650</calories>
   </food>
</breakfast_menu>
```

# Calculating Statistics over the Data

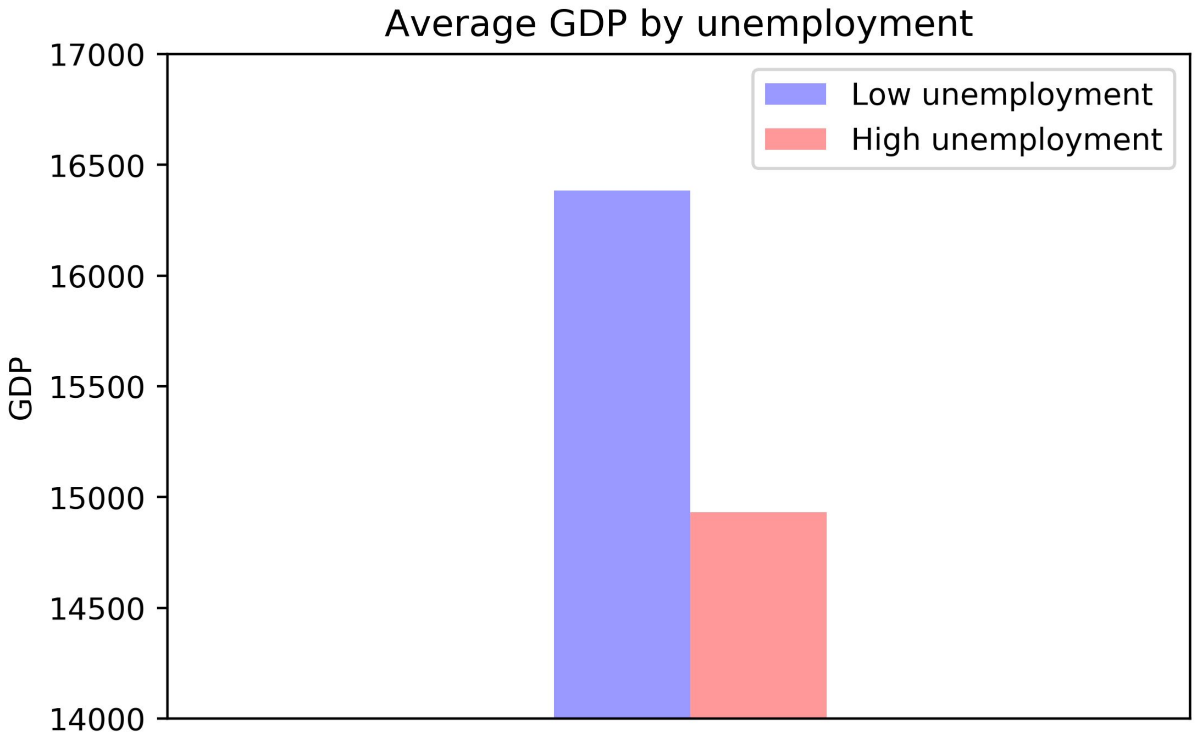


```
In [3]:  data["GDP per Capita (PPP USD)"].mean()

Out[3]:  15616.289378881998
```

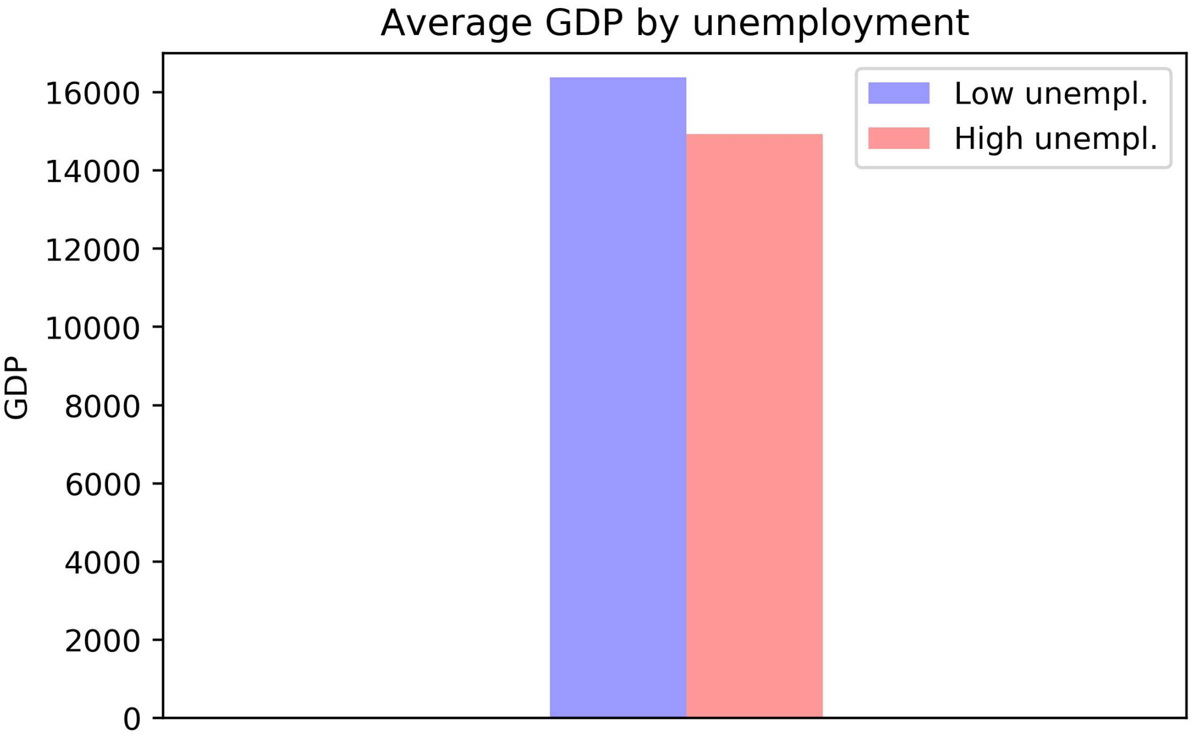


```
In [4]:  low_unemployment_countries = data[data["Unemployment, Total (%)"] < 7]
         low_unemployment_countries["GDP per Capita (PPP USD)"].mean()

Out[4]:  16383.713421052627

In [5]:  high_unemployment_countries = data[data["Unemployment, Total (%)"] >= 7]
         high_unemployment_countries["GDP per Capita (PPP USD)"].mean()

Out[5]:  14930.121999999996
```

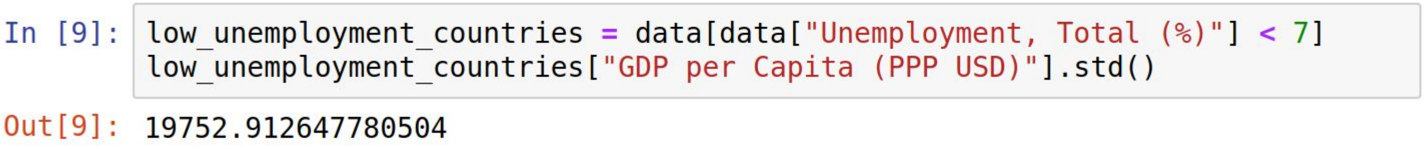
# Calculating Statistics over the Data



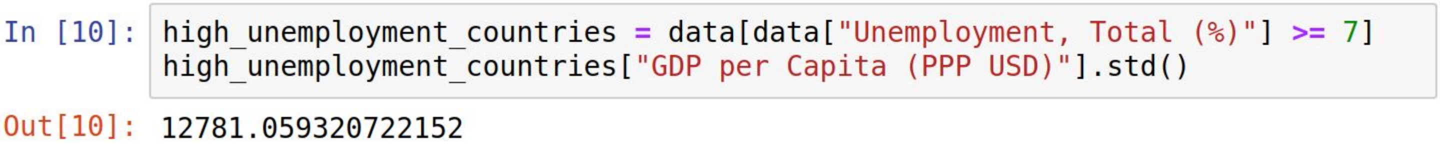
# Calculating Statistics over the Data



# Calculating Statistics over the Data

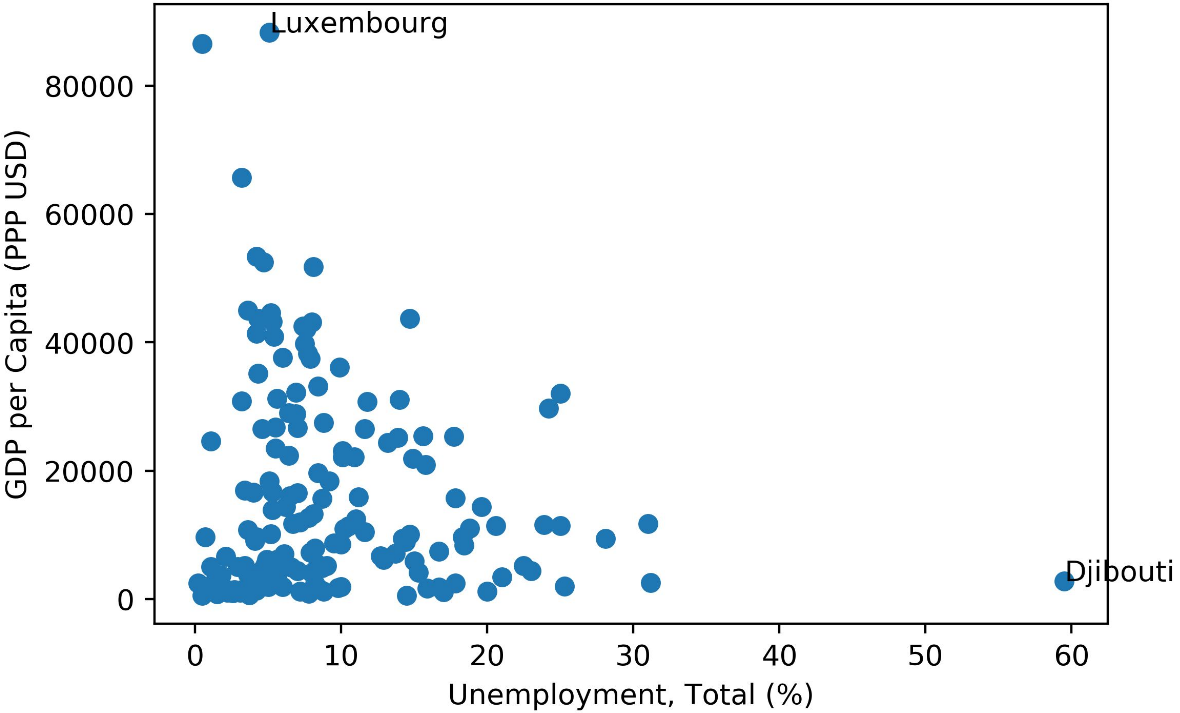


```
In [9]:  low_unemployment_countries = data[data["Unemployment, Total (%)"] < 7]
          low_unemployment_countries["GDP per Capita (PPP USD)"].std()

Out[9]:  19752.912647780504
```



```
In [10]:  high_unemployment_countries = data[data["Unemployment, Total (%)"] >= 7]
           high_unemployment_countries["GDP per Capita (PPP USD)"].std()

Out[10]:  12781.059320722152
```

# Calculating Statistics over the Data



# Course Logistics

# Course Objectives

Focusing on the practical aspects of data science

After this course you should be able to

1. Understand the principles of data science
2. Use the necessary software tools for data processing, statistics and machine learning
3. Visualize data, both for exploration and presentation
4. Rigorously analyze your data using a variety of approaches

# Course Format

8 lectures

4 practicals

Assessment

- 20% from practicals (5% for each tick)
- 80% from take-home assignment

Final assignment

- Practical exercise
- Given out at the last lecture
- Submit a report
- The report will be marked by two assessors

# Course Syllabus

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|---|---|
| 1. Introduction | Friday, 2 November |
| 2. Linear Regression | Monday, 5 November |
| 3. **Practical:** Linear Regression | Wednesday, 7 November |
| 4. Classification | Friday, 9 November |
| 5. **Practical:** Classification | Monday, 12 November |
| 6. Deep Learning, part I | Wednesday, 14 November |
| 7. Deep Learning, part II | Friday, 16 November |
| 8. **Practical:** Deep Learning | Monday, 19 November |
| 9. Visualization, part I | Wednesday, 21 November |
| 10. Visualization, part II | Friday, 23 November |
| 11. **Practical:** Visualization | Monday, 26 November |
| 12. Challenges in Data Science | Wednesday, 28 November |

# Lecturers

**Marek Rei**
mr472

**Ekaterina Kochmar**
ek358

**Damon Wischik**
djw1005

**Ted Briscoe**
ejb1

# Course Pages

Course homepage: https://www.cl.cam.ac.uk/teaching/1819/DataSciII/

Azure Notebooks: https://notebooks.azure.com/marekrei/libraries/cl-datasci-pnp

Getting started with Azure Notebooks:
https://cldatascipnp-marekrei.notebooks.azure.com/j/notebooks/getting-started.ipynb

Github: https://github.com/marekrei/cl-datasci-pnp