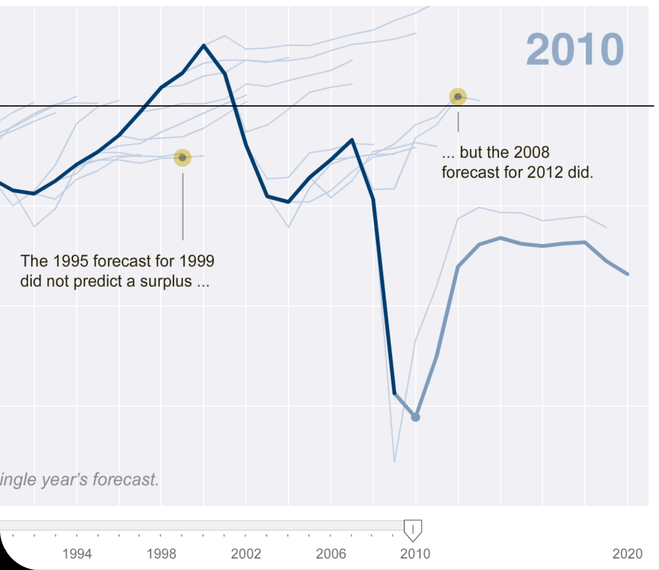
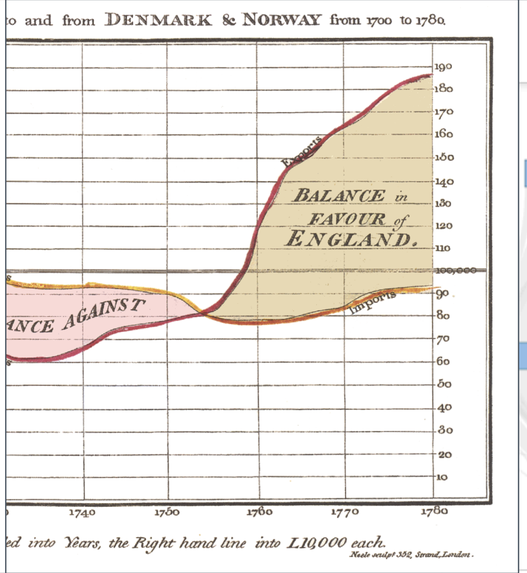
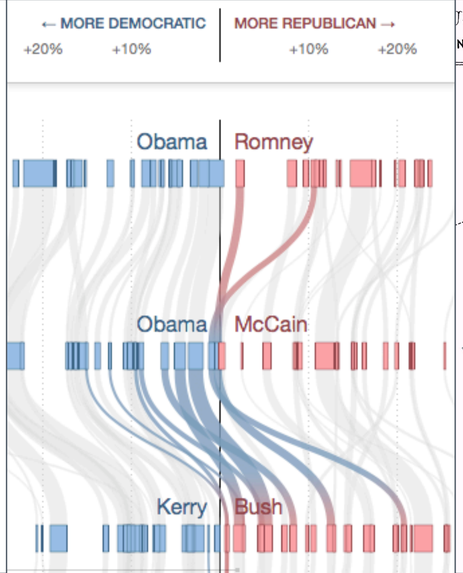
6.894: Interactive Data Visualization

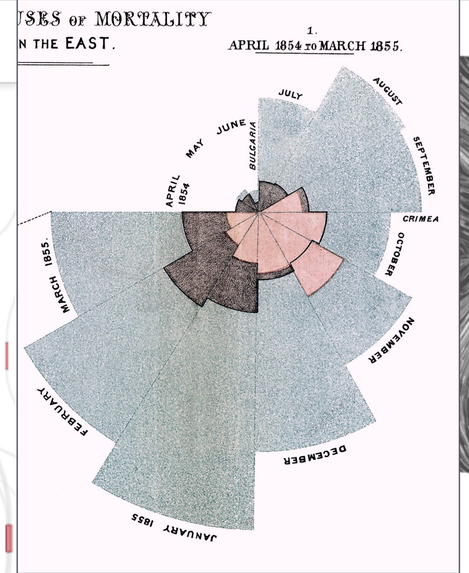
The Value of Visualization

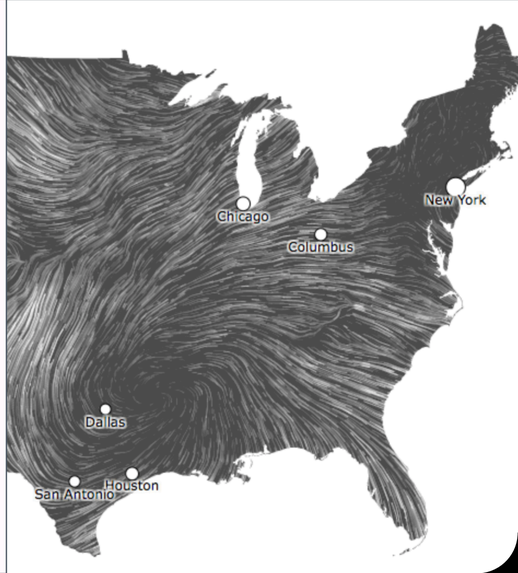
Arvind Satyanarayan





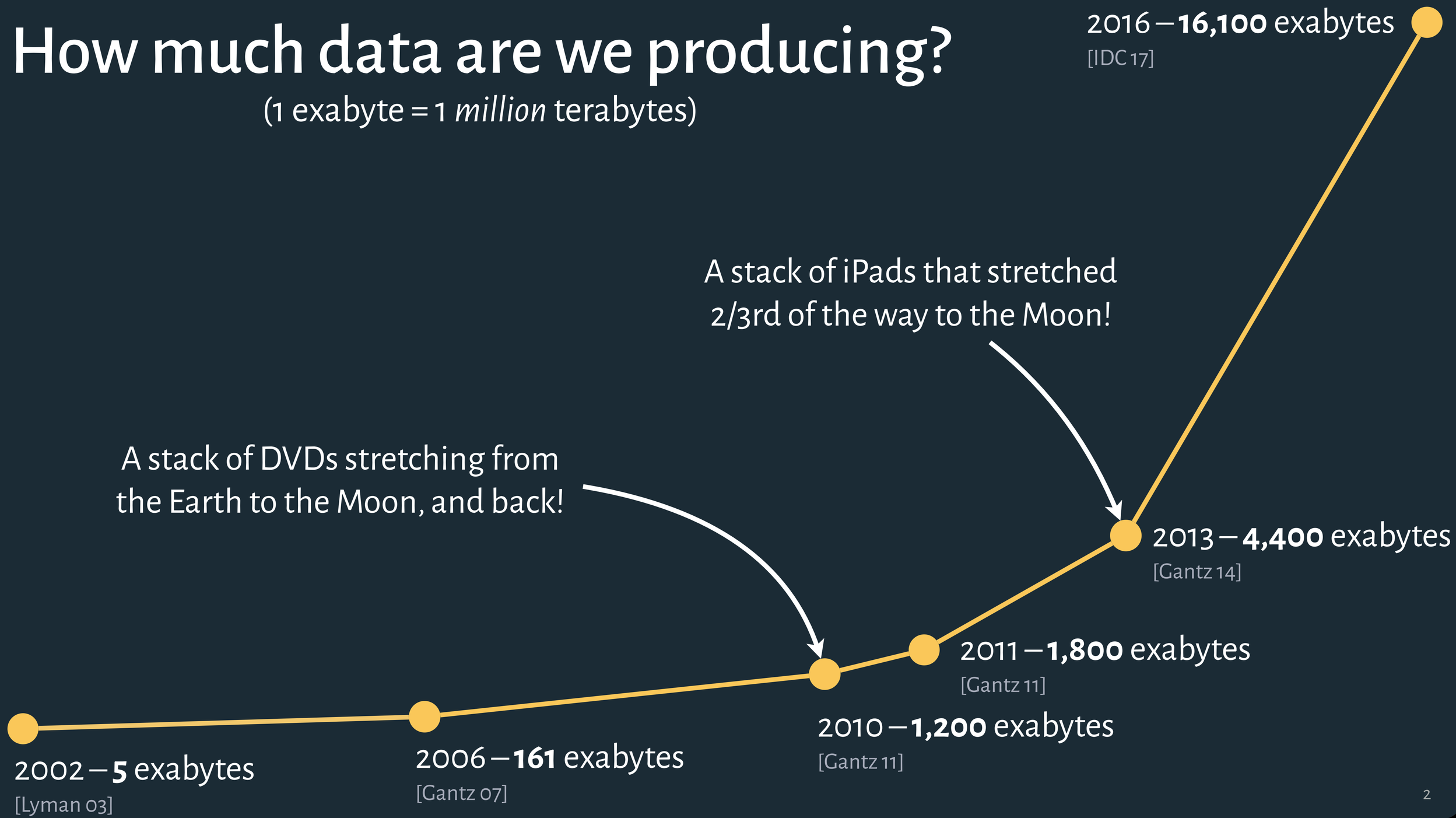




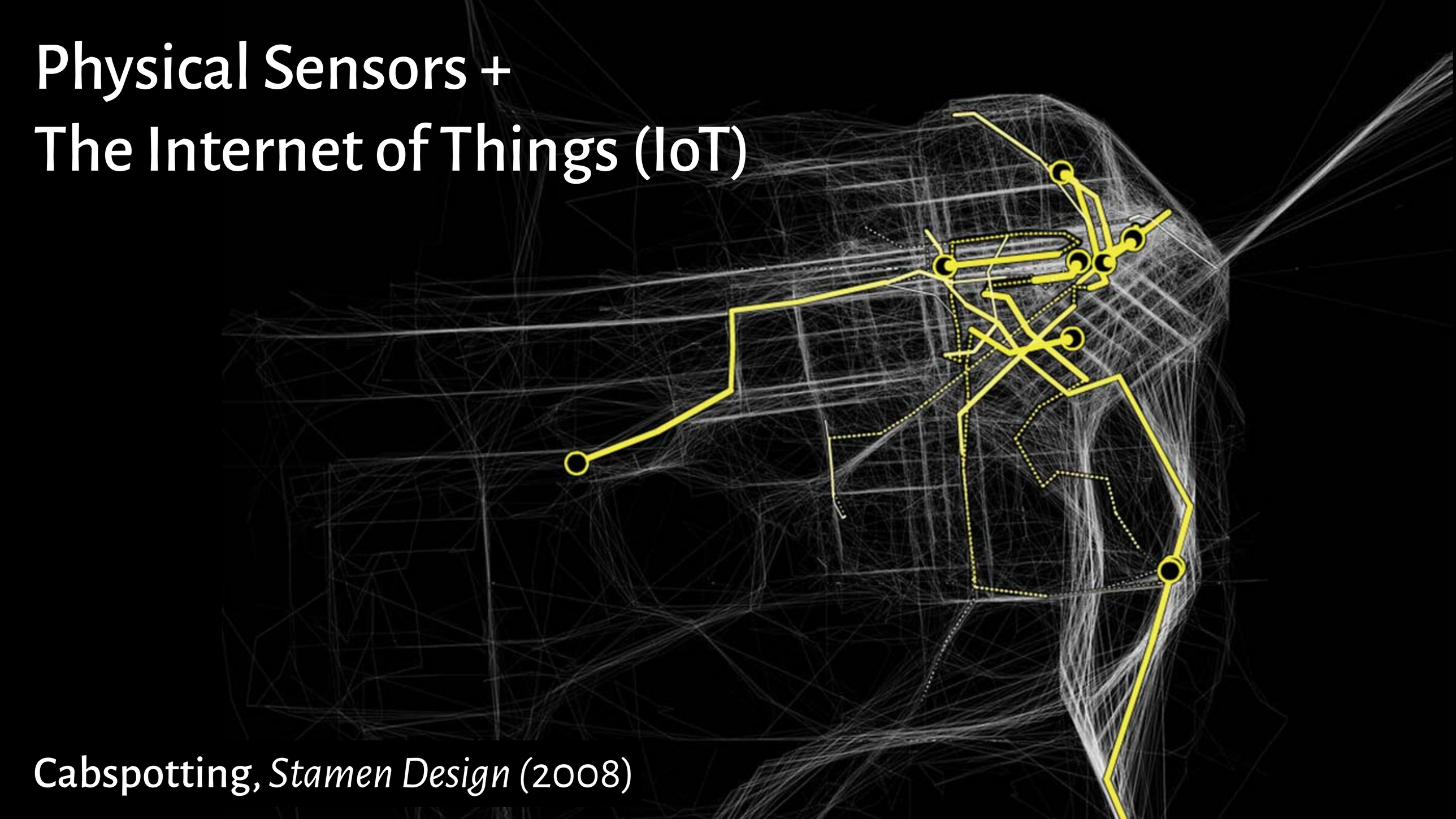


How much data are we producing?

(1 exabyte = 1 *million* terabytes)



Physical Sensors + The Internet of Things (IoT)

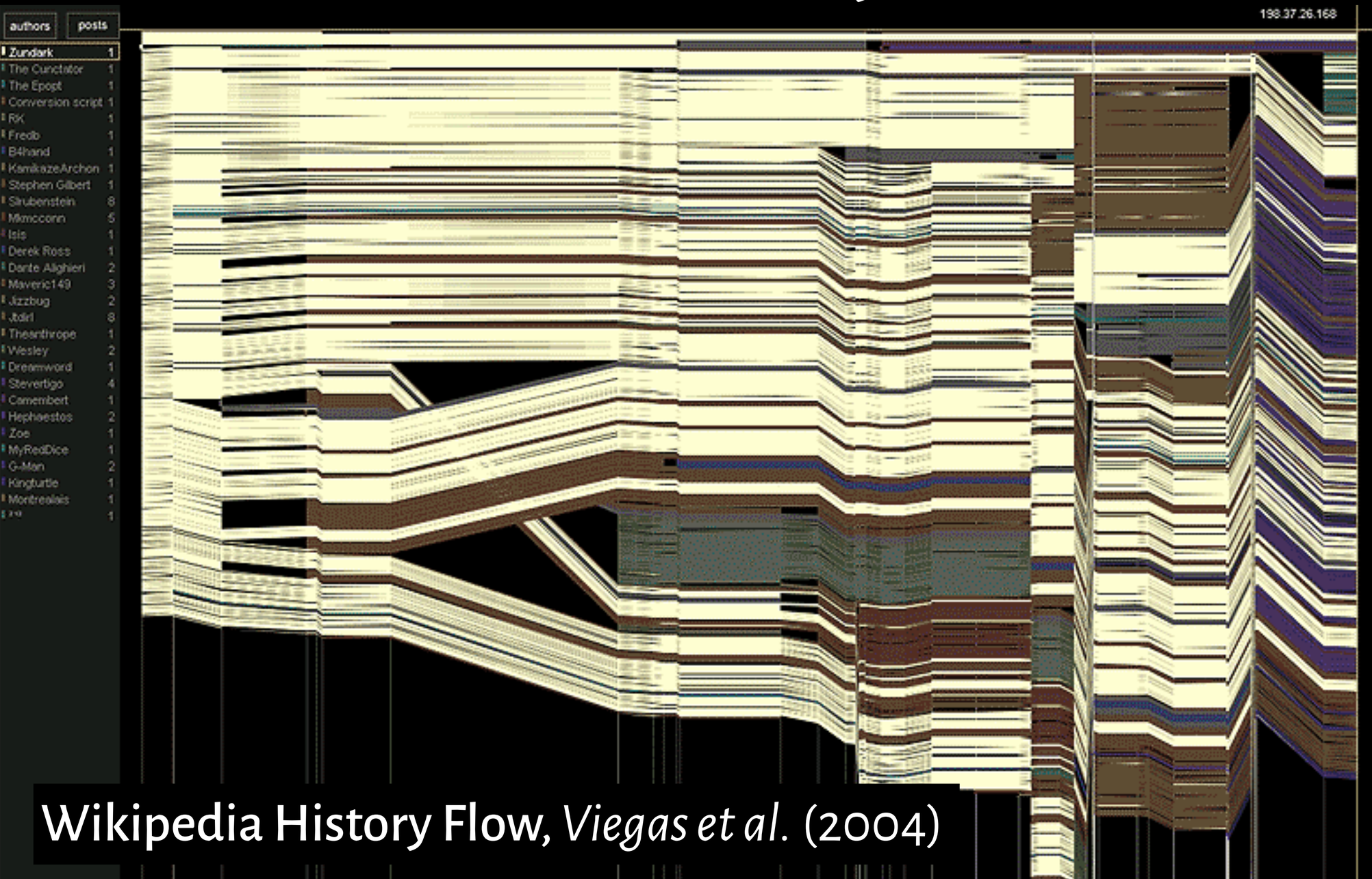


Cabspotting, *Stamen Design* (2008)

Health & Medicine

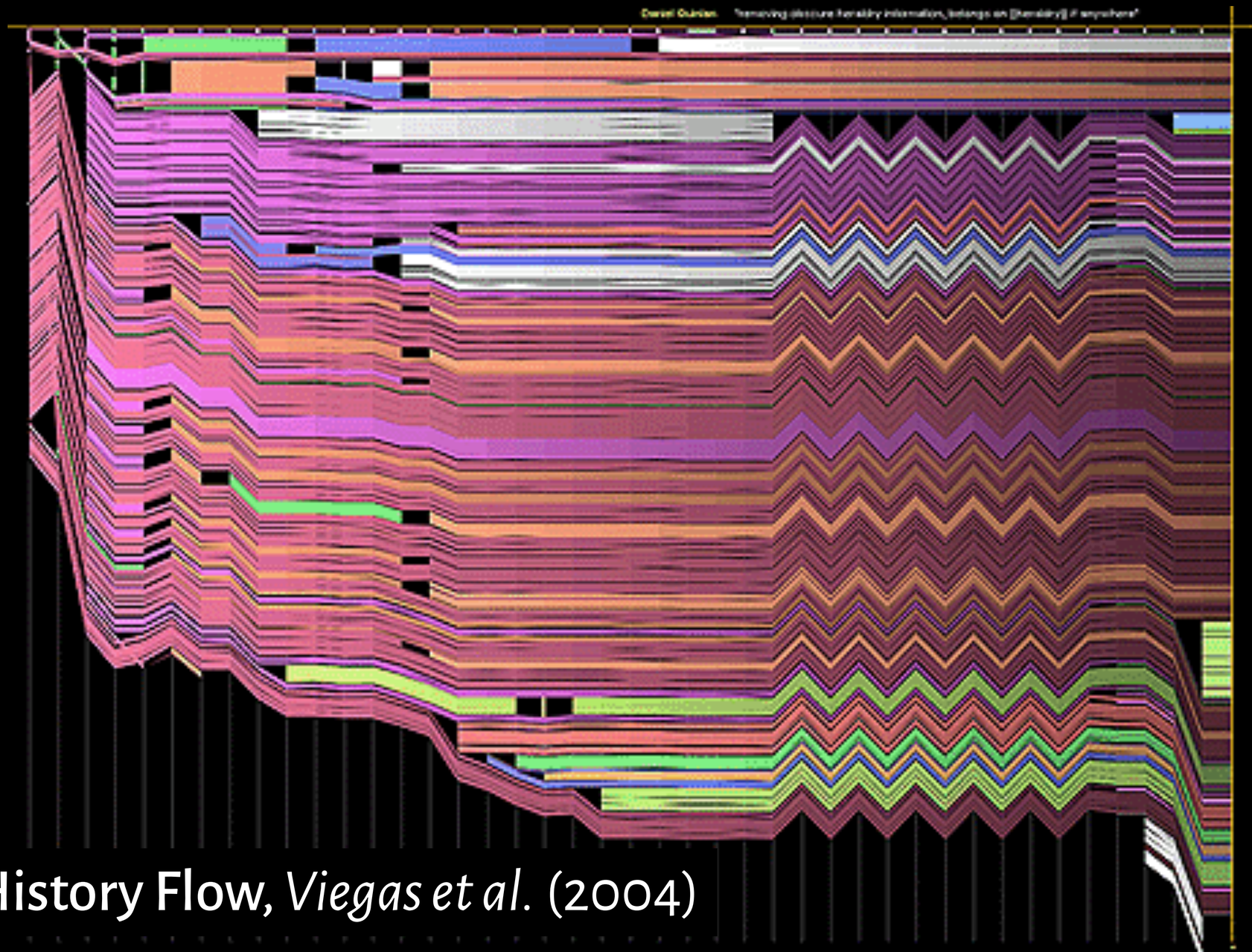
Records of Human Activity

Records of Human Activity



Wikipedia History Flow, *Viegas et al.* (2004)

Records of Human Activity



Wikipedia History Flow, *Viegas et al.* (2004)

"The ability to take data—to be able to **understand** it, to **process** it, to **extract value** from it, to **visualize** it, to **communicate** it—that's going to be a hugely important skill in the next decades, [...] because now we really do have **essentially free and ubiquitous data**. So the complimentary scarce factor is the ability to understand that data and extract value from it."

Hal Varian, Google's Chief Economist
The McKinsey Quarterly, Jan 2009

"The ability to take data—to be able to **understand** it, to **process** it, to **extract value** from it, to **visualize** it, to **communicate** it—that's going to be a hugely important skill in the next decades, [...] because now we really do have **essentially free and ubiquitous data**. So the complimentary scarce factor is the ability to understand that data and extract value from it."

Machine Learning!

Hal Varian, Google's Chief Economist
The McKinsey Quarterly, Jan 2009

"The ability to take data—to be able to **understand** it, to **process** it, to **extract value** from it, to **visualize** it, to **communicate** it—that's going to be a hugely important skill in the next decades, [...] because now we really do have **essentially free and ubiquitous data**. So the complimentary scarce factor is the ability to understand that data and extract value from it."

Machine Learning?

Hal Varian, Google's Chief Economist
The McKinsey Quarterly, Jan 2009

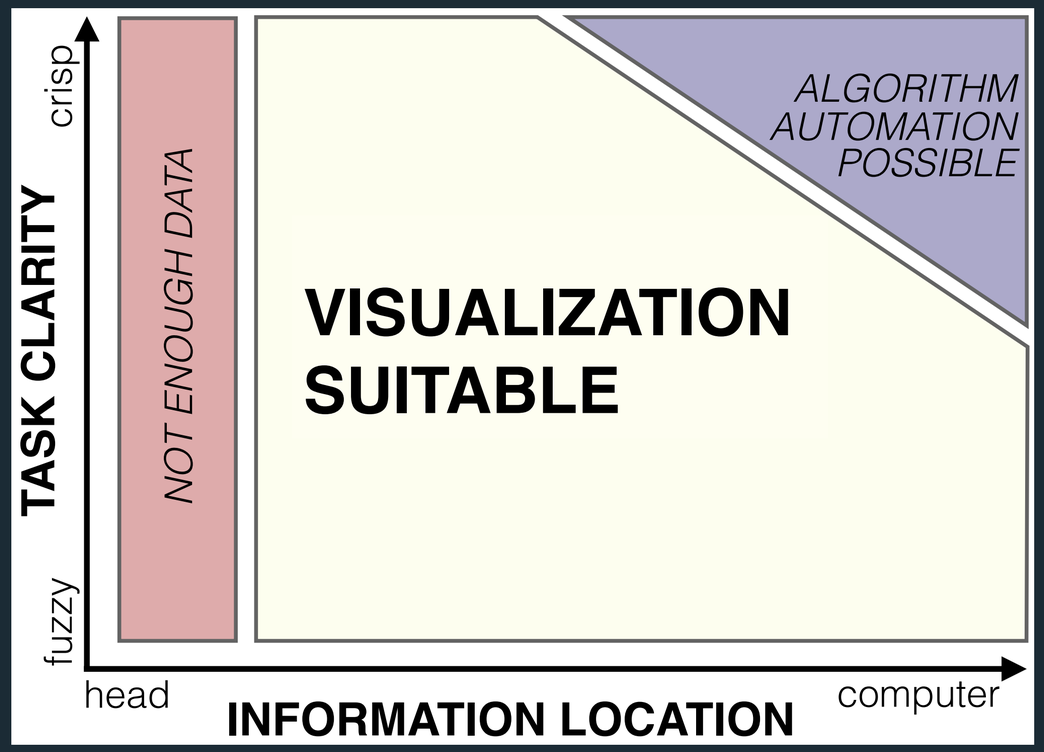
Activity!

Imagine a system to analyze large amounts of data.

1. Why would you have a human in-the-loop?
2. Why would you have a computer in-the-loop?

Process:

1. Think (2 minutes)
2. Pair (5 minutes)
3. Share



[Sedlmair, Meyer, and Munzner 2012]

Set A		Set B		Set C		Set D	
X	Y	X	Y	X	Y	X	Y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.1	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.1	4	5.39	19	12.5
12	10.84	12	9.11	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

Summary Statistics

$u_X = 9.0$ $\sigma_X = 3.317$

$u_Y = 7.5$ $\sigma_Y = 2.03$

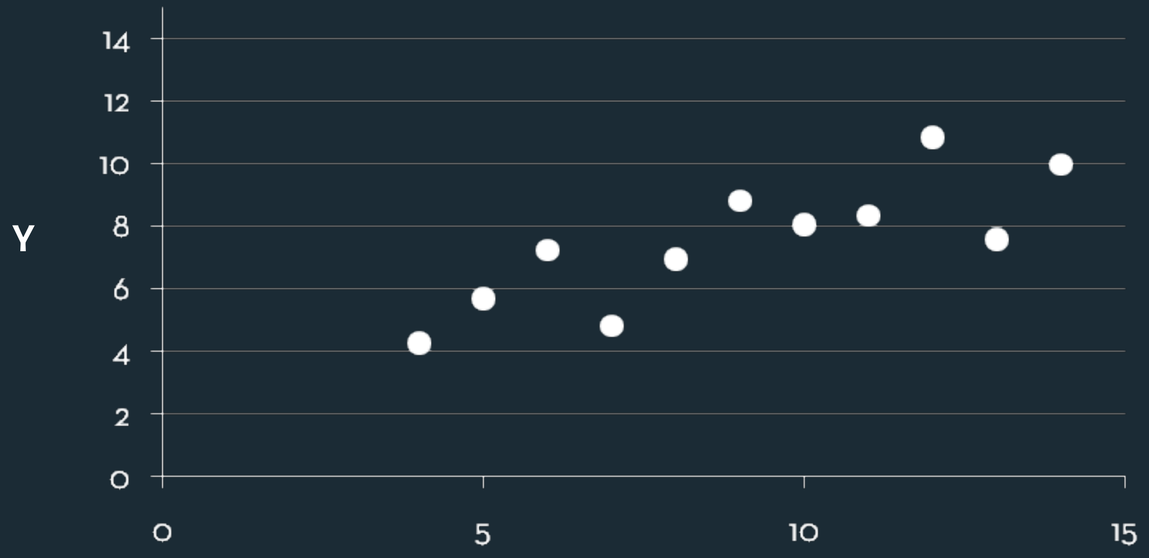
Linear Regression

$Y = 3 + 0.5\,X$

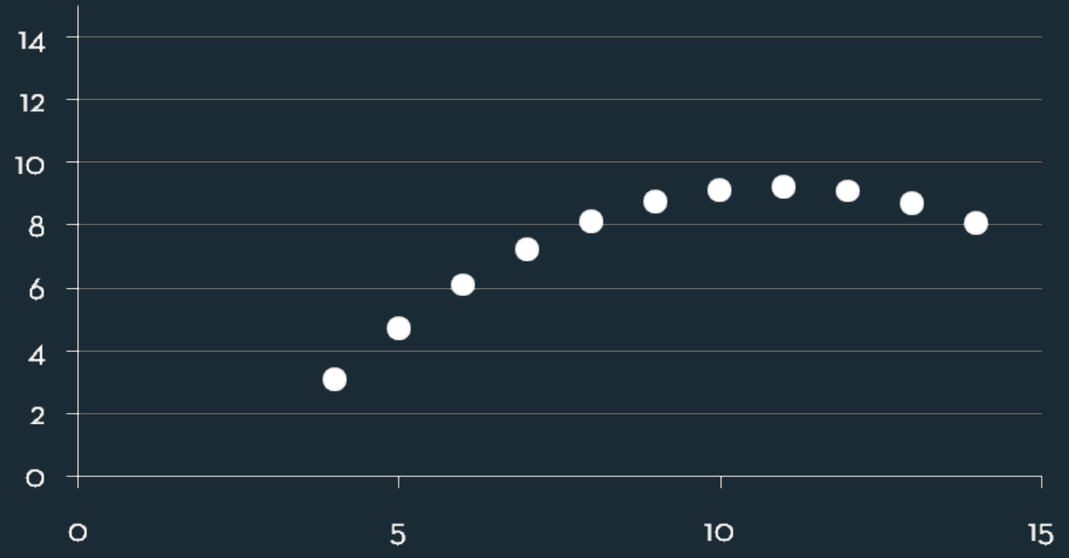
$R^2 = 0.67$

[Anscombe 1973]

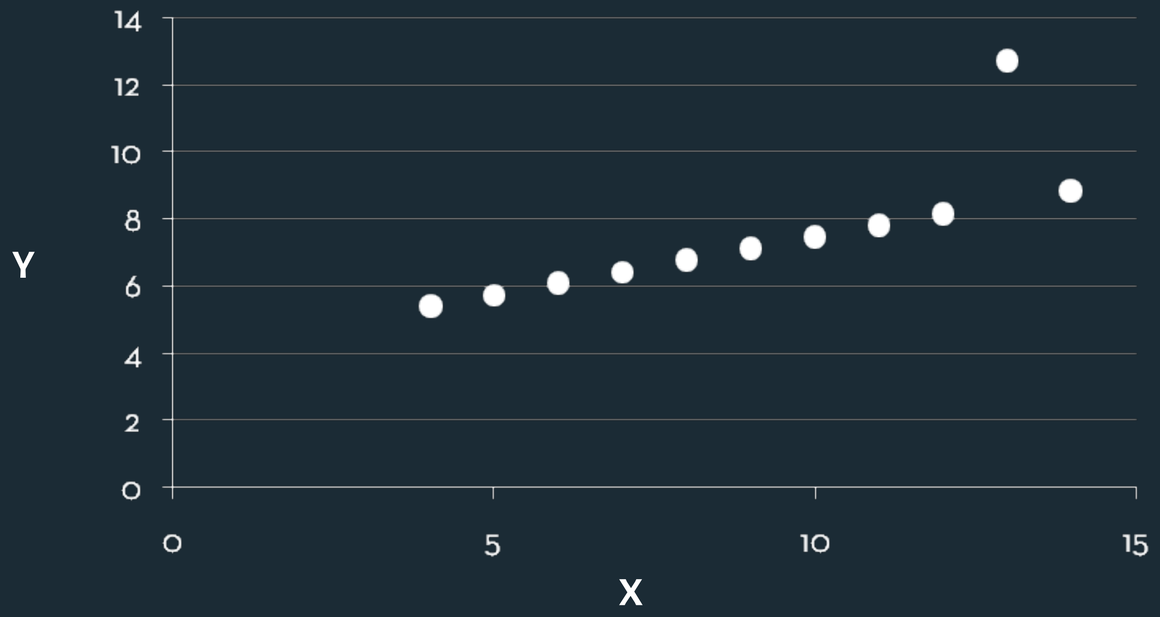
Set A



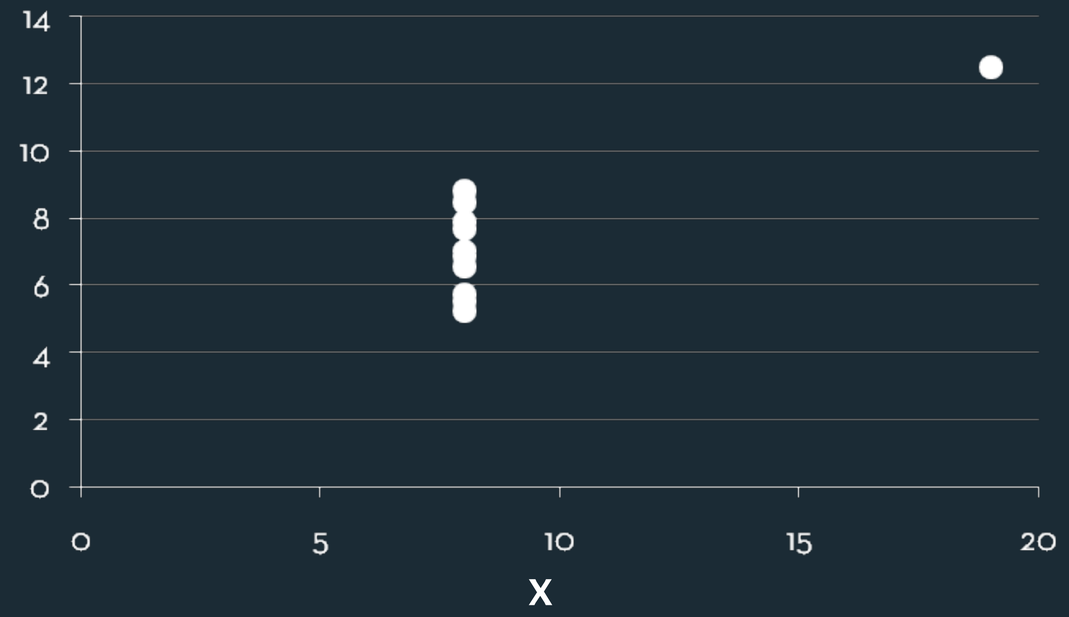
Set B



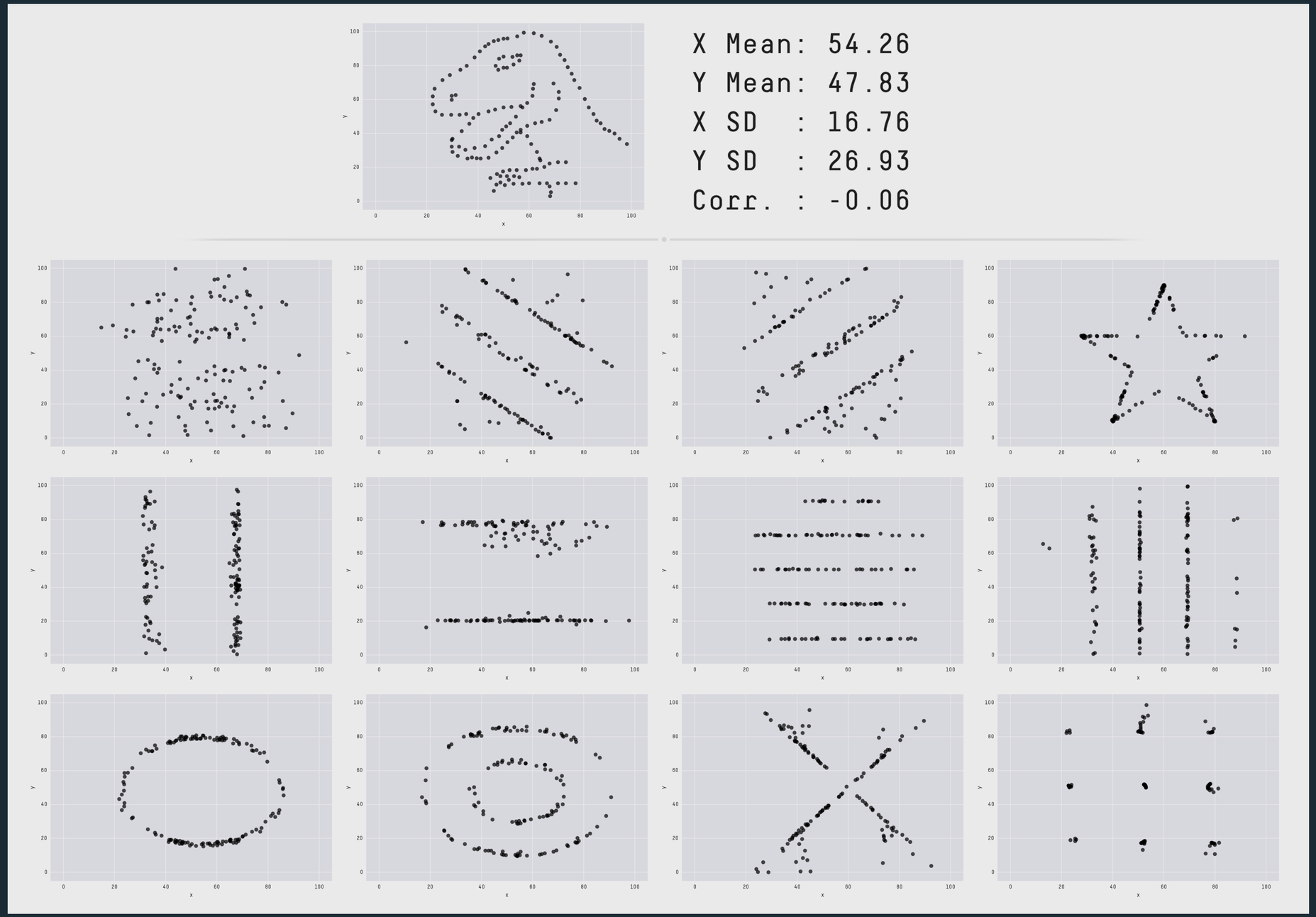
Set C



Set D




Alberto Cairo
@albertocairo
Following
Don't trust summary statistics. Always visualize your data first
robertgrantstats.co.uk/drawmydata.html
N = 157 ; X mean = 50.7333 ; X SD = 19.5661 ; Y mean = 46.495 ; Y SD = 27.2828 ;
Pearson correlation = -0.1772
Y
X
0
10
20
30
40
50
60
70
80
90
100
5:47 AM - 15 Aug 2016
952 Retweets
1,023 Likes



The Datasaurus Dozen, *Matejka & Fitzmaurice* (2008)

The Value of Visualization

Aka why create visualizations?

Record information

- Blueprints, photographs, seismographs, ...

Analyze data to support reasoning (exploratory visualization)

- Develop and assess hypotheses
- Find patterns / Discover errors in data
- Expand memory

Communicate information to others (explanatory visualization)

- Share and persuade
- Collaborate and revise

The Value of Visualization

Aka why create visualizations?

Record information

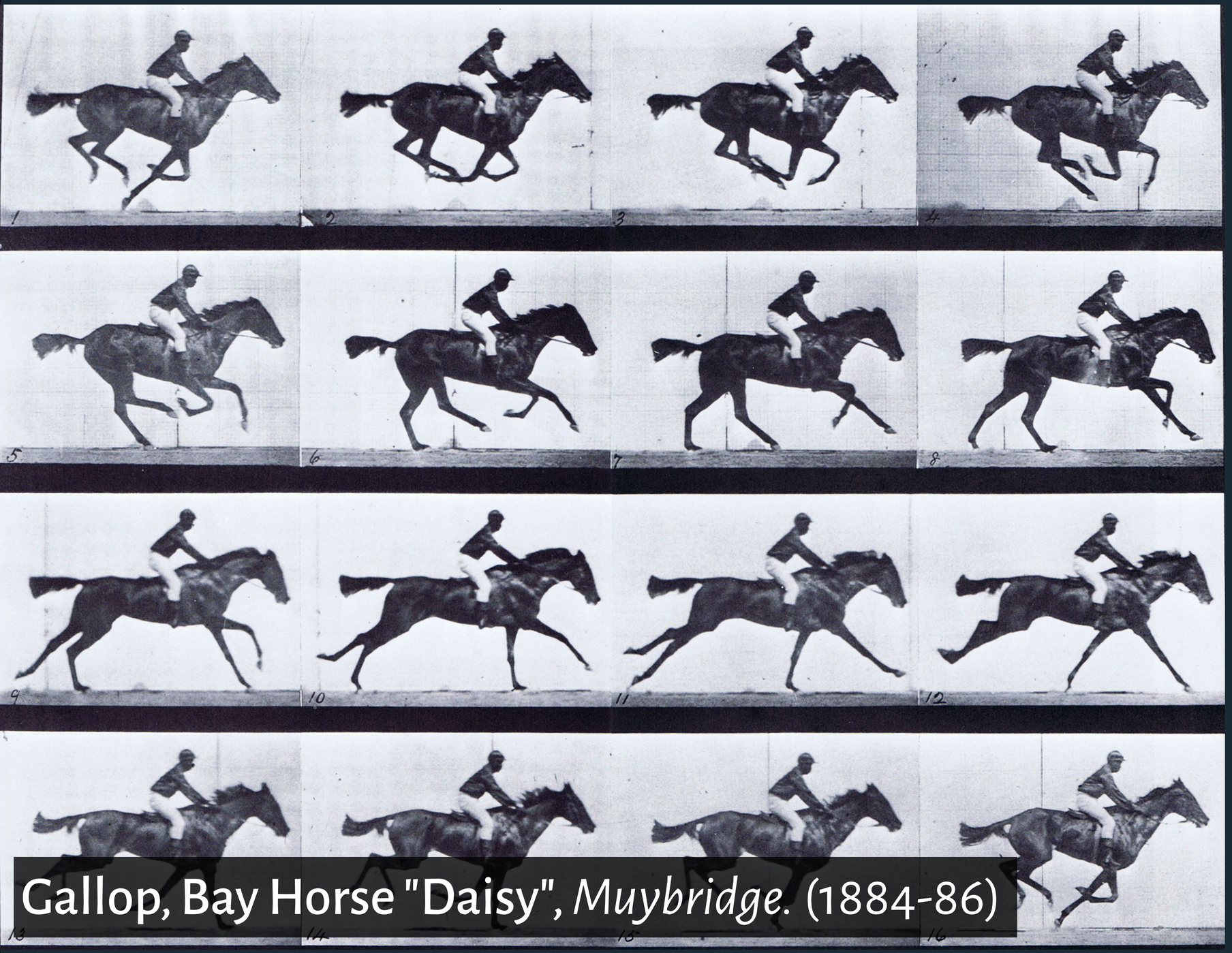
- Blueprints, photographs, seismographs, ...

Analyze data to support reasoning (exploratory visualization)

- Develop and assess hypotheses
- Find patterns / Discover errors in data
- Expand memory

Communicate information to others (explanatory visualization)

- Share and persuade
- Collaborate and revise



Gallop, Bay Horse "Daisy", *Muybridge.* (1884-86)

Record Info

To answer a question:

Do all 4 hooves leave the ground when a horse gallops?

Record Info

E.J. Marey's **sphygmograph** (1863)
First external, non-intrusive way to measure blood pressure.

Directly recorded pulse as a waveform.

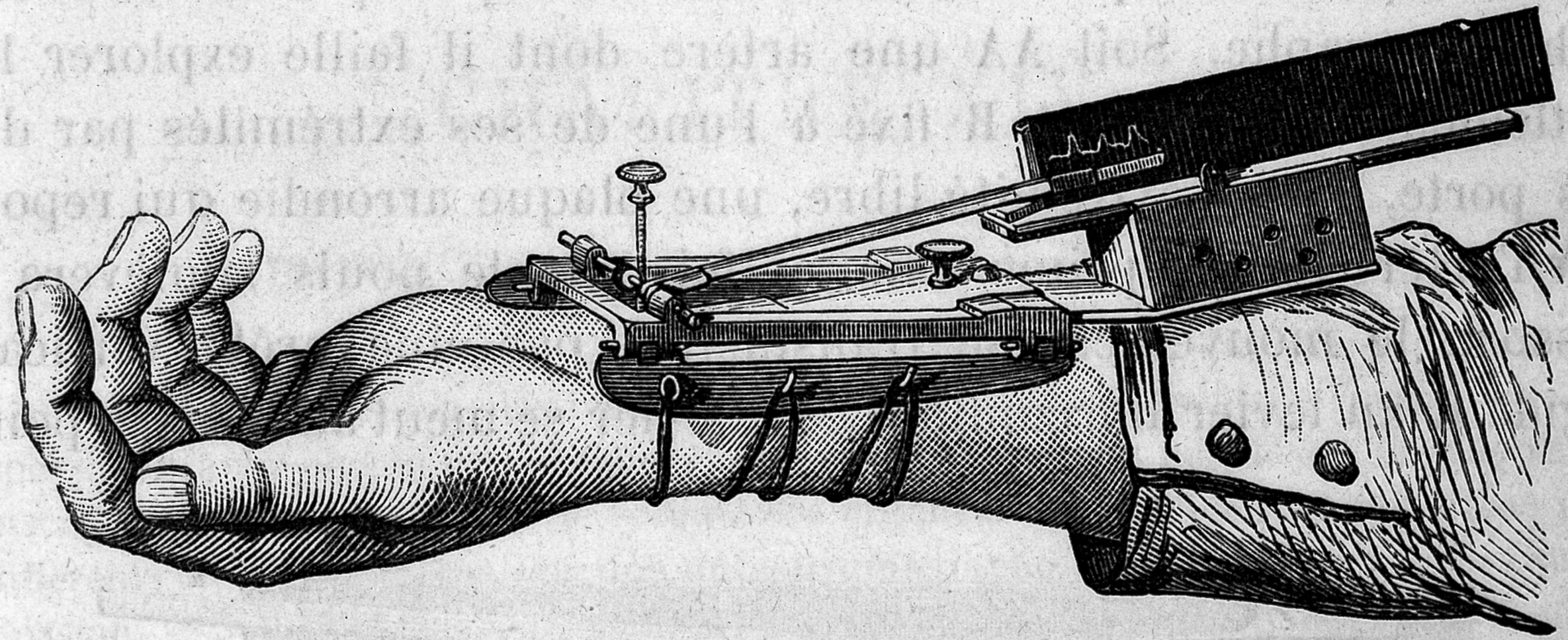
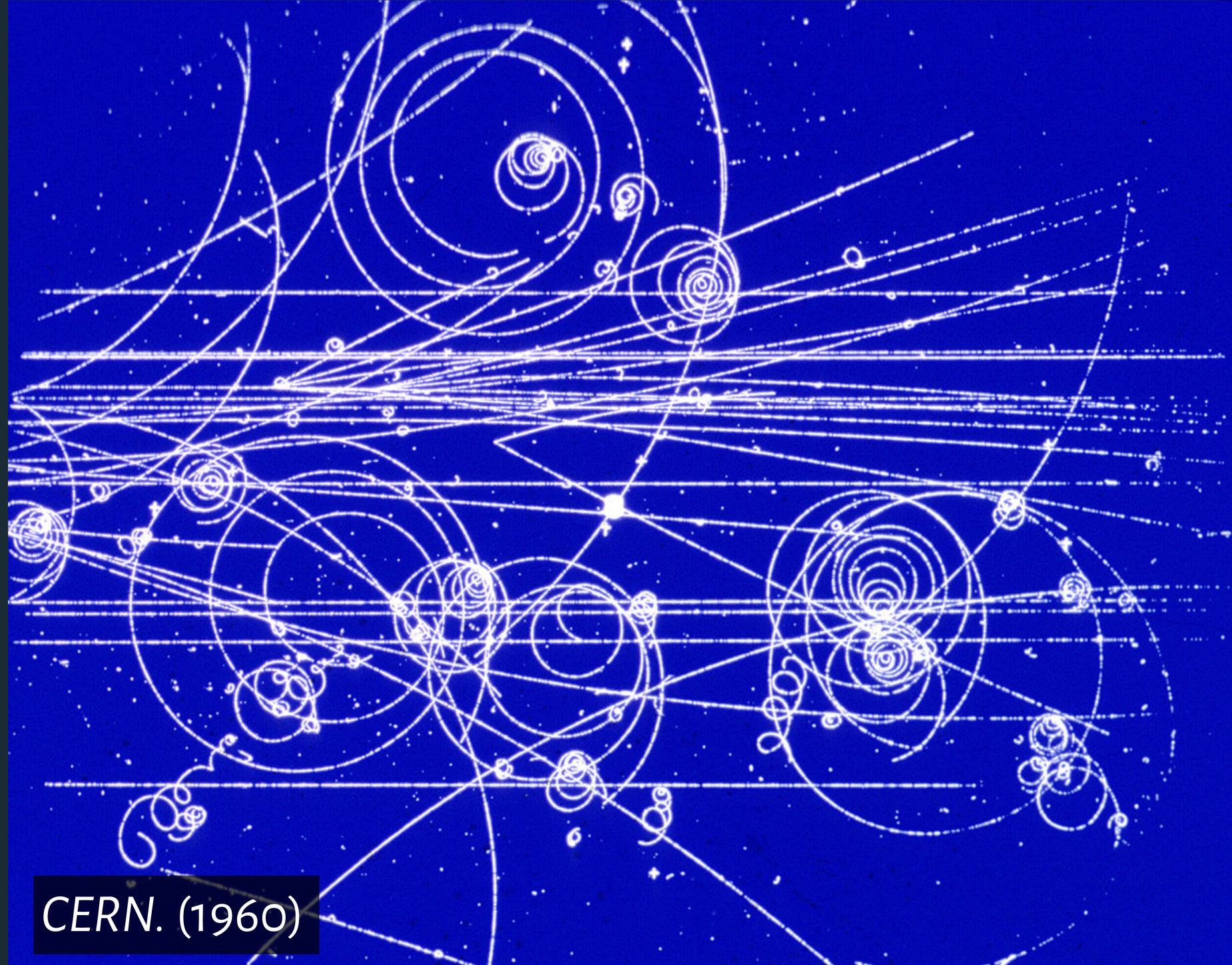


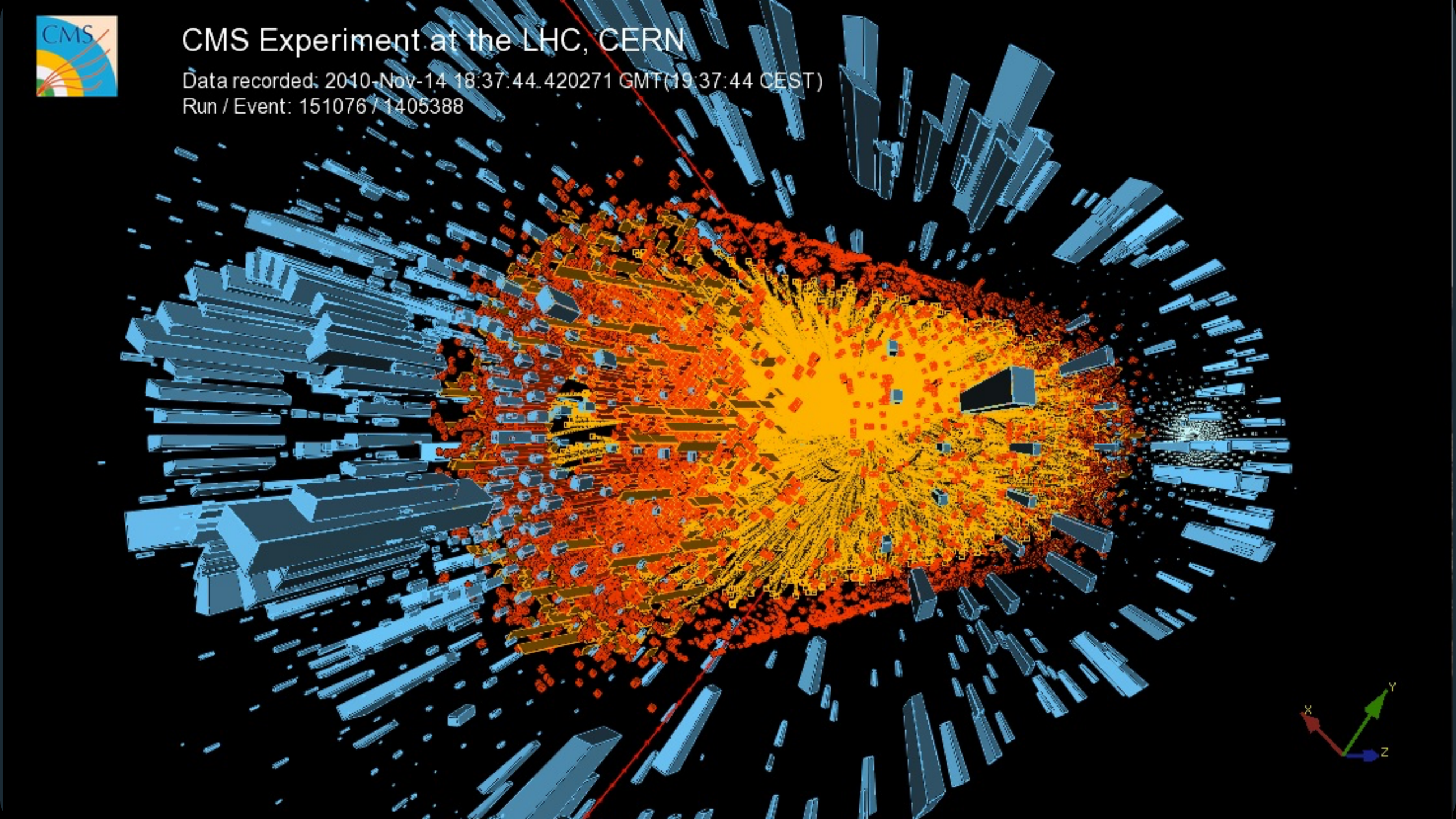
Fig. 109. Sphygmographe direct.

Record Info

Cloud and **bubble chambers** reveal properties of subatomic particles by making their tracks visible.



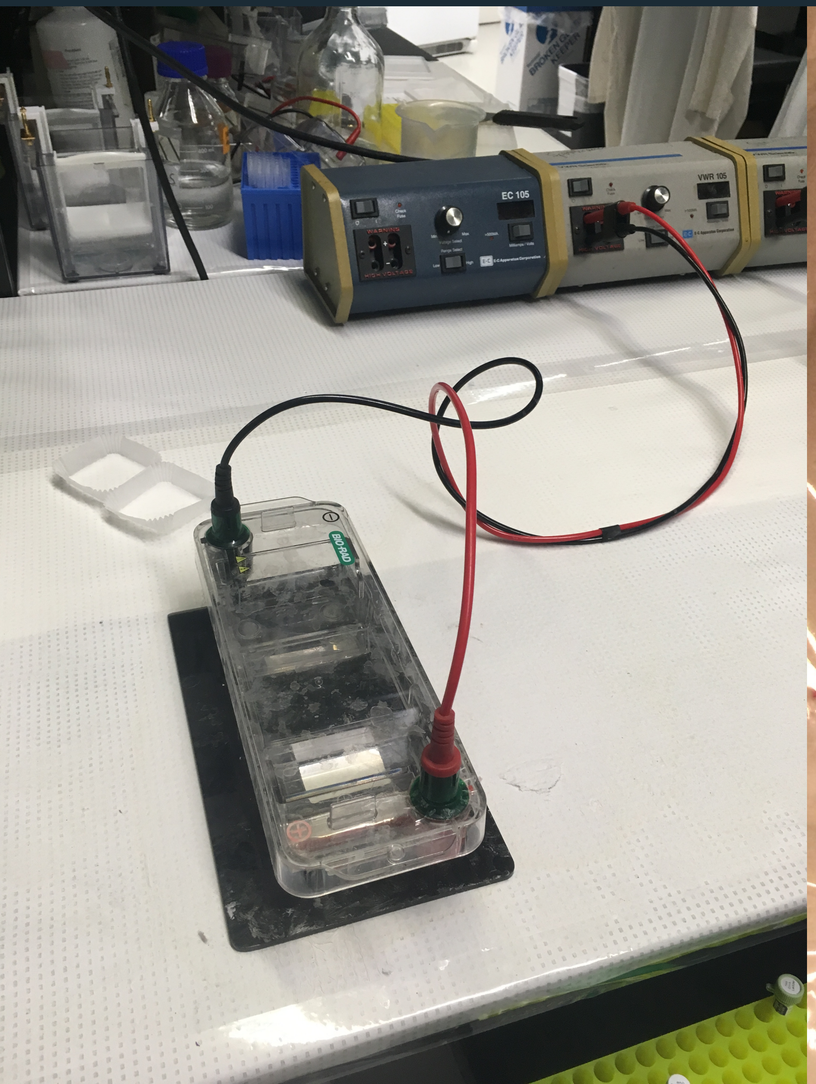
CERN. (1960)

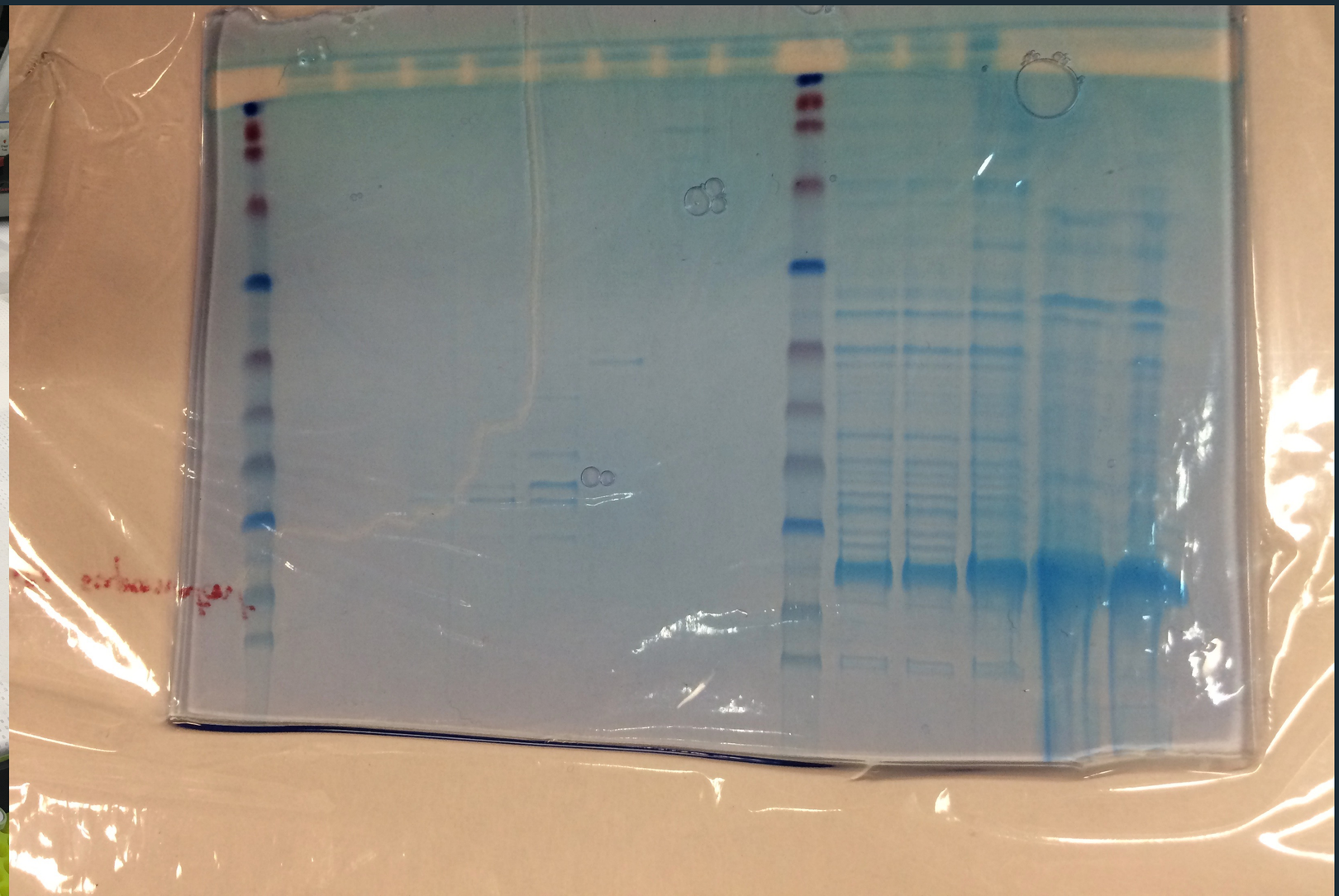

CMS Experiment at the LHC, CERN
Data recorded: 2010-Nov-14 18:37:44.420271 GMT(19:37:44 CEST)
Run / Event: 151076 / 1405388
Y
X
Z

Record Info

Gel electrophoresis is a technique to separate DNA, RNA, or proteins by their size.

The visualization *is* the data.





The Value of Visualization

Aka why create visualizations?

Record information

- Blueprints, photographs, seismographs, ...

Analyze data to support reasoning (exploratory visualization)

- Develop and assess hypotheses
- Find patterns / Discover errors in data
- Expand memory

Communicate information to others (explanatory visualization)

- Share and persuade
- Collaborate and revise

The Value of Visualization

Aka why create visualizations?

Record information

- Blueprints, photographs, seismographs, ...

Analyze data to support reasoning (exploratory visualization)

- Develop and assess hypotheses
- Find patterns / Discover errors in data
- Expand memory

Communicate information to others (explanatory visualization)

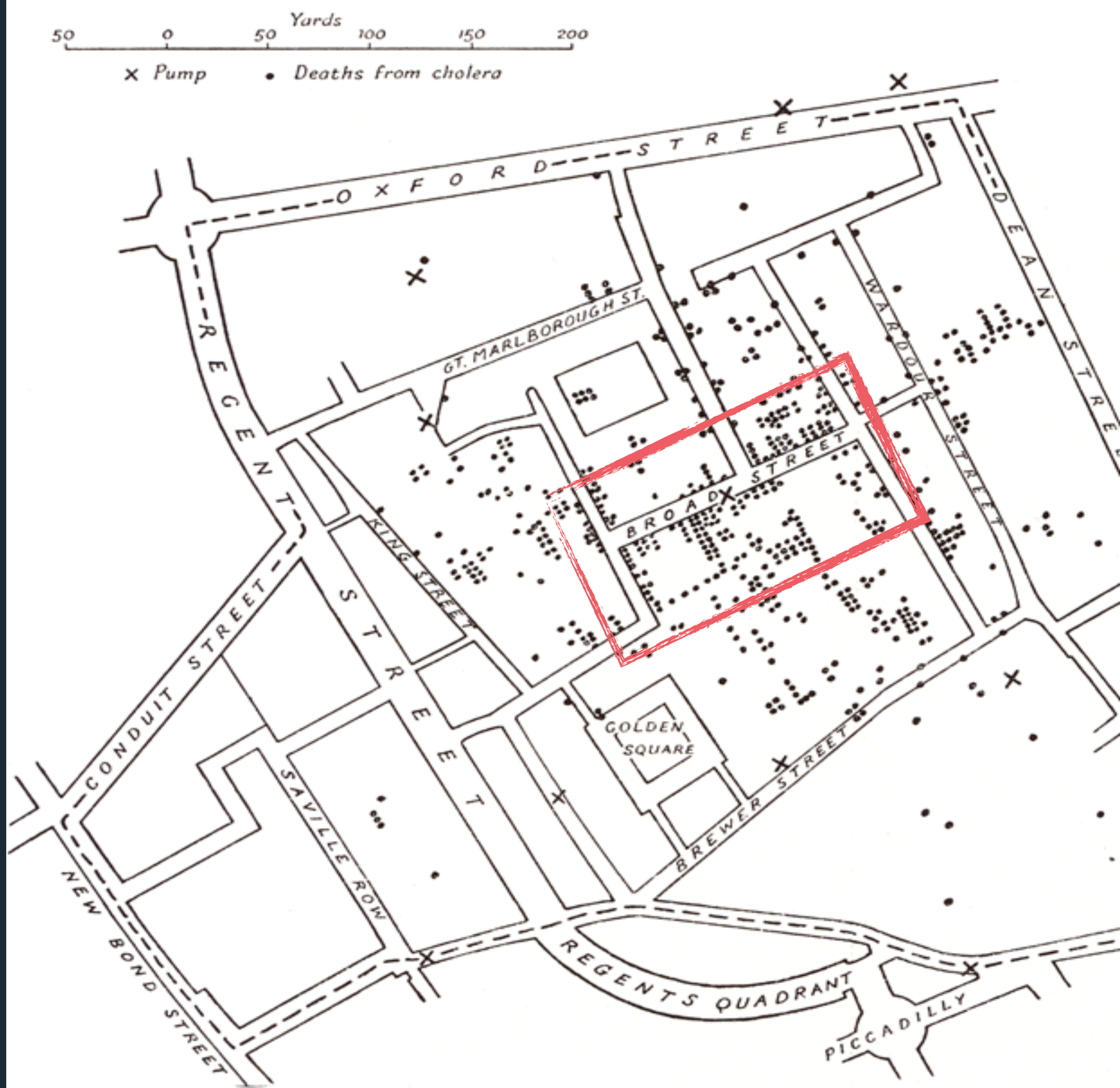
- Share and persuade
- Collaborate and revise

Support Reasoning

To investigate London's 1854 cholera epidemic, **John Snow** plotted position of each case on a map.

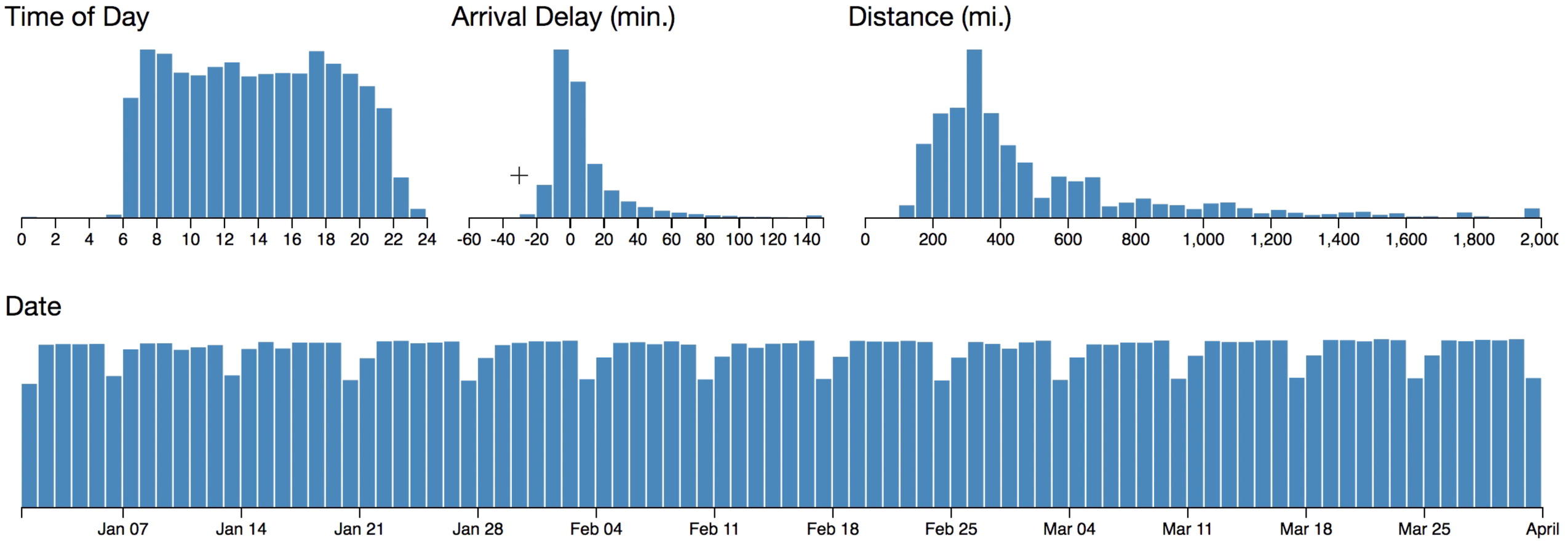
Map put the data in context.

Used to support hypothesis that Broad St. pump was the cause.



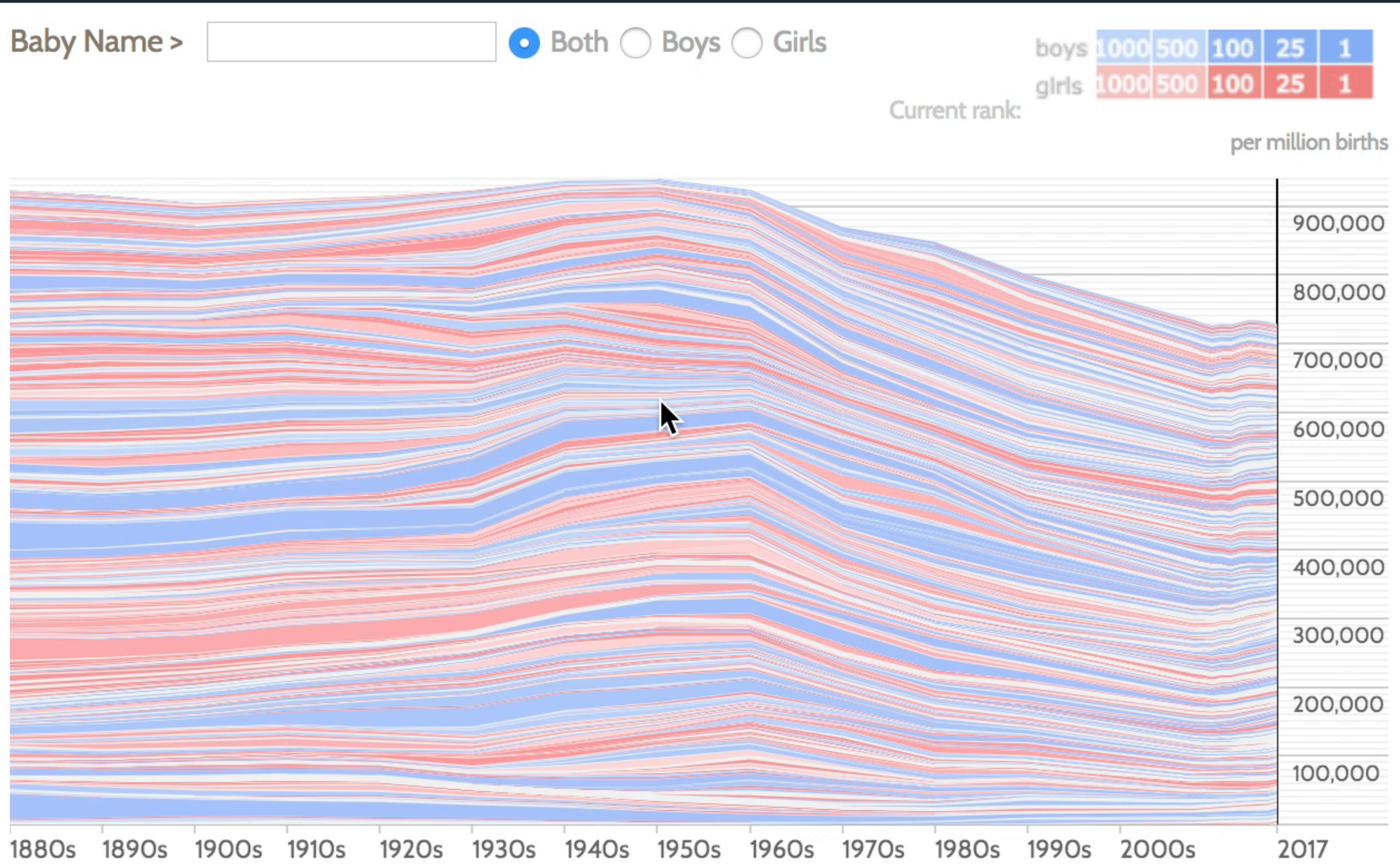
Support Reasoning

Interactively generate and evaluate hypotheses.



Crossfilter.js, *Bostock*. (2015)

Support Reasoning



NameVoyager, *Wattenberg*. (2005)

One of the first interactive visualizations that enabled **social data analysis**.

Engaging design + data fueled collaborative exploration.

- > *"Which letter has gone down most consistently? W? Observation: Note the recent upsurge in Y; basically all due to Hispanic (and some Middle Eastern) names"*
- < *"You're right, W has gone most consistently down, although F is pretty close (if it weren't for Faith...)"*

Try it out at:
babynamewizard.com/voyager

Support Reasoning

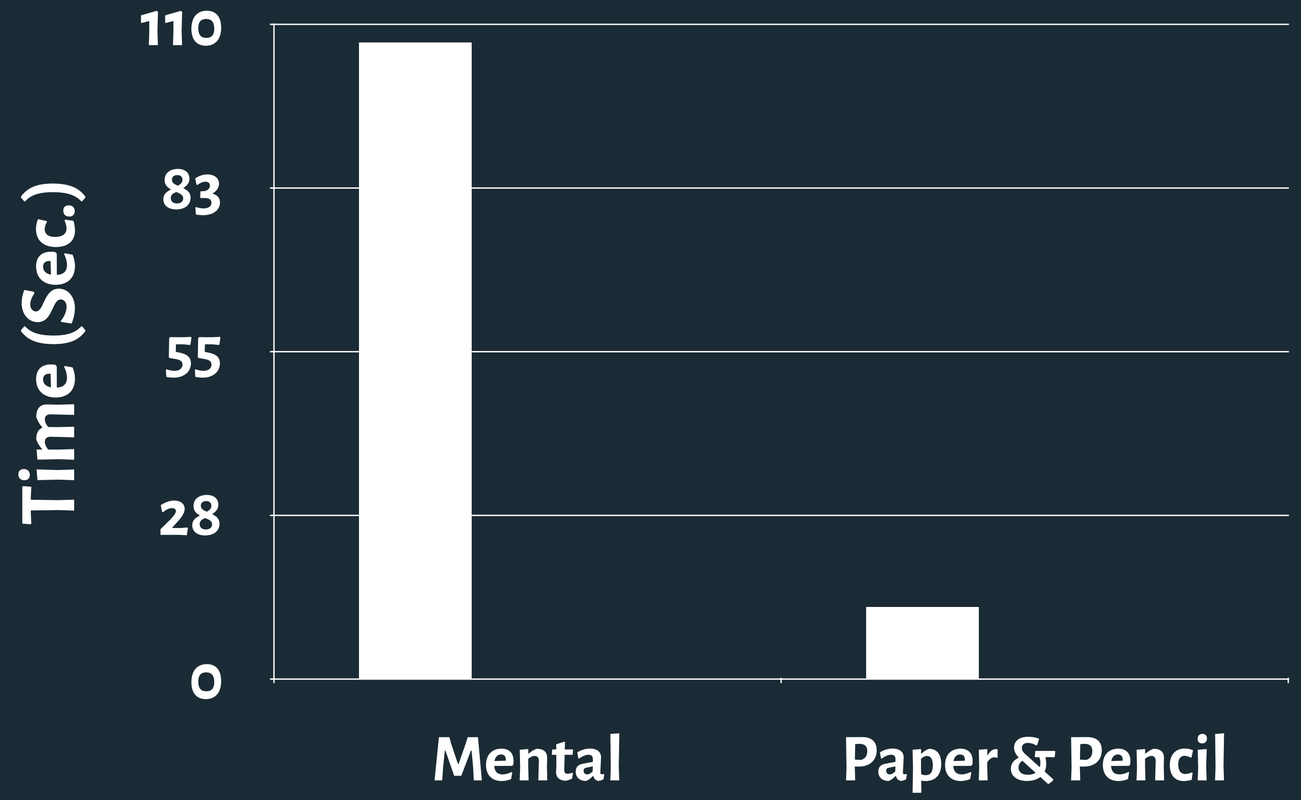
Class Exercise!

Support Reasoning

$$\begin{array}{rr} & 34 \\ \times & 72 \end{array}$$

Support Reasoning

```
   34
x  72
-----
   68
 2380
-----
 2448
```



The Value of Visualization

Aka why create visualizations?

Record information

- Blueprints, photographs, seismographs, ...

Analyze data to support reasoning (exploratory visualization)

- Develop and assess hypotheses
- Find patterns / Discover errors in data
- Expand memory

Communicate information to others (explanatory visualization)

- Share and persuade
- Collaborate and revise

The Value of Visualization

Aka why create visualizations?

Record information

- Blueprints, photographs, seismographs, ...

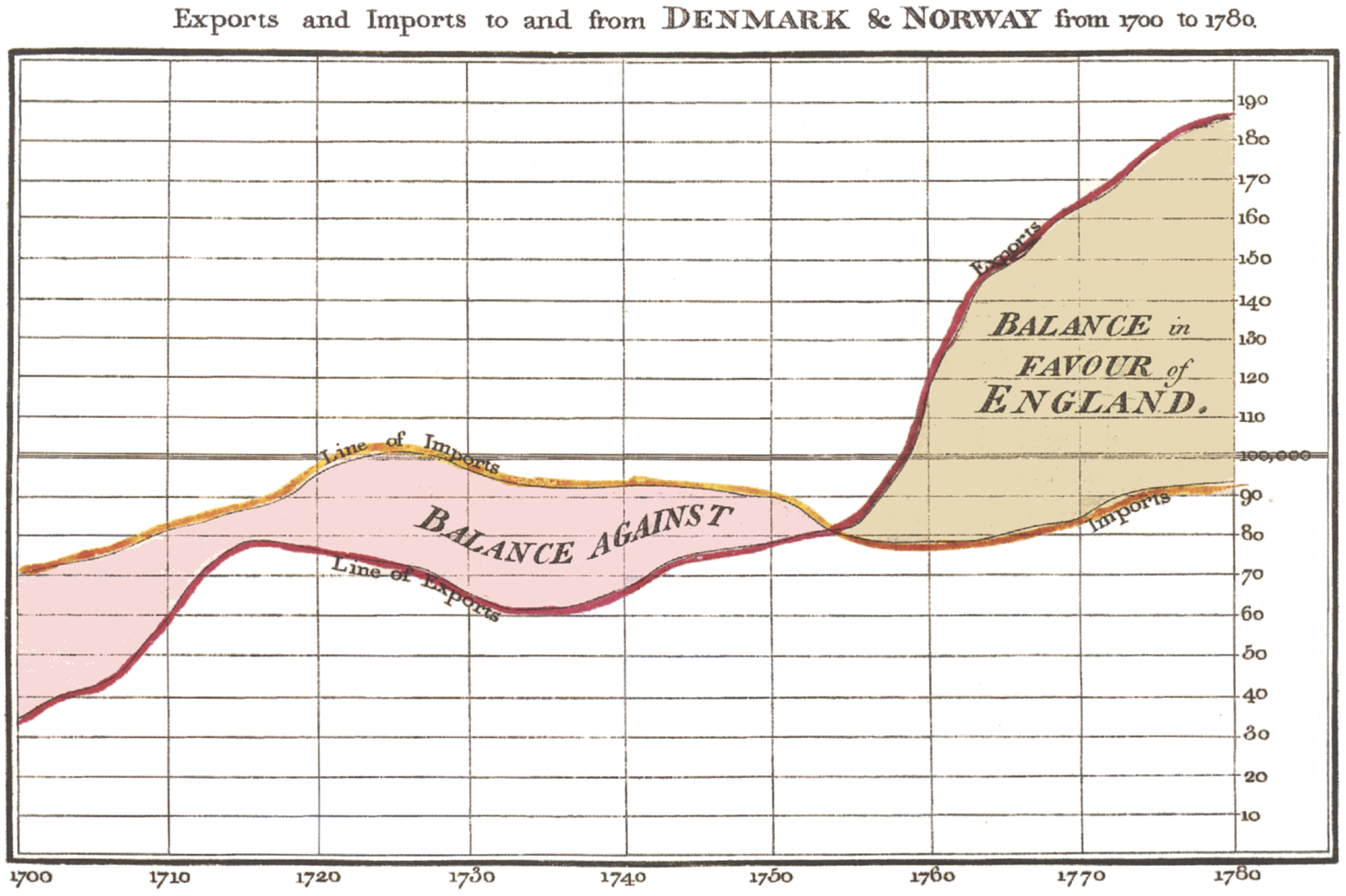
Analyze data to support reasoning (exploratory visualization)

- Develop and assess hypotheses
- Find patterns / Discover errors in data
- Expand memory

Communicate information to others (explanatory visualization)

- Share and persuade
- Collaborate and revise

Communicate Info

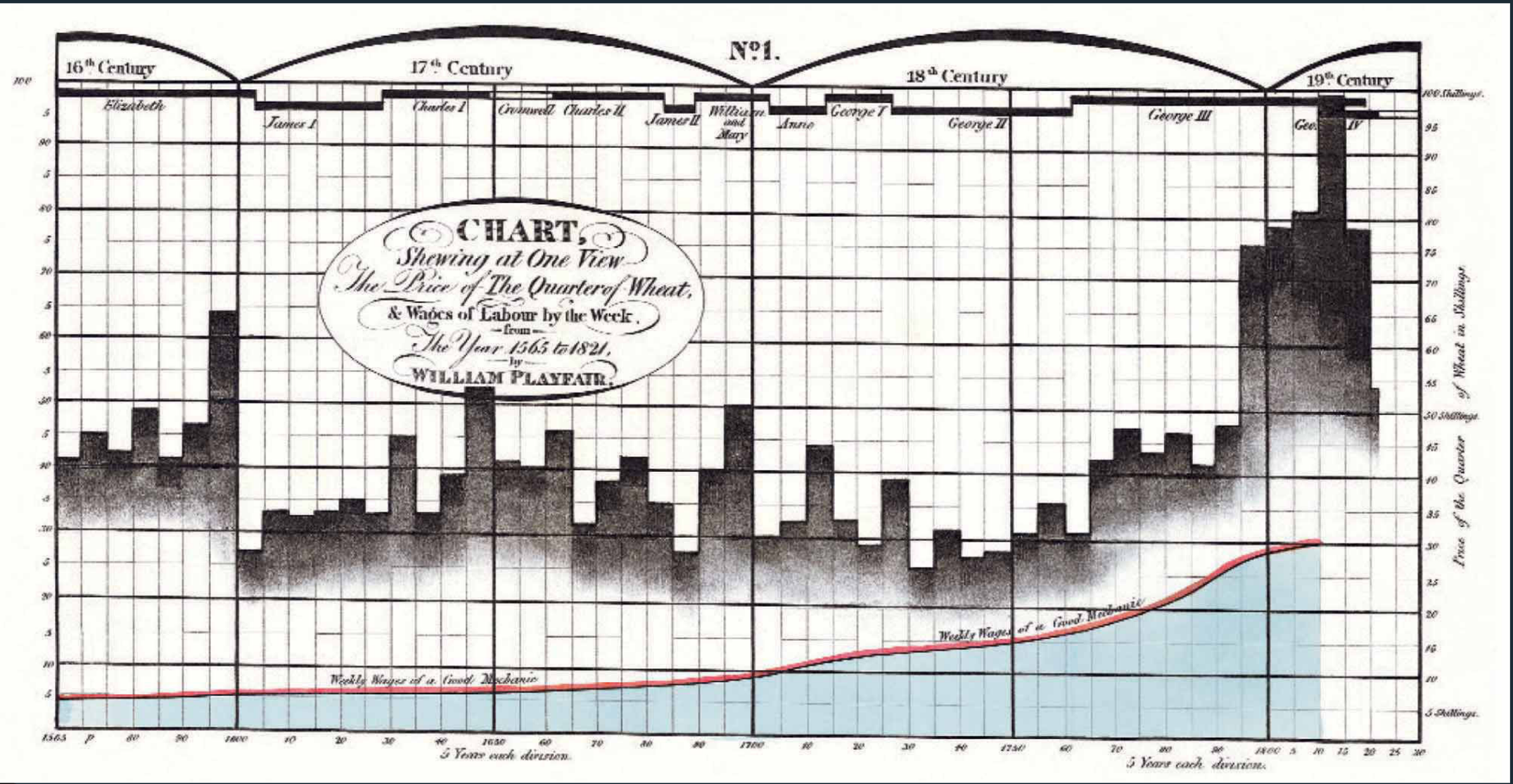


William Playfair, a Scottish engineer and economist, is credited with inventing modern graphical methods.

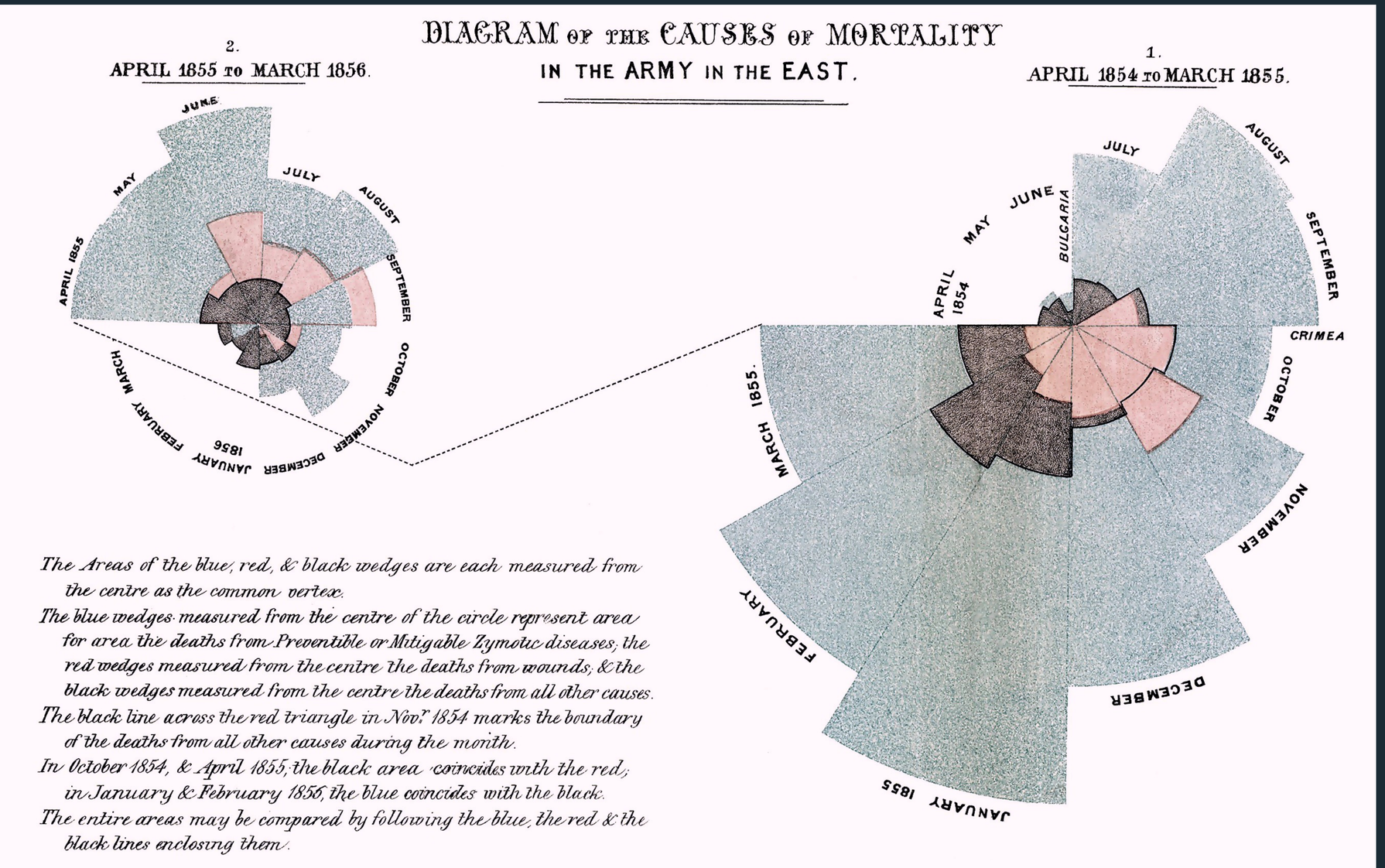
In 1786, published *The Commercial and Political Atlas* which contained the first time-series and bar charts.

Communicate Info

"You have before you, my Lords and Gentlemen, a chart of the prices of wheat for 250 years [...] the main fact deserving of consideration is, that never at any former period was wheat so cheap, in proportion to mechanical labour, as it is at the present time" — William Playfair, 1822 letter to Parliament.



Communicate Info



"to affect thro' the Eyes what we fail to convey to the public through their word-proof ears"

— Florence Nightingale on her "coxcomb" of Crimean War Deaths (1856).

Chart vividly depicts that the main cause of deaths was not war wounds but unsanitary conditions.

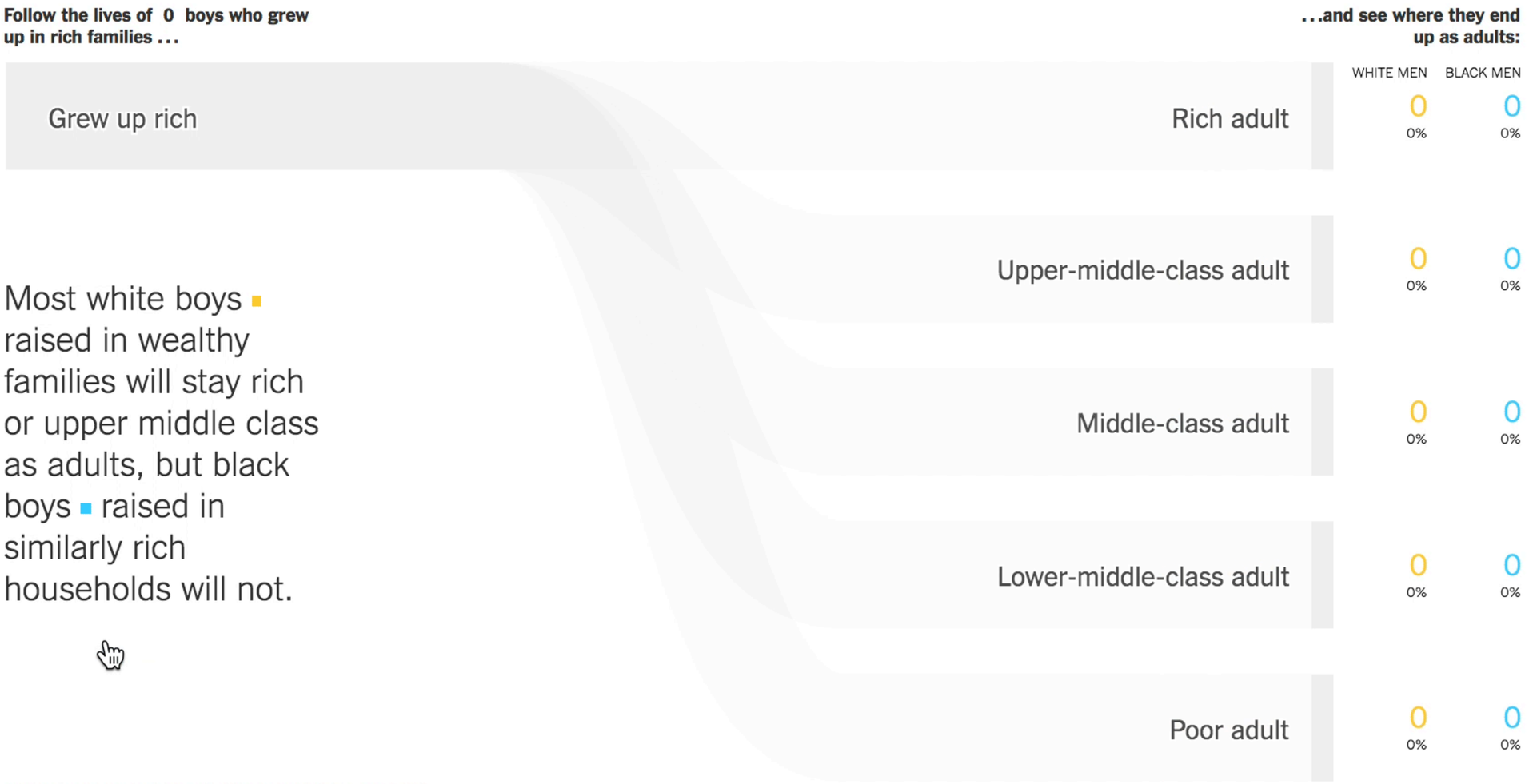
Returned to Britain and led a successful campaign for better conditions in barracks and hospitals.

Communicate Info

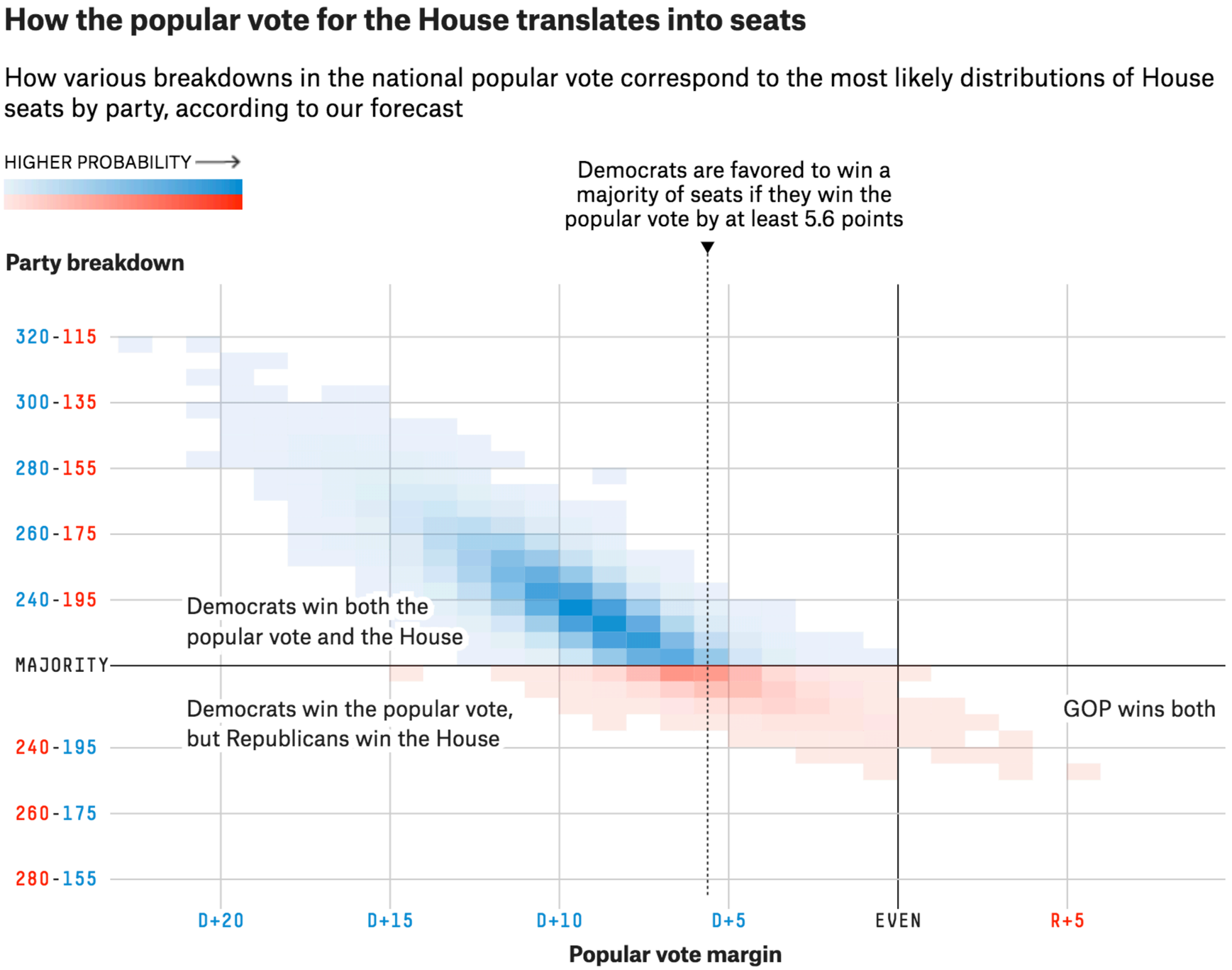
The Best Stats You've Ever Seen, *Hans Rosling* (2006).

Extensive Data Shows Punishing Reach of Racism for Black Boys

By **EMILY BADGER, CLAIRE CAIN MILLER, ADAM PEARCE** and **KEVIN QUEALY** MARCH 19, 2018



Adult outcomes reflect household incomes in 2014 and 2015.



House Forecast, *FiveThirtyEight* (2018).

The Value of Visualization

Aka why create visualizations?

Record information

- Blueprints, photographs, seismographs, ...

Analyze data to support reasoning (exploratory visualization)

- Develop and assess hypotheses
- Find patterns / Discover errors in data
- Expand memory

Communicate information to others (explanatory visualization)

- Share and persuade
- Collaborate and revise

The Value of Visualization

Aka why create visualizations?

Record information

- Blueprints, photographs, seismographs, ...

Analyze data to support reasoning (exploratory visualization)

- Develop and assess hypotheses
- Find patterns / Discover errors in data
- Expand memory

Communicate information to others (explanatory visualization)

- Share and persuade
- Collaborate and revise

Course Mechanics

http://vis.mit.edu/classes/6.894/

Course Goals

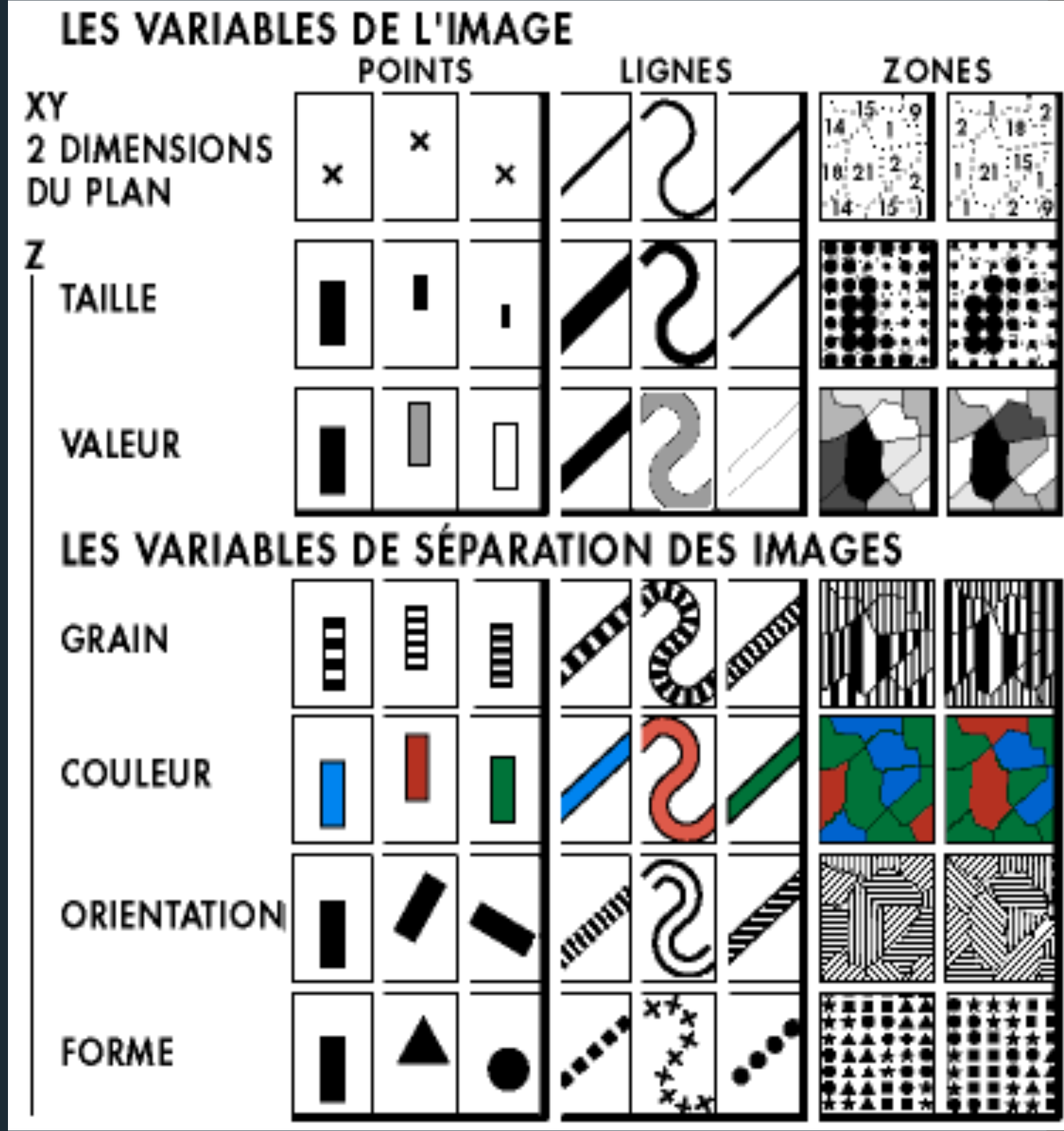
By the end of the course, you should expect to be able to:

1. *Design*, *evaluate*, and *critique* visualizations.
2. *Wrangle*, *explore*, and *explain* datasets using visualizations.
3. *Understand* visualization techniques and theory.
4. *Implement* interactive data visualizations.
5. *Develop* a substantial visualization project.

Course Topics

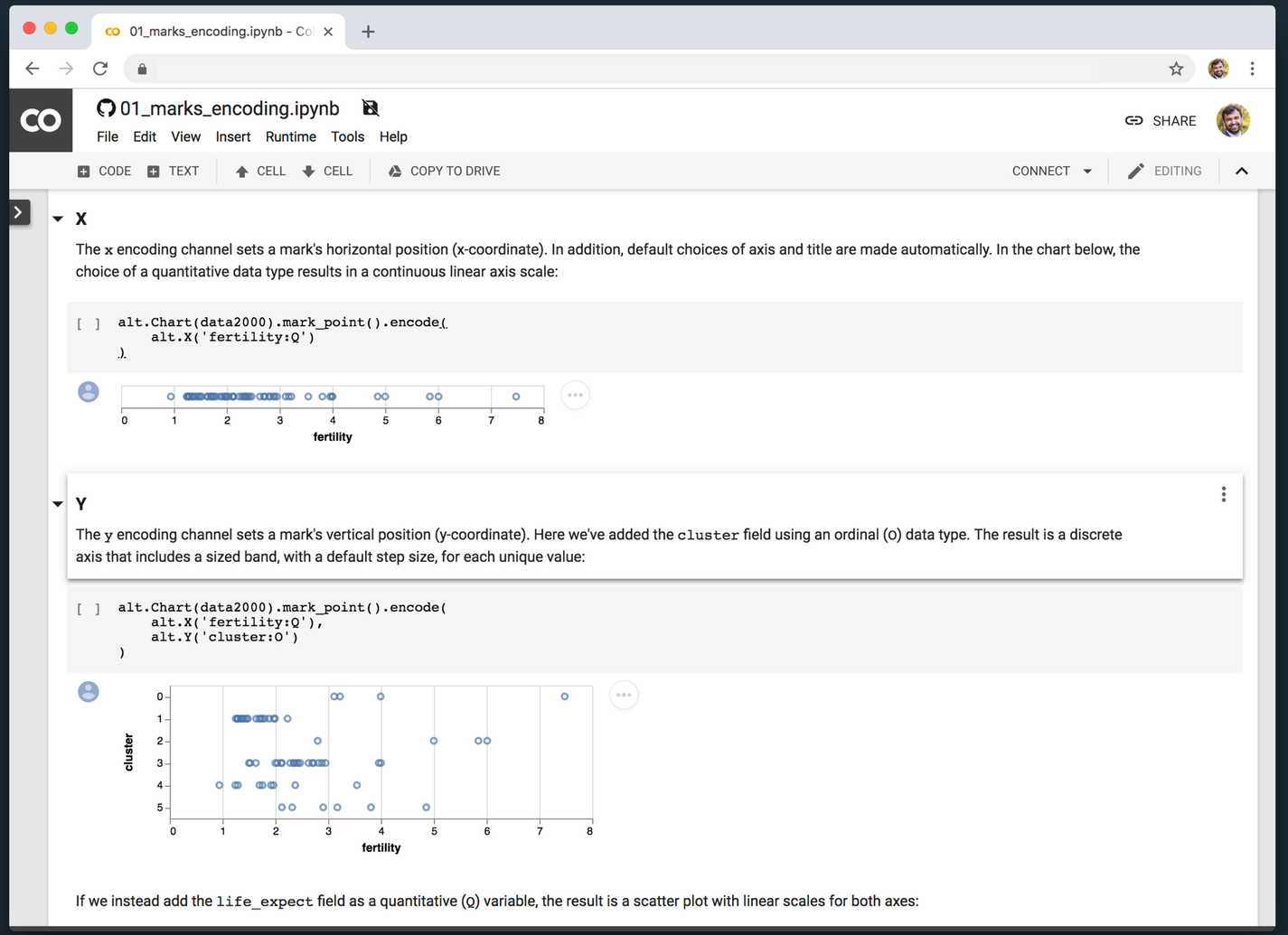
Course Topics

Data & Image Models



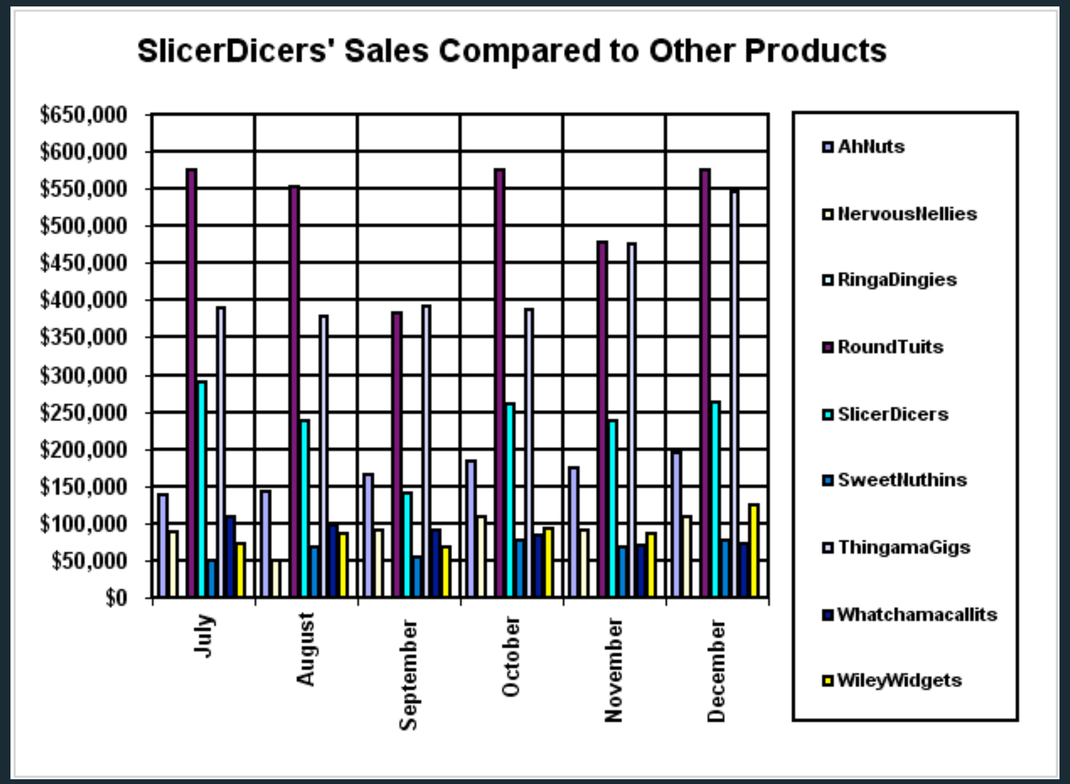
Course Topics

Visual Encoding with Vega-Lite & Altair

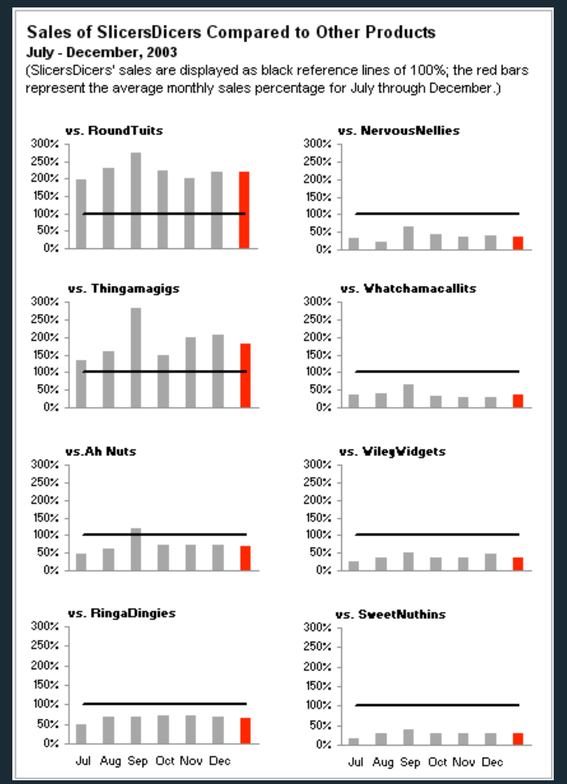


Course Topics

(Re-)Design



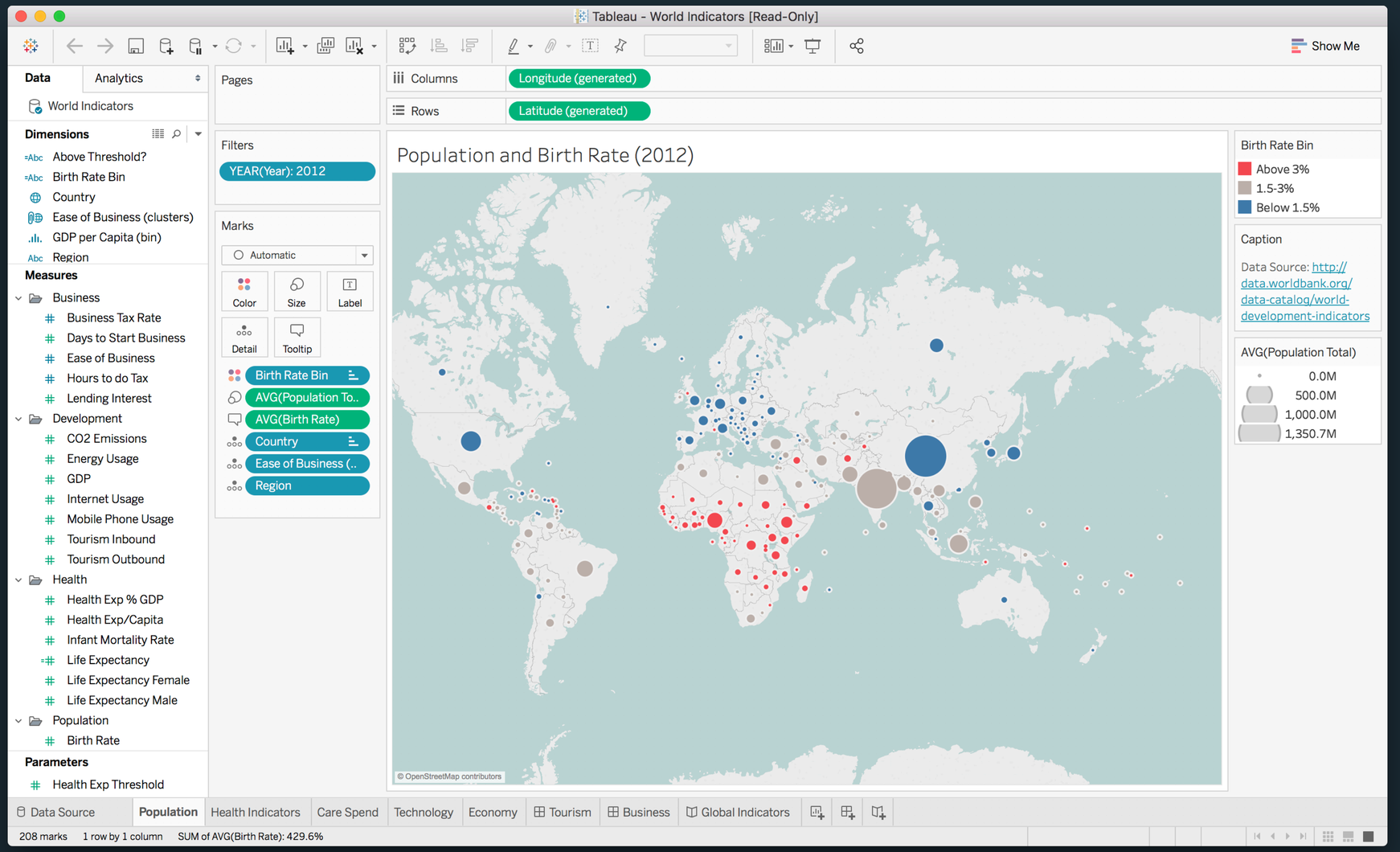
Problematic Design



Redesign

Course Topics

Exploratory Data Analysis (EDA)



Course Topics

Perception

blue

yellow

red

green

orange

purple

Course Topics

Perception

blue

yellow

red

green

orange

purple

Course Topics

Perception

blue

yellow

red

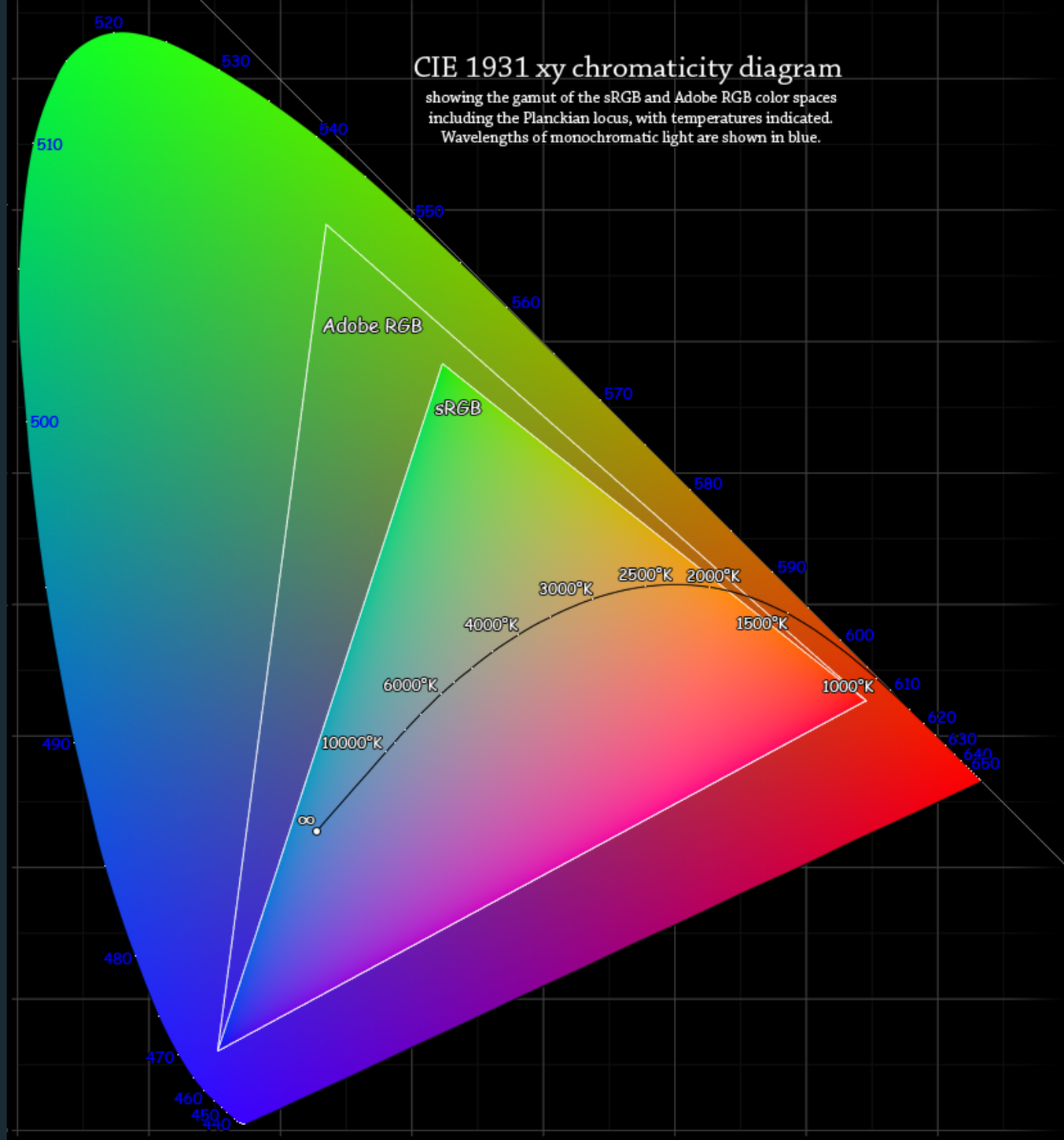
green

orange

purple

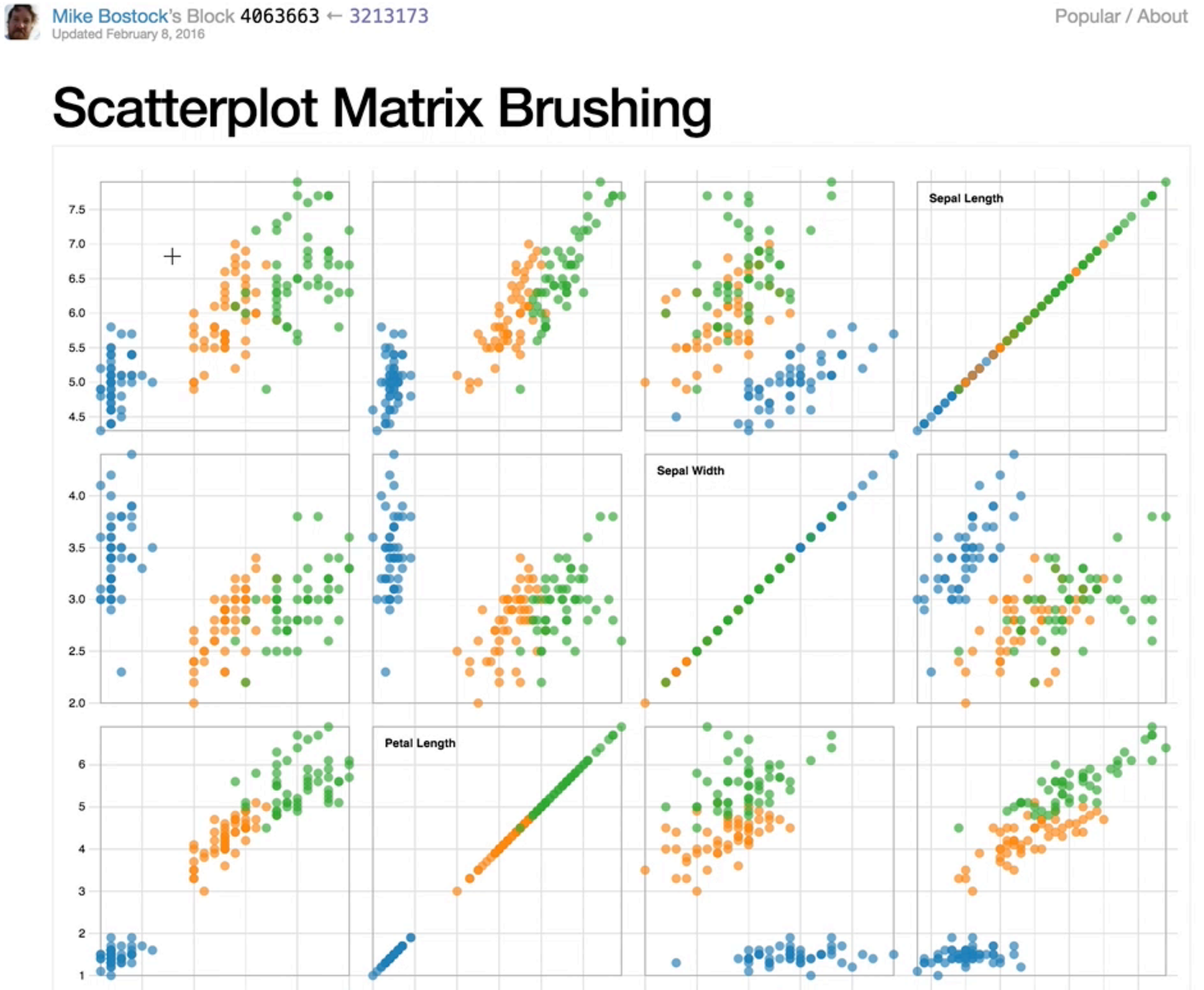
Course Topics

Color



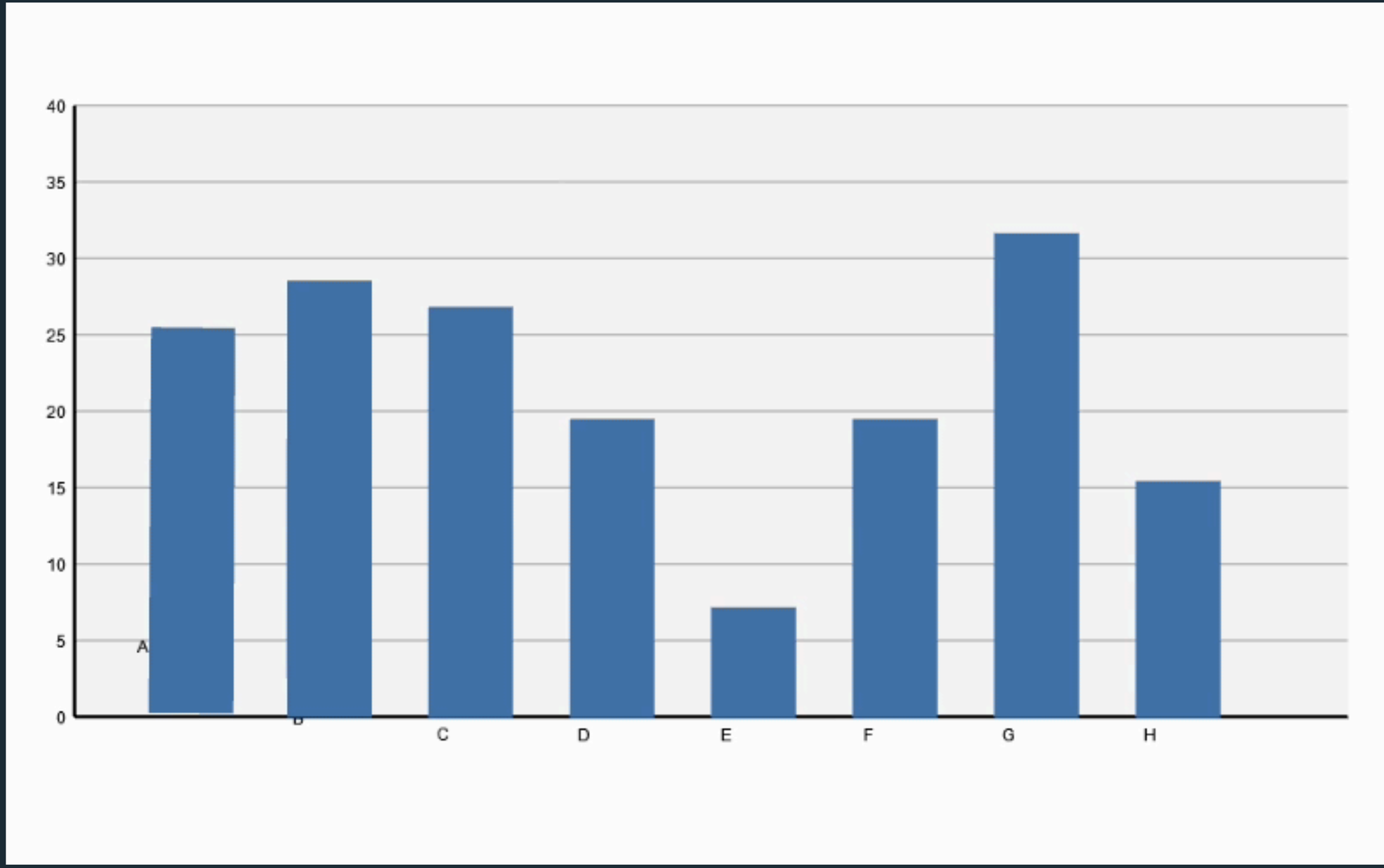
Course Topics

Interactivity



Course Topics

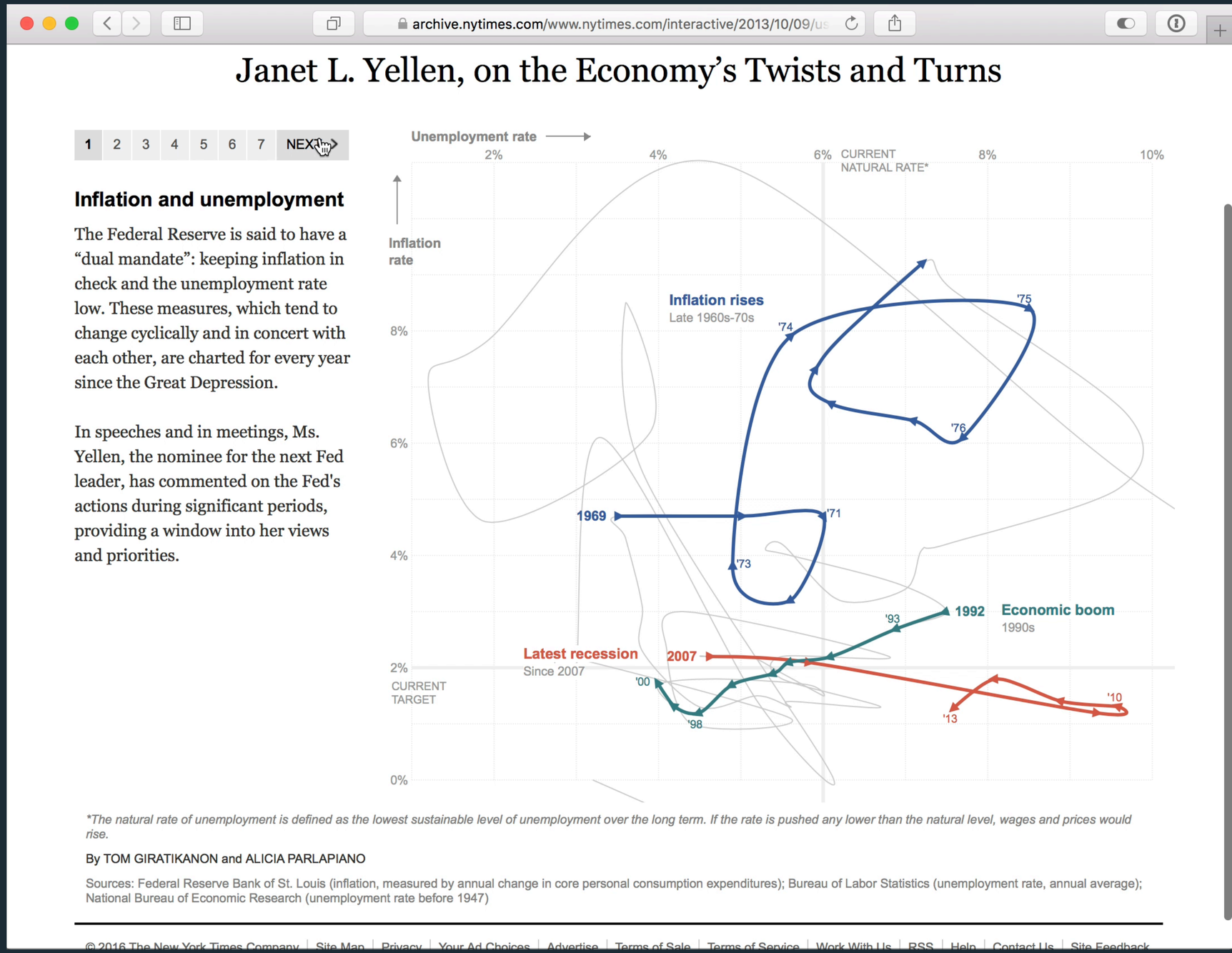
Animation



Heer & Robertson. (2007).

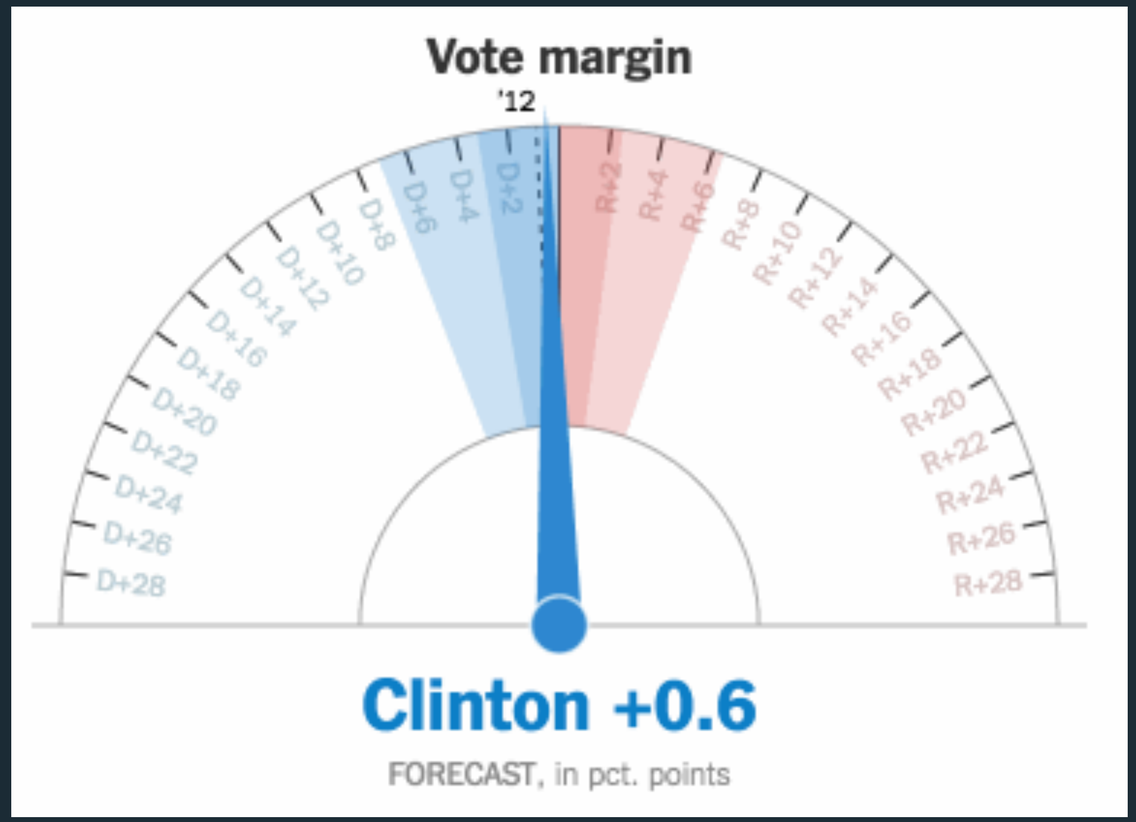
Course Topics

Narrative



Course Topics

Error & Uncertainty



Course Topics

Mapping & Cartography

Dymaxion Maps, *Fuller.* (1946)

Course Staff

Course Staff

My career:

- CS all the way through!
- BS, UC San Diego
- PhD, Stanford (+UW)
- Visiting Researcher, Google Brain
- New faculty @ MIT

Interests:

- Interactive Data Visualization Tools
- Machine Learning Interpretability

Arvind Satyanarayan

Course Staff

2nd year PhD student advised by David Karger

Study online collaboration and build systems to help people get their work done.

#information retrieval #automation #task management

http://people.csail.mit.edu/soya/

Soya Park

Course Grading

Class Participation	5%	
Reading Commentaries	10%	
A1: Visualization Design	7.5%	Due 2/13
A2: Exploratory Data Analysis	12.5%	Due 2/27
A3: Interactive Prototype	20%	Due 3/13
A3 Peer Evaluation	5%	Due 3/22
Final Project	40%	
Proposal		Due 4/3
MVP + Presentations		Due 4/22
Poster Session + Final Deliverables		Due 5/13

Course Grading

Class Participation	5%
Reading Commentaries	10%
A1: Visualization Design	7.5%
A2: Exploratory Data Analysis	12.5%
A3: Interactive Prototype	20%
A3 Peer Evaluation	5%
Final Project	40%
Proposal	
MVP + Presentations	
Poster Session + Final Deliverables	

Readings posted on nb.mit.edu – sign-up emails EOD today, sign-up link in LMOD.

2 readings per week – a mix of research papers, articles, textbook chapters.

On nb, post 1 paragraph per reading.

- Should not be a summary.
- Start a new thread, respond to an existing thread, etc.
- We'll discuss readings in class, so have commentaries posted **by noon**.
- You have 2 "passes" for the semester.

Course Grading

Class Participation	5%
Reading Commentaries	10%
A1: Visualization Design	7.5%
A2: Exploratory Data Analysis	12.5%
A3: Interactive Prototype	20%
A3 Peer Evaluation	5%
Final Project	40%
Proposal	
MVP + Presentations	
Poster Session + Final Deliverables	

Major visualization project on topic/ dataset of your choice.

Second half of the course, starting after spring break.

Teams of 1–3 people with a 1 page project proposal.

In-class presentations of minimal viable product (MVP). Peer review/critique.

Final poster presentation on May 13.

Course Grading

Class Participation	5%
Reading Commentaries	10%
A1: Visualization Design	7.5%
A2: Exploratory Data Analysis	12.5%
A3: Interactive Prototype	20%
A3 Peer Evaluation	5%
Final Project	40%
Proposal	
MVP + Presentations	
Poster Session + Final Deliverables	

Design a static visualization for a dataset.

Every 10 years, the census documents the demographic make-up of the U.S., influencing congressional districting and social services. This dataset contains a summary of census data for two years a century apart: 1900 and 2000.

You must choose the message you want to convey. What question(s) do you want to answer? What insight do you want to communicate?

Course Grading

Class Participation	5%
Reading Commentaries	10%
A1: Visualization Design	7.5%
A2: Exploratory Data Analysis	12.5%
A3: Interactive Prototype	20%
A3 Peer Evaluation	5%
Final Project	40%
Proposal	
MVP + Presentations	
Poster Session + Final Deliverables	

Pick a **guiding question**, use it as your title.

Design **a static visualization** to answer it.

You are free to use any tools (inc. pen & paper).

Deliverables (upload via LMOD; see A1 page).

Image of your visualization (PNG or JPG format).

Short description + design rationale (≤ 4 paragraphs).

Due by **noon, Wednesday, Feb 13**.

Questions?

http://vis.mit.edu/classes/6.894/