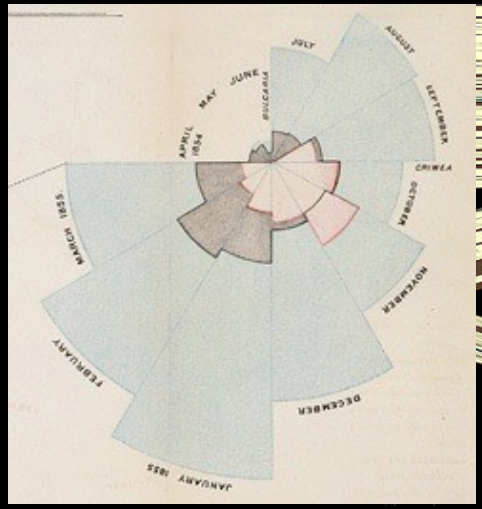
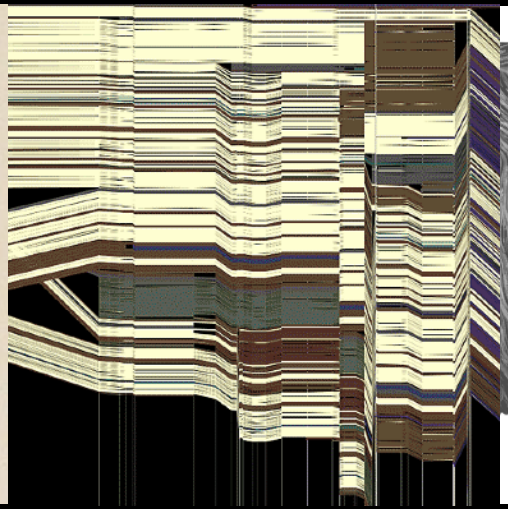
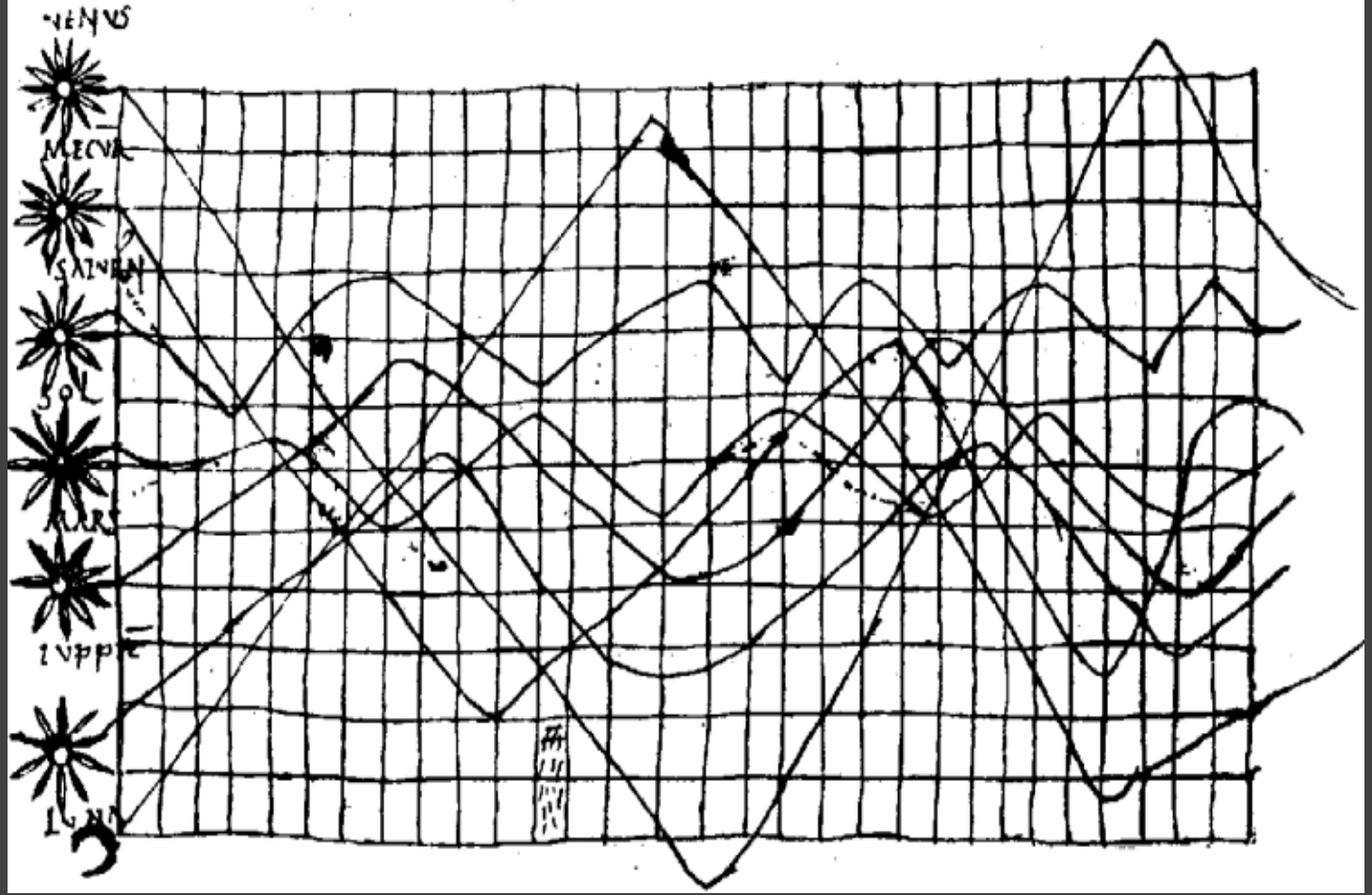
CSE 512 - Data Visualization

Introduction

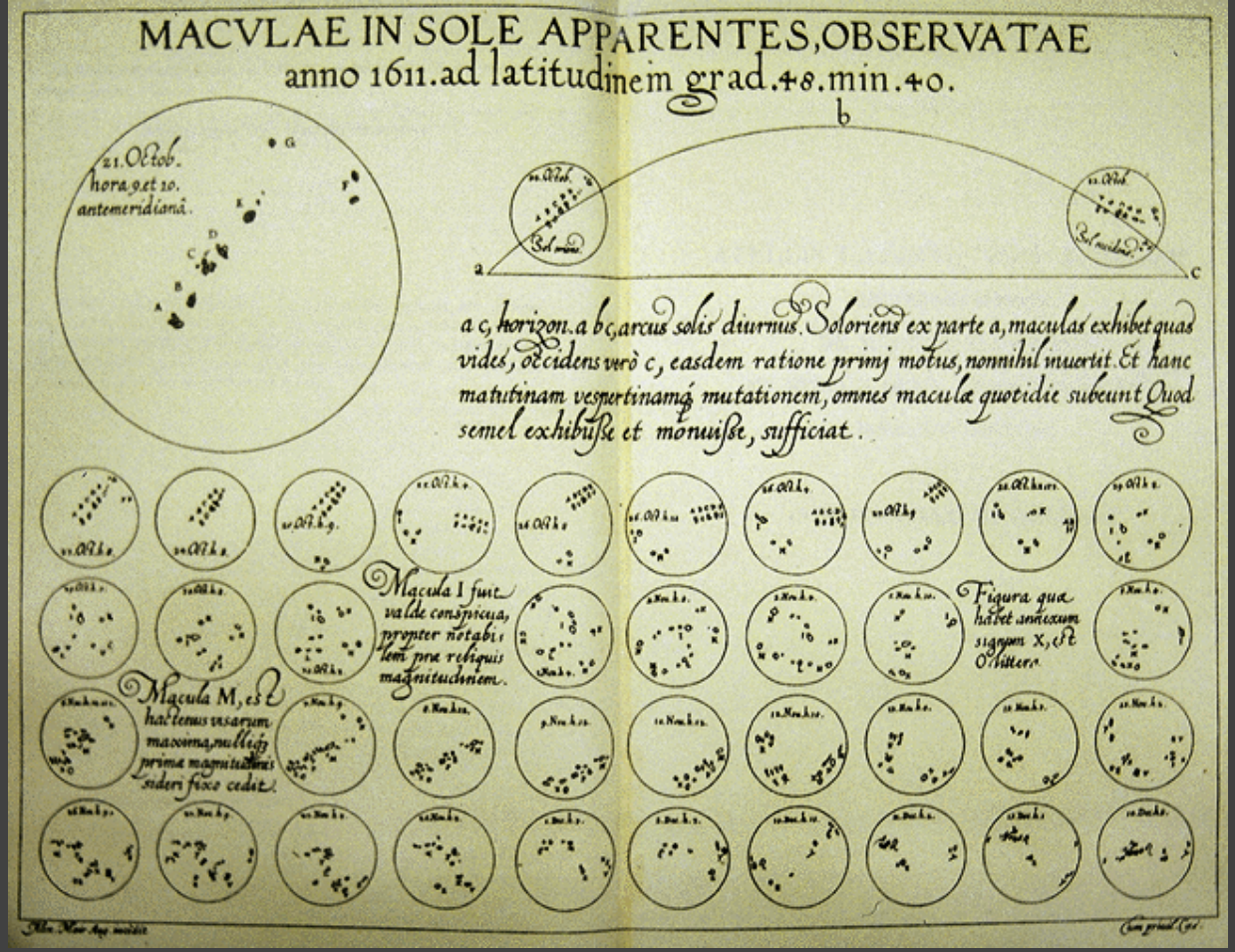




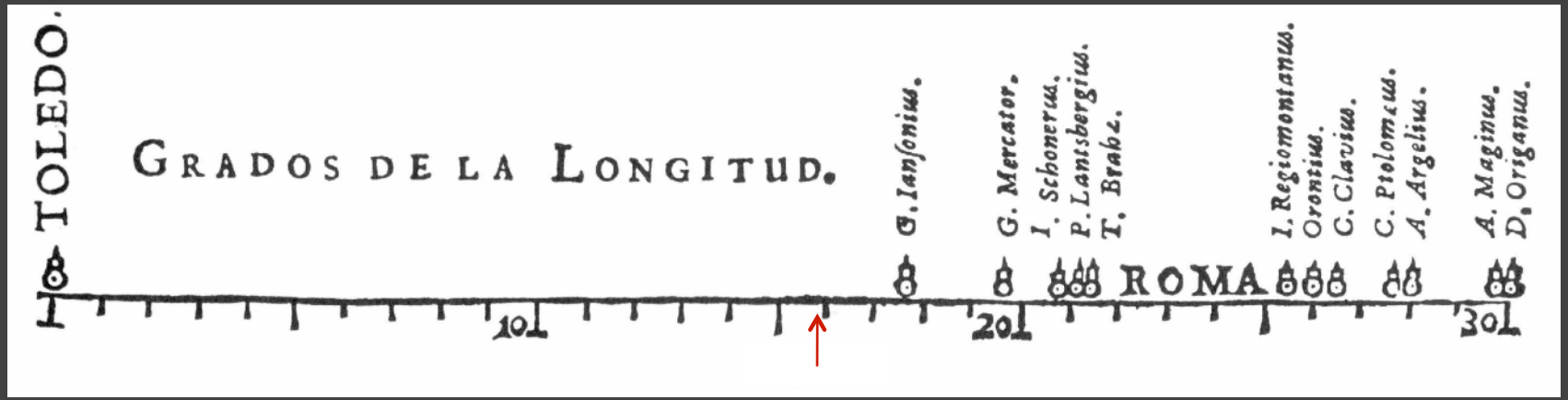
Jeffrey Heer University of Washington



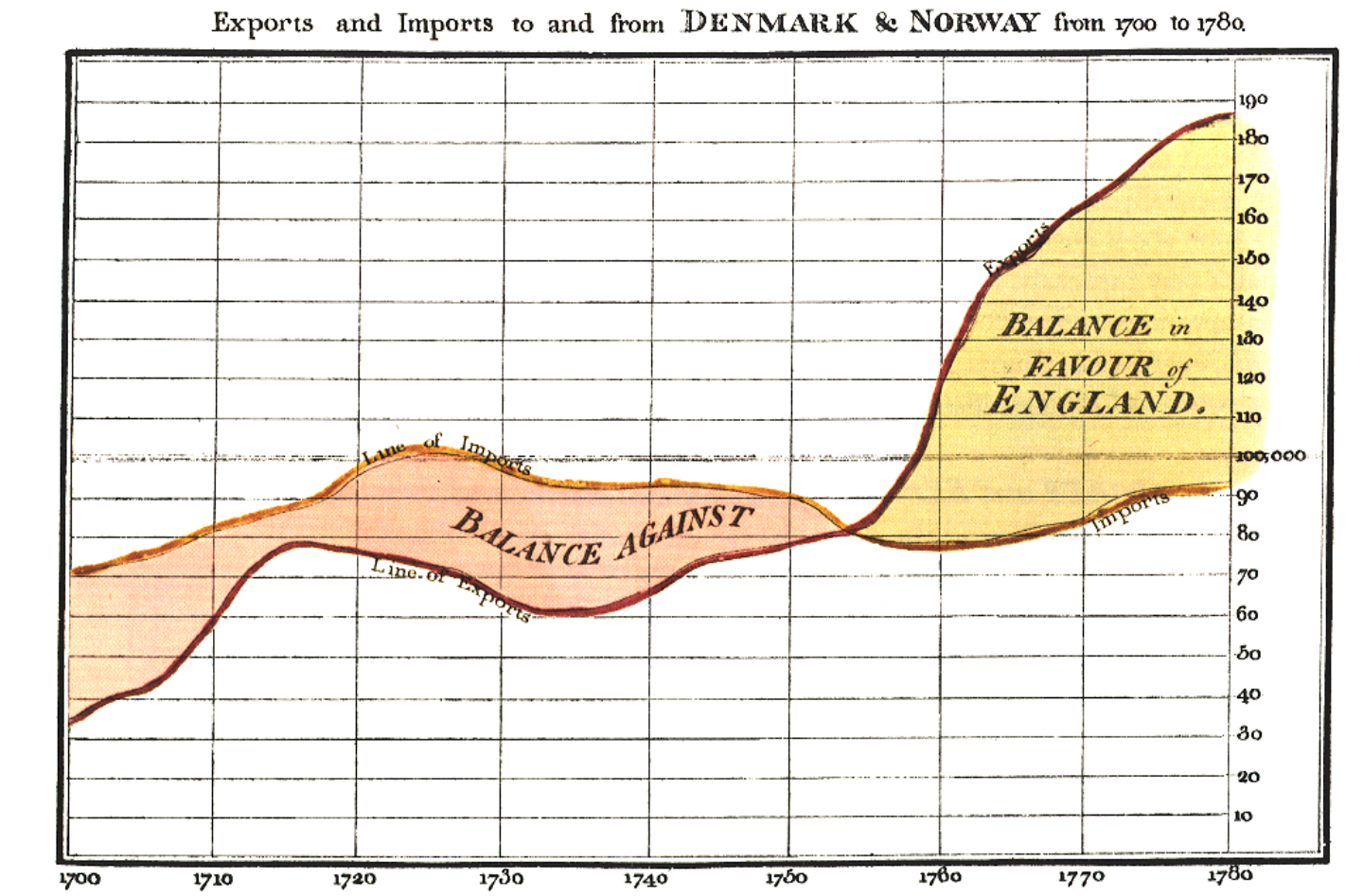
~950 AD Position of Sun, Moon and Planets



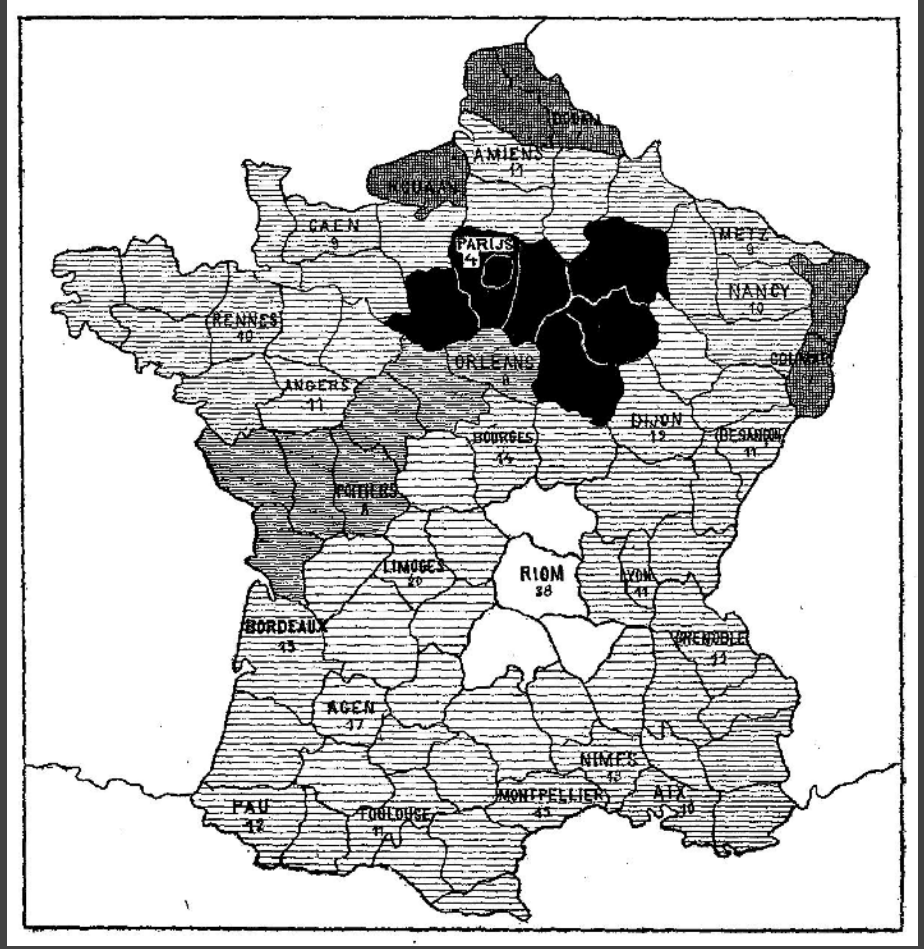
Sunspots over time, Scheiner 1626



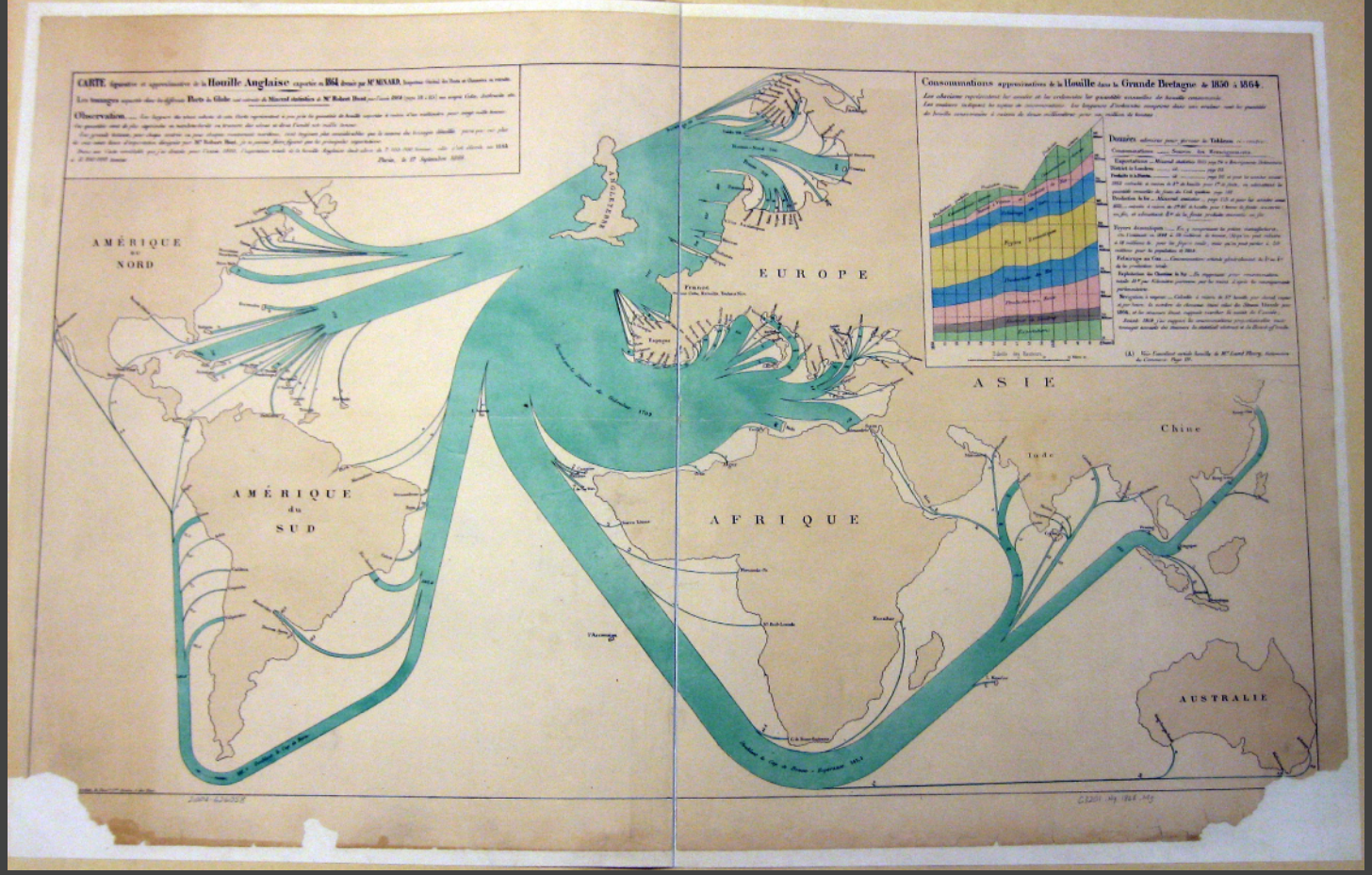
Longitudinal distance between Toledo and Rome, van Langren 1644



The Commercial and Political Atlas, William Playfair 1786



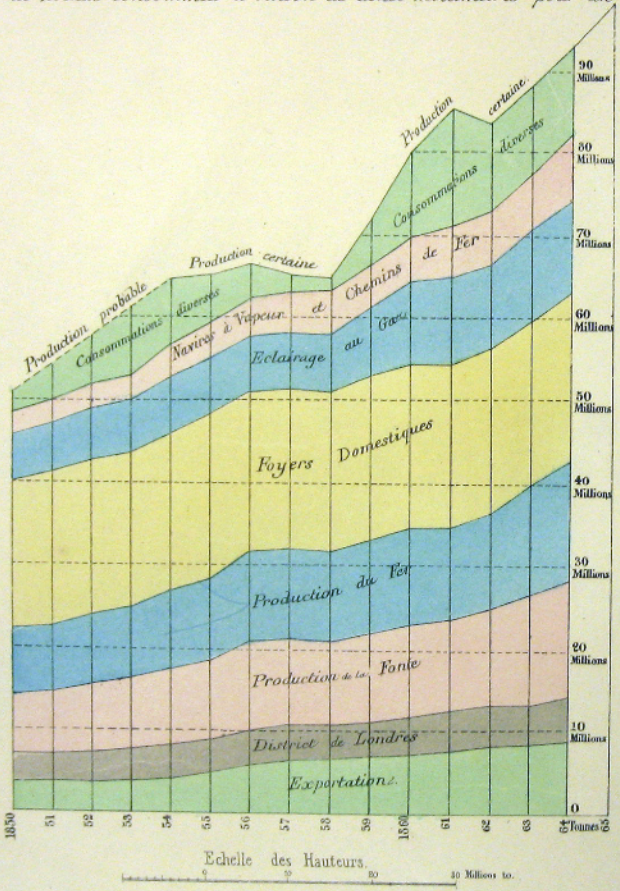
1826(?) Illiteracy in France, Pierre Charles Dupin



1864 British Coal Exports, Charles Minard

Consommations approximatives de la Houille dans la Grande Bretagne de 1850 à 1864.

Les abscisses représentent les années et les ordonnées les quantités annuelles de houille consommée.
Les couleurs indiquent les espèces de consommations. Les longueurs d'ordonnées comprises dans une couleur sont les quantités de houille consommées à raison de deux millimètres pour un million de tonnes.



Données admises pour former le Tableau ci-contre.

Consommations. — Sources des Renseignements.

Exportations. — *Mineral statistics 1865 page 214 et Renseignements Parlementaires.*

District de Londres. — *id.* — *page 213*

Produits de la Fonte. — *id* — *page 215 et pour les années avant 1855 calculée à raison de 3 to de houille pour 1 to de fonte, en admettant les quantités annuelles de fonte du* Coal question *page 192.*

Production du fer — *Mineral statistics — page 215 et pour les années avant 1855 — calculée à raison de 3 to 35 de houille pour 1 tonne de fonte convertie en fer, et admettant 9/10 de la fonte produite convertis en fer.*

Foyers domestiques. — *En y comprenant les petites manufactures.*

On l'estimait en 1848 à 19 millions de tonnes, (A) qu'on peut réduire à 18 millions to. pour les foyers seuls, mais qu'on peut porter à 20 millions pour la population de 1864.

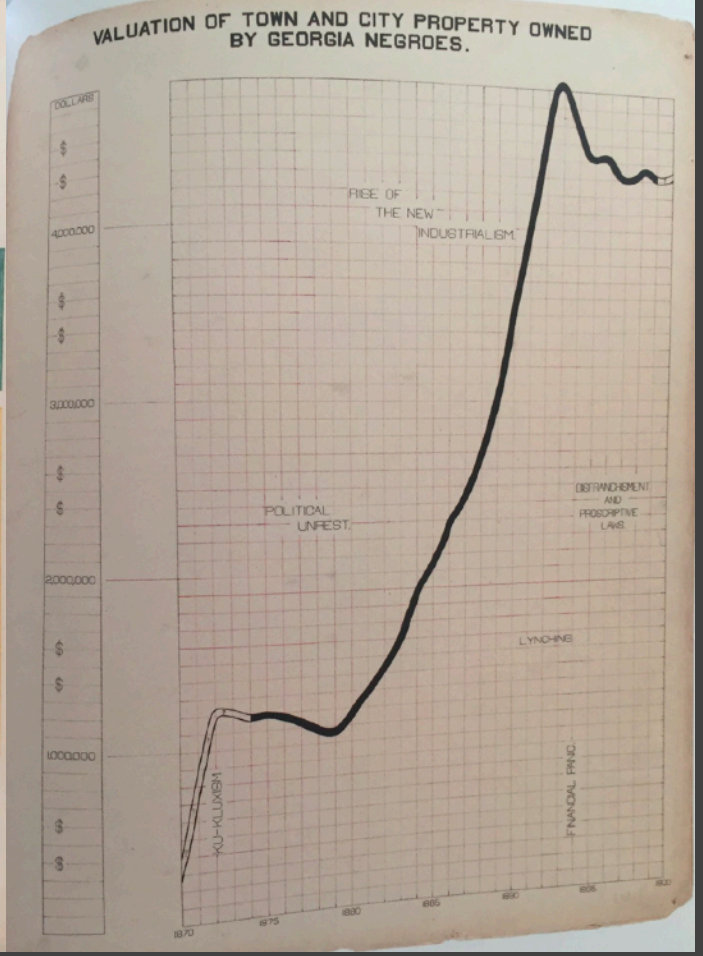
Eclairage au Gaz. — *Consommation estimée généralement du 1/9 au 1/8 de la production totale.*

Exploitation des Chemins de Fer. — *En supposant pour consommation totale 10 par Kilomètre parcouru par les trains d'après les renseignements parlementaires.*

Navigation à vapeur. — *Calculée à raison de 5 houille par cheval vapeur et par heure, le nombre de chevaux étant celui du Steam Vessels pour 1864, et les steamers étant supposés marcher la moitié de l'année;*

Avant 1864 j'ai supposé les consommations proportionnelles aux tonnages annuels des steamers du statistical abstract et du Board of trade.

(A) *Voir l'excellent article houille de M. Lamé Fleury, Dictionnaire du Commerce Page 111.*



1900 Visualizing Black America , W. E. B. DuBois et al.

Entering the 1900s…

Rise of **formal statistical methods** in the physical and social sciences

Little innovation in graphical methods

A period of **application and popularization**

Graphical methods enter textbooks, curricula, and **mainstream use**

Four major influences act on data analysis today:

1. The formal theories of statistics.
2. Accelerating developments in computers and display devices.
3. The challenge, in many fields, of more and larger bodies of data.
4. The emphasis on quantification in a wider variety of disciplines.

Data Analysis & Statistics, Tukey & Wilk 1966

While some of the influences of statistical theory on data analysis have been helpful, others have not.

Data Analysis & Statistics, Tukey & Wilk 1966

Exposure, the effective laying open of the data to **display the unanticipated**, is to us a major portion of data analysis…

It is not clear how the **informality** and **flexibility** appropriate to the **exploratory character** of exposure can be fitted into any of the structures of formal statistics so far proposed.

Data Analysis & Statistics, Tukey & Wilk 1966

Accordingly, both approaches and techniques need to be structured so as to **facilitate human involvement and intervention**.

Some implications for effective analysis are: (1) it is essential to have convenience of **interaction of people and intermediate results** and (2) at all stages of data analysis, the outputs need to be **matched to the capabilities of the people who use it and want it.**

Data Analysis & Statistics, Tukey & Wilk 1966

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

$u_X = 9.0$ $\sigma_X = 3.317$

$u_Y = 7.5$ $\sigma_Y = 2.03$

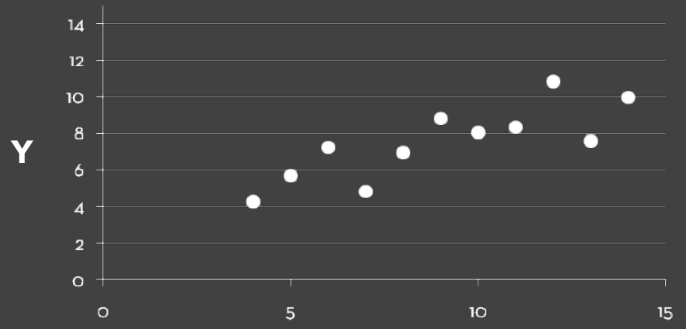
Linear Regression

$Y = 3 + 0.5\ X$

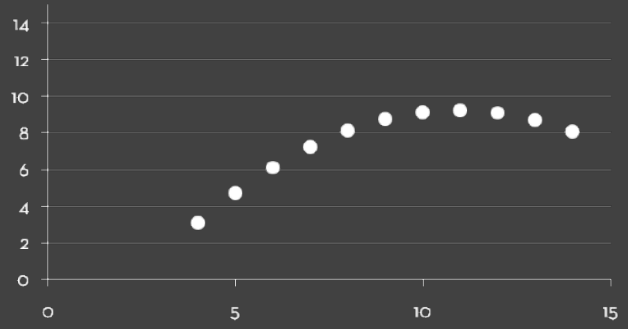
$R^2 = 0.67$

[Anscombe 1973]

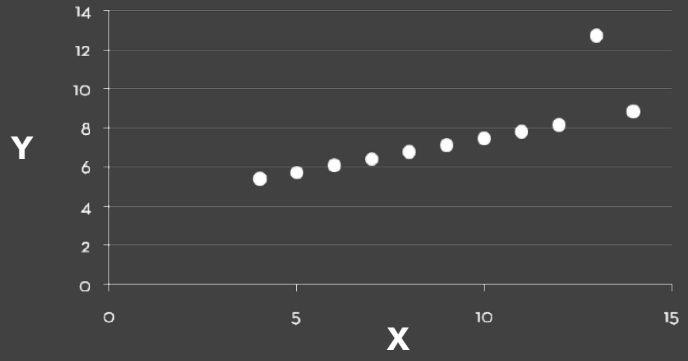
Set A



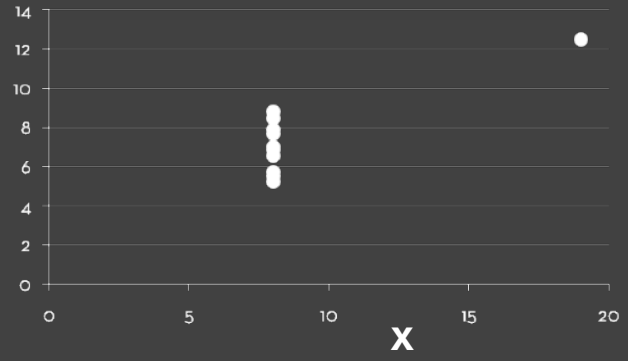
Set B



Set C



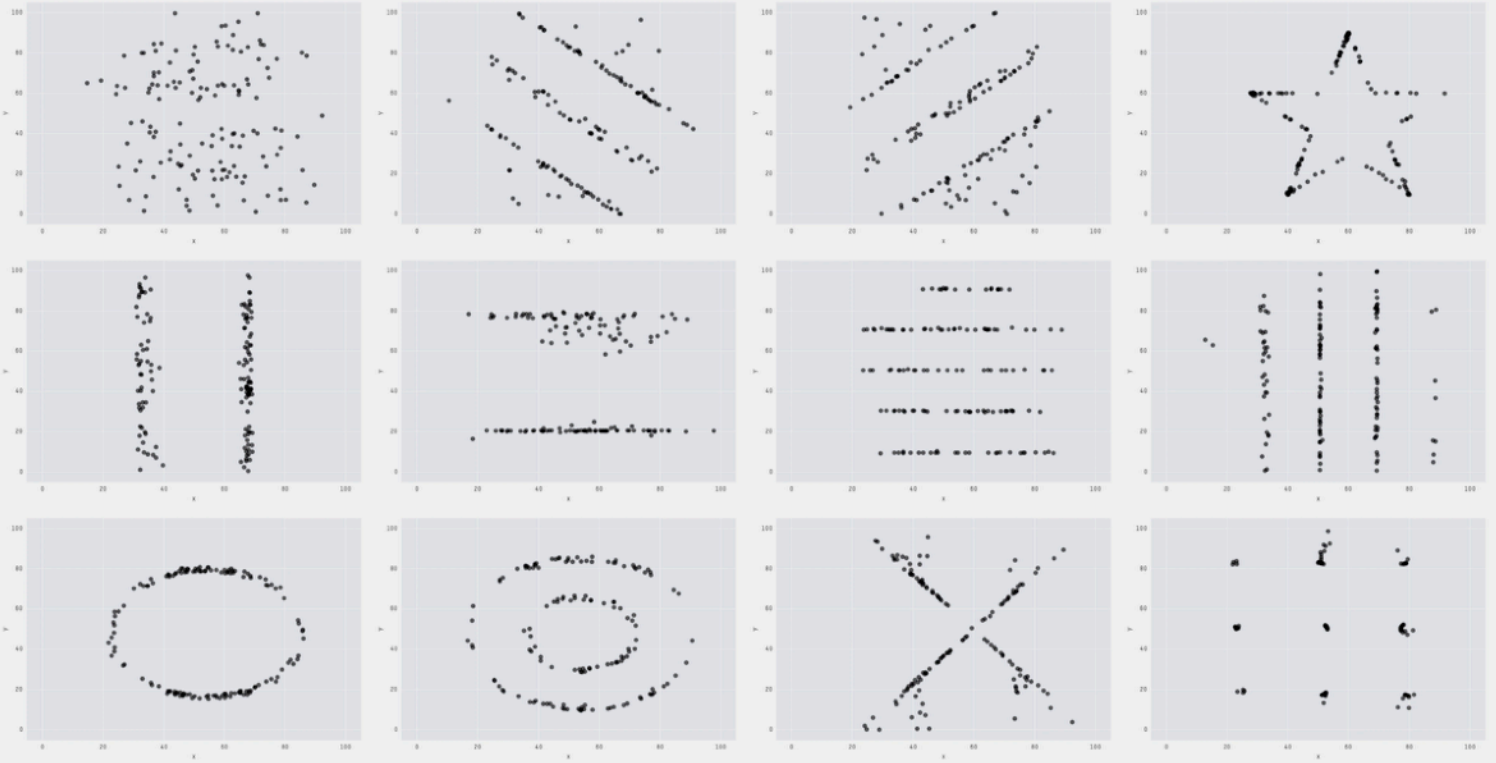
Set D



[Anscombe 1973]

X Mean: 54.26
Y Mean: 47.83
X SD : 16.76
Y SD : 26.93
Corr. : -0.06

[Matejka 2017]



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]

Goals of Visualization Research

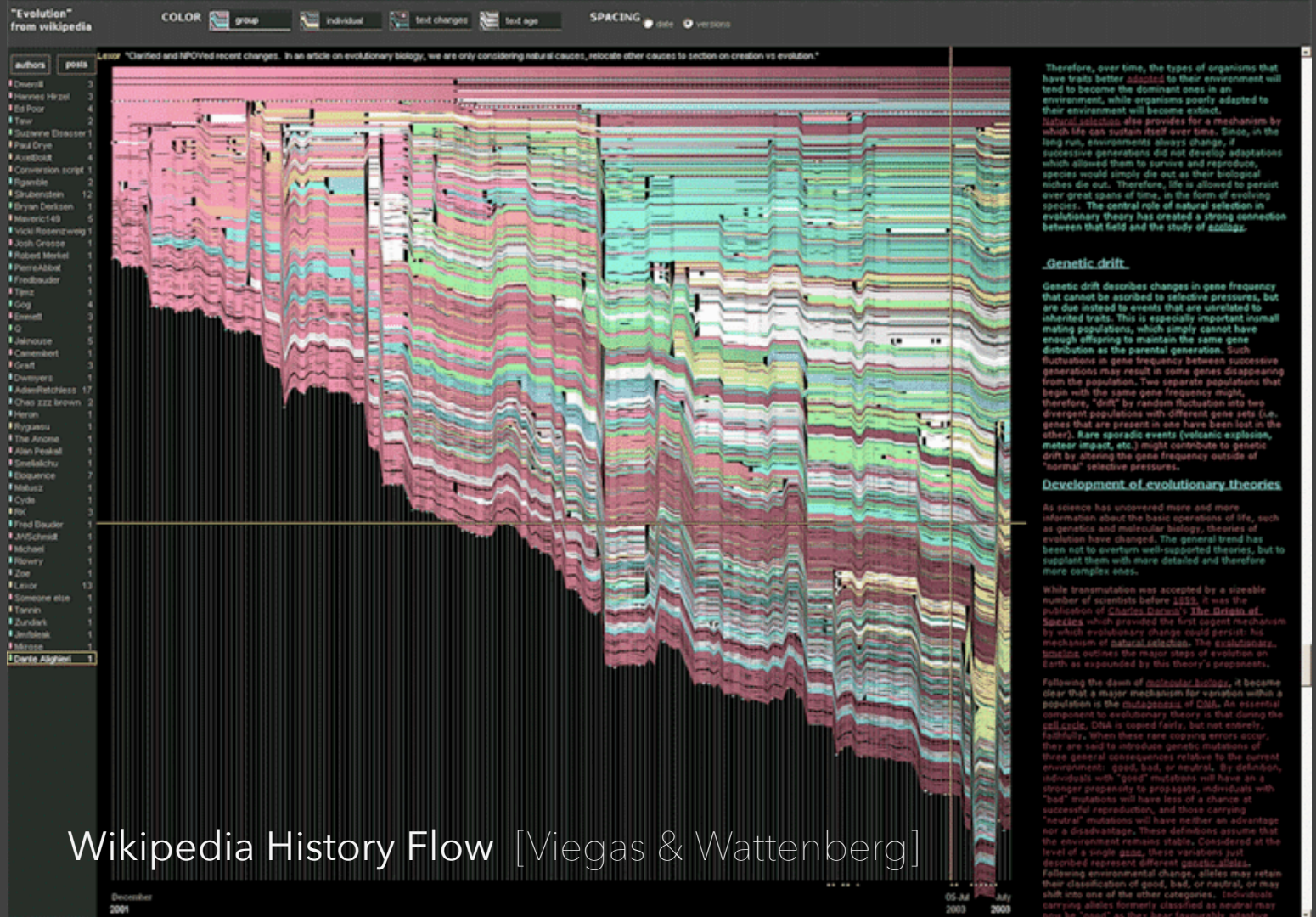
1 **Understand** how visualizations convey information

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

Example:
Wikipedia Edits

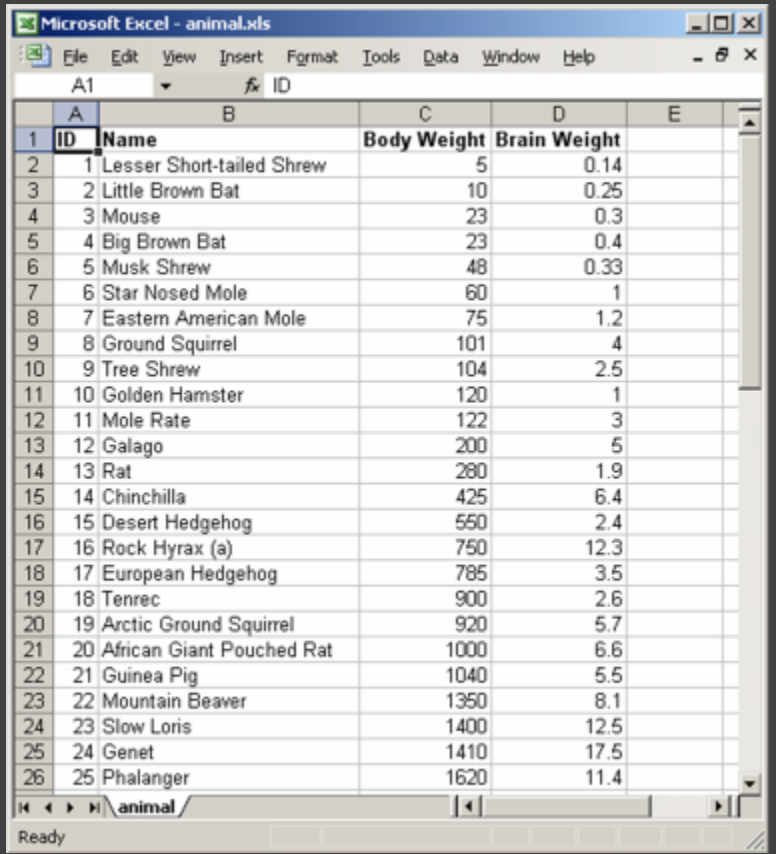


Wikipedia History Flow [Viegas & Wattenberg]

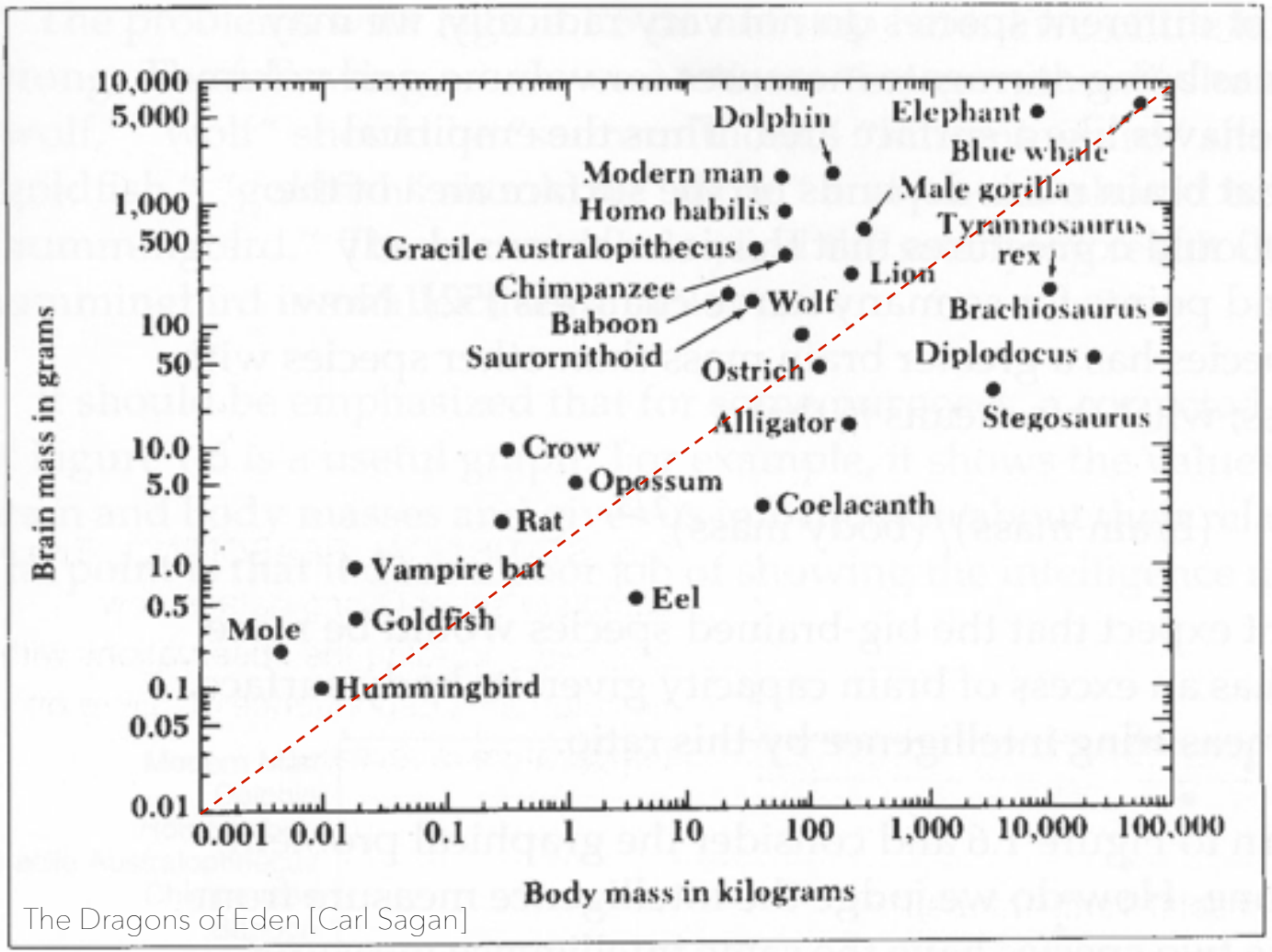
Wikipedia History Flow [Viegas & Wattenberg]

Example:
Animal Brains

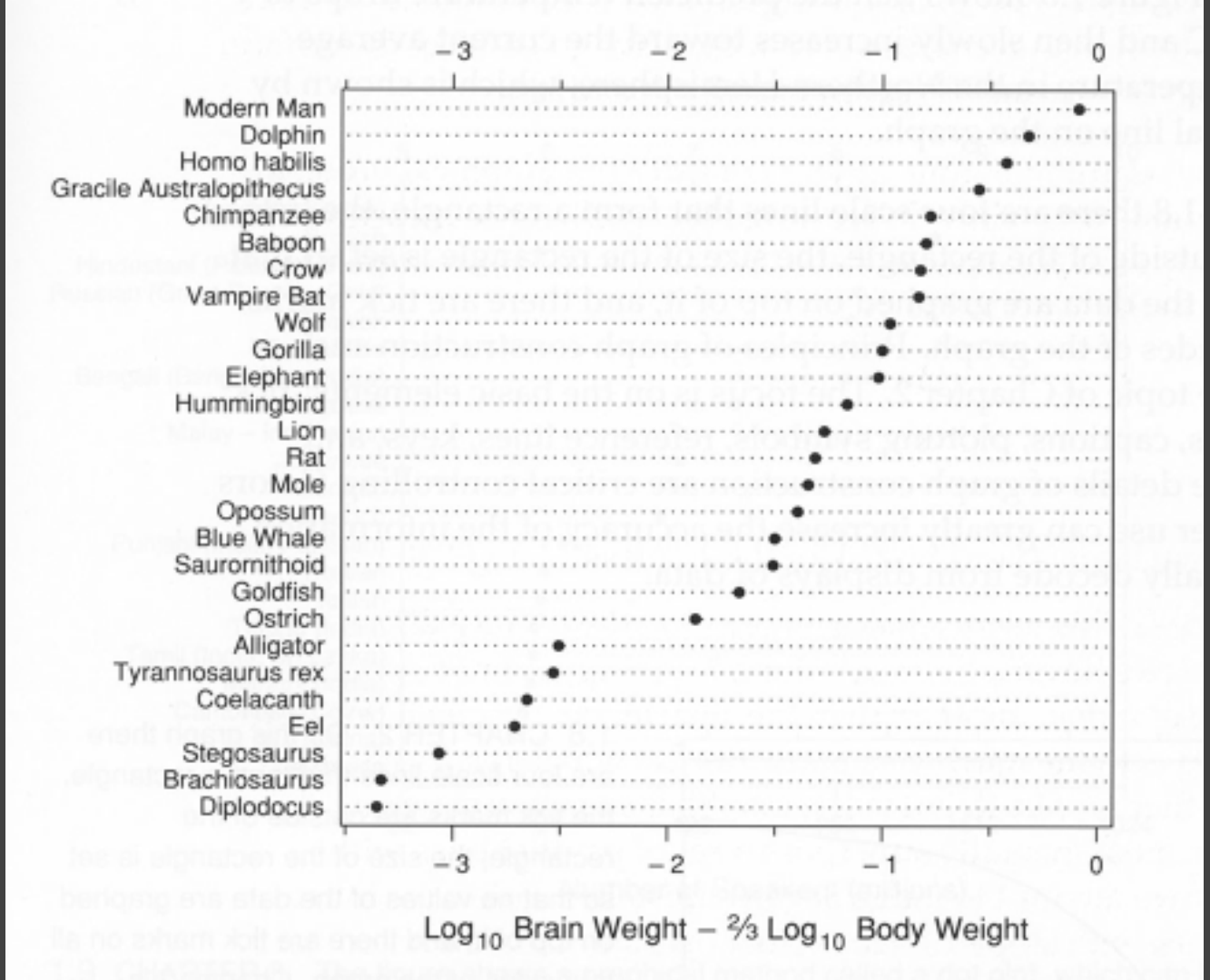
Which animals are the “smartest”?



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

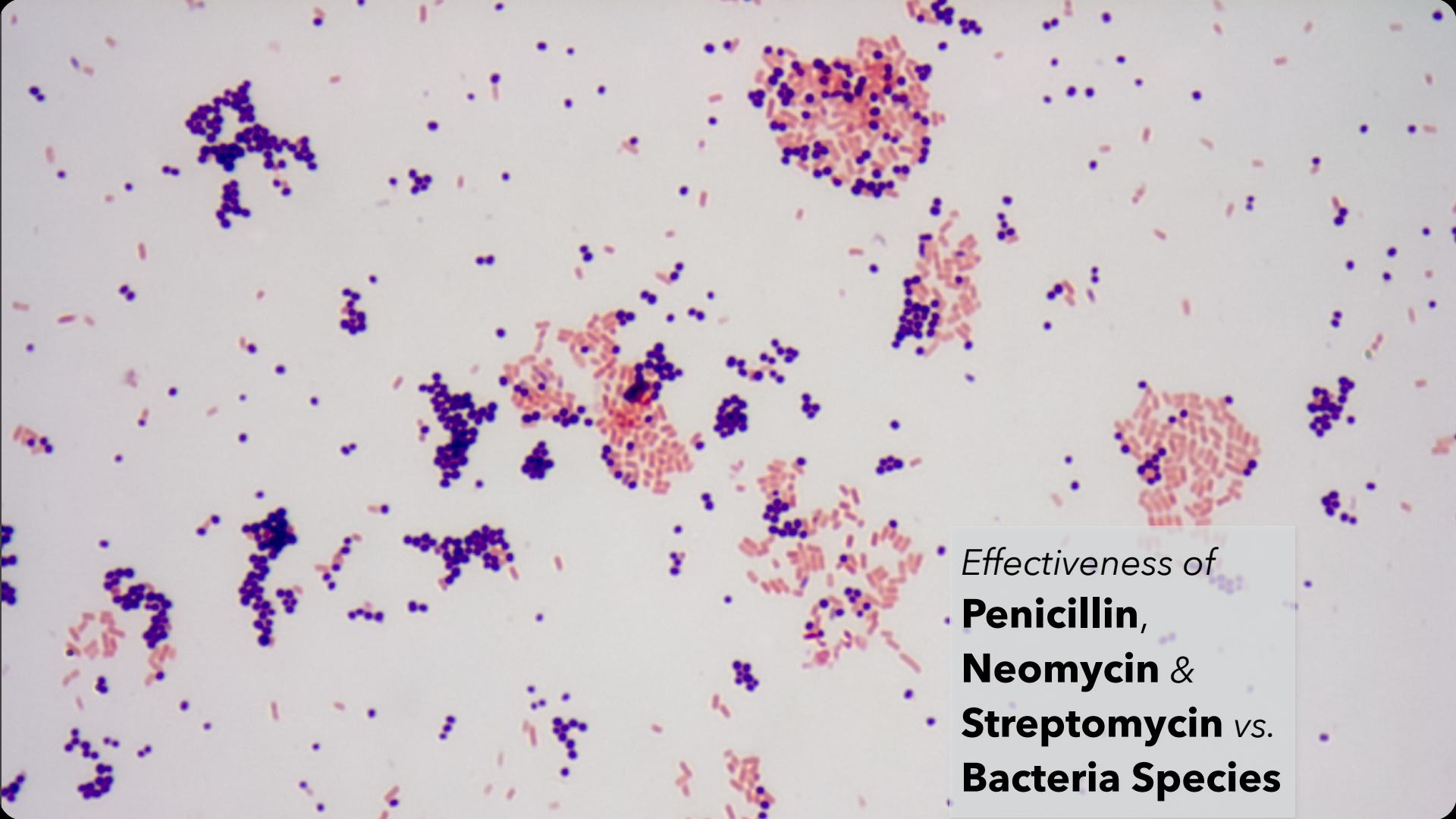


The Dragons of Eden [Carl Sagan]



The Elements of Graphing Data [Cleveland]

Example:
Antibiotic Effectiveness

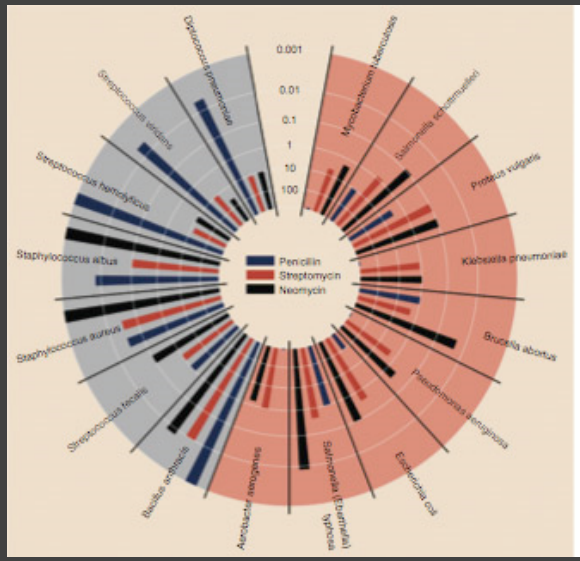

Effectiveness of
Penicillin,
Neomycin *&*
Streptomycin *vs.*
Bacteria Species

What questions might we ask?

Table 1: Burtin's data.

Bacteria	Antibiotic			Gram Staining
	Penicillin	Streptomycin	Neomycin	
Aerobacter *aerogenes*	870	1	1.6	negative
Brucella *abortus*	1	2	0.02	negative
Brucella *anthracis*	0.001	0.01	0.007	positive
Diplococcus *pneumoniae*	0.005	11	10	positive
Escherichia *coli*	100	0.4	0.1	negative
Klebsiella *pneumoniae*	850	1.2	1	negative
Mycobacterium *tuberculosis*	800	5	2	negative
Proteus *vulgaris*	3	0.1	0.1	negative
Pseudomonas *aeruginosa*	850	2	0.4	negative
Salmonella (Eberthella) *typhosa*	1	0.4	0.008	negative
Salmonella *schottmuelleri*	10	0.8	0.09	negative
Staphylococcus *albus*	0.007	0.1	0.001	positive
Staphylococcus *aureus*	0.03	0.03	0.001	positive
Streptococcus *fecalis*	1	1	0.1	positive
Streptococcus *hemolyticus*	0.001	14	10	positive
Streptococcus *viridans*	0.005	10	40	positive

Which antibiotic is most effective?



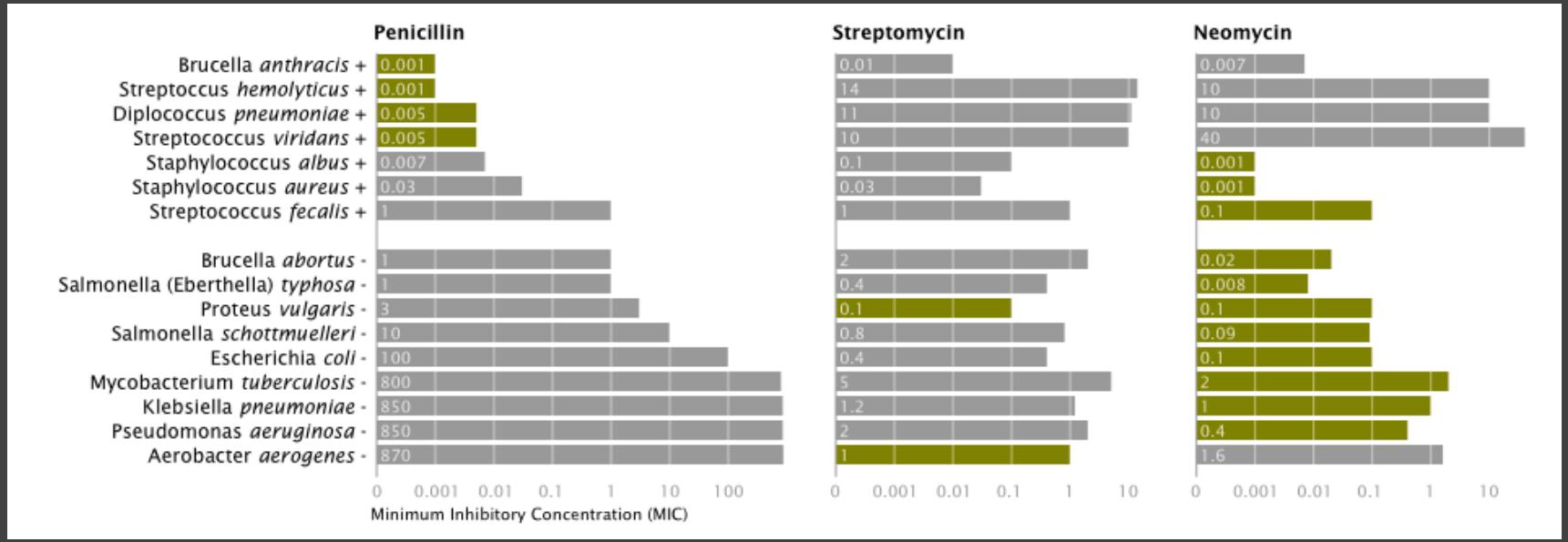
Bacteria	Penicillin	Antibiotic Streptomycin	Neomycin	Gram stain
Aerobacter aerogenes	870	1	1.6	–
Brucella abortus	1	2	0.02	–
Bacillus anthracis	0.001	0.01	0.007	+
Diplococcus pneumoniae	0.005	11	10	+
Escherichia coli	100	0.4	0.1	–
Klebsiella pneumoniae	850	1.2	1	–
Mycobacterium tuberculosis	800	5	2	–
Proteus vulgaris	3	0.1	0.1	–
Pseudomonas aeruginosa	850	2	0.4	–
Salmonella (Eberthella) typhosa	1	0.4	0.008	–
Salmonella schottmuelleri	10	0.8	0.09	–
Staphylococcus albus	0.007	0.1	0.001	+
Staphylococcus aureus	0.03	0.03	0.001	+
Streptococcus fecalis	1	1	0.1	+
Streptococcus hemolyticus	0.001	14	10	+
Streptococcus viridans	0.005	10	40	+

Radius: 1 / log(MIC)

Bar Color: Antibiotic

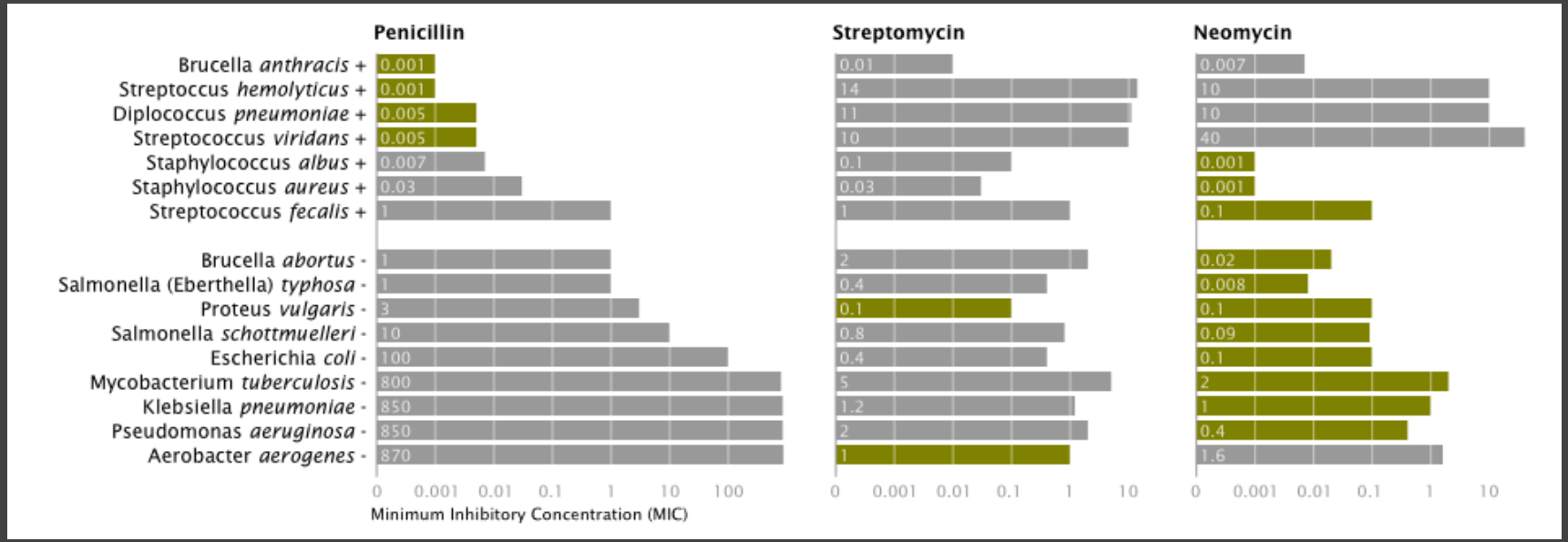
Background Color: Gram Staining

Which antibiotic is most effective?



Mike Bostock

Which antibiotic is most effective?



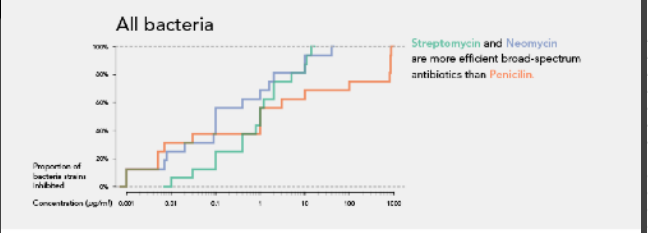
X-axis: Antibiotic | log(MIC)

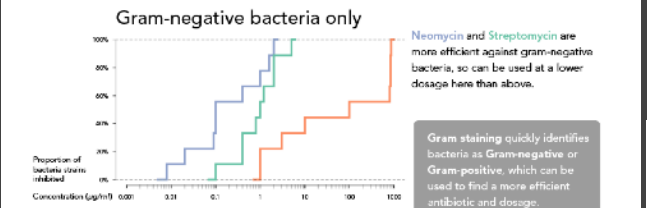
Y-axis: Gram-Staining | Species

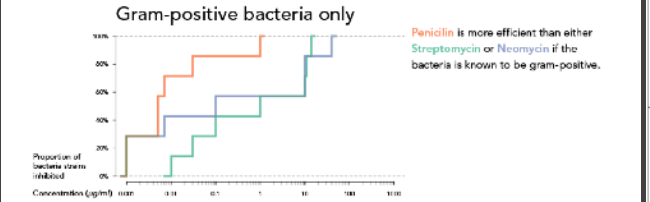
Color: Most-Effective?

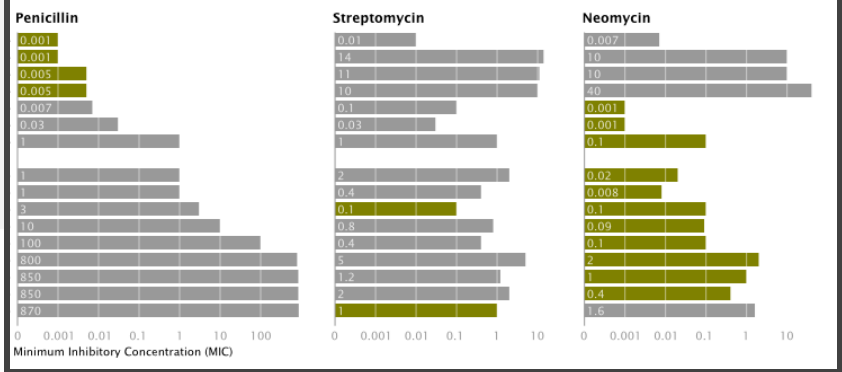
penicillin
streptomycin
neomycin
E. aerogenes
B. abortus
E. coli
K. pneumoniae
M. tuberculosis
P. vulgaris
P. aeruginosa
S. typhi
S. schottmuelleri
B. anthracis
S. pneumoniae
S. albus
S. aureus
E. faecalis
S. pyogenes
S. viridans
Gram positive
Gram negative
0.1 (µg/ml)
1
10
100
500
minimum inhibitory concentration of antibiotics
bowen li
cs448b

Bowen Li

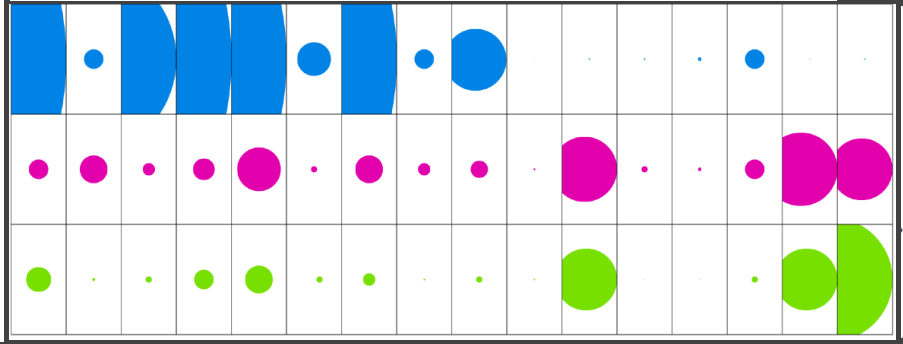

All bacteria
Streptomycin and Neomycin are more efficient broad-spectrum antibiotics than Penicillin.
Proportion of bacteria strains inhibited
Concentration (μg/ml)

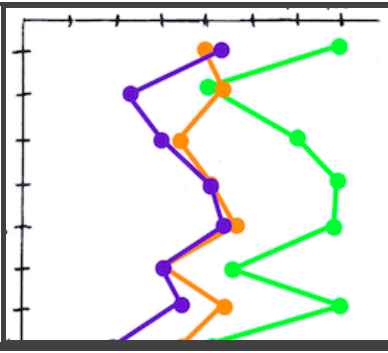

Gram-negative bacteria only
Neomycin and Streptomycin are more efficient against gram-negative bacteria, so can be used at a lower dosage here than above.
Gram staining quickly identifies bacteria as Gram-negative or Gram-positive, which can be used to find a more efficient antibiotic and dosage.
Proportion of bacteria strains inhibited
Concentration (μg/ml)

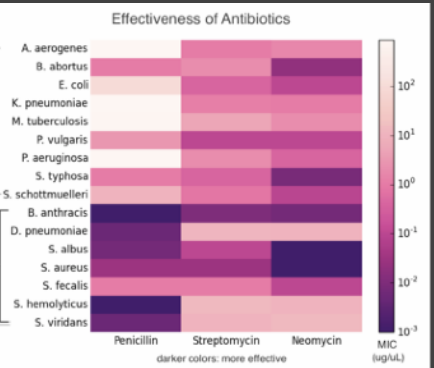

Gram-positive bacteria only
Penicillin is more efficient than either Streptomycin or Neomycin if the bacteria is known to be gram-positive.
Proportion of bacteria strains inhibited
Concentration (μg/ml)

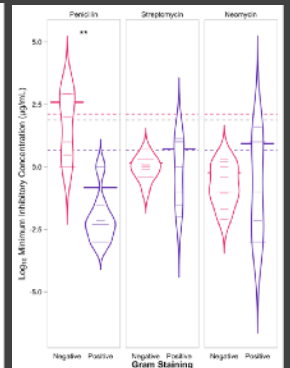

Penicillin
Streptomycin
Neomycin
Minimum Inhibitory Concentration (MIC)

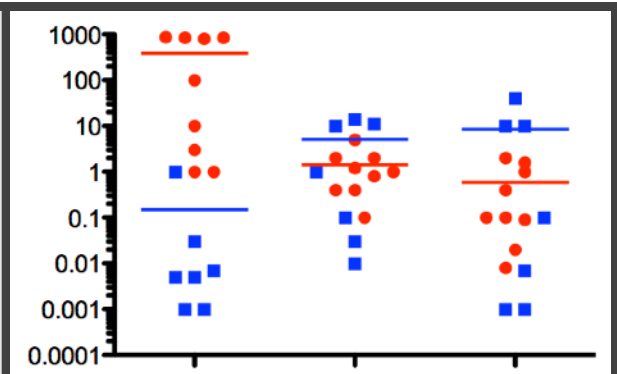

Gram-Positive
Diplococcus pneumoniae
Streptococcus viridans
Staphylococcus albus
Staphylococcus hemolyticus
Staphylococcus aureus
Streptococcus fecalis

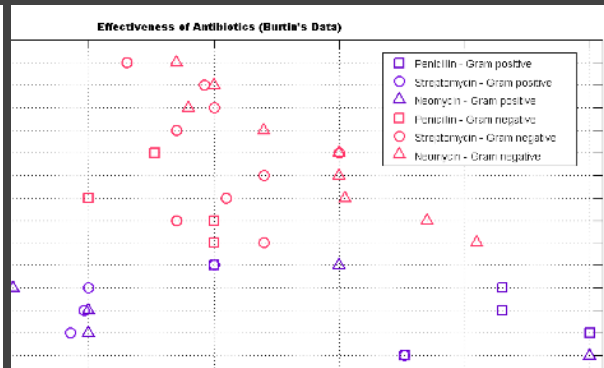


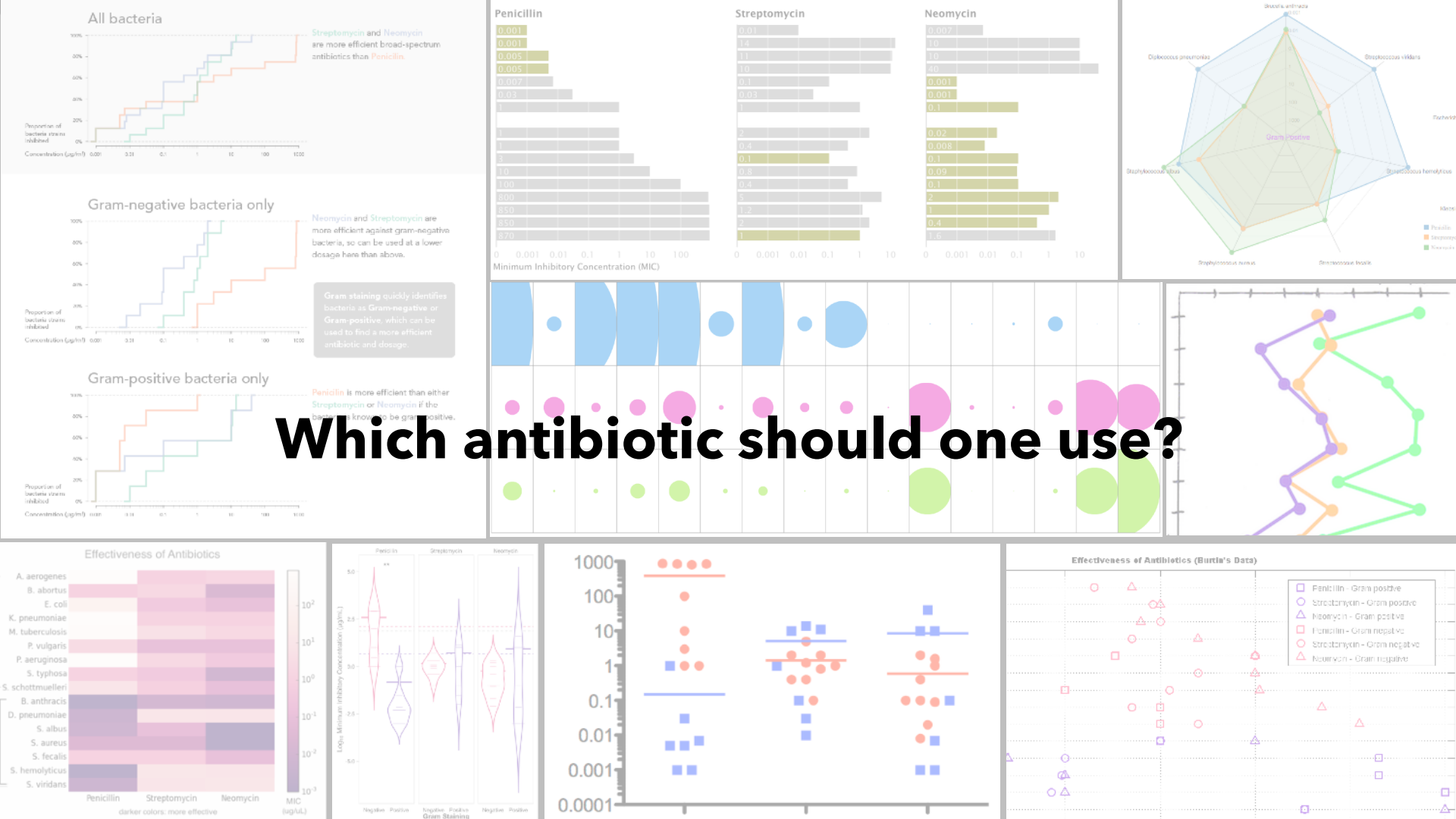



Effectiveness of Antibiotics
A. aerogenes
B. abortus
E. coli
K. pneumoniae
M. tuberculosis
P. vulgaris
P. aeruginosa
S. typhosa
S. schottmuelleri
B. anthracis
D. pneumoniae
S. albus
S. aureus
S. fecalis
S. hemolyticus
S. viridans
Penicillin
Streptomycin
Neomycin
MIC (ug/uL)
darker colors: more effective


Penicillin
Streptomycin
Neomycin
Log10 Minimum Inhibitory Concentration (ug/mL)
Negative
Positive
Gram Staining


1000
100
10
1
0.1
0.01
0.001
0.0001


Effectiveness of Antibiotics (Burtis's Data)
Penicillin - Gram positive
Streptomycin - Gram positive
Neomycin - Gram positive
Penicillin - Gram negative
Streptomycin - Gram negative
Neomycin - Gram negative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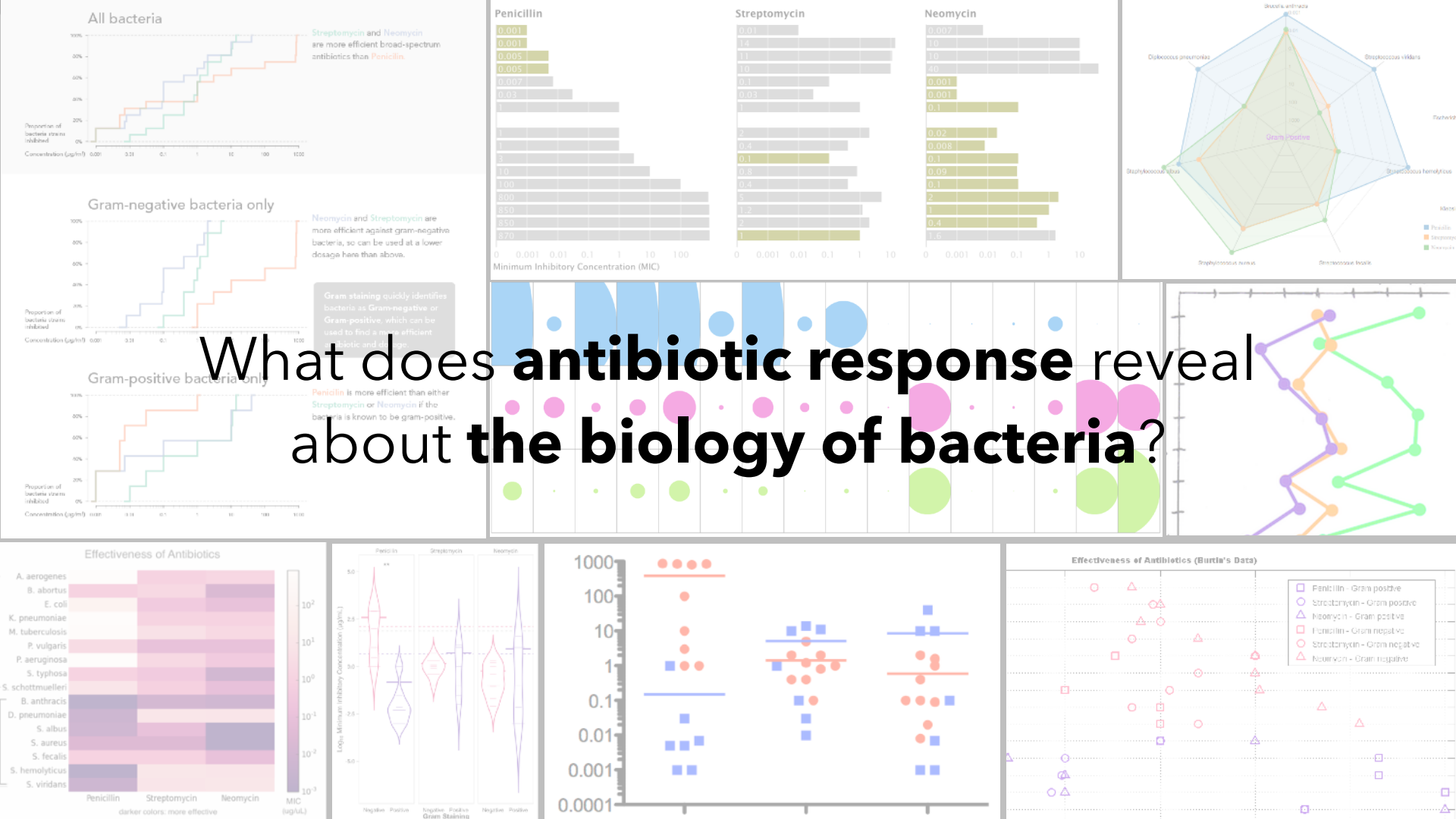
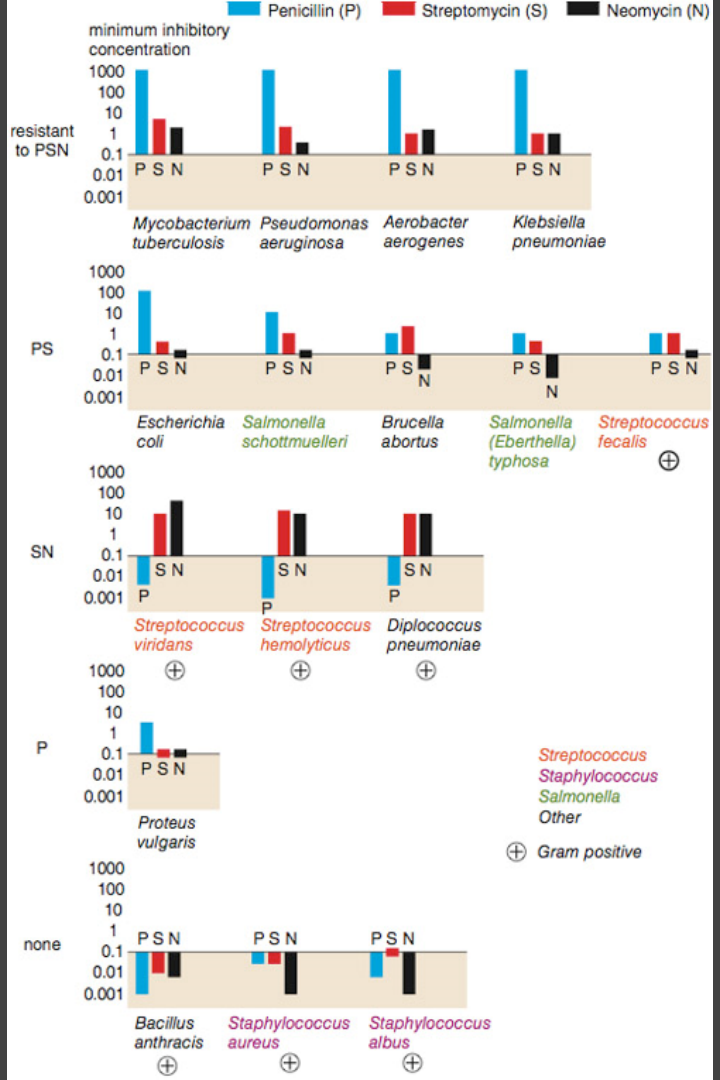
Gram-negative bacteria only
Neomycin and Streptomycin are more efficient against gram-negative bacteria, so can be used at a lower dosage here than above.
Gram staining quickly identifies bacteria as Gram-negative or Gram-positive, which can be used to find a more efficient antibiotic and dosage.
Gram-positive bacteria only
Penicillin is more efficient than either Streptomycin or Neomycin if the
Penicillin
Streptomycin
Neomycin
Minimum Inhibitory Concentration (MIC)
Gram-Positive
Which antibiotic should one use?
Effectiveness of Antibiotics
A. aerogenes
B. abortus
E. coli
K. pneumoniae
M. tuberculosis
P. vulgaris
P. aeruginosa
S. typhosa
S. schottmuelleri
B. anthracis
D. pneumoniae
S. albus
S. aureus
S. fecalis
S. hemolyticus
S. viridans
Penicillin
Streptomycin
Neomycin
MIC (ug/uL)
darker colors: more effective
Log10 Minimum Inhibitory Concentration (ug/mL)
Gram Staining
Effectiveness of Antibiotics (Burtis's Data)
Penicillin - Gram positive
Streptomycin - Gram positive
Neomycin - Gram positive
Penicillin - Gram negative
Streptomycin - Gram negative
Neomycin - Gram negative



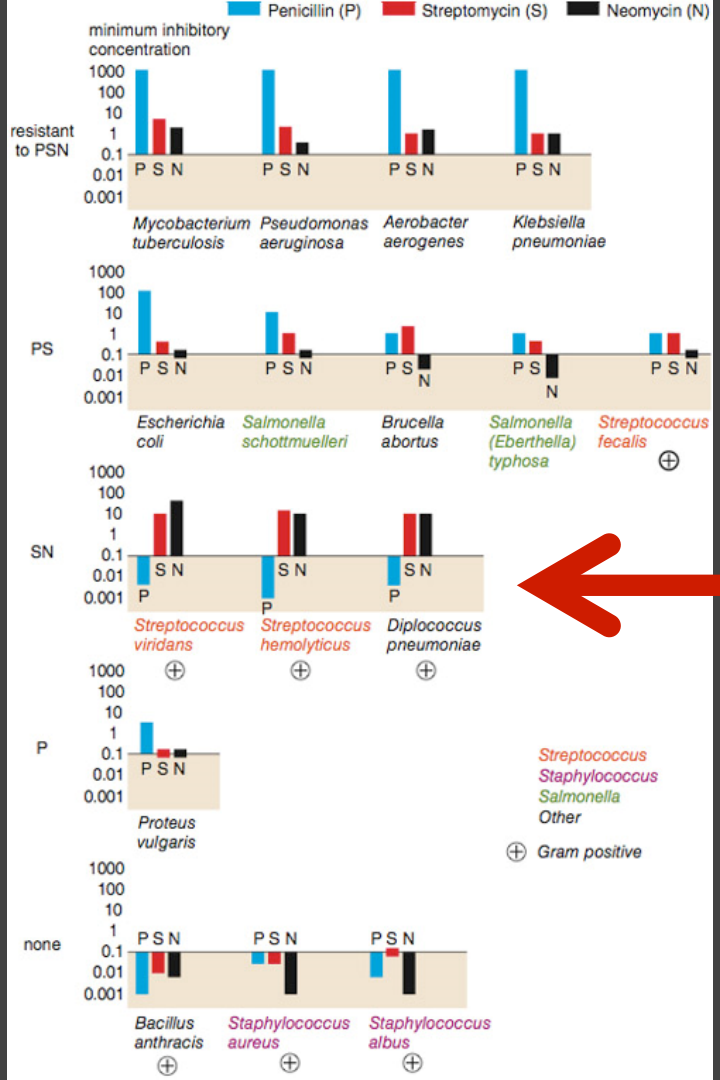
What does **antibiotic response** reveal about **the biology of bacteria**?

Do the bacteria group by antibiotic resistance?



Do the bacteria group by antibiotic resistance?

Wainer & Lysen
American Scientist, 2009



Do the bacteria group by antibiotic resistance?

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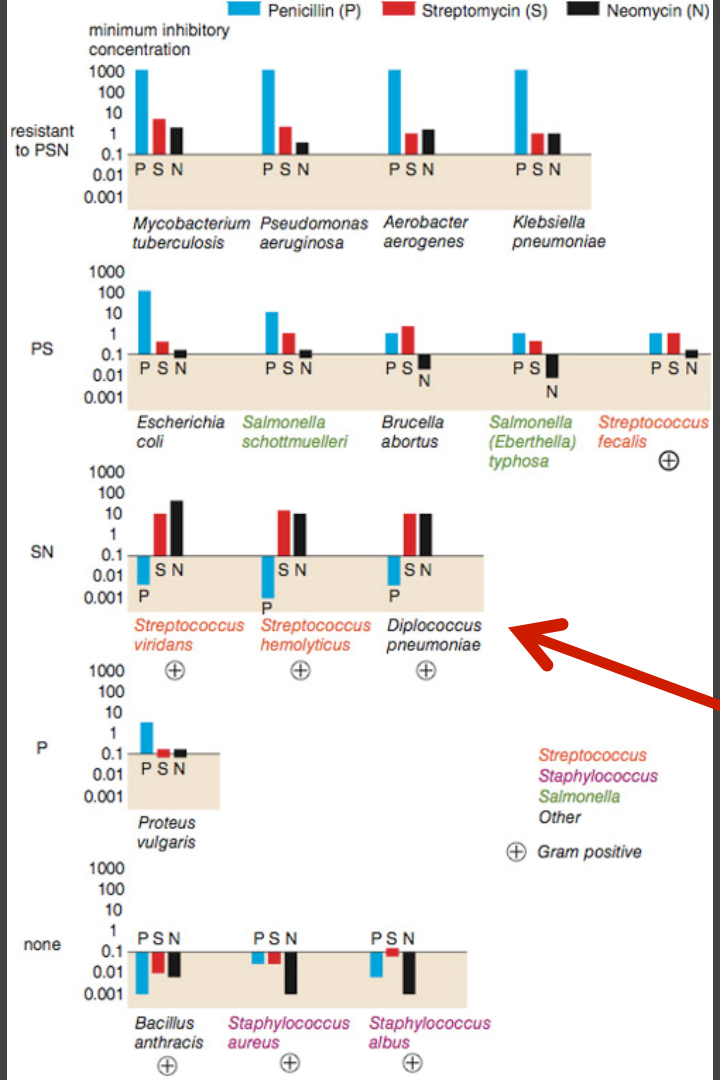
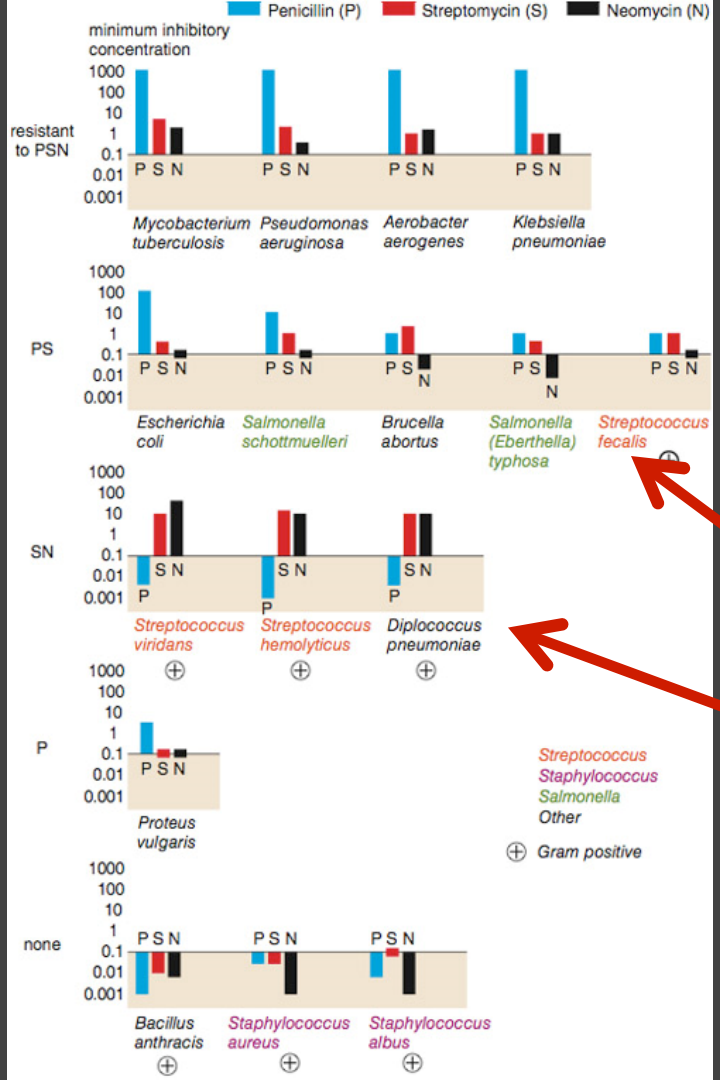


Do the bacteria group by antibiotic resistance?

Really a streptococcus!
(realized ~20 yrs later)

Wainer & Lysen
American Scientist, 2009

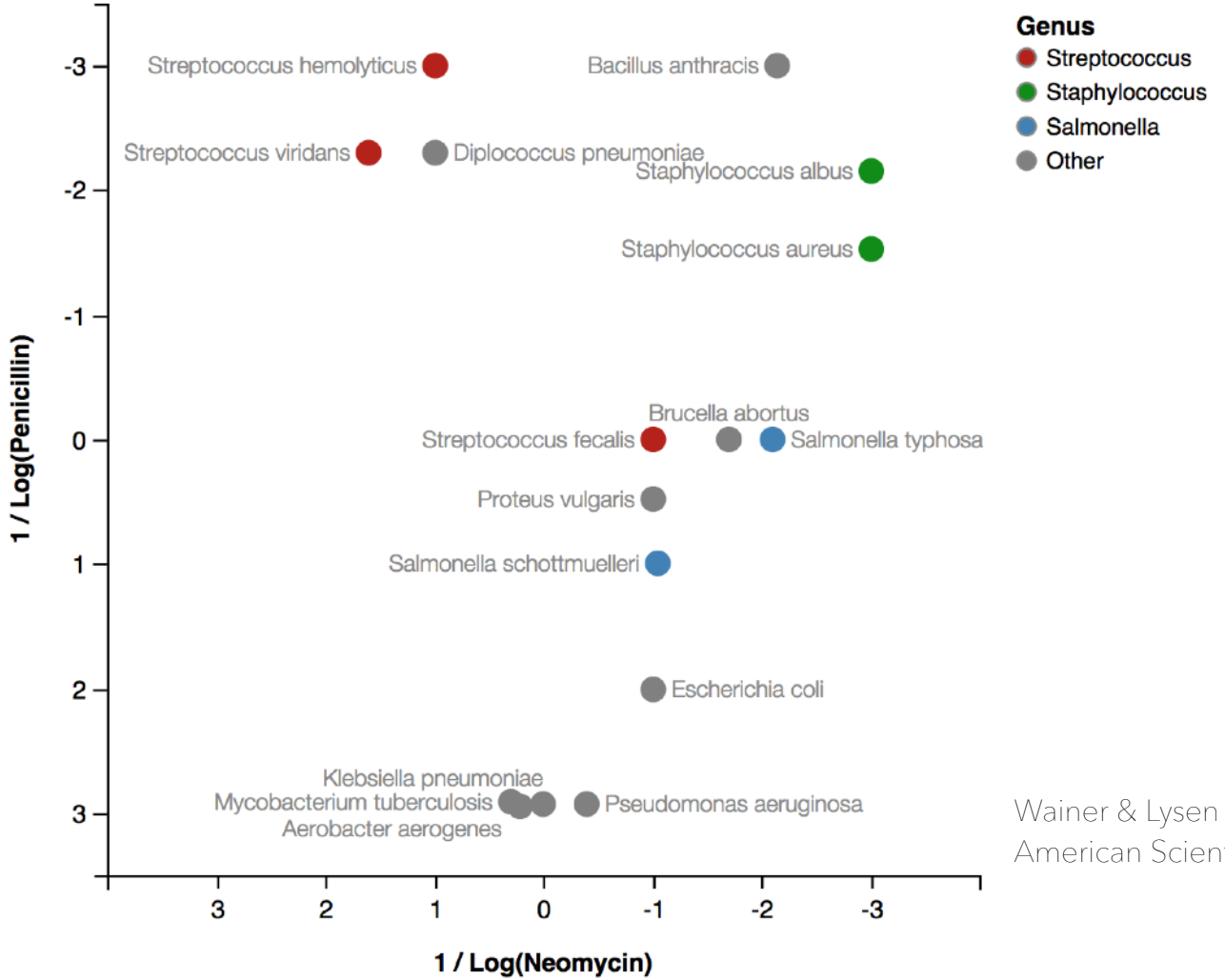


Do the bacteria group by antibiotic resistance?

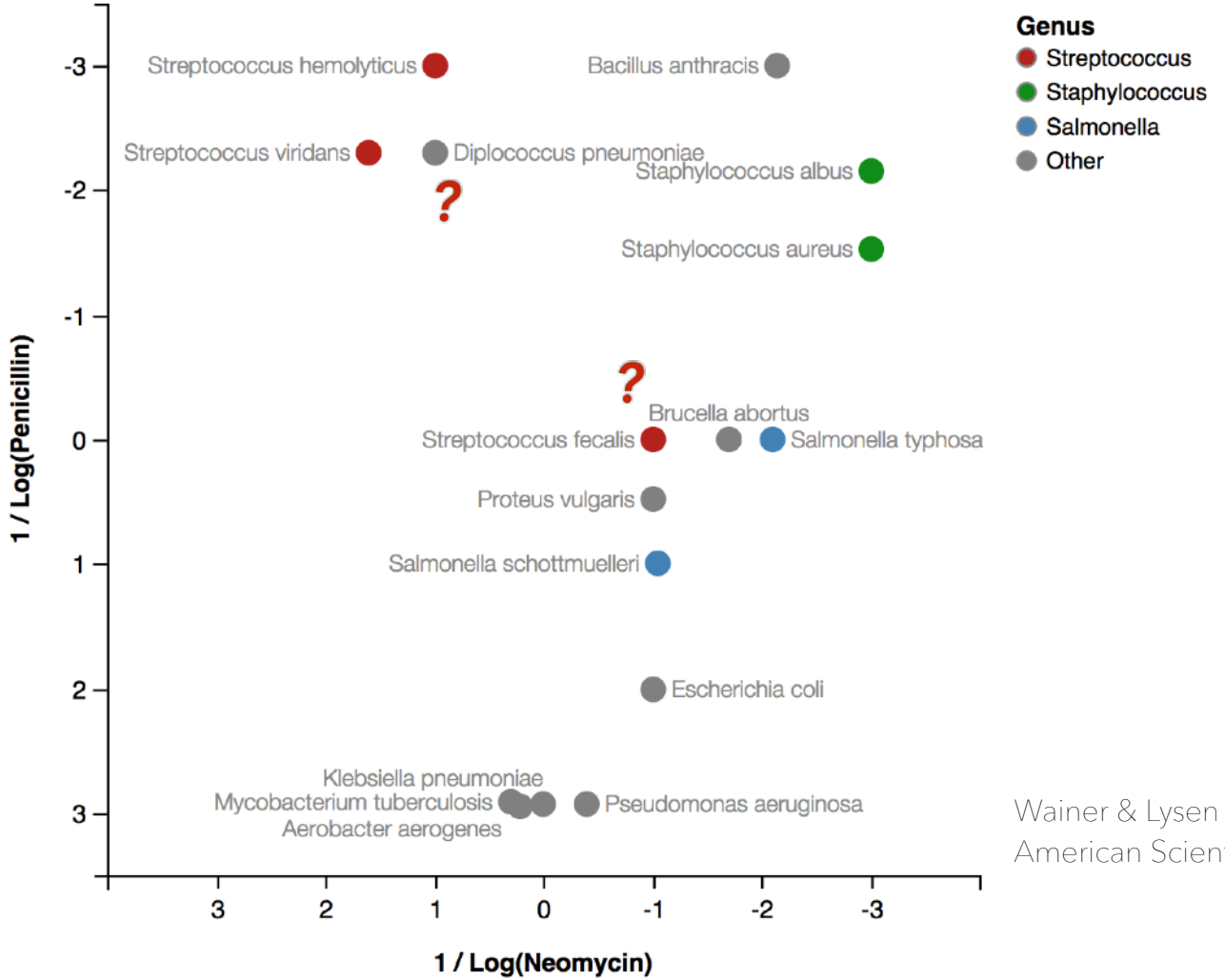
Not a streptococcus!
(realized ~30 yrs later)

Really a streptococcus!
(realized ~20 yrs later)

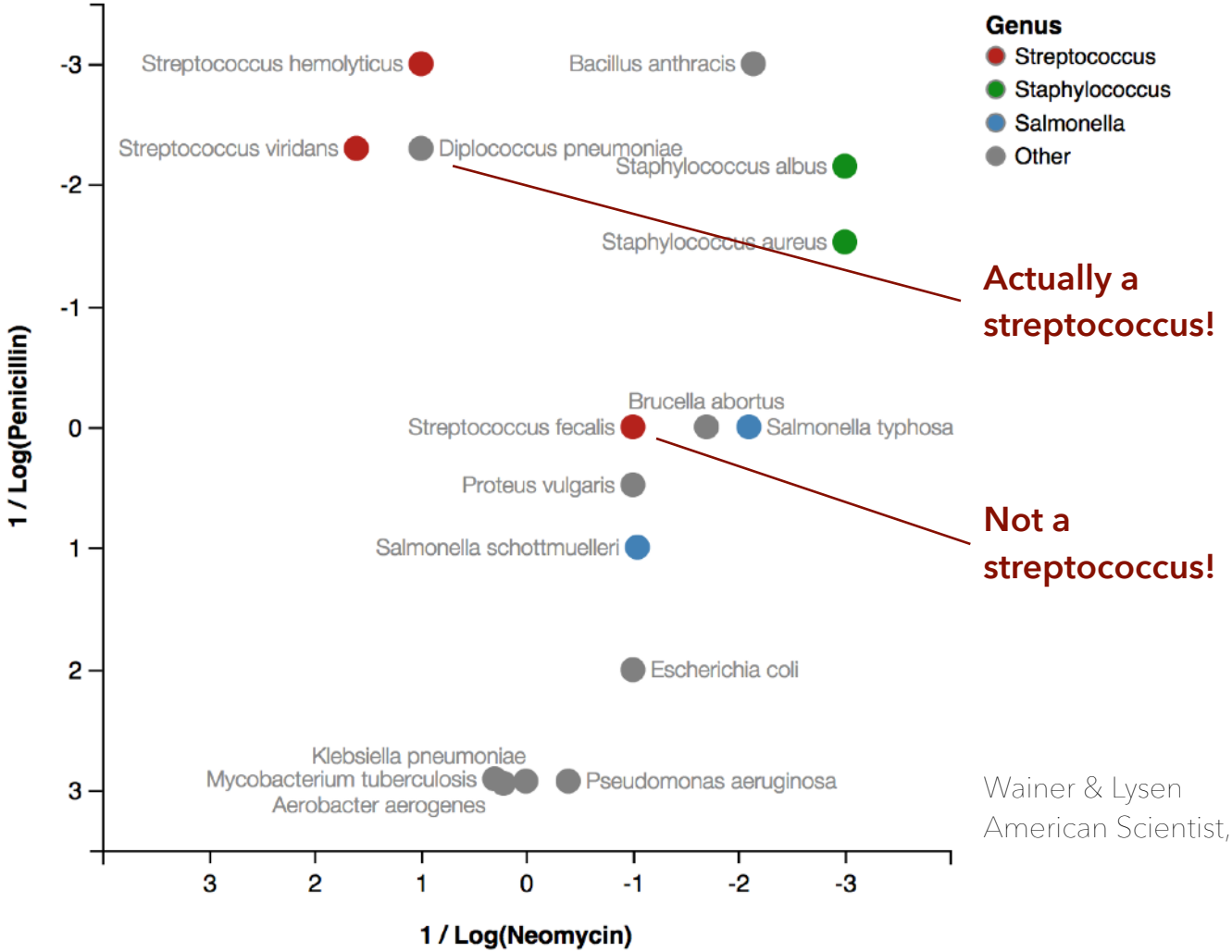
Wainer & Lysen
American Scientist, 2009



Wainer & Lysen
American Scientist, 2009



Wainer & Lysen
American Scientist, 2009



Wainer & Lysen
American Scientist, 2009

Lesson: Iterative Exploration

Exploratory Process

1 Construct graphics to address questions
2 Inspect “answer” and assess new questions
3 Repeat…

Transform data appropriately (e.g., invert, log)

Formulate clear analysis questions & goals

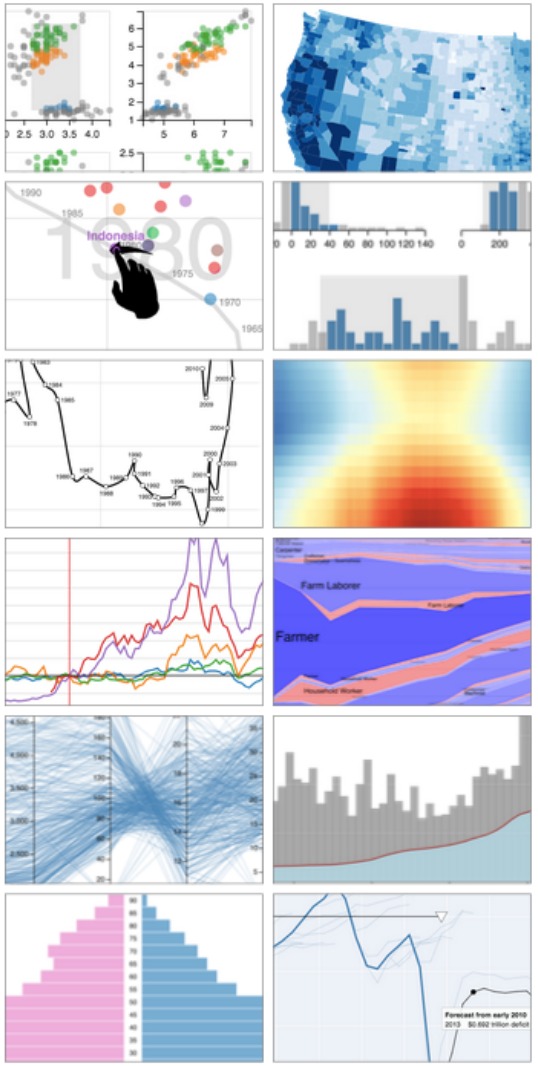
Don’t trust your data!

Exploration Tasks

Data Exploration Tasks

Profile: learn the shape and structure of the data, assess data quality, check modeling assumptions

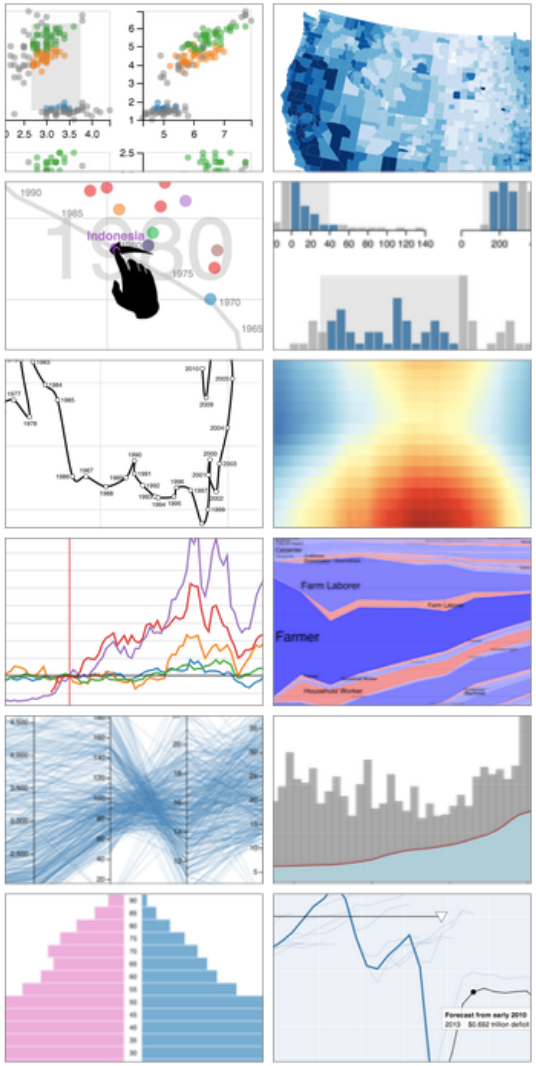
GOAL: Is the data actionable? What can we ask?



Data Exploration Tasks

Profile: learn the shape and structure of the data, assess data quality, check modeling assumptions
GOAL: Is the data actionable? What can we ask?

Search: identify specific data points or relations of interest to form an evidentiary chain
GOAL: Fact-finding, isolate important points/connections

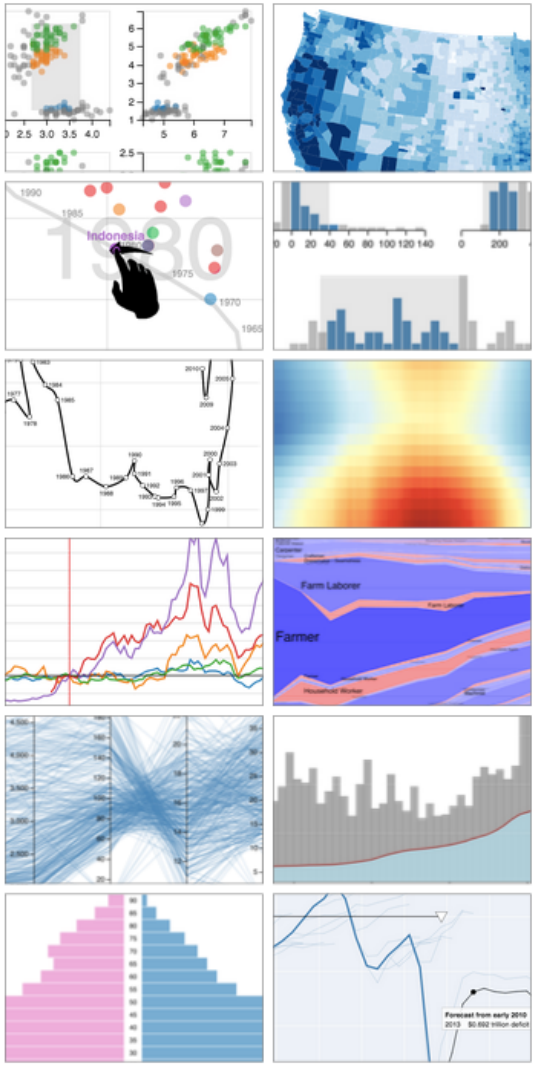


Data Exploration Tasks

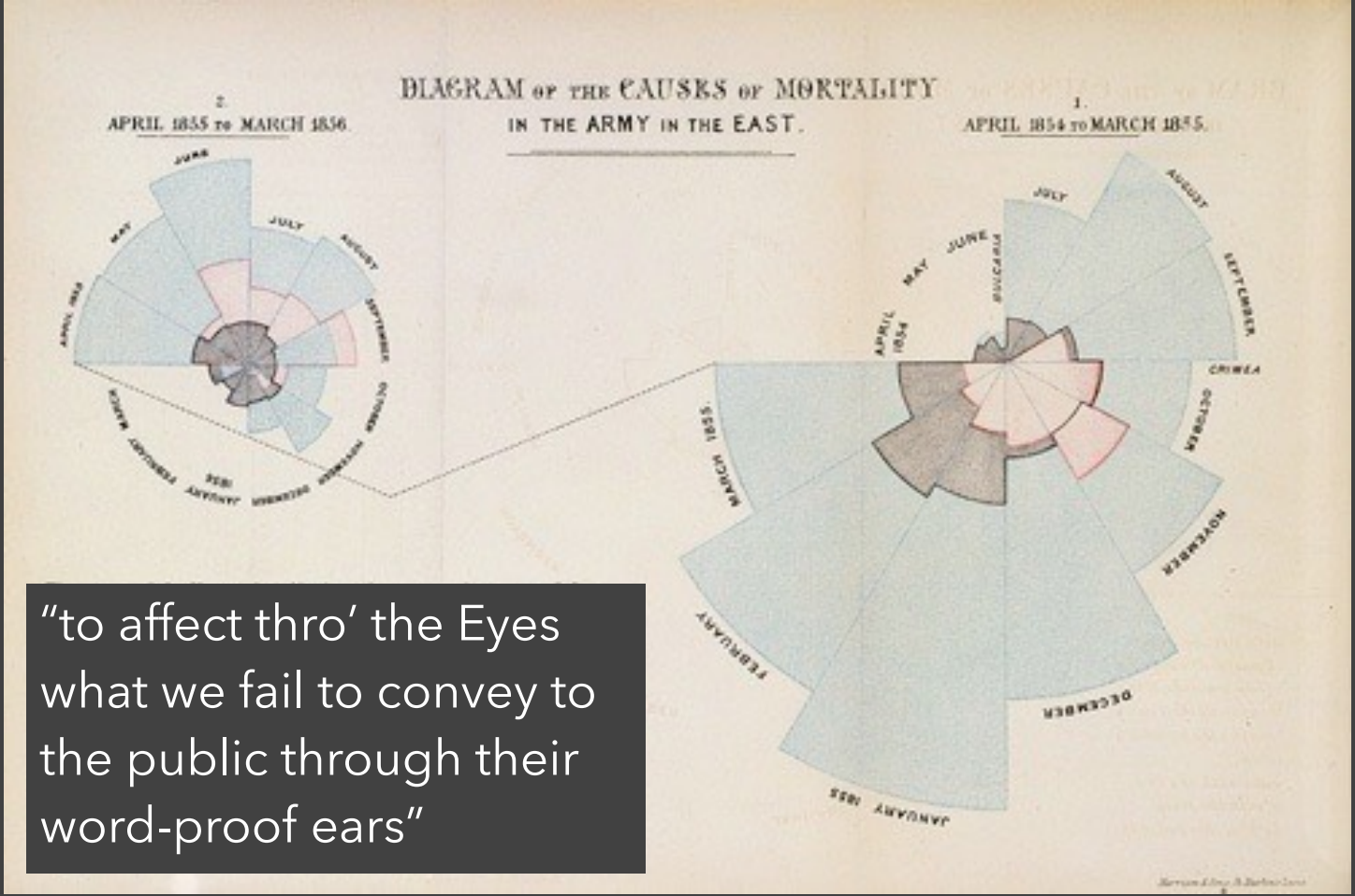
Profile: learn the shape and structure of the data, assess data quality, check modeling assumptions
GOAL: Is the data actionable? What can we ask?

Search: identify specific data points or relations of interest to form an evidentiary chain
GOAL: Fact-finding, isolate important points/connections

Infer: generalize from observed patterns, ascribe observations to specific factors or causes
GOAL: Inform modeling and decision making



Communication Tasks

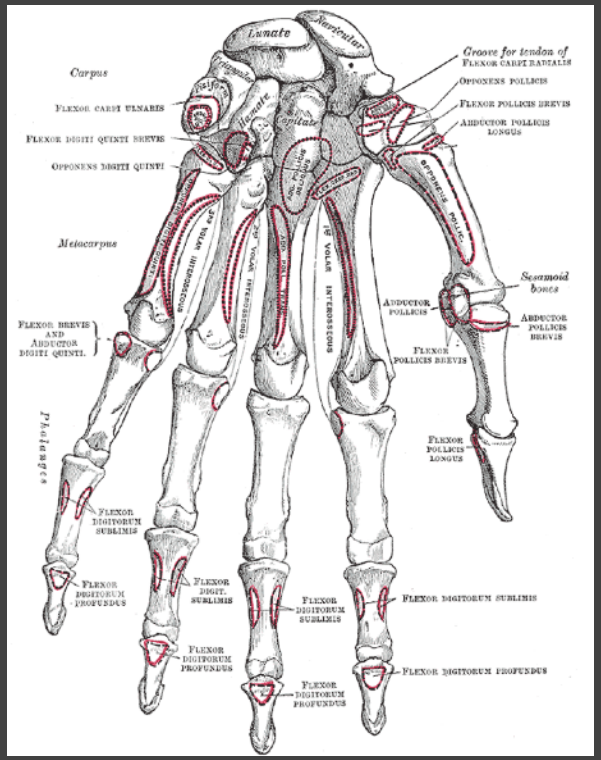


"to affect thro' the Eyes what we fail to convey to the public through their word-proof ears"

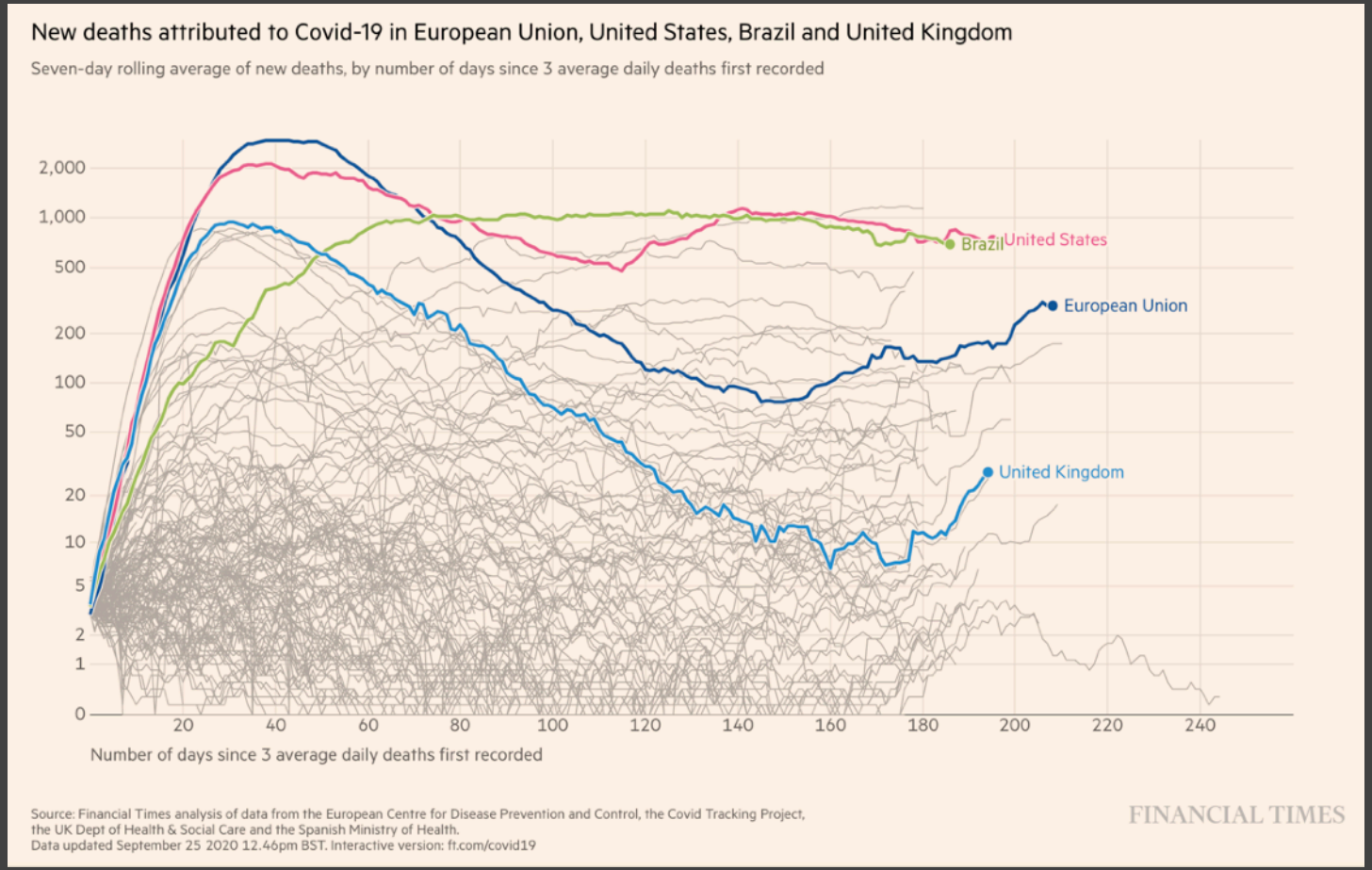
1856 "Coxcomb" of Crimean War Deaths, Florence Nightingale

Communicate, Inform, Inspire

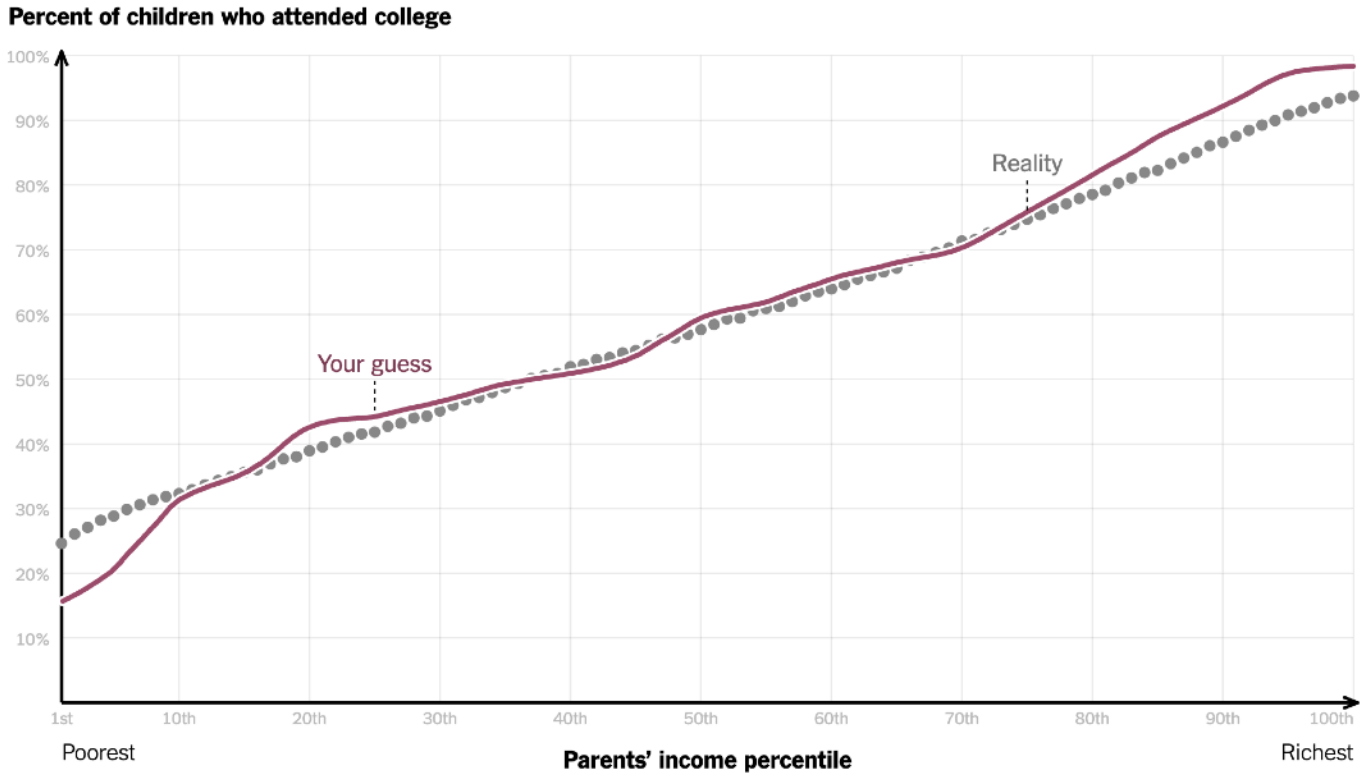
Visualizing Black America, Du Bois et al. 1900



Bones in hand, Gray's Anatomy 1918 ed.

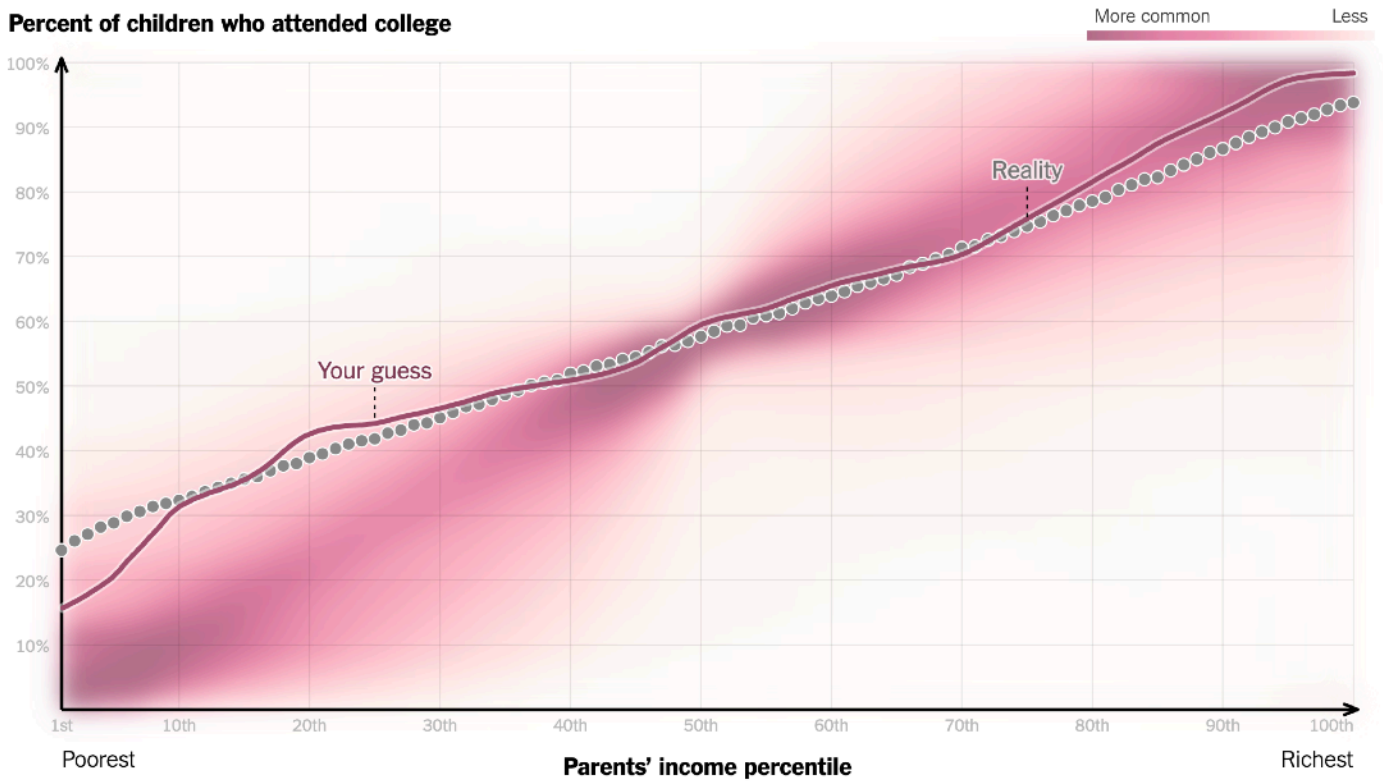


Coronavirus Tracked John Burn-Murdoch & Financial Times



You Draw It: How Family Income Predicts Children's College Chances

[New York Times, May 28, 2015]



You Draw It: How Family Income Predicts Children's College Chances

[New York Times, May 28, 2015]

Course Overview

Course Overview

W1: Introduction to Visualization and Vega-Lite

W2: Visual Encoding & Deceptive Visualization

W3: Data Transformation & Dim. Reduction

W4: Interaction & Mapping

W5: Visualization Tools (D3.js)

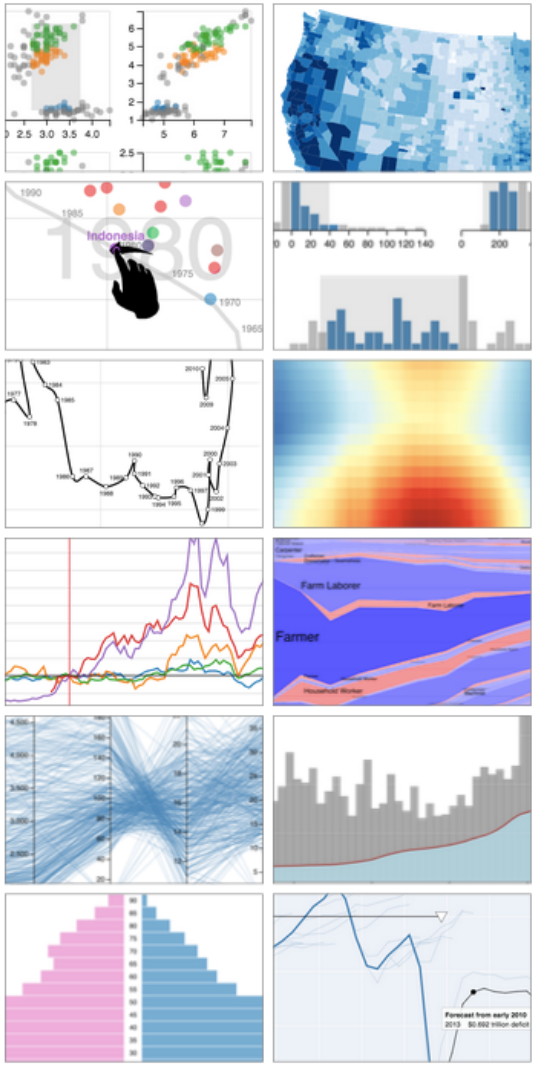
W6: Animation & Color

W7: Perception & Final Project Kick-Off

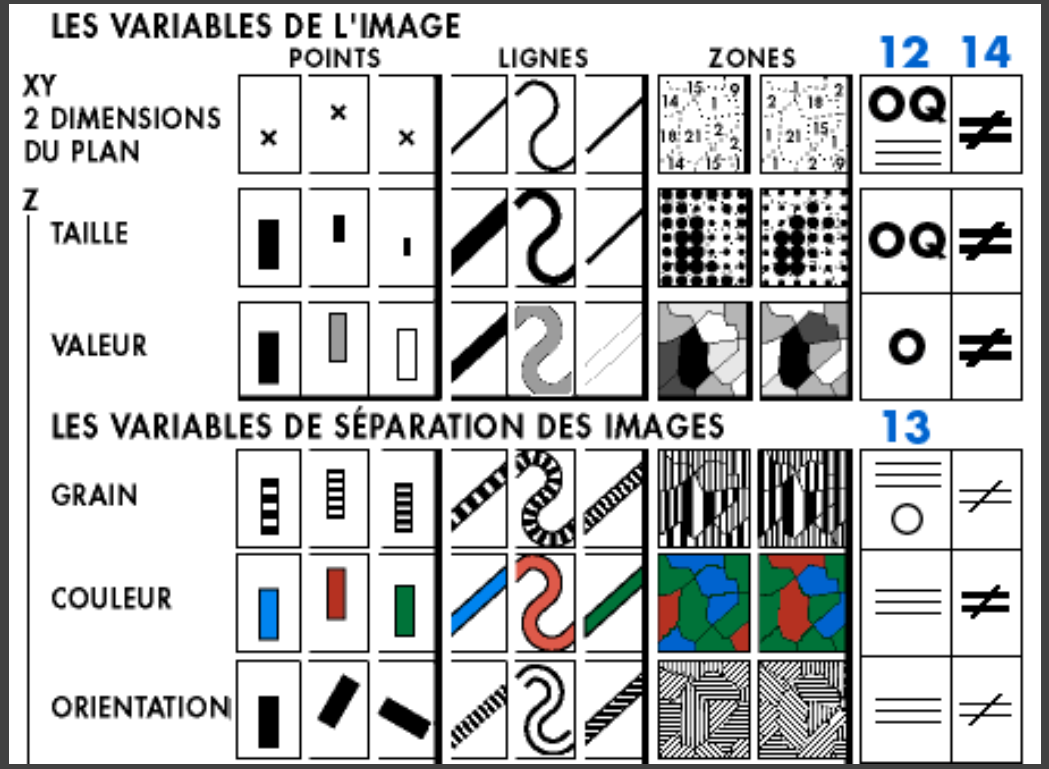
W8: Networks & Uncertainty

W9: Scalability & Final Project Review

W10: Evaluation & Final Project Showcase

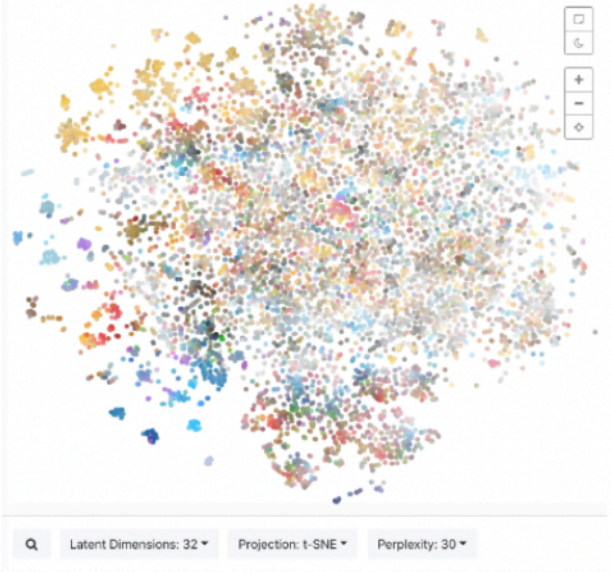


Visual Encoding

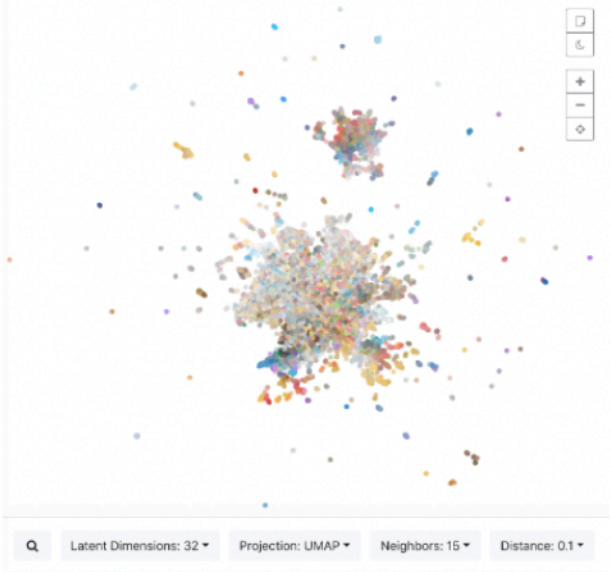


Sémiologie Graphique [Bertin 67]

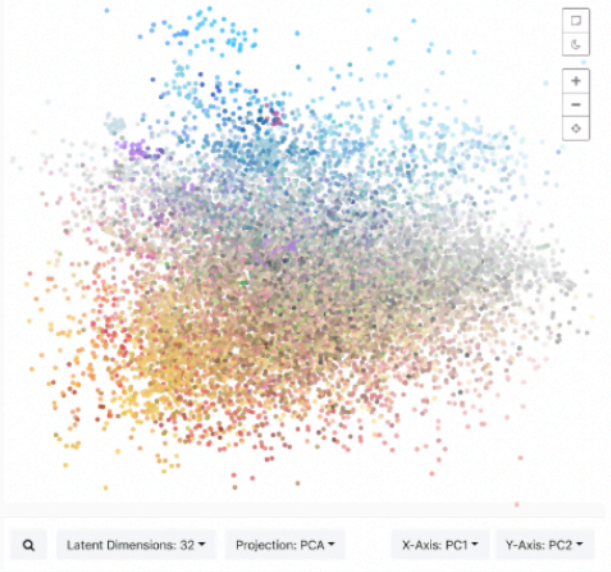
Data Transformation



t-SNE

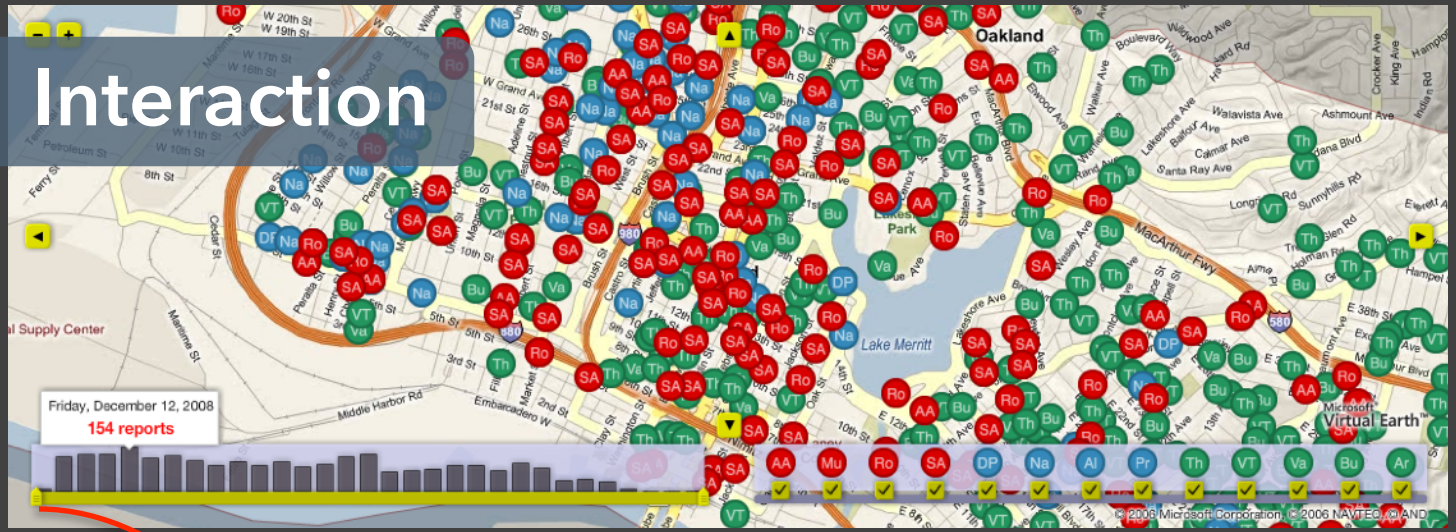


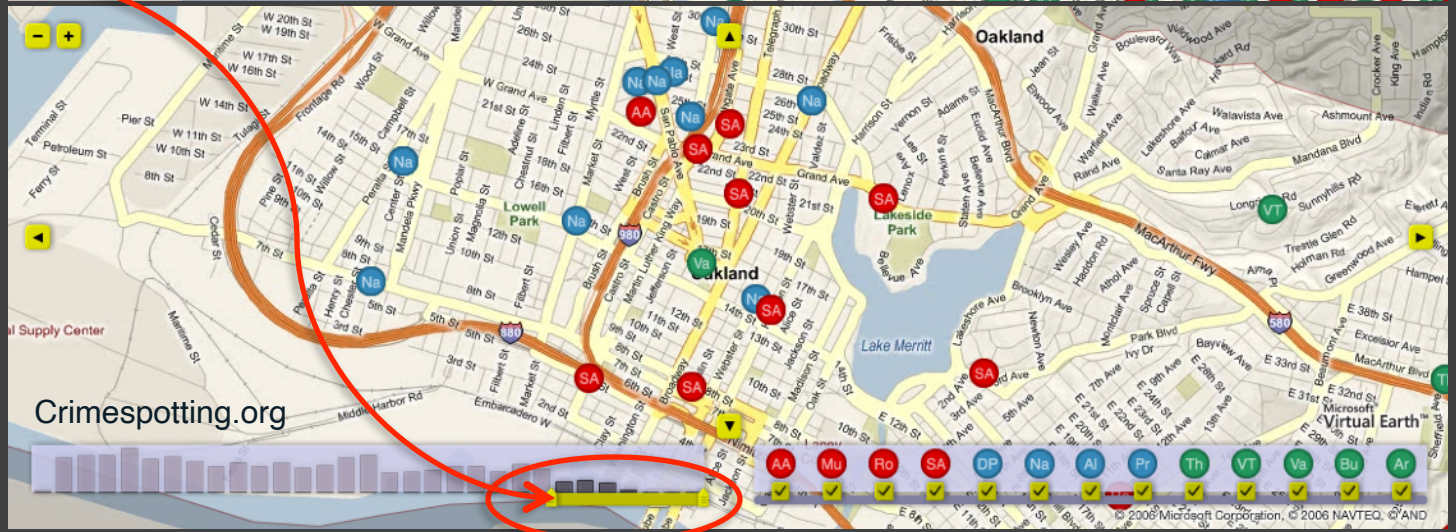
UMAP



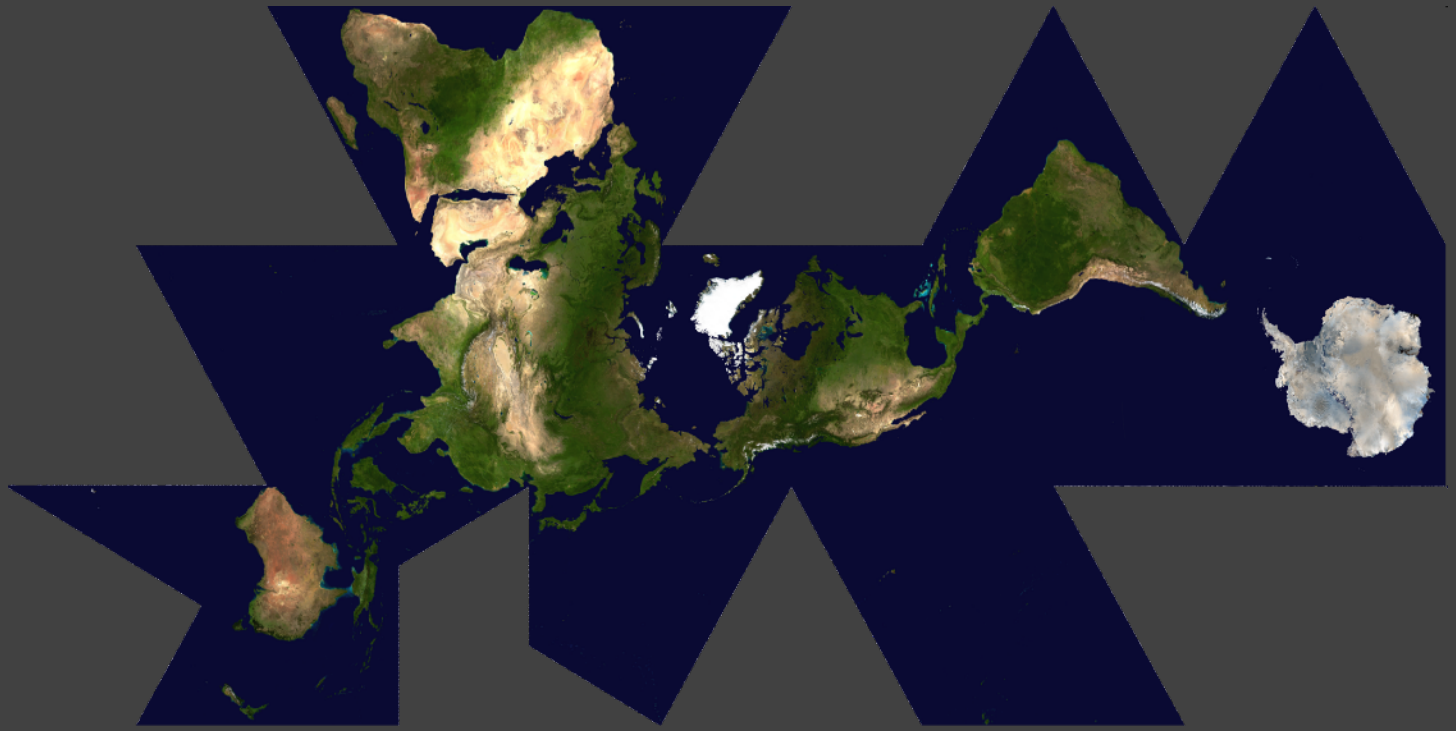
PCA

Interaction



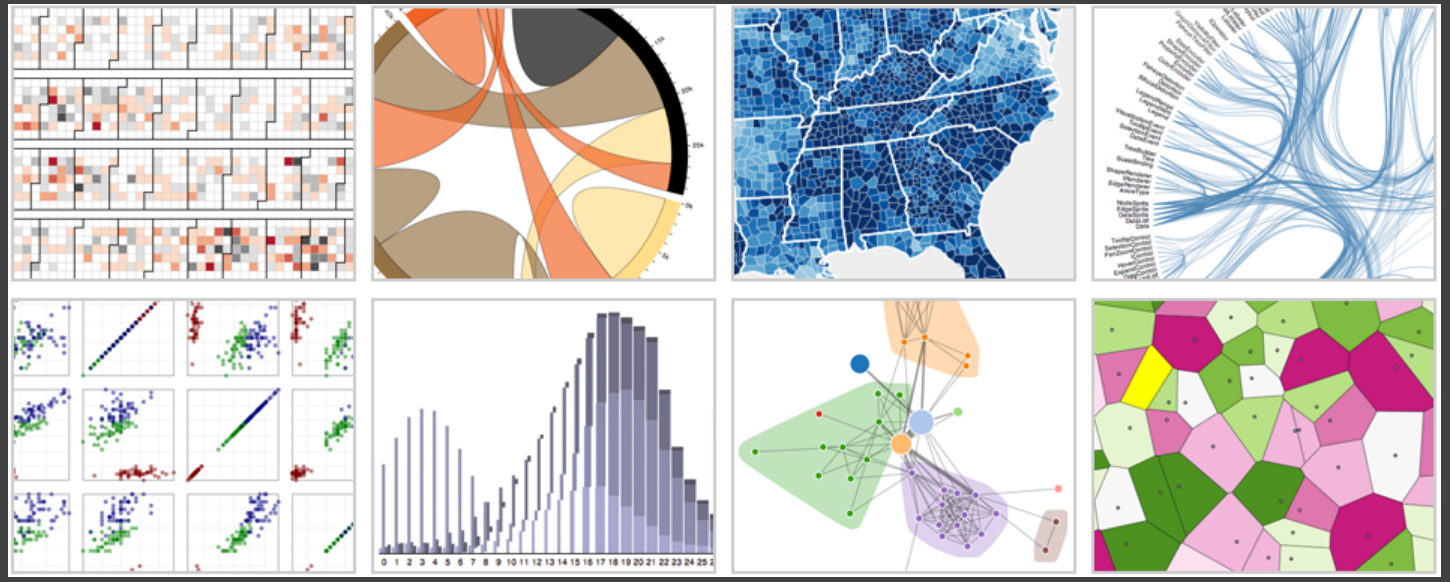


Mapping & Cartography



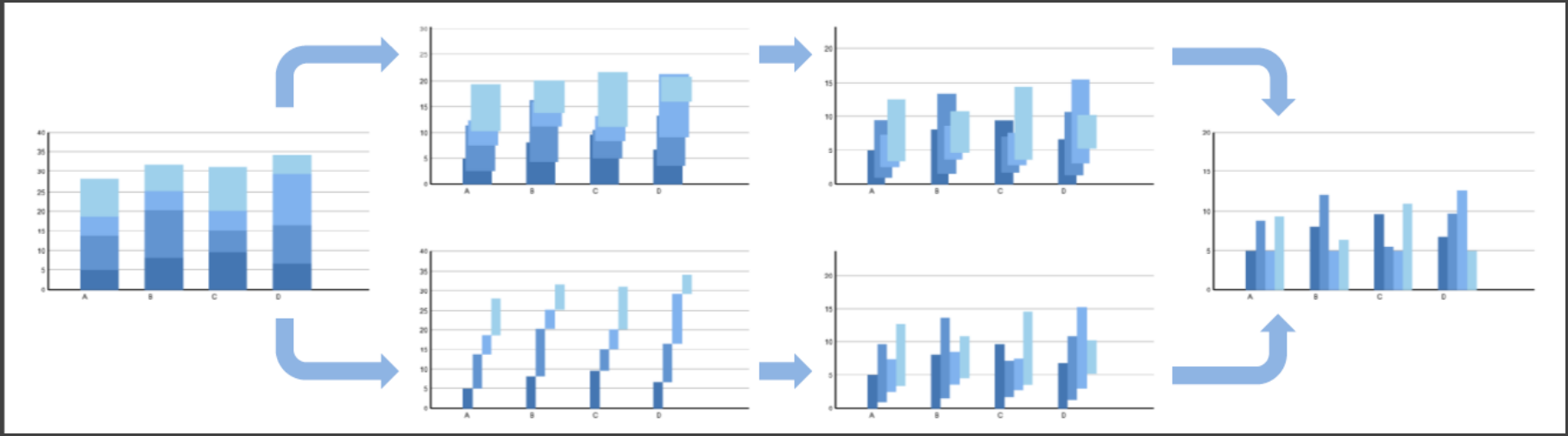
Dymaxion Maps [Fuller 46]

Visualization Tools



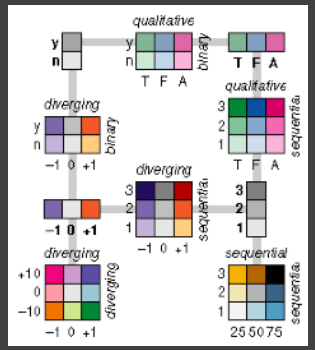
D3: Data-Driven Documents

Animation

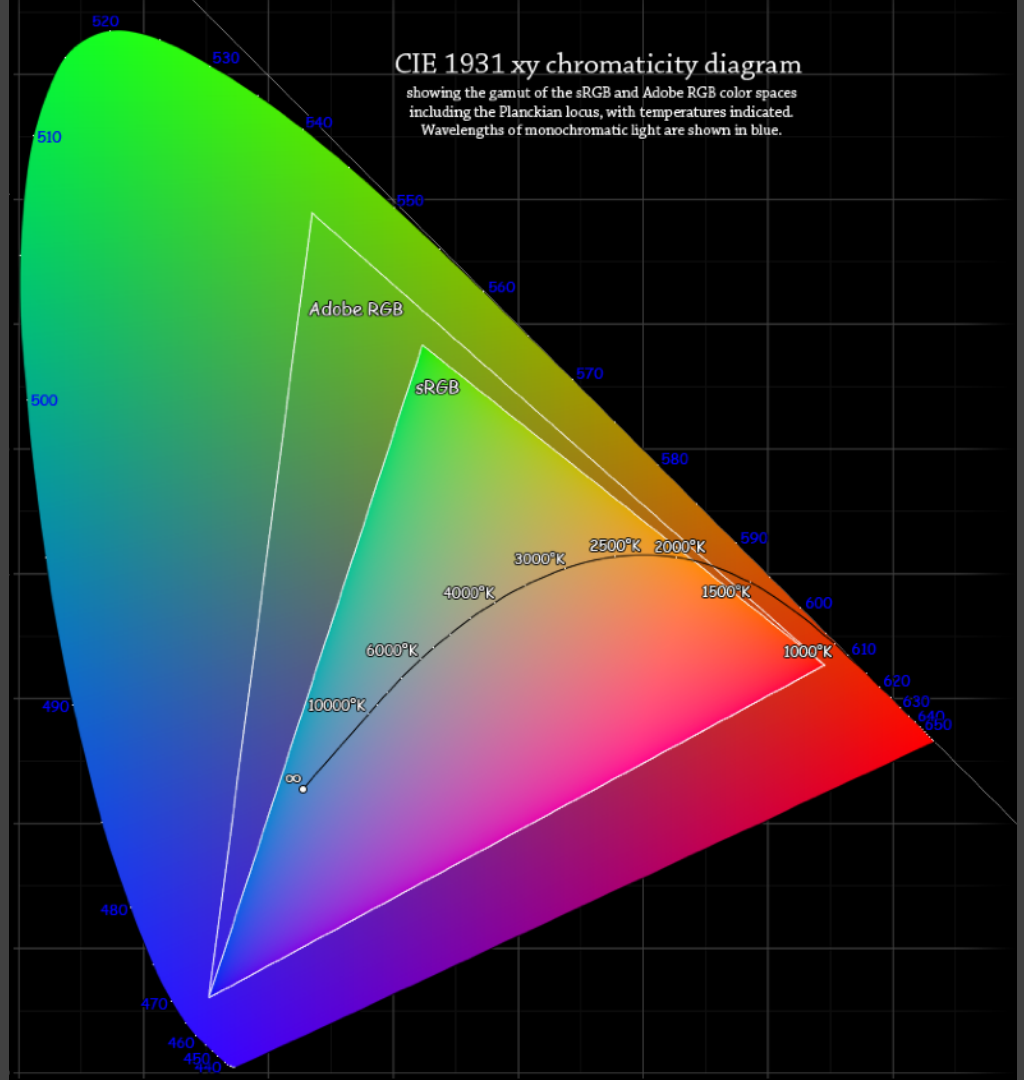


Animated transitions in statistical data graphics [Heer & Robertson 07]

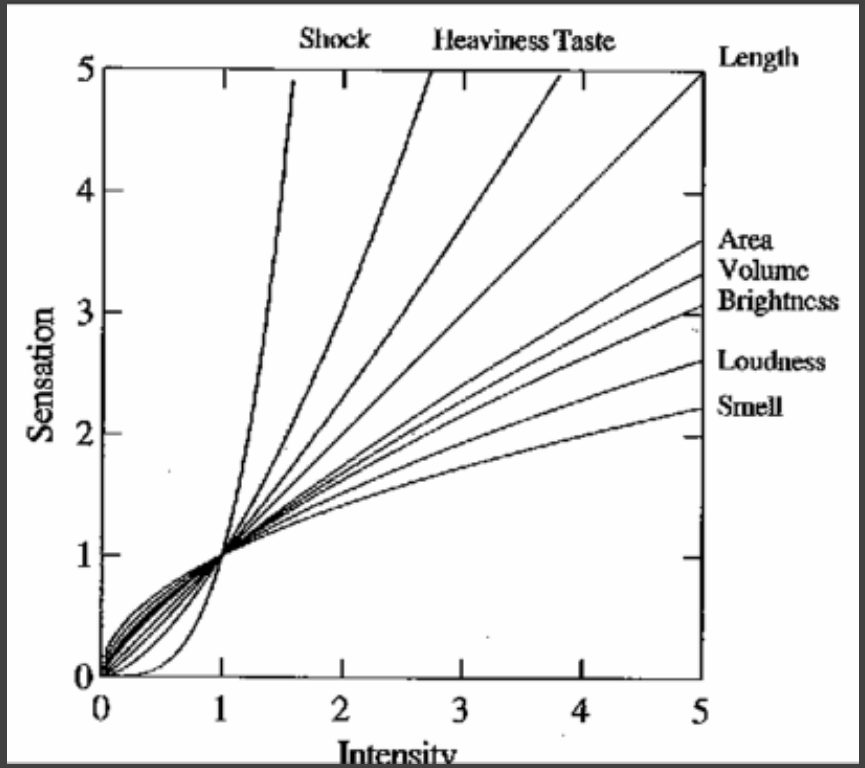
Color



Color Brewer

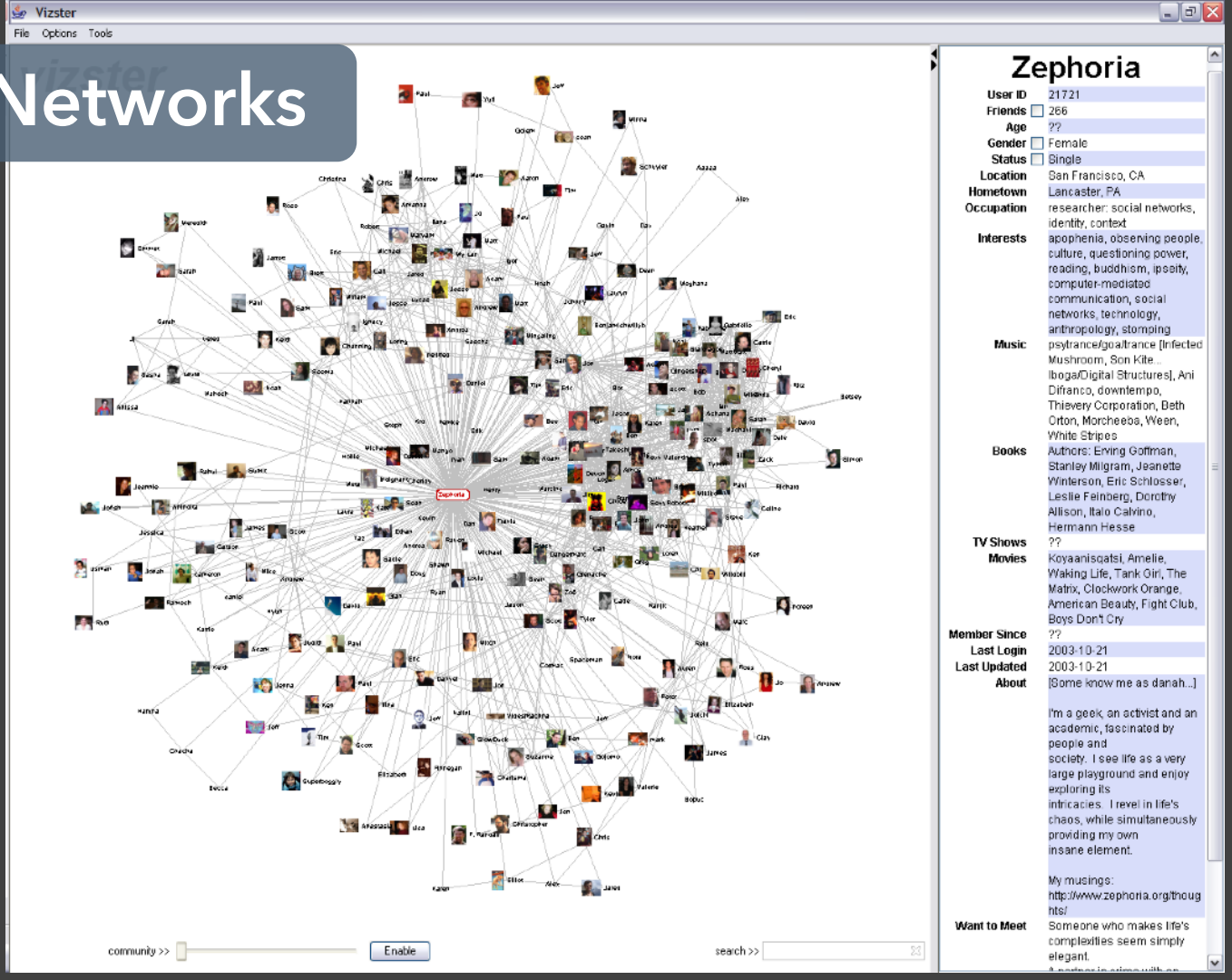


Graphical Perception

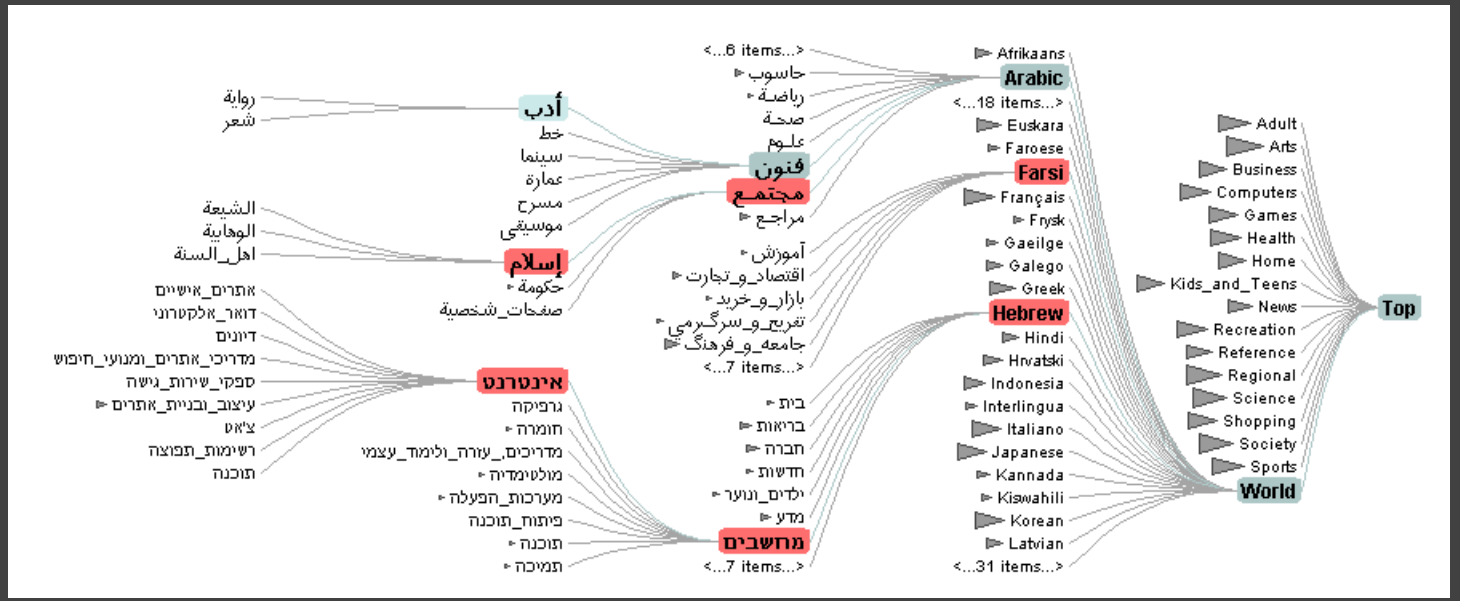


The psychophysics of sensory function [Stevens 61]

Networks

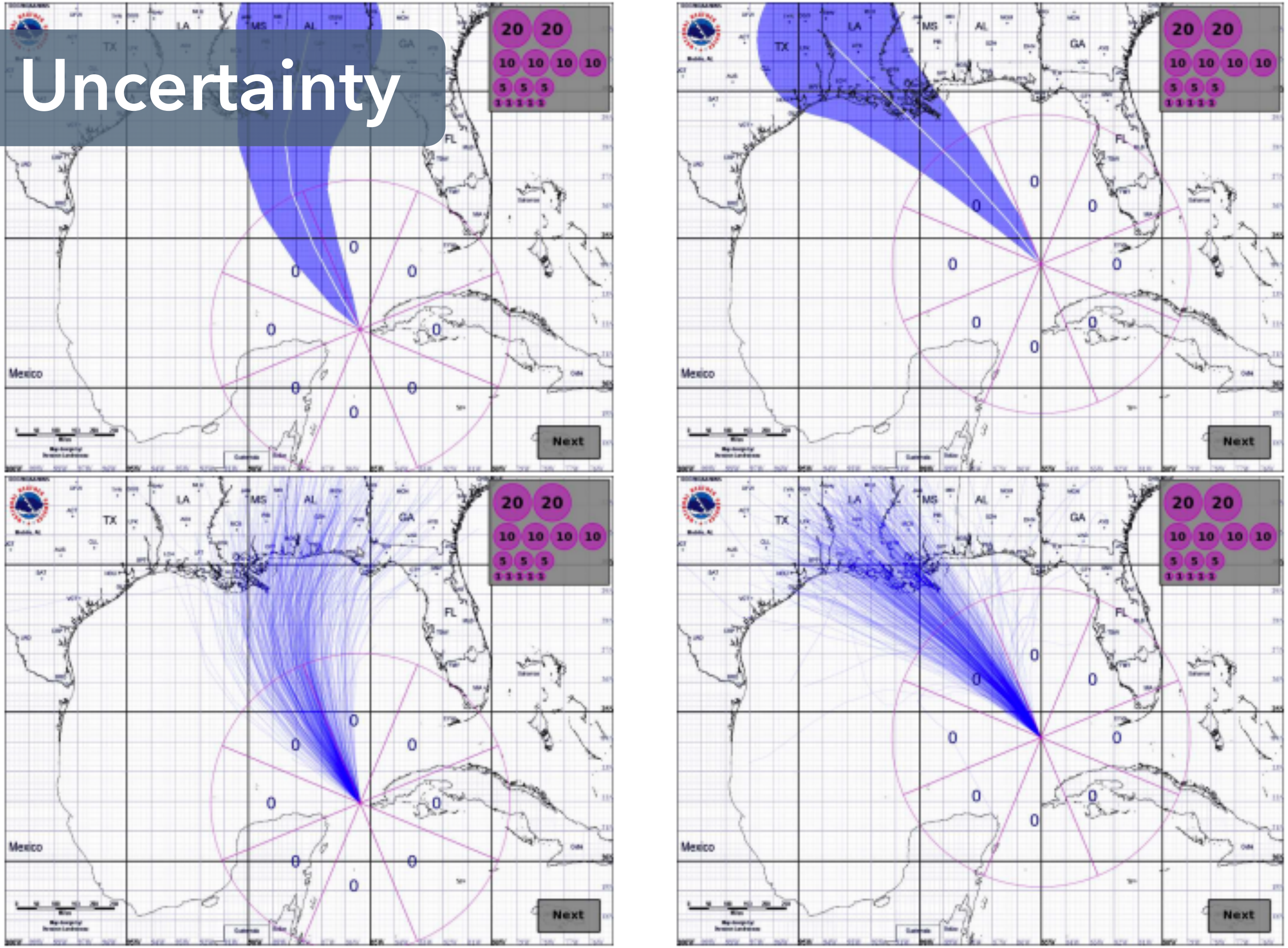

Vizster
File
Options
Tools
community >>
Enable
search >>
Zephoria
User ID 21721
Friends 266
Age ??
Gender Female
Status Single
Location San Francisco, CA
Hometown Lancaster, PA
Occupation researcher: social networks, identity, context
Interests apophenia, observing people, culture, questioning power, reading, buddhism, ipseity, computer-mediated communication, social networks, technology, anthropology, stomping
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.

Networks

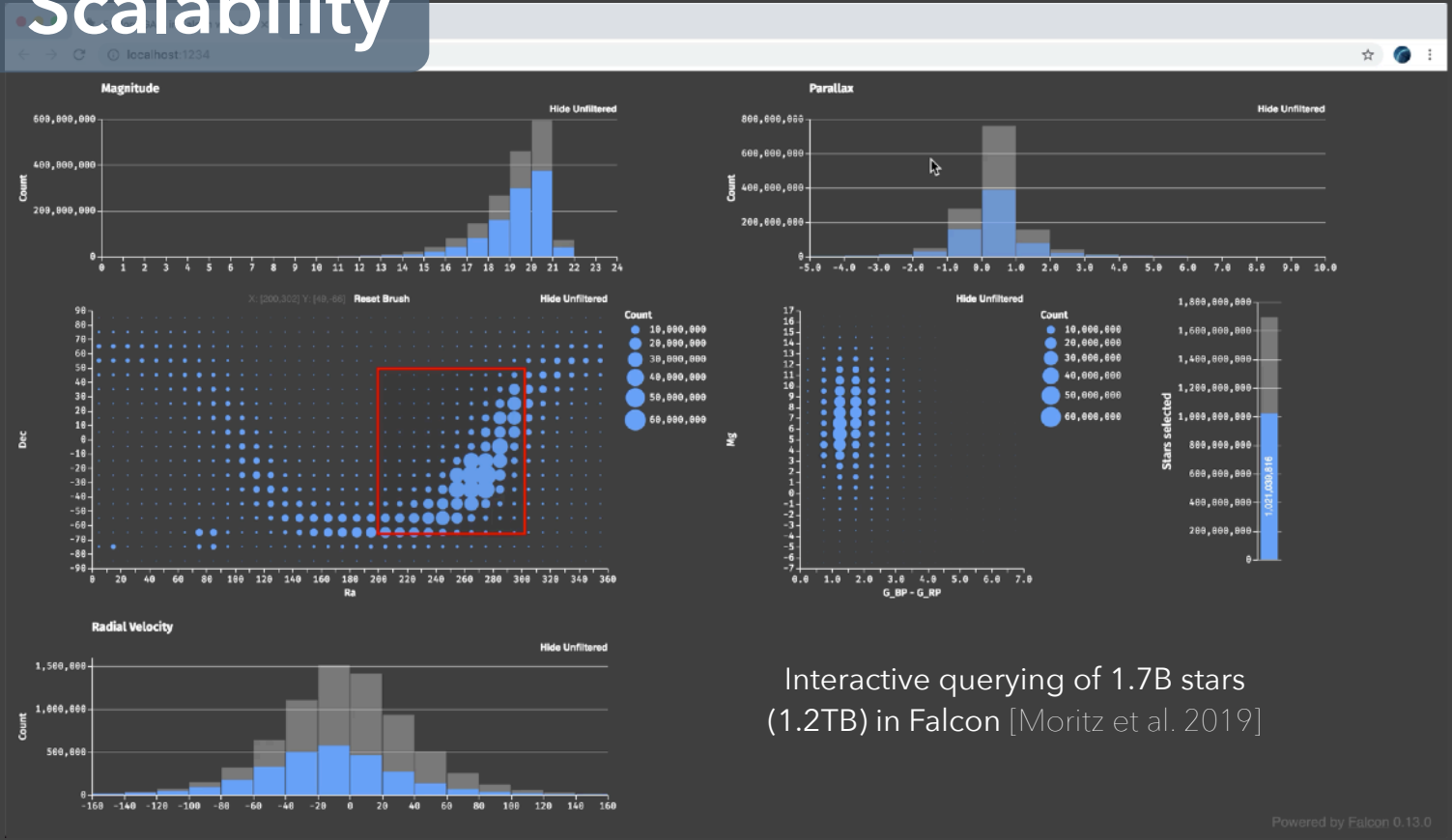


Degree-Of-Interest Trees [Heer & Card 04]

Uncertainty



Scalability



Interactive querying of 1.7B stars (1.2TB) in Falcon [Moritz et al. 2019]

Powered by Falcon 0.13.0

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

Lead Instructor

Jeffrey Heer OH: Tue 10-11am

Teaching Assistants

Shaan Chopra OH: Thu 1-2pm

Lisa Elkin OH: Mon 4:30-5:30pm

Heer Patel OH: Online / Ed or By Appt.

Luke Snyder OH: Wed 2-3pm

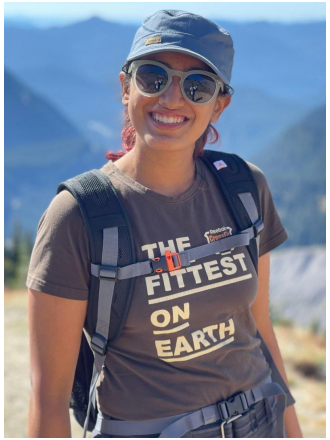
Shaan Chopra *(she/her)* | 4th year, CSE PhD

Research:

- Human-Computer Interaction
- AI & Personal Health Informatics
- Participatory & Inclusive Design of Health Technologies
- Personal Data Use in Clinical Settings
- Health Equity & Community-Based Health

Personal Interests / Hobbies:

- Outdoor / sports: rowing, hiking, biking, basketball, discus throw, swimming…
- Creative: painting, live sketching, crocheting
- Food-related: drinking mochas, baking & eating desserts



Office Hours:
TBD

https://shaan15.github.io/

Heer Patel

heerpate@cs.washington.edu

- 4th year BS/MS
- 3rd time TAing Data Viz
- **Interests**
  - Data Science
  - HCI
  - Business
- **Hobbies**
  - Squash (sport, not veggie)
  - Traveling
  - Henna
  - Anything crafty

Lisa Elkin (she/her)

Academic Background

BMath, C&O and Pure Math, University of Waterloo, 2012

MET, Entertainment Technology, Carnegie Mellon, 2015

MMath, Computer Science, University of Waterloo, 2018

PhD, UW CSE, 2018 - ???

TA Experience

Data Viz, HCI, Linear Algebra, Calculus, Intro CS, CS for non-majors

Hobbies

Skiing, reality TV, mediocre nail art, being obsessed with my dog

Winston Elkin

Academic Background

Doggy School Level 1*

PhD, UW CSE, 2019 - ???

Dissertation: Evaluating the Impact of Tree Species on a Dog's Desire to Pee on it: an Autoethnography

Hobbies

Barking at ghosts, barking at water bottles, hopefully not barking at you

* Indicates candidate did not complete all requirements but passed due to being very cute.

Luke Snyder

snyderl@cs.washington.edu

OH: Wed 2-3pm

Research

- Visualization and HCI
- Dynamically Interactive Visualization (DIVI)
    - Automatically add interaction to static charts
    - uwdata.github.io/divi
- Chart augmentations to aid learning

Technical Experience

- JavaScript / web programming, D3, Vega-Lite

For Fun

- Music, running, new cultures (India, Australia)
- Progressive Jazz, Weather Report, Pat Metheny

Lectures, Activities & Office Hours

Course sessions will alternate among lecture and in-class exercises. Thursdays will typically be activity days.

All lectures will be in-person and recorded.

Please attend in-person but **NOT** if you feel ill.

Office hours are a mix of in-person and Zoom.

Links for virtual office hours are on Canvas.

Use Ed to post questions and seek help!

Readings

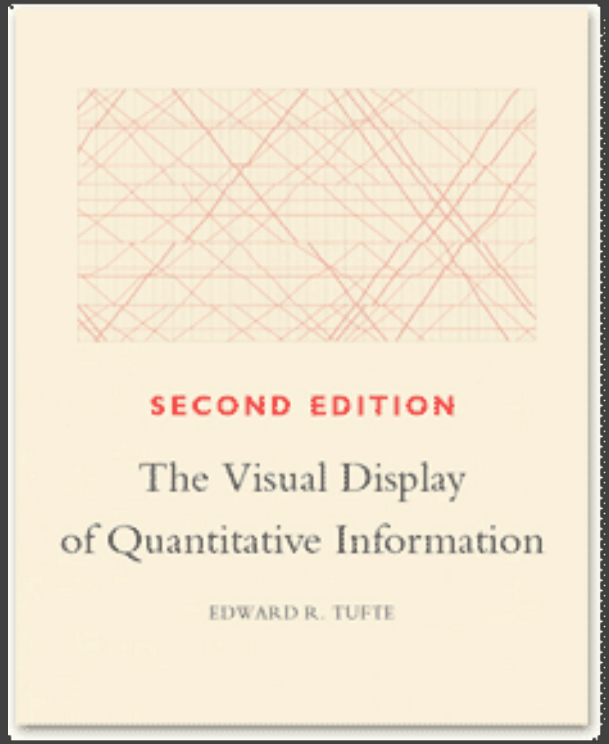
There is no one universal textbook on visualization!

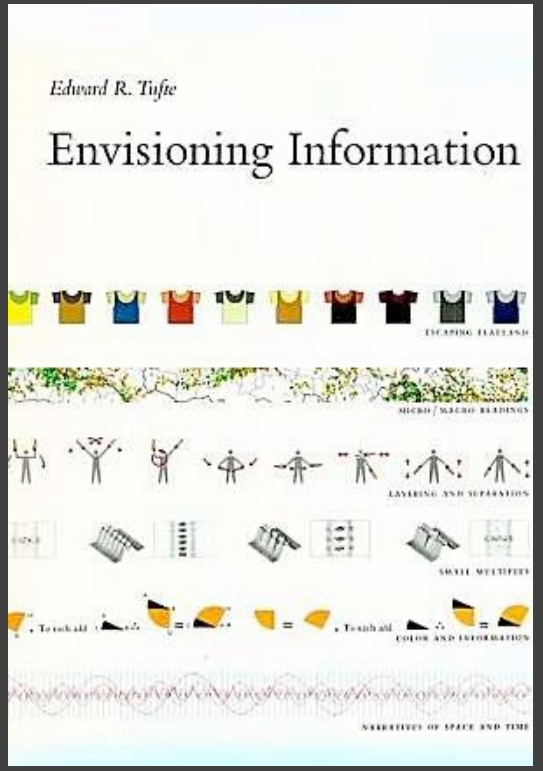
So we will draw on books, notebooks, and linked articles…

Material in class will loosely follow readings.

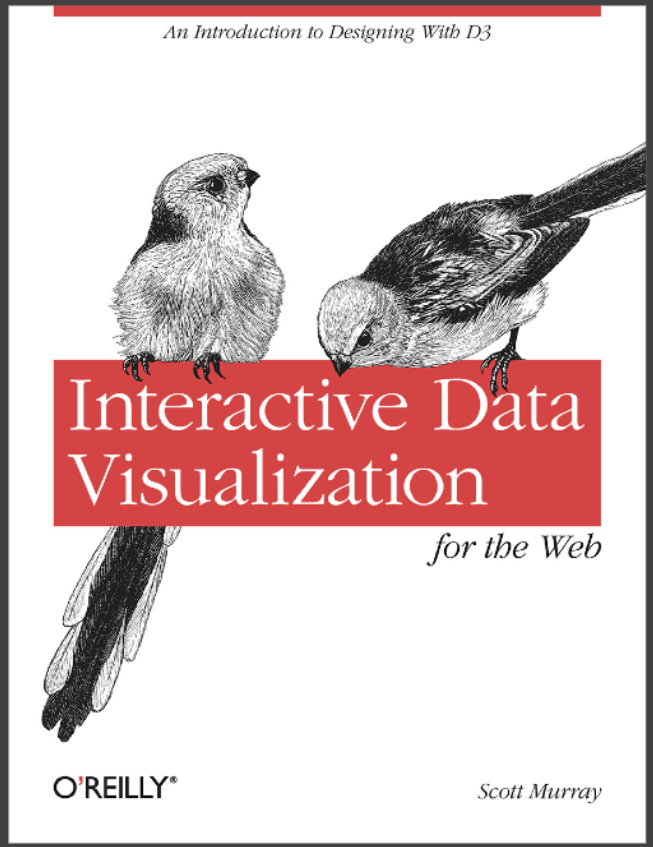
Readings should be read by start of class.

“Textbooks”


SECOND EDITION
The Visual Display
of Quantitative Information
EDWARD R. TUFTE


Edward R. Tufte
Envisioning Information

Optional Book

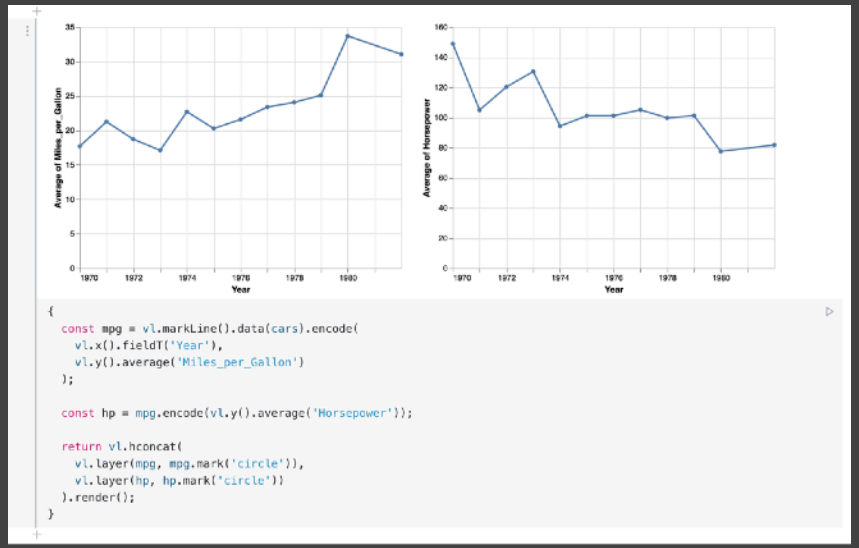


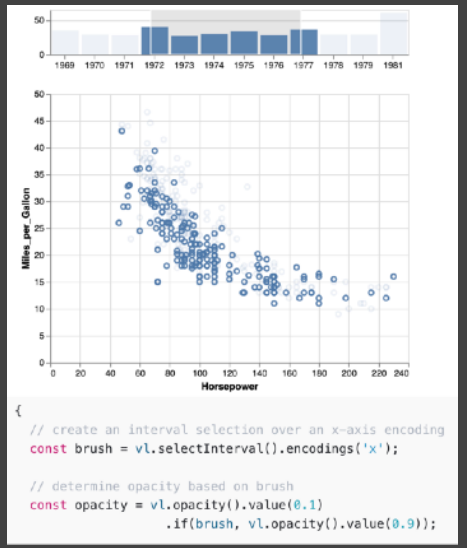
Interactive Data Visualization for the Web, 2nd Edition

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

We will be using D3 v7.
https://d3js.org

Interactive Notebooks





Hands-on engagement with course concepts and visualization tools (Vega-Lite / Altair), in both JavaScript (Observable) *and* Python (Jupyter).

Assignments

CP Class Participation (10%)

A1 Expository Visualization (10%)

A2 Deceptive Visualization (15%)

Peer Review (5%)

A3 Interactive Prototype (20%)

Peer Review (5%)

FP Final Project (35%)

Proposal

Demonstration Video

Final Prototype

Grading Philosophy

A *great* submission gets a *great grade* (A- to A, 3.6 – 3.8), but an *exceptional* grade (A+, 3.9 – 4.0) requires *exceptional* effort.

Example: Typical A1 grades (out of 10 points).

Everyone starts with a high score (9/10).

We then *deduct* points for errors and also *add* points for going above and beyond the assignment requirements.

The median score for A1 is typically 8.5 out of 10, which maps to an A-.

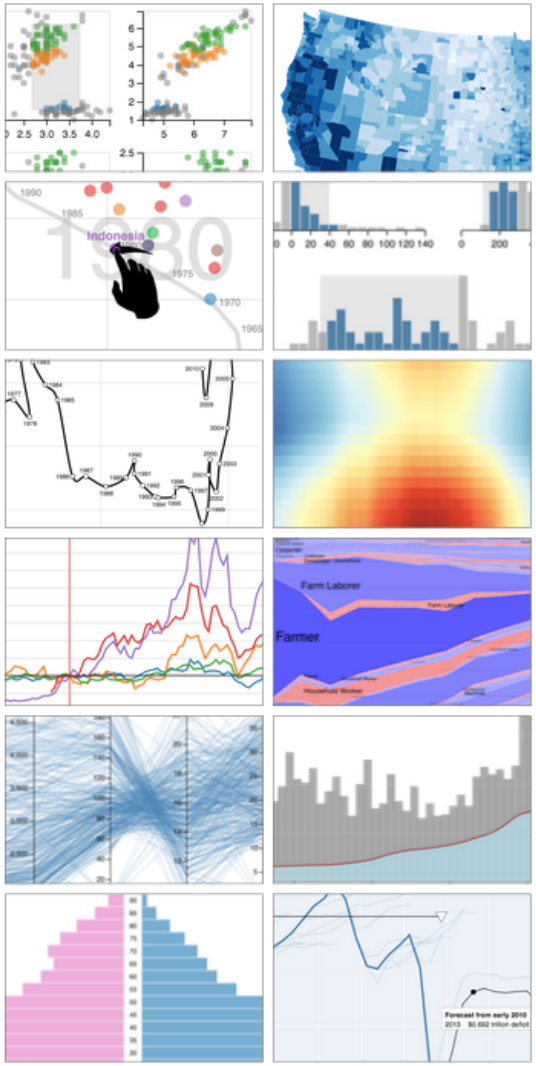
Course Participation

Lecture Attendance

Please attend lectures in person! That said, we know that illness, travel, etc. can prevent attendance. If you can't attend class, please review the recordings online.

Weekly Exercises

We have in-class exercises each week. Complete them even if you can't attend in person. We use "best-effort" grading, so it's OK if you don't complete everything during class time. Focus on assignments, not exercises, between sessions. You also get one exercise "pass".



Warm-Up Design Activity

Visual Encoding Exercise

5 17

How many visualizations can you think of for conveying these two numbers? Feel free to invent tasks or contexts. **Sketch as many as you can!**

Don’t stress over quality, go for quantity.

Time: ~5 minutes

Visual Encoding Exercise

5 17

Take a photo or screenshot of your visualizations, and post it to the shared thread on Ed.

Visual Encoding Exercise

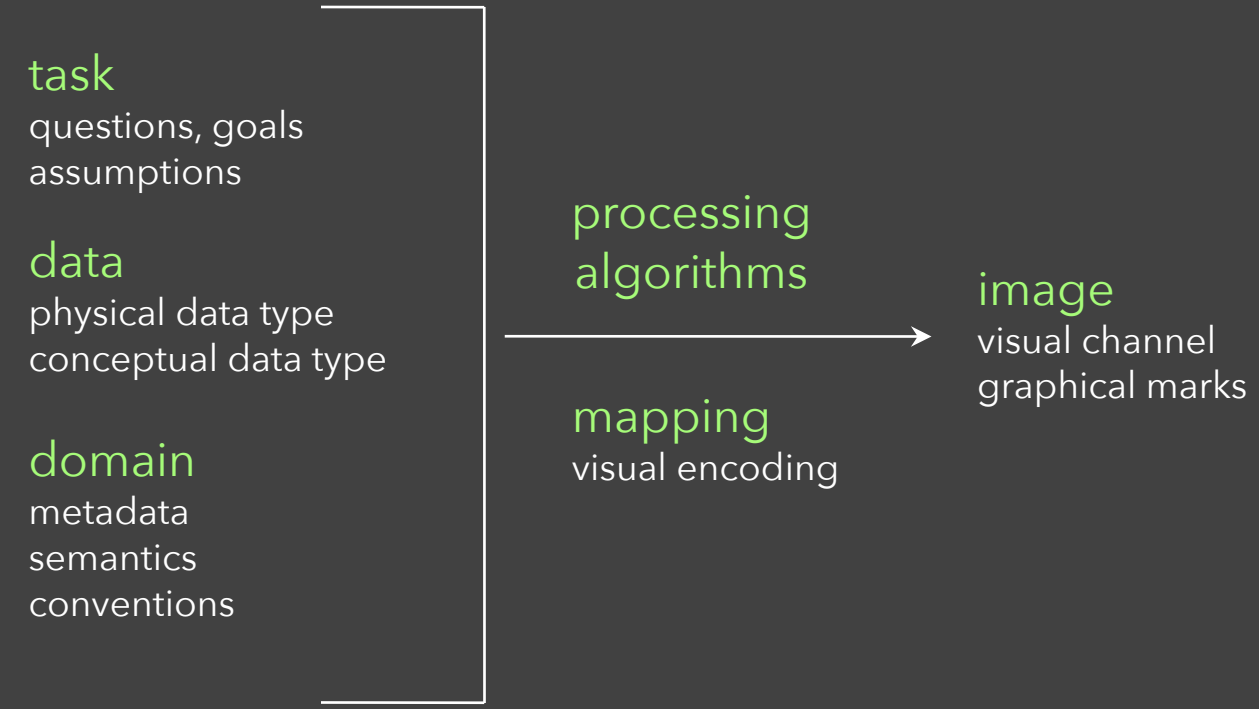
5 17

Share your designs with students near you. Introduce yourselves! Then compare your designs. How many ideas are the same? How many are different?

What do you find highly effective? Highly creative?

Visual Encoding Design

The Big Picture



Data Models

Represent data as a *table* (relation)

Each *row* (tuple) represents a record

Each *column* (field) represents a typed variable

Physical Type: integer, float, date, boolean, string…

Conceptual Type: temperatures, dollars, products…

For visualization it is helpful to classify fields according to the type of comparisons we wish to make:

Nominal (N), *Ordinal* (O), and *Quantitative* (Q) types

Nominal, Ordinal & Quantitative

Nominal, Ordinal & Quantitative

N - Nominal (labels or categories)

- Fruits: apples, oranges, …

Nominal, Ordinal & Quantitative

N - Nominal (labels or categories)

- Fruits: apples, oranges, …

O - Ordered

- Quality of meat: Grade A, AA, AAA

Nominal, Ordinal & Quantitative

N - Nominal (labels or categories)

- Fruits: apples, oranges, …

O - Ordered

- Quality of meat: Grade A, AA, AAA

Q - Interval (location of zero arbitrary)

- Dates: Jan, 19, 2006; Location: (LAT 33.98, LON -118.45)
- Only differences (i.e., intervals) may be compared

Nominal, Ordinal & Quantitative

N - Nominal (labels or categories)

- Fruits: apples, oranges, …

O - Ordered

- Quality of meat: Grade A, AA, AAA

Q - Interval (location of zero arbitrary)

- Dates: Jan, 19, 2006; Location: (LAT 33.98, LON -118.45)
- Only differences (i.e., intervals) may be compared

Q - Ratio (zero fixed)

- Physical measurement: Length, Mass, Time duration, …
- Counts and amounts

Nominal, Ordinal & Quantitative

N - Nominal (labels or categories)

- Operations: =, ≠

O - Ordered

- Operations: =, ≠, <, >

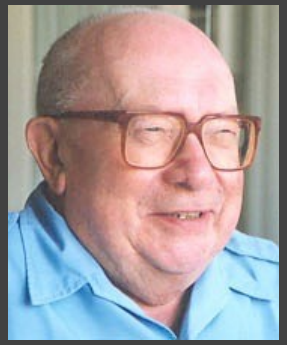
Q - Interval (location of zero arbitrary)

- Operations: =, ≠, <, >, -
- Can measure distances or spans

Q - Ratio (zero fixed)

- Operations: =, ≠, <, >, -, %
- Can measure ratios or proportions

Visual Language is a Sign System



Jacques Bertin

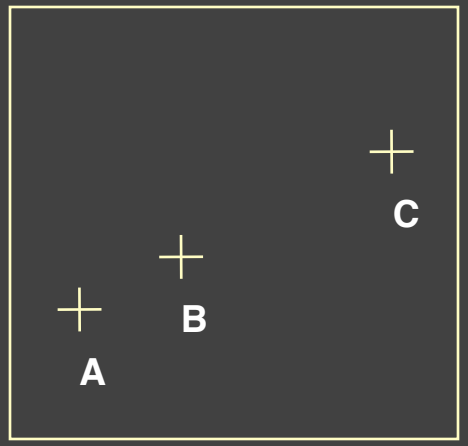
Images perceived as a set of signs

Sender encodes information in signs

Receiver decodes information from signs

Sémiologie Graphique, 1967

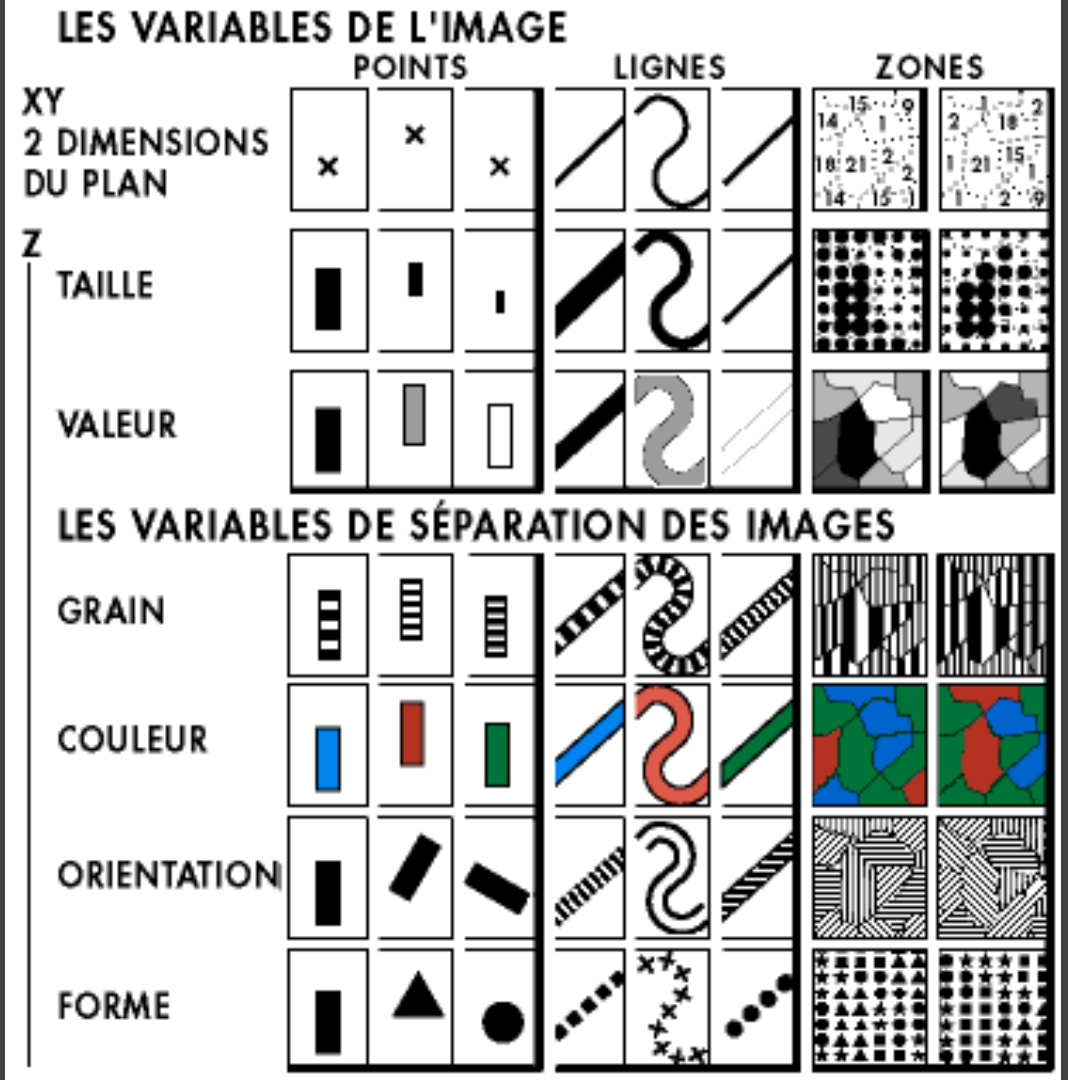
Bertin's Semiology of Graphics



1. A, B, C are distinguishable
2. B is between A and C.
3. BC is twice as long as AB.

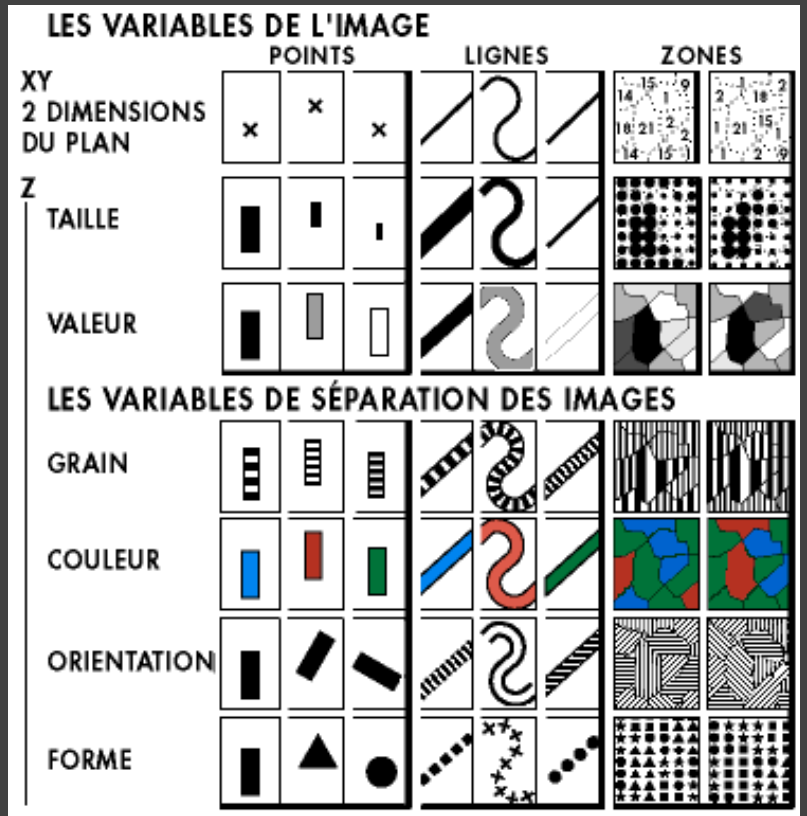
∴ Encode quantitative variables

"Resemblance, order and proportional are the three signfields in graphics." - Bertin


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

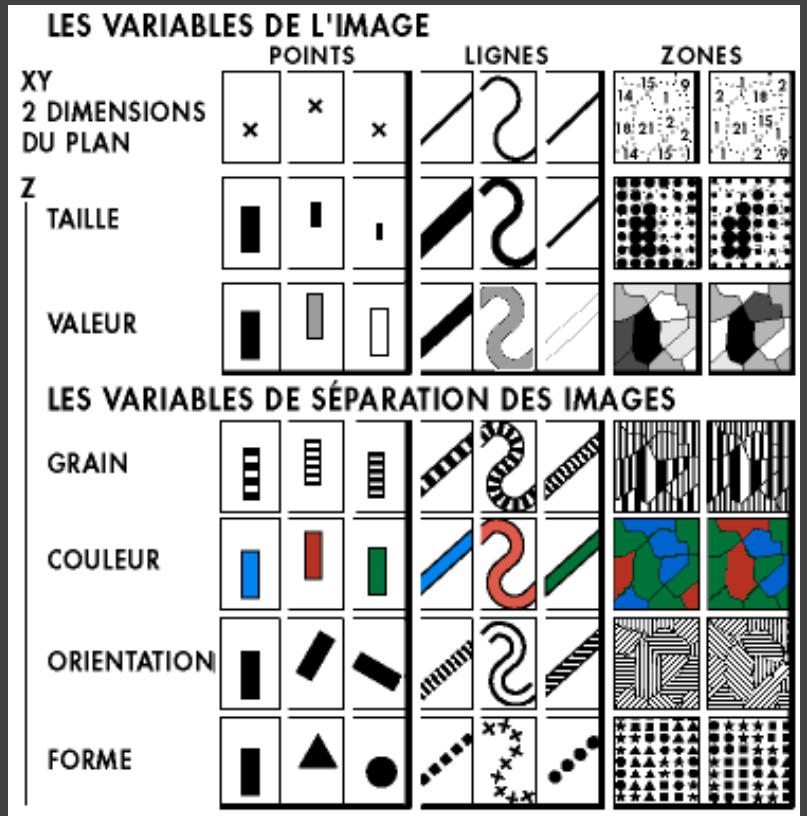
Visual Encoding Channels

Position (x 2)
Size
Value
Texture
Color
Orientation
Shape

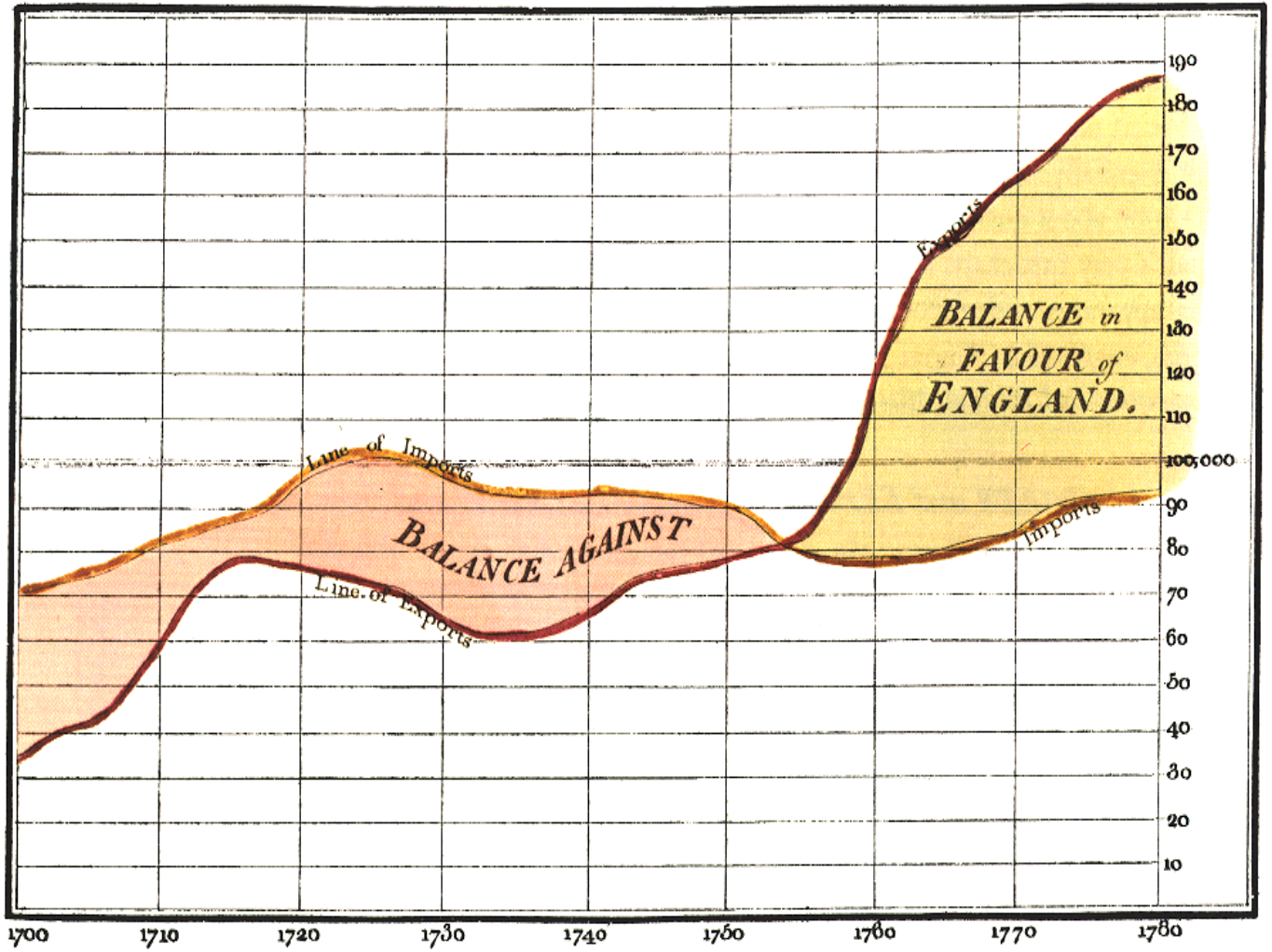


Visual Encoding Channels

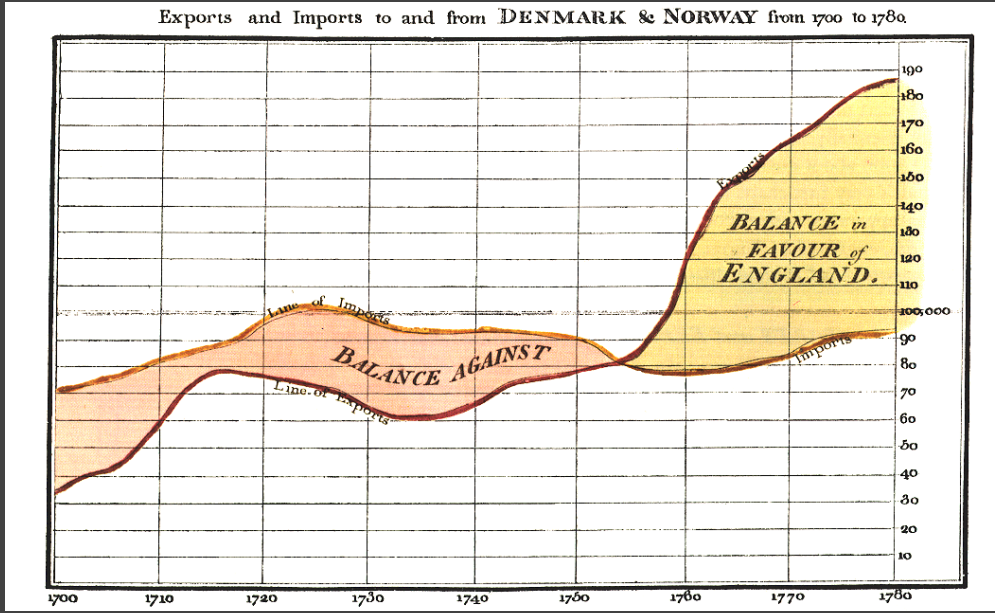
Position
Length
Area
Volume
Value
Texture
Color
Orientation
Shape
Transparency
Blur / Focus ...



Exports and Imports to and from DENMARK & NORWAY from 1700 to 1780.



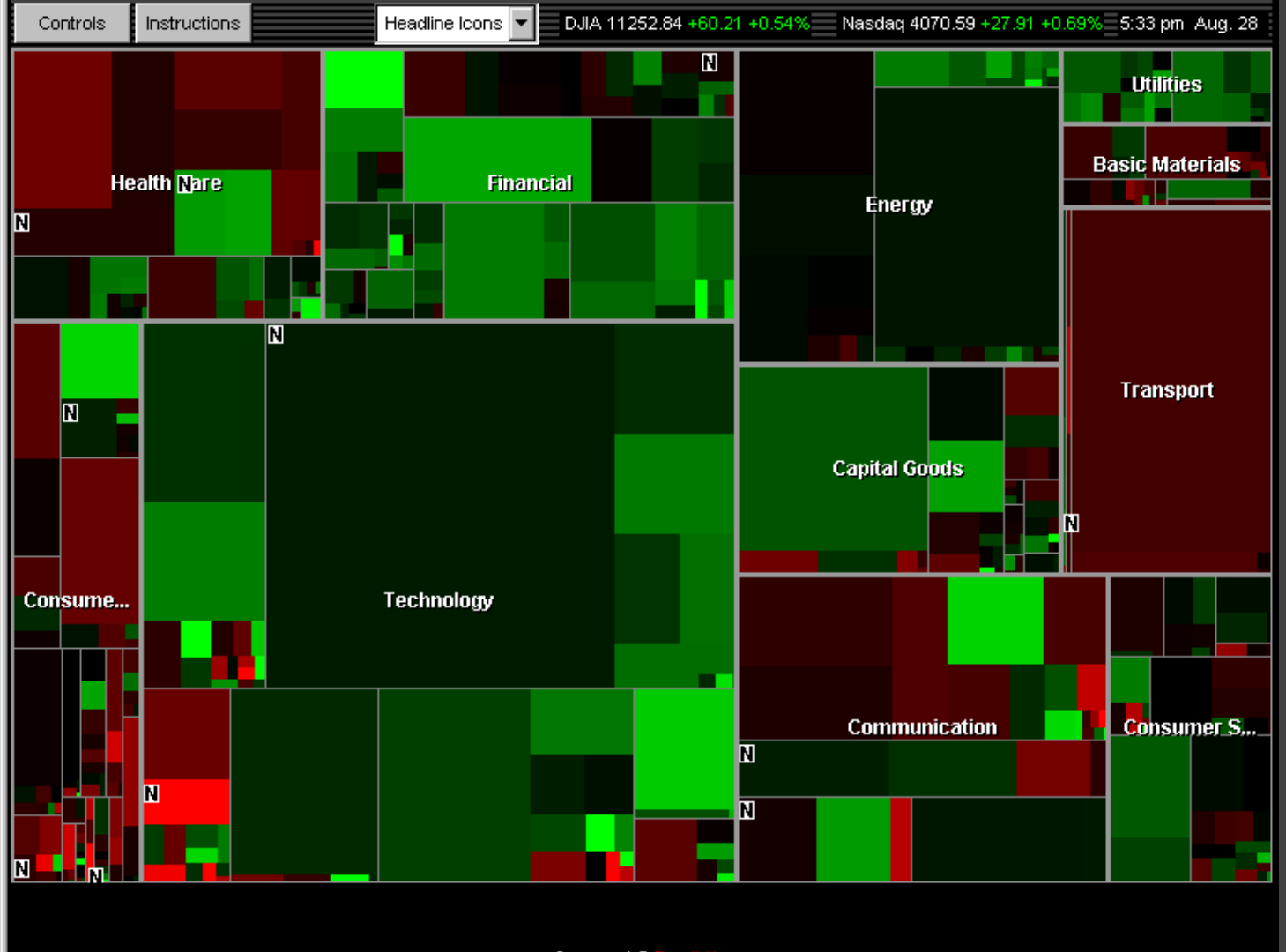
William Playfair, 1786



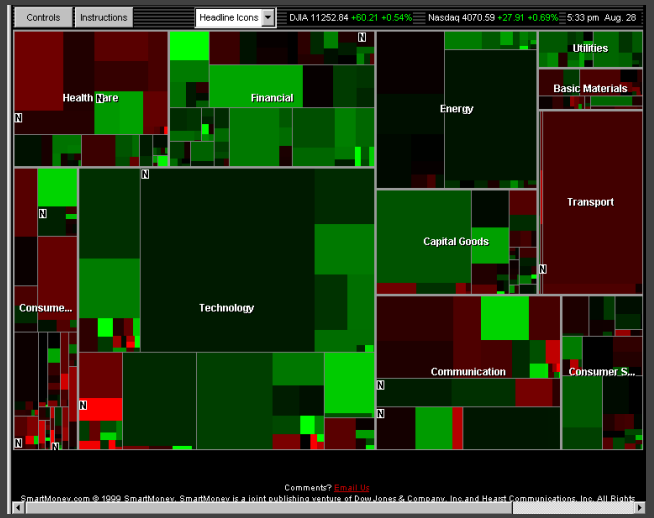
X-axis: year (Q)

Y-axis: currency (Q)

Color: imports/exports (N, O)


Controls
Instructions
Headline Icons
DJIA 11252.84 +60.21 +0.54%
Nasdaq 4070.59 +27.91 +0.69%
5:33 pm Aug. 28
Health Care
Financial
Energy
Utilities
Basic Materials
Transport
Capital Goods
Consume...
Technology
Communication
Consumer S...

Wattenberg's Map of the Market



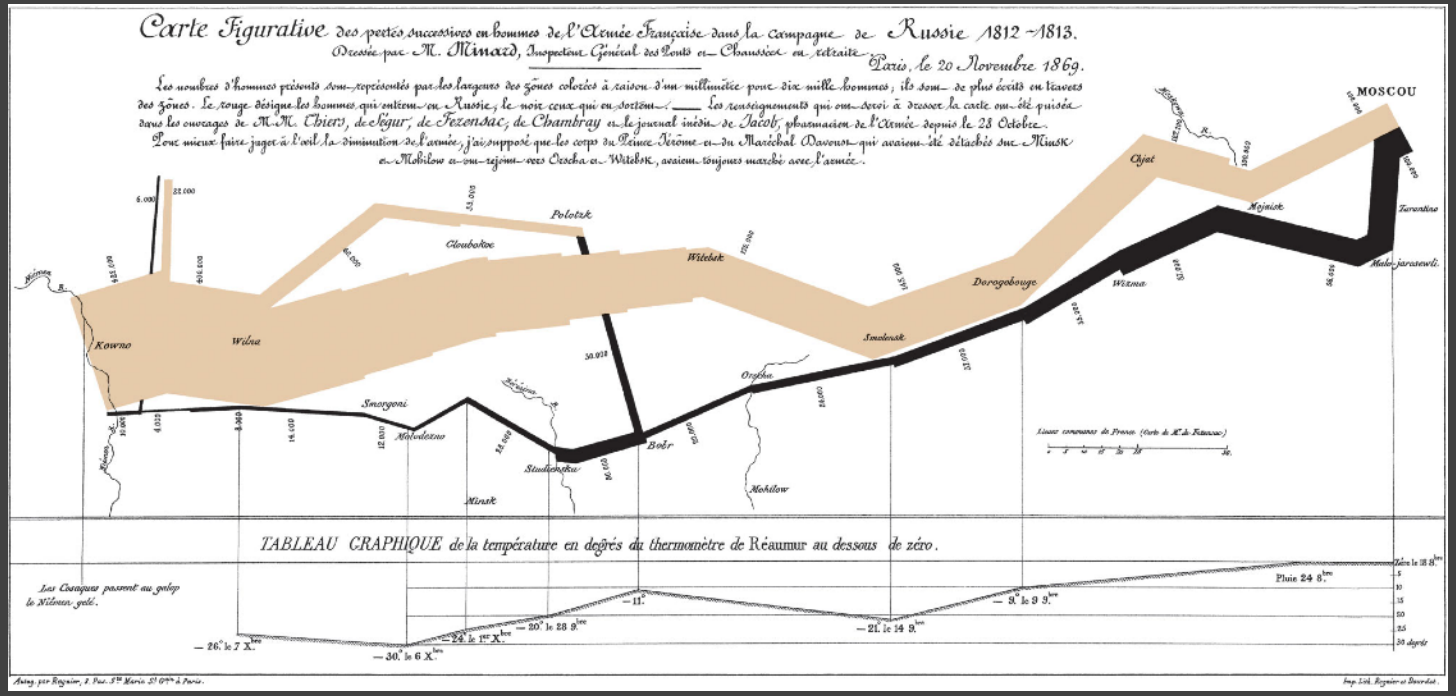
Rectangle Area: market cap (Q)

Rectangle Position: market sector (N), market cap (Q)

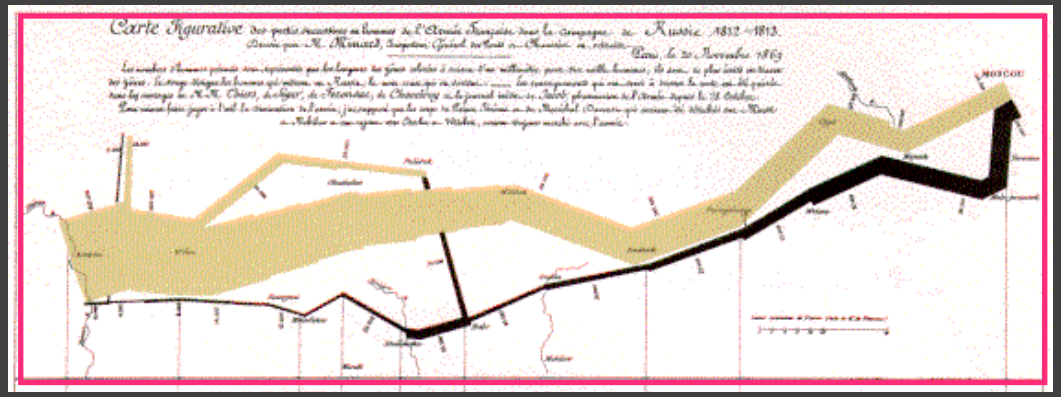
Color Hue: loss vs. gain (N, O)

Color Value: magnitude of loss or gain (Q)

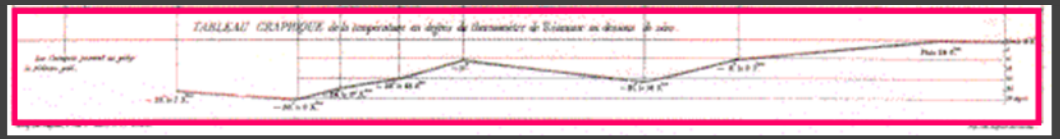
Minard 1869: Napoleon's March



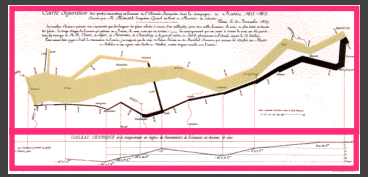
Single-Axis Composition



+



=



Mark Composition

Y-axis: temperature (Q)

\+ **X-axis**: longitude (Q) / time (O)

=

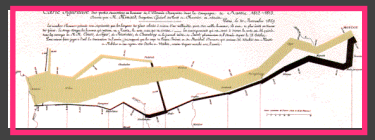
Temp over space/time (Q x Q)

Mark Composition

Y-axis: latitude (Q)

\+ **X-axis**: longitude (Q)

\+ **Width**: army size (Q)



= Army position (Q x Q) and army size (Q)

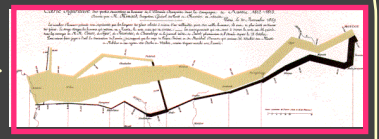
latitude (Q)

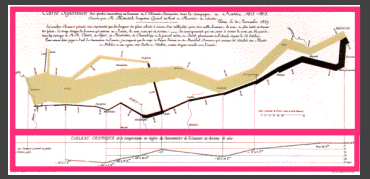
longitude (Q)

army size (Q)

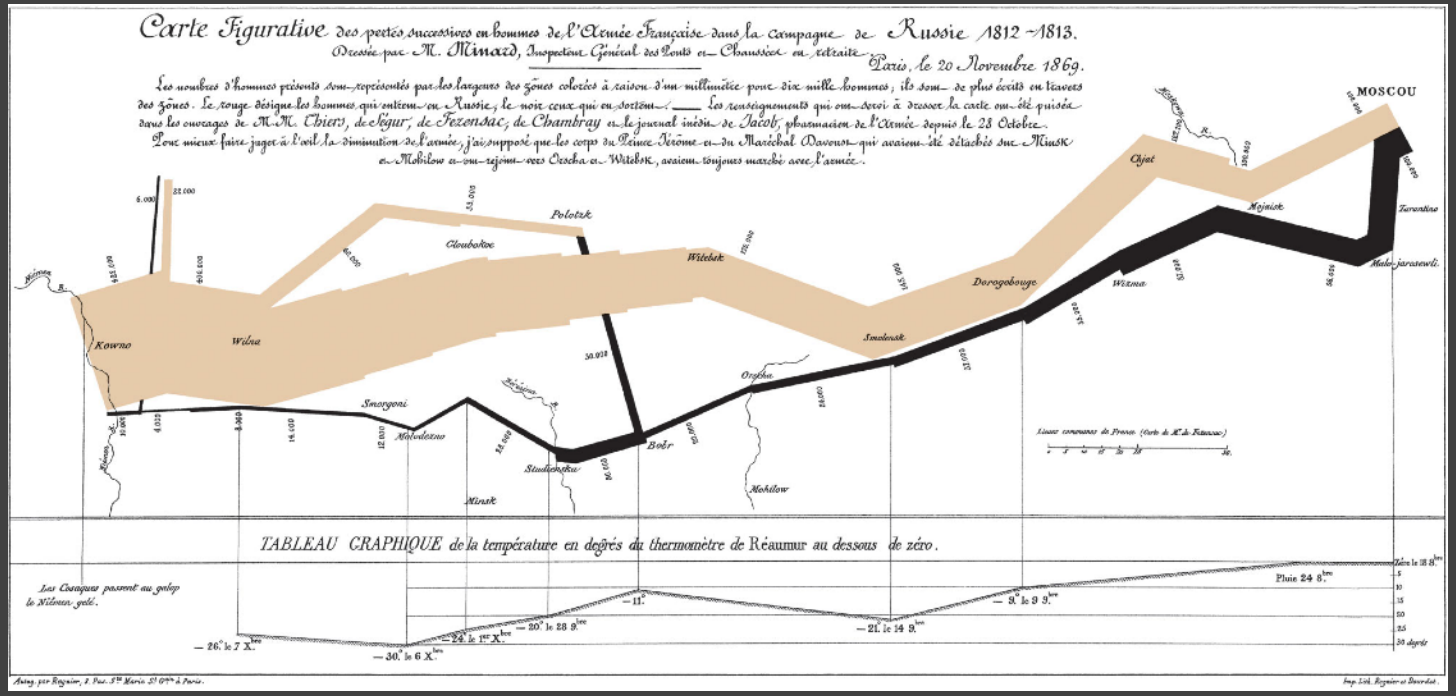
temperature (Q)

longitude (Q) / time (O)





Minard 1869: Napoleon's March



Depicts at least 5 quantitative variables. Any others?