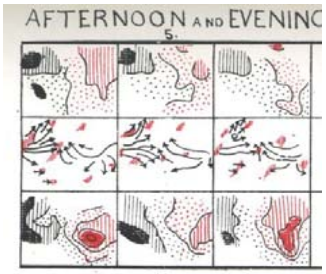



A Very Brief History of Visualization: Visions, Stories and Pictures (20,000 years in 45 minutes)

Michael Friendly, York University
@datavisFriendly
Chicago Humanities Festival, Nov. 11, 2018

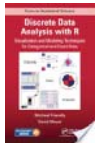
Slides: http://datavis.ca/papers/CHF-2x2.pdf

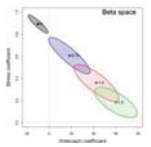
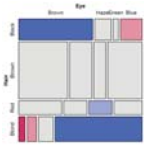
Introducing: me

I wear two hats, both reflected on my license plate

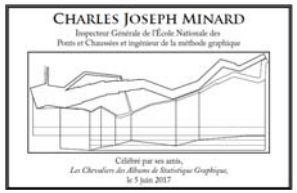
Yours to Discover

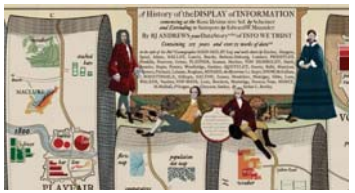
Statistical graphics developer (categorical & multivariate data analysis)

History of data visualization: *Milestones Project*; *A Gleam in the Mind's Eye* (2019)

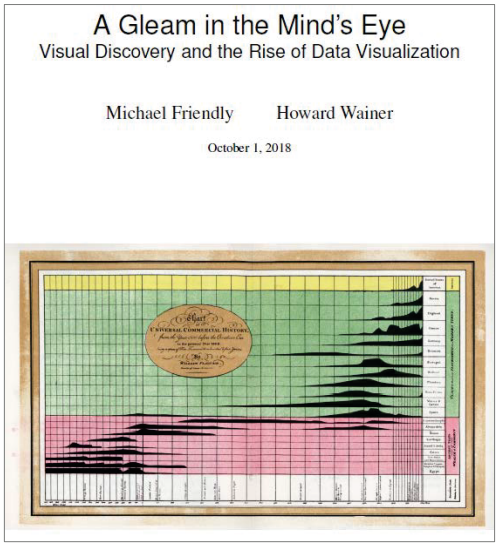


Plan for today

- Introduction: Context for history of data vis
  - Data visualization today: problems & challenges
  - Communication: Words, numbers & pictures
  - Visualization & scientific discovery
  - Prehistory of visualization
- The *Milestones Project*
  - Visualizing history
  - Milestones tour of the history of data vis
- The Golden Age of Statistical Graphics
  - A.-M. Guerry & the rise of social science
  - Visual thinking: C.J. Minard
  - Francis Galton's graphical discoveries
  - Graphical excellence: *Albums de Statistique Graphique*
- Golden Lessons

Obligatory shameless plug

This talk is based on our new book, Harvard University Press, 2019



Cover image: A long view of history--- William Playfair (1805), *Chart of Universal Commercial History*.

How and when did civilizations rise and fall from 1500 BCE to 1800 AD?

Datavis today: Problems & challenges

- Today: Immersed in a sea of data
  - fitness trackers, election polls, economic forecasts, what's trending on Twitter
- Big data, complex, high-dimensional problems
  - Personal:
    - how to monitor my heart health? blood sugar?
    - how to manage my investment portfolio?
  - Societal:
    - Tracking disease outbreaks of measles, Ebola, etc.
    - Understanding crime, gun violence, poverty, etc.
    - Effects of climate change on extreme weather, forest fires, etc.
- How can data vis help?
  - Role of graphics in communication & persuasion?

Powerful graphs: Measels and vaccines

Visualizing the impact of health policy interventions

In 2015 Tynan DeBold & Dov Friedman in the *Wall Street Journal* tried to show the effect of the introduction of vaccination programs in the US states on disease incidence, using color-coded heat maps for a variety of diseases

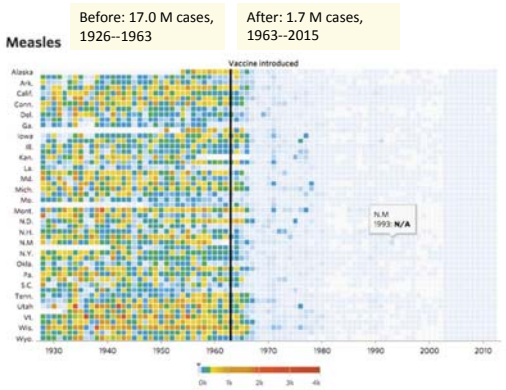
Measles was decimated!

The message hits you between the eyes!

Powerful graphs make comparison easy

In 2014, vaccination rates declined and measles re-emerged in those areas

Effective graphs can cure ignorance, but not stupidity.



Source: http://graphics.wsj.com/infectious-diseases-and-vaccines/

Gun homicides

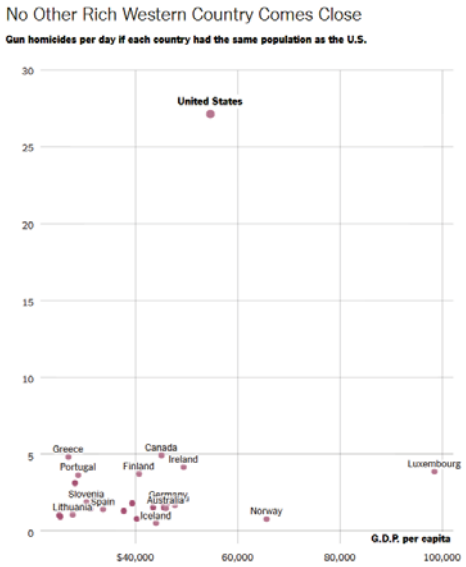
Compared to what??

Kevin Quealy and Margot Sanger-Katz in the *New York Times* compared gun homicides in the U.S. to other Western democracies.

The graph was carefully constructed to allow sensible comparisons.

The conclusion is inescapable

Causes are arguable, but the graph demands an explanation



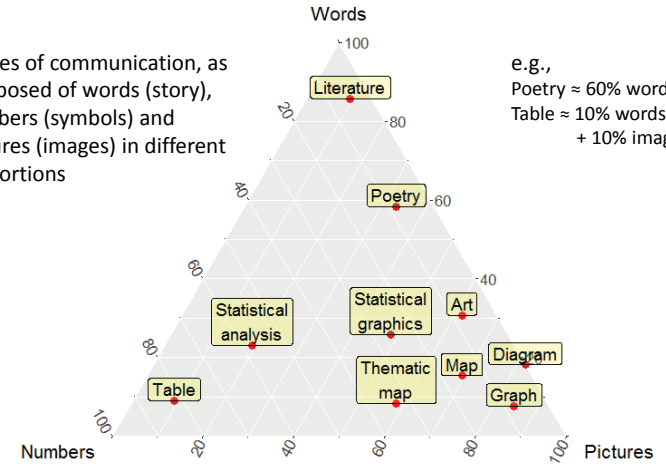
From: http://nyti.ms/28yRifm

Words, numbers and pictures

GRAPHIC CHICAGO HUMANITIES FESTIVAL 2018

Pictures and images in a wider context

Modes of communication, as composed of words (story), numbers (symbols) and pictures (images) in different proportions



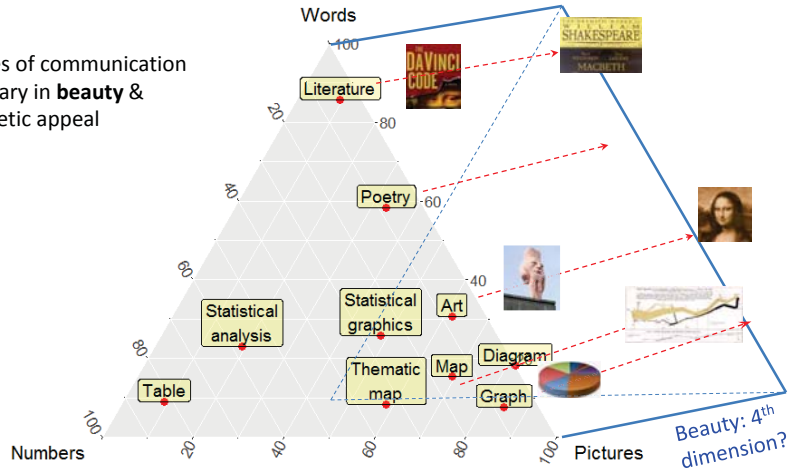
e.g.,
Poetry ≈ 60% words + 40% images
Table ≈ 10% words + 80% numbers + 10% images

Words, numbers and pictures

GRAPHIC CHICAGO HUMANITIES FESTIVAL 2018

Beauty: The 4th dimension

Modes of communication also vary in **beauty** & aesthetic appeal



Orienting Questions

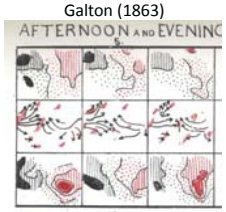
- Visualization in prehistory?
  - When did pictorial, symbolic representation arise?
  - Why? What purpose did it serve?
- How did the graphic depiction of numbers ("data") arise?
- Why?
  - What purpose did it serve?
  - What were the scientific questions promoting this?
  - How did graphic inventions make a difference?

Orienting Q: Visualization-based discoveries ??

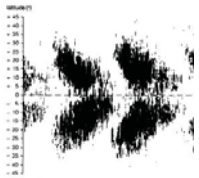
- When have graphics led to discoveries that might not have been achieved otherwise?
  - Snow (1854): cholera as a water-borne disease
  - Galton (1883): anti-cyclonic weather patterns
  - E.W. Maunder (1904): 11-year sunspot cycle
  - Hertzsprung/Russell (1911): spectral classes of stars

Snow (1854)

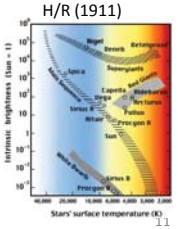
Galton (1863)



Maunder (1904)



H/R (1911)

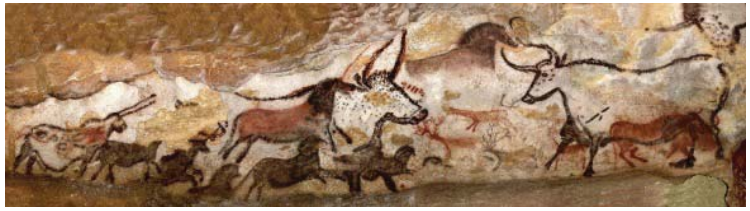


Prehistory of visualization

Lascaux Cave, ~ 15000 BCE, the "Sistine Chapel of pre-historic art"

Lascaux II, Main chamber

Lascaux: What were they thinking?



Lascaux II, Chamber of the Bulls

- Visual features:
  - show perspective, a sense of motion, rich use of color & texture
- What was the purpose?
  - Hunting success? NO (they hunted reindeer)
  - mostly symbolic – visual language, story of communal myths
- How to understand them?
  - A **cognitive revolution:** evidence for the modern human mind in Cro Magnon man
  - inner vision, visual thinking, mental imagery– a gleam in the mind's eye
- Other cave art [20000BC – 10000BC]: Altamira (Spain); Chauvet (France), Cueva de las Manos (Argentina), …

Prehistory: Diagrams, graphic stories

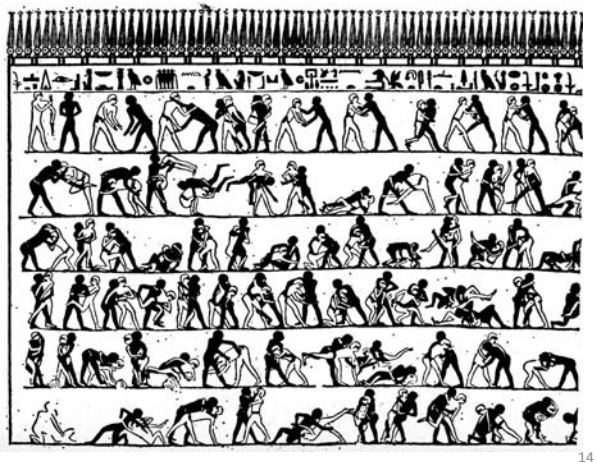
Early Egyptian animated graphic diagram

Wrestling scene on east wall, tomb of Baqt at Beni Hasan (ca. 2000 BCE).

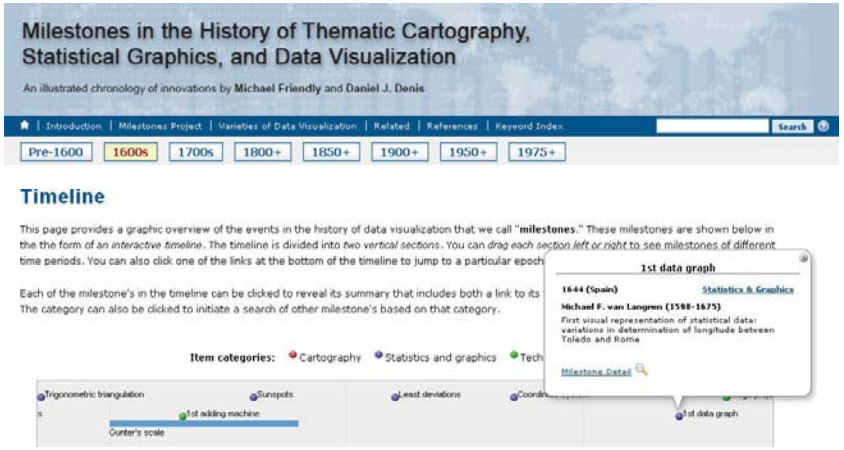
A **visual explanation** of a wrestling match

Anticipates modern graphic novels

Why? Perhaps Baqt's last lesson as a wrestler in his youth and later as a coach



Milestones Project



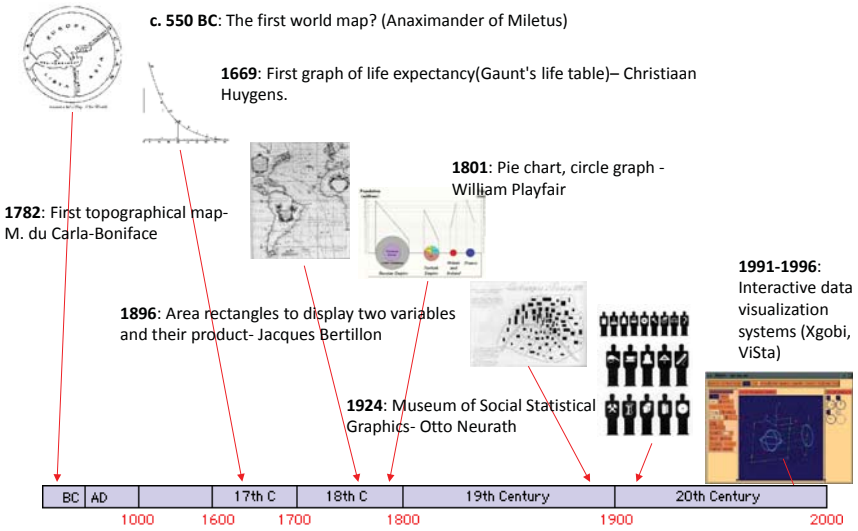
Web site: http://datavis.ca/milestones

Milestones: Roots of Data Visualization

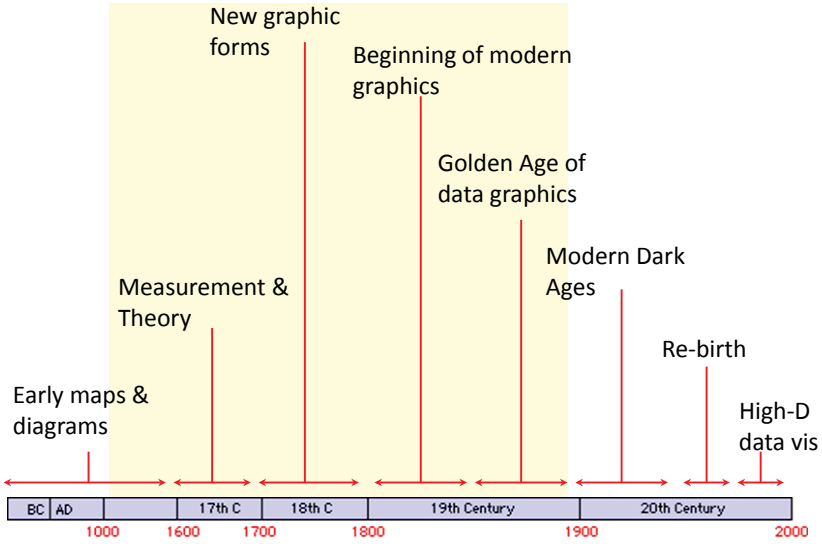
- **Cartography**: map-making, geo-measurement, thematic cartography, GIS, geo-visualization
- **Data**: population, economic, social, moral, medical, …
- **Statistics**: probability theory, distributions, estimation, models, stat-graphics,
- **Visual thinking**: geometry, functions, mechanical diagrams, EDA, …
- **Technology**: printing, lithography, computing, …
- **Aesthetics:** Graphs and diagrams as beautiful objects

Milestones: Content Overview

Every picture has a story – Rod Stewart

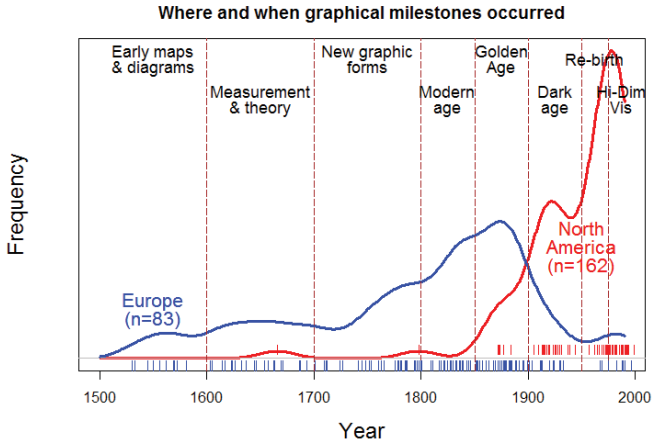


Parsing history: Milestones tour



Visualizing history

What does history look like? How do you draw time?



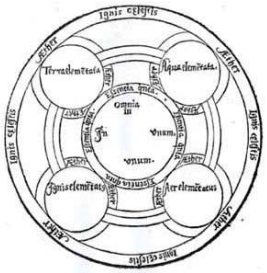
245 milestones events, classified by place of development

Pre 17th C: Early maps & diagrams

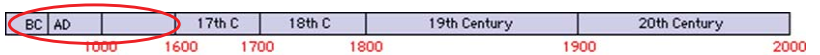
c. 550 BC: The first world map? (Anaximander of Miletus)

1350: Bar graph of theoretical function- Nicholas Oresme, France

1305: Mechanical diagram of knowledge- Ramon Llull, Spain

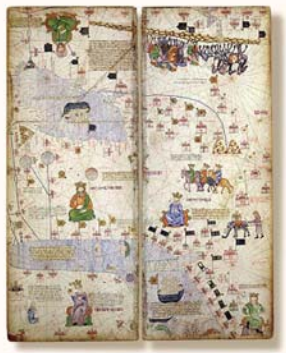


1375: Catalan Atlas, an exquisitely beautiful visual cosmography, perpetual calendar, and thematic representation of the known world- Abraham Cresques, Spain



1375: Catalan Atlas, an exquisitely beautiful visual cosmography, perpetual calendar, and thematic representation of the known world- Abraham Cresques, Majorca, Spain [BNF: ESP 30]

Western world

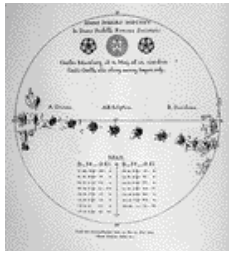


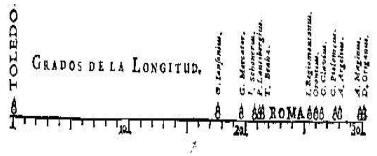
Eastern world (Marco Polo)

Perpetual calendar

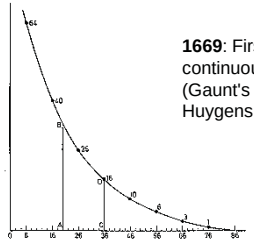
1600-1699: Measurement and Theory

1626: Visual representations used to chart the changes in sunspots over time- Christopher Scheiner

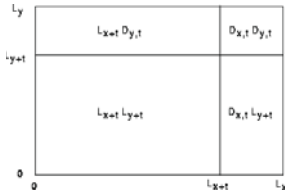




1644: First visual representation of statistical data- M.F. van Langren, Spain

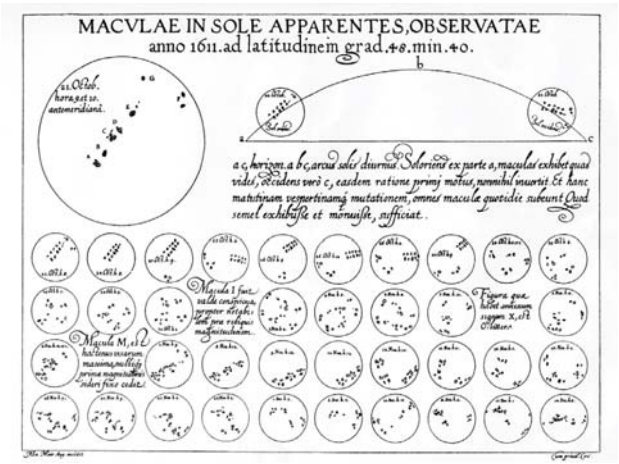


1669: First graph of a continuous distribution function (Gaunt's life table)– Christiaan Huygens.



1693: First use of areas of rectangles to display probabilities of independent binary events- Edmund Halley, England

Sunspots: Great graph, wrong theory

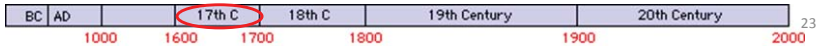


1626: Christopher Scheiner's graph of **changes** in sunspots over time.

- "small multiples"
- allows comparison
- multiple legends
- A+ for info design!

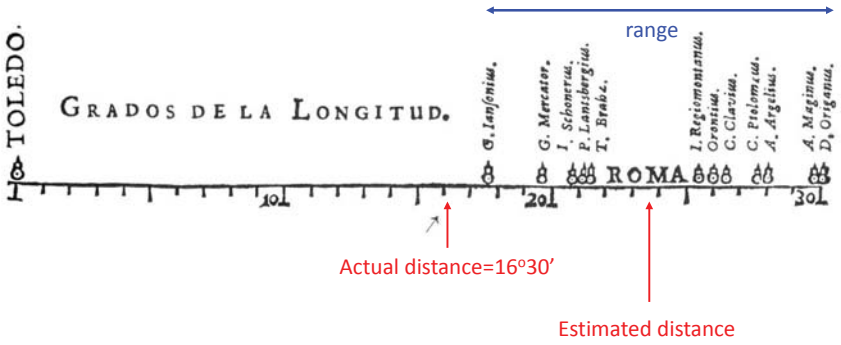
He argued (incorrectly) that these were evidence for solar satellites.

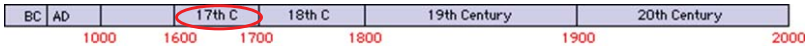
The idea of graphs for visualizing phenomena had arrived.



First statistical graph

1644: First visual representation of statistical data: determination of longitude between Toledo and Rome- M. F. van Langren, Spain



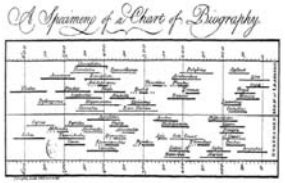


1700-1799: New graphic forms

Mapping the **invisible**, inventing new ways to visualize history & information

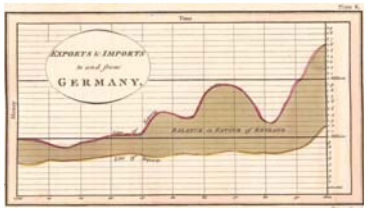
1701: Isobar map, lines of equal magnetic declination – Edmund Halley

1765: Historical time line (life spans of famous people) Joseph Priestley



1782: First topographical map- Marcellin du Carla-Boniface

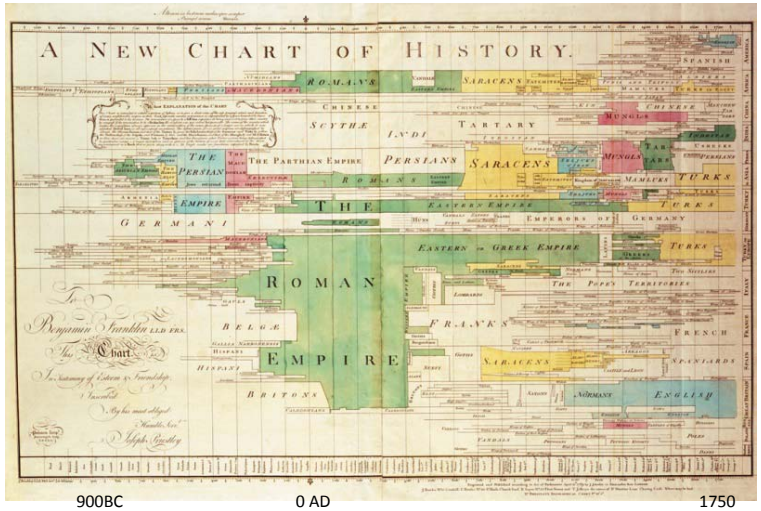
1786: Bar chart, line graphs of economic data- William Playfair



BC | AD | 17th C | 18th C | 19th Century | 20th Century

1000 1600 1700 1800 1900 2000

1769: Visualizing world history (duration, influence, domination) – Joseph Priestley



Place ↓ ↓

Africa

China

Turkey

Germany

Italy

France

Spain

G.B.

900BC 0 AD 1750

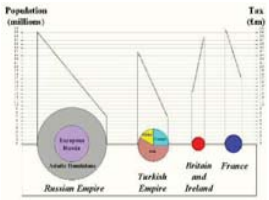
Time →→→→→→

https://en.wikipedia.org/wiki/A_New_Chart_of_History

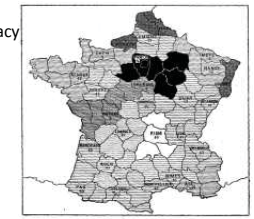
1800-1849: Beginning of modern data graphics

An age of data, and enthusiasm for graphics

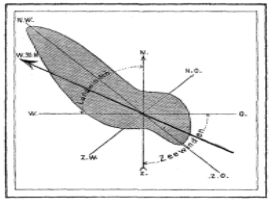
1801: Pie chart, circle graph invented- William Playfair

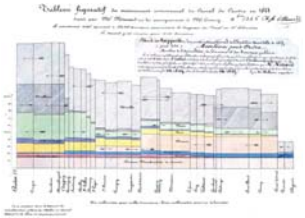


1819: First modern statistical map (illiteracy in France)- Charles Dupin



1843: Wind-rose (polar coordinates)- L. Lalanne





1844: variable-width, divided bars, area ~ cost of transport- C. J. Minard

BC | AD | 17th C | 18th C | 19th Century | 20th Century

1000 1600 1700 1800 1900 2000

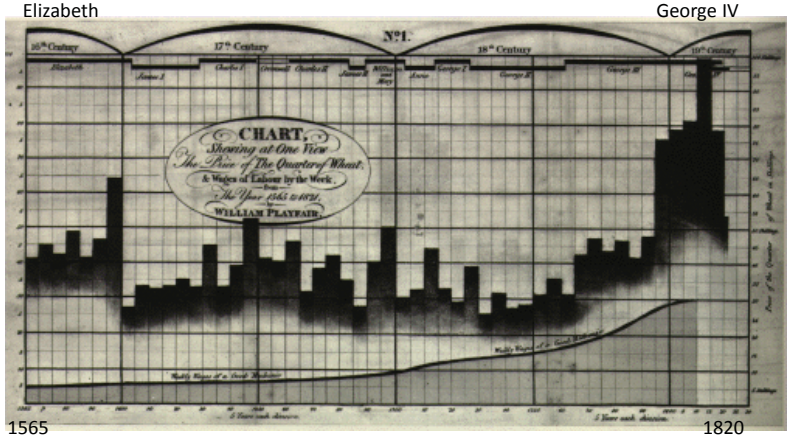
1821: Bar chart and line graph showing three time series: Price of wheat, weekly wages and reigning monarch over a 250+ year span- William Playfair

Elizabeth George IV

monarch

price of wheat

wages

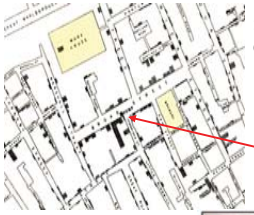


1565 1820

BC | AD | 17th C | 18th C | 19th Century | 20th Century

1000 1600 1700 1800 1900 2000

1850-1900: Golden Age



1855: Dot map of disease data (cholera)- John Snow

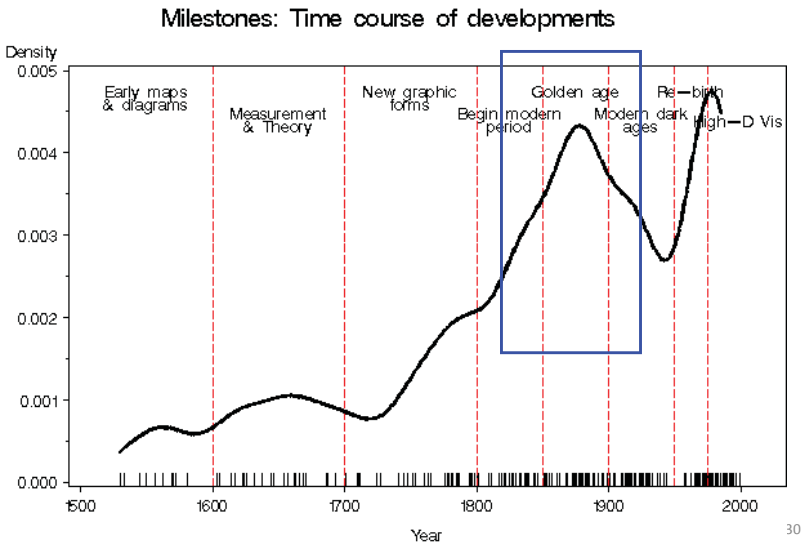
Broad St. pump

1879: Stereogram (3D population pyramid)- Luigi Perozzo

1884: Recursive multi-mosaic on a map- Emile Cheysson

1896: Area rectangles on a map to display two variables and their product- Jacques Bertillon

Why a golden age?



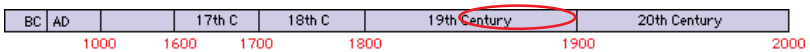
Stories from the Golden Age (1850-1900)

Stories:

- A.-M. Guerry & the rise of social science
- Graphic vision of C. J. Minard
- Galton's graphical discoveries
- Statistical albums

Themes:

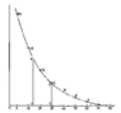
- Statistics: numbers of the state
- Rise of visual thinking
- Escaping flatland: 2D → 3D
- Visualization → Theory (graphic discovery)
- Data → Theory → Practice
- Graphical excellence



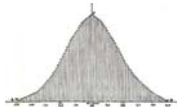
Big questions of the early 1800s

- Issues for European states
  - Demography: taxes, raising an army (Süssmilch, 1741)
  - "Statistik": Numbers of the state (Achenwall, 1748)
  - Social problems: crime, suicide, literacy, etc.
  - Disease epidemics, e.g., cholera

- Anthropometry: the measure of Man
  - Distributions of human characteristics
  - Birth, mortality, lifespan



- Beginnings of statistical theory and application
  - Normal dist^{n} (de Moivre, 1733)
  - *L'homme moyen* (Quetelet, 1835)



Big data of the early 1800s:
"An avalanche of social numbers"

- J.-B.J. Fourier: *Recherches statistique sur la ville de Paris* (1821-1829)
  - Massive tabulations: births, deaths (by cause), admission to insane asylums (age, sex, affliction)
- Ministry of Justice: *Compte generale (1825--)*
  - First national compilation of criminal justice data
  - All charges & dispositions, quarterly, 86 departments
- Other sources:
  - Bureau de Longitudes (illegitimate births)
  - Parent-Duchatelet (prostitution); Min. of War (desertions)
  - Suicide notes in Paris collected and analyzed for motives
- Social issues could now be addressed with **DATA**

1. A. M. Guerry and the rise of social science

Essai sur la statistique moral de la France
The launching pad of modern social science

- Presented to Academie des Sciences Français July 2, 1832
- First systematic analysis of comprehensive data on crime, suicide, and other social variables.
- Along with Quetelet (1831, 1835), established the study of "moral statistics" ↦ modern social science, criminology, sociology


ESSAI
LA STATISTIQUE
MORALE
DE LA FRANCE,
A. M. GUERRY,

Social context of crime in 1820s France

- Crime a serious concern:
  - Explosive growth in Paris
  - Widespread unemployment,
  - Emergence of "dangerous classes"
- Liberal ("philanthrope") view
  - Increase education
  - Better prison conditions, diet (bread ***and*** soup)
  - Religious instruction
- Conservative view
  - Build more prisons
  - Harsher treatment of recidivists
- Now, there was finally some DATA!

The discovery of "social facts"
Stability and Variation

Guerry's results were both compelling and startling:

- Rates of crime and suicide remained remarkably invariant over time, yet varied sytematically by region, sex of accused, type of crime, etc.
- In any given French city or department, almost the same number committed suicide, stole, gave birth out of wedlock, etc.

Year	1826	1827	1828	1829	1830	Avg
Sex			All accused (%)			
Male	79	79	78	77	78	78
Female	21	21	22	23	22	22
Age			Accused of Theft (%)			
16–25	37	35	38	37	37	37
25–25	31	32	30	31	32	31
Crime			Committed in summer (%)			
Indecent assault	.	36	36	35	38	36
Assault & battery	.	28	27	27	27	28

The discovery of "social facts"

Social laws á la physical laws

Do crime and other moral variables represent:

- structural, lawful characteristics of society, or are they
- simply indicants of individual behaviour?

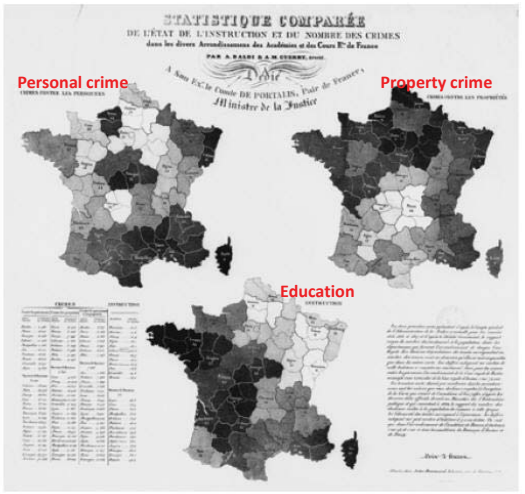
Guerry argued:

> *Each year sees the same number of crimes of the same degree reproduced in the same regions.(Guerry, 1833, p.10)*

> *... We are forced to recognize that the facts of the moral order are subject, like those of the physical order, to invariable laws (Guerry, 1833, p14)*

1829: *Statistique comparée de l'état de l'instruction...*

- First shaded thematic maps of crime data
- First comparative maps of social data
- ↦ crime against persons seemed inversely related to crime against property!
- Instruction: ↦ *France obscure* and *France éclairée* (Dupin, 1826)
- North of France highest in education, but also in property crime!



1833: *Essai sur la statistique morale de la France*

- Divided the 86 departments into 5 regions
- Supplemented data from the *Compte général* with:
  - Suicides in Paris, 1794–1832
  - Prostitutes in Paris (Parent-Duchâtelet)
  - Wealth (taxes per inhabitant)
  - Distribution of clergy
  - ...
- First study to use crime data to 'test' hypotheses
- Attracted widespread interest in Europe

Guerry's 1833 map of literacy in France

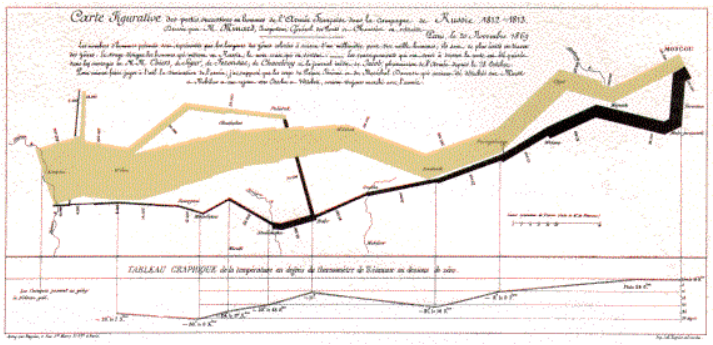
1833: Semi-graphic tables

Crimes against persons

- Indecent assault on adults (*viol sur des adultes*) decreases with age
- Indecent assault on children increases with age (top for 70+)
- Paricide rises to max at age 60–70

Figure: Ranking of crimes against persons at different ages

2. The graphic vision of C. J. Minard



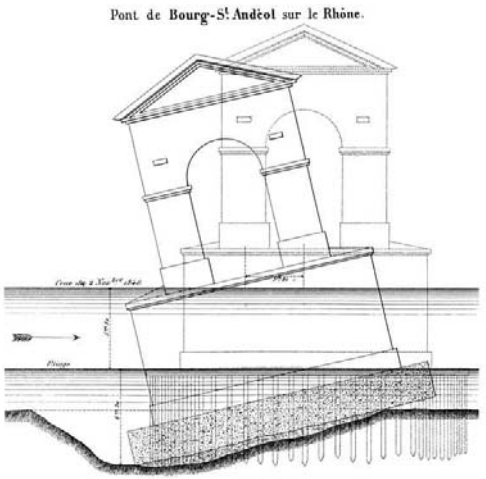
- Marey (1878): *"defies the pen of the historian in its brutal eloquence"*
- Tufte (1983): *"the best statistical graphic ever produced"*

Visual thinking, visual explanation

Minard's main career was a as a civil engineer for the ENPC (bridges & roads)

1840: Why did the bridge at Bourg-St. Andèol collapse?

Minard's report consisted essentially of this self-explaining diagram.



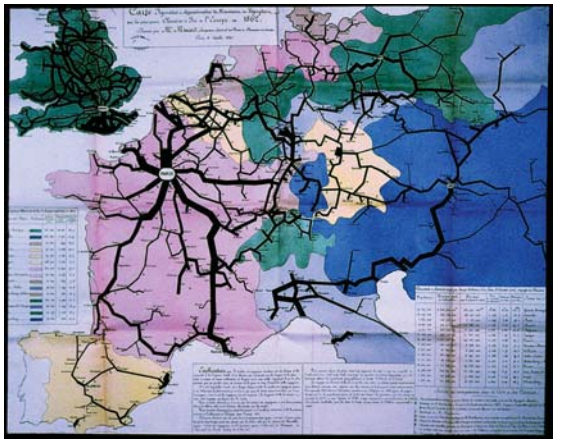
Big questions of the mid 1800s

- 1830—1860: emergence of modern French state, dawn of globalization
- Trade, commerce, transportation:
  - Where to build railroads, canals?
  - How to compete with imports/exports?
  - Visualizing changes over time, differences over space
  - → Flow maps and other graphical innovations
- These questions motivated the Golden Age.

See: Friendly, M. (2008). The Golden Age of Statistical Graphics, *Statistical Science, 23*, 502-535

Flow maps as visual tools

Transport of passengers on the principal railroads in Europe in 1862



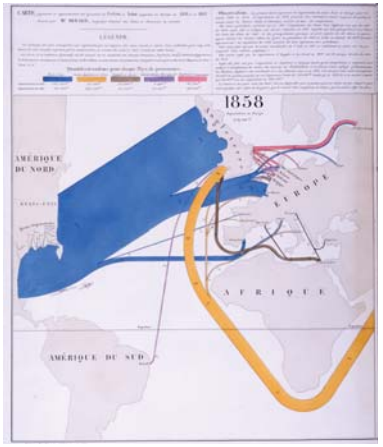
The dominant principle which characterizes my graphic tables and my figurative maps is to make immediately appreciable to the eye, as much as possible, the proportions of numeric results.

...Not only do my maps speak, but even more, they count, they calculate by the eye.

-- Minard (1862)

Effect of US Civil War on cotton trade

Before



After

3. Galton's visual discoveries-
Bivariate normal correlation surface (1886)

Table 9.1 One of Galton's correlation tables

Height of the mid-parent in inches	Height of the adult child													
	<61.7	62.2	63.2	64.2	65.2	66.2	67.2	68.2	69.2	70.2	71.2	72.2	73.2	>73.7
>73.0	—	—	—	—	—	—	—	—	—	—	—	1	3	—
72.5	—	—	—	—	—	—	—	1	2	1	2	7	2	4
71.5	—	—	—	—	1	3	4	3	5	10	4	9	2	2
70.5	1	—	1	—	1	1	3	12	18	14	7	4	3	3
69.5	—	—	1	16	4	17	27	20	33	25	20	11	4	5
68.5	1	—	7	11	16	25	31	34	48	21	18	4	3	—
67.5	—	3	5	14	15	36	38	28	38	19	11	4	—	—
66.5	—	3	3	5	2	17	17	14	13	4	—	—	—	—
65.5	1	—	9	5	7	11	11	7	7	5	2	1	—	—
64.5	1	1	4	4	1	5	5	—	2	—	—	—	—	—
<64.0	1	—	2	4	1	2	2	1	1	—	—	—	—	—
Totals	5	7	32	59	48	117	138	120	167	99	64	41	17	14
Medians	—	—	66.3	67.8	67.9	67.7	67.9	68.3	68.5	69.0	69.0	70.0	—	—

Source: Galton (1886), p. 68.

Visual smoothing → Insight

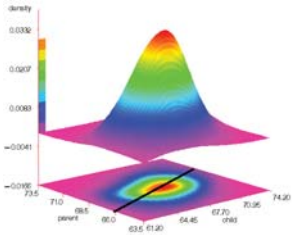
Table 9.1 One of Galton's correlation tables

Height of the mid-parent in inches	Height of the adult child													
	<61.7	62.2	63.2	64.2	65.2	66.2	67.2	68.2	69.2	70.2	71.2	72.2	73.2	>73.7
>73.0	—	—	—	—	—	—	—	—	—	—	—	1	3	—
72.5	—	—	—	—	—	—	—	1	2	1	2	7	2	4
71.5	—	—	—	—	1	3	4	3	5	10	4	9	2	2
70.5	1	—	1	—	1	1	3	12	18	14	7	4	3	3
69.5	—	—	1	16	4	17	27	20	33	25	20	11	4	5
68.5	1	—	7	11	16	25	31	34	48	21	18	4	3	—
67.5	—	3	5	14	15	36	38	28	38	19	11	4	—	—
66.5	—	3	3	5	2	17	17	14	13	4	—	—	—	—
65.5	1	—	9	5	7	11	11	7	7	5	2	1	—	—
64.5	1	1	4	4	1	5	5	—	2	—	—	—	—	—
<64.0	1	—	2	4	1	2	2	1	1	—	—	—	—	—
Totals	5	7	32	59	48	117	138	120	167	99	64	41	17	14
Medians	—	—	66.3	67.8	67.9	67.7	67.9	68.3	68.5	69.0	69.0	70.0	—	—

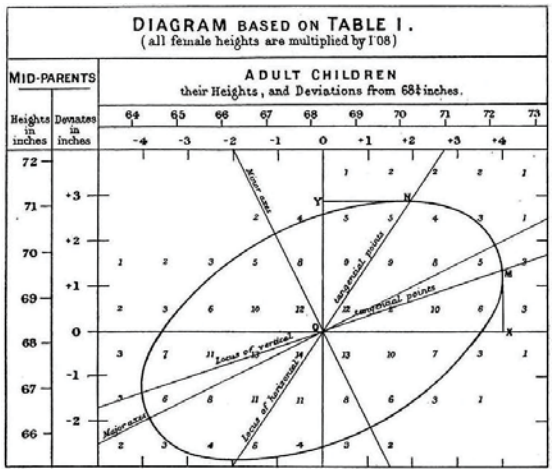
Source: Galton (1886), p. 68.

Visual insight → Theory

- Level curves are **ellipses**
- Regression lines are loci of conjugate **tangents**



… that Galton should have evolved all this … is to my mind one of the most note-worthy scientific discoveries arising from analysis of pure observation (Pearson 1920, p37)



Galton (1886, Pl X): Smoothed contours of heights of parents and children

Galton's discovery of weather patterns-

Perhaps the most notable *purely graphic* discovery ever!

METEOROGRAPHICA,

OR

METHODS OF MAPPING THE WEATHER;

ILLUSTRATED BY UPWARDS OF 600 PRINTED AND LITHOGRAPHED DIAGRAMS

REFERRING TO

THE WEATHER OF A LARGE PART OF EUROPE,

During the Month of December 1861.

By FRANCIS GALTON, F.R.S.

(Galton, 1863)

Method: All weather stations across Europe asked to record data 3x/day for all of Dec., 1861

Data: recordings of barometric pressure, wind dir/speed, rain, temp., cloud: 3x/day, 50 weather stations in Europe.

Graphic analysis: 3x31=**93** maps, each with multivariate glyphs showing all variables

Visual ideas:
- Iconic symbols
- Multivariate glyphs (stamps!)

Visual abstraction → Patterns

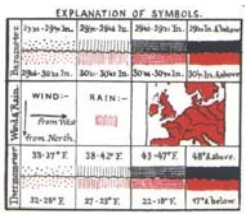
How to see patterns of geographical variation over time?
- Iconic symbols on a geographical grid
- "Small multiples:" separate graphs laid out for direct comparison

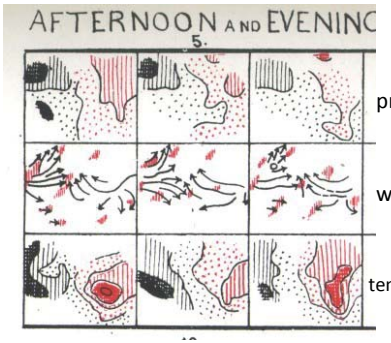
Symbols in Barometrical Charts.

	Inches. Inches.	Inches. Inches.	Inches. Inches.	Inches.
Black -	29.95 to 29.71	29.70 to 29.46	29.45 to 29.21	29.20 and below.
	○	⊙	✳	●
Red -	29.96 to 30.20	30.21 to 30.45	30.46 to 30.70	30.71 and above.

Visual abstraction → Patterns

What varies with what, over time and space?
- mini, abstract maps: vars x TOD
- iso-contours, shading to show equivalence
- arrows to show wind direction





Data for Dec 5, 1861

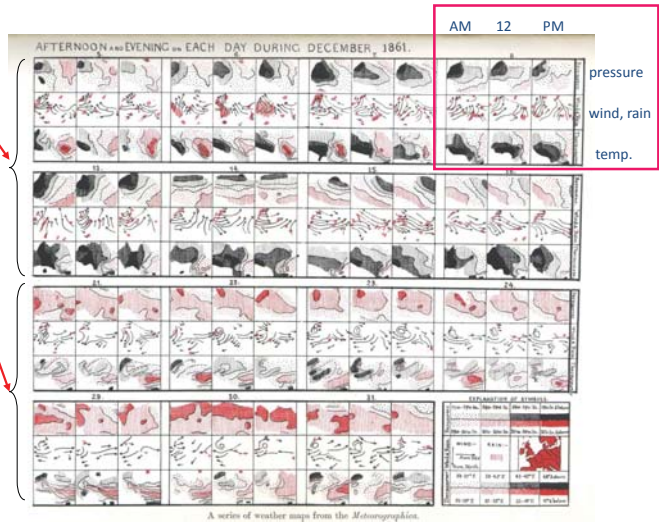
The large picture → Insight

Pattern:
Low pressure (black) in early Dec. → CCW wind

High pressure (red) in late Dec. → CW wind

Graphic: 3x3x31 grid, mapping {pressure, wind/ rain, temperature} x {AM, 12, PM} x day {1:31}

(try this with your software!)

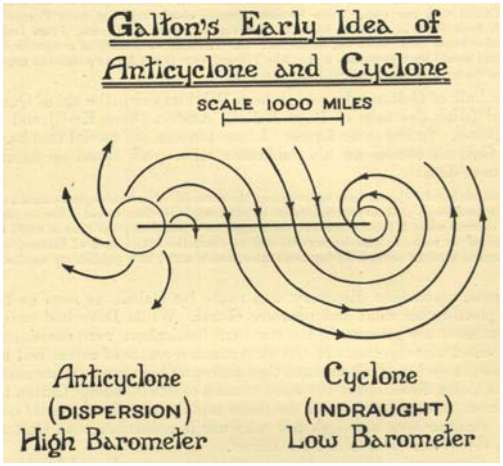


Visual insight → Theory

Visual insight from 93 (3x31) high-D graphs:
- Changes in wind dir w/ pressure over time
- → Winds revolve inwardly (CCW) in low pressure areas– as in a cyclone;
- → revolve outwardly (CW) in high pressure areas– "anti-cyclone"

Theory:

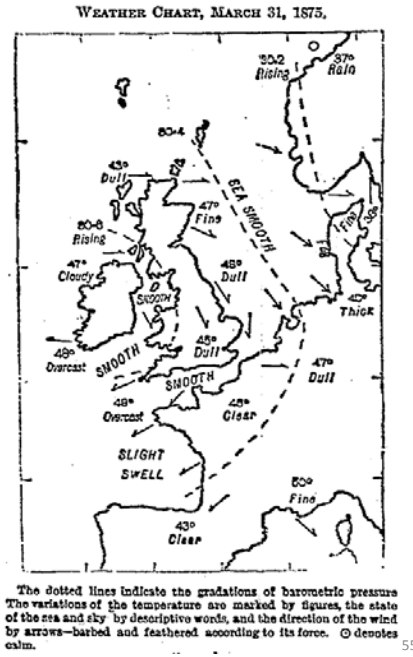
- Explained by Dove's 'Law of Gyration'
- Prediction: reversed pattern (CW/CCW) in southern hemisphere – confirmed!



Theory → Practice

The first modern weather map, *London Times*, Apr. 1, 1875

Galton did for weathermen what Kepler did for Tycho Brahe. This is no small accomplishment. (Wainer 2005)

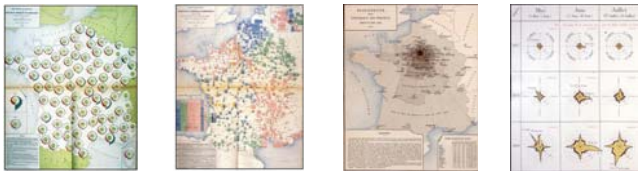


4. Statistical atlases: Data → practice, national identity & graphical excellence

- Widespread collection of gov't statistics on pop., trade, moral & political issues in Europe & US, starting ~ 1820
- How to use this?
  - Visualizing progress, goals yet to be achieved
  - Visualize a national identity, present a graphic portrait of a nation
- Statistical albums ~ 1870—1910
  - France: *Album de Statistique Graphique*: 1879-1899
  - USA: Census atlases: 1870/80/90
  - Germany: local albums (Berlin, Frankfurt, etc.)
  - Switzerland: *Atlas graphique de la Suisse:1897, 1914*
  - *Others: Latvia, Romania, Bulgaria, etc.*

Album de statistique graphique

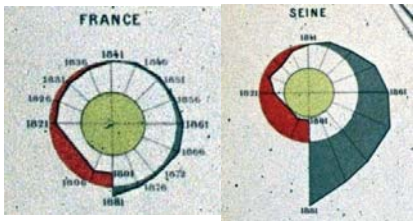
- Published by the *Statistical Graphics Bureau*, Ministry of Public Works, Émile Cheysson, director
- 18 volumes: 1879-1899, 12—34 plates each, ~ 11”x15” pages
- Graphic forms:
  - Flow maps (simple, double, multi)
  - Pie maps, star, radial, polar time-series, proportional circles
  - Mosaic maps, anamorphic maps, planetary diagrams
  - Choropleth, bi-polar scales
  - Charts: line, bar, time-series
- **Pinnacle of the Golden Age**: exquisite sampler of all known graphic forms!



Album de statistique graphique

Spiral time-series on a map

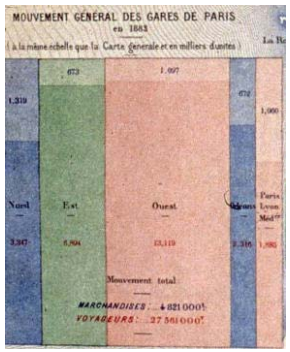
Changes in the population of France from 1801—1881, by department [Album, 1881, plate 25]

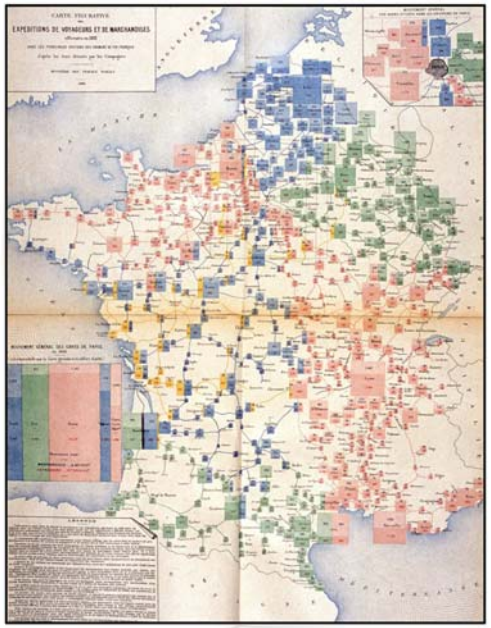


Recursive multi-mosaic map

Distribution of **passengers** and **goods** from the Paris railways to the rest of France [Album, 1884, pl. 11]

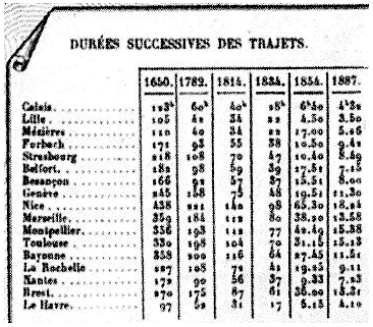
(The image that launched my interest in the history of data vis.)





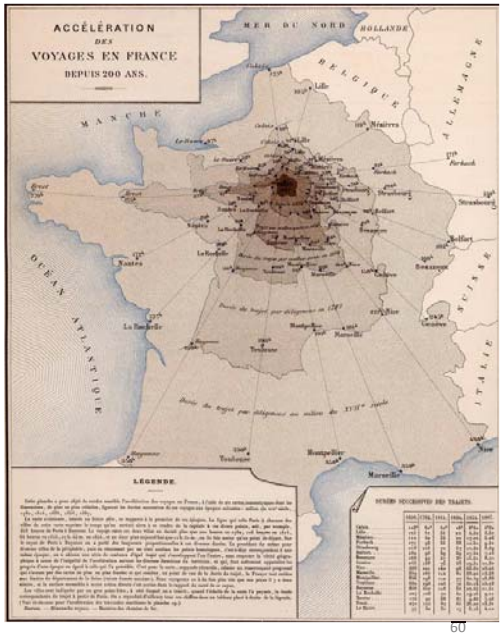
Anamorphic map

Shrinking France to show change in travel time over 200 years [Album, 1888, plate 8]



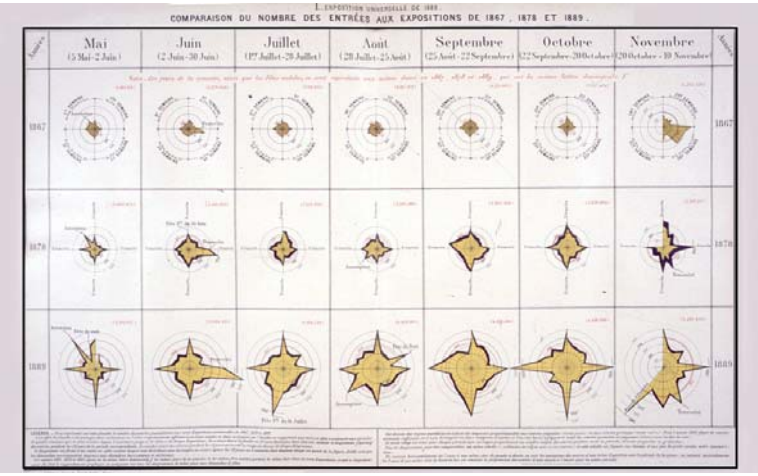
DURÉES SUCCESSIVES DES TRAJETS.

	1650.	1782.	1814.	1834.	1854.	1887.
Calais	12j3	6j	4j	2j	0j20	0j2s
Lille	10s	4s	3s	2s	4.30	3.30
Médières	11c	4c	3s	2s	17.00	5.16
Forbach	17s	9s	5s	3s	10.30	9.4s
Strasbourg	21s	10s	7c	4j	10.40	8.49
Belfort	18s	9s	5j	3j	17.5s	7.15
Besançon	16c	9s	5j	3j	12.5s	8.00
Genève	24s	13s	7s	4s	19.5s	11.30
Nice	43s	22s	14s	9s	65.30	18.24
Marseille	35j	18s	11s	8c	38.20	13.58
Montpellier	33c	19s	11s	7j	40.40	15.38
Toulouse	33j	19s	10s	7j	31.1s	15.13
Bayonne	35s	20c	11s	6s	27.45	11.5s
La Rochelle	28j	16s	7s	4s	19.25	9.11
Nantes	17s	9c	5s	3j	9.33	7.23
Brest	27c	17s	8j	6s	36.0c	15.3s
Le Havre	9j	5j	3s	1j	5.1s	4.1c



Two-way table of star/radar diagrams

Attendance at the universal expositions in 1867, 1878, 1889 (rows), by month (cols) and days (rays). [Album, 1889, plate 21]

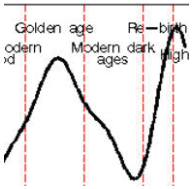


ASG now online: David Rumsey

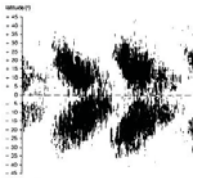
17 volumes, https://www.davidrumsey.com/luna/servlet/s/nl72bu

Golden Age → Modern Dark Ages

- Albums: discontinued (cost), became routinized
- Statistics: enthusiasm for graphics replaced by rise of quantification
  - Statistical models (regression, correlation)
  - Estimates +- standard errors: precise!
- Few innovations, but popularization
  - College courses, text books
- Some significant graphical discoveries
  - E.W. Maunder (1904): "butterfly diagram" of sunspots
  - Hertzsprung-Russell (1911) diagram: stellar physics
  - Henry Moseley (1913): atomic number

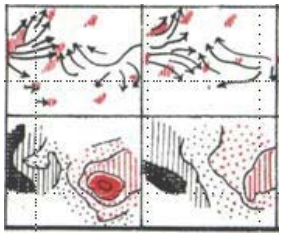


Maunder (1904)



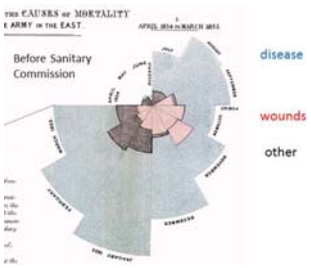
Golden Lessons: worthy goals

- What are the lessons for the future?
- Phenomena, not numbers
  - Playfair, Guerry, Minard, Galton, etc. all developed new graphic forms to show **phenomena** of deep interest:
    - balance of trade, rates of crime, patterns in weather data, …
- **1st lesson**: data visualization today should strive for a similar focus



Golden Lessons: graphical impact

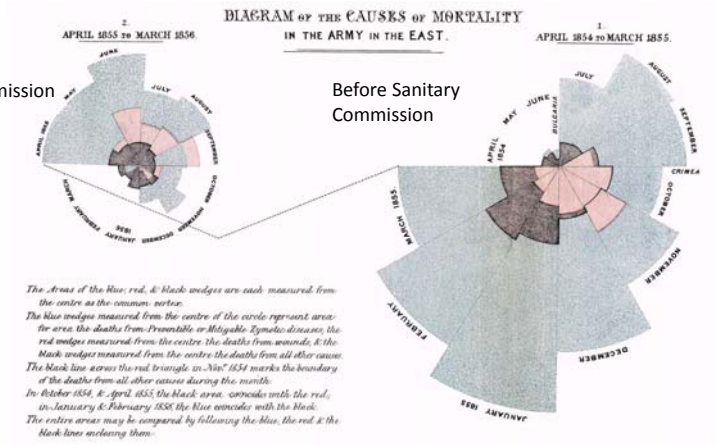
- Impact = Interocularity, Immediacy, Inescapability
  - Playfair, Guerry: data should "speak to the eyes"
  - Minard, Lalanne: allow "calculation by the eyes"
  - Nightingale: graphs should speak to the heart and mind, influence public policy & practice
- **2nd lesson**: graphic designers should strive for visual impact in graphs and tables



Impact: Nightingale's coxcomb

Florence Nightingale: Deaths in the Crimean war from battle vs. other causes

→ Preventable death from disease always dominated death on the battle field



Golden Lessons: Expressive power

- Hand-made graphics were often beautiful, but entailed much sweat and hard work.
- Today: software– ease of use (menus) vs. expressive power (code)
- Theories of graphics → graphic "languages"

- **3rd lesson**: Reduce the distance between a graphic idea and appearance on screen or paper.

Thank you!

Questions?