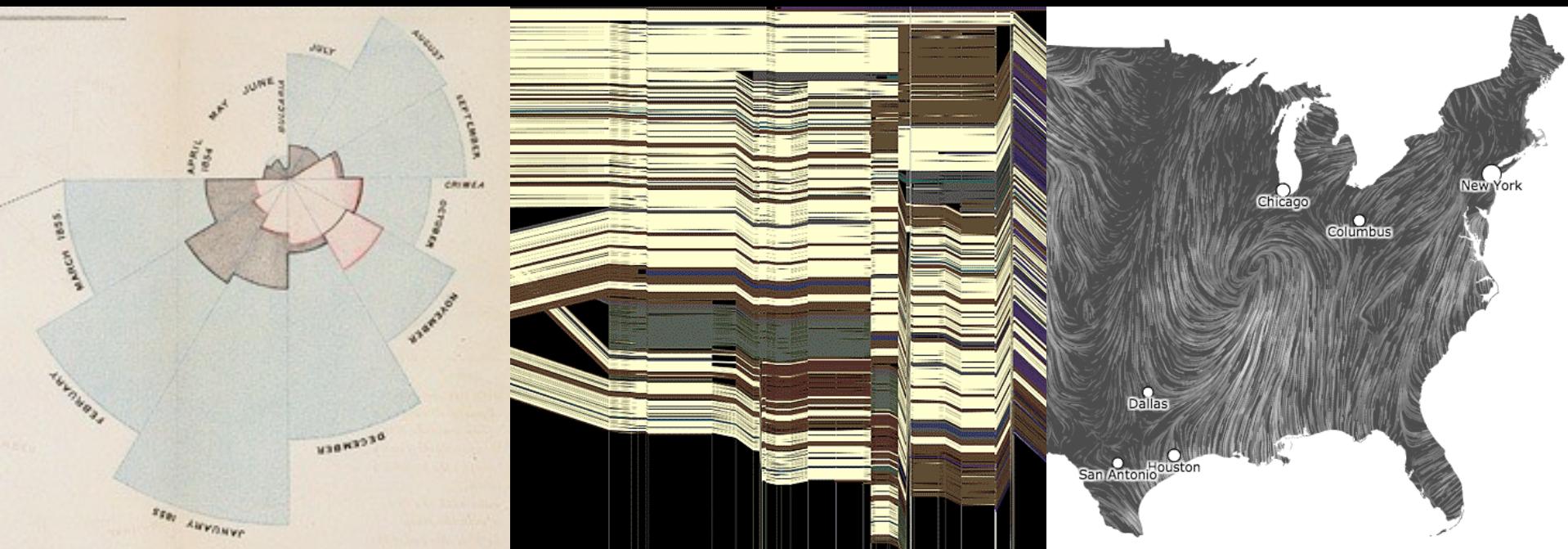


CSE 512 - Data Visualization

# The Value of Visualization

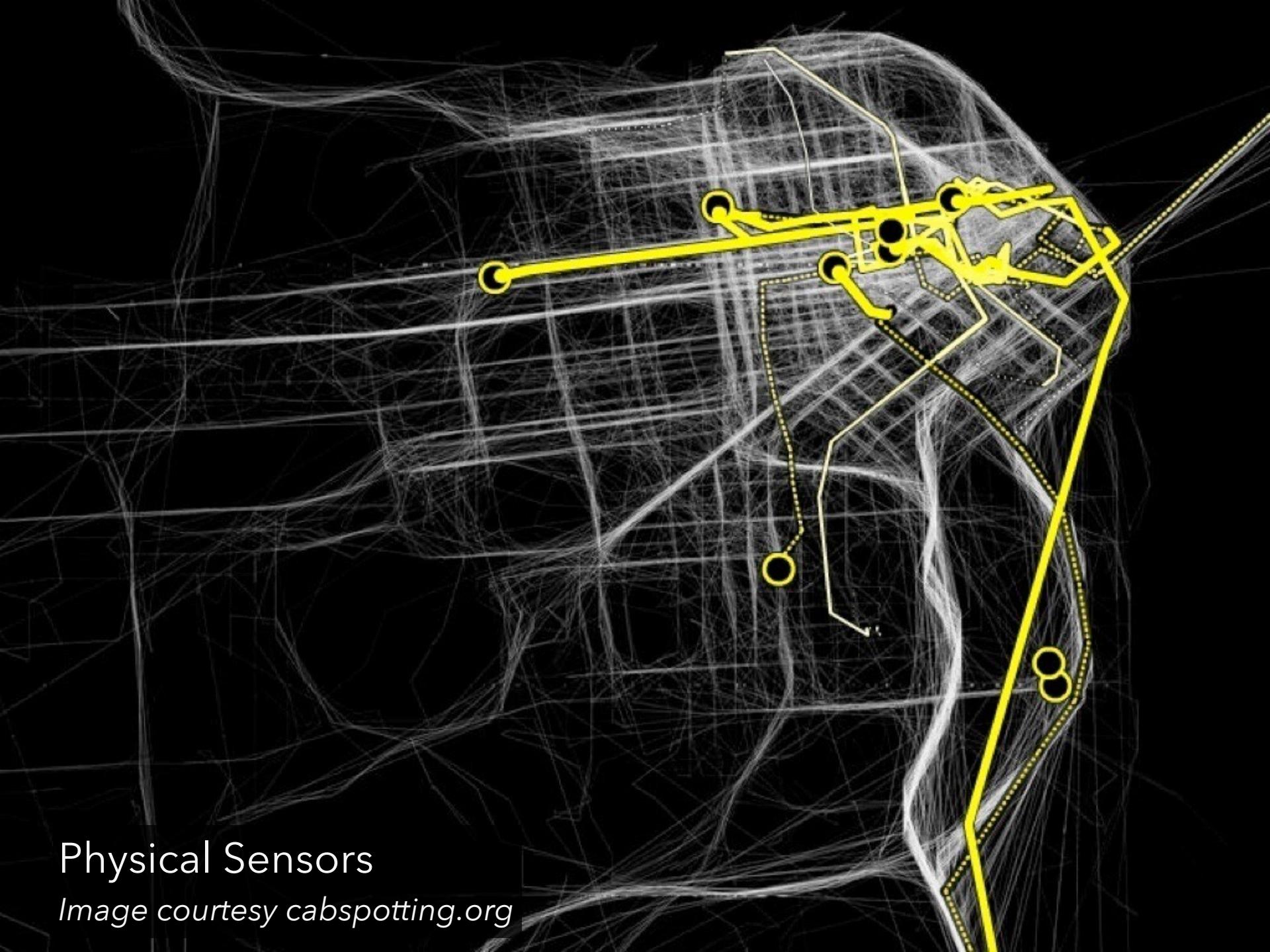


Jeffrey Heer University of Washington

How much data (bytes)  
did we produce in 2010?

2010: 1,200 exabytes  
10x increase over 5 years

Gantz et al, 2008, 2010

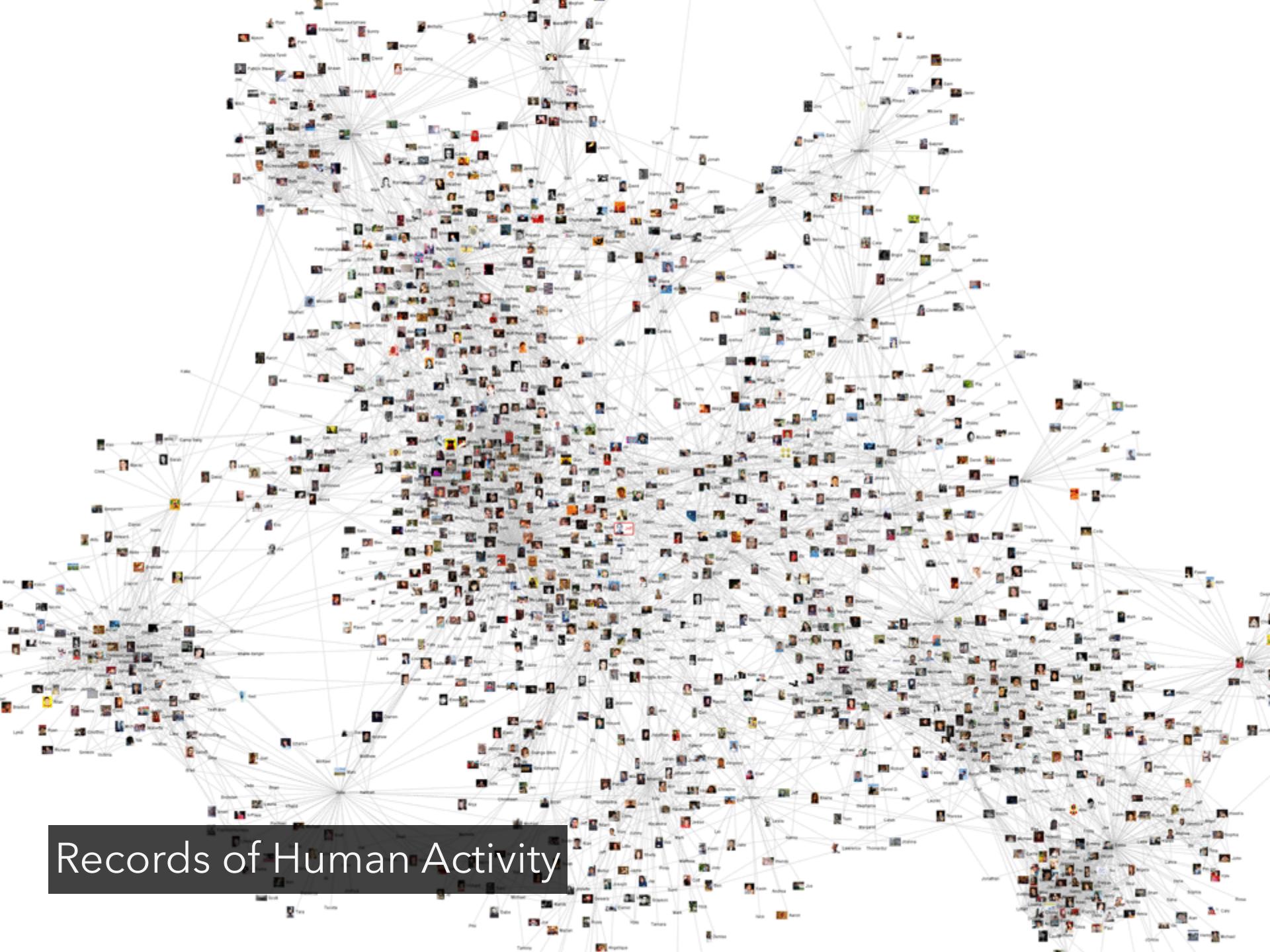


Physical Sensors

*Image courtesy cabspotting.org*



# Records of Human Activity



## Abortion

(Revision as of 22:56 4 Jun 2003)

"**Abortion**," in its most commonly used sense, refers to the deliberate early termination of a pregnancy, resulting in the death of the embryo or fetus. [1] Medically, the term also refers to the early termination of a pregnancy by natural ("spontaneous abortion" or *miscarriage*, which occurs in 1 in 5 of all pregnancies, usually within the first 12 weeks) or to the cessation of normal growth of a body part or organ. What follows is a discussion of the issues related to deliberate or "induced" abortion.

## Methods

Depending on the stage of pregnancy an abortion can be performed by a number of different methods. In the earliest terminations (before nine weeks), a **chemical abortion** is the usual method, though **methotrexate** is usually the only legal method available, although research has uncovered similar effects from **methotrexate** and **misoprostol**. Consequently, with chemical abortion and extending up until around the fifteenth week, **suction-aspiration** and **vacuum abortion** is the most common approach, replacing the more risky **dilation and curettage** (D & C). From the fifteenth week up until around the eighteenth week, a **surgical dilation and extraction** (S & X) or a **hysterotomy abortion**, similar to a **cesarean section**.

As the fetus size increases other techniques may be used to secure abortion in the third trimester. Premature expulsion of the fetus can be induced with **prostaglandin**, this can be coupled with injecting the amniotic fluid with saline or urea solution. Very late abortions can be brought about by the controversial **intact dilation and extraction** (I & X) or a **hysterotomy abortion**, similar to a **cesarean section**.

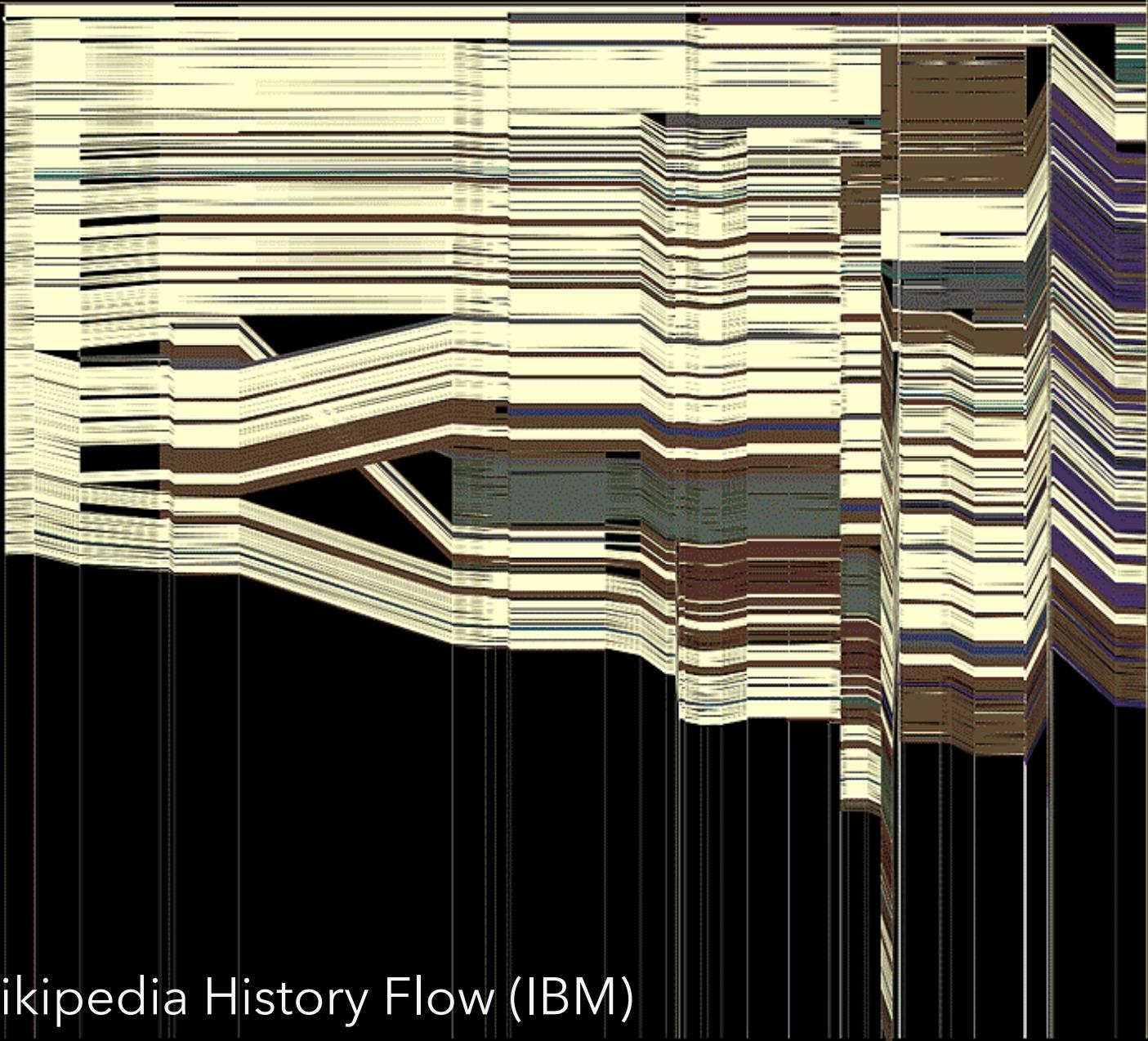
## The controversy

The morality and legality of abortion is a highly controversial topic in **applied ethics**, and is also discussed by **legal scholars** and **religious philosophers**. Important facts about abortion are also reported by **sociologists** and **historians**.

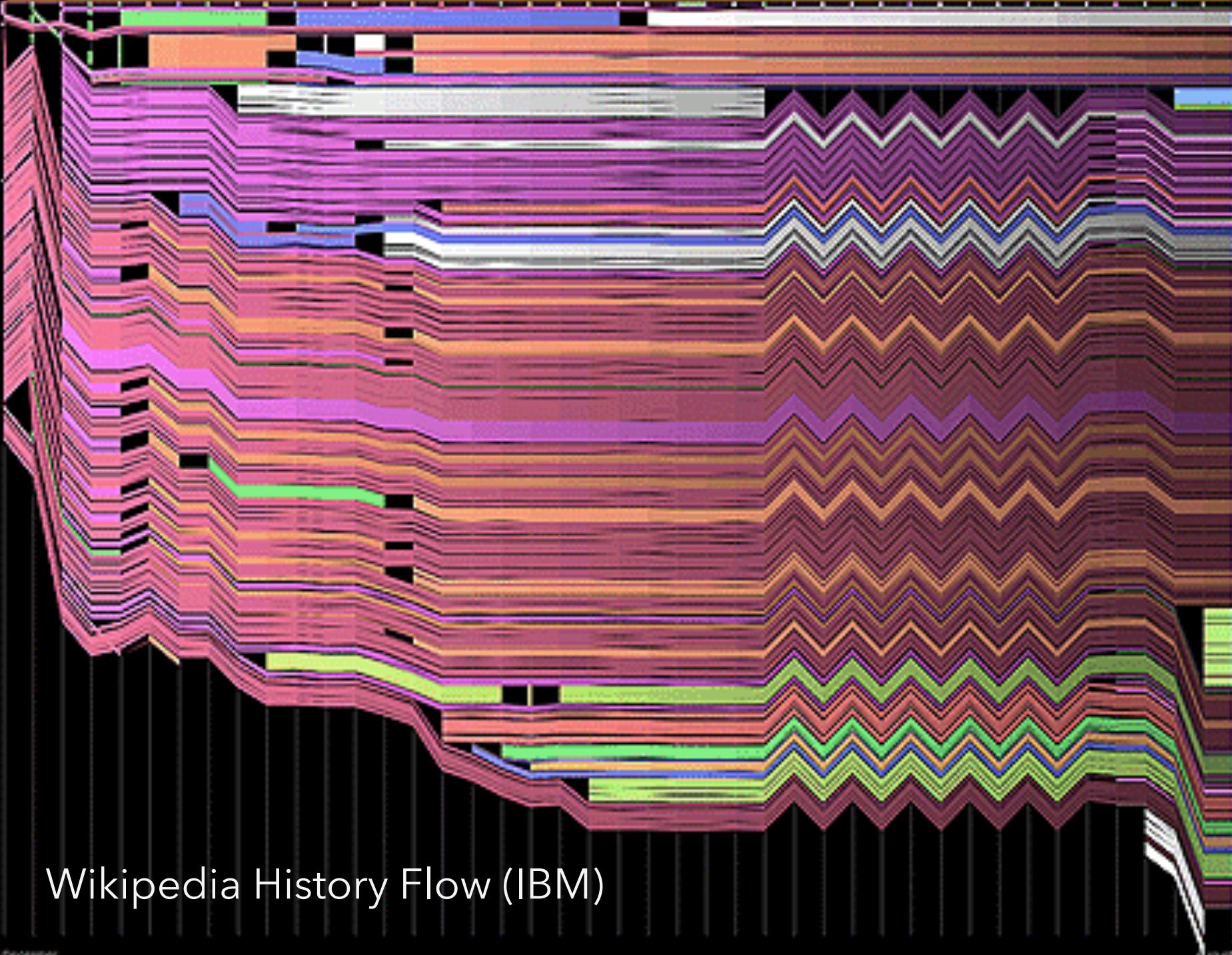
Abortion has been common in most societies, although it has often been opposed by some institutionalized religions and governments. In the **United States** and **Europe**, abortion became commonly accepted by the end of the 20th century. Additionally, abortion is accepted in **China**, **India** and other populous countries. The **Catholic Church** remains opposed to the procedure, however, and in other countries, notably the **United States** and the (predominantly Catholic) **Republic of Ireland**, the controversy is extremely active, to the extent that even supporters of the respective positions are subject to heated debate. While those on both sides of the issue are generally peaceful, if heated, in their expression of their positions, the debate is sometimes characterized by violence. Though true supporters of both sides, this is more marked on the side of those who are opposed to abortion, because of what they see as the gravity and urgency of their views.

## The central question

The central question in the abortion debate is the clash of presumed or perceived rights. On one hand, is a fetus (sometimes called the "unborn") pro-life/anti-abortion advocates) a human being with a right to life, and if so, at what point in pregnancy does the fetus become human? On the other hand, is a fetus part of a woman's body?



## Wikipedia History Flow (IBM)



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

# A Poverty of Attention

"What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it."



*Herb Simon*  
as quoted by Hal Varian  
Scientific American  
September 1995

# What is Visualization?

“Transformation of the symbolic into the geometric”

[McCormick et al. 1987]

“... finding the artificial memory that best supports our natural means of perception.” [Bertin 1967]

“The use of computer-generated, interactive, visual representations of data to amplify cognition.”

[Card, Mackinlay, & Shneiderman 1999]

Set A

X	Y
10	8.04
8	6.95
13	7.58
9	8.81
11	8.33
14	9.96
6	7.24
4	4.26
12	10.84
7	4.82
5	5.68

Set B

X	Y
10	9.14
8	8.14
13	8.74
9	8.77
11	9.26
14	8.1
6	6.13
4	3.1
12	9.11
7	7.26
5	4.74

Set C

X	Y
10	7.46
8	6.77
13	12.74
9	7.11
11	7.81
14	8.84
6	6.08
4	5.39
12	8.15
7	6.42
5	5.73

Set D

X	Y
8	6.58
8	5.76
8	7.71
8	8.84
8	8.47
8	7.04
8	5.25
19	12.5
8	5.56
8	7.91
8	6.89

**Summary Statistics**

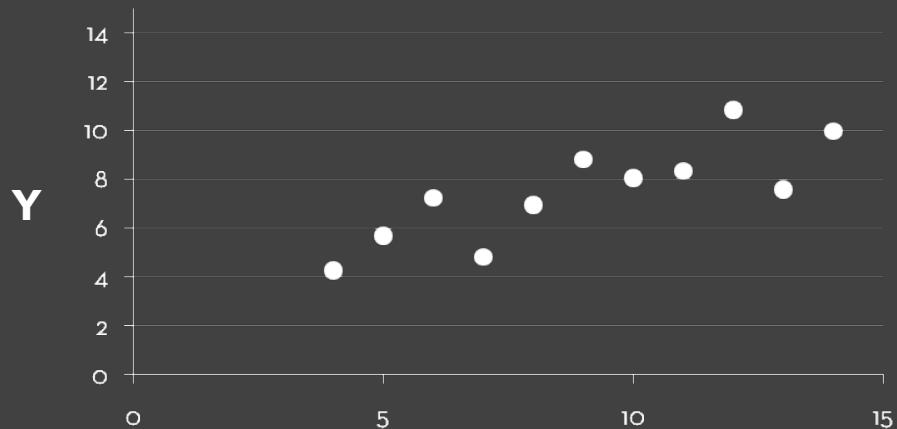
$$\begin{aligned} u_X &= 9.0 & \sigma_X &= 3.317 \\ u_Y &= 7.5 & \sigma_Y &= 2.03 \end{aligned}$$

**Linear Regression**

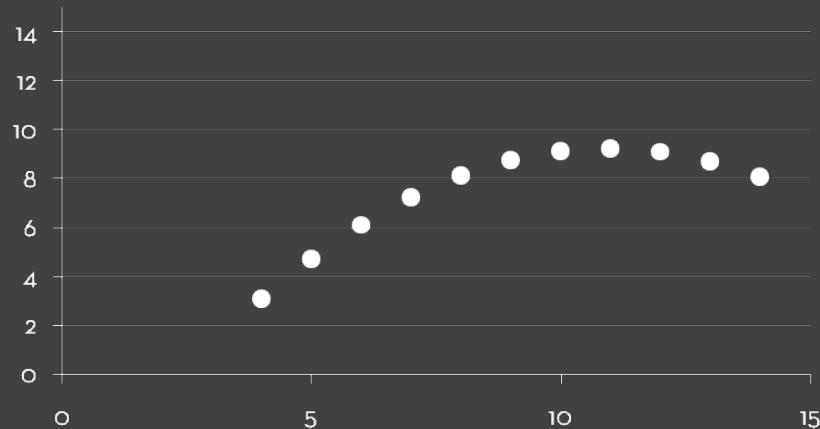
$$\begin{aligned} Y &= 3 + 0.5 X \\ R^2 &= 0.67 \end{aligned}$$

[Anscombe 1973]

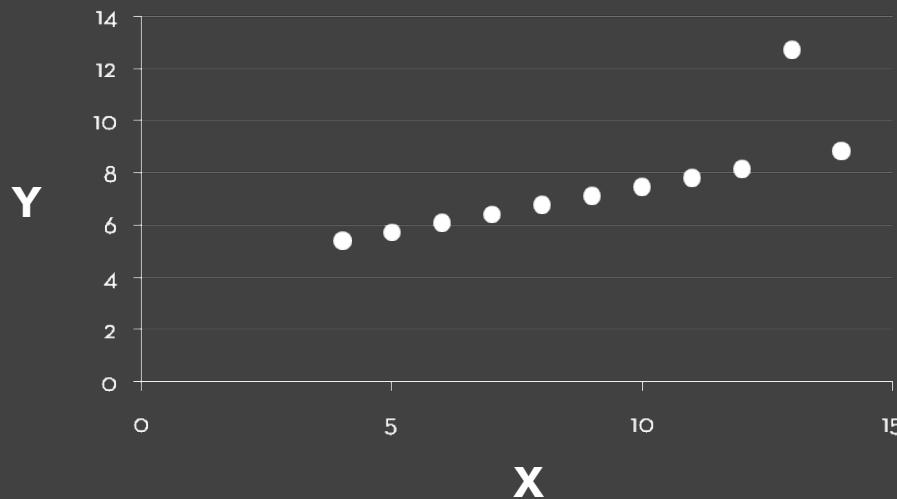
# Set A



# Set B



# Set C



# Set D



# Why Create Visualizations?

# Why Create Visualizations?

Answer questions (or discover them)

Make decisions

See data in context

Expand memory

Support graphical calculation

Find patterns

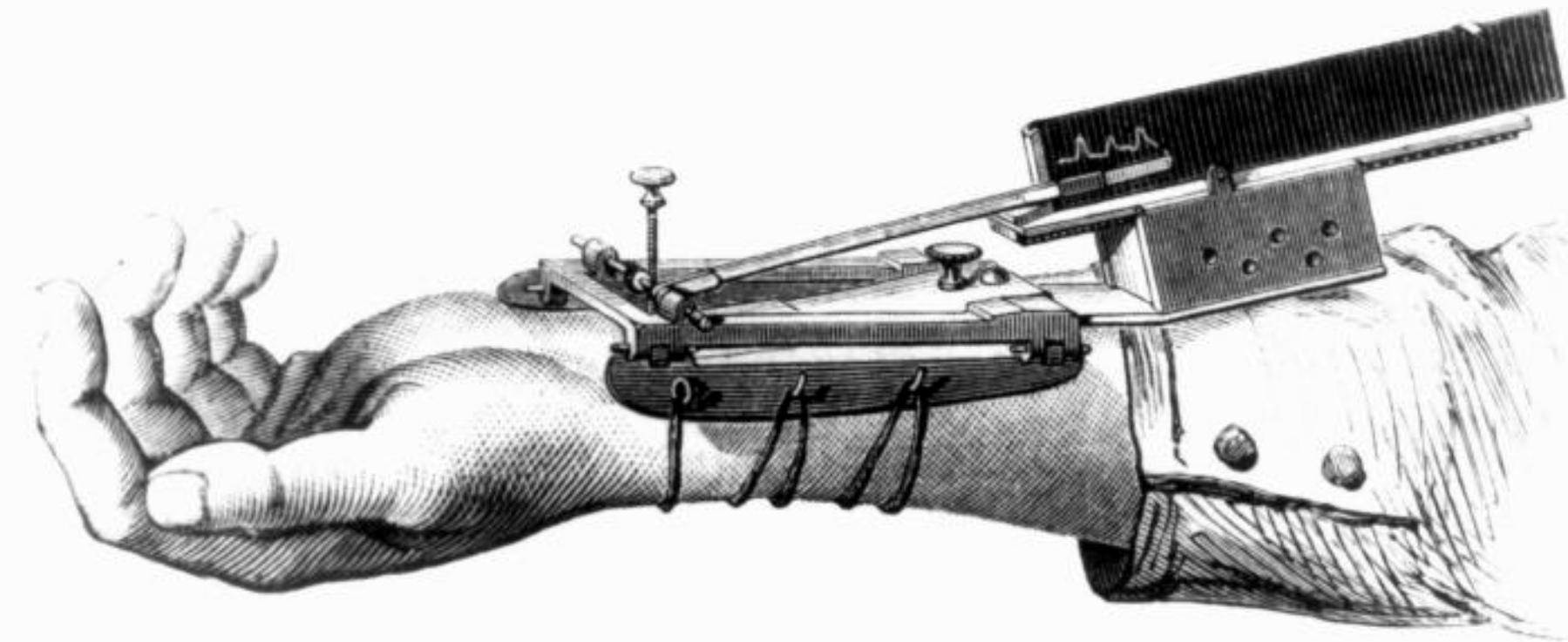
Present argument or tell a story

Inspire

# Record Information



Gallop, Bay Horse "Daisy" [Muybridge 1884-86]

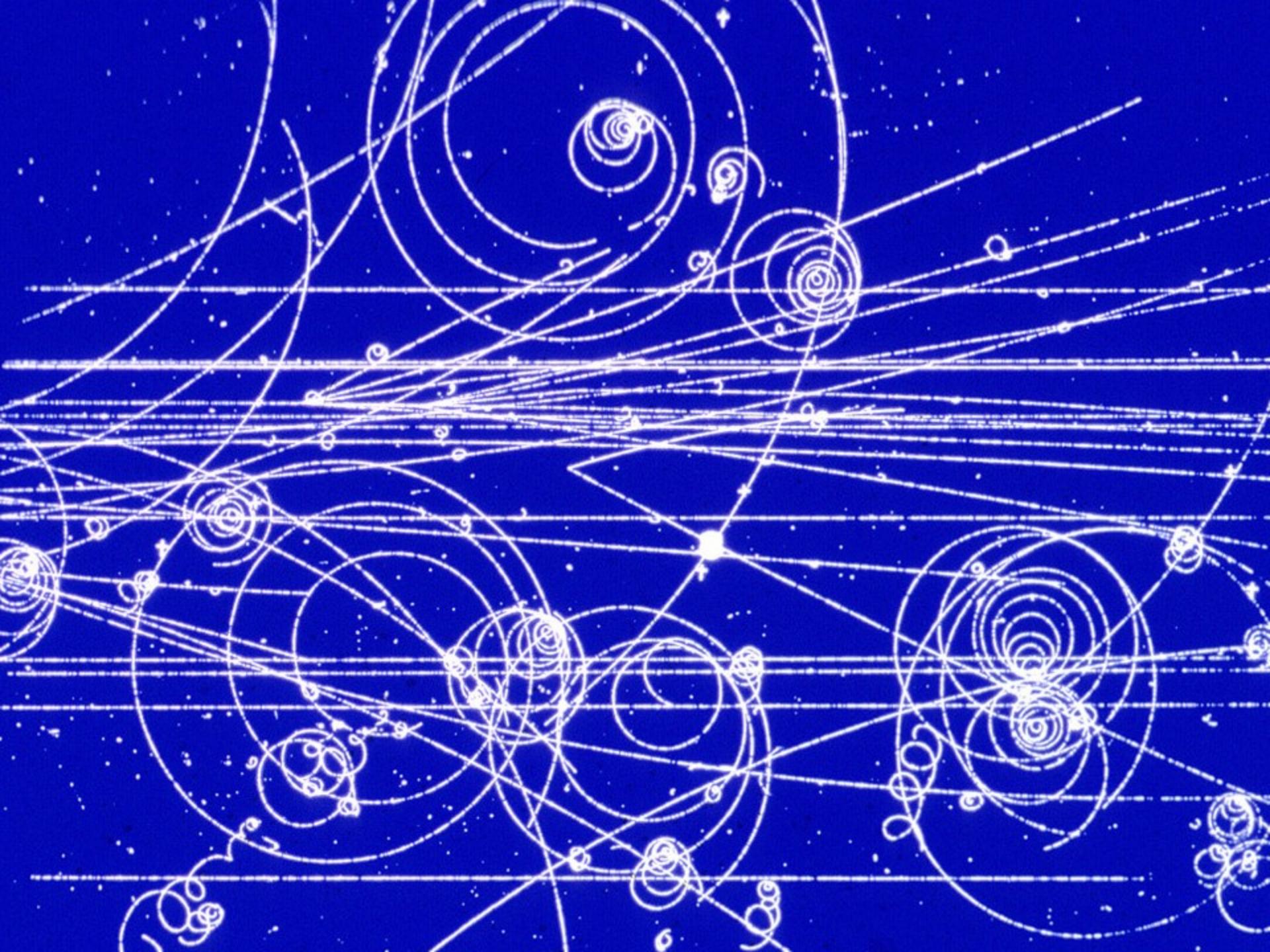


1.

Marey's **sphygmograph** in use.

1860. *La méthode graphique dans les sciences expérimentales et principalement en physiologie et en médecine.*

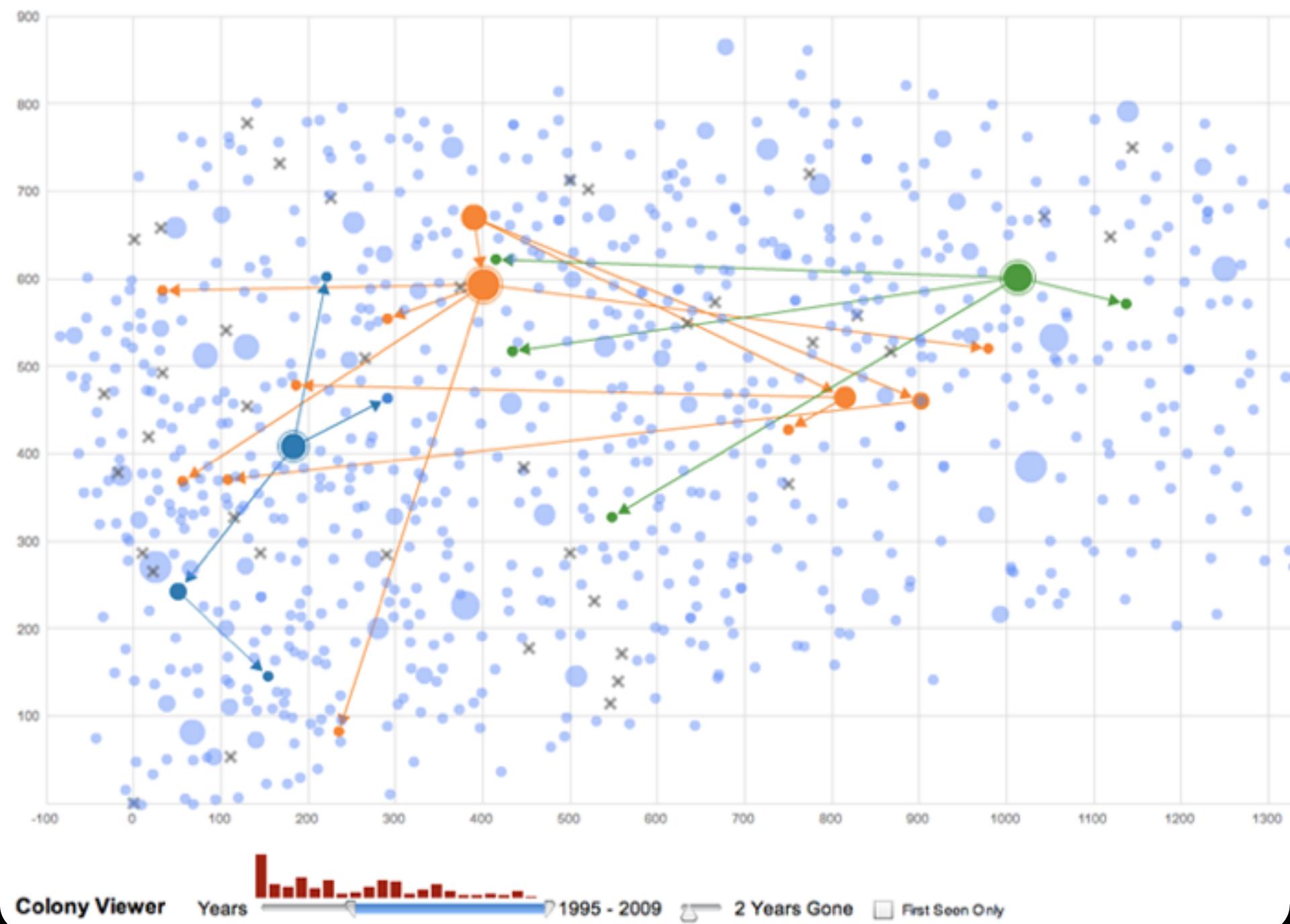
E.J. Marey's sphygmograph [from Braun 83]





Expected live in 06

The diagram illustrates a complex network of connections between numerous nodes, each labeled with a unique number. The connections are represented by lines that link adjacent nodes. A significant portion of the network is highlighted with thick black lines, indicating a primary route or backbone. Numerous nodes are circled, drawing attention to specific points of interest or key junctions. The overall structure is highly interconnected, with many nodes having multiple incoming and outgoing links.



# Support Reasoning

## HISTORY OF O-RING DAMAGE ON SRM FIELD JOINTS

	SRM No.	Cross Sectional View			Top View		Clocking Location (deg)
		Erosion Depth (in.)	Perimeter Affected (deg)	Nominal Dia. (in.)	Length Of Max Erosion (in.)	Total Heat Affected Length (in.)	
0	61A LH Center Field**	22A	None	0.280	None	None	36°--66°
	61A LH CENTER FIELD**	22A	NONE	0.280	NONE	NONE	338°-18°
0	51C LH Forward Field**	15A	0.010	154.0	0.280	4.25	5.25
	51C RH Center Field (prim)***	15B	0.038	130.0	0.280	12.50	58.75
y	51C RH Center Field (sec)***	15B	None	45.0	0.280	None	354
	41D RH Forward Field	13B	0.028	110.0	0.280	3.00	None
	41C LH Aft Field*	11A	None	0.280	None	None	--
	41B LH Forward Field	10A	0.040	217.0	0.280	3.00	14.50
STS-2	STS-2 RH Aft Field	2B	0.053	116.0	0.280	--	90

\*Hot gas path detected in putty. Indication of heat on O-ring, but no damage.

\*\*Soot behind primary O-ring.

\*\*\*Soot behind primary O-ring, heat affected secondary O-ring.

Clocking location of leak check port - 0 deg.

OTHER SRM-15 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY AND NO SOOT NEAR OR BEYOND THE PRIMARY O-RING.

SRM-22 FORWARD FIELD JOINT HAD PUTTY PATH TO PRIMARY O-RING, BUT NO O-RING EROSION AND NO SOOT BLOWBY. OTHER SRM-22 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY.

## BLOW BY HISTORY

## SRM-15 WORST BLOW-BY

- 2 CASE JOINTS (80°), (110°) Arc
- MUCH WORSE VISUALLY THAN SRM-22

## SRM 22 BLOW-BY

- 2 CASE JOINTS (30-40°)

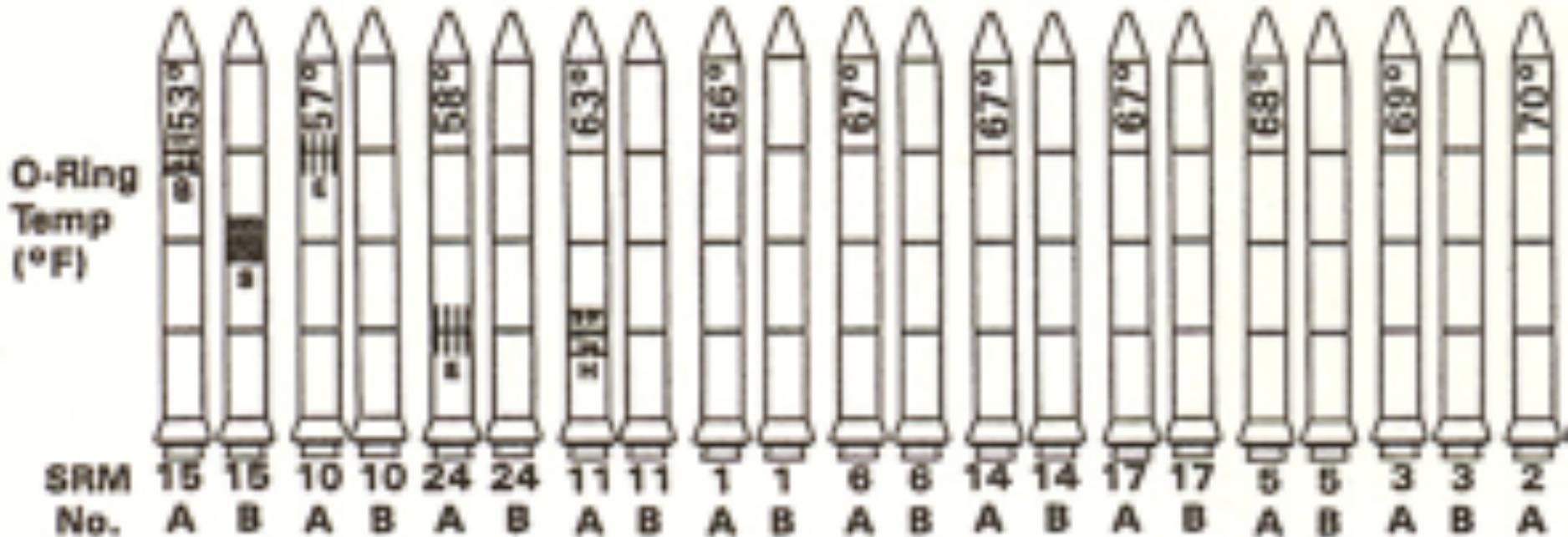
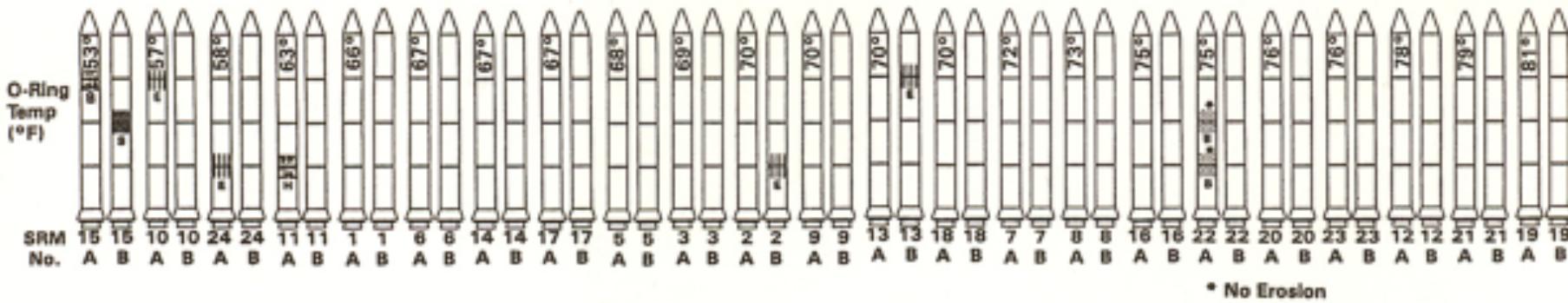
## SRM-13A, 15, 16A, 18, 23A 24A

- NOZZLE Blow-by

## HISTORY OF O-RING TEMPERATURES (DEGREES - F)

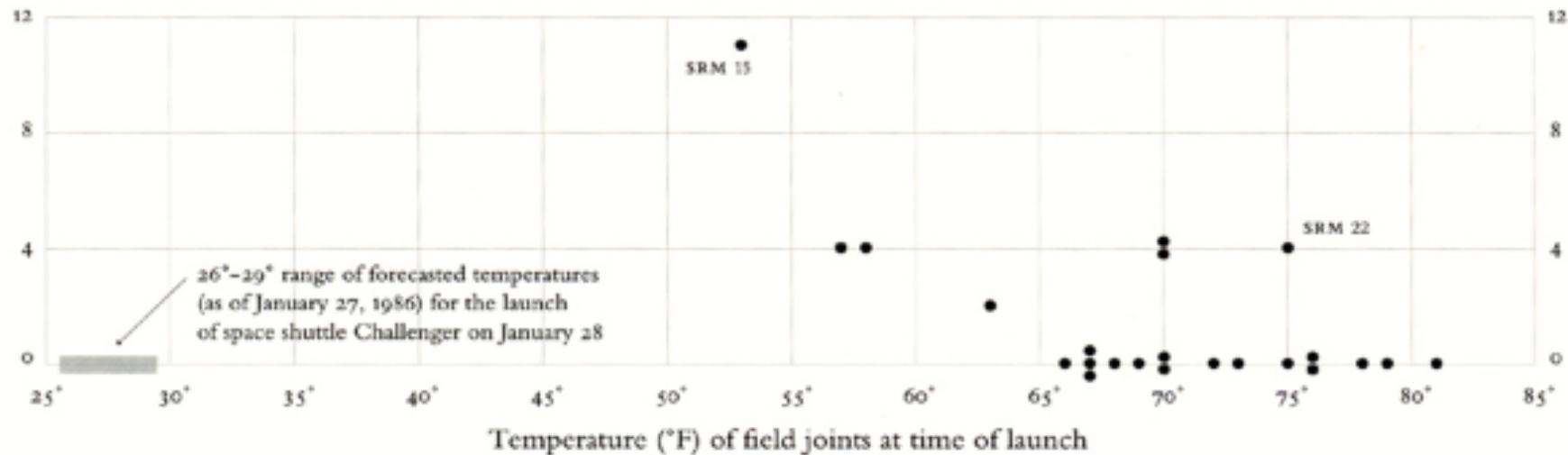
MOTOR	MGT	AMB	O-RING	WIND
DM-4	68	36	47	10 MPH
DM-2	76	45	52	10 MPH
QM-3	72.5	40	48	10 MPH
QM-4	76	48	51	10 MPH
SRM-15	52	64	53	10 MPH
SRM-22	77	78	75	10 MPH
SRM-25	55	26	29	10 MPH
			27	25 MPH

# Make a Decision: Challenger



# Make a Decision: Challenger

O-ring damage  
index, each launch



Visualizations drawn by Tufte show how low temperatures damage O-rings [Tufte 97]

# Data in Context: Cholera Outbreak



In 1854 John Snow plotted the position of each cholera case on a map. [from Tufte 83]

# Data in Context: Cholera Outbreak



Used map to hypothesize that pump on Broad St. was the cause. [from Tufte 83]

# Expand Memory: Multiplication

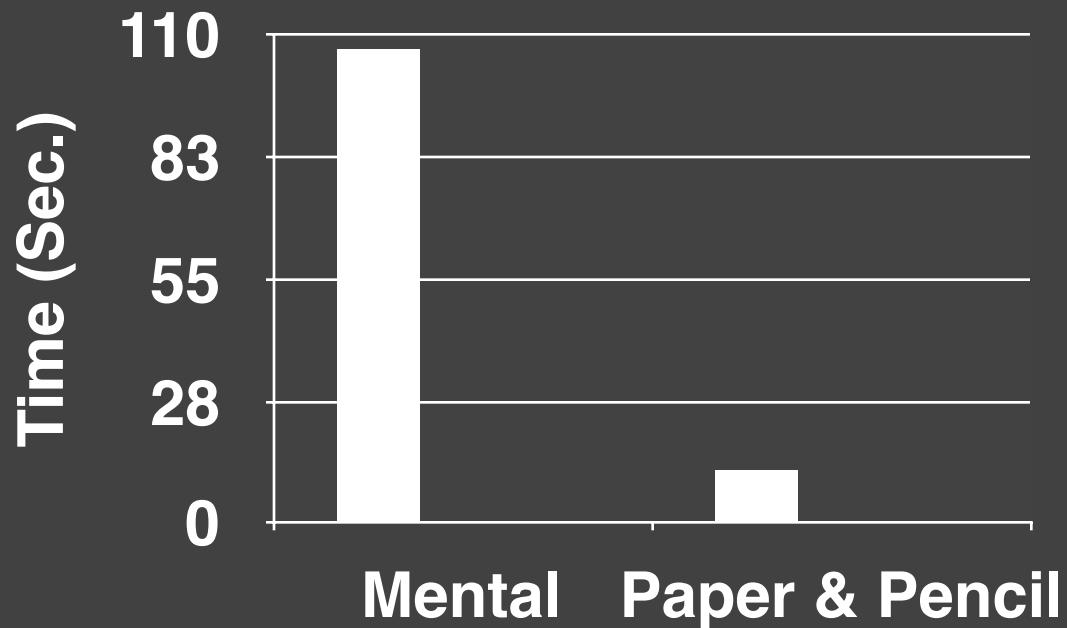
Class Exercise!

# Expand Memory: Multiplication

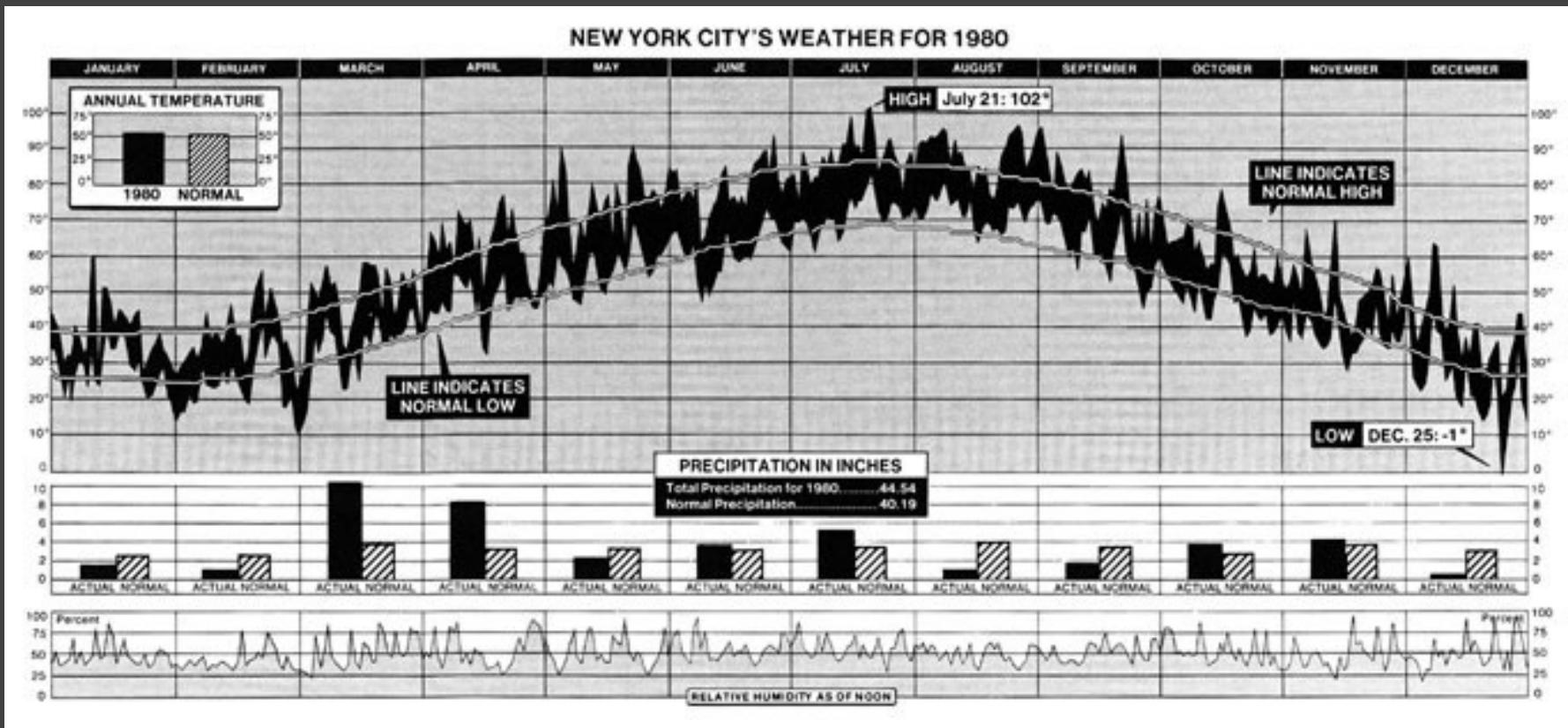
$$\begin{array}{r} 34 \\ \times 72 \\ \hline \end{array}$$

# Expand Memory: Multiplication

$$\begin{array}{r} 34 \\ \times 72 \\ \hline 68 \\ 2380 \\ \hline 2448 \end{array}$$

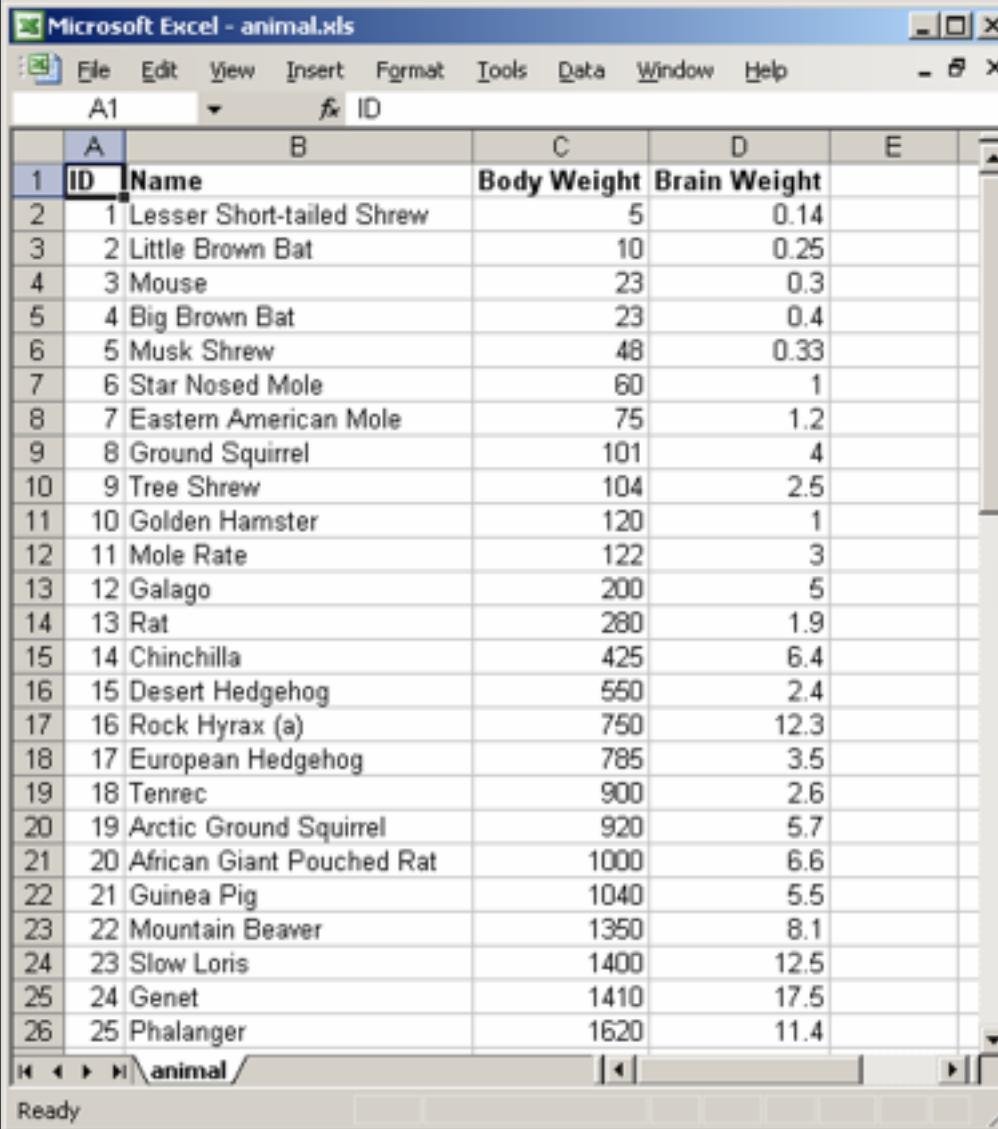


# Find Patterns: NYC Weather



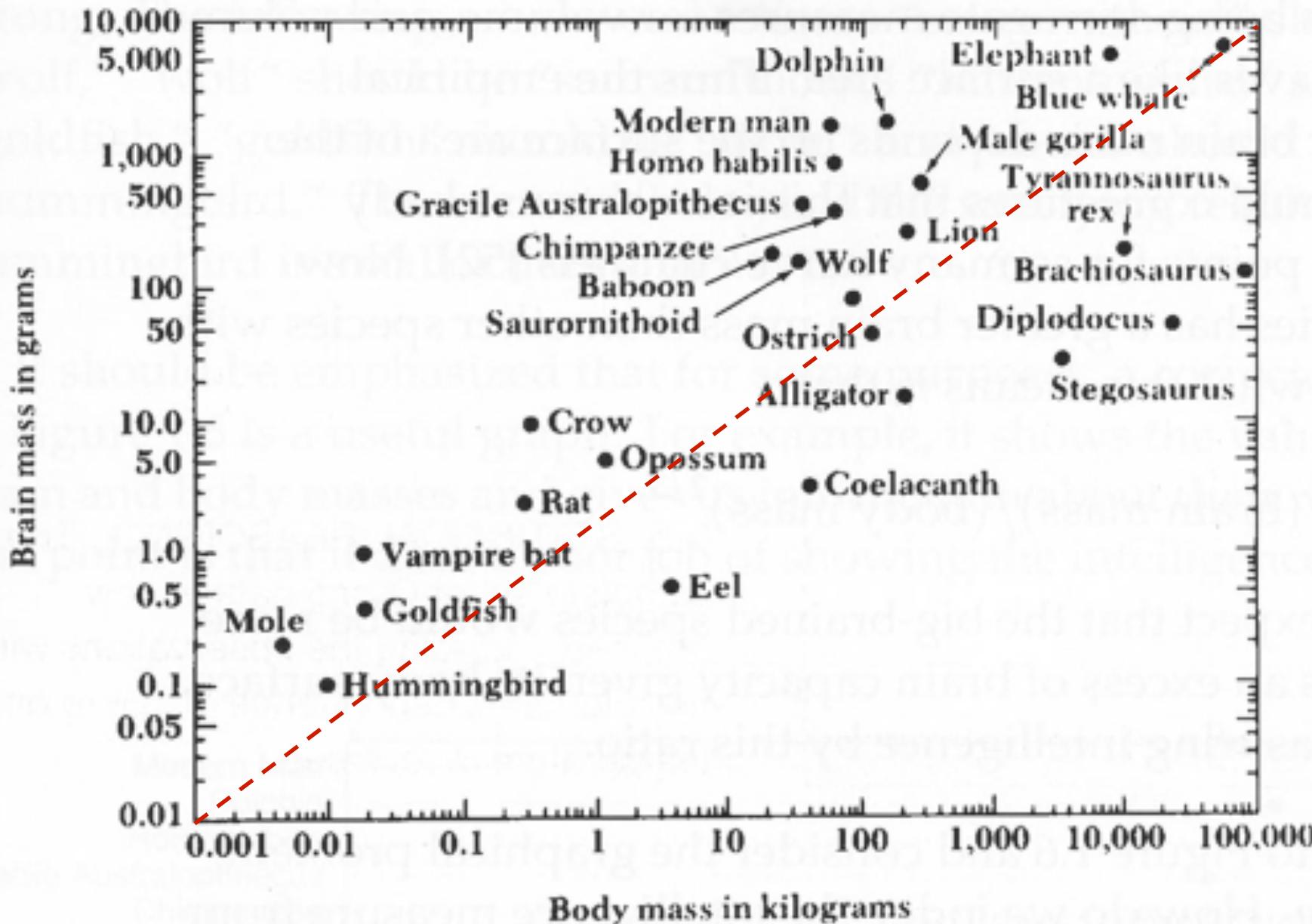
[New York Times 1981]

# The Most Powerful Brain?

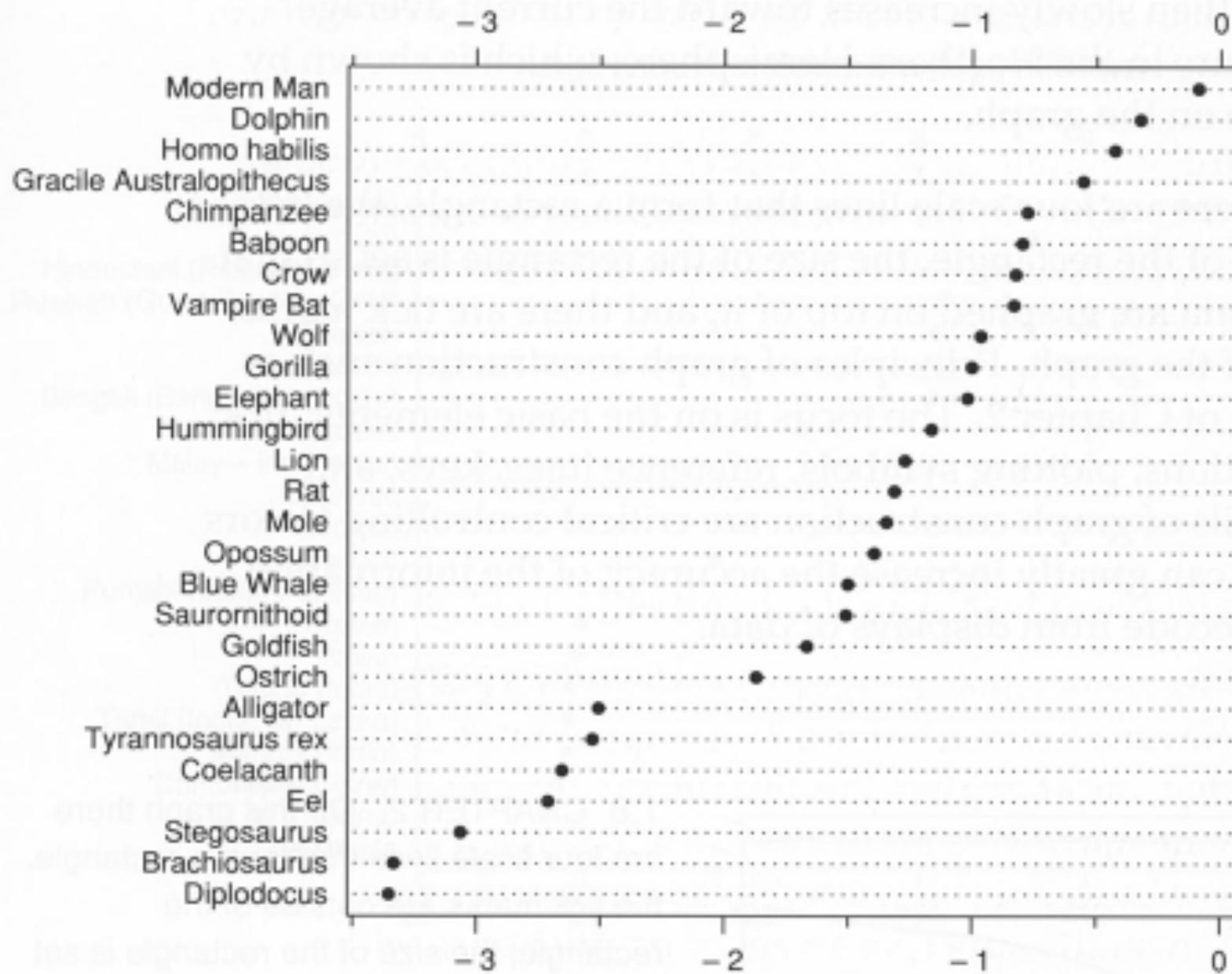


A screenshot of a Microsoft Excel spreadsheet titled "animal.xls". The spreadsheet contains data about various animals, specifically their ID, name, body weight, and brain weight. The columns are labeled A, B, C, D, and E. The data starts at row 1 and continues down to row 26. The first column (A) contains IDs from 1 to 26. The second column (B) contains the names of the animals. The third column (C) contains the body weight in grams. The fourth column (D) contains the brain weight in grams.

	A	B	C	D	E
1	ID	Name	Body Weight	Brain Weight	
2	1	Lesser Short-tailed Shrew	5	0.14	
3	2	Little Brown Bat	10	0.25	
4	3	Mouse	23	0.3	
5	4	Big Brown Bat	23	0.4	
6	5	Musk Shrew	48	0.33	
7	6	Star Nosed Mole	60	1	
8	7	Eastern American Mole	75	1.2	
9	8	Ground Squirrel	101	4	
10	9	Tree Shrew	104	2.5	
11	10	Golden Hamster	120	1	
12	11	Mole Rat	122	3	
13	12	Galago	200	5	
14	13	Rat	280	1.9	
15	14	Chinchilla	425	6.4	
16	15	Desert Hedgehog	550	2.4	
17	16	Rock Hyrax (a)	750	12.3	
18	17	European Hedgehog	785	3.5	
19	18	Tenrec	900	2.6	
20	19	Arctic Ground Squirrel	920	5.7	
21	20	African Giant Pouched Rat	1000	6.6	
22	21	Guinea Pig	1040	5.5	
23	22	Mountain Beaver	1350	8.1	
24	23	Slow Loris	1400	12.5	
25	24	Genet	1410	17.5	
26	25	Phalanger	1620	11.4	



The Dragons of Eden [Carl Sagan]



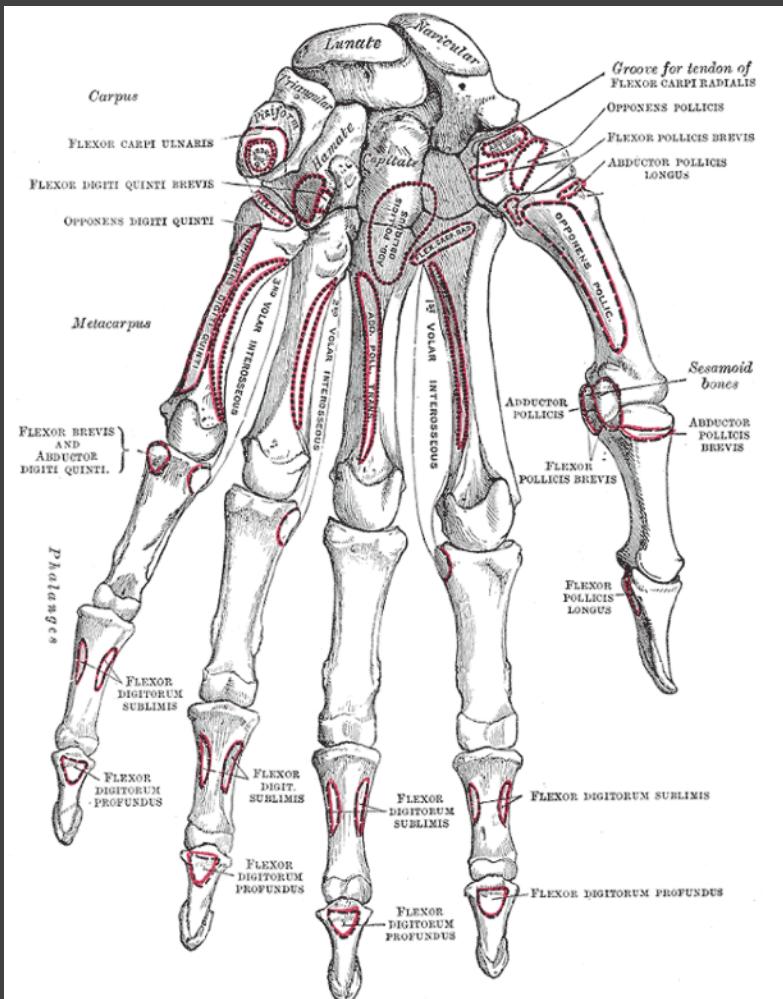
The Elements of Graphing Data

[Cleveland]

$\text{Log}_{10} \text{Brain Weight} - \frac{2}{3} \text{Log}_{10} \text{Body Weight}$

**Convey Information  
to Others**

# Inspire



Bones in hand [from 1918 edition]



Double helix model [Watson and Crick 53]

2.  
APRIL 1855 TO MARCH 1856.

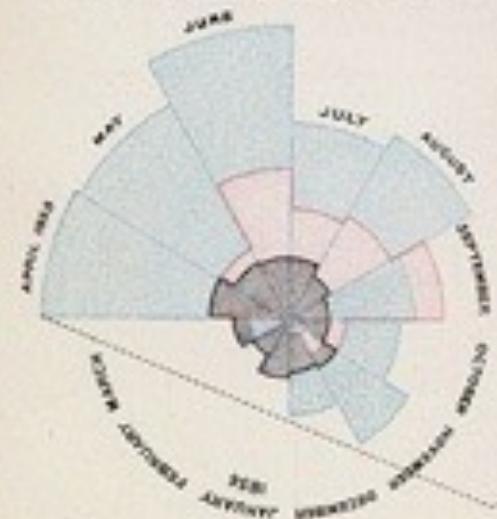
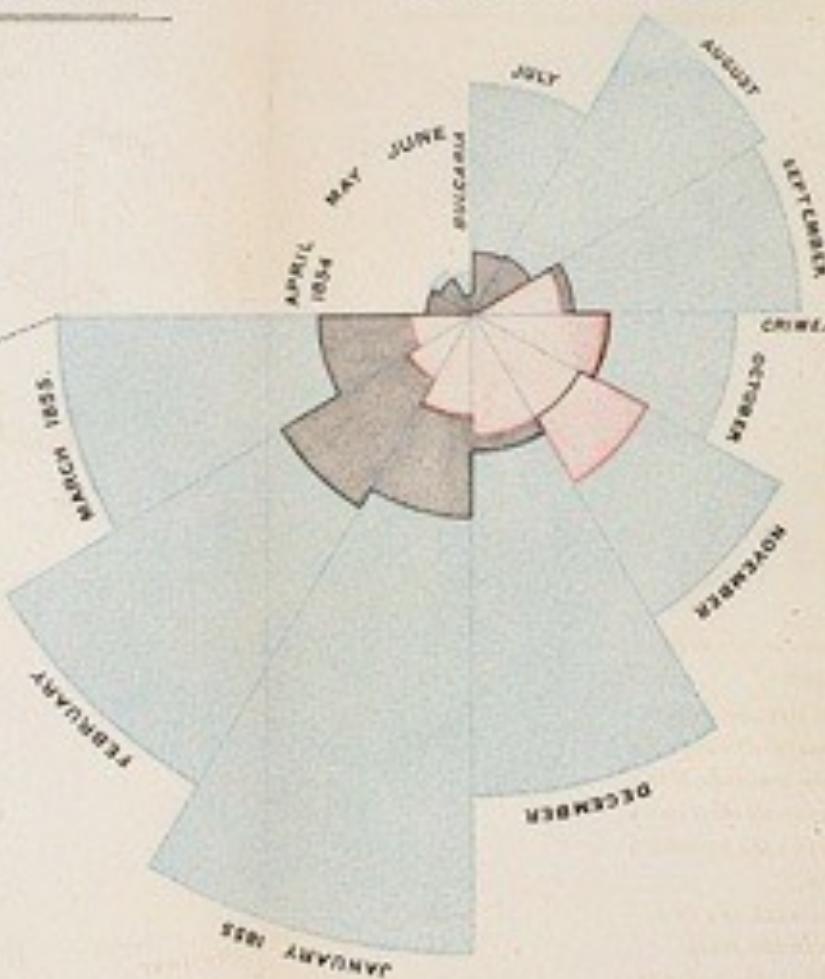


DIAGRAM OF THE CAUSES OF MORTALITY  
IN THE ARMY IN THE EAST.

1.  
APRIL 1854 TO MARCH 1855.



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

© National Gallery of Victoria

1856 "Coxcomb" of Crimean War Deaths, Florence Nightingale

# The Value of Visualization

**Record** information

Blueprints, photographs, seismographs, ...

**Analyze** data to support reasoning

Develop and assess hypotheses

Find patterns / Discover errors in data

Expand memory

**Communicate** information to others

Share and persuade

Collaborate and revise

# Goals of Visualization Research

**1 Understand** how visualizations convey information

What do people perceive/comprehend?

How do visualizations inform mental models?

**2 Develop principles and techniques** for creating effective visualizations and supporting analysis

Leverage perception & augment cognition

Improve ties between visualization & mental model

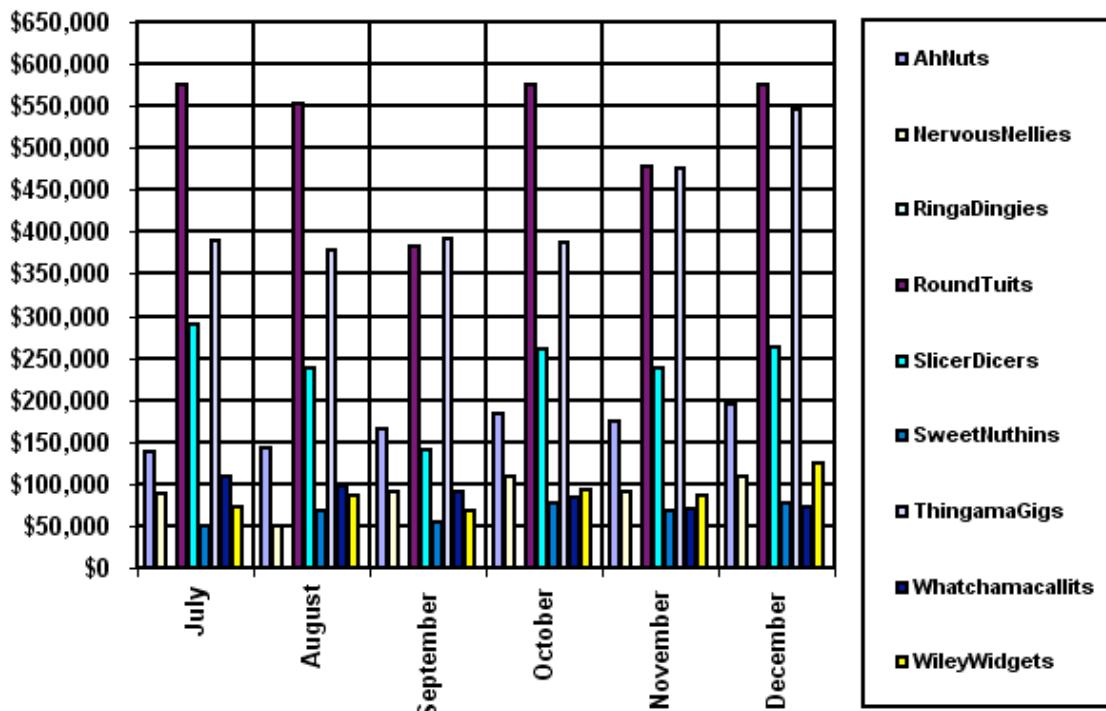
# Course Topics

# Data and Image Models

LES VARIABLES DE L'IMAGE								12	14	
	POINTS		LIGNES		ZONES					
XY 2 DIMENSIONS DU PLAN	x	x	x	12	14	15	16	17	18	19
Z TAILLE	■	■	.	12	14	15	16	17	18	19
VALEUR	■	■	■	12	14	15	16	17	18	19
LES VARIABLES DE SÉPARATION DES IMAGES								13		
GRAIN	■■■	■■■	■■■	12	14	15	16	17	18	19
COULEUR	■	■	■	12	14	15	16	17	18	19
ORIENTATION	■	■	■	12	14	15	16	17	18	19

# Visualization (Re-)Design

SlicerDicers' Sales Compared to Other Products

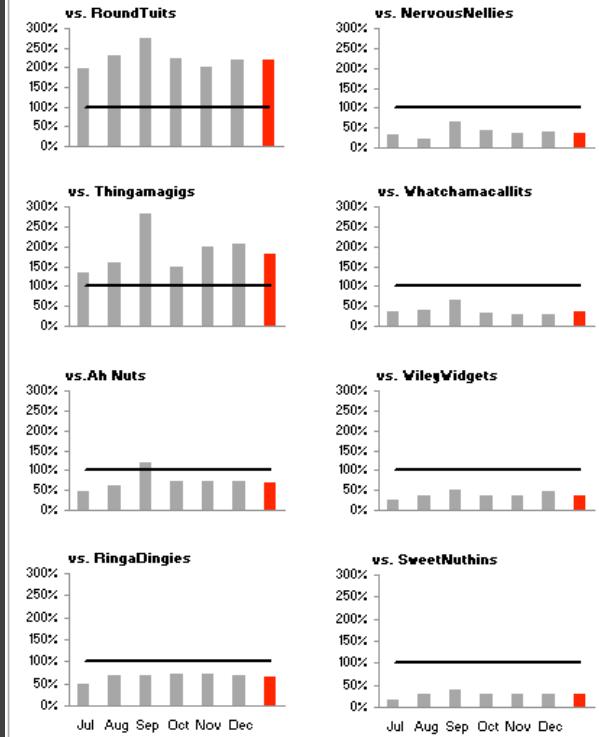


Problematic design

Sales of SlicerDicers Compared to Other Products

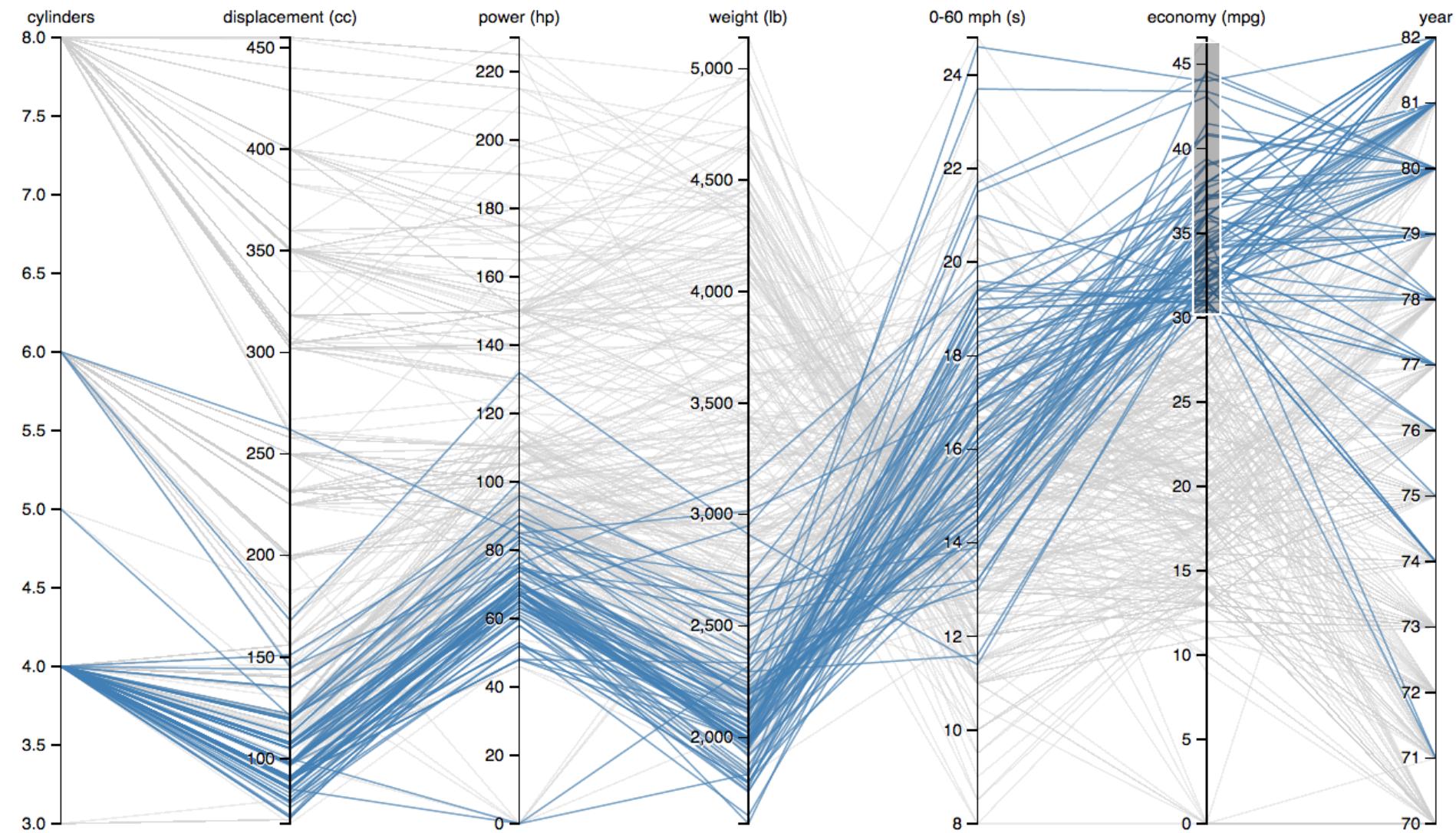
July - December, 2003

(SlicerDicers' sales are displayed as black reference lines of 100%; the red bars represent the average monthly sales percentage for July through December.)

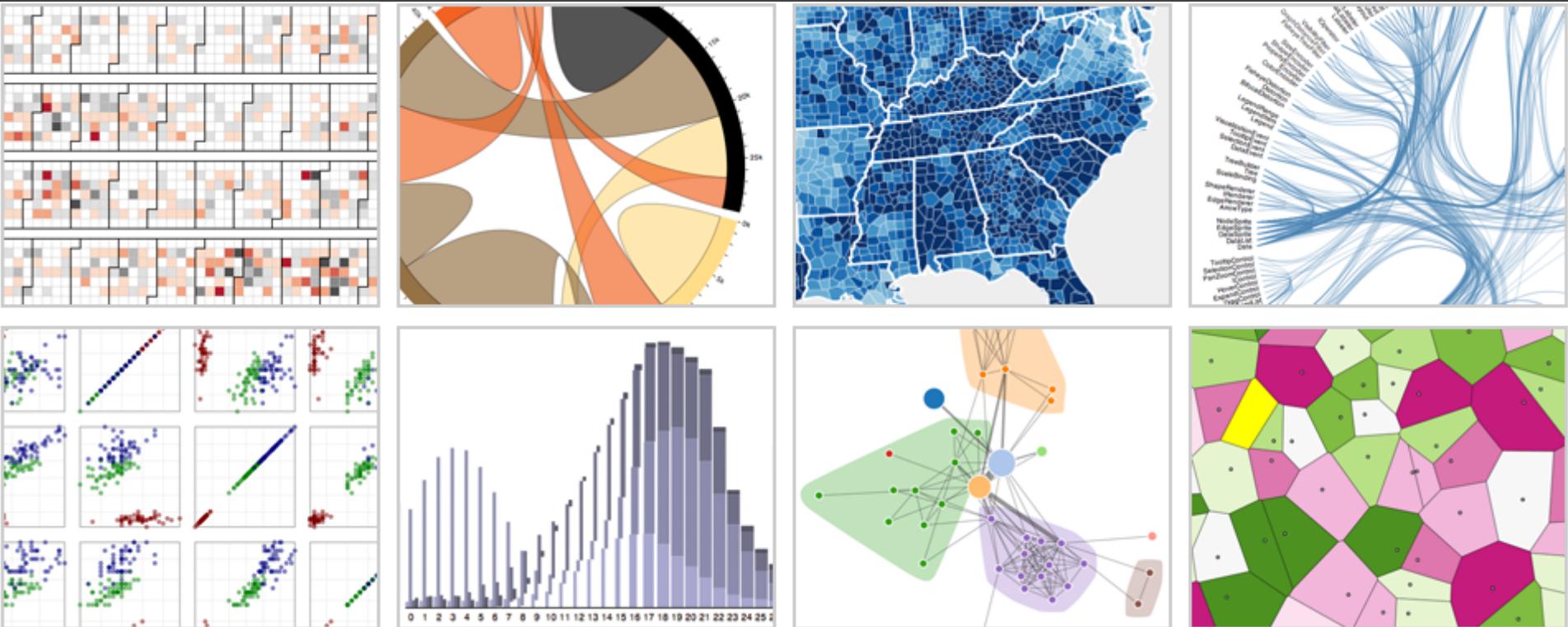


Redesign

# Exploratory Data Analysis

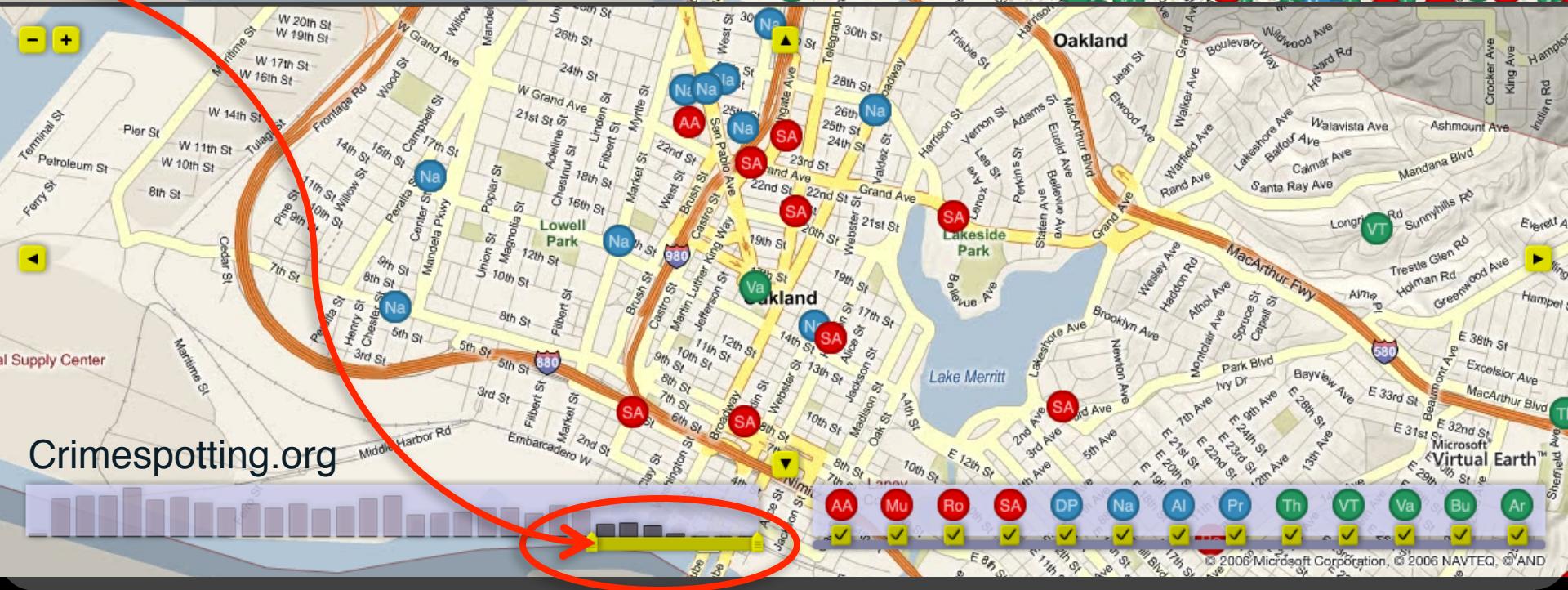
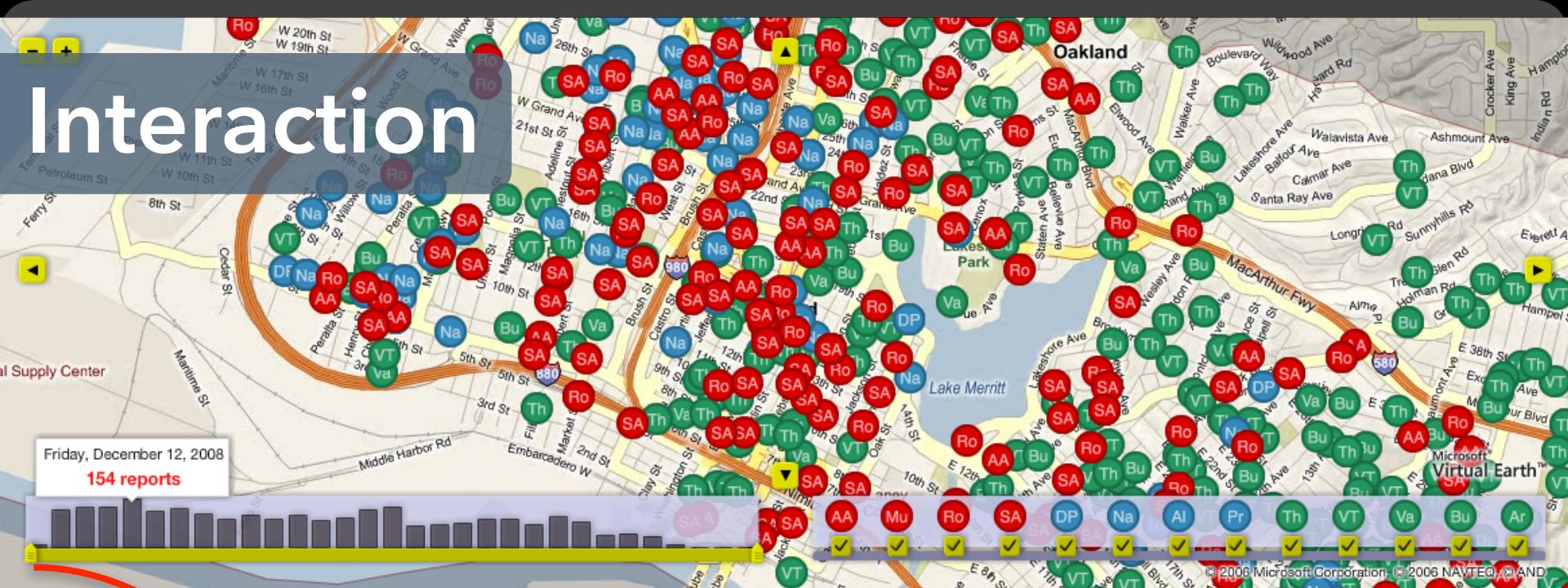


# Visualization Software

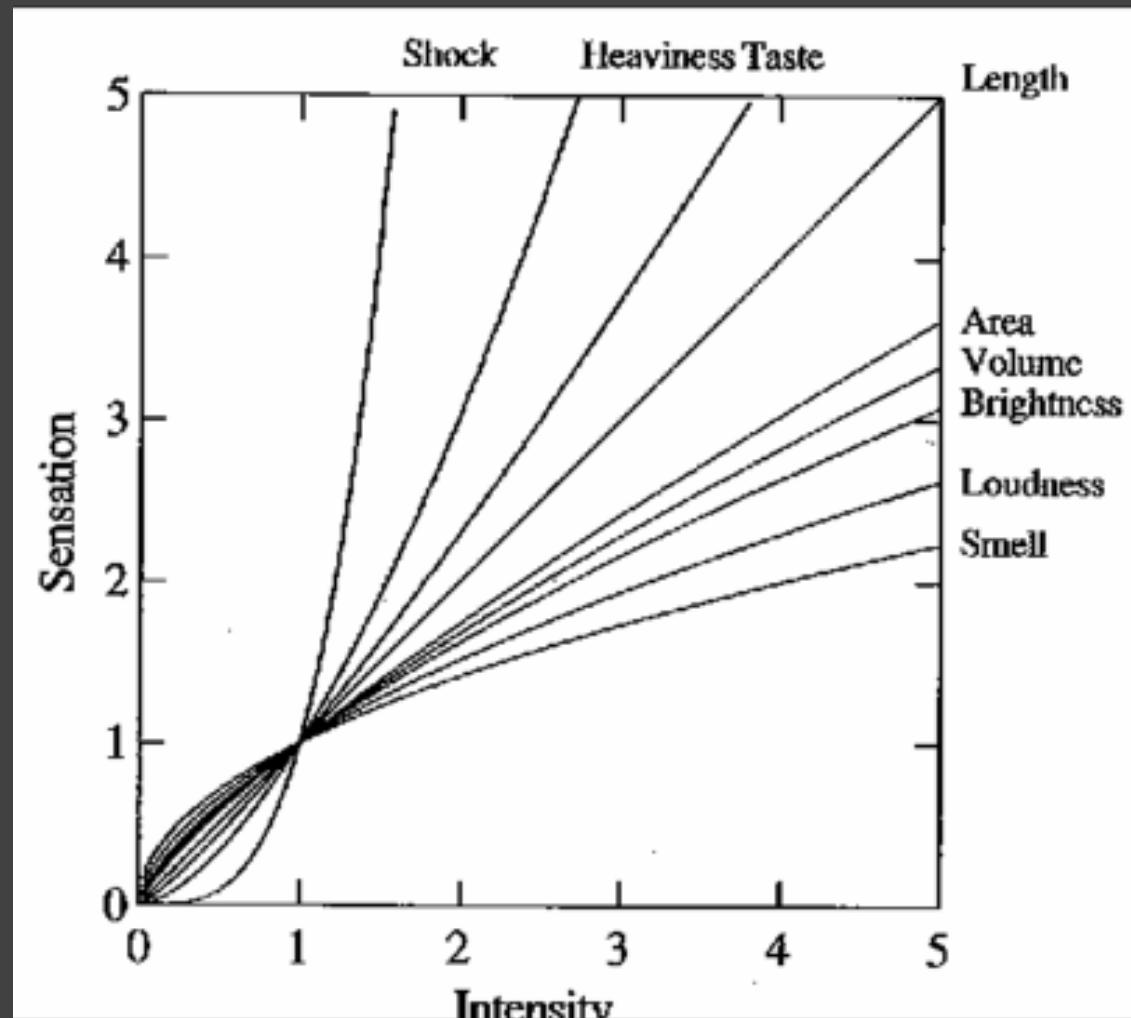


D3: Data-Driven Documents

# Interaction

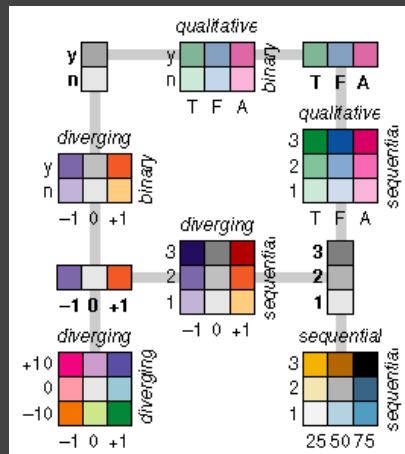


# Graphical Perception

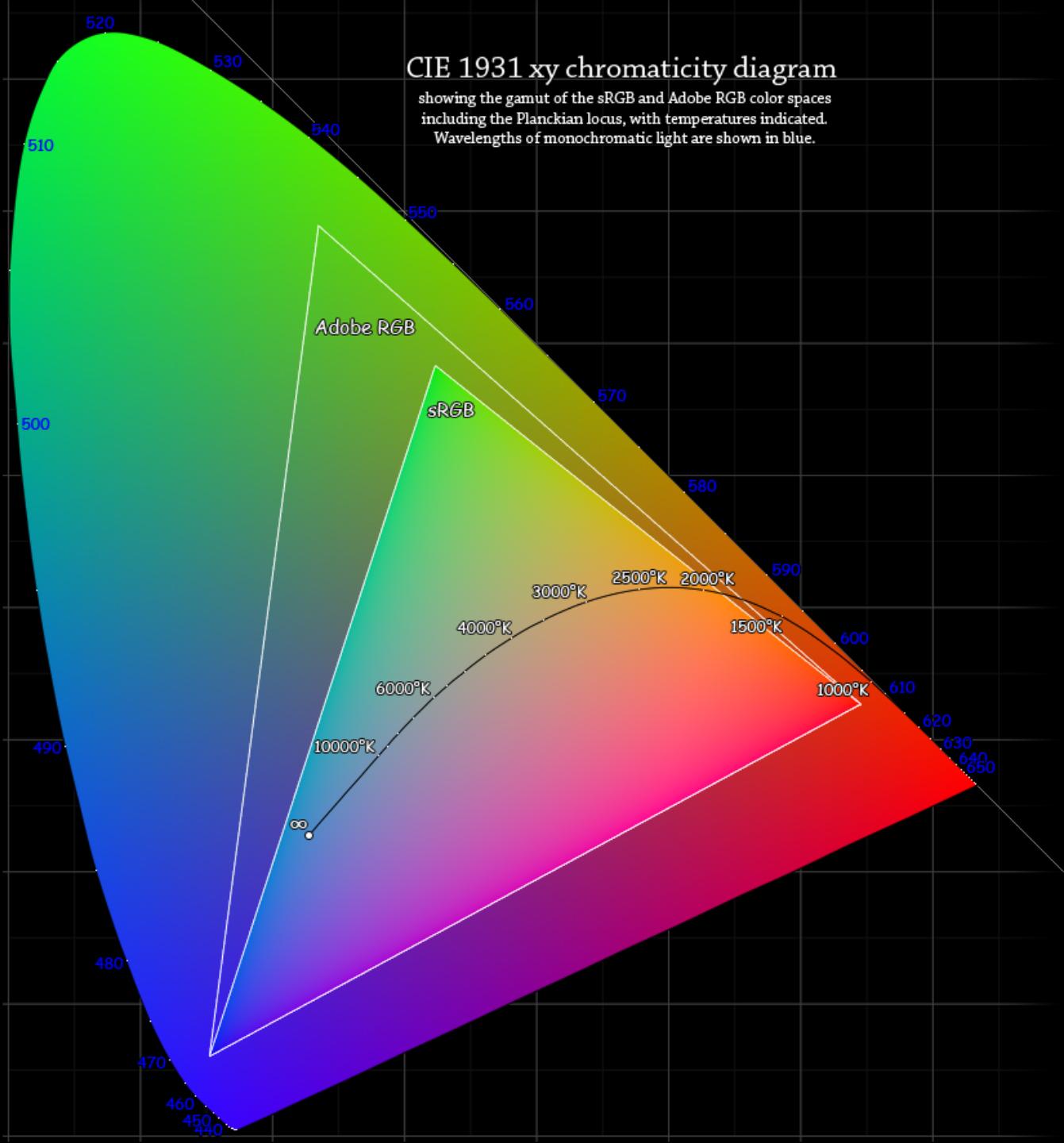


The psychophysics of sensory function [Stevens 61]

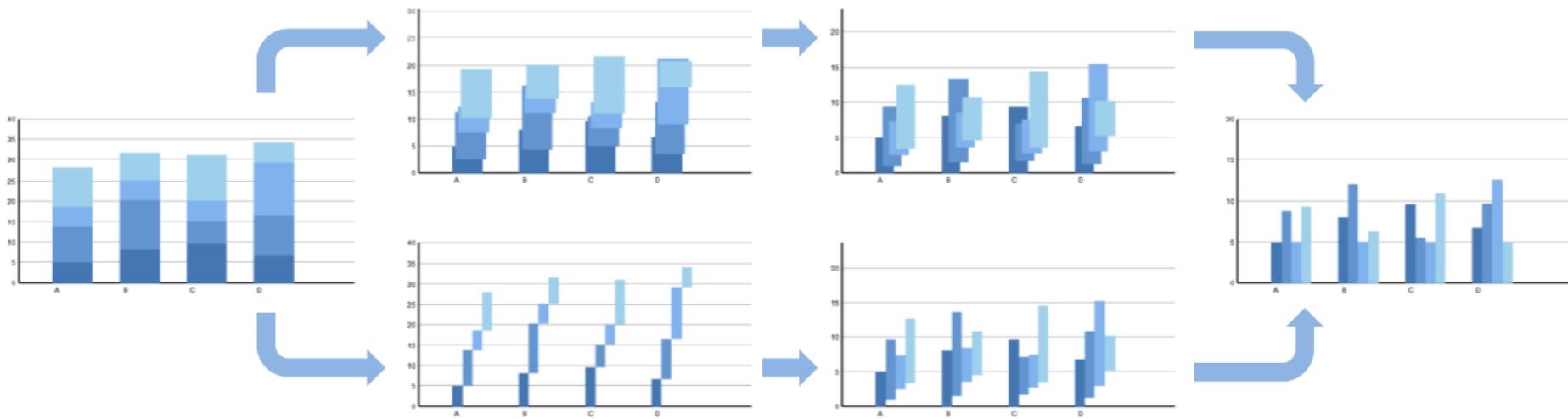
# Color



Color Brewer

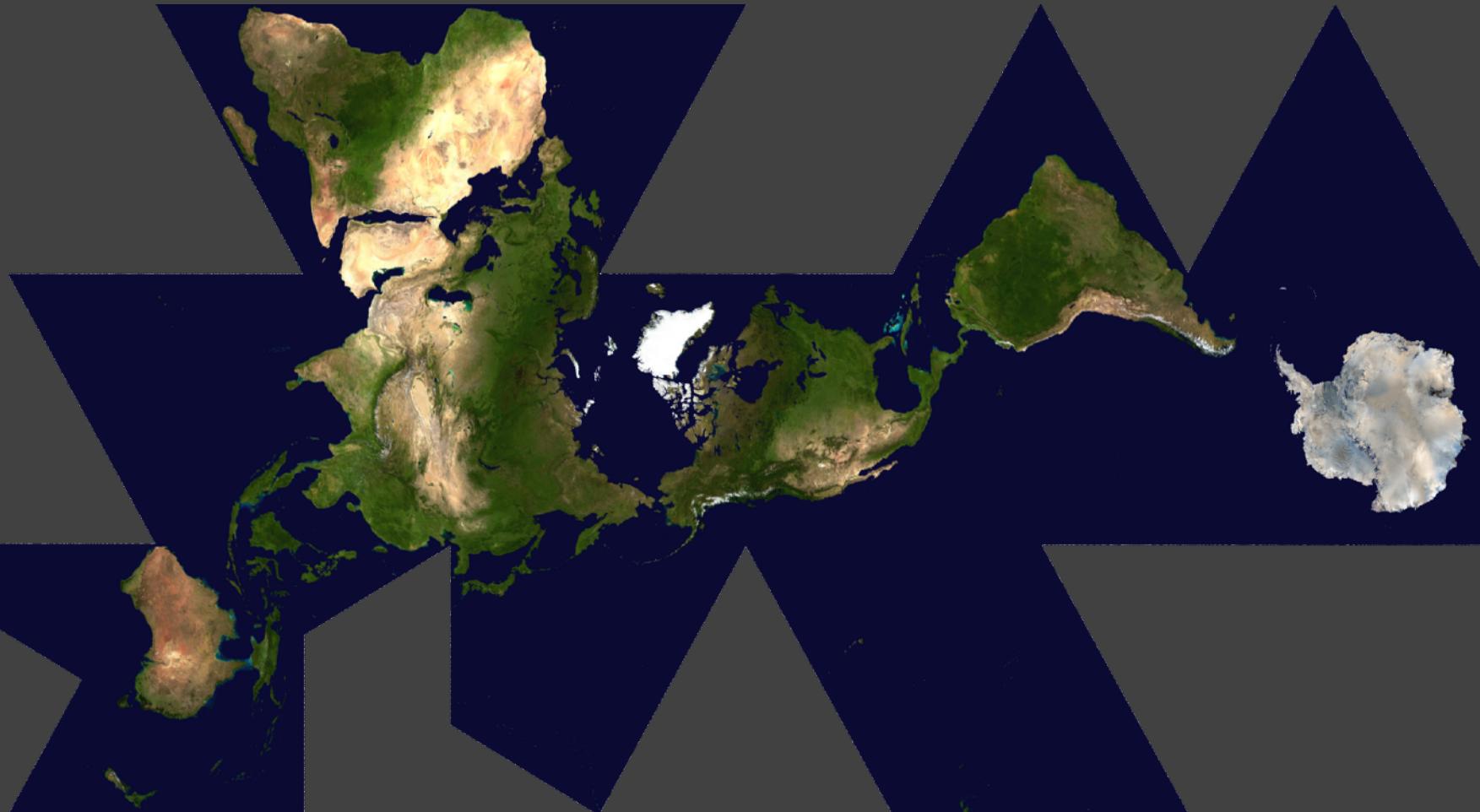


# Animation



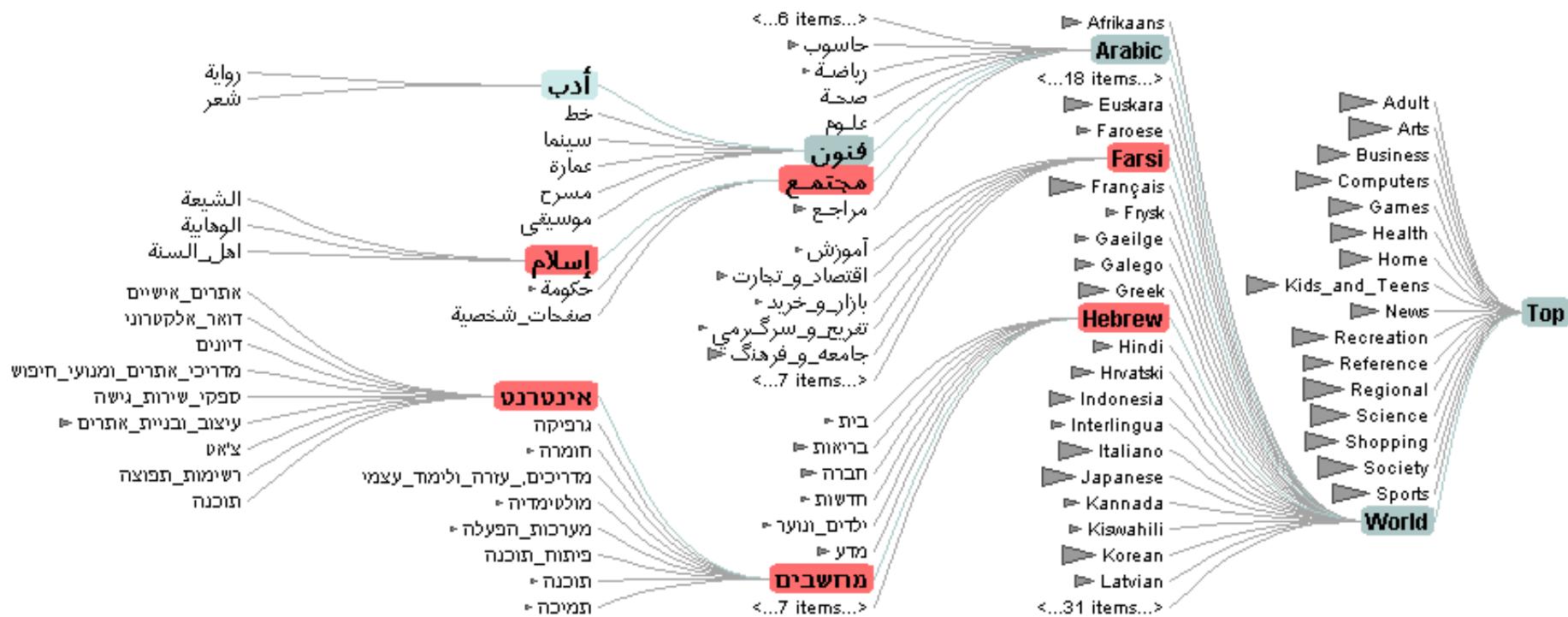
Animated transitions in statistical data graphics [Heer & Robertson 07]

# Maps



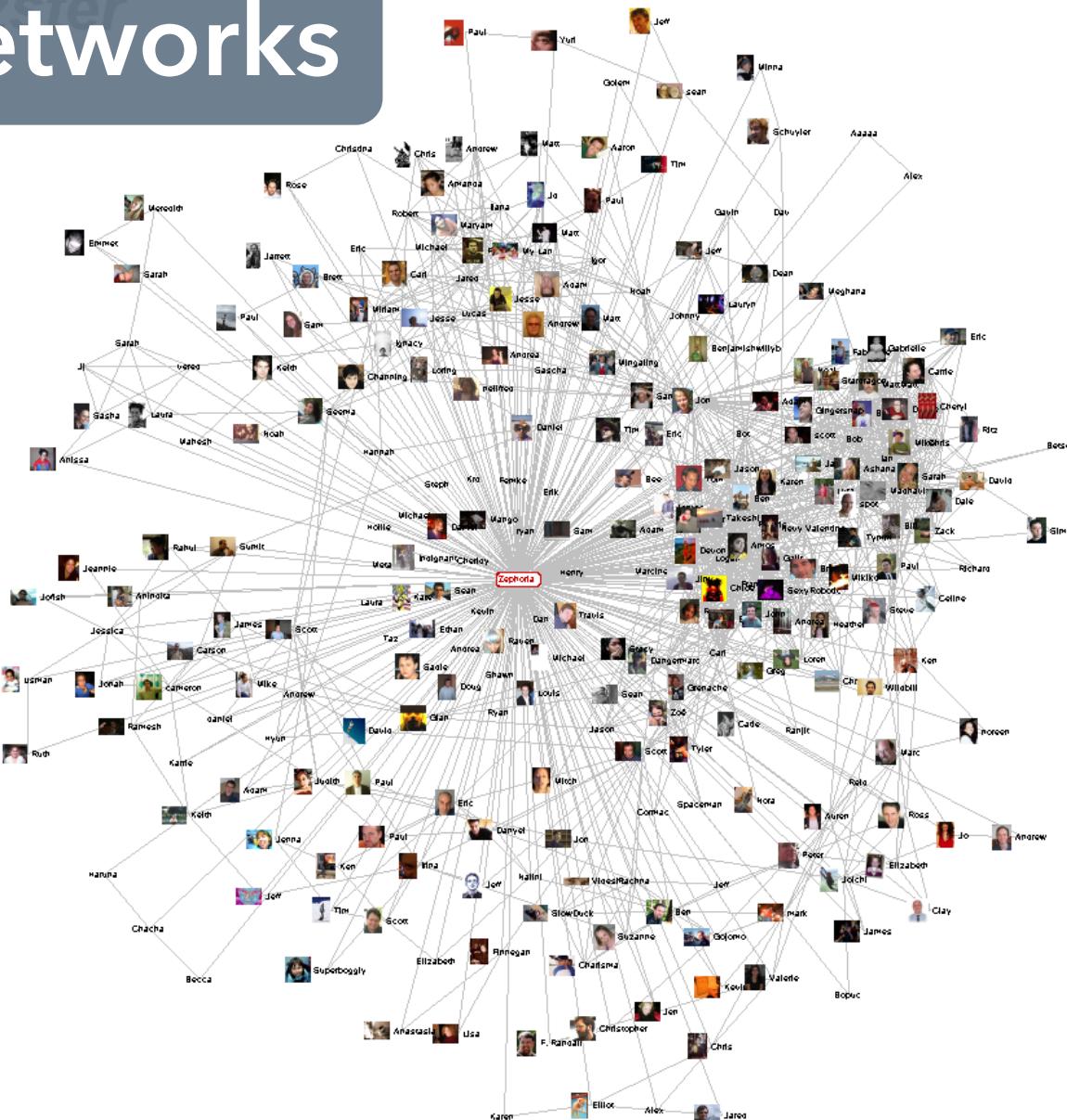
Dymaxion Maps [Fuller 46]

# Hierarchies



Degree-Of-Interest Trees [Heer & Card 04]

# Nizster Networks



community &gt;&gt;



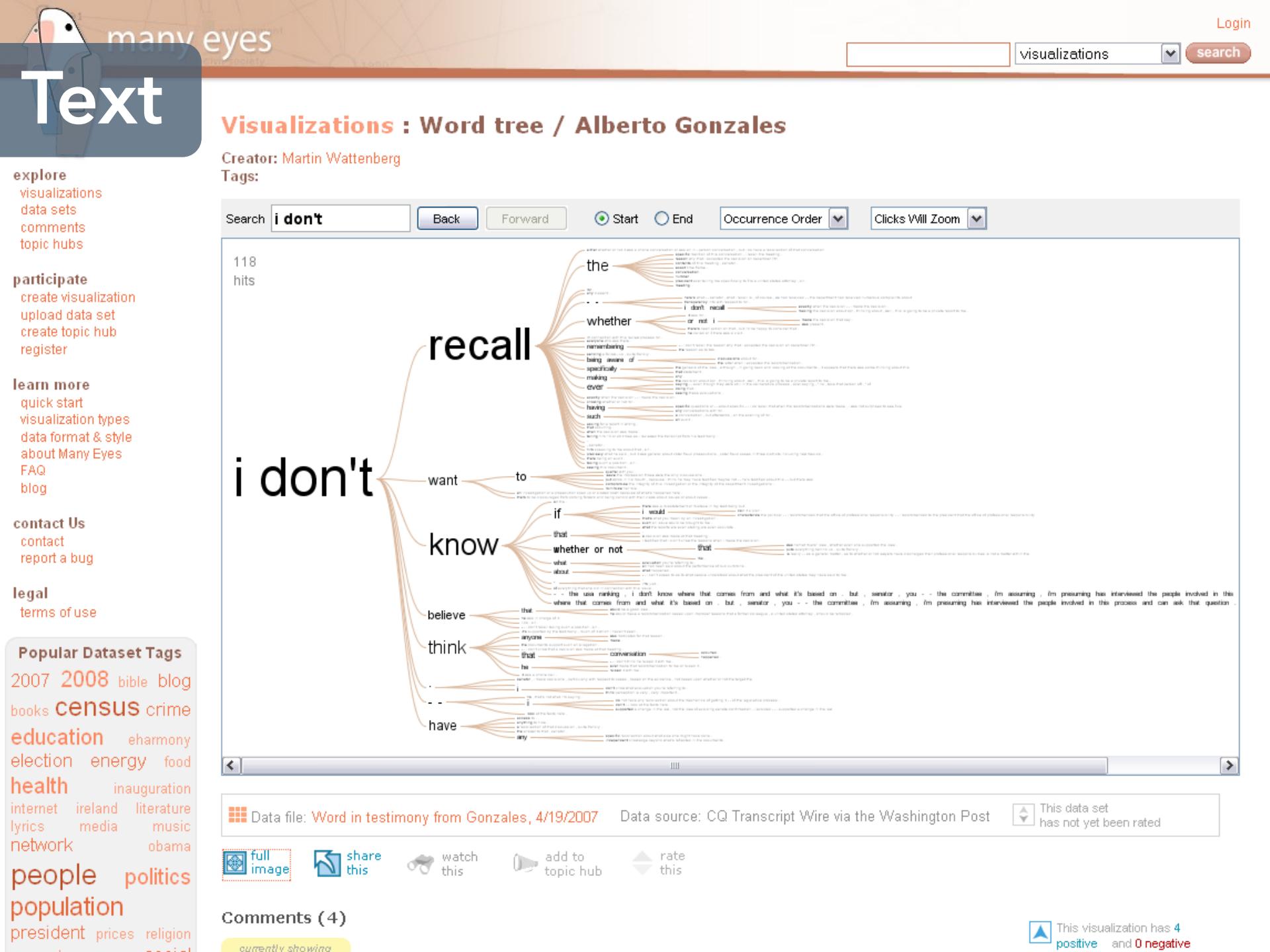
Enable

search &gt;&gt;

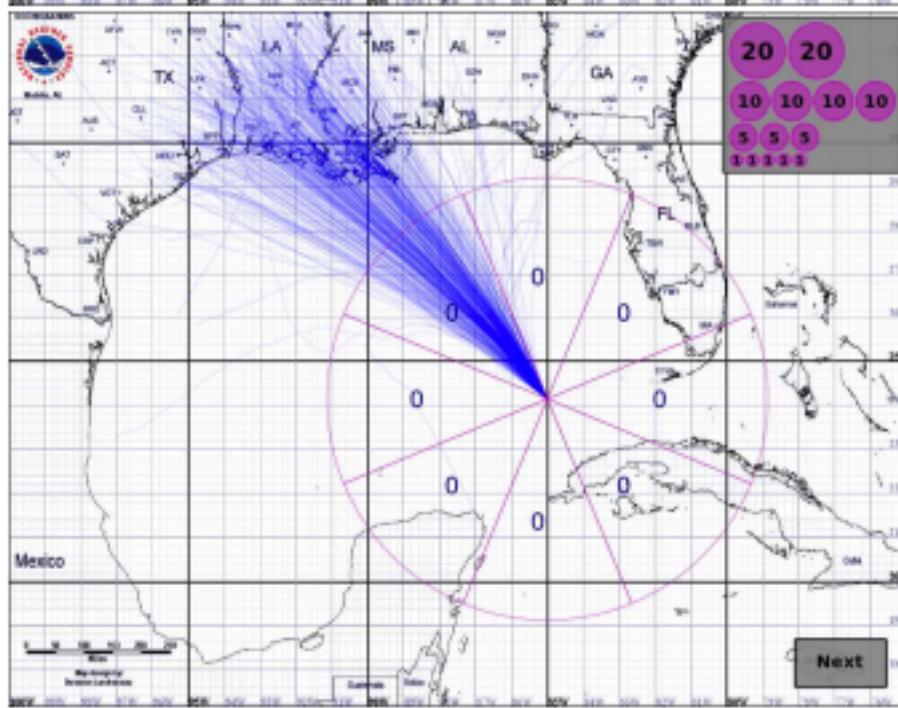
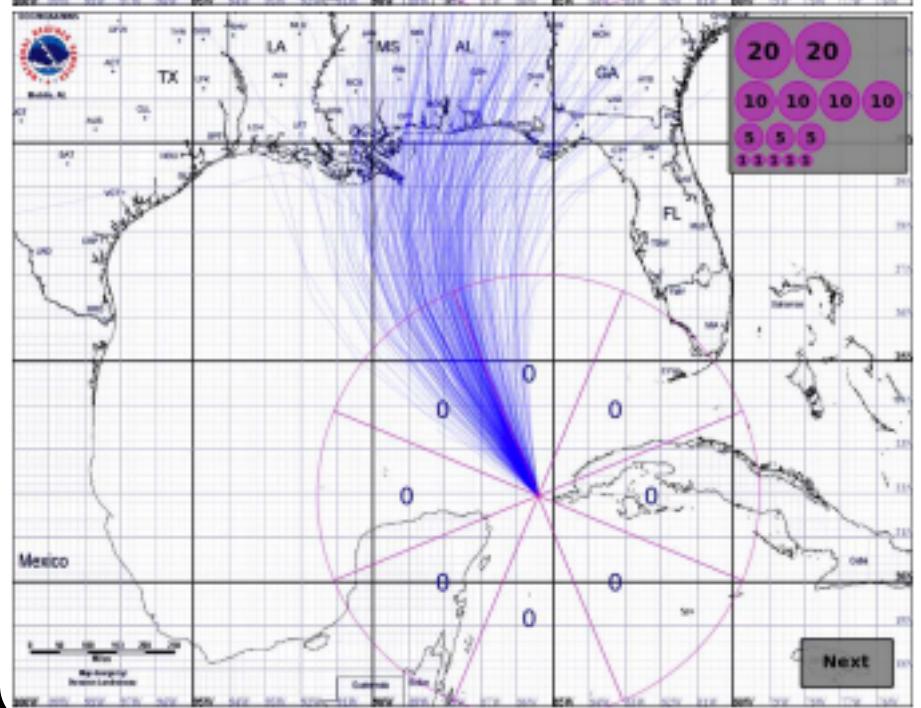
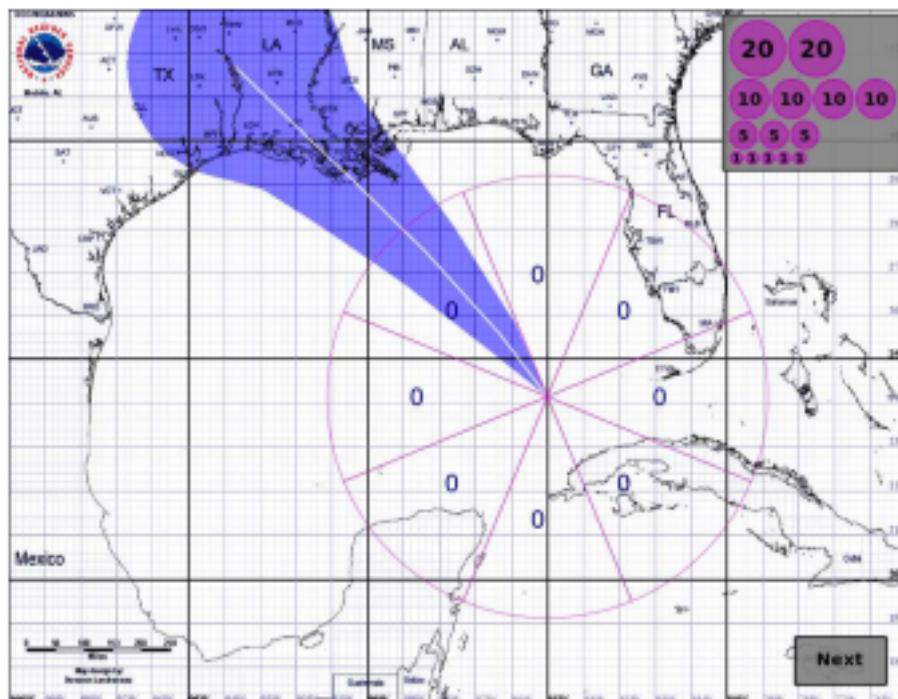
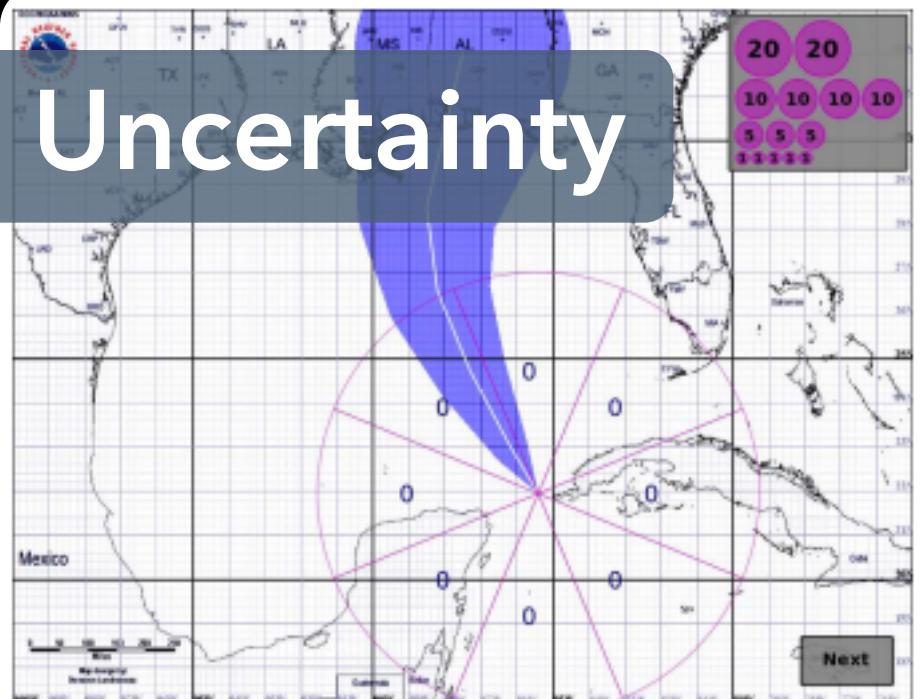
X

## Zephoria

User ID	21721
Friends	266
Age	??
Gender	Female
Status	Single
Location	San Francisco, CA
Hometown	Lancaster, PA
Occupation	researcher: social networks, identity, context
Interests	apophenia, observing people, culture, questioning power, reading, buddhism, ipseity, computer-mediated communication, social networks, technology, anthropology, stomping, psytrance/goa/trance [Infected Mushroom, Son Kite... Iboga/Digital Structures], Ani Difranco, downtempo, Thievery Corporation, Beth Orton, Morcheeba, Ween, White Stripes
Music	Authors: Erving Goffman, Stanley Milgram, Jeanette Winterson, Eric Schlosser, Leslie Feinberg, Dorothy Allison, Italo Calvino, Hermann Hesse
Books	??
TV Shows	Koyaanisqatsi, Amelie, Waking Life, Tank Girl, The Matrix, Clockwork Orange, American Beauty, Fight Club, Boys Don't Cry
Movies	??
Member Since	2003-10-21
Last Login	2003-10-21
Last Updated	[Some know me as danah...]
About	I'm a geek, an activist and an academic, fascinated by people and society. I see life as a very large playground and enjoy exploring its intricacies. I revel in life's chaos, while simultaneously providing my own insane element.  My musings: <a href="http://www.zephoria.org/thoughts/">http://www.zephoria.org/thoughts/</a>
Want to Meet	Someone who makes life's complexities seem simply elegant. A partner in crime with an



# Uncertainty



Recent elections have placed a heavy emphasis on “swing states” — Ohio, Florida and the other competitive states. You can see how many more states shifted between the Democratic and Republican parties. A look at how the states stuck to one side or the other, and how they have shifted over past elections.

# Narrative

Each box represents a state sized by number of electoral votes.

Each curve shows how much it shifted left or right between elections

Chart  
Size of Lead

Chart  
Electoral Votes

≥50% +40% +30% +20% +10% ← MORE DEMOCRATIC → MORE REPUBLICAN → +10% +20% +30% +40% ≥50%

## Obama Re-elected

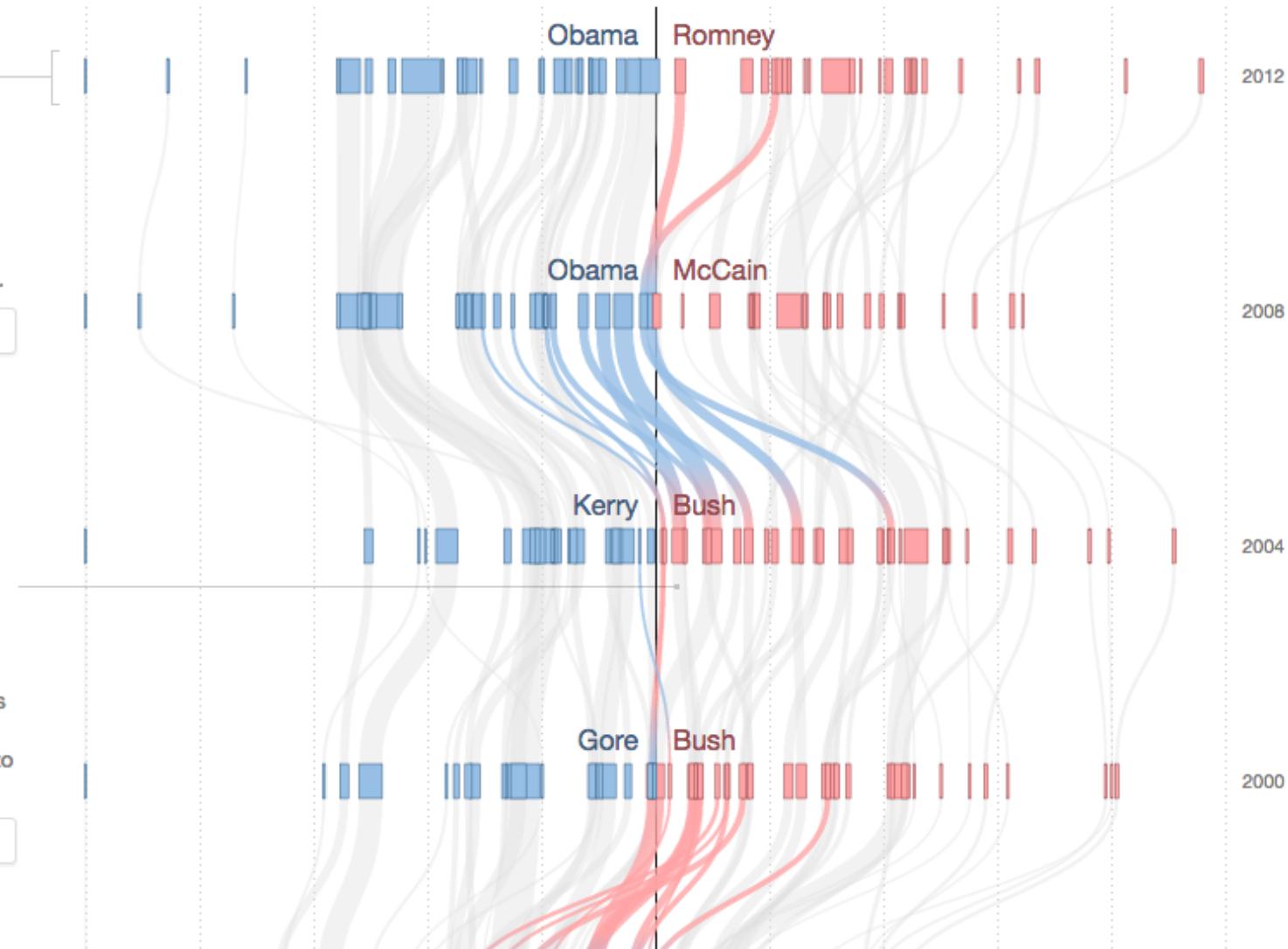
The country voted about 5 percentage points more Republican in 2012 than in 2008. Obama lost North Carolina and Indiana, but won every tossup except Florida, which remains too close to call.

Highlight Tossups

## As Goes Ohio

Ohio, which has voted for the winner in every election since 1964, provided the decisive electoral votes in 2004, and it is the state likeliest to play that role again this year, according to the FiveThirtyEight model.

Highlight Ohio



# Course Mechanics

# You should expect to:

- 1 *Evaluate and critique* visualization designs
- 2 *Learn* visualization techniques & theory
- 3 *Implement* interactive data visualizations
- 4 *Develop* a substantial visualization project

# Instructors

cse512@cs

## *Instructor*

**Jeffrey Heer** OH: *Tu 10:15-11:15a, 642 CSE*  
Assoc Prof, CSE <http://jheer.org>

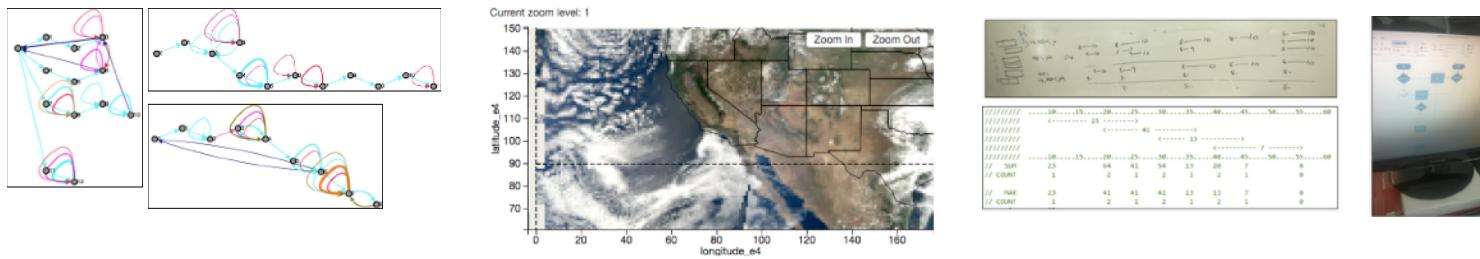
## *Assistants*

**Leilani Battle** OH: *Fri 3:30-4:30p, CSE 2nd Floor*  
**Shobhit Hathi** OH: *Mon 1-2p, CSE 5th Floor*  
**Halden Lin** OH: *Mon 1-2p, CSE 5th Floor*

# Leilani Battle

Office Hours 3:30-4:30pm Fridays  
CSE 2nd Floor Breakout  
(Out of town 4/20)

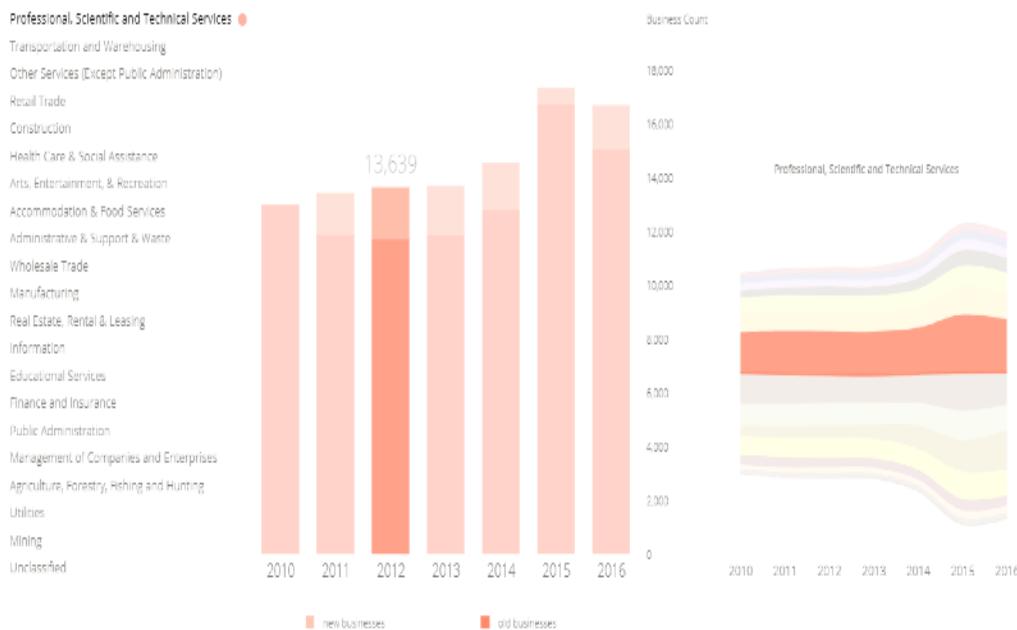
I'm a postdoc working on making big data analysis systems fast and easy to use. I often build user behavior models for visualization prediction and recommendation.



# Shobhit Hathi

Hi! I'm a combined BS/MS student in my first quarter as a graduate student. I took data visualization last Spring, and I'm really excited to be a part of 512 this quarter!

My office hours will be 1-2  
Mondays in the 5<sup>th</sup> floor  
breakout.



# Halden Lin

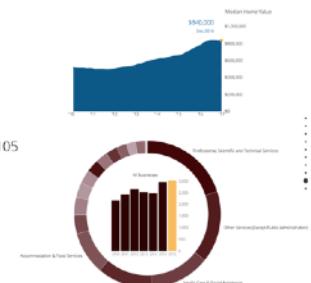
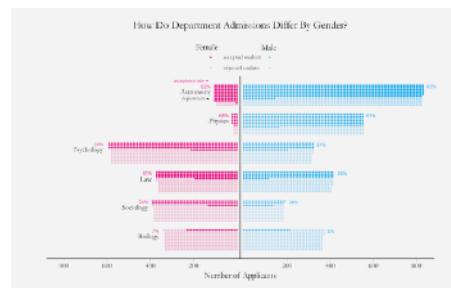
OH: Monday 1-2pm, CSE 5th Floor

Hello!

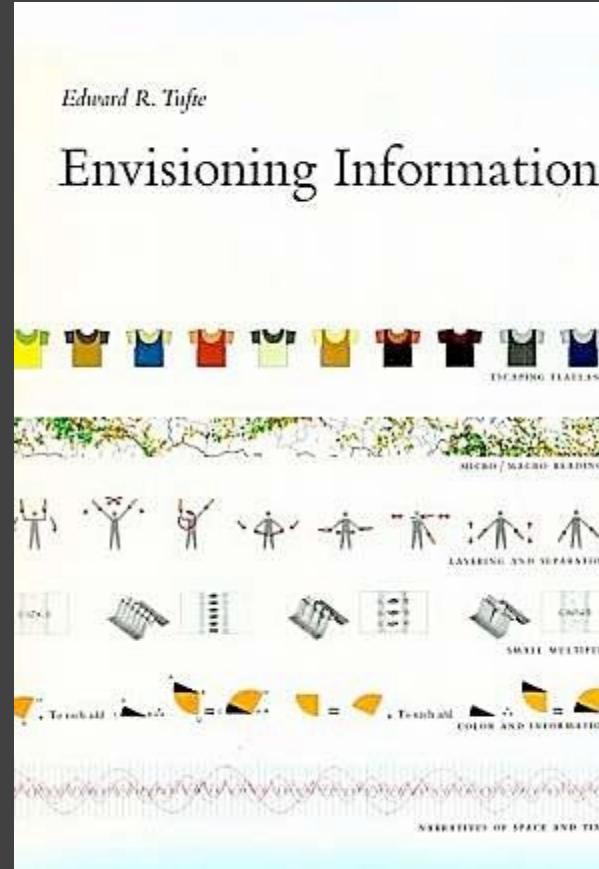
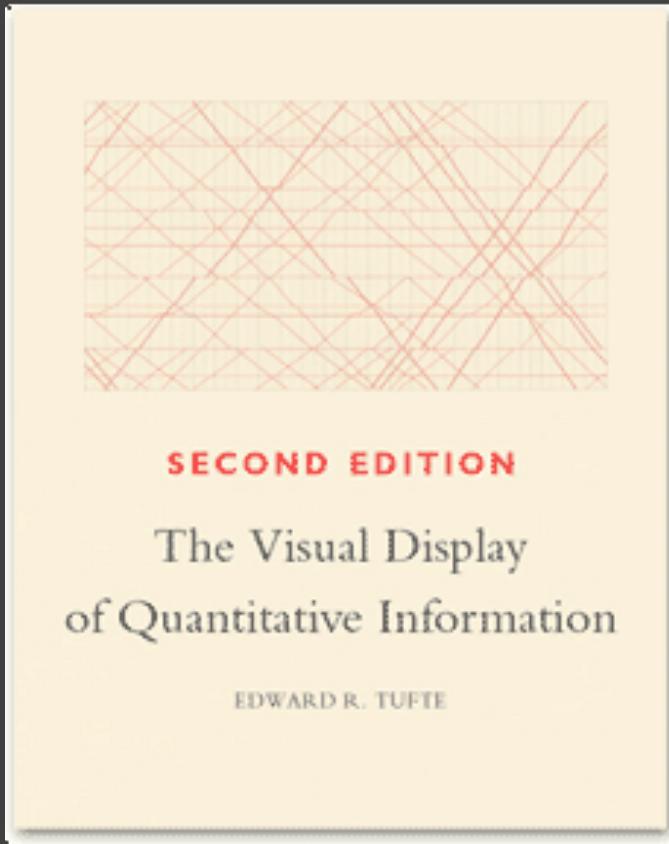
I'm a combined B.S./M.S. Computer Science student with research interests in automated visualization design, currently working with Kanit 'Ham' Wongsuphasawat and Dominik Moritz in Jeff's lab (IDL).

I'm also a huge fan of visual and user experience design.

Always happy to chat.

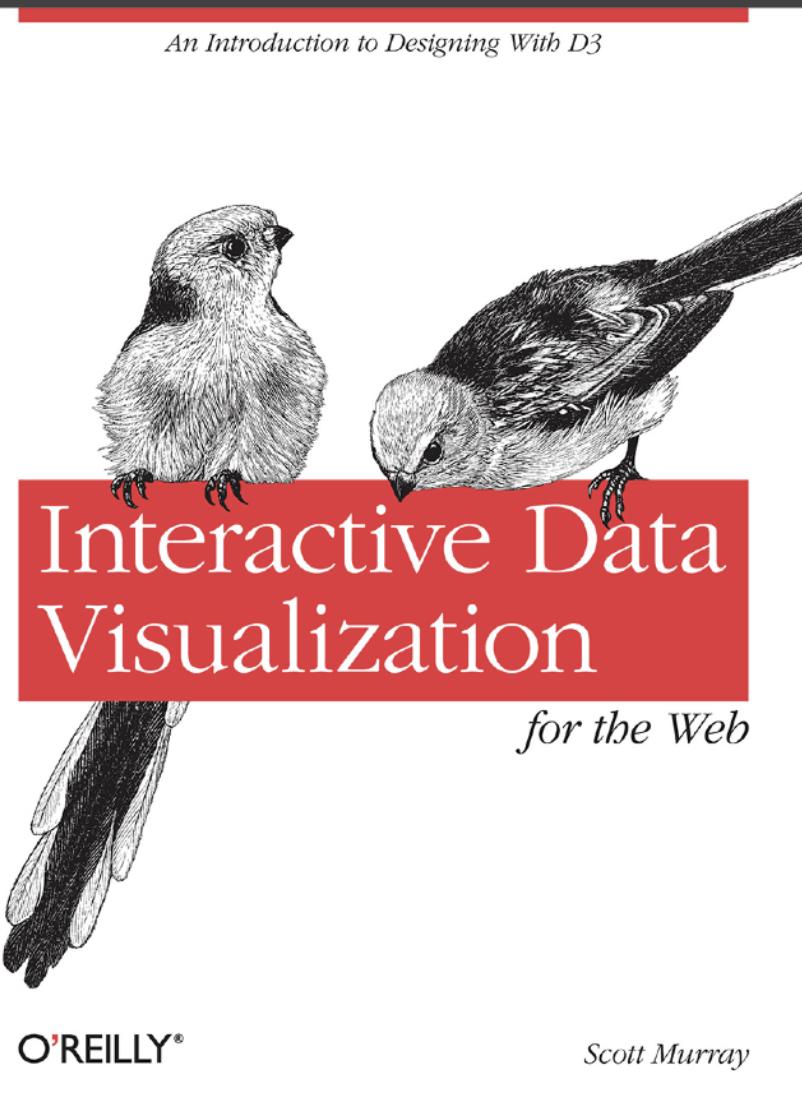


# Textbooks



See also: [www.edwardtufte.com](http://www.edwardtufte.com)

# Optional Textbook



## Interactive Data Visualization for the Web, 2nd Edition

*For learning D3!*  
Book available online.  
Code / examples on GitHub.

We will be using **D3 v5**.  
<https://d3js.org>

# Readings

Some from textbooks, also many articles.

Material in class will loosely follow readings.

Readings should be read by start of class.

Post discussion comments on class Canvas forum.

One comment per week (up through week 8).

Comments must be posted by Friday 11:59pm.

You have 1 “pass” for the quarter.

# Assignments

Class Participation (10%)

A1: Visualization Design (10%) - Due 4/2

A2: Exploratory Data Analysis (15%) - Due 4/13

A3: Interactive Prototype (25%) - Due 4/30

Peer Evaluation - Due 5/7

FP: Final Project (40%)

Proposal - Due 5/10

Initial Prototype - Due 5/21

Project Deliverables - Due 5/30 (*tentative*)

# Final Project

**Visualization research project** on topic of choice

Initial **prototype** and **peer evaluation**

**Design reviews** and **final presentation**

Submit and publish on GitHub

Projects from **previous classes** have been:

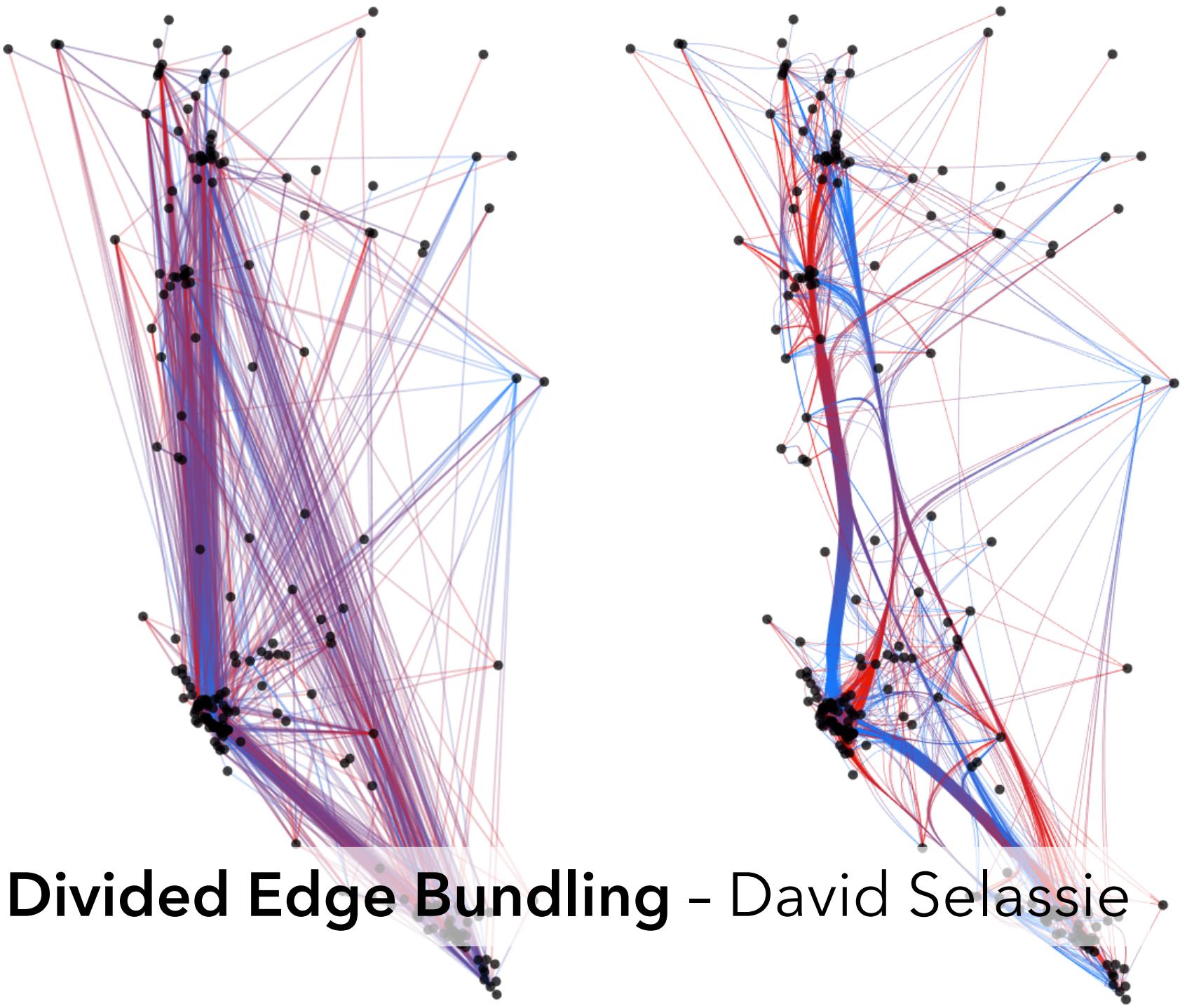
- Published as research papers
- Featured in the New York Times
- Released as successful open source projects



# RunMonster

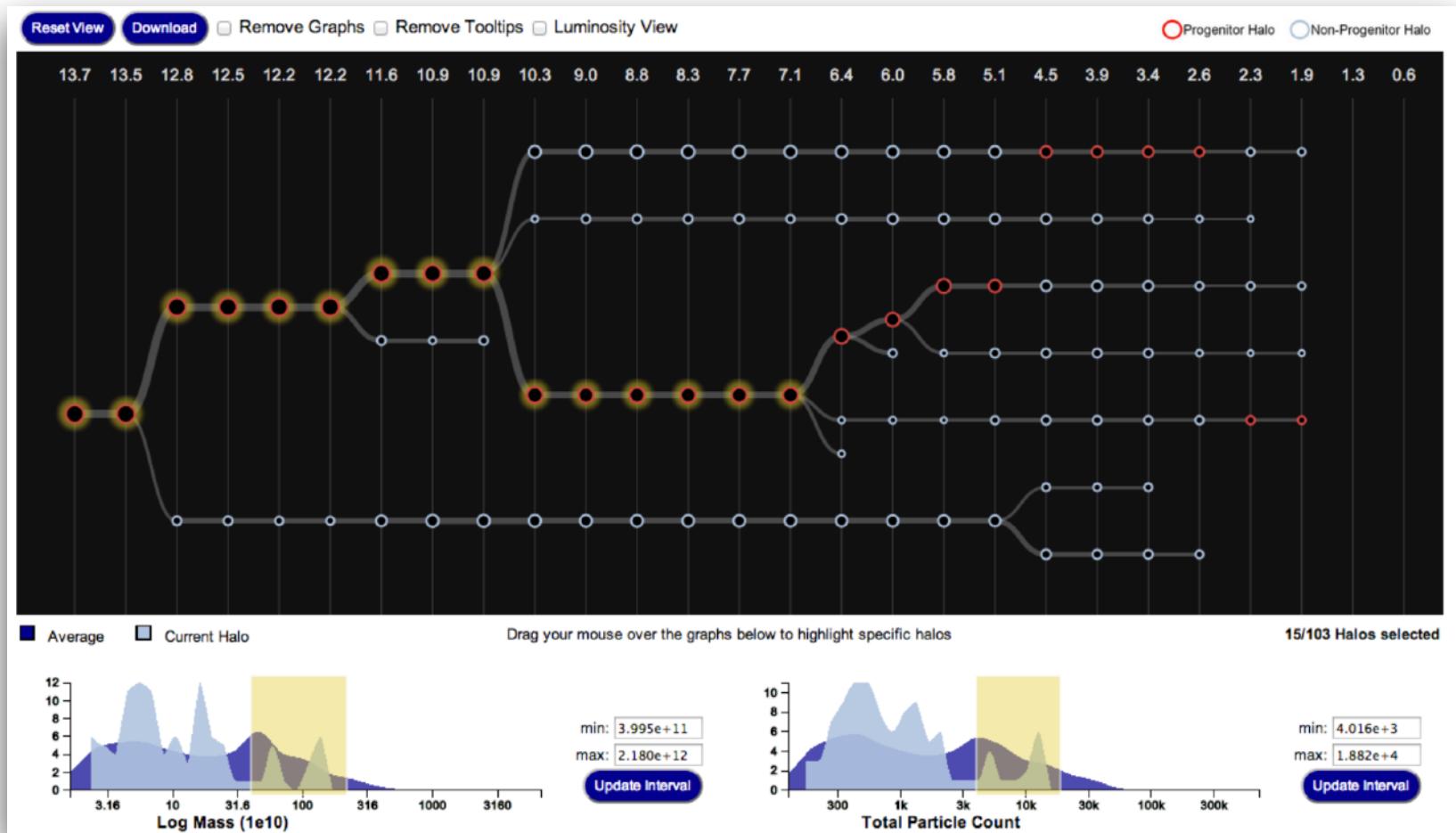
Troy Brant & Steve Marmon





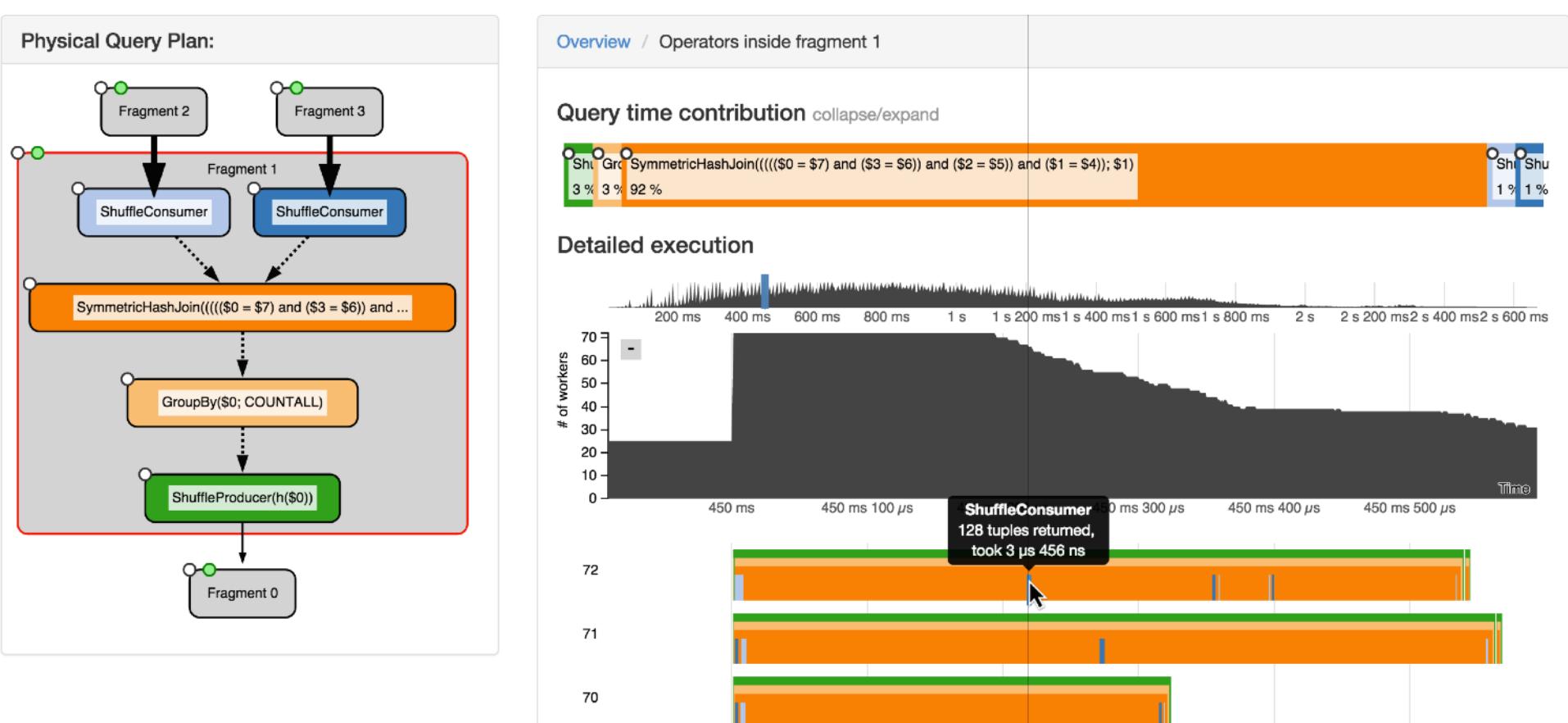
**Divided Edge Bundling - David Selassie**

# Visualizing Galaxy Merger Trees



S. Loebman, J. Ortiz, L. Orr, M. Balazinska, T. Quinn et al. [SIGMOD '14]

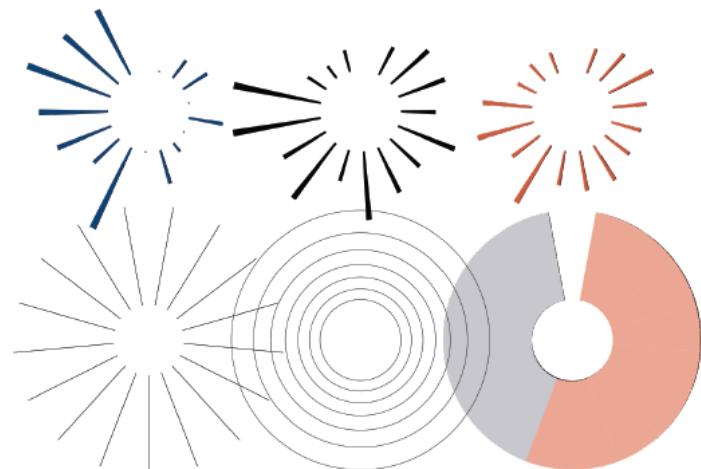
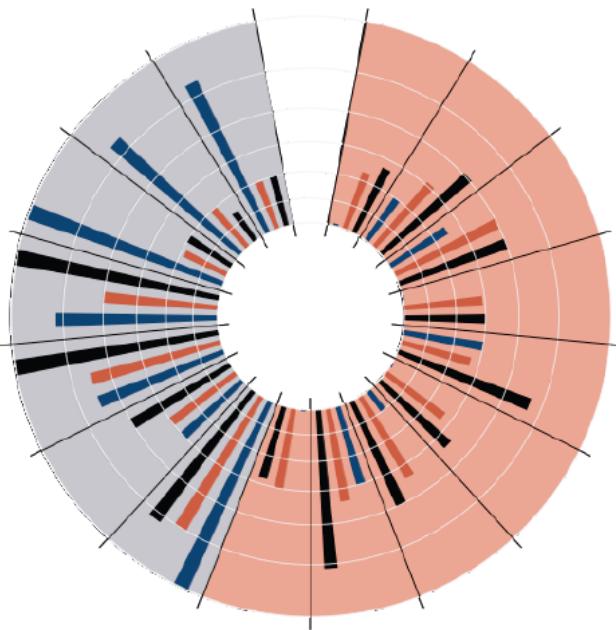
# Perfopticon Distributed Query Performance

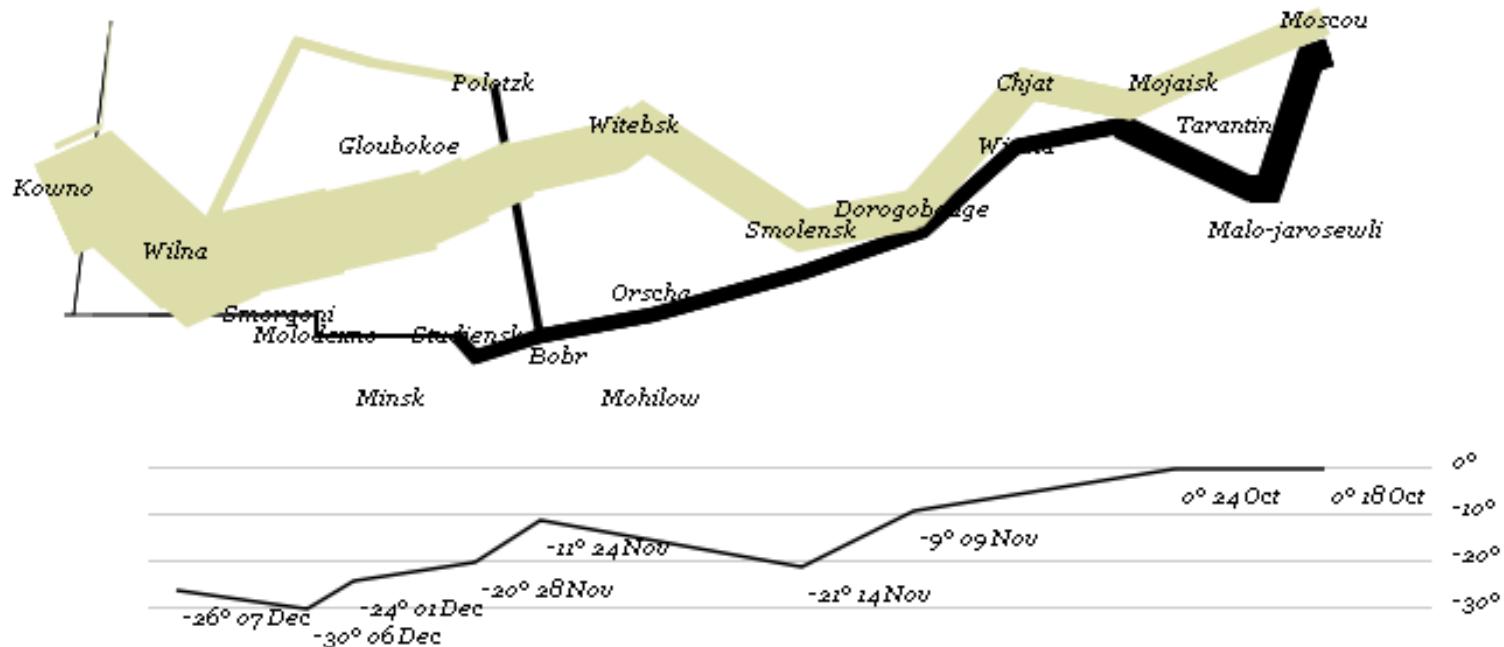


Dominik Moritz et al. [EuroVis '15]

# **Protopis**: A Graphical Toolkit for Visualization

**Mike Bostock**





```

var army = pd.nest(napoleon.army, "dir", "group");
var vis = new pv.Panel();

var lines = vis.add(pv.Panel).data(army);
lines.add(pv.Line)
  .data(function() army[this.idx])
  .left(lon).top(lat).size(function(d) d.size/8000)
  .strokeStyle(function() color[army[panelIndex][0].dir]);

vis.add(pv.Label).data(napoleon.cities)
  .left(lon).top(lat)
  .text(function(d) d.city).font("italic 10px Georgia")
  .textAlign("center").textBaseline("middle");

```

```

vis.add(pv.Rule).data([0,-10,-20,-30])
  .top(function(d) 300 - 2*d - 0.5).left(200).right(150)
  .lineWidth(1).strokeStyle("#ccc")
  .anchor("right").add(pv.Label)
  .font("italic 10px Georgia")
  .text(function(d) d+"°").textBaseline("center");

vis.add(pv.Line).data(napoleon.temp)
  .left(lon).top(tmp).strokeStyle("#0")
  .add(pv.Label)
  .top(function(d) 5 + tmp(d))
  .text(function(d) d.temp+"° "+d.date.substr(0,6))

```

# Visualizing the Republic of Letters

Daniel Chang, Yuankai Ge, Shiwei Song

## Republic of Letters

1700

United Kingdom

France

Spain

Denmark

Germany

Italy

Polar

Ireland

Letters: (97 max)  
97  
68  
44  
11  
5  
3



## FILTER BY AUTHOR

[Clear All](#)

Damien Desormes

Daniel Cornabs

Daniel de Pury

Daniel Defoe

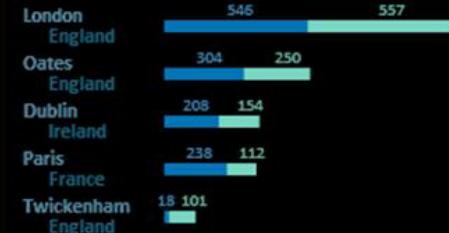
Daniel Malthus

Daniel Marc Antoine Chardon

Daniel Muller

## TOP CITIES AND AUTHORS

█ Letters received      █ Letters sent



# Questions?

# A1: Visualization Design

**Design a static visualization for a data set.**

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?

# A1: Visualization Design

Pick a **guiding question**, use it to title your vis.

Design a **static visualization** for that question.

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

**Deliverables** (upload via Canvas; see A1 page)

Image of your visualization (PNG or JPG format)

Short description + design rationale ( $\leq 4$  paragraphs)

Due by **8:00 pm, Monday April 2.**