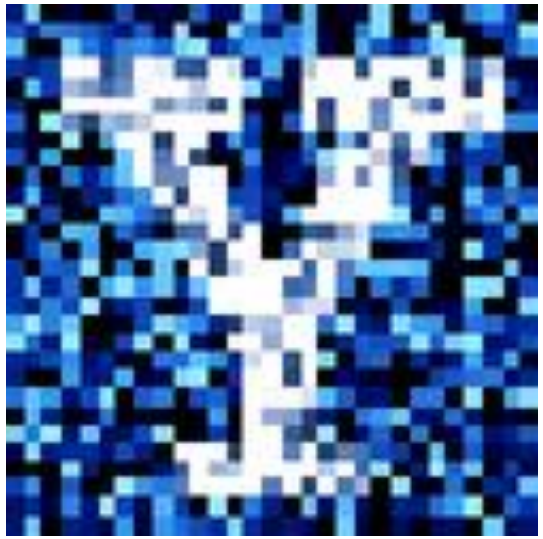
# YData: Introduction to Data Science



## Class 01: Introduction

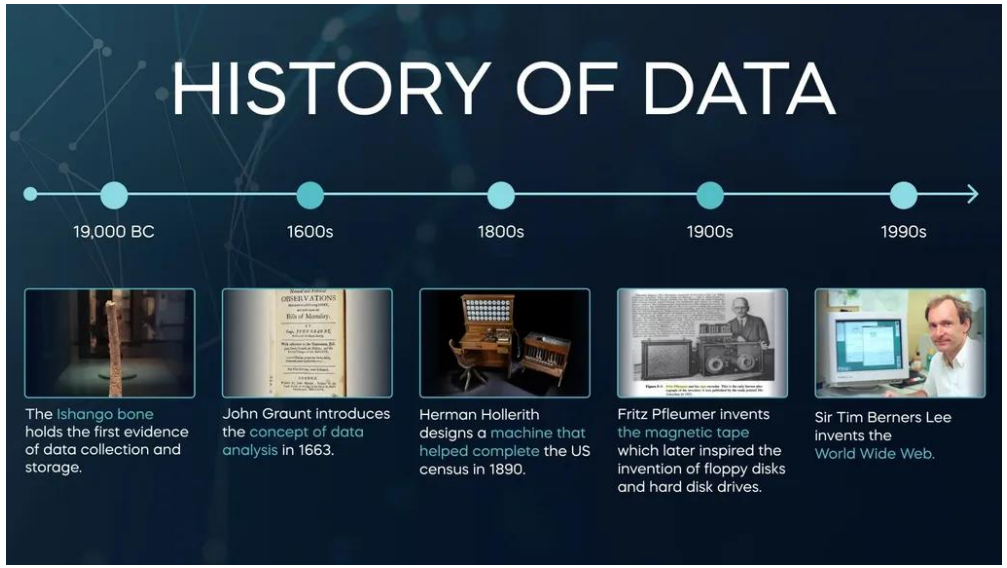
# Overview

Course overview

- Introductions
- Syllabus and logistics

What is data science?

- Brief history of data science



# Office hours and contact information

Ethan Meyers (he/him)

Email: ethan.meyers@yale.edu

Office hours:

- Mondays and Wednesdays, 3-4pm
  - (subject to change)

Office: Kline Tower, room 1253

- https://yale.zoom.us/j/99249012912

# Teaching Assistants

Preceptor

- Shivam Sharma: shivam.sharma@yale.edu

Teaching Fellows

- TBD

Undergraduate Learning Assistants

- Kyle Levesque: kyle.levesque@yale.edu
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- Sloane Huey: sloane.huey@yale.edu
- Christian Baca: christian.baca@yale.edu


TA office hours are on the calendar on Canvas

# Introductions

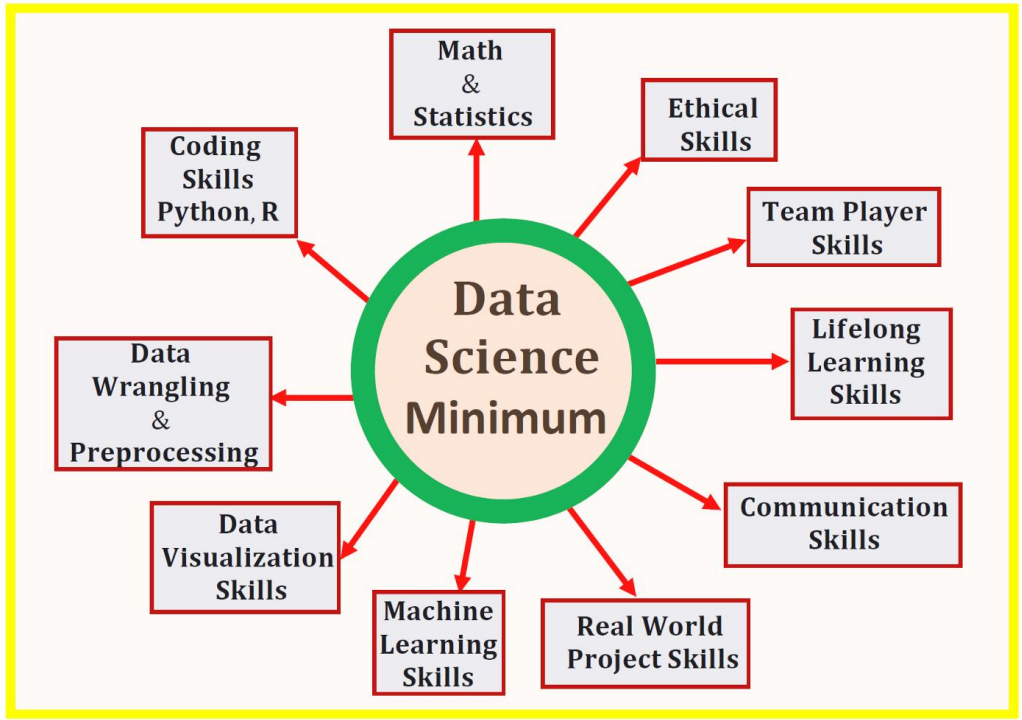
Let’s do some quick introductions

Create groups of 3-4 people:

- Your name and preferred gender pronouns
- Your major/grad dept  (research area)
- Why you are interested in this class
- Anything else you would like to share with your group

# About this class

# Topics covered




What is Data Science?

Python basics

Descriptive statistics

Array computations

Manipulating data tables

Data visualization

Mapping

Text manipulation and data cleaning

Statistical perspective: hypothesis tests and confidence intervals

Machine learning perspective: supervised and unsupervised learning

# Tentative plan for the semester: subject to change!

| Week | Date | Topic | HW Assigned | HW Due |
|---|---|---|---|---|
| 1 | Aug 28 | Class overview | 0 | |
| 2 | Sep 2-4 | Introduction to Python | 1 | 7-Sep |
| 3 | Sep 9-11 | Descriptive statistics and plots | 2 | 14-Sep |
| 4 | Sep 16-18 | Array computations | 3 | 21-Sep |
| 5 | Sep 23-25 | Tables and data manipulation | 4 | 28-Sep |
| 6 | Sep 30, Oct 2 | Data visualization | 5 | 5-Oct |
| 7 | Oct 7-9 | Review and midterm exam | | |
| 8 | Oct 14 | Interactive graphics | | |
| | Oct 15 | October break | | |
| 9 | Oct 21-23 | Mapping and writing functions | 6 | 26-Oct |
| 10 | Oct 28-30 | Intro to statistical inference and hypothesis tests | 7 | 2-Nov |
| 11 | Nov 4-6 | Hypothesis tests continued and confidence intervals | 8 | 9-Nov |
| 12 | Nov 11-13 | Machine learning: classification | Draft of final project | 16-Nov |
| 13 | Nov 18-20 | Machine learning: regression and unsupervised learning | 9 | 30-Nov |
| | Nov 26-28 | November recess | | |
| | Dec 2-4 | Ethics and odds and ends | Final project | 7-Dec |
| Final exam | Dec 17 (Wed) 2pm | In person final exam | | |

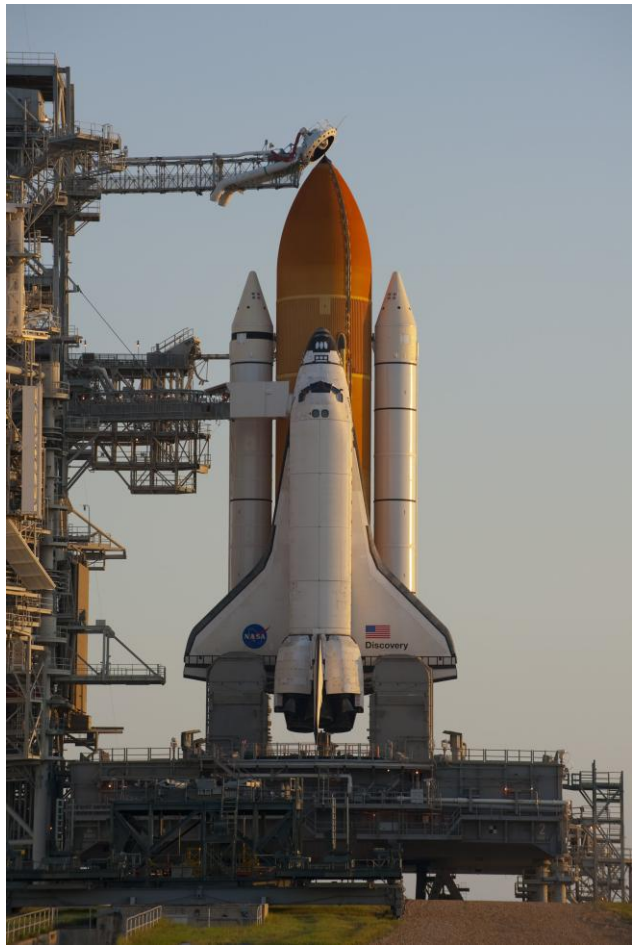
# Learning goals

1. Understand concepts in data science
    - Learn basic computational skills for analyzing data
    - Understand concepts in statistics and machine learning

2. Gain practical data science skills applicable to any domain

3. See how data science analyses can be applied to real-world data from a variety of domains
    - There will be ~weekly readings on data science related topics

There are no prerequisites for this class
    - E.g., no prior knowledge of statistics or programming is required



# Course structure

Two lectures per week

Weekly Python practice sessions (optional)

Weekly homework assignments

A class project

Weekly drop-in office hours to get help on homework (see Canvas)

Midterm and final exam

# Python practice sessions


Shivam is hosting one-hour practice sessions each week

- Each session will be offered at several different times each week
- Please fill in class survey to let us know what times work for you

Sessions will be a great opportunity to practice Python and get your questions answered!

Highly recommended to attend these sessions

- Attendance is optional
- If you score below a median cutoff score on the exams, a point will be added to your score for each weekly practice session you attend (up to 5 points)

# Class readings

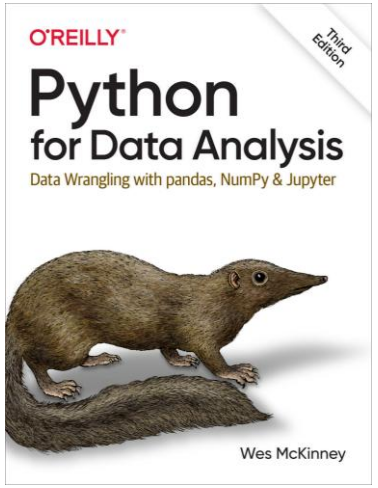
There will be short readings on data science topics approximately every week

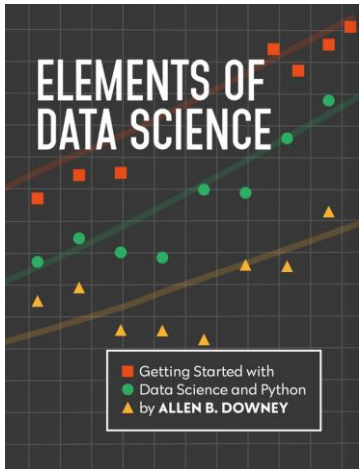
- Links to the readings will be on the homework

Readings will also be taken from:

- Brett M (2020). Data Science for Everyone: course text
- McKinney (2022). Python for Data Analysis, 3E
- Downey (2024). Elements of Data Science
- Other sources posted to Canvas/on the Internet

Resources related to programming will also be posted on Canvas under the appropriate class



# Assignments and grades

1. Homework problem sets (48%)
   - Exploring concepts and analyzing data using Python
   - Weekly:  9 in total

## Homework policies

- You may discuss questions with other but the work you turn in must be your own!
- Homework released by class on Tuesdays and are due at 11pm on Sundays
  - (with a 59 minute grace period)
- Late homework (90%) credit if turned in by 11pm on Monday
  - For any other extensions a Deans Excuse is needed
- Lowest scoring homework will be dropped

# A typical homework assignment

## 3. Basic statistics: Differences between Universities

**Question 3.1 (8 points)** Suppose you'd like to *quantify* how *dissimilar* two universities are, using three quantitative characteristics. The US Department of Education data on Yale and Cal describes the following three traits (among many others):

| Trait | Yale | Cal |
|---|---|---|
| Average annual cost to attend ($) | 16,341 | 15,240 |
| Graduation rate (percentage) | 97 | 94 |
| Socioeconomic Diversity (percentage) | 20 | 23 |

You decide to define the dissimilarity between two universities as the maximum of the absolute values of the 3 differences in their respective trait values.

Using this method, compute the dissimilarity between Yale and CAL. Name the result `dissimilarity`. Use a single expression (a single line of code) to compute the answer. Let Python perform all the arithmetic (like subtracting 97 from 93) rather than simplifying the expression yourself. Be sure that the final answer is printed out in the .pdf file you upload to show that you have the correct answer.

Hint: The built-in `abs()` function takes absolute values.

```
dissimilarity = ...
```

# Assignments and grades

2. Project (10%)
   - A draft of your class project is due 2/3$^{rds}$ of the way through the semester
   - You will give and receive feedback from your peers
   - Final version of the project will be turned in at the end of the semester

3. Exams (40% total)
   - Midterm: October 9$^{th}$ during the regular class time (15%)
   - Final Exam: Monday December 17$^{th}$ at 2pm (25%)
   - **To take the class you must be able to attend these exams at their scheduled times!**

4. Participation (2%)
   - Active asking and answering questions on Ed Discussions

# Grade distribution

Grade cut-off are

- A [94-100],  A- [90-94), B+ [87-90), B [80-84), etc.
  - I might slightly modify these downward if the class too hard

No strict grade distribution but roughly:

- 25% A, 25% A-, 25% B+, 25% everything else

Students generally score high on the homework  (> 90) and exam scores tend to be lower (~80)

If an exam is too hard, I sometimes curve them by adding "free points"

- E.g., if an exam is out of 85 points, I might add a free 15 bonus points so the exam is out of 100

**Please focus on learning rather than on grades!**

# Accommodations and Academic honesty

**Accommodation**: please let me know if you have accommodations for homework and/or exams

Plagiarism/cheating

- Yale's Academic Integrity Statement

You are allowed to talk with others about the homework, but the work you turn in must be your own

- Do not share answers
- Do not copy answers off the Internet
- Do not look at past year's homework

# ChatGPT and other LLMs

You can use LLMs as a reference

- E.g., "What is the function to do x?"
  - i.e., ok to use it like Google/Stack Overflow

**Do not use it to answer homework questions**

- i.e., do not type a homework question into ChatGPT
- Do not have it complete code you started writing

If it appears your homework answers were generated by ChatGPT or another LLM (Claude, Gemini, etc.) you will be referred Yale Executive Committee

- Also, if you cheat on the homework you will do very poorly on the exams

# Running Jupyter Notebooks


In order to do the homework, you will need to be able to run Jupyter Notebooks

The strongly preferred way to do this is to use the [YCRC Jupyter server]


Homework 0 allows you to test that you have a working Jupyter Notebook environment

- Homework 0 is not turned in, but please try it soon
- Ask questions on **Ed Discussions** or go to office hours to get help


# Class survey

In order to get to know you and to adjust the class to everyone's interests, please fill out the class survey on canvas

- Under the Quizzes link on the left

Any questions about the class logistics???

- Ask on Ed Discussions!

# Let's test the YCRC Jupyter notebook server…

Before we get started, let's test the YCRC Jupyter notebook server

A link to the server is at the top of the class Canvas page

**If you can’t log in, let us know on the background survey…**

Shivam will contact the YCRC and have you added to the server

# What is Data Science?

# Brief history of Data Science: data

The first data we know of:

- The **Ishango bone** is a bone tool and possible mathematical device discovered at in the Democratic Republic of Congo
- Believed to about 20,000 years old

Cuneiform tablets from Uruk, a Mesopotamian settlement 5,000 years old contained transaction data on commodities

# Brief history of Data Science: demography and probability

John Graunt (1620-1674) develops statistical census methods that provided a framework for modern demography. He is credited with producing the first life table, giving probabilities of survival to each age


The mathematics of probability began to be developed in Europe starting in the 17th century

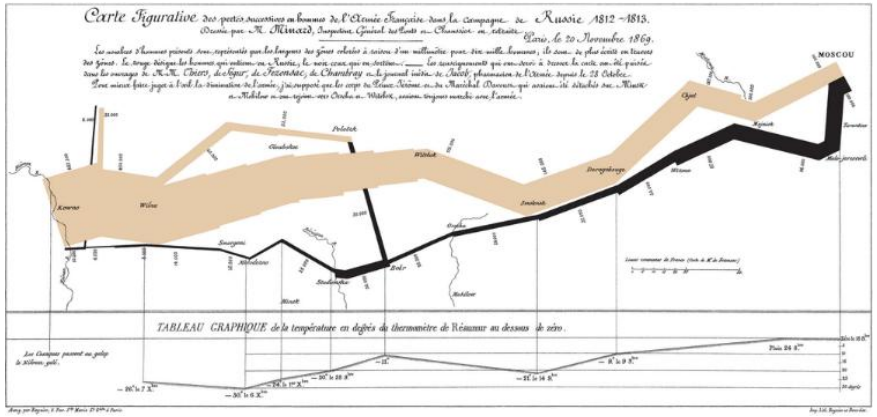
- Fermat and Pascal (1654), Bernoulli (1713), De Moivre (1718), Gauss and Laplace (1812)

# Brief history of Data Science: visualization and math

In the second half of the 19th century:

1. The field of Statistics uses probability models to analyze data

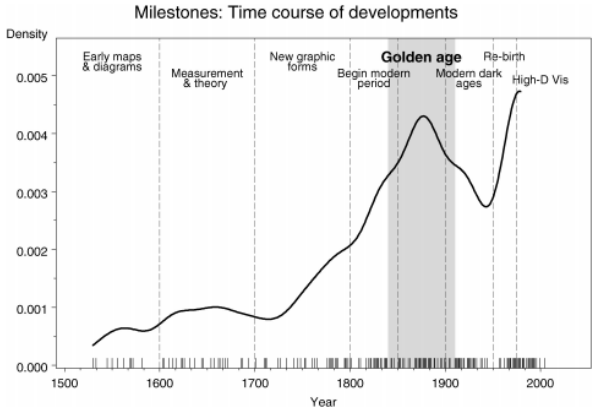
2. Elaborate visualizations of data were published

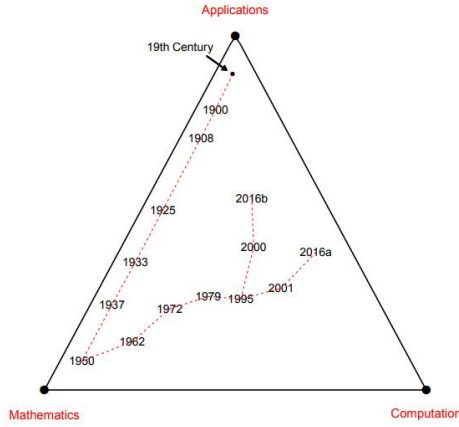



**Probability models dominate Statistics in the 20th century**

Experimental data becomes dominant in the science and medicine in the second half of the 20th century

- E.g., Randomized Controlled Trials in Medicine

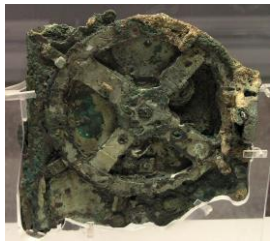


# Brief history of Data Science: the rise of computers

Early computational devices include:

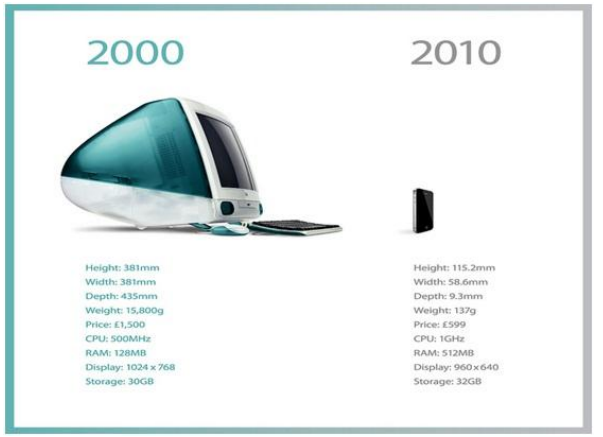
- The abacus comes from Babylon in 2400 BCE
- Antikythera mechanism (~100 BCE) is an ancient Greek hand-powered device used to predict astronomical positions



Herman Hollerith develops the Hollerith Tabulating Machine for the 1890 census (reduces 10 years of work to 3 months). Creates IBM


Computer technology develops rapidly in the second half of the 20th century

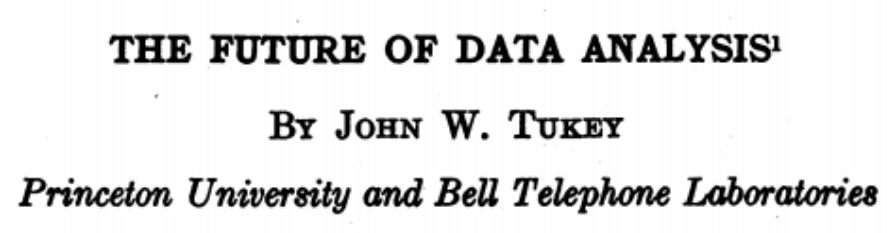
| | |
|---|---|
| 1940's | Mainframe computers |
| 1970's | Relational databases |
| 1980's | Personal computers |
| 1989 | The world wide web |
| 2007 | iPhone |



# Brief history of Data Science: the rise of Data Science

The rise of powerful computers and plentiful data has given rise to new approaches to analyzing data

- John Tukey (1962) looks for a broadening of data analysis beyond mathematics
- Breiman (2001) describes a mathematical modeling culture and algorithmic culture
- The term "Data Science" starts being used in the 2000's to describe computational approaches to analyzing data
  - E.g., Cleveland 2001



THE FUTURE OF DATA ANALYSIS[1]

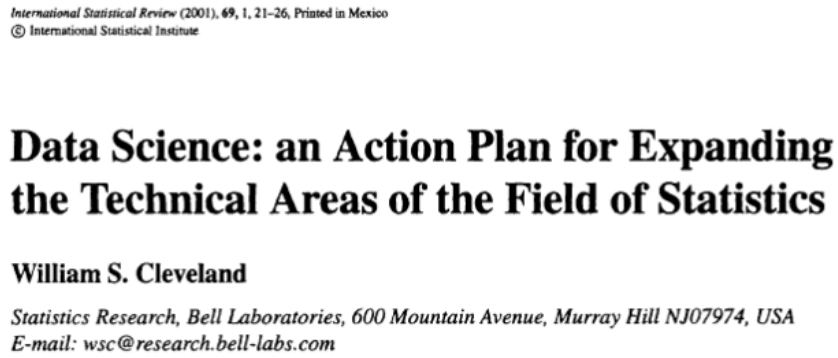
BY JOHN W. TUKEY

*Princeton University and Bell Telephone Laboratories*

*Statistical Science*
2001, Vol. 16, No. 3, 199–231

**Statistical Modeling: The Two Cultures**

Leo Breiman



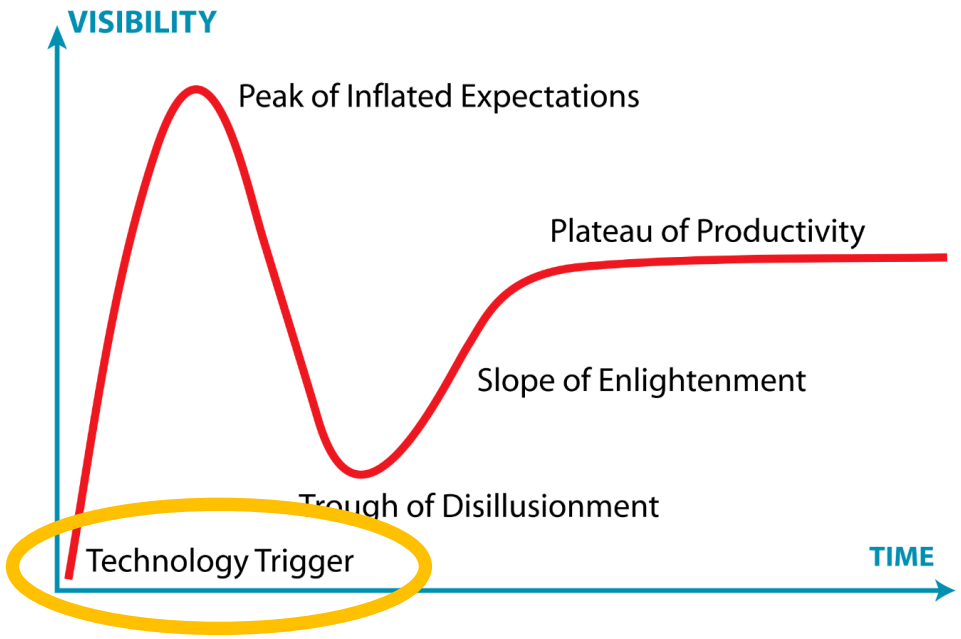
*International Statistical Review* (2001), 69, 1, 21–26, Printed in Mexico
© International Statistical Institute

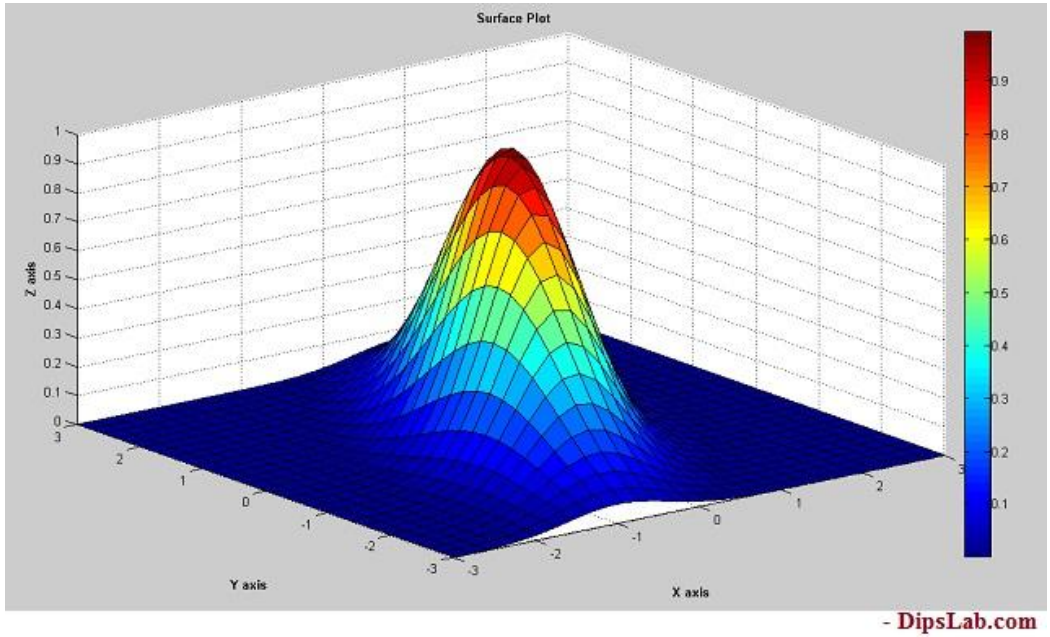
**Data Science: an Action Plan for Expanding the Technical Areas of the Field of Statistics**

William S. Cleveland

*Statistics Research, Bell Laboratories, 600 Mountain Avenue, Murray Hill NJ07974, USA*
*E-mail: wsc@research.bell-labs.com*

# Brief history of Data Science: Technology Trigger



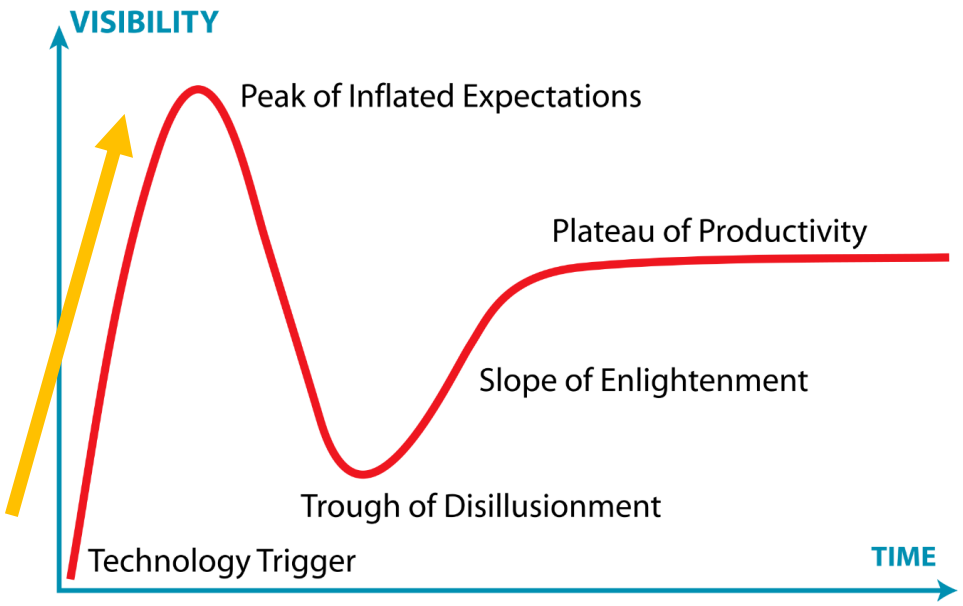




Early 2000's rise of the internet, personal computers and data analysis programming languages changes how data can be analyzed

- MATLAB
- Python: matplotlib 2003, numpy 2005, scikit-learn 2007, pandas 2009

From Downey 2024

# Brief history of Data Science




2009


Data Science rises with data science competitions, blog posts, and industry jobs

- Data Scientists viewed as “unicorns” because they had to know both statistics and how to program

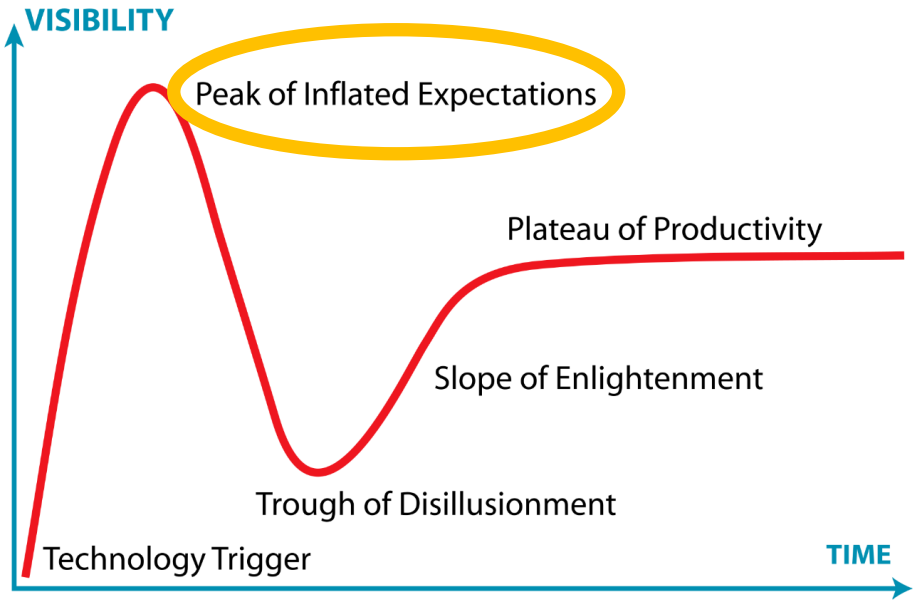
2010

kaggle

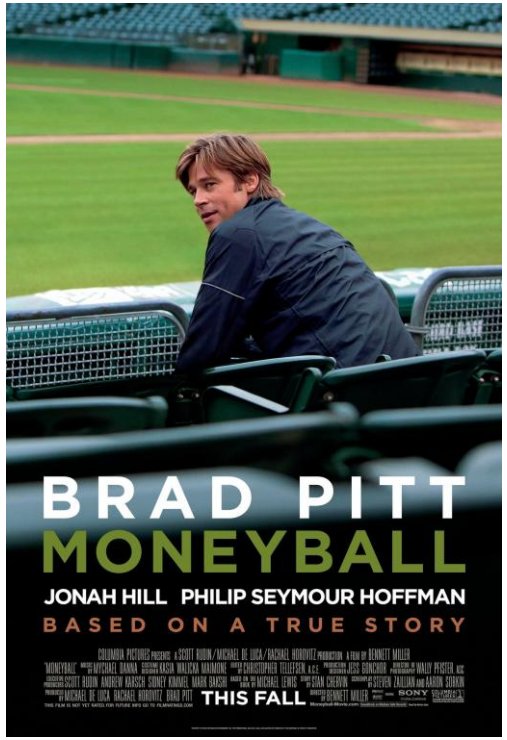
Blog: 2009-2010

okcupid

# Brief history of Data Science



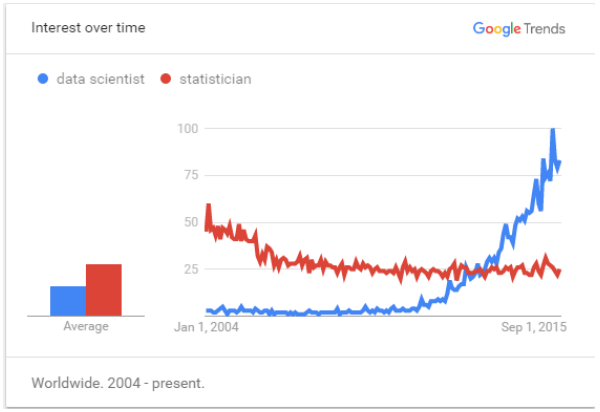

2011



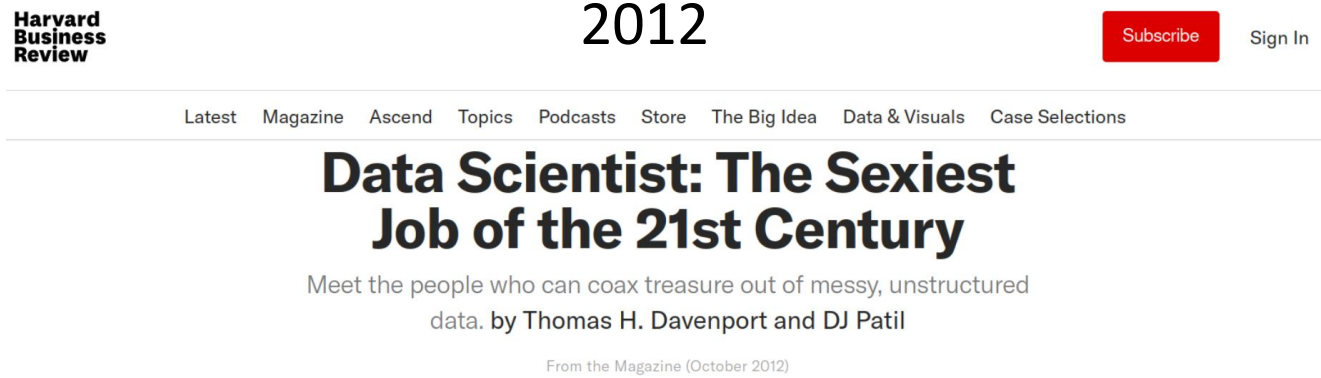

2012



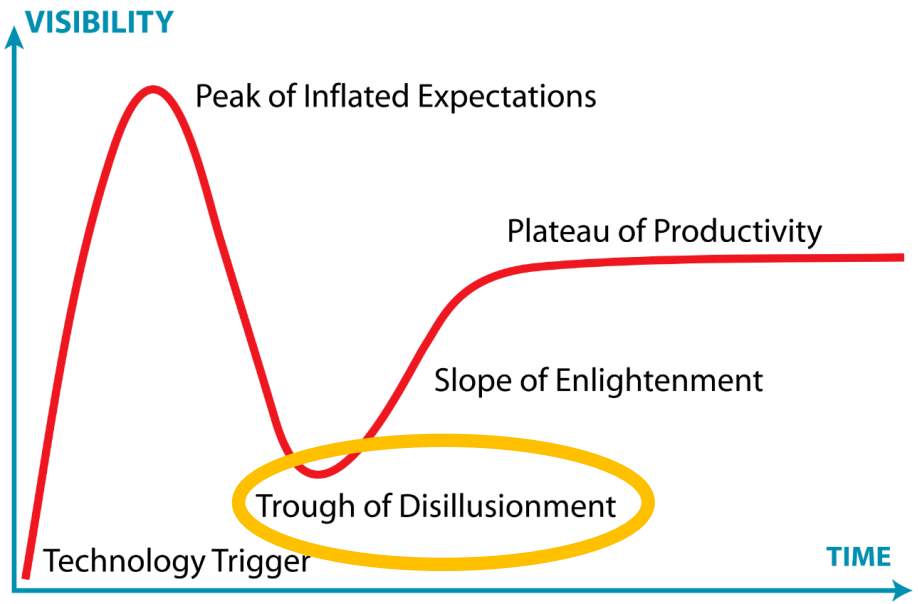
Data Science hits "peak of inflated expectations" around 2012-14




2012



# Brief history of Data Science: Technology Trigger

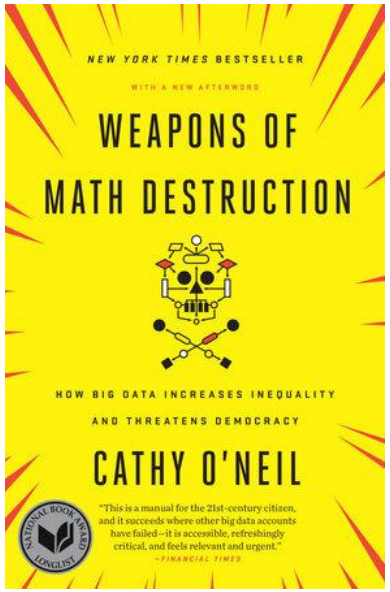


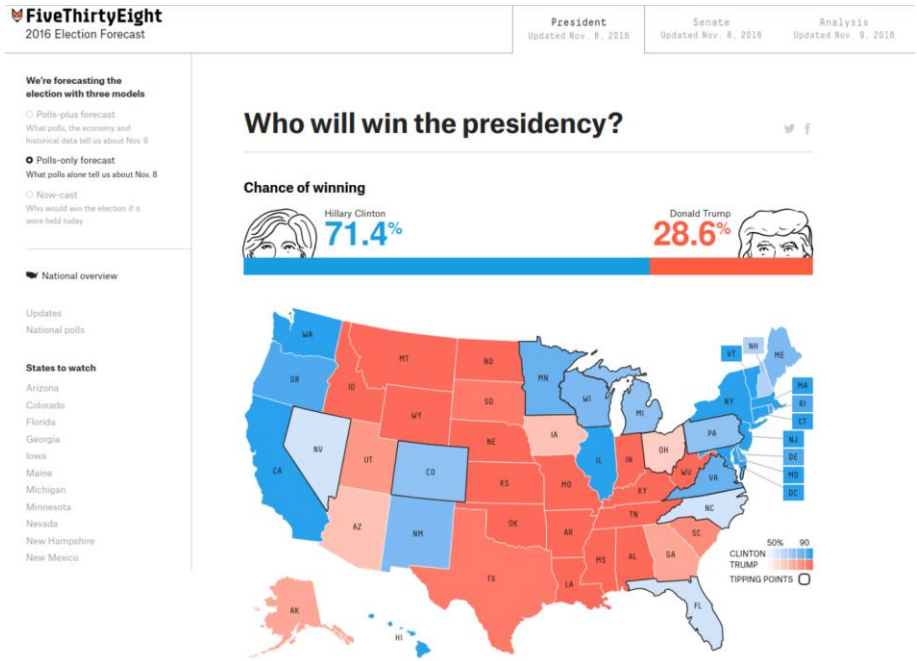

PROPUBLICA

**Machine Bias**

There's software used across the country to predict future criminals. And it's biased against blacks.

*by Julia Angwin, Jeff Larson, Surya Mattu and Lauren Kirchner, ProPublica*
May 23, 2016

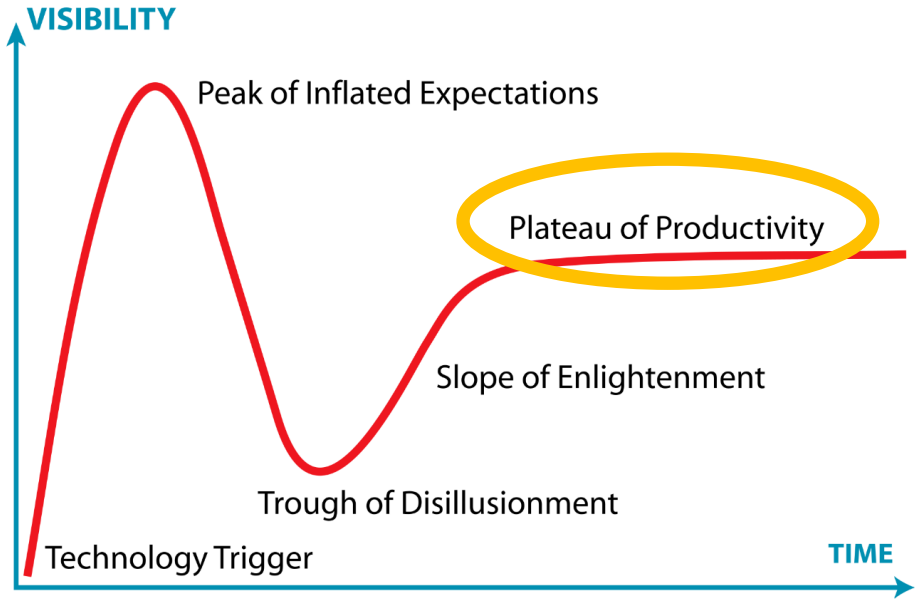


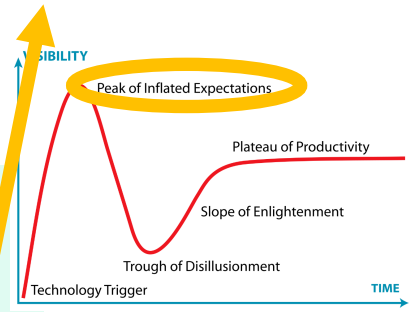


Negative consequences of predictive models were highlighted circa 2016

# Brief history of Data Science: now








Yale S&DS

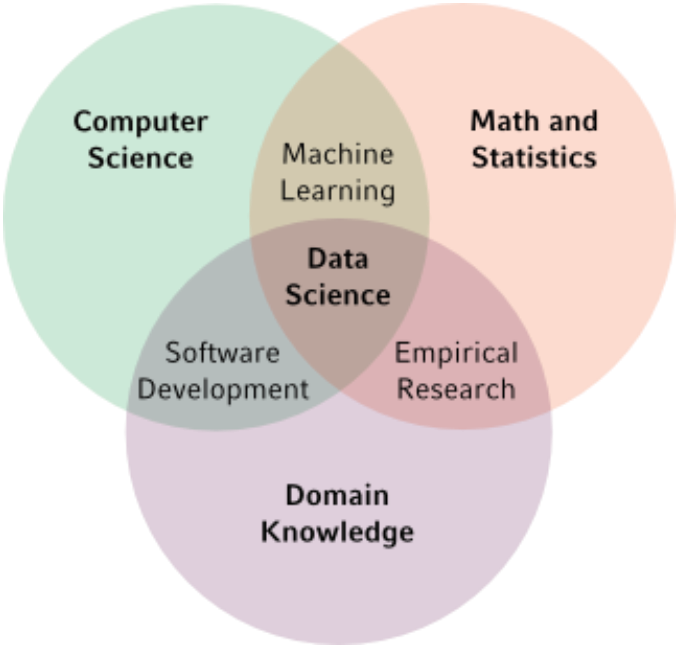
Data Scientists roles in many industries

- E.g., Data journalism (NYTimes TheUpshot)

Many universities have Data Science programs

- In March 2017 Yale renames the Department of Statistics to be the Department of Statistics and Data Science

# What is Data Science?




Data Science is a broadening of data analyses:

- Beyond what traditional Statistical mathematical/inferential analyses
- To using more computation

**Classical statistical analysis**

**Descriptives**

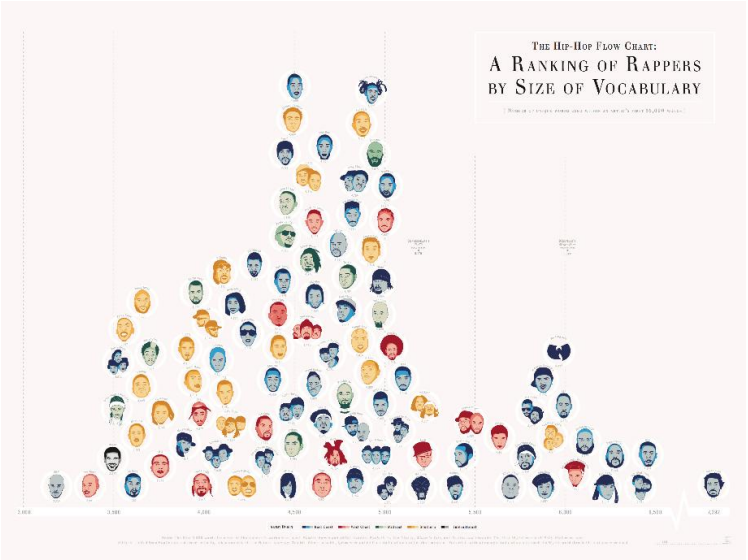
Bronchial reactivity

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Sulfur dioxide | 5 | 18.840 | 9.6919 | 4.3344 | 6.806 | 30.874 | 5.1 | 30.1 |
| Nitrous dioxide | 6 | 6.617 | 3.9448 | 1.6105 | 2.477 | 10.757 | 2.2 | 11.9 |
| Oxygen | 4 | 4.975 | 3.4092 | 1.7046 | -.450 | 10.400 | 2.1 | 9.3 |
| Total | 15 | 10.253 | 8.6514 | 2.2338 | 5.462 | 15.044 | 2.1 | 30.1 |

**ANOVA**

Bronchial reactivity

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 559.450 | 2 | 279.725 | 6.873 | .010 |
| Within Groups | 488.408 | 12 | 40.701 | | |
| Total | 1047.857 | 14 | | | |




Examples:

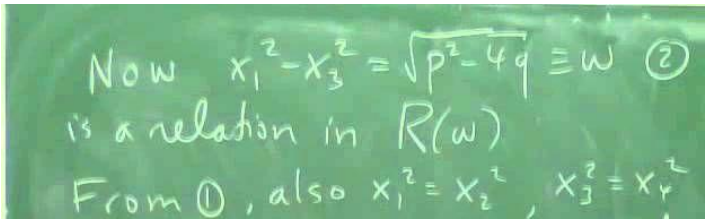
- NYC city bikes
- Wind map visualization

# New ways to choose the best methods

**Statistics** focuses on mathematical models (probability distributions) to analyze data

- Best methods are the ones that have mathematical guarantees (proofs)

**The proof is in the math**




**Data Science** empirically evaluates data analysis methods

- Best methods are the one that gives the most insight in practice

**The proof is in the pudding**

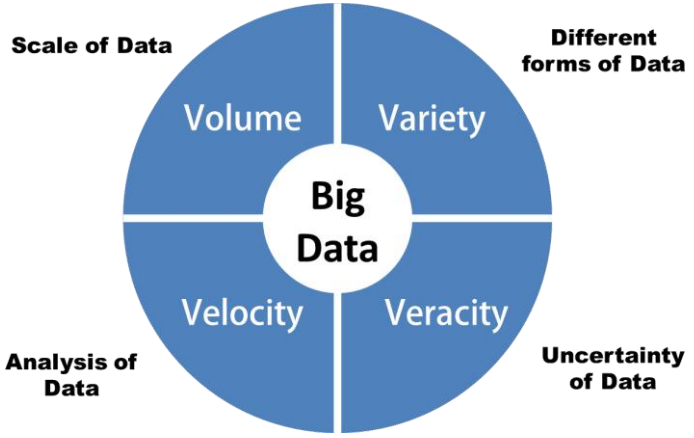
# Big Data


**New insights:**

- Lots of new data from Internet, sensors etc., can be mined to transform our understanding in a range of fields
  - E.g., health, cosmology, social sciences, etc.

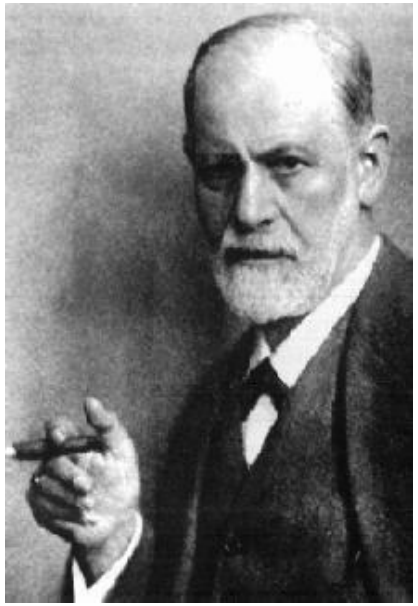
**New analysis and approaches:**

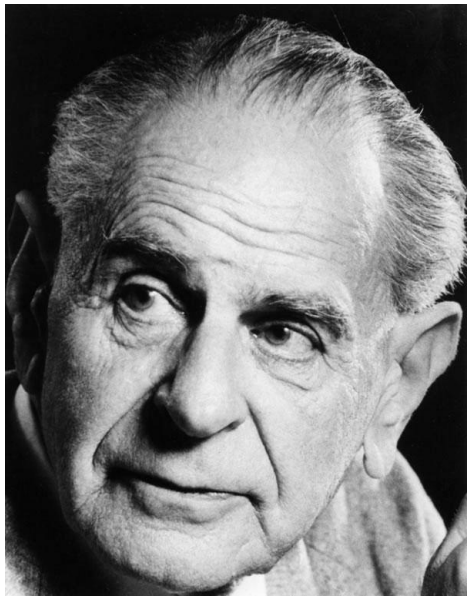
- Hypothesis test pick up on very small (meaningless) effects with very large samples
- Data manipulation and programming are needed to extract insights
- Also, new standards for choosing the best data analysis methods




Data Science vs. Statistician video

# Short paper to read from the book Everybody Lies





Much of Freud's theory dealt with the subconscious

- E.g., Freudian slips

Karl Popper claimed that Freud's theories were unscientific because they couldn't be falsified

- i.e., can come up with any 'just so' story to explain a behavior

New data science analyses might make it possible to actually test Freud's theories

# Things to do for next class…

1. Complete class survey

2. Do short reading on Canvas from the book "Everybody lies"

3. Make sure you can log into the YCRC Juypter Server