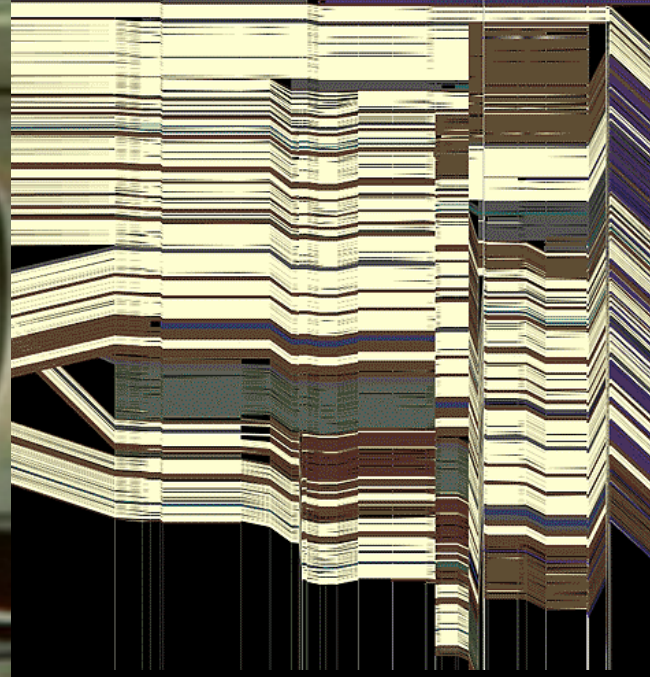
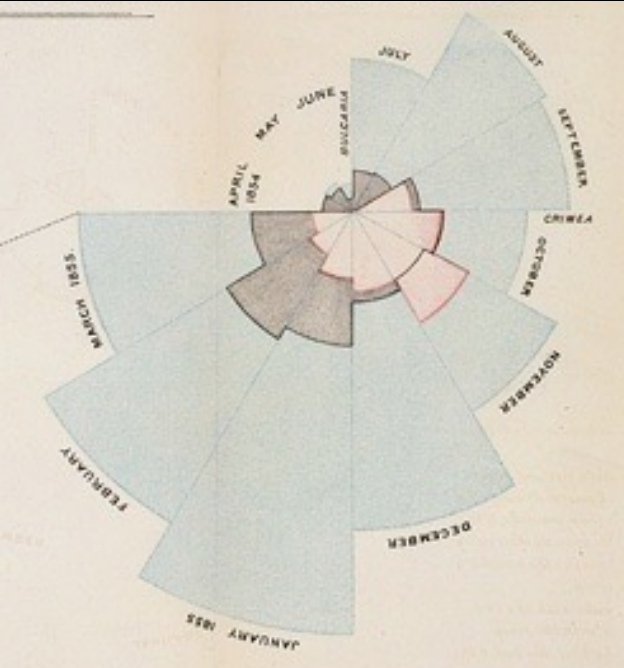


CSE 512 - Data Visualization

# The Value of Visualization

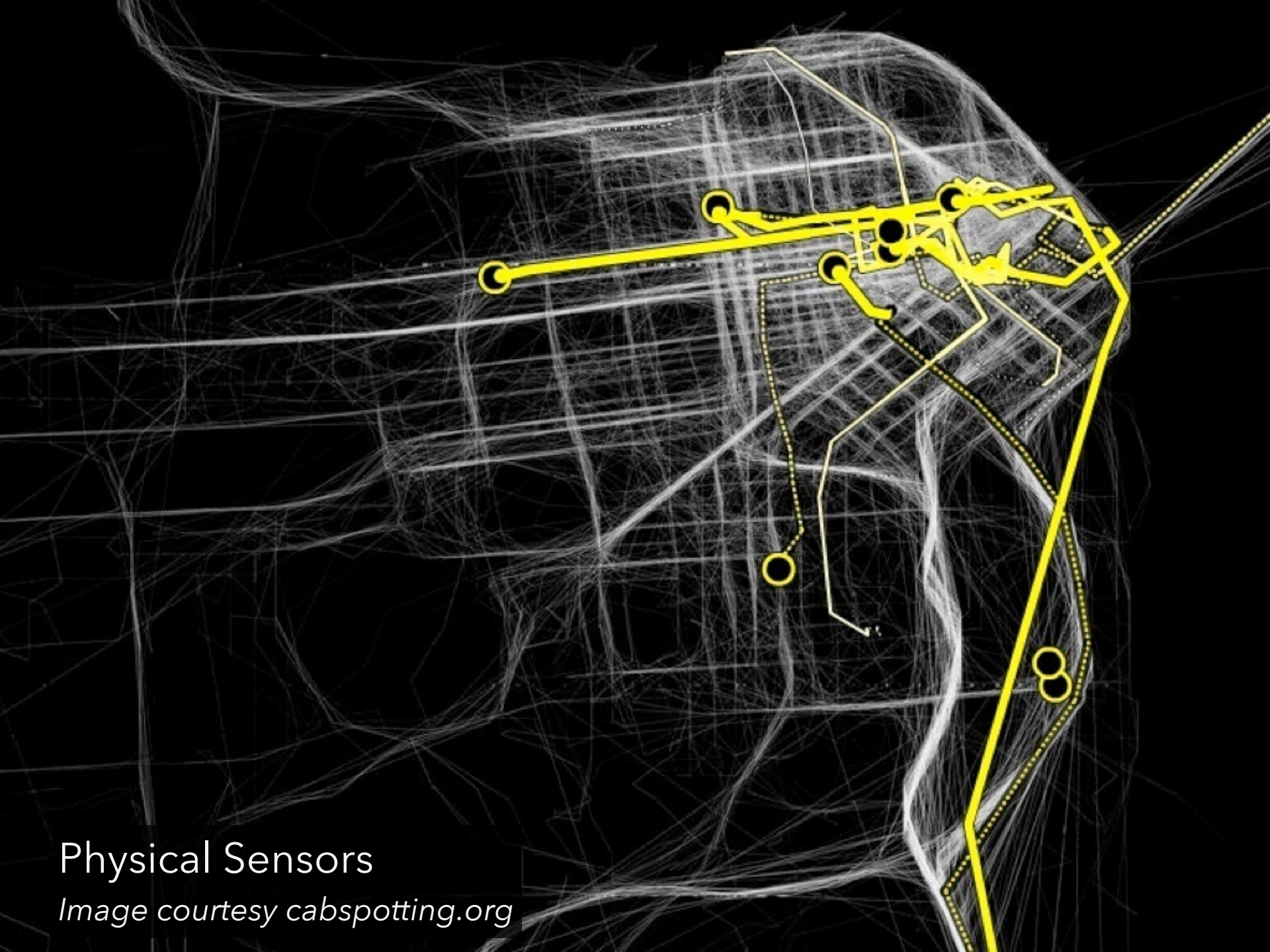


Jeffrey Heer University of Washington

**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*





157

HR/ECG  
1/min

130/65

Art  
mmHg sys/dia

93

SpO2  
%

RR/CO2  
1/min

97

HR/ECG  
1/min

82/60

Art  
mmHg sys/dia

99

SpO2  
%

RR/CO2  
1/min

79

HR/ECG  
1/min

152/79

Art  
mmHg sys/dia

95

SpO2  
%

RR/CO2  
1/min

64

HR/ECG  
1/min

93/55

mmHg sys/dia

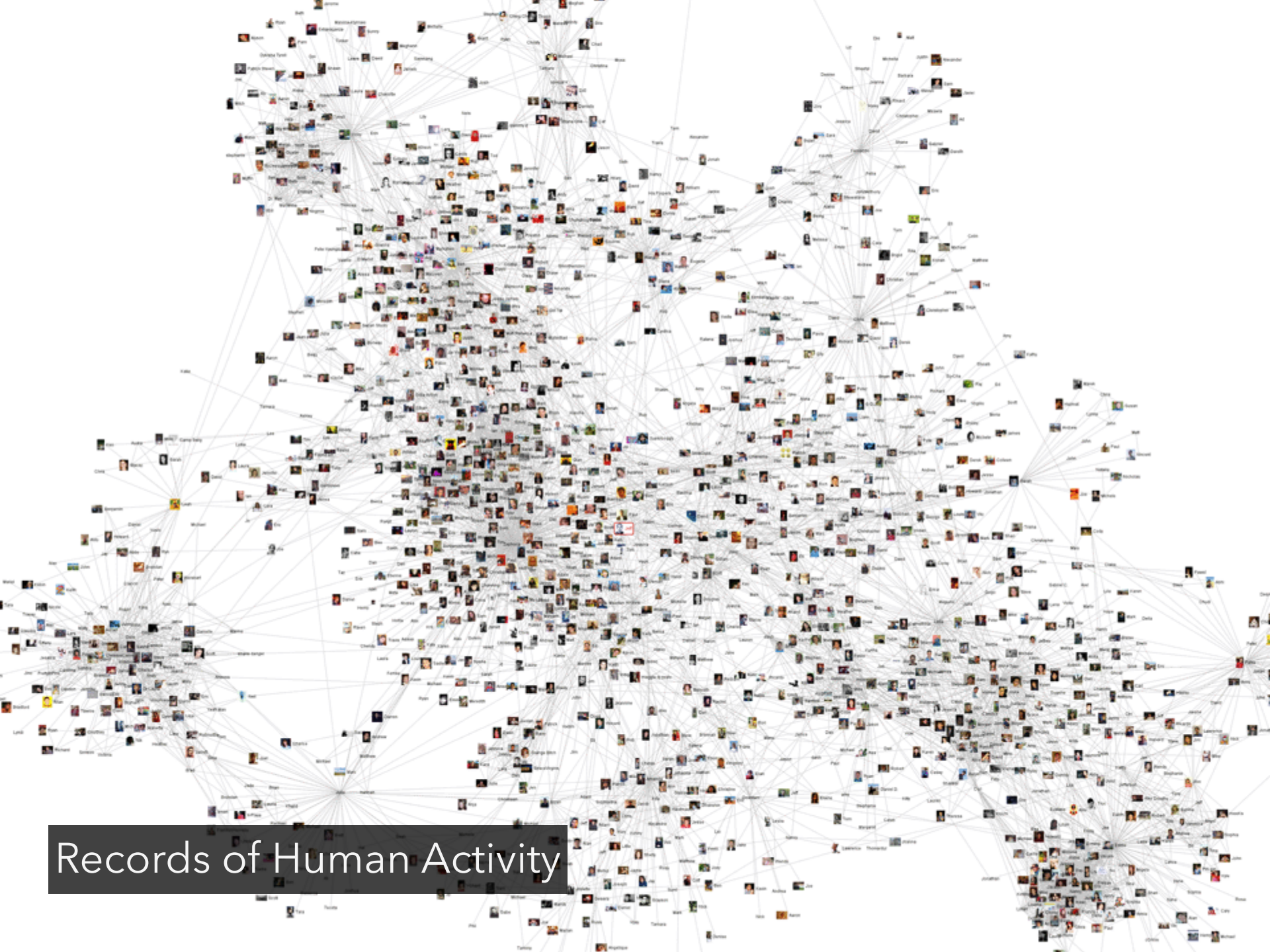
99

SpO2  
%

RR/Imp  
1/min

99

Health & Medicine

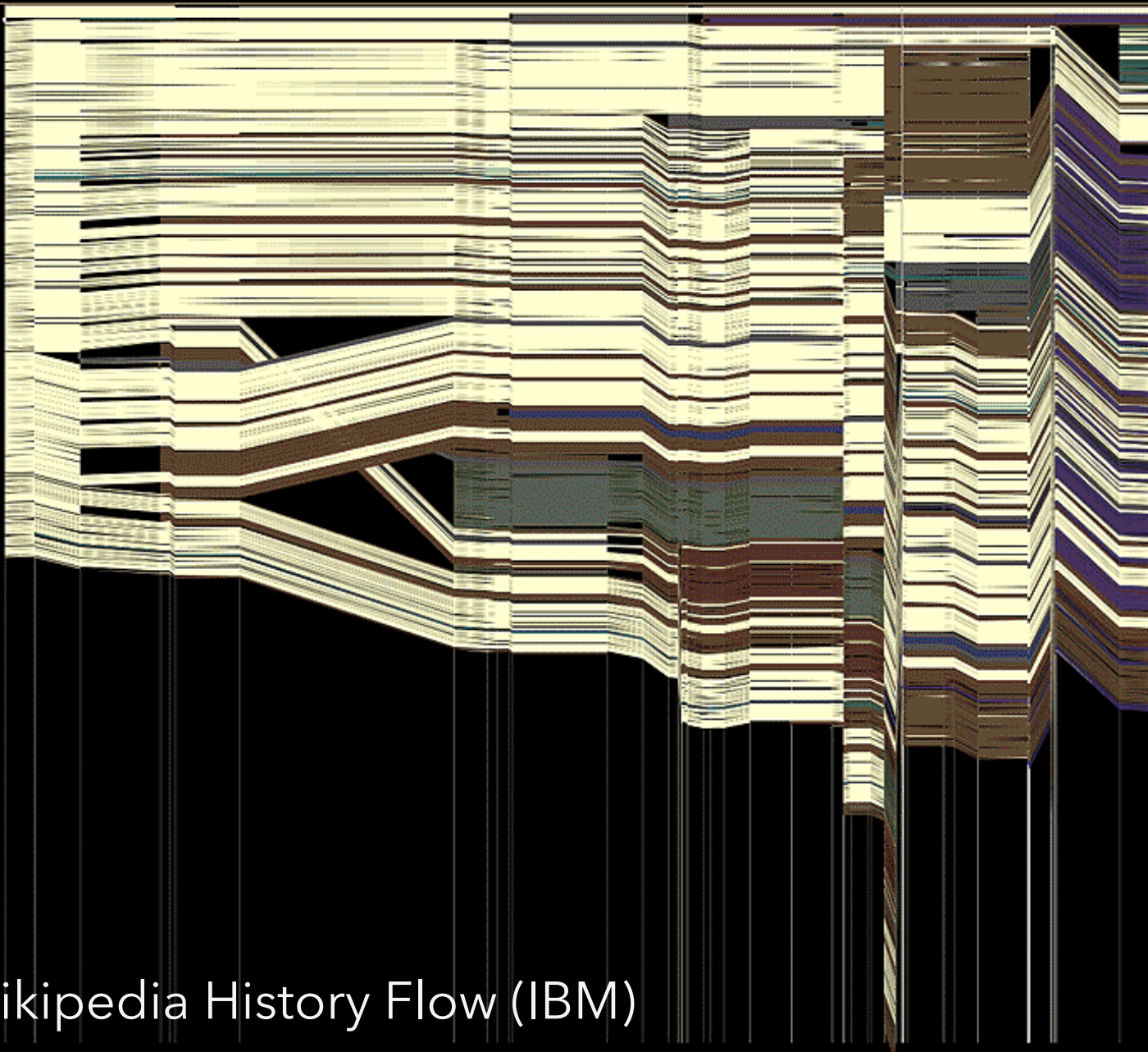


Records of Human Activity



authors posts

Zundark	1
The Conductor	1
The Epost	1
Conversion script	1
FK	1
Freob	1
B4hand	1
KarakizeArchon	1
Stephen Gilbert	1
Srubenstein	8
Mimccorn	5
Isls	1
Derek Ross	1
Dante Alighieri	2
Maveric149	3
Jzzbug	2
Jdirl	8
Theanthrope	1
Wesley	2
Dreamword	1
Stevetigo	4
Camembert	1
Hephaestus	2
Zoe	1
MyRedDice	1
G-Man	2
Kingturtle	1
Montrealais	1
210	1



## 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 means ("spontaneous abortion" or *miscarriage*), or to the cessation of normal growth of the embryo or fetus (1 in 5 of all pregnancies, usually within the first 12 weeks) or to the cessation of normal growth of the 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 is performed by a number of different methods. The earliest terminations (before nine weeks) are usually performed by a chemical abortion. A chemical abortion is the usual method, though *mifepristone* is usually the only legal method. Although research has uncovered similar effects from *methotrexate* and *misoprostol*. Concern with chemical abortion and extending up until around the fifteenth week, suction-aspiration 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 (D & E) is used.

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 (D & X) or a hysterotomy abortion, similar to a caesarian section.

### The controversy

The morality and legality of abortion is a highly important 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.

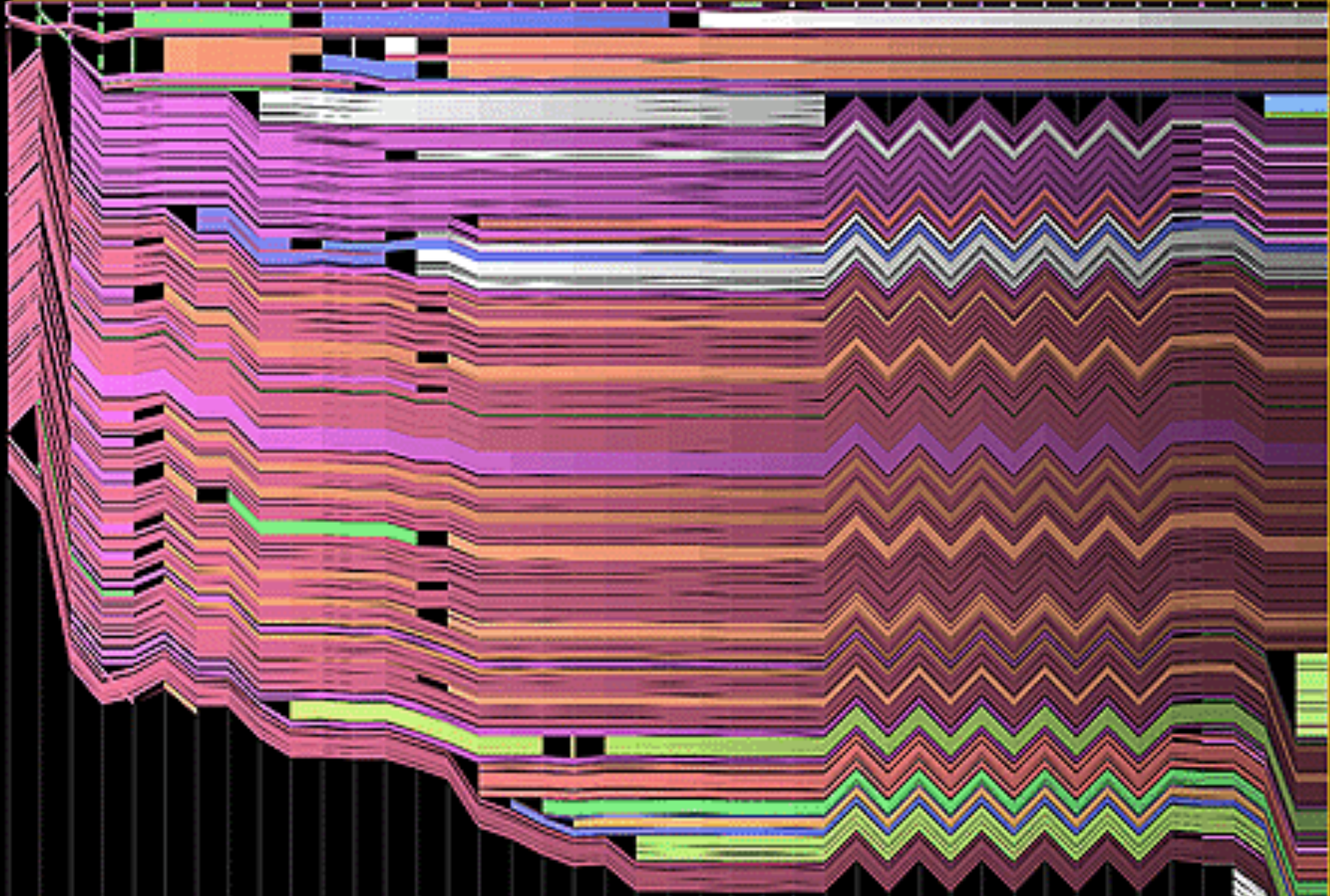
Abortion has been common in most societies throughout history, although it has often been opposed by some institutionalized religions and governments. In the 19th century, politics in the United States and Europe over abortion became commonly accepted by the end of the 20th century. Additionally, abortion 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 the positions of the respective sides are subject to heated debate. While those on both sides of the debate are generally peaceful, if heated, in their defense of their positions, the debate is sometimes characterized by violence. Though true of both sides, this is more marked on the side of those opposed to abortion, because of what they perceive as the gravity and urgency of their views.

### The central question

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

Wikipedia History Flow (IBM)





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

# 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

$$u_X = 9.0 \quad \sigma_X = 3.317$$

$$u_Y = 7.5 \quad \sigma_Y = 2.03$$

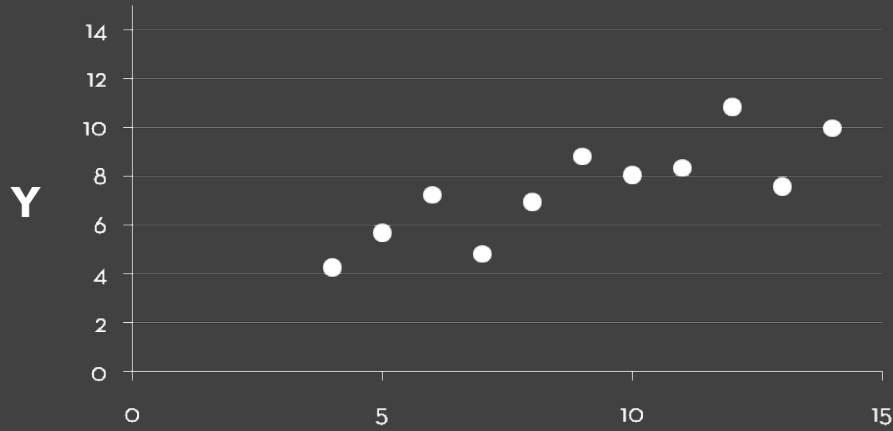
### Linear Regression

$$Y = 3 + 0.5 X$$

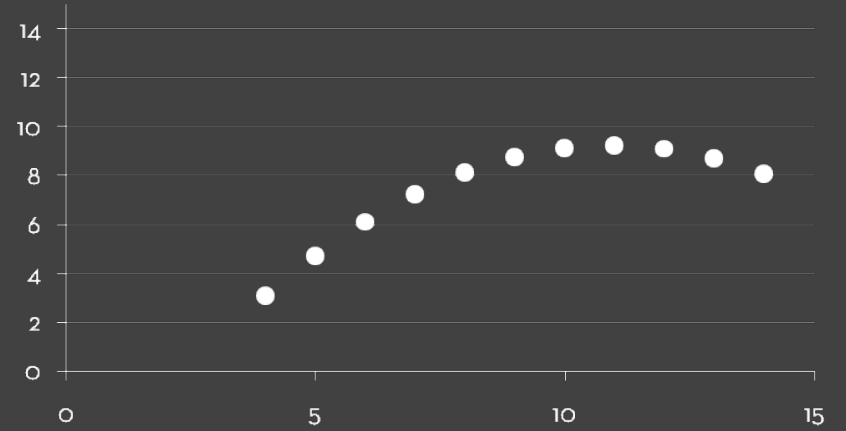
$$R^2 = 0.67$$

[Anscombe 1973]

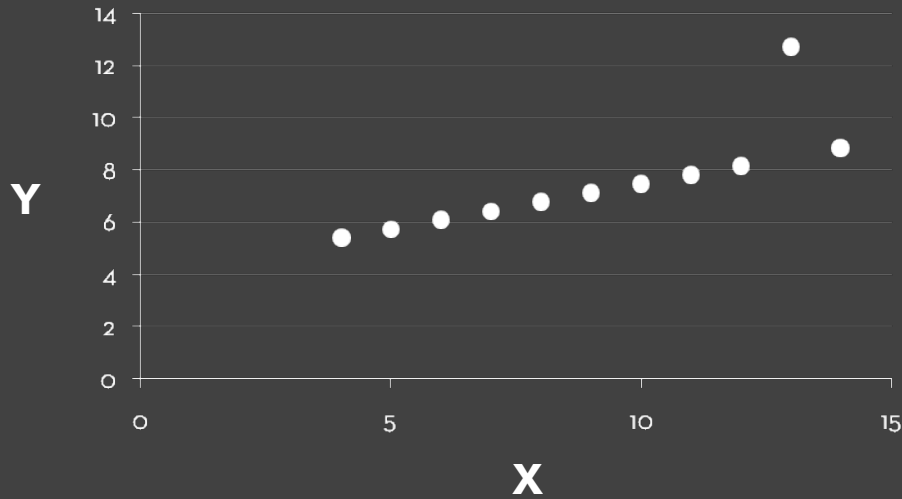
# Set A



# Set B



# Set C



# Set D





# Why Create Visualizations?

# Why Create Visualizations?

Answer questions (or discover them)

Make decisions

See data in context

Expand memory

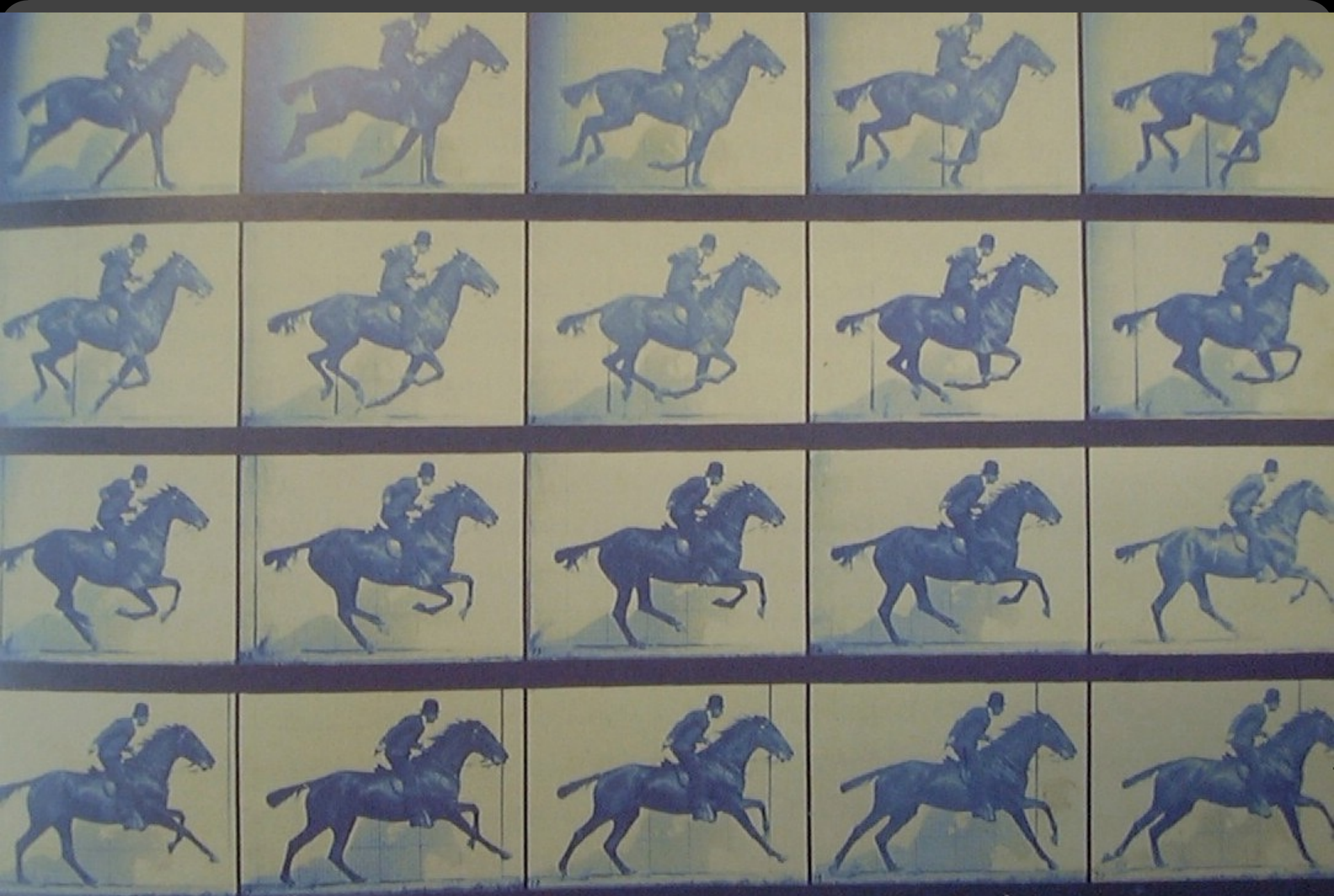
Support graphical calculation

Find patterns

Present argument or tell a story

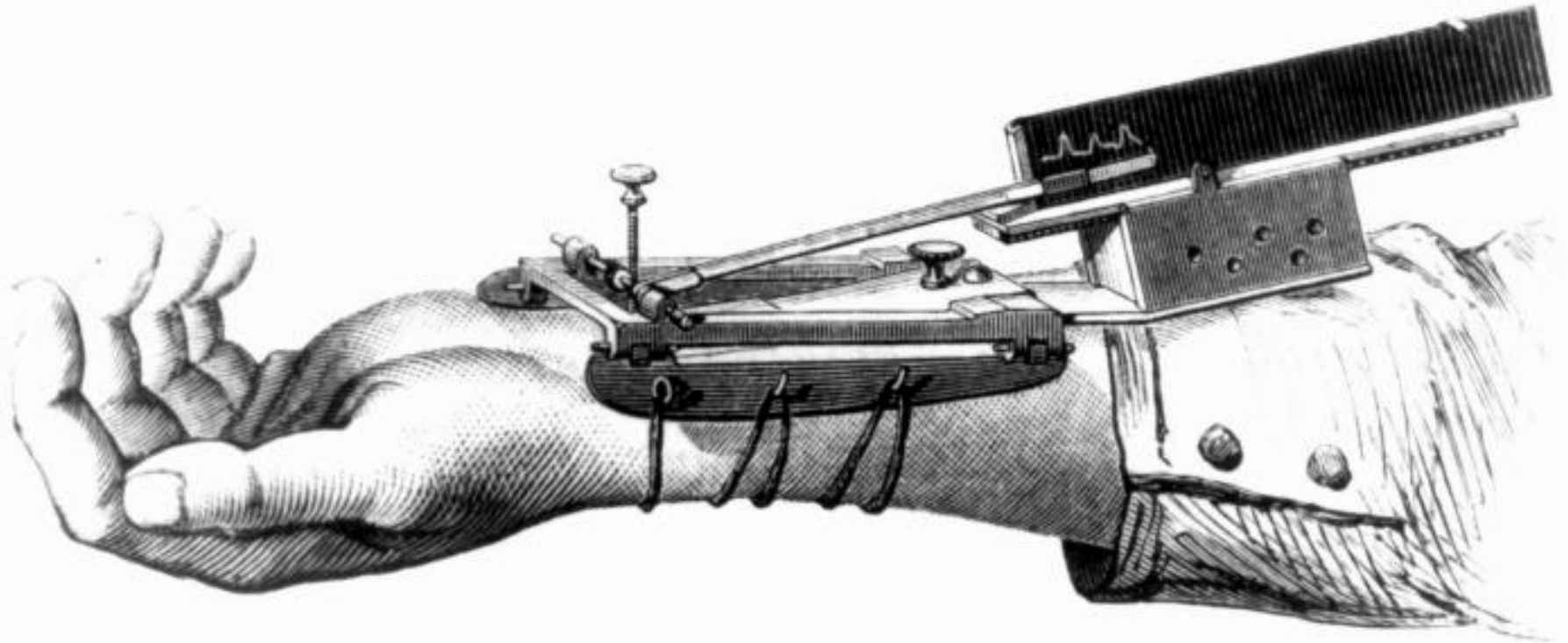
Inspire

# Record Information



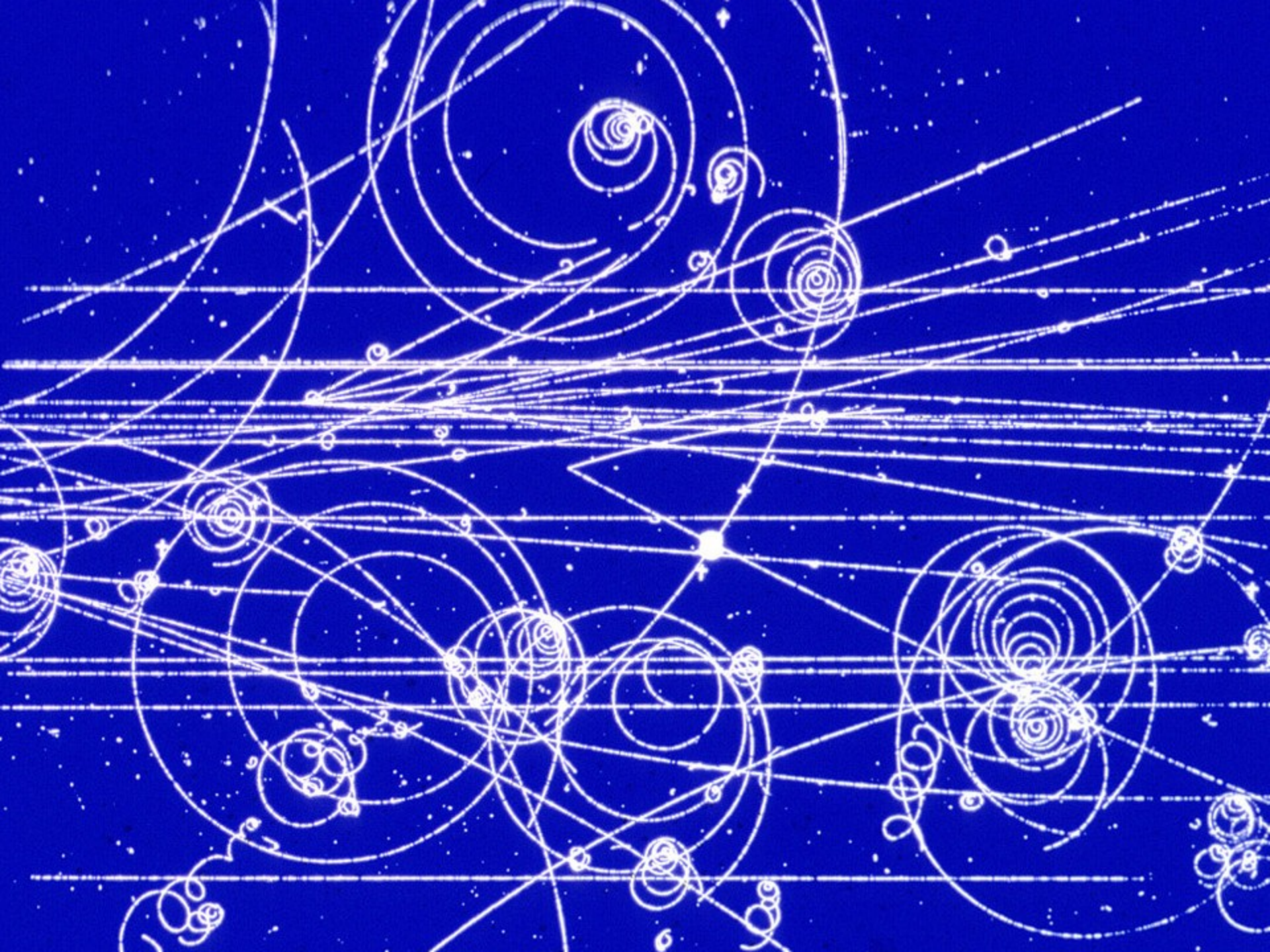
Gallop, Bay Horse "Daisy" [Muybridge 1884-86]





1.  
Marey's **sphygmograph** in use,  
1860. *La méthode graphique dans  
les sciences expérimentales et  
principalement en physiologie et en  
médecine.*





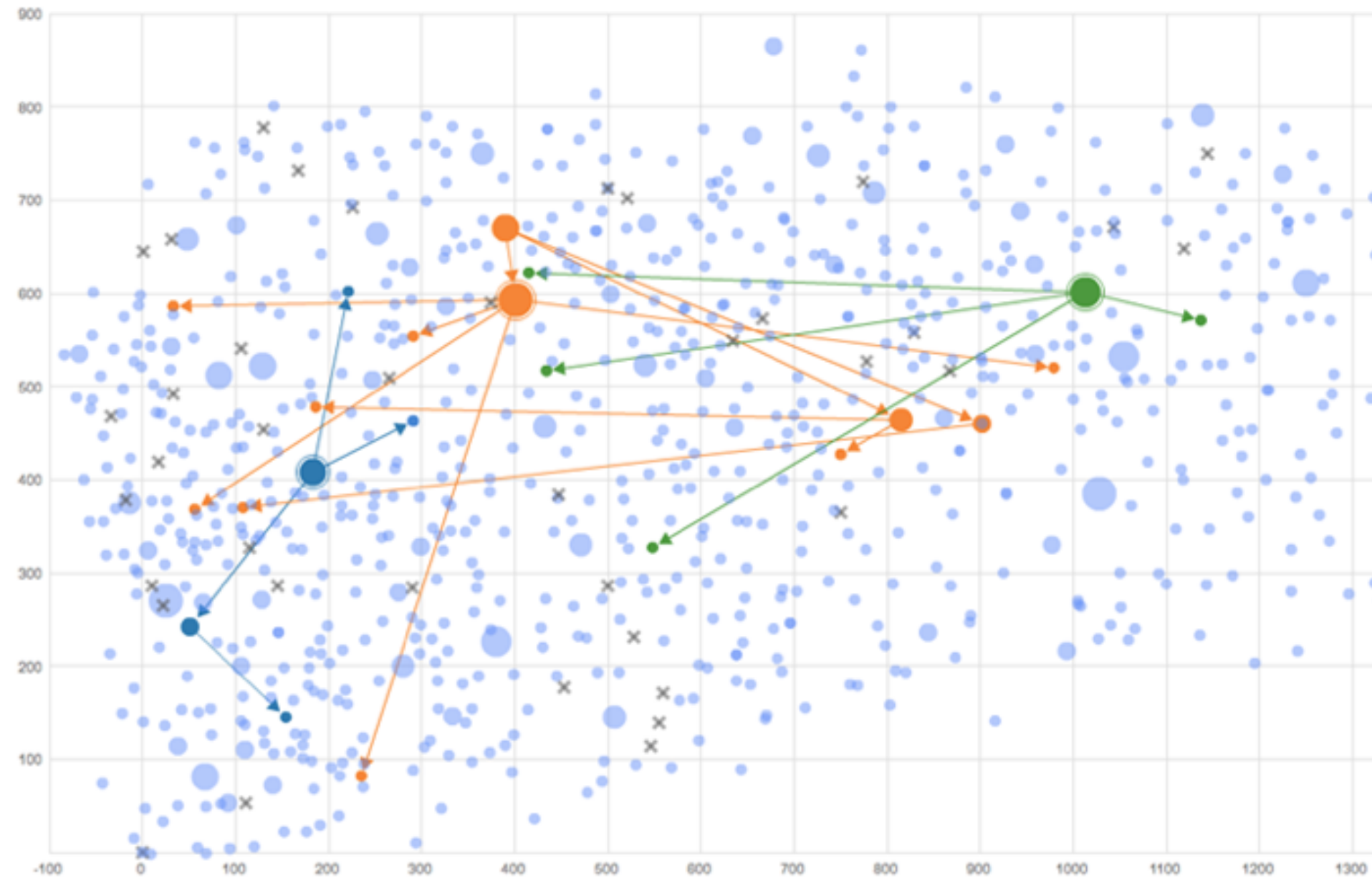












# Support Reasoning

HISTORY OF O-RING DAMAGE ON SRM FIELD JOINTS

1161  
Oct 30, 1985  
y

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.)		
61A LH Center Field**	22A	None	None	0.280	None	None	36° - 66°
61A LH CENTER FIELD**	22A	NONE	NONE	0.280	NONE	NONE	338° - 18°
51C LH Forward Field**	15A	0.010	154.0	0.280	4.25	5.25	163
51C RH Center Field (prim)***	15B	0.038	130.0	0.280	12.50	58.75	354
51C RH Center Field (sec)***	15B	None	45.0	0.280	None	29.50	354
41D RH Forward Field	13B	0.028	110.0	0.280	3.00	None	275
41C LH Aft Field*	11A	None	None	0.280	None	None	--
41B LH Forward Field	10A	0.040	217.0	0.280	3.00	14.50	351
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.

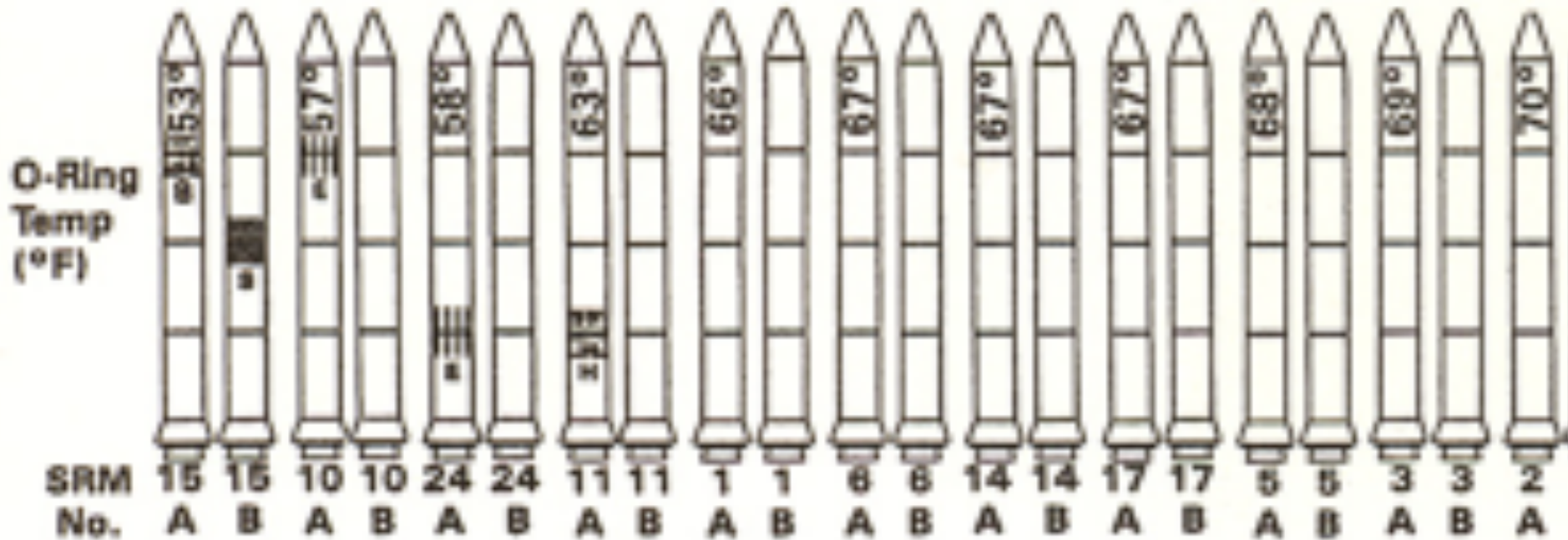
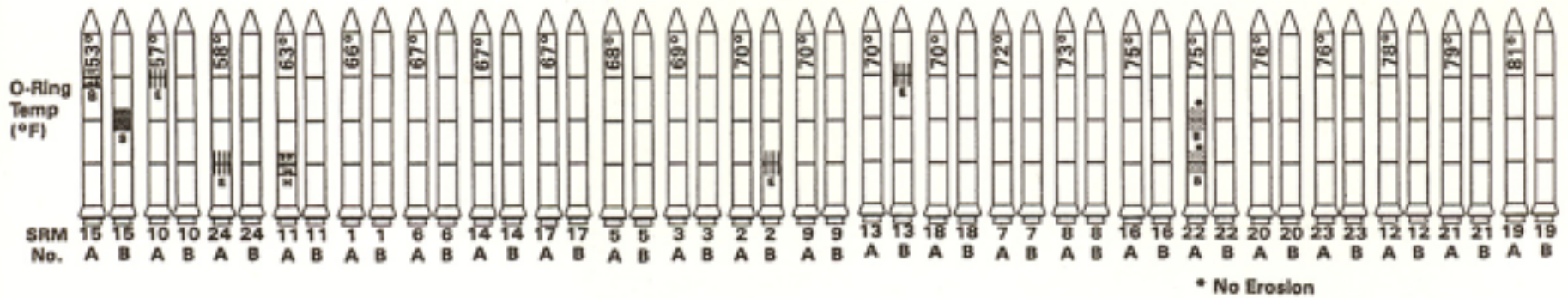
SRM-22 FORWARD FIELD JOINT HAD PUTTY PATH TO PRIMARY O-RING, BUT NO O-RING EROSION AND NO SOOT BLOWBY. OTHER SRM-22 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY.

*BLOW BY HISTORY*  
 SRM-15 WORST BLOW-BY  
 o 2 CASE JOINTS (80°), (110°) ARC  
 o MUCH WORSE VISUALLY THAN SRM-22  
 SRM 22 BLOW-BY  
 o 2 CASE JOINTS (30-40°)  
 SRM-13A, 15, 16A, 18, 23A 24A  
 o NOZZLE BLOW-BY

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

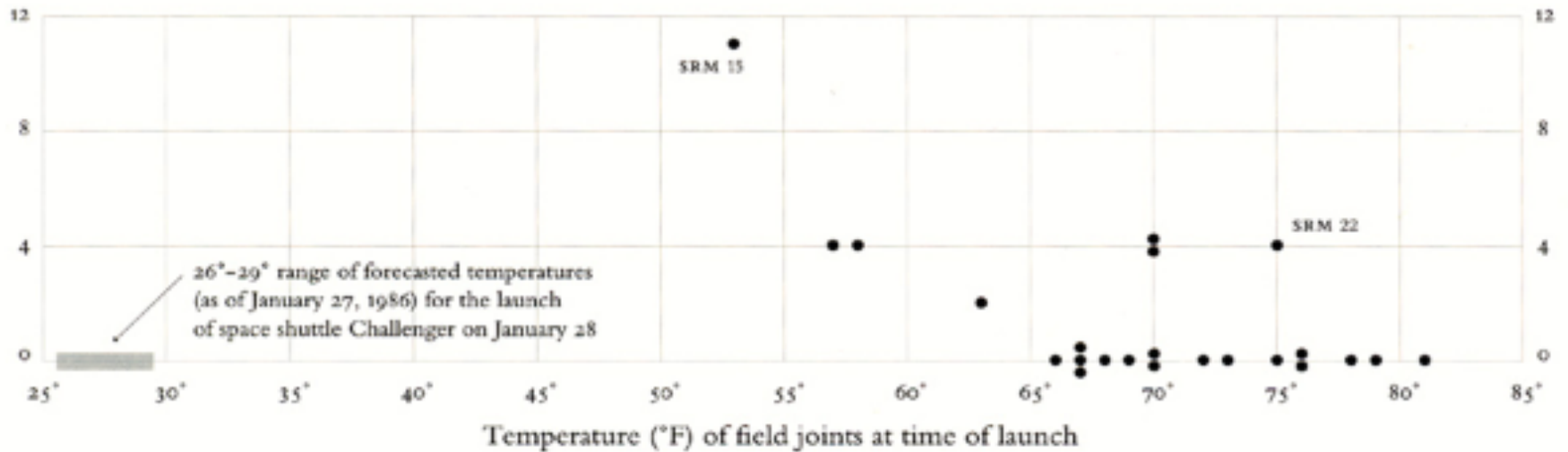
MOTOR	MBT	AMB	O-RING	WIND
DM-4	68	36	47	10 MPH
DM-2	76	45	52	10 MPH
QM-3	72.5	40	48	10 MPH
QM-4	76	48	51	10 MPH
SRM-15	52	64	53	10 MPH
SRM-22	77	78	75	10 MPH
SRM-25	55	26	29	10 MPH
			27	25 MPH

# 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

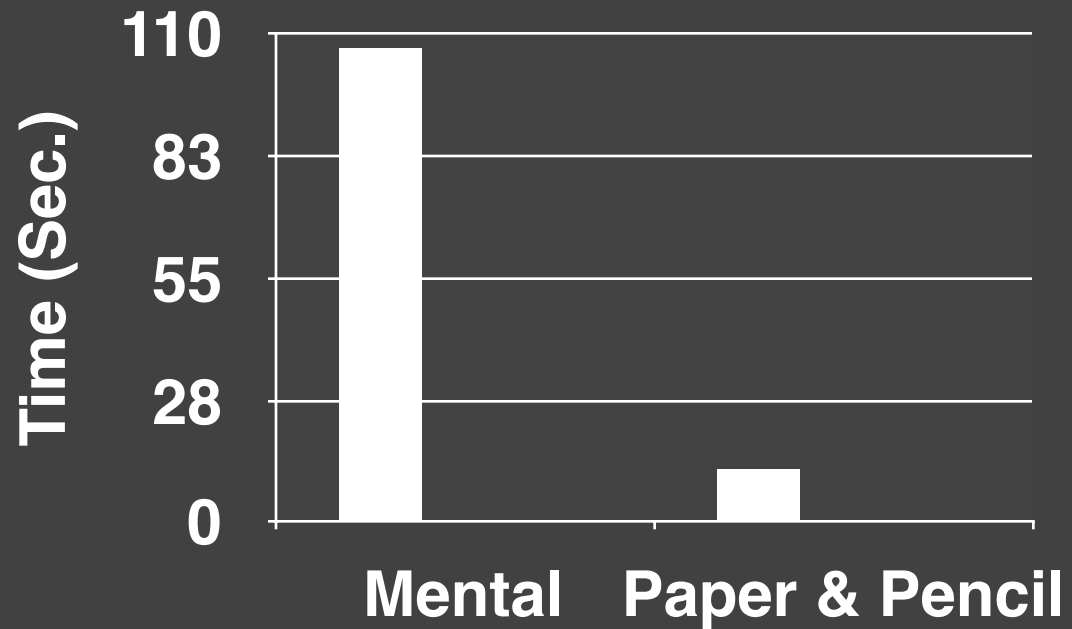


# Expand Memory: Multiplication

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

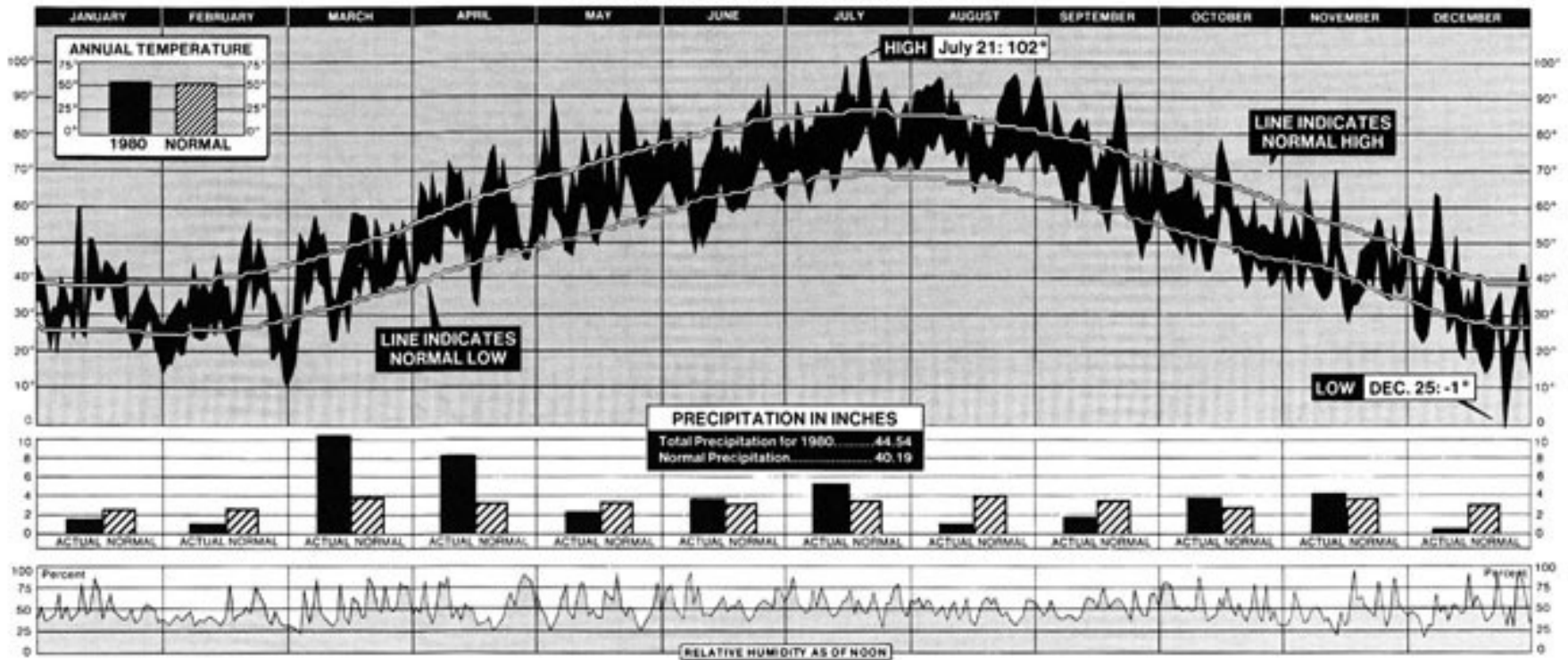
# Expand Memory: Multiplication

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



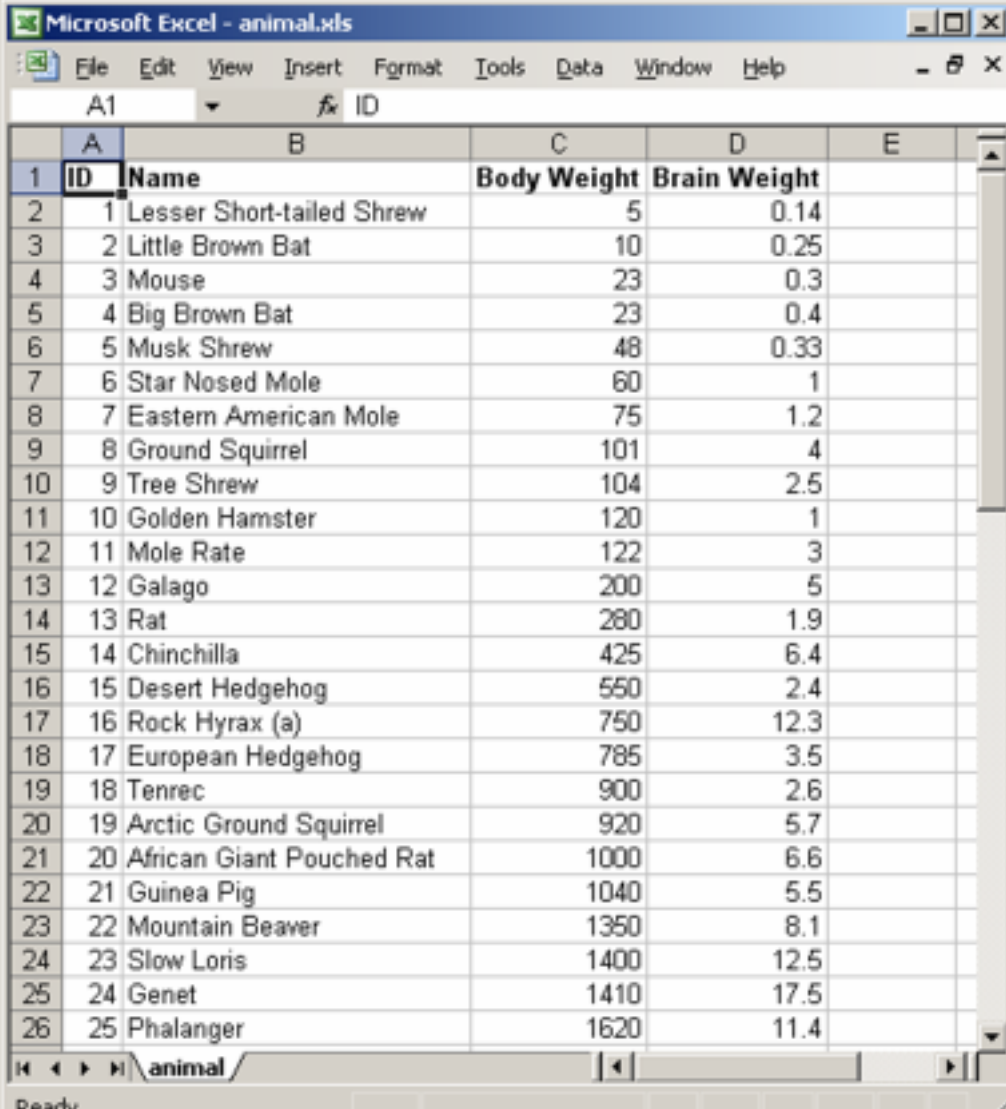
# Find Patterns: NYC Weather

NEW YORK CITY'S WEATHER FOR 1980



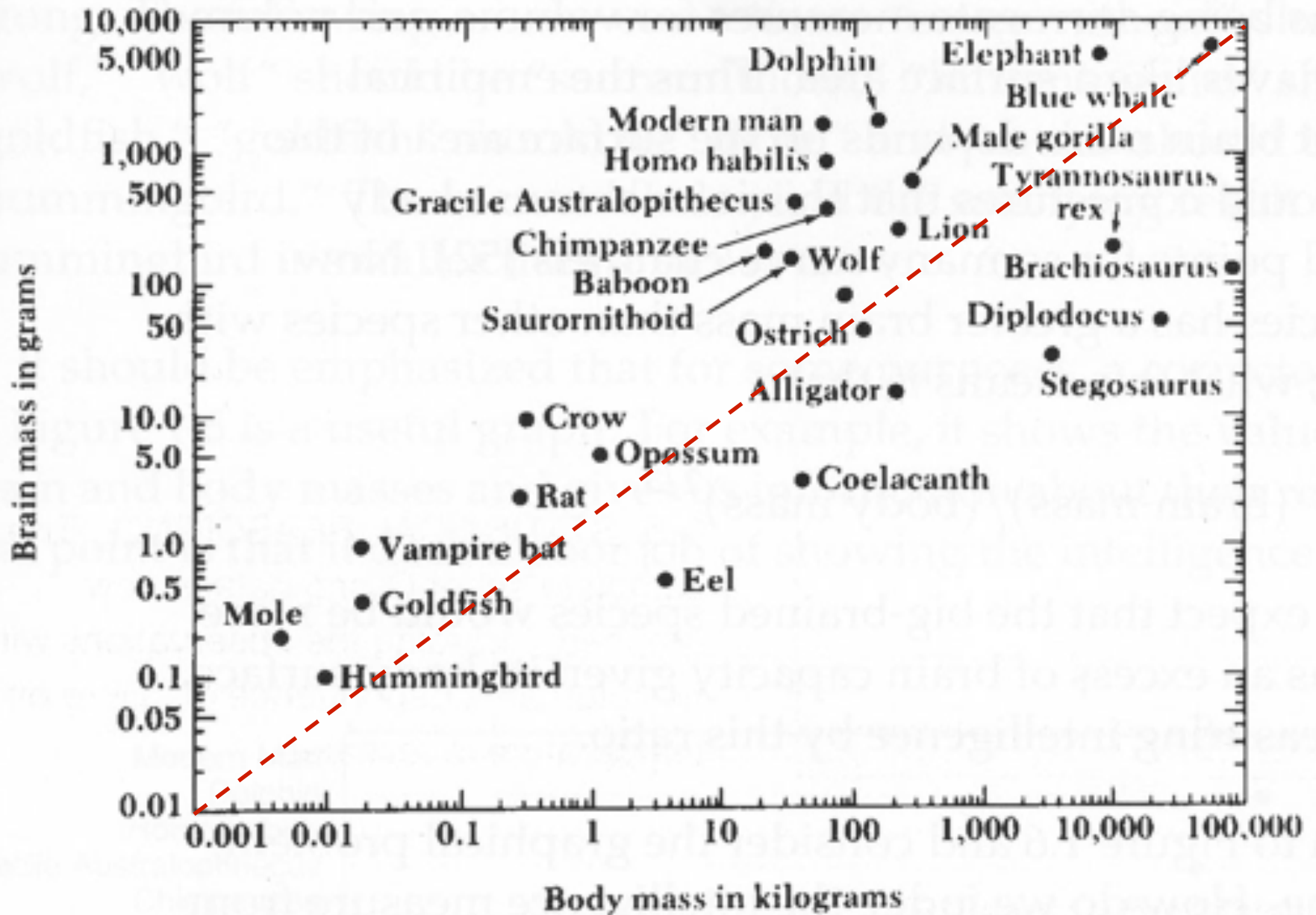
[New York Times 1981]

# The Most Powerful Brain?

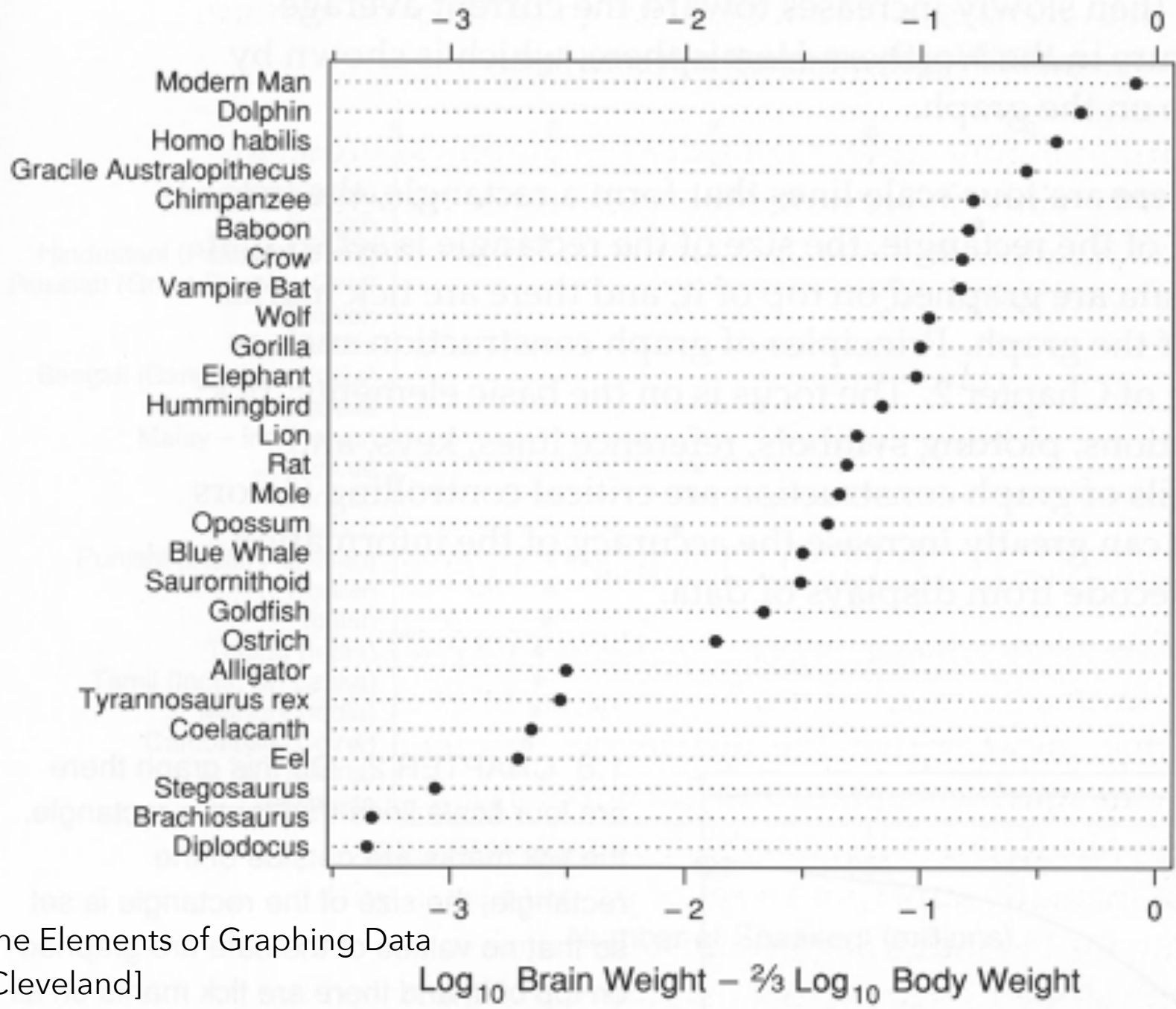


A screenshot of a Microsoft Excel spreadsheet titled "animal.xls". The spreadsheet contains a table with 26 rows of animal data. The columns are labeled "ID", "Name", "Body Weight", and "Brain Weight". The data shows a positive correlation between body weight and brain weight across the listed animals.

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



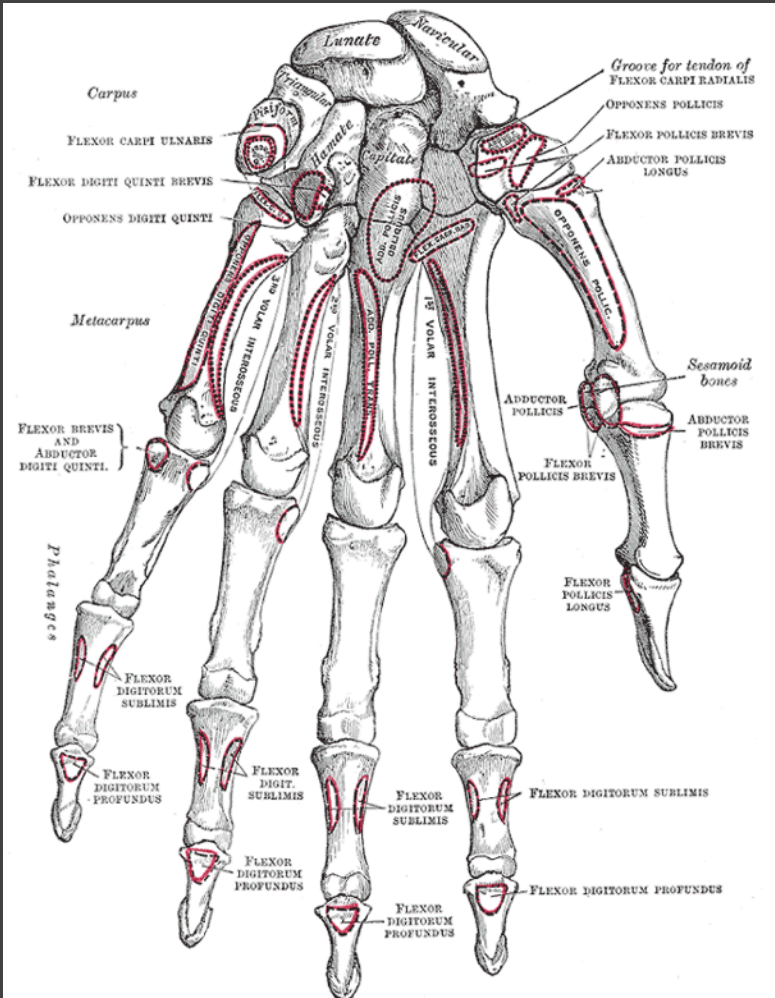
The Dragons of Eden [Carl Sagan]



The Elements of Graphing Data  
 [Cleveland]

**Convey Information  
to Others**

# Inspire



Bones in hand [from 1918 edition]

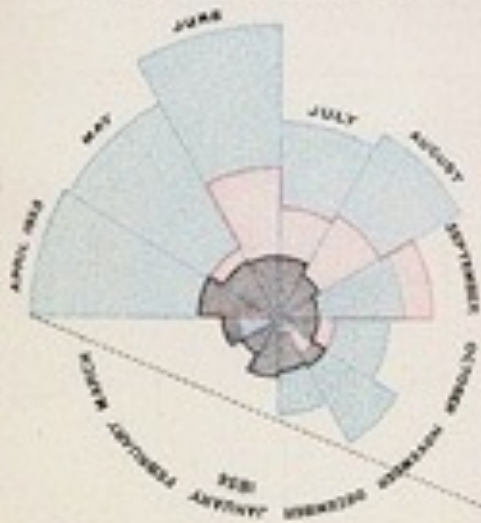


Double helix model [Watson and Crick 53]

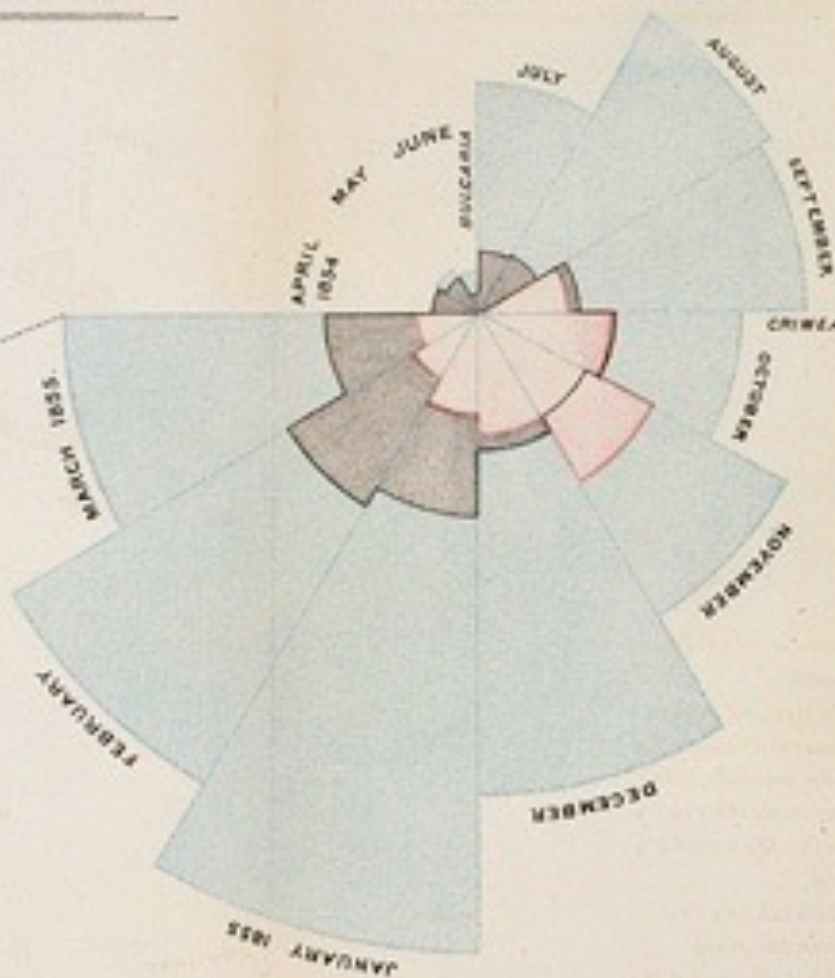


DIAGRAM OF THE CAUSES OF MORTALITY  
IN THE ARMY IN THE EAST.

2.  
APRIL 1855 TO MARCH 1856.



1.  
APRIL 1854 TO MARCH 1855.



“to affect thro’ the Eyes  
what we fail to convey to  
the public through their  
word-proof ears”

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

# Visualization Research

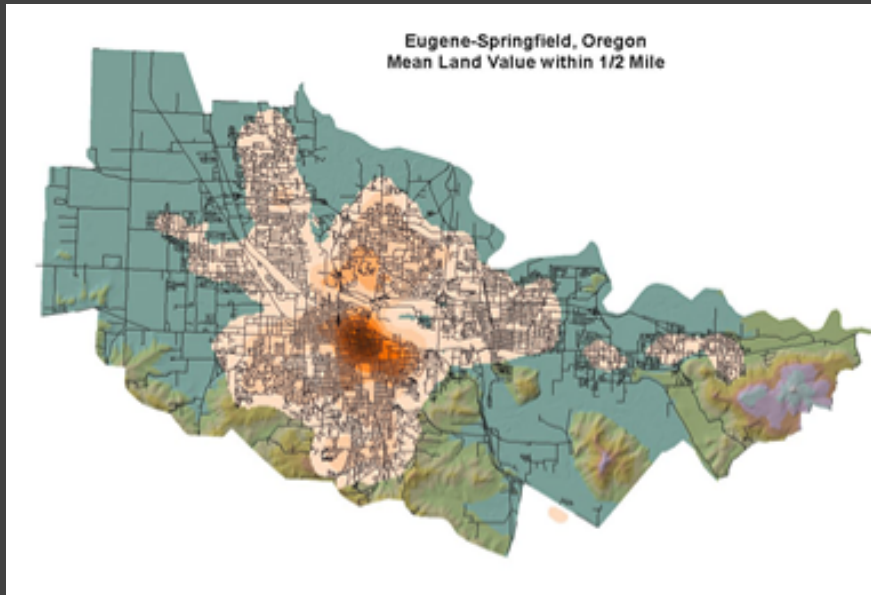
# Challenge

More and more unseen data  
Faster creation and collection



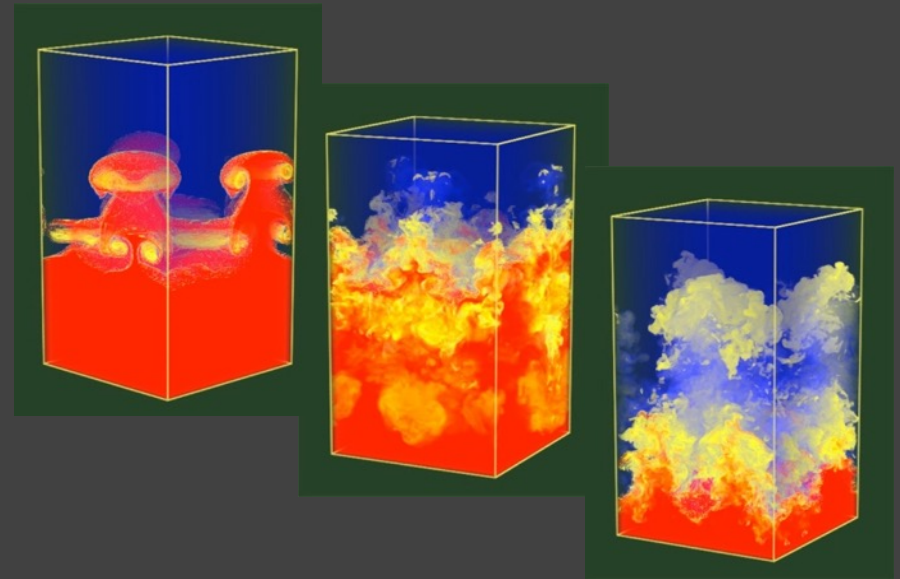
# Challenge

More and more unseen data  
Faster creation and collection



Urban development planning

[www.urbansim.org](http://www.urbansim.org)



Fluid flow

[ctr.stanford.edu](http://ctr.stanford.edu)

Simulation

# Challenge

More and more unseen data  
Faster creation and collection



Sloan digital sky survey

[www.sdss.org](http://www.sdss.org)



Sensor networks [Hill 02]

[www.xbow.com](http://www.xbow.com)



Digital photography

Sensing

# Challenge

More and more unseen data  
Faster creation and collection; Faster dissemination

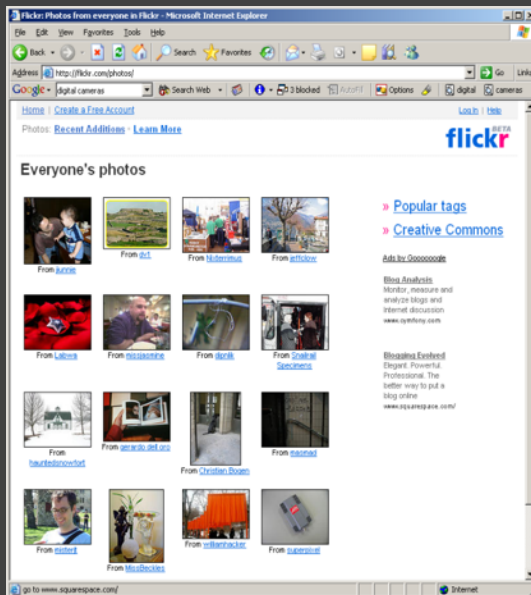
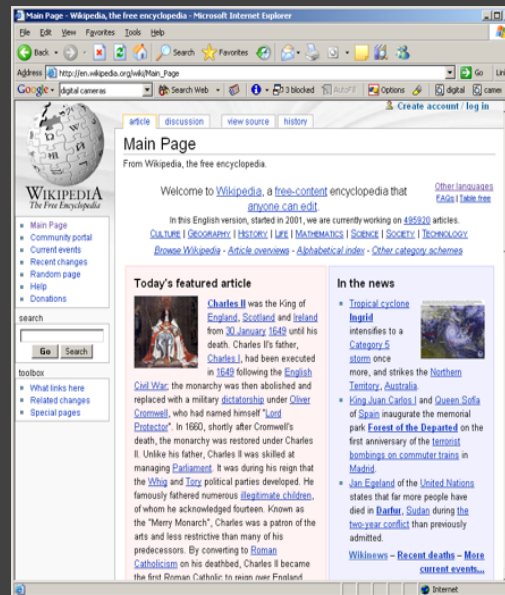
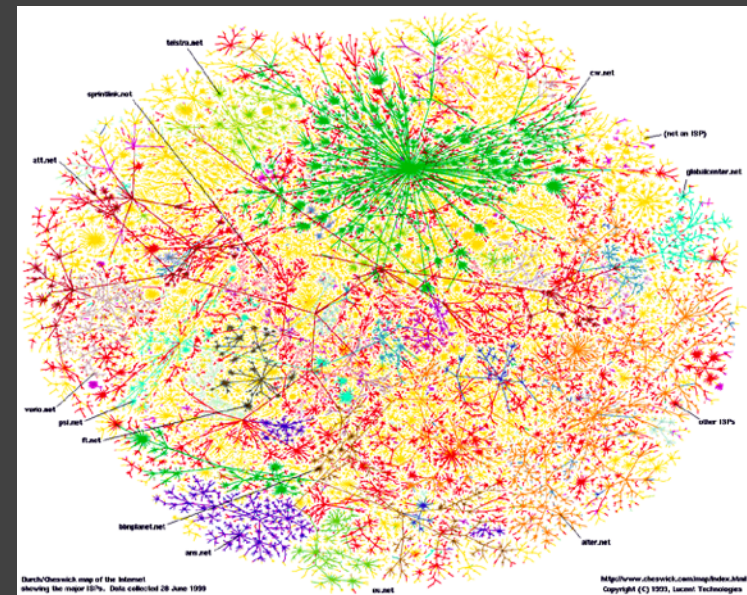


Photo sharing/annotation  
[flickr.com](http://flickr.com)



Group Authoring  
[wikipedia.org](http://wikipedia.org)



Map of the Internet [Cheswick 99]  
[research.lumeta.com](http://research.lumeta.com)

Internet

# Challenge

More and more unseen data

Faster creation and collection; Faster dissemination

5 exabytes of new information in 2002 [Lyman 03]

161 exabytes in 2006 [Gantz 07]

1,200 exabytes in 2010 [Gantz 10]

Necessitates **better tools and algorithms** for  
**visually conveying information**



# 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

# 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
  - Amplify perception and cognition
  - Improve ties between visualization & mental model

# Course Topics

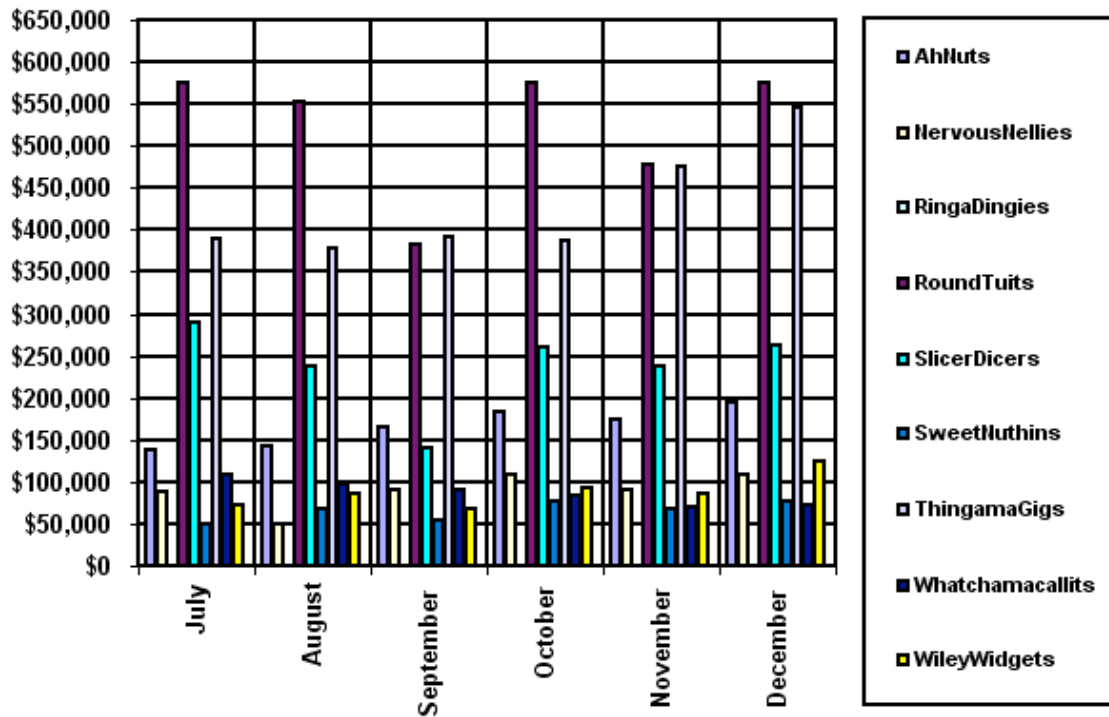
# Data and Image Models

		LES VARIABLES DE L'IMAGE									
		POINTS			LIGNES			ZONES		12	14
Z	XY 2 DIMENSIONS DU PLAN										
	TAILLE										
	VALEUR										
		LES VARIABLES DE SÉPARATION DES IMAGES								13	
	GRAIN										
	COULEUR										
	ORIENTATION										



# Visualization (Re-)Design

## SlicerDicers' Sales Compared to Other Products

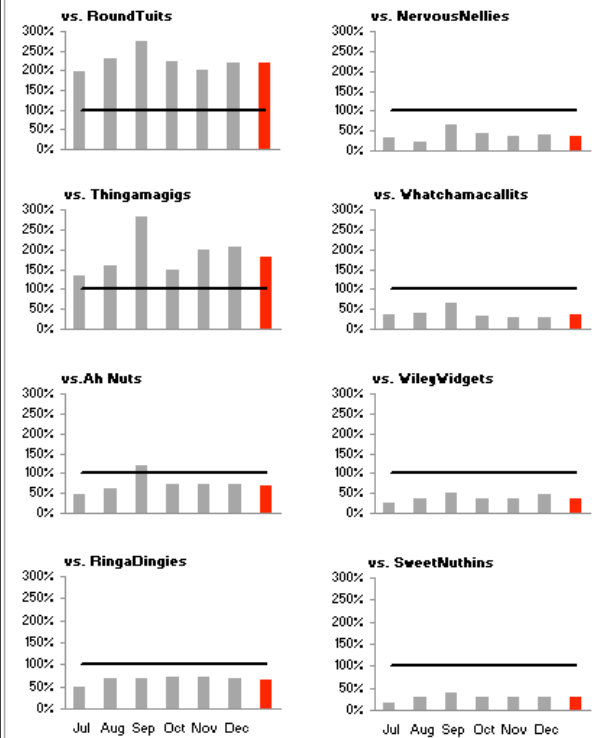


Problematic design

## Sales of SlicersDicers Compared to Other Products

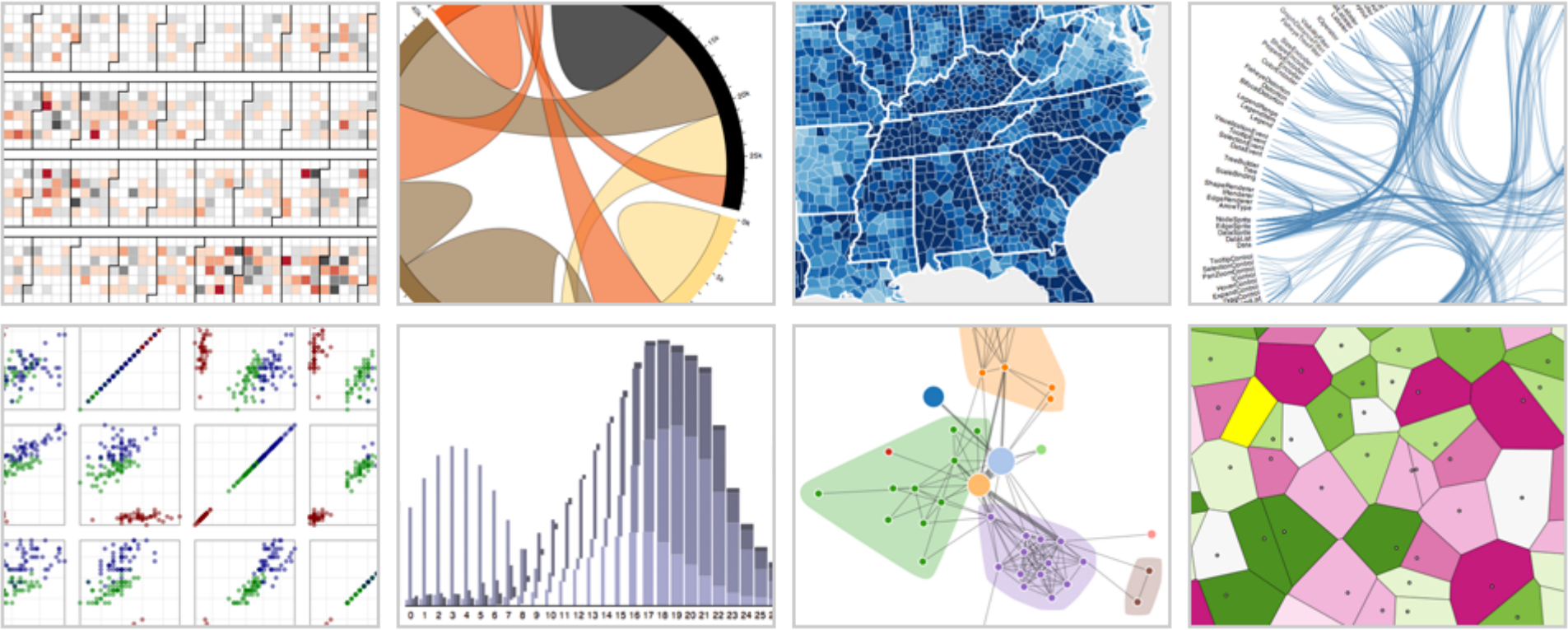
July - December, 2003

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



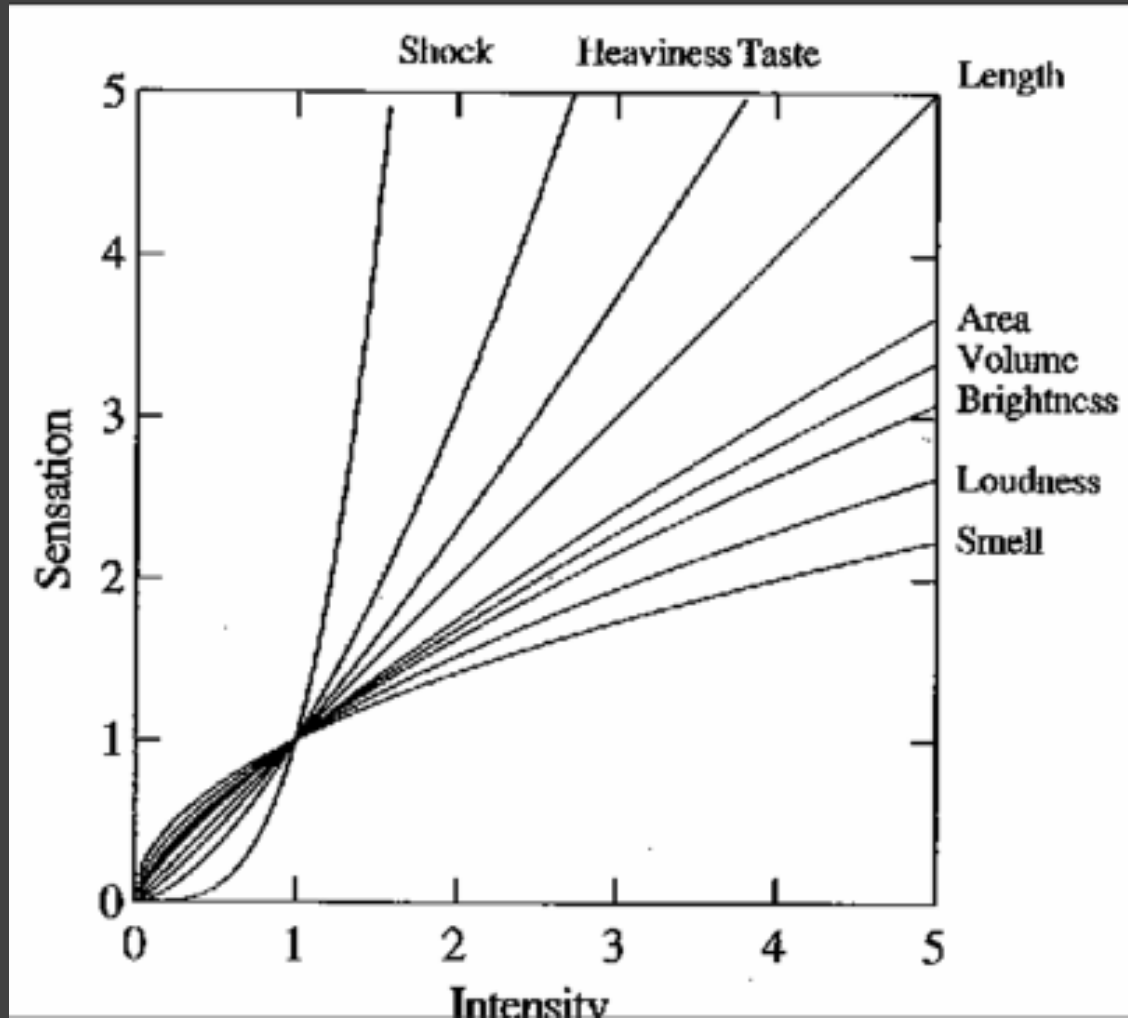
Redesign

# Visualization Software



D3: Data-Driven Documents

# Graphical Perception

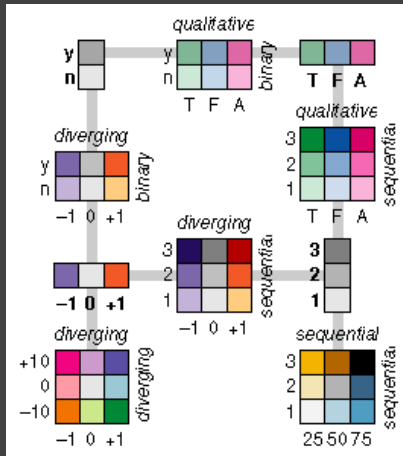
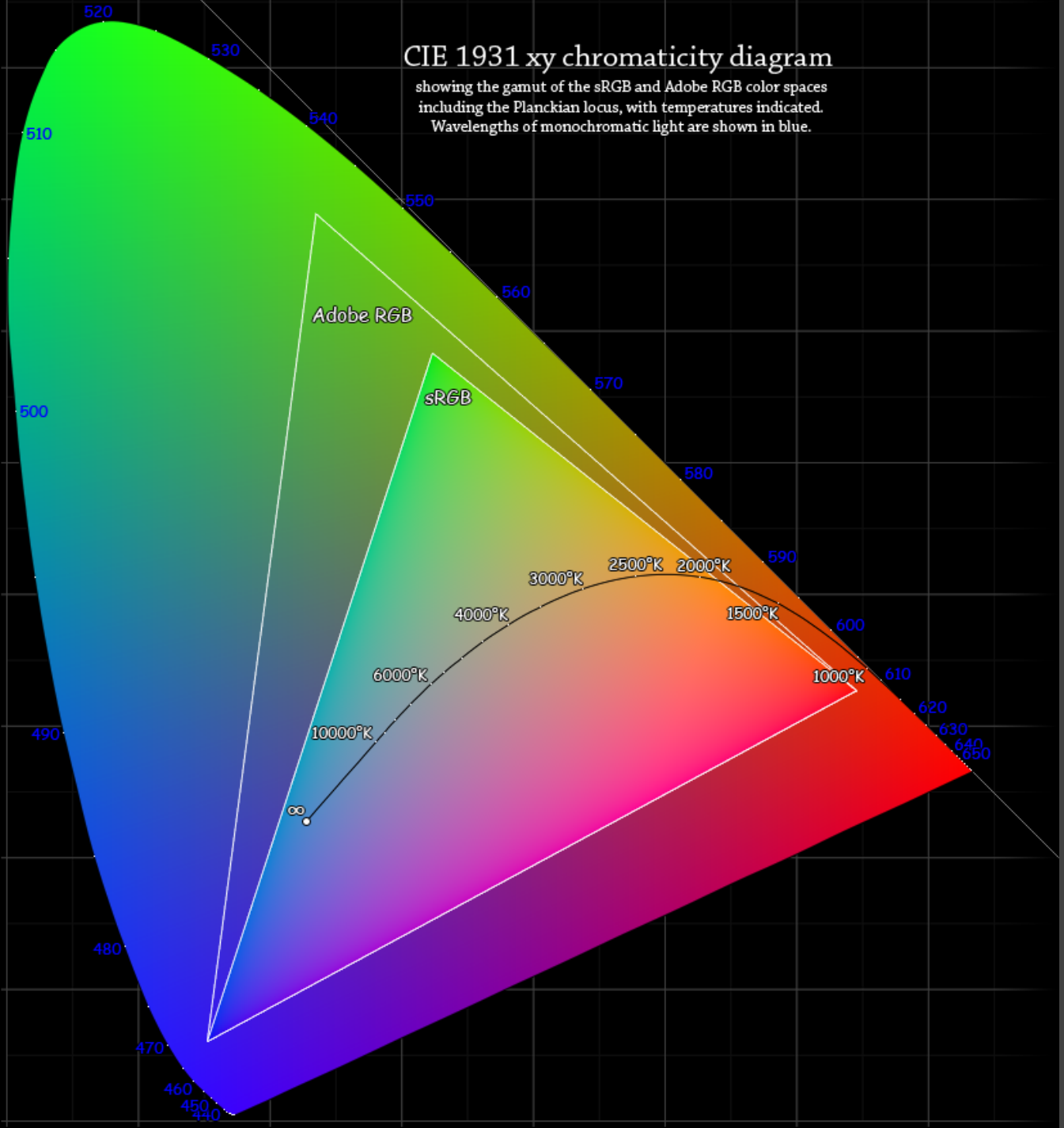


The psychophysics of sensory function [Stevens 61]

# Color

## CIE 1931 xy chromaticity diagram

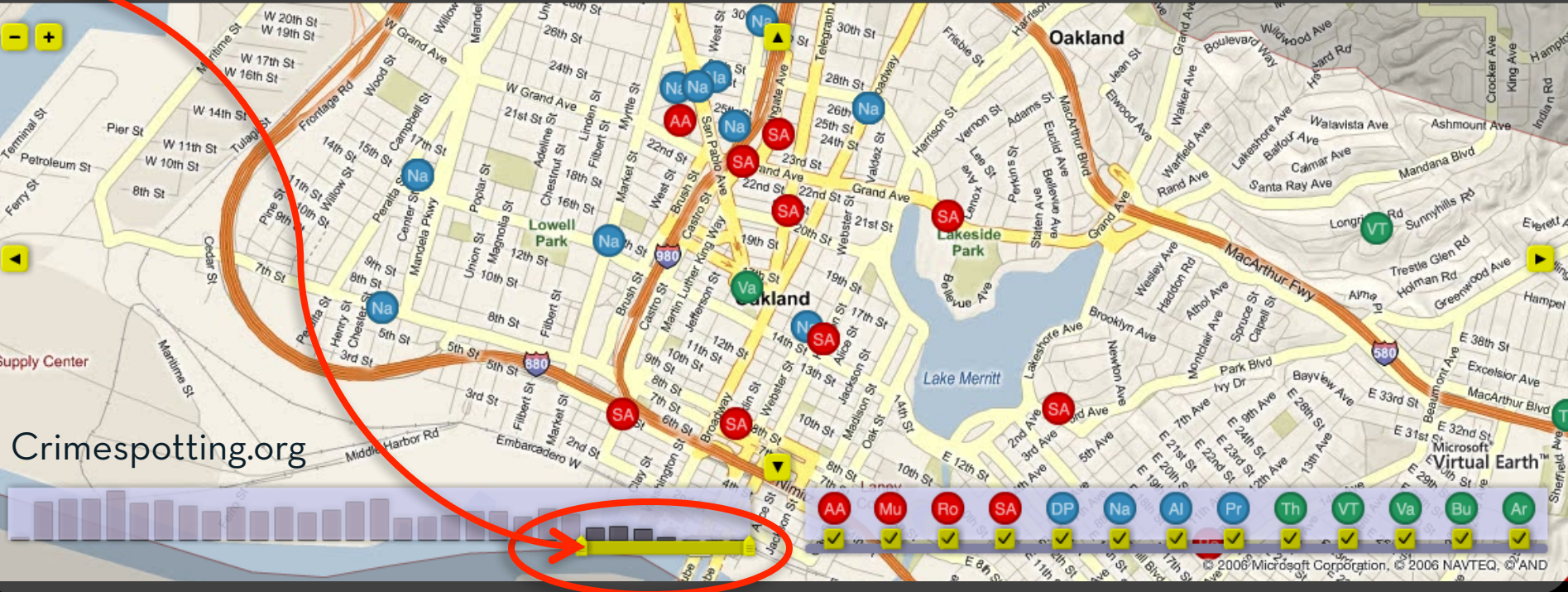
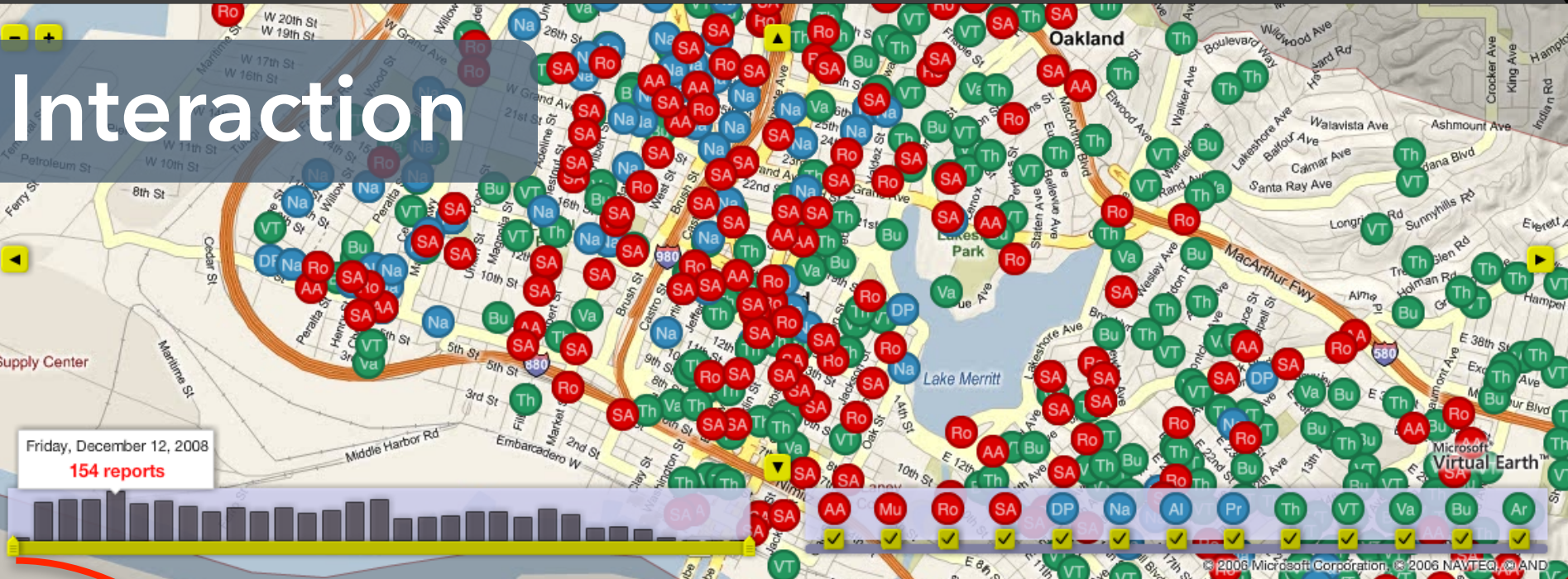
showing the gamut of the sRGB and Adobe RGB color spaces including the Planckian locus, with temperatures indicated. Wavelengths of monochromatic light are shown in blue.



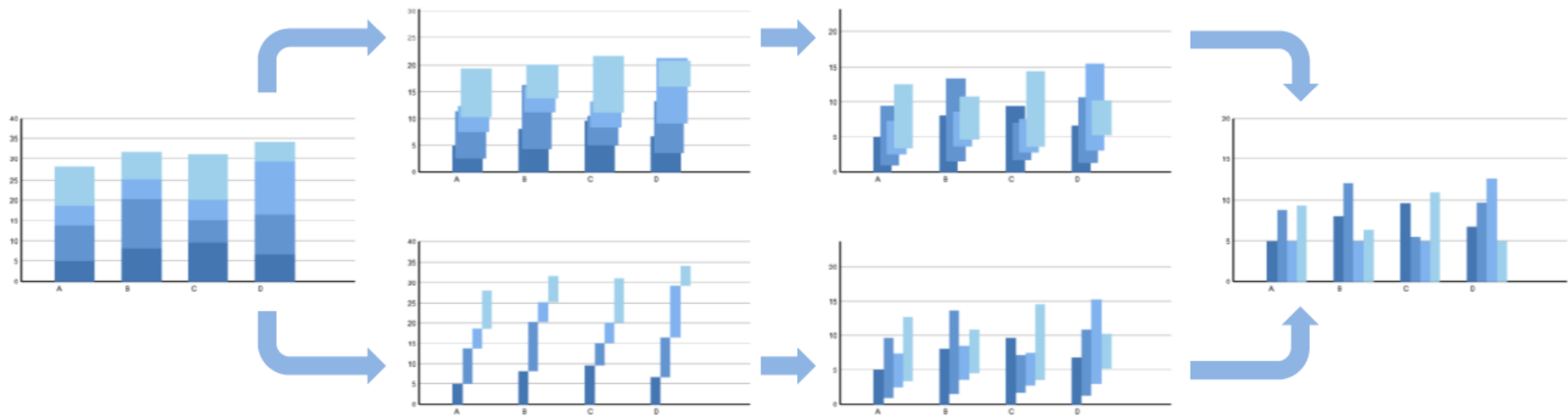
## Color Brewer



# Interaction



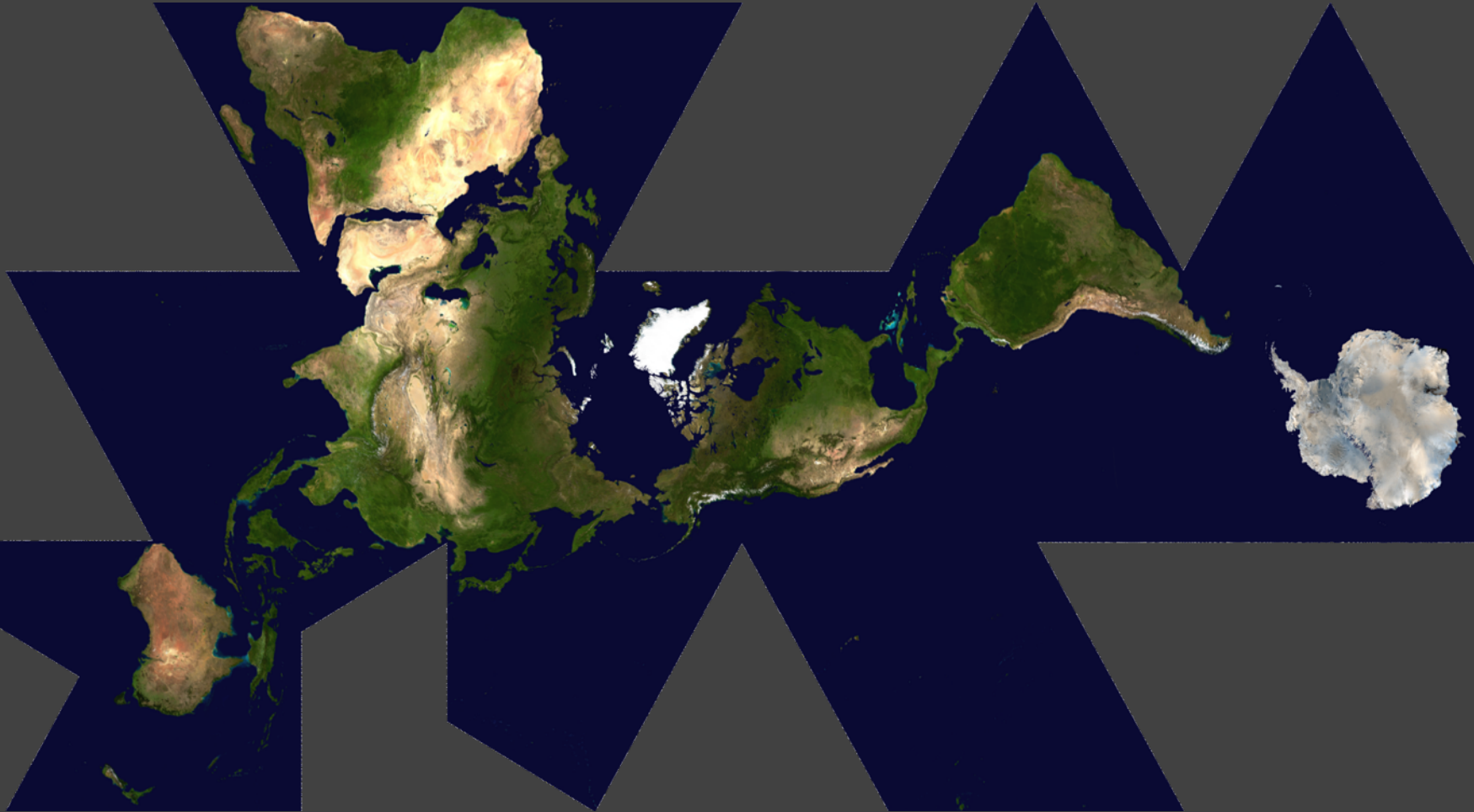
# Animation



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

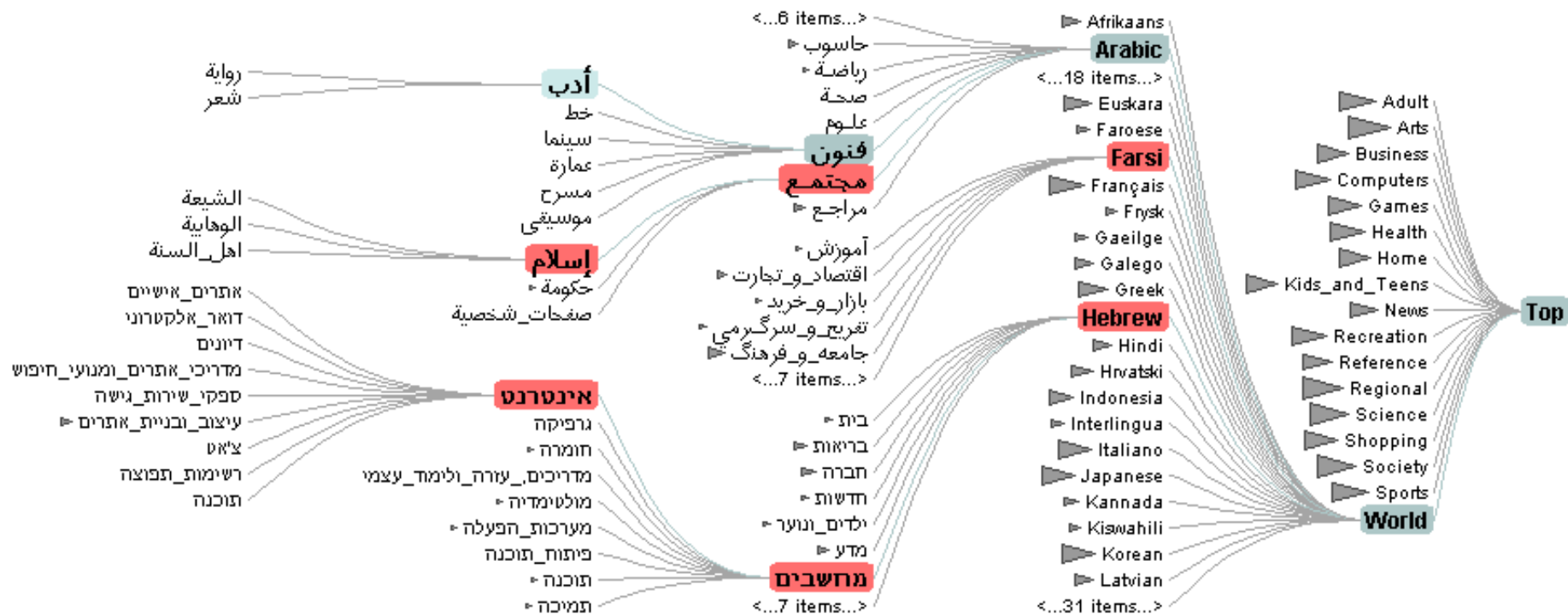


# Mapping & Cartography



Dymaxion Maps [Fuller 46]

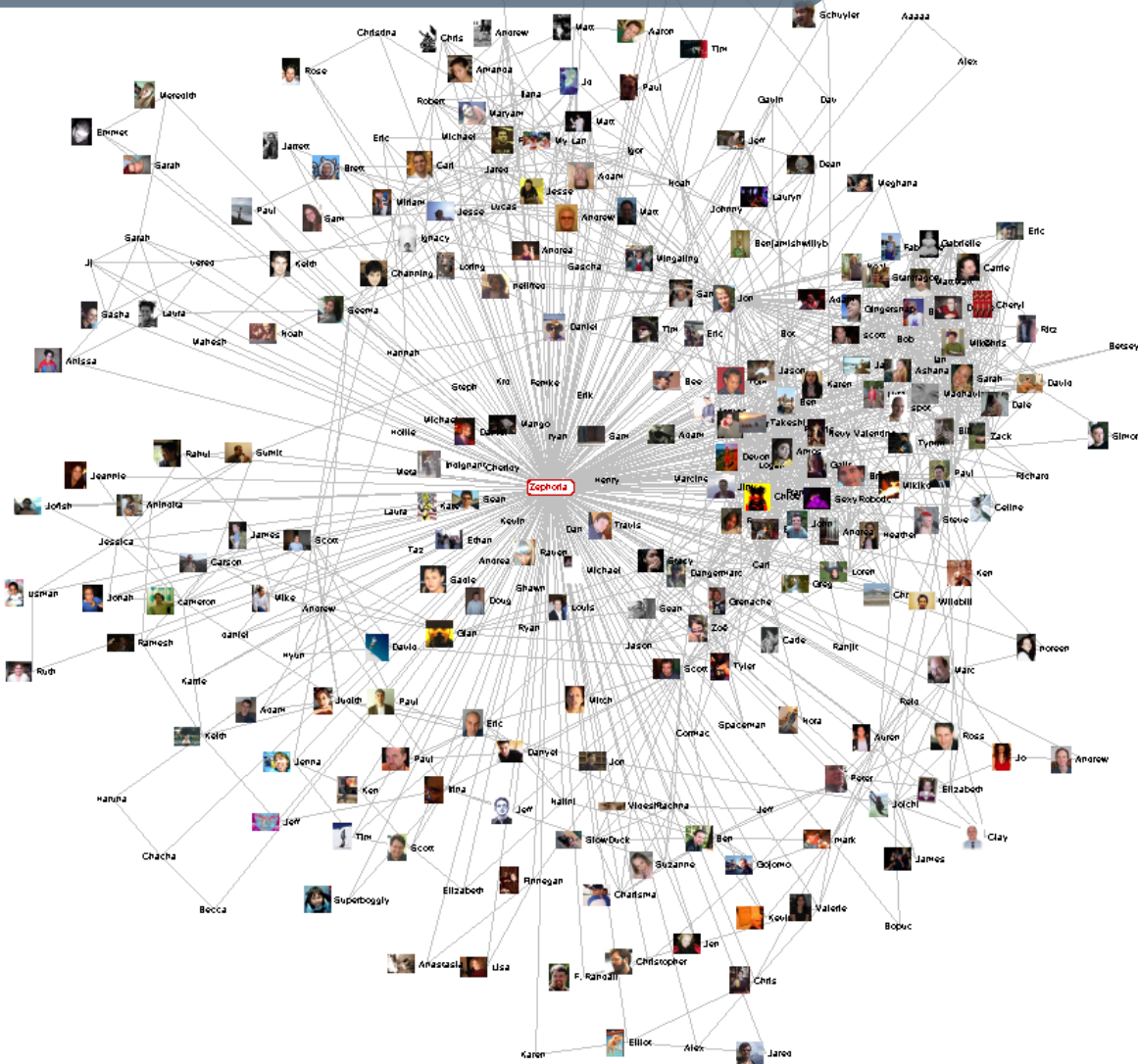
# Graphs and Trees



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



# Graphs and Trees



community >>

Enable

search >>

## Zephoria

User ID	21721
Friends	<input type="checkbox"/> 266
Age	??
Gender	<input type="checkbox"/> Female
Status	<input type="checkbox"/> 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
Music	psytrance/goa/trance [Infected Mushroom, Son Kite... Iboga/Digital Structures], Ani Difranco, downtempo, Thievery Corporation, Beth Orton, Morcheeba, Ween, White Stripes
Books	Authors: Erving Goffman, Stanley Milgram, Jeanette Winterson, Eric Schlosser, Leslie Feinberg, Dorothy Allison, Italo Calvino, Hermann Hesse
TV Shows	??
Movies	Koyaanisqatsi, Amelie, Waking Life, Tank Girl, The Matrix, Clockwork Orange, American Beauty, Fight Club, Boys Don't Cry
Member Since	??
Last Login	2003-10-21
Last Updated	2003-10-21
About	[Some know me as danah...]

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.

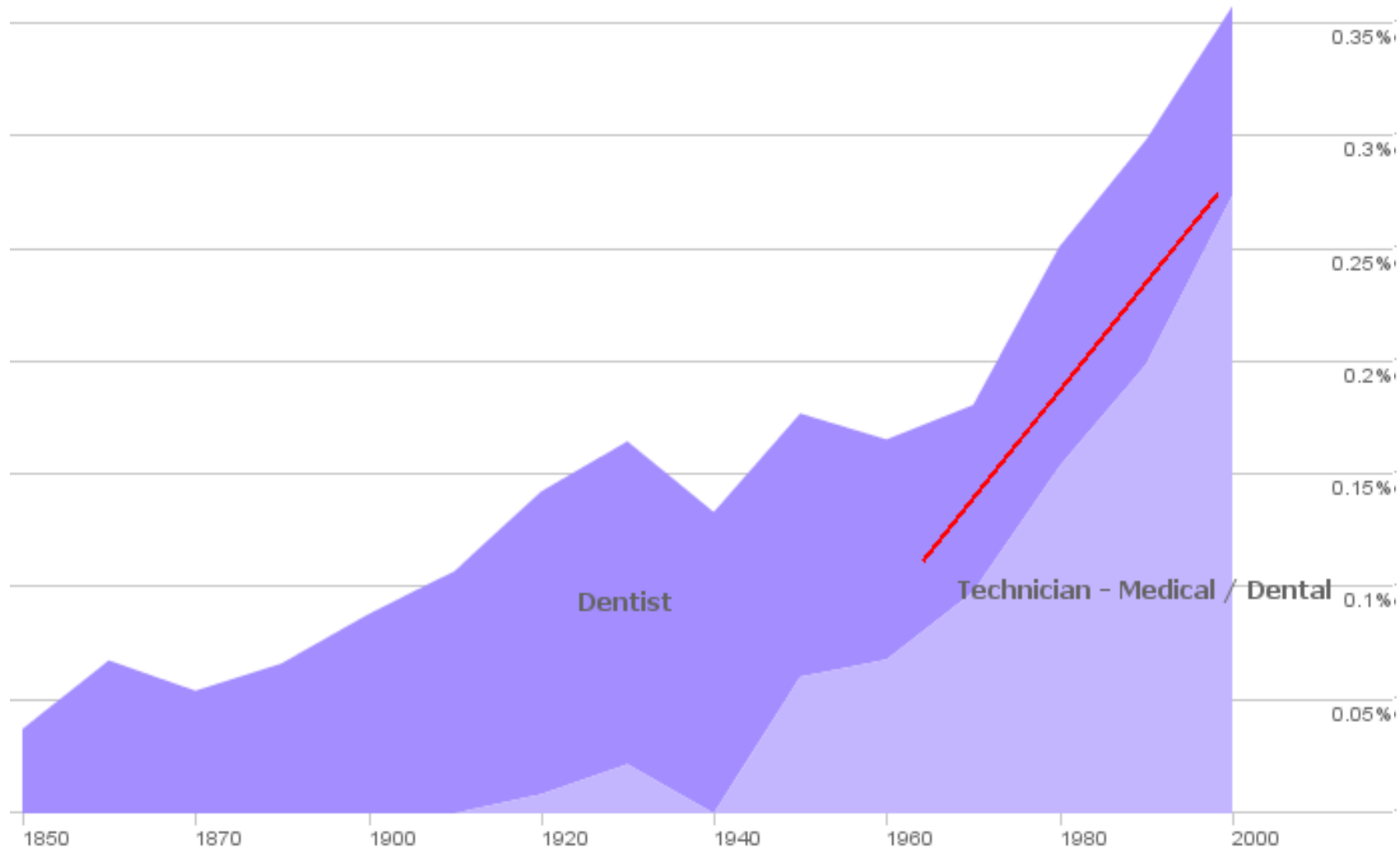
My musings:  
<http://www.zephoria.org/thoughts/>

Want to Meet  
Someone who makes life's complexities seem simply elegant.



# Collaboration and History

Where have all the dentists gone?



# Course Mechanics



# You should expect to:

- 1 *Evaluate and critique* visualization designs
- 2 *Implement* interactive data visualizations
- 3 *Gain* an overview of research & techniques
- 4 *Develop* a substantial visualization project

# Instructors

*cse512@cs*

## *Instructor*

**Jeffrey Heer**

Assoc Prof, CSE

OH: *Tue 2-3pm, 642 CSE*

<http://jheer.org>

## *Assistants*

**Michael Correll**

**Jane Hoffswell**

OH: *Mon 2-3pm, 278 CSE*

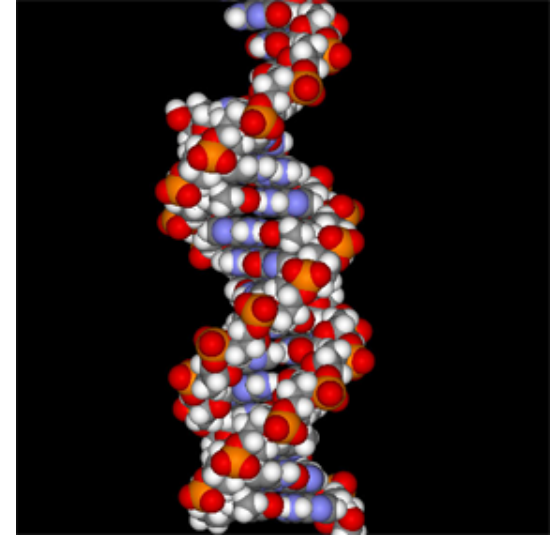
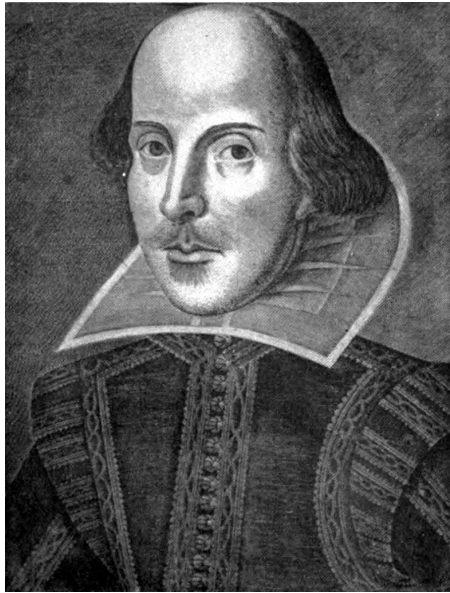
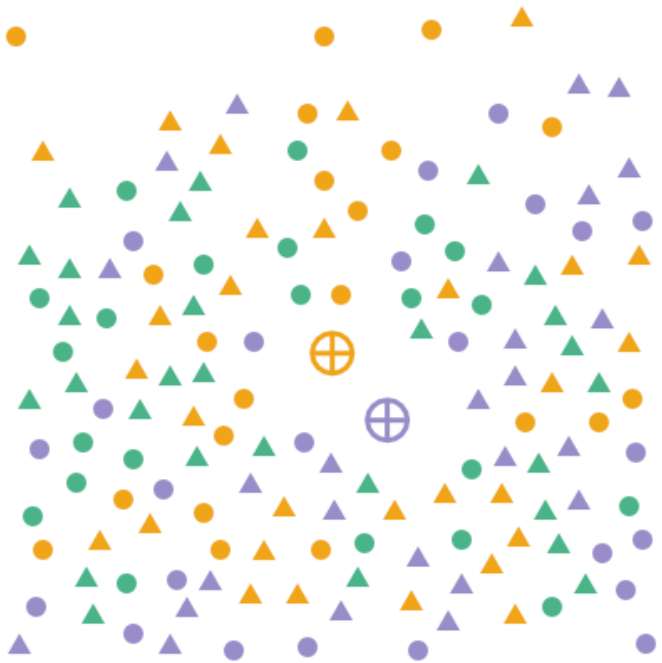
OH: *Fri 2-3pm, 218 CSE*

# Michael Correll

Office: CSE 278

Office Hours: Monday 2-3

# Michael Correll



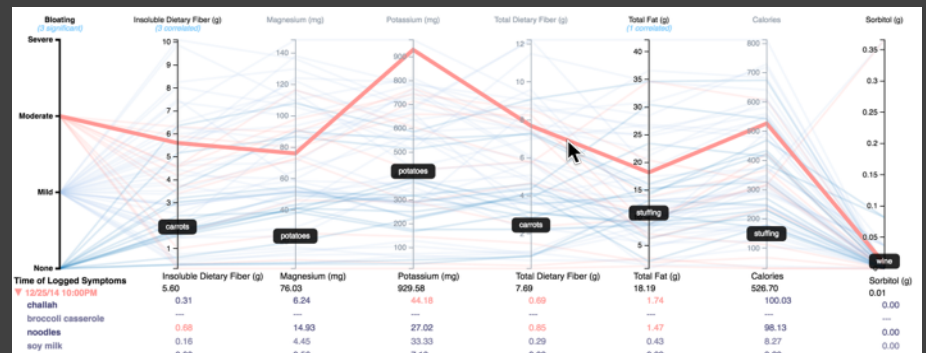
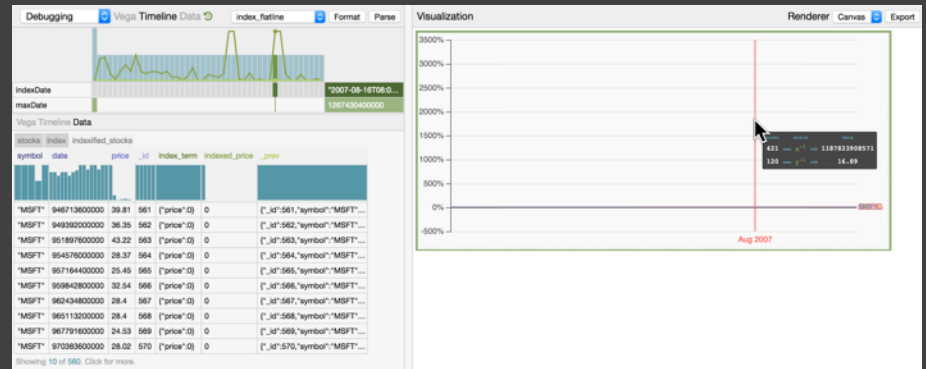
Office: CSE 278

Office Hours: Monday 2-3



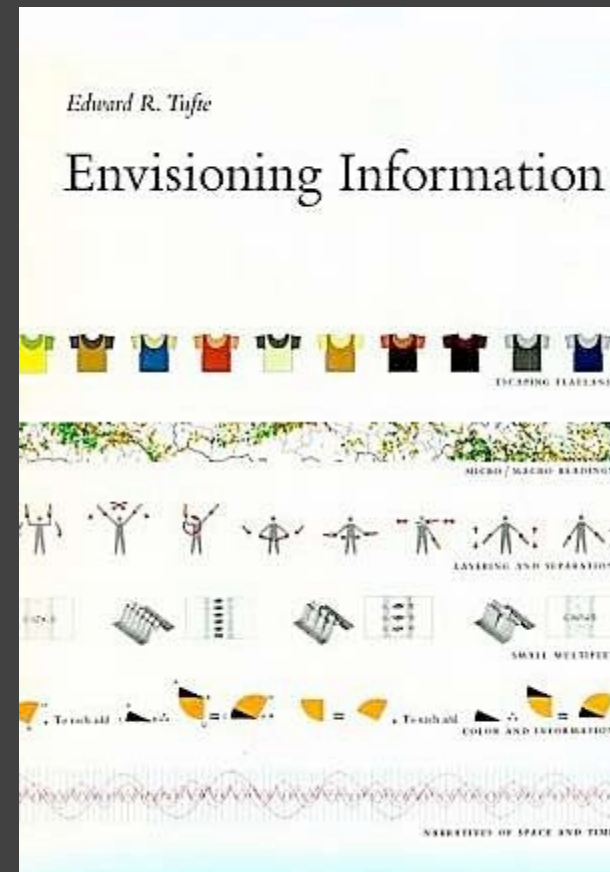
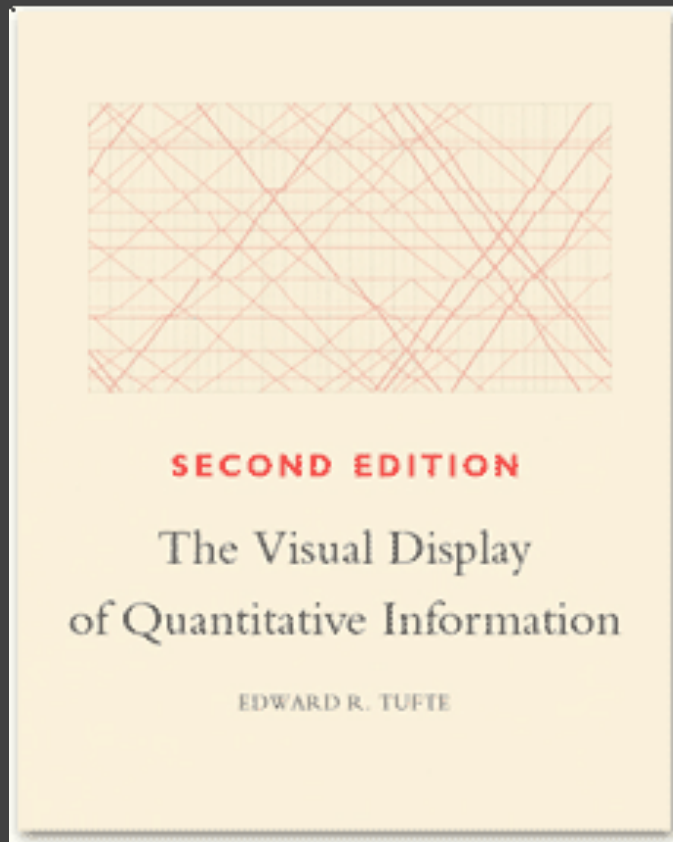
# Jane Hoffswell

OH: Fri 2-3pm CSE218



Graduated from Harvey Mudd College 2014  
2nd year PhD student working with Jeff Heer  
*Research interests: visualizing program behavior*

# Textbooks



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

# Readings

Some from textbooks, also many papers

Material in class will loosely follow readings

Readings should be read by start of class

Post discussion comments on class Canvas forum

Comments must be posted within 1 day of lecture

You have 2 "passes" for the quarter

# Assignments

Class Participation (10%)

A1: Visualization Design (10%)

A2: Exploratory Data Analysis (15%)

A3: Interactive Visualization Software (25%)

FP: Final Project (40%)



# Final Project

**Visualization research project** on topic of choice

Project write-up in form of a **short research paper**

Project **check-ins** and **final poster/demo show**

Projects from **previous classes** have been:

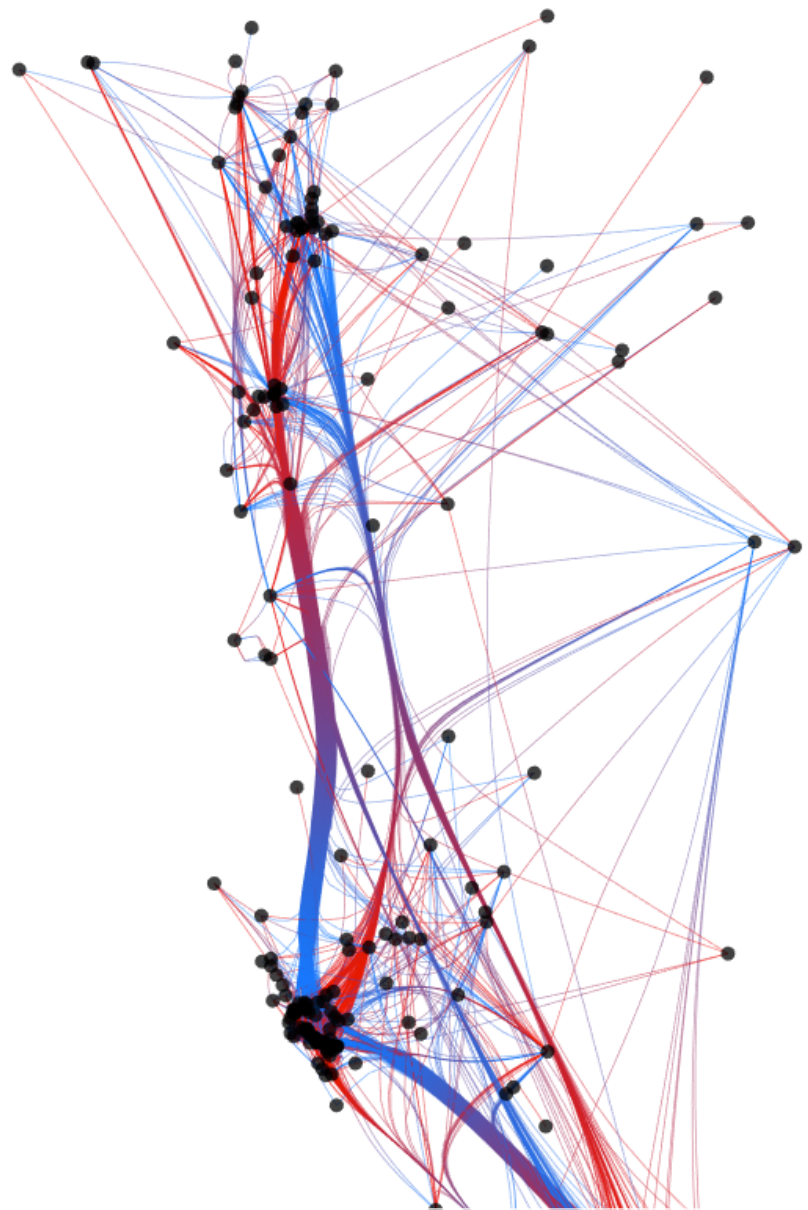
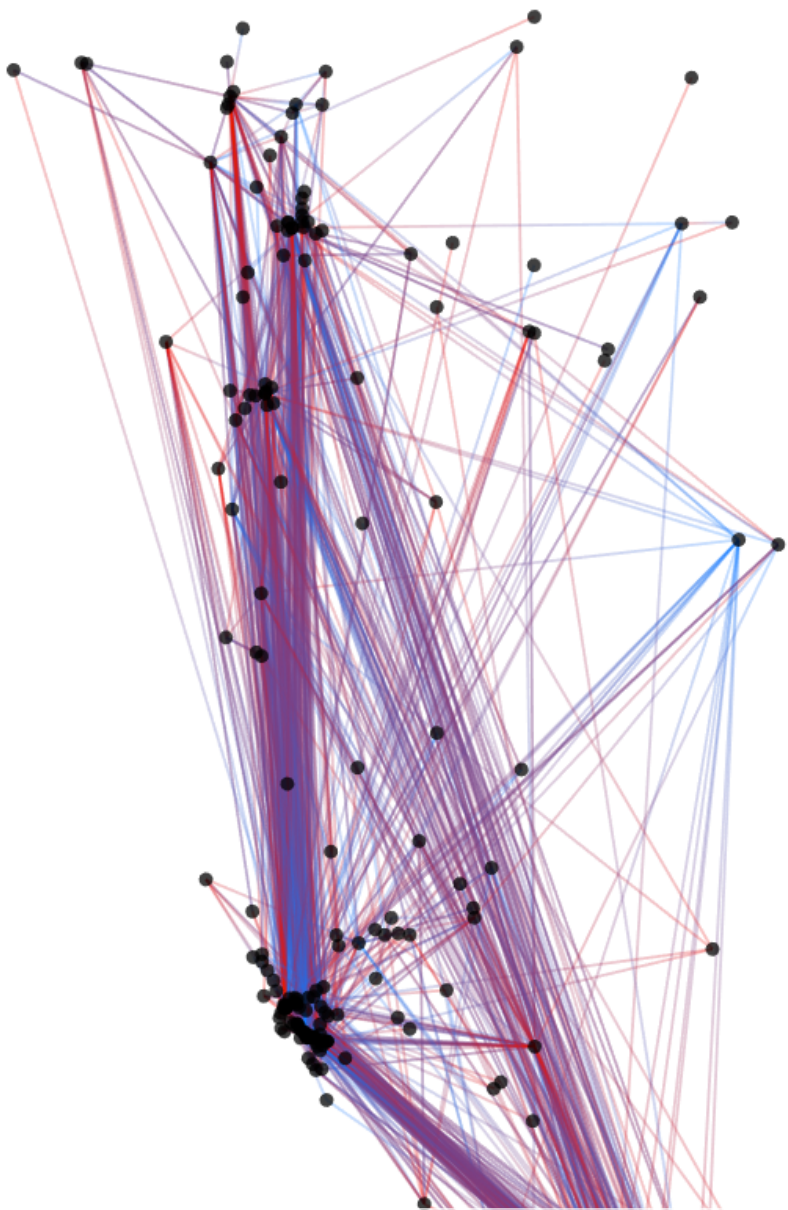
- Published (e.g., at the IEEE InfoVis conference)
- Featured in the New York Times
- Released as successful open source projects



# RunMonster

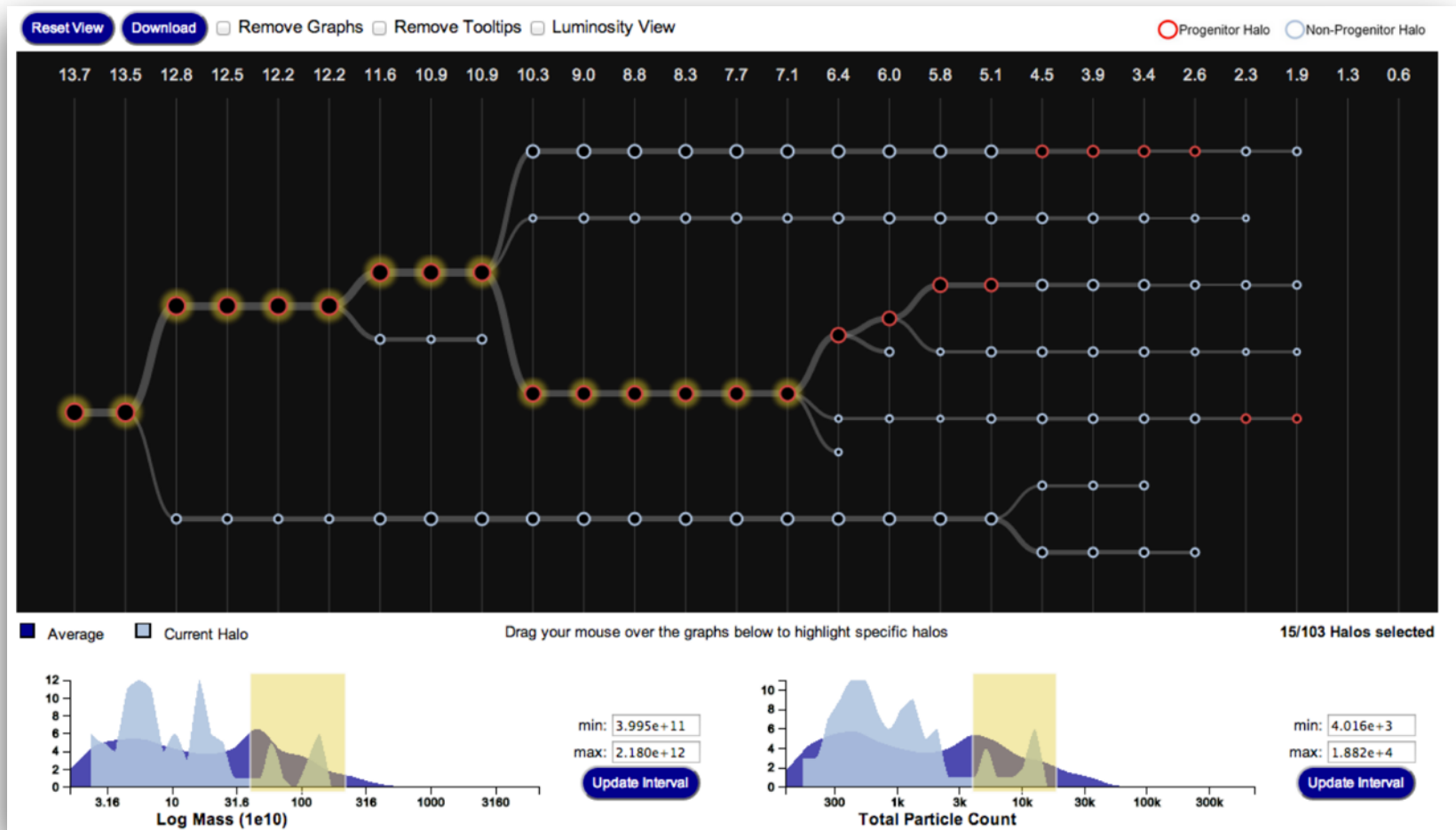
Troy Brant & Steve Marmon





**Divided Edge Bundling** – David Selassie

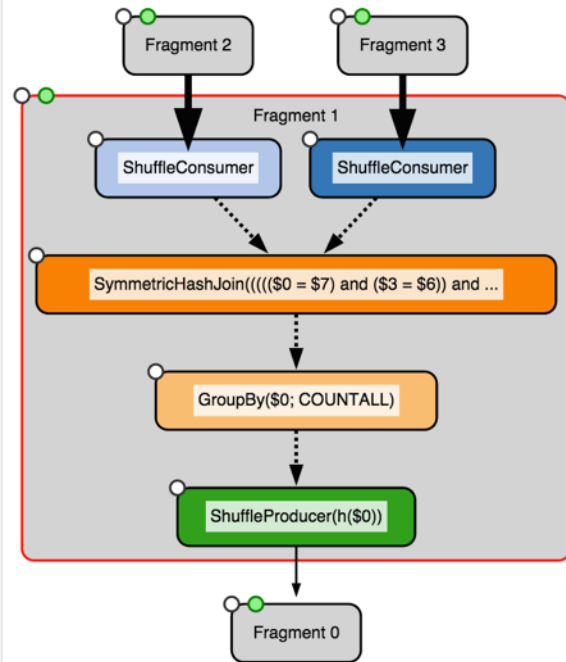
# Visualizing Galaxy Merger Trees



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

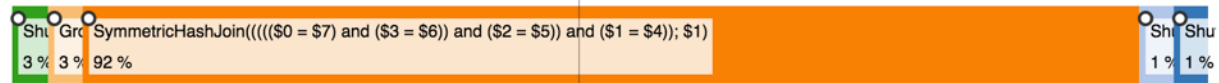
# Perfopticon Distributed Query Performance

Physical Query Plan:

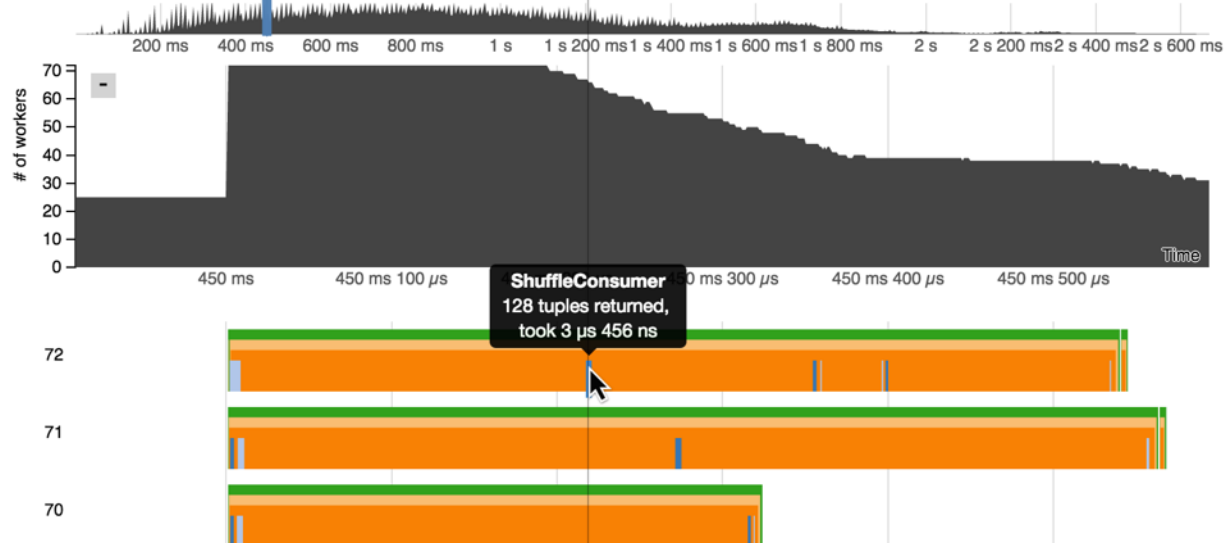


Overview / Operators inside fragment 1

Query time contribution collapse/expand



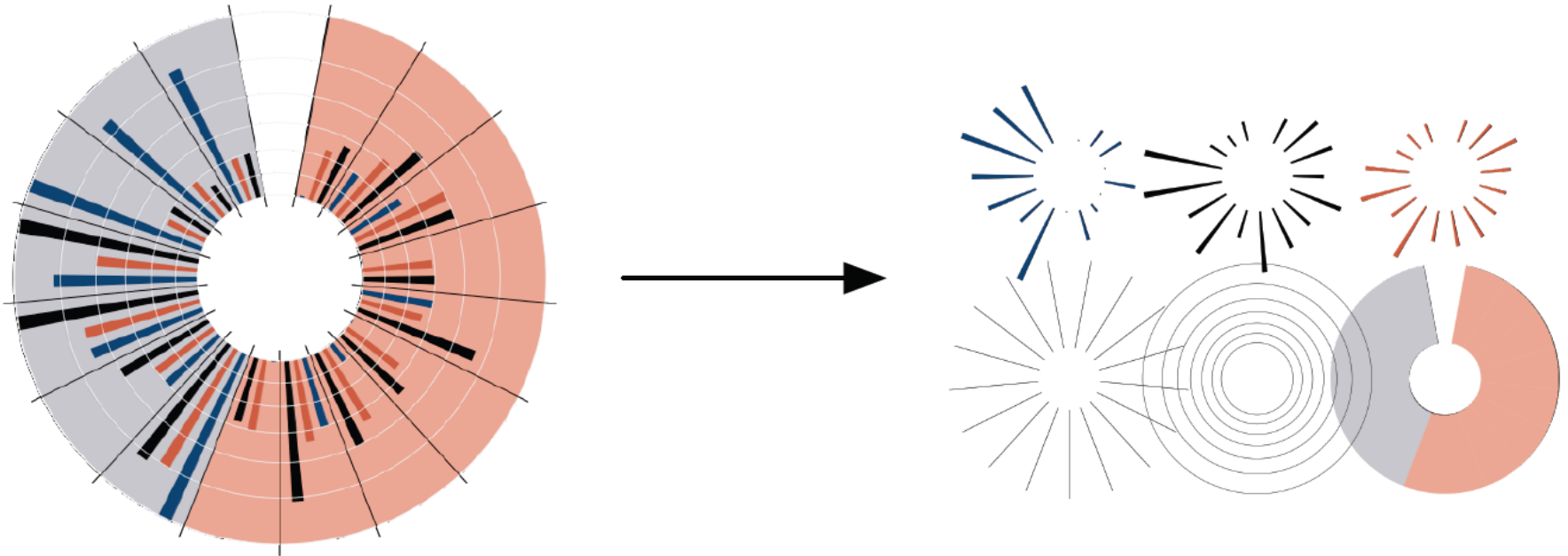
Detailed execution

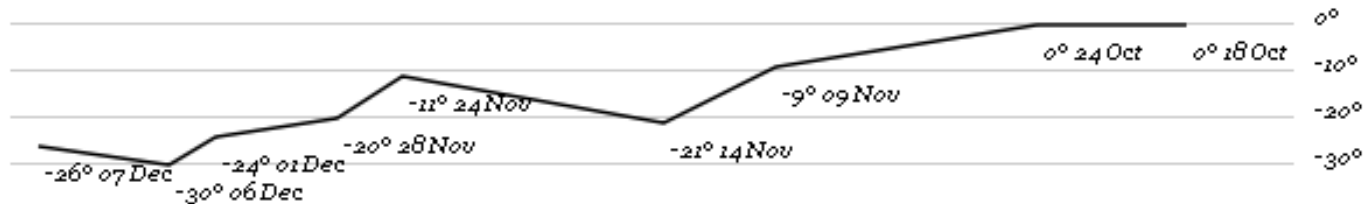
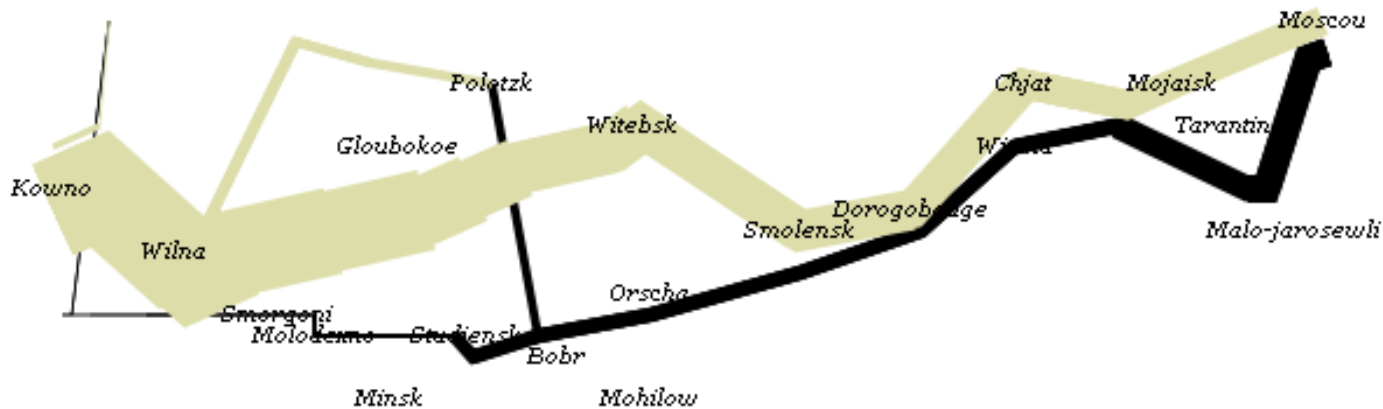




# Protovis: A Graphical Toolkit for Visualization

**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))
  .textBaseline("top").font("italic 10px Georgia");

```

# Visualizing the Republic of Letters

Daniel Chang, Yuankai Ge, Shiwei Song

## Republic of Letters

1700



## 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



**Questions?**

# Assignment 1: Visualization Design

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

College admissions can play a profound role in determining one's future life and career. We've collected admissions data (grouped by gender) for selected departments at a major university.

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



# Assignment 1: 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 **5:00 pm, Monday April 4.**