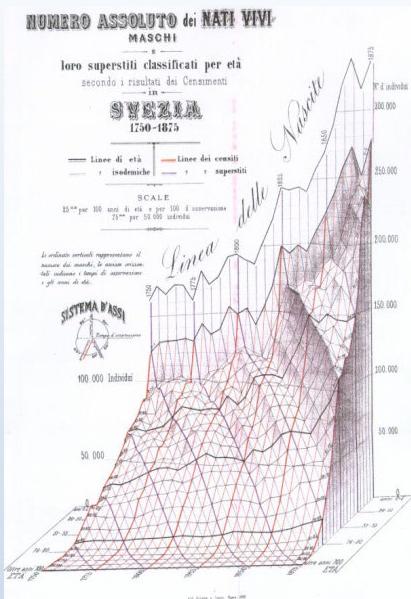
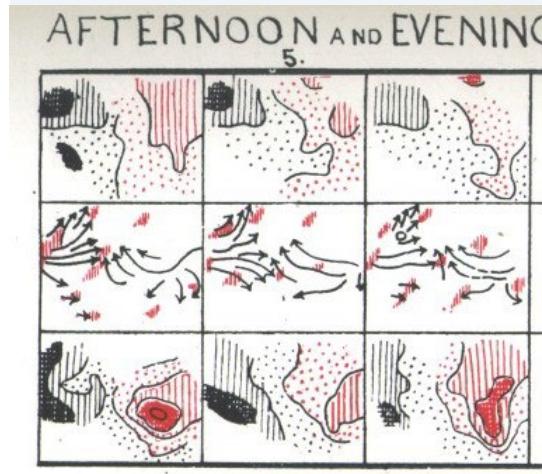


## Anaximander's Map of the World

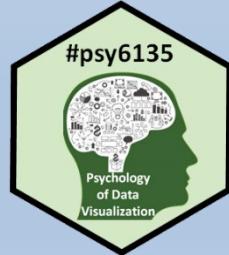
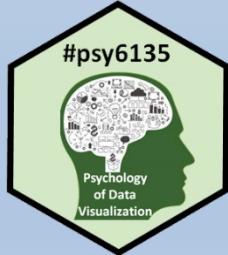
Galton (1863)



# History of Data Visualization

# Michael Friendly

# Psych 6135



<https://friendly.github.io/6135>

# Outline

- Overview:
  - Roles of graphics in scientific discovery
  - Visualizing history: The *Milestones Project*
- Milestones tour of the history of data vis
  - Pre-history of visualization
  - The first statistical graph
  - The Big Bang: William Playfair
  - Influence of data, technology & visual thinking
- Other topics (later):
  - Moral statistics: the birth of social science
  - Graphs in the public interest: Nightingale, Farr and Snow
  - The Golden Age of statistical graphics

# Orienting questions

History in  
context



What  
motivated  
graphical  
inventions?

What was the  
communication  
goal?

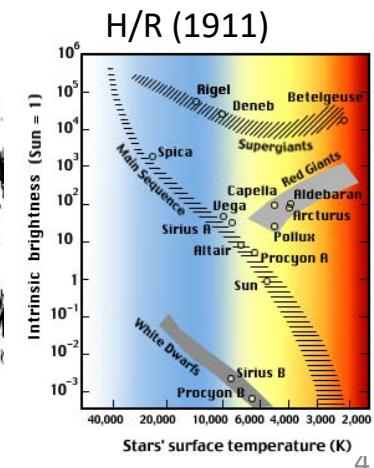
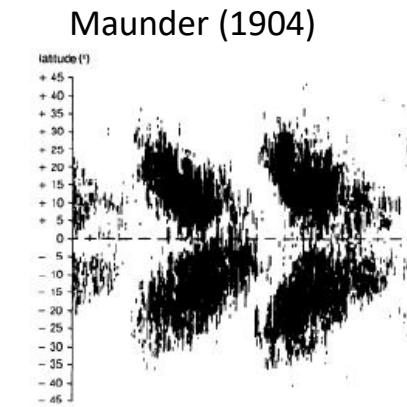
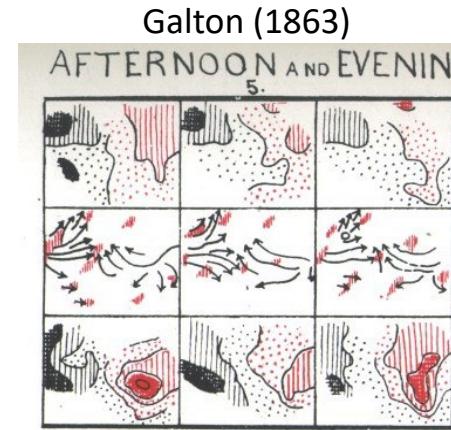
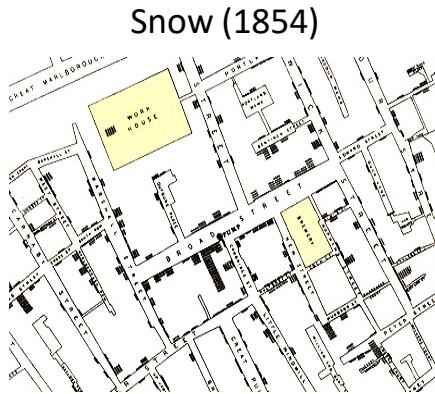
How does it  
relate to other  
developments?

- What were the  
pre-cursors?

How has this  
idea been  
used or re-  
invented  
today?

# 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

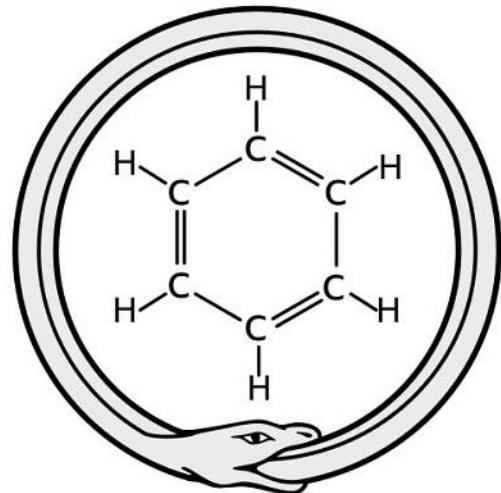


# Orienting Q: Visualization-based discoveries ??

- In the history of graphs, what features, and data led to such discoveries?
  - What were they thinking??
  - What visual ideas/representations were available?
  - What was needed to see/understand something new?
- As we go forward, are there any lessons?
  - What are the Big Questions for today?
  - How can data visualization help?

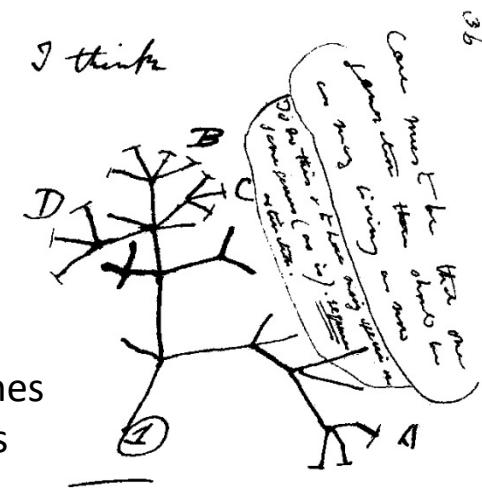


# Visual thinking & scientific discovery



**Dreams and snakes**  
August Kekulé (1862)  
discovers the structure of  
benzene in a dream

**Tree of evolution**  
Darwin (1859) imagines  
generations of species



ESSAI D'UNE SYSTEME DES ELEMENTS  
D'APRES LEURS POIDS ATOMIQUES ET FONCTIONS CHIMIQUES,  
par D. Mendeleeff,  
professeur de l'Univers. à S.-Petersbourg.

Autograph of two periodic tables of elements by Dmitri Mendeleev, dated 1869.

Handwritten notes on the left side of the table:

- 1869
- Ca = 40 He = 8 J = 12
- F = 19 Cl = 35,5 Ar = 80 I = 177
- O = 16 S = 32 Ne = 20 Fe = 56
- N = 14 P = 31 As = 76 Se = 112
- C = 12 Si = 28 Ti = 46 Mn = 56
- H = 1 B = 18 Co = 59 Ni = 59
- Li = 7 Na = 23 K = 39 Cs = 133
- Be = 9,4 Mg = 24 Zn = 65,5 Cd = 112
- B = 11 Al = 27,4 P = 31 As = 75 Sb = 122 Bi = 210?
- C = 12 Si = 28 S = 32 Se = 78,4 Te = 128?
- N = 14 P = 31 As = 75 Sb = 122 Bi = 210?
- O = 16 S = 32 Se = 78,4 Te = 128?
- F = 19 Cl = 35,5 Br = 80 I = 127
- Li = 7 Na = 23 K = 39 Rb = 85,4 Cs = 133 Tl = 204
- Be = 9,4 Mg = 24 Zn = 65,5 Cd = 112
- B = 11 Al = 27,4 P = 31 As = 75 Sb = 122 Bi = 210?
- C = 12 Si = 28 S = 32 Se = 78,4 Te = 128?
- N = 14 P = 31 As = 75 Sb = 122 Bi = 210?
- O = 16 S = 32 Se = 78,4 Te = 128?
- F = 19 Cl = 35,5 Br = 80 I = 127
- Li = 7 Na = 23 K = 39 Rb = 85,4 Cs = 133 Tl = 204
- Ca = 40 Sr = 87,6 Ba = 137 Pb = 207,
- Sc = 45 Ce = 92 La = 94
- Yt = 69 Dl = 95
- Lu = 175 Th = 182

Ref. 2.  
Автограф двух периодических таблиц элементов  
117 Февраль 1869 г.

18<sup>м</sup> 69

**Solitaire and the periodic table**  
Mendeleev (1869) organized chemical  
elements after a mental image of cards on a  
table.

See: <https://medium.com/@michael.friendly/visual-thinking-graphic-discoveries-128468677592>

# How to visualize travel? A route map!

In 1675, chartmaker John Ogliby told a graphic story of what you would see on a travel from London to Land's End

What was he thinking?

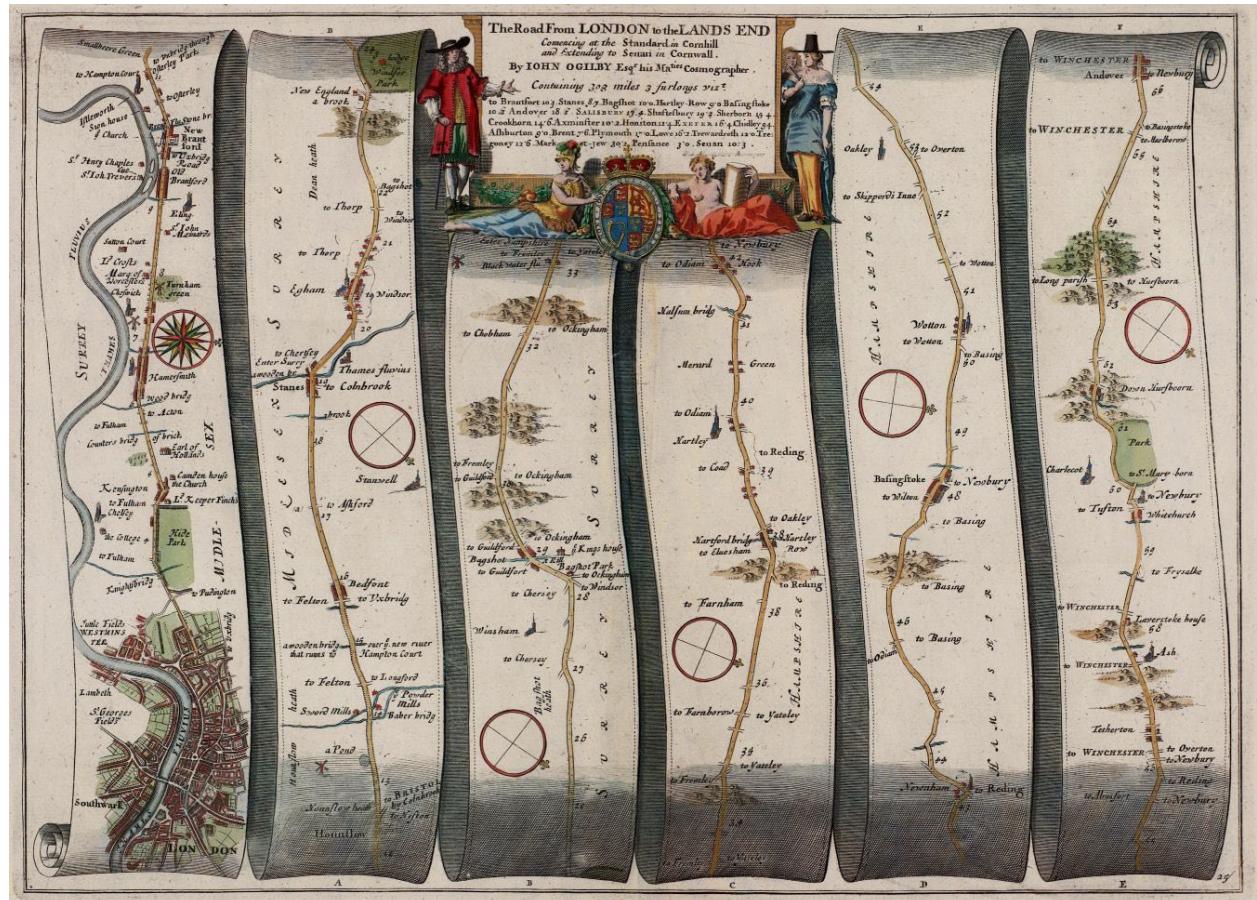
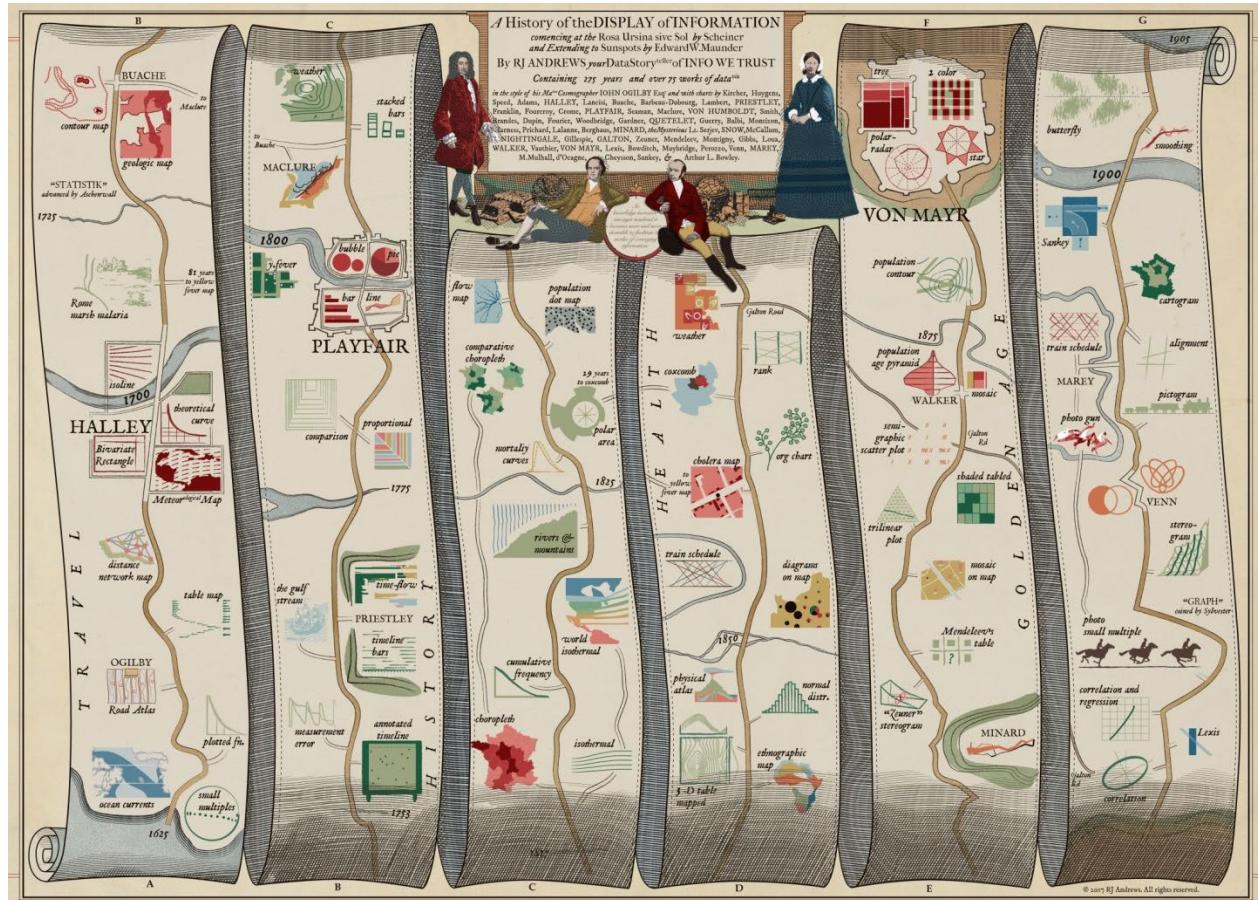


Image: [https://commons.wikimedia.org/wiki/File:Ogilby\\_-\\_The\\_Road\\_From\\_LONDON\\_to\\_the\\_LANDS\\_END\\_\(1675\).jpg](https://commons.wikimedia.org/wiki/File:Ogilby_-_The_Road_From_LONDON_to_the_LANDS_END_(1675).jpg)

# How to visualize history? A route map!

In 2017, graphic storyteller RJ Andrews adopted Ogilby's form to show the history of data visualization.



The online version, <https://history.infowetrust.com/> is fully interactive, with details about the images on this journey.

# The Milestones Project

## Milestones in the History of Thematic Cartography, Statistical Graphics, and Data Visualization

An illustrated chronology of innovations by Michael Friendly and Daniel J. Denis

[Home](#) | [Introduction](#) | [Milestones Project](#) | [Varieties of Data Visualization](#) | [Related](#) | [References](#) | [Keyword Index](#)

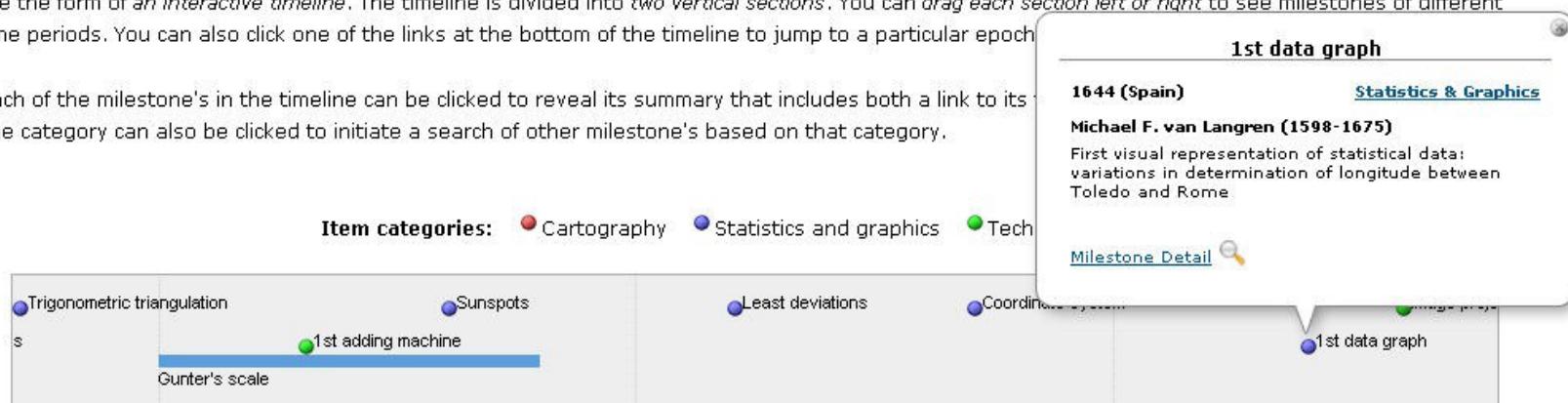
[Search](#)

[Pre-1600](#) [1600s](#) [1700s](#) [1800+](#) [1850+](#) [1900+](#) [1950+](#) [1975+](#)

### Timeline

This page provides a graphic overview of the events in the history of data visualization that we call "**milestones**." These milestones are shown below in the form of an *interactive timeline*. The timeline is divided into two vertical sections. You can drag each section left or right to see milestones of different time periods. You can also click one of the links at the bottom of the timeline to jump to a particular epoch.

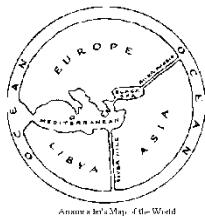
Each of the milestone's in the timeline can be clicked to reveal its summary that includes both a link to its category and a search of other milestone's based on that category.



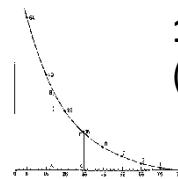
The web site: <http://datavis.ca/milestones> has an interactive timeline, allowing different kinds of search

# Milestones: Content Overview

*Every picture has a story* – Rod Stewart

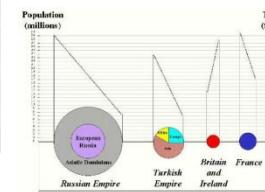
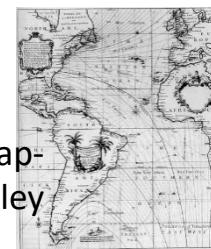


c. 550 BC: The first world map? (Anaximander of Miletus)



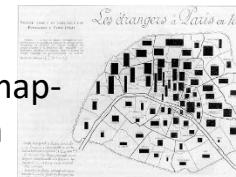
1669: First graph of a continuous distribution function (Gaunt's life table)– Christiaan Huygens.

1701: First contour map– Edmund Halley

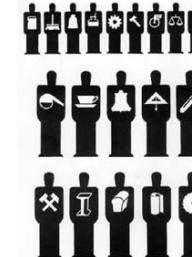


1801: Pie chart, circle graph - William Playfair

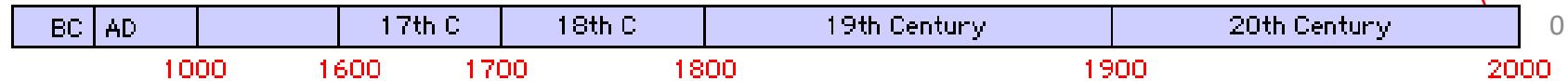
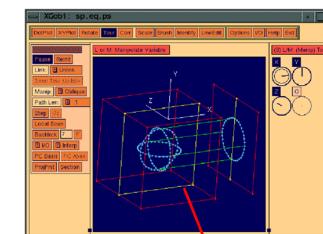
1896: Bivariate map– Jacques Bertillon



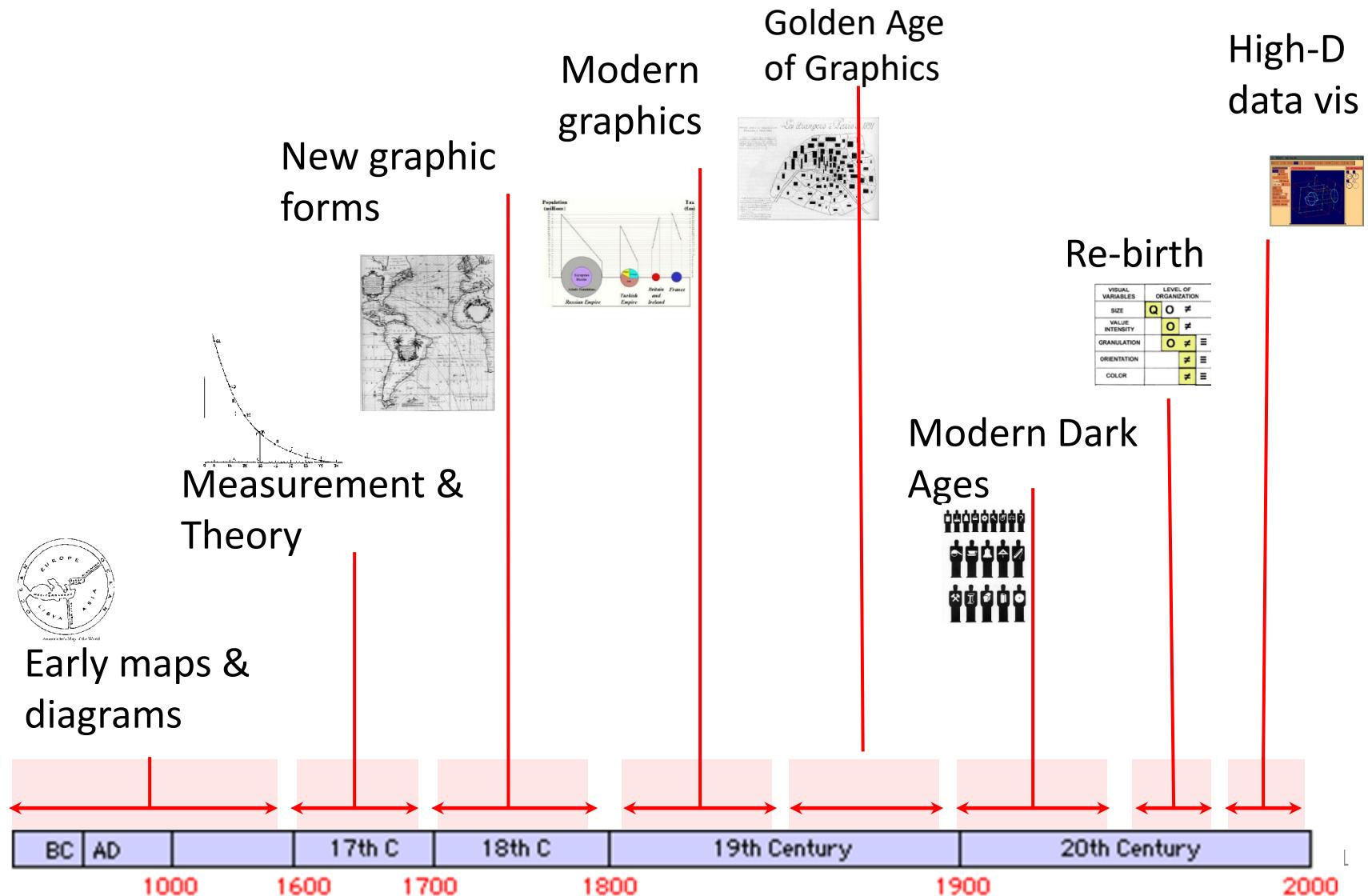
1924: ISOTYPE– Otto Neurath



1991-1996: Interactive data visualization systems (Xgobi, ViSta)

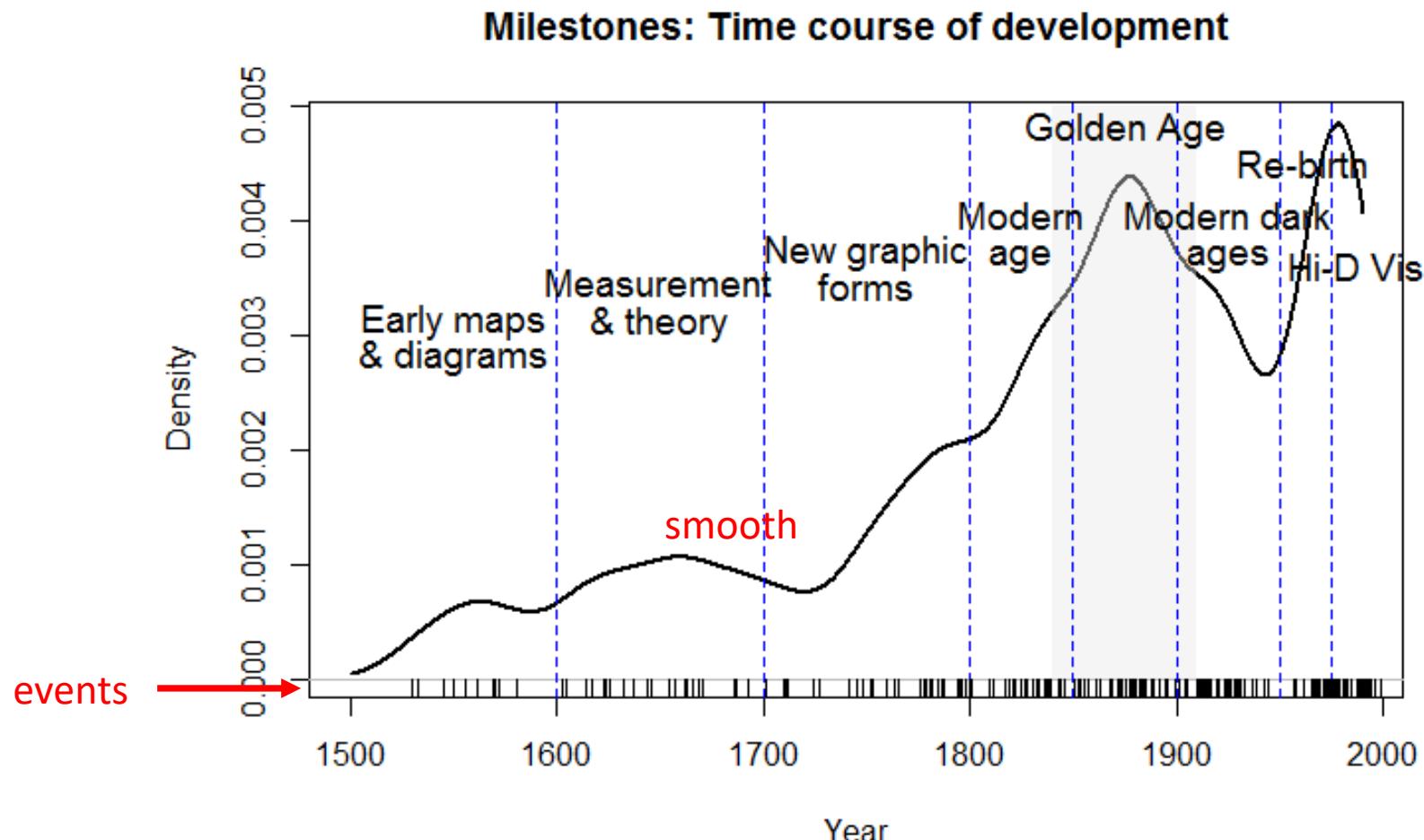


# Milestones Tour: Epochs



# Statistical historiography

Historical information, suitably organized can be treated as data, and analyzed. This plot shows a smoothed frequency distribution of 248 milestones items over time, in relation to the named time periods.



# 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

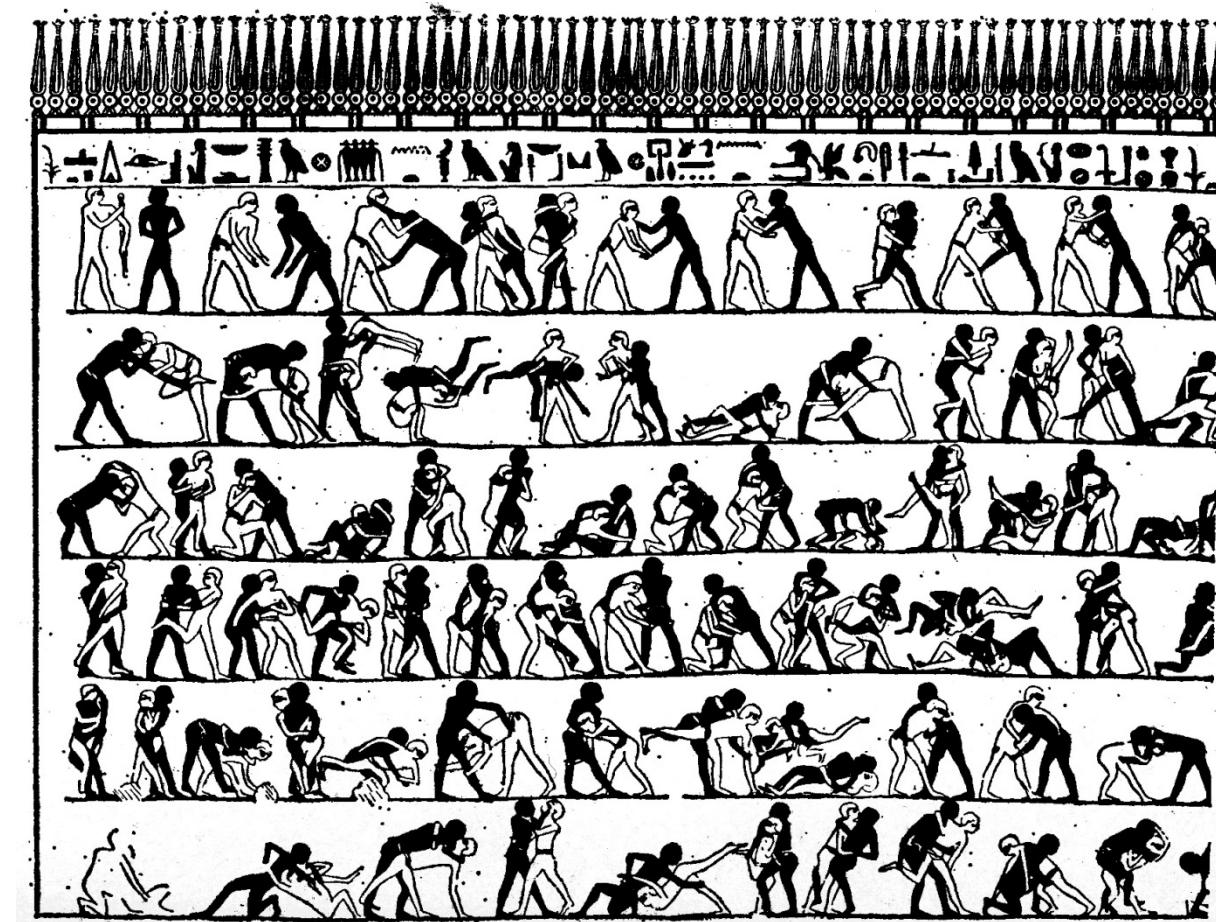
Early Egyptian animated graphic diagram

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



# Pre 17<sup>th</sup> C.: Early maps & diagrams

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

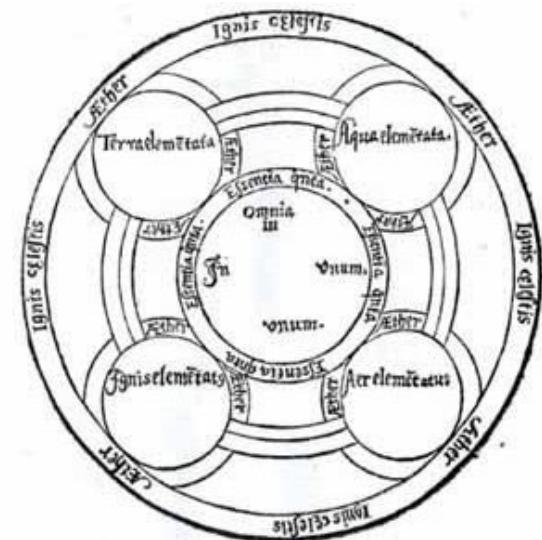


1350: Bar graph of theoretical function N. Oresme, France



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

1305: Mechanical diagram of knowledge- Ramon Llull, Spain



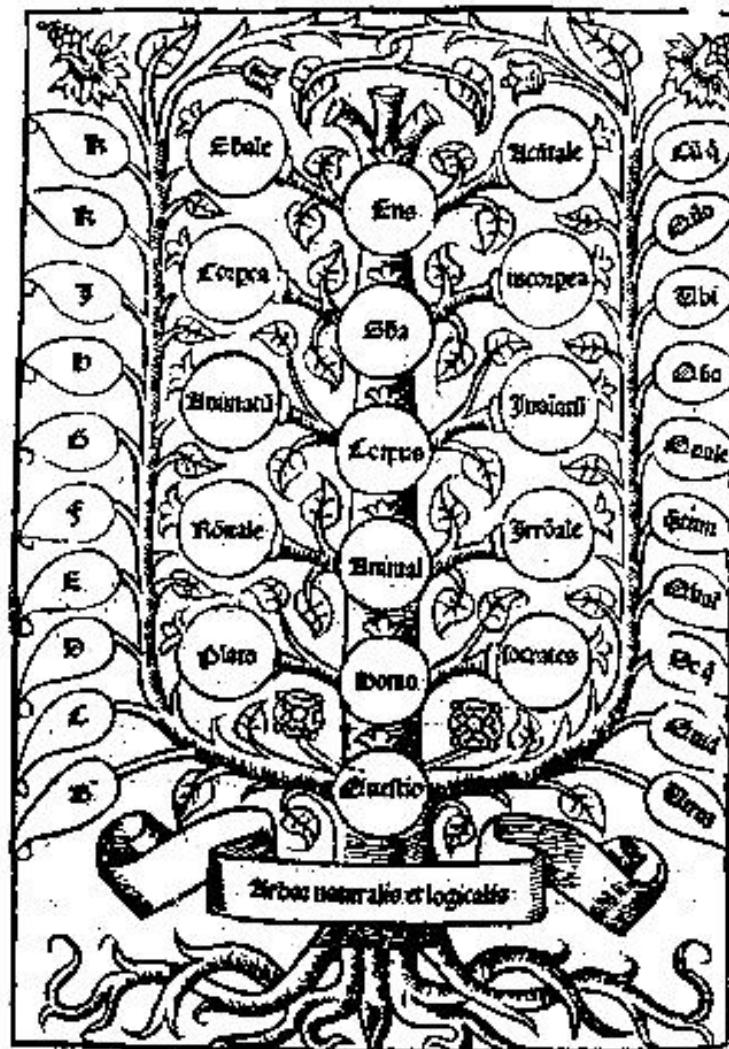
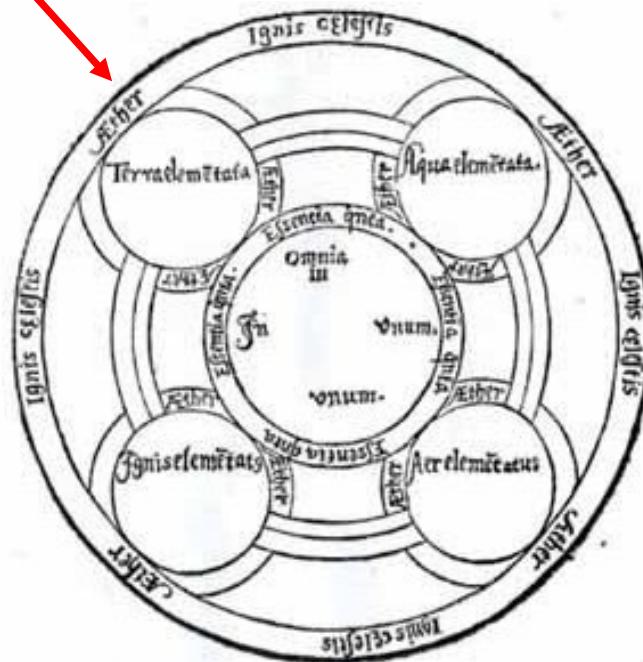
| BC   | AD   | 17th C | 18th C | 19th Century | 20th Century |    |
|------|------|--------|--------|--------------|--------------|----|
| 1000 | 1600 | 1700   | 1800   | 1900         | 2000         | 16 |

## **1305: Mechanical diagram of knowledge- Ramon Llull, Spain**

*Ars Magna* → inspiration for symbolic logic

## *Tree of porphyry:* Aristotle's categories of knowledge (center)

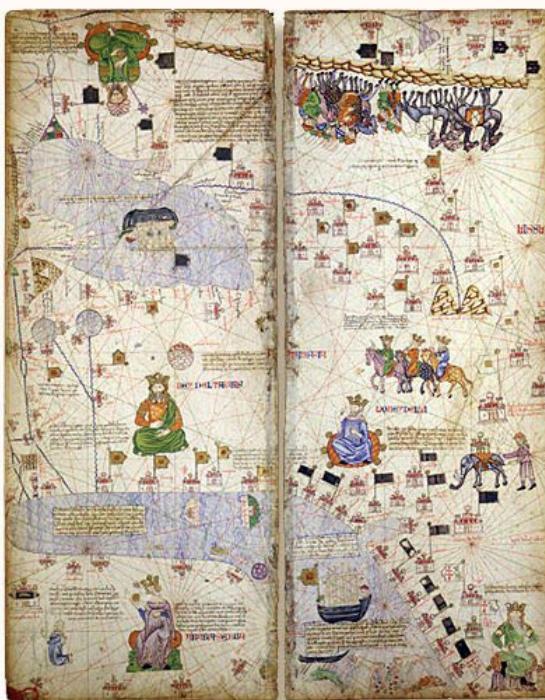
- Left: questions
  - Right: rotating disks → answers



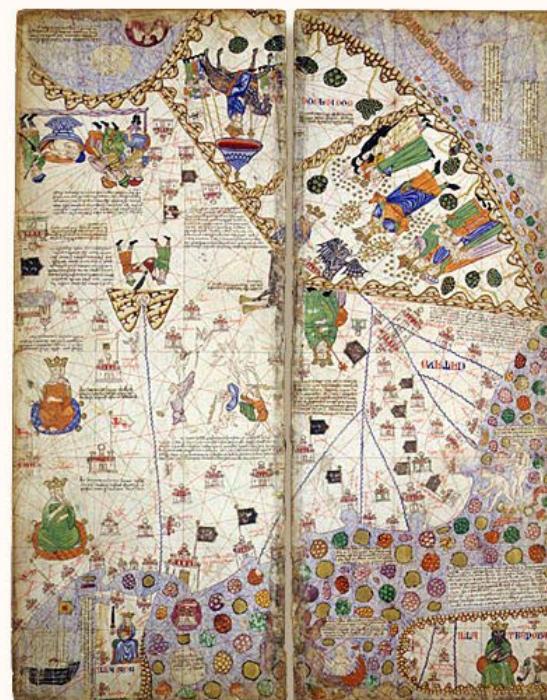
| BC | AD |  | 17th C | 18th C | 19th Century | 20th Century |      |      |
|----|----|--|--------|--------|--------------|--------------|------|------|
|    |    |  | 1000   | 1600   | 1700         | 1800         | 1900 | 2000 |

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

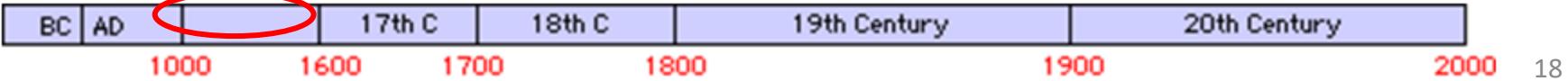
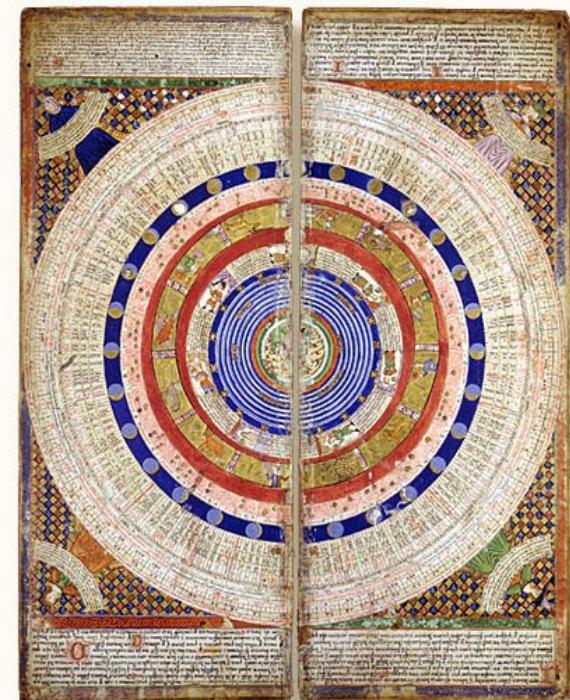
Western world



Eastern world (Marco Polo)



Perpetual calendar

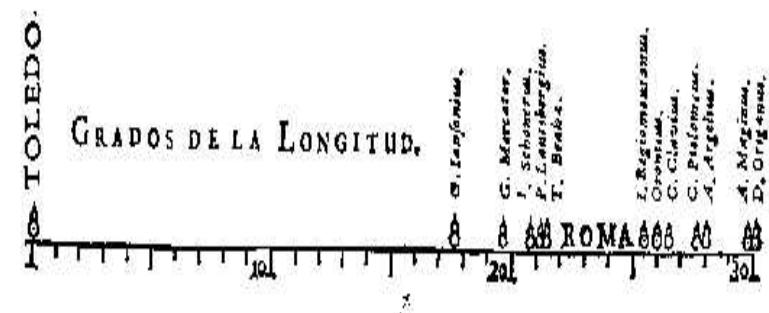
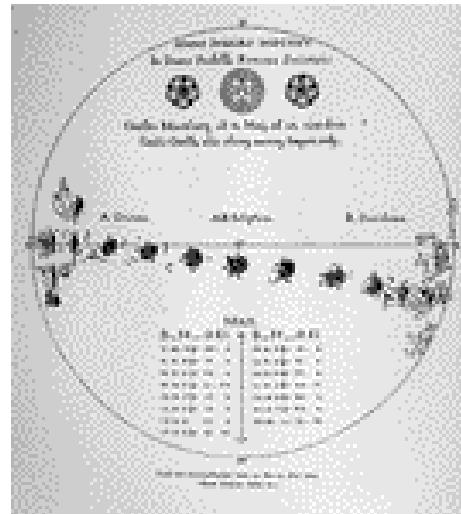


# 1600-1699: Measurement and Theory

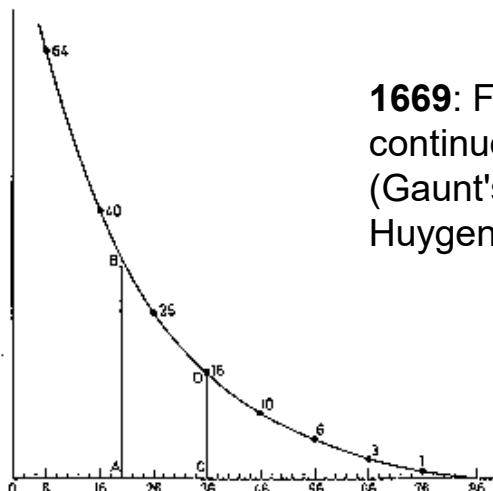
- The 17<sup>th</sup> century saw growth in theory and the dawn of attempts at visualization.
- Featured in this were:
  - the rise of **analytic geometry**: (x, y) coordinates (Descartes),
  - theories of **errors of measurement**: astronomical observations (Laplace)
  - the birth of **probability theory**-- games of chance, annuities (Fermat, DeMoivre, ...),
  - automatic **graphic recording** (Scheiner)
  - the first graphical representations of **statistical data** (van Langren)

# 1600-1699: Measurement and Theory

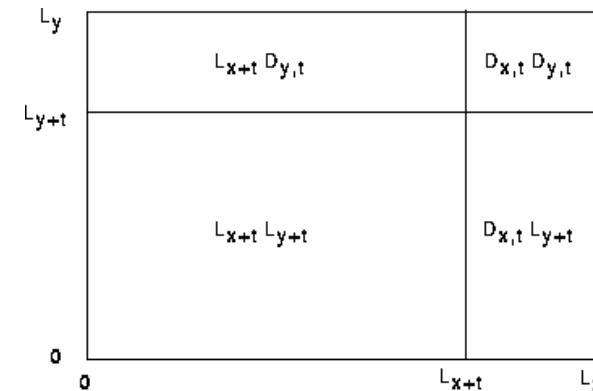
1626: Visual representations used to chart the changes in sunspots over time—Christopher Scheiner



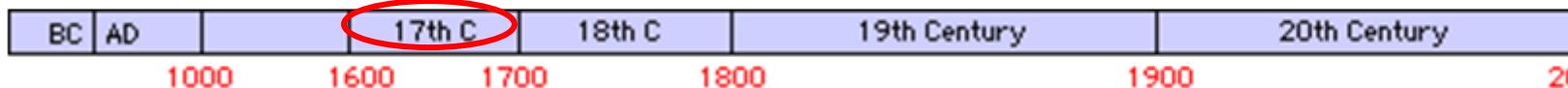
1644: First visual representation of statistical data—M.F. van Langren, Spain



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

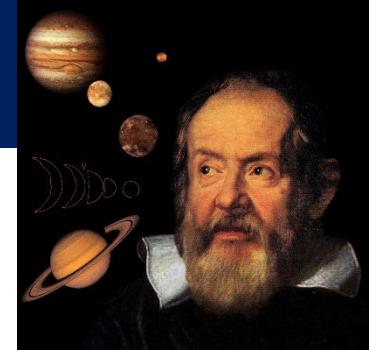


1693: First use of areas of rectangles to display probabilities of independent binary events—Edmund Halley, England





# Sunspots: Galileo



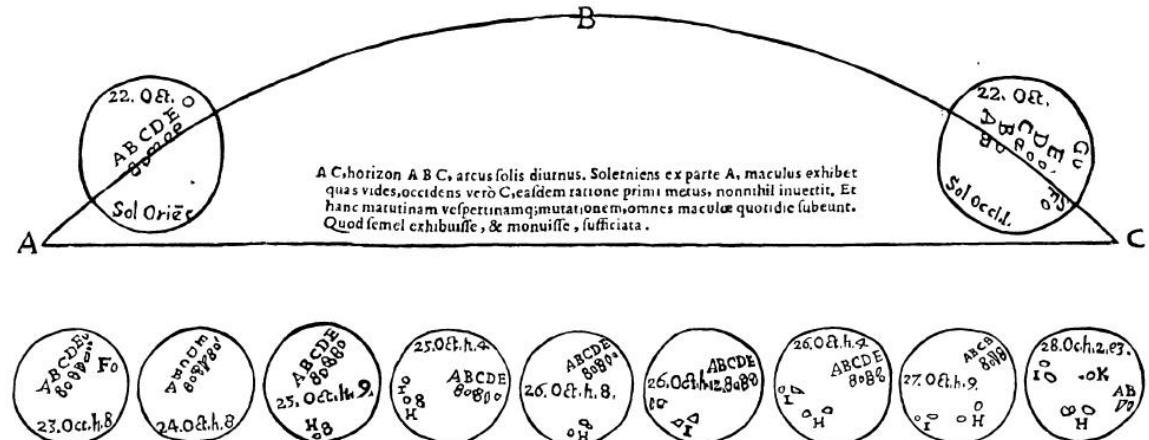
1608: telescope (Hans Lippershey, NL)

↓  
1610: Galileo (*Sidereus Nuncius*)

1611: Galileo records **movement** of sunspots over time (*Three letters on sunspots*, 1613)

## Visual ideas:

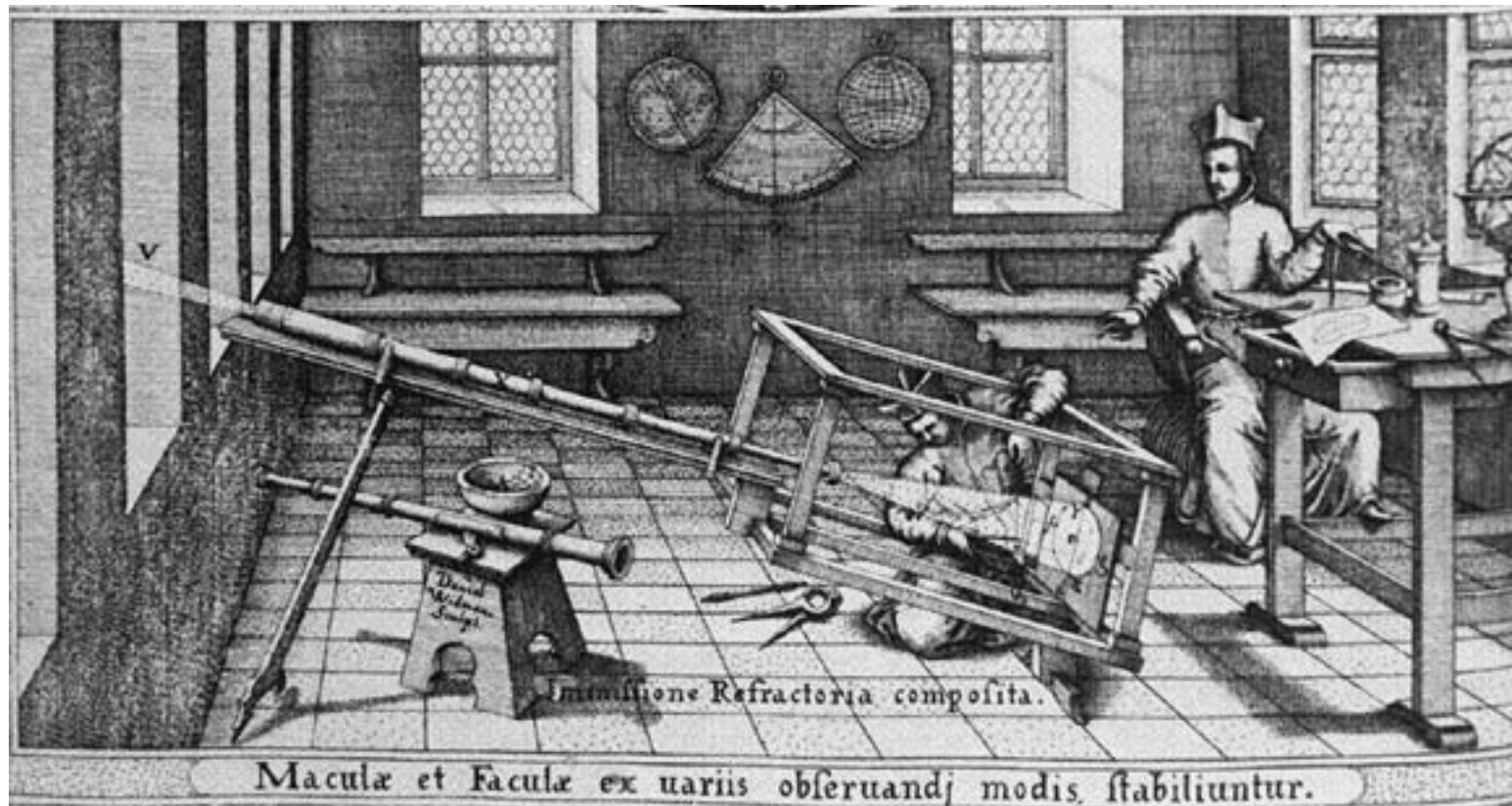
- Animated graphic
- “Small multiples”
- Allows comparison
- Self-explaining diagram



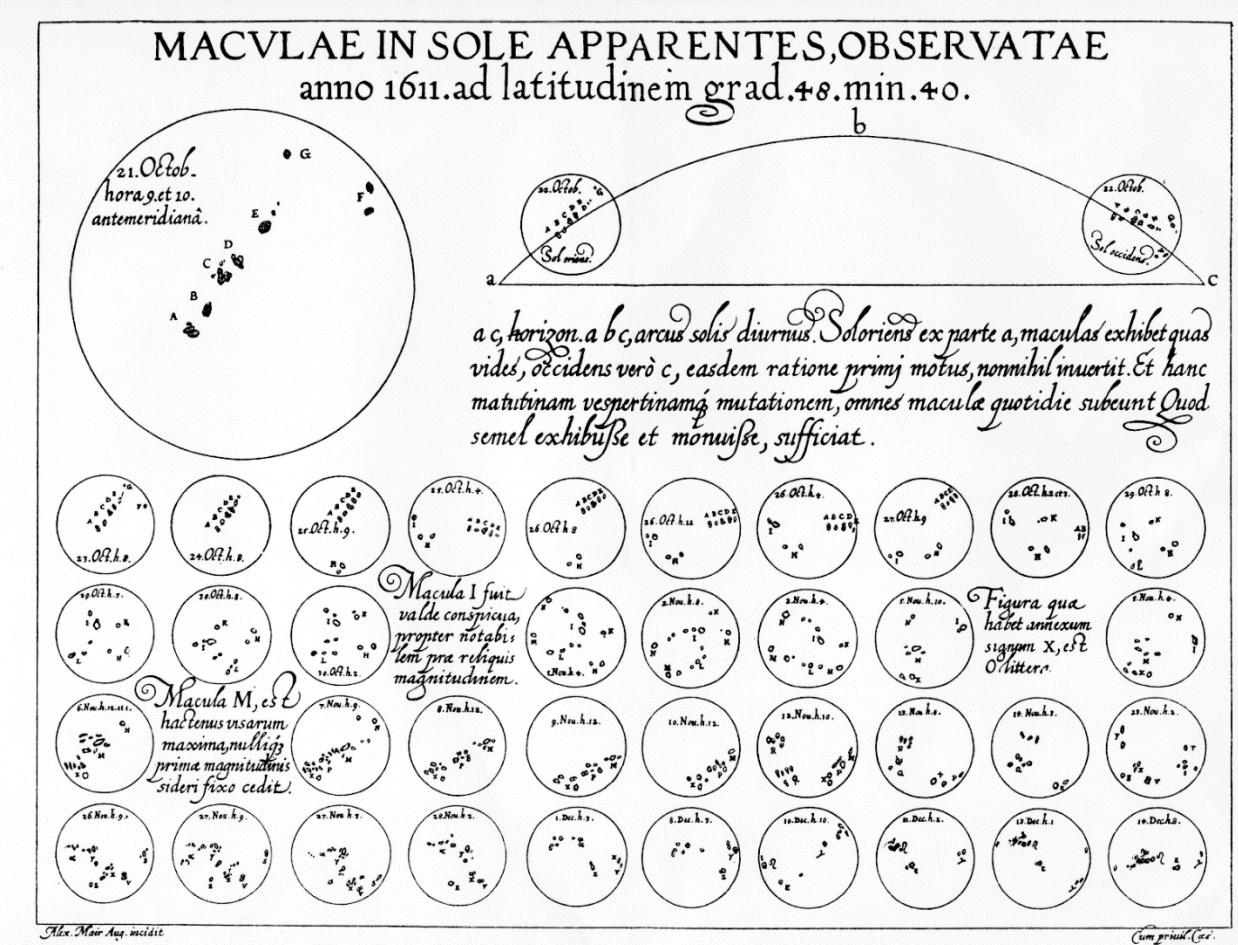
A+ for info design!

# Scheiner: systematic recording

1626: Christoph Scheiner invents helioscope & camera obscura to record sunspots  
(*Rosa Ursina sive Sol*, 1626-1630)



# 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!

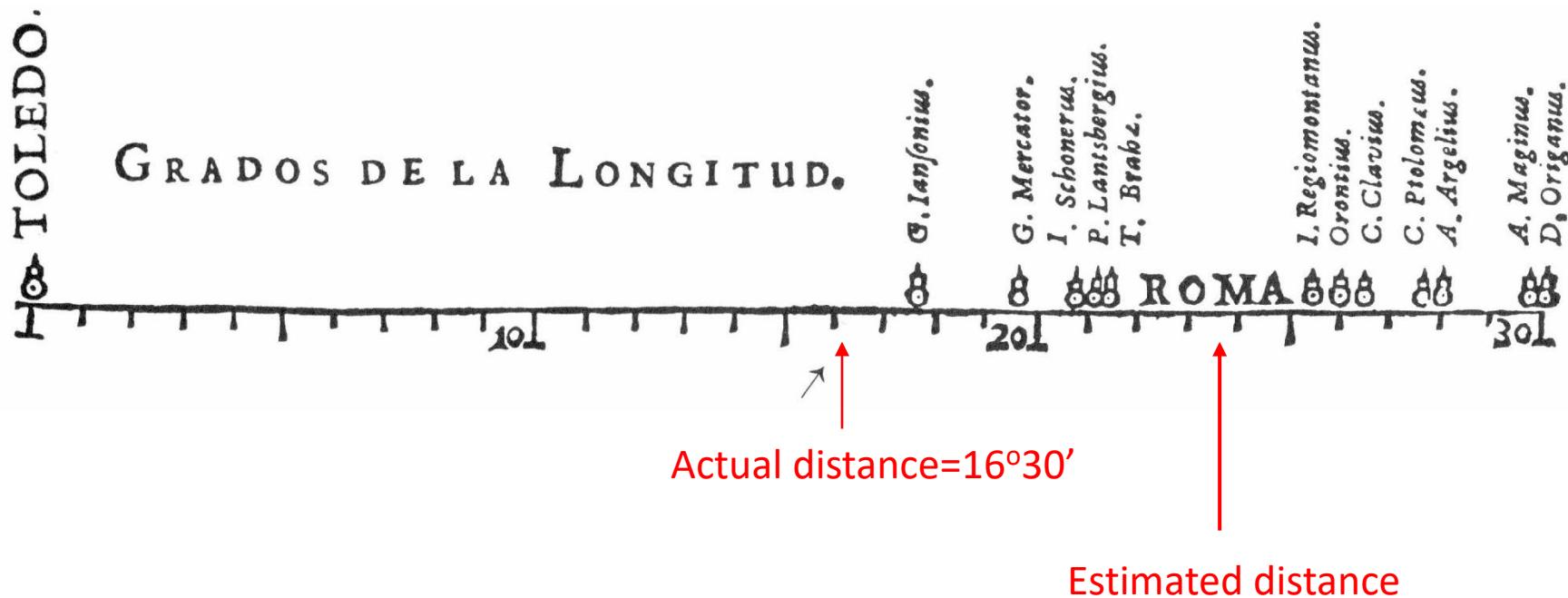
He argued (incorrectly) that these were evidence for solar satellites.

The idea of graphs for visualizing phenomena had arrived.

| BC | AD | 17th C | 18th C | 19th Century | 20th Century |      |      |
|----|----|--------|--------|--------------|--------------|------|------|
|    |    | 1000   | 1600   | 1700         | 1800         | 1900 | 2000 |

# Why the 1<sup>st</sup> statistical graph got it right

1644: First visual representation of statistical data: determination of longitude between Toledo and Rome- Michael Florent van Langren, Spain



| BC | AD | 1000 | 1600 | 1700   | 1800   | 1900         | 2000         |
|----|----|------|------|--------|--------|--------------|--------------|
|    |    |      |      | 17th C | 18th C | 19th Century | 20th Century |

# What else could he have done?

- What would occur to men of his time to convey a message to the king?
- ... he could used a *table* have sorted by *year* to establish *priority* (or show change).

Sorted by Priority

| Year | Name             | Longitude | Where    |
|------|------------------|-----------|----------|
| 150  | Ptolomeus, C.    | 27.7      | Egypt    |
| 1471 | Regiomontanus,   | 25.4      | Germany  |
| 1501 | Ianfonius, G.    | 17.7      |          |
| 1530 | Lantsbergius, P. | 21.1      |          |
| 1536 | Schonerus, I.    | 20.8      | Germany  |
| 1541 | Argelius, A.     | 28.0      |          |
| 1542 | Ortonius         | 26.0      | France   |
| 1567 | Mercator, G.     | 19.6      | Flanders |
| 1567 | Clavius, C.      | 26.5      | Germany  |
| 1578 | Brahe, T.        | 21.5      | Denmark  |
| 1582 | Maginus, A.      | 29.8      | Italy    |
| 1601 | Organus, D.      | 30.1      |          |

Sorted by Authority

| Name              | Longitude | Year | Where      |
|-------------------|-----------|------|------------|
| Argelius, A.      | 28.0      | 1541 |            |
| Brahe, T.         | 21.5      | 1578 | Denmark    |
| Clavius, C.       | 26.5      | 1567 | Germany    |
| Ianfonius, G.     | 17.7      | 1501 |            |
| Lantsbergius, P.  | 21.1      | 1530 |            |
| Maginus, A.       | 29.8      | 1582 | Italy      |
| Mercator, G.      | 19.6      | 1567 | Flanders   |
| Organus, D.       | 30.1      | 1601 |            |
| Orontius          | 26.0      | 1542 | France     |
| Ptolomeus, C.     | 27.7      | 150  | Alexandria |
| Regiomontanus, I. | 25.4      | 1471 | Germany    |
| Schonerus, I.     | 20.8      | 1536 | Germany    |



Sorted by Longitude

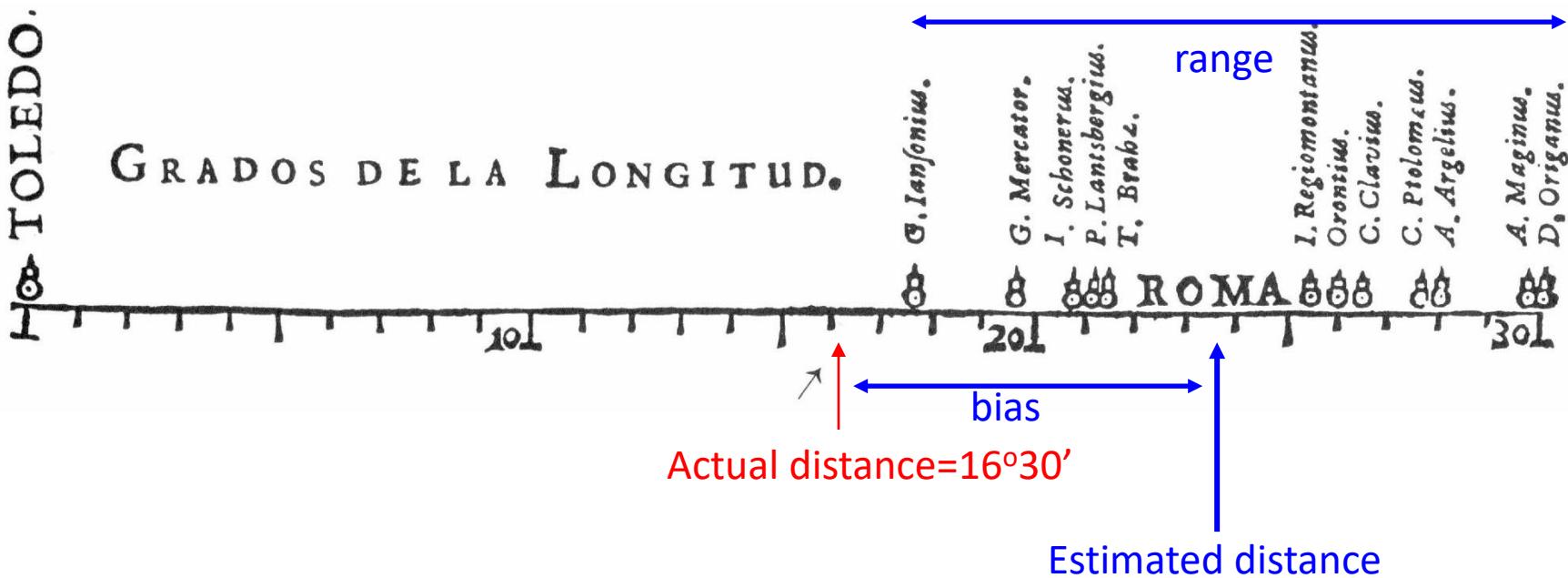
| Longitude | Name             | Year | Where    |
|-----------|------------------|------|----------|
| 17.7      | G. Ianfonius     | 1501 |          |
| 19.6      | G. Mercator      | 1567 | Flanders |
| 20.8      | I. Schonerus     | 1536 | Germany  |
| 21.1      | P. Lantsbergius  | 1530 |          |
| 21.5      | T. Brahe         | 1578 | Denmark  |
| 25.4      | I. Regiomontanus | 1471 | Germany  |
| 26.0      | Orontius         | 1542 | France   |
| 26.5      | C. Clavius       | 1567 | Germany  |
| 27.7      | C. Ptolomeus     | 150  | Egypt    |
| 28.0      | A. Argelius      | 1541 |          |
| 29.8      | A. Maginus       | 1582 |          |
| 30.1      | D. Organus       | 1601 |          |



- ... he could have sorted by *name*, to show *authority*.
- ... he could have sorted by *longitude* to show the *range*.

# Only a graph shows...

- central location
- bias
- name labels— avoiding overplotting
- wide variability
- clustering, detached observations



See: Friendly, M., & Kwan, E. (2003). Effect Ordering for Data Displays. *Computational Statistics and Data Analysis*, 43(4), 509–539;  
Friendly et al (2010), The First (Known) Statistical Graph: Michael Florent van Langren and the "Secret" of Longitude  
*The American Statistician*, 64, 185-191

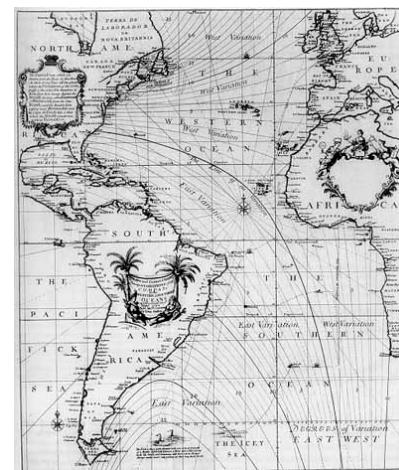
# 1700-1799: New graphic forms

- The 18<sup>th</sup> century witnessed the germination of the seeds of visualization & visual thinking, planted earlier.
  - Map-makers began to try to show more than just geographical position-- the beginnings of **thematic mapping** of physical quantities
    - topographical maps
    - iso-contour maps
  - New graphic forms were invented:
    - bar chart,
    - line chart,
    - timelines
- } The Big Bang

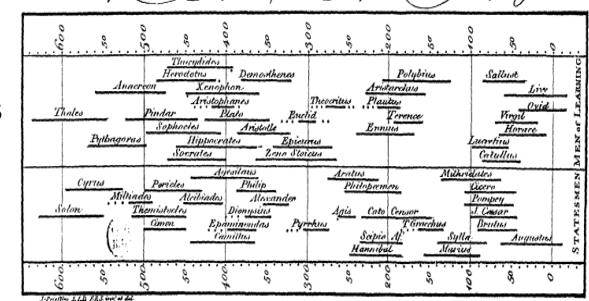


# 1700-1799: New graphic forms

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

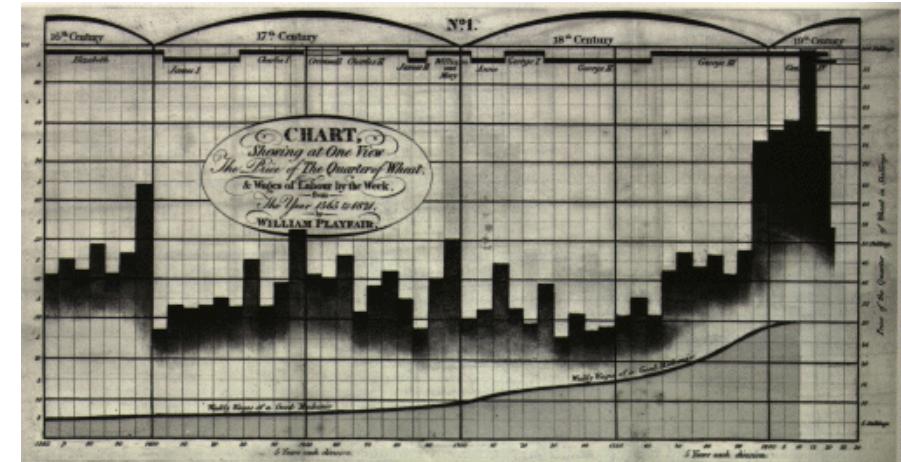


1765: Historical time line (life spans of famous people) Joseph Priestley

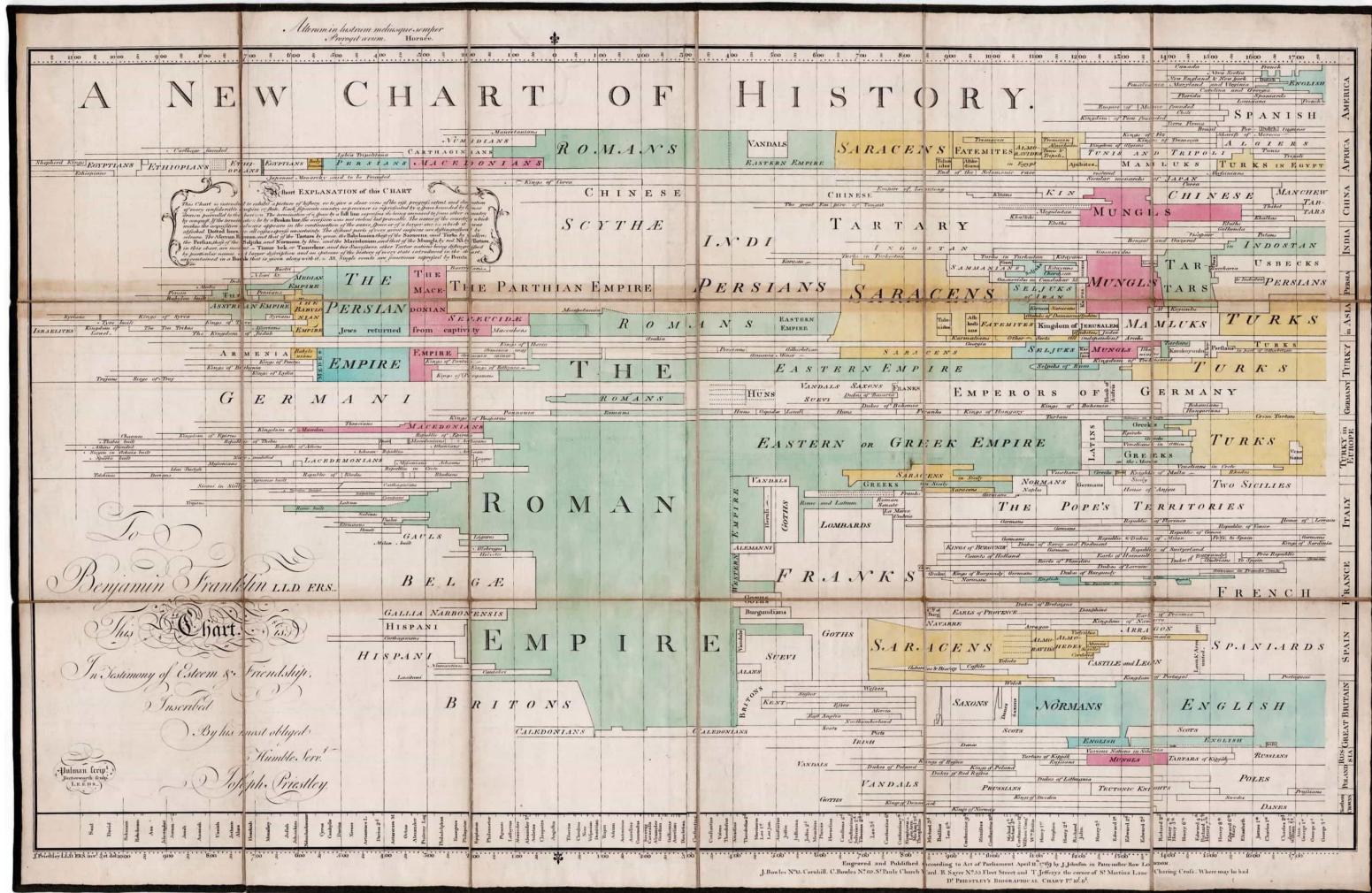


1782: First topographical map- Marcellin du Carla-Boniface

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



# 1769: Visualization of the history of civilizations & empires over ~3000 years --Joseph Priestley



1000 BC

0

1000

30

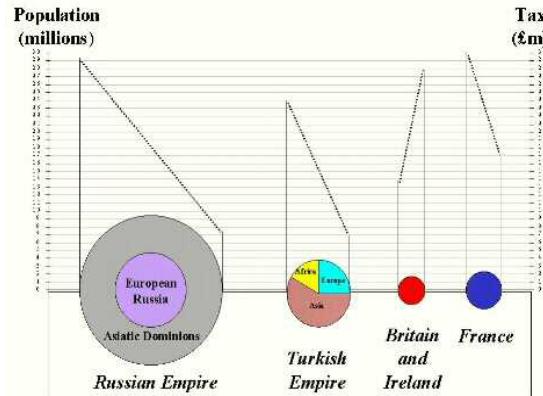
# 1800-1849: Beginning of modern data graphics

- The first half of the 19<sup>th</sup> century witnessed an explosive growth in statistical graphics and thematic mapping
  - Polar coordinates, log axes
  - Shaded (choropleth) maps of social data (literacy, crime)
- The **birth of data**: widespread national collection of data on social and medical issues
  - France: data on crime, literacy, prostitution, ... collected centrally
  - England: Births, deaths, disease mortality collected by Registrar General (William Farr)

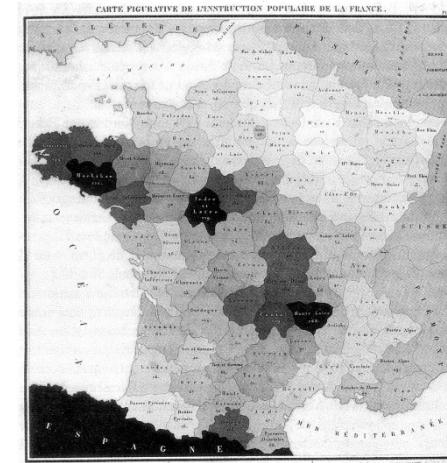


# 1800-1849: Beginning of modern data graphics

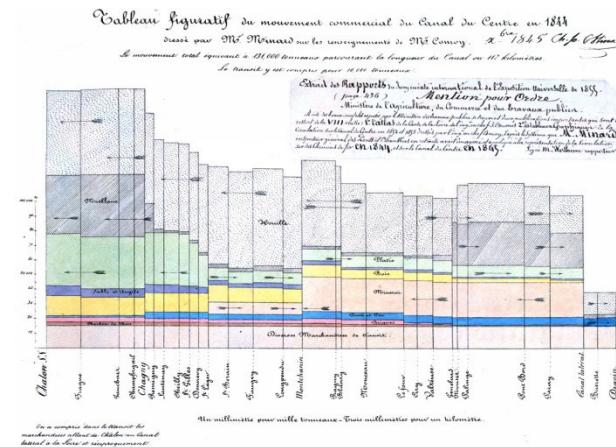
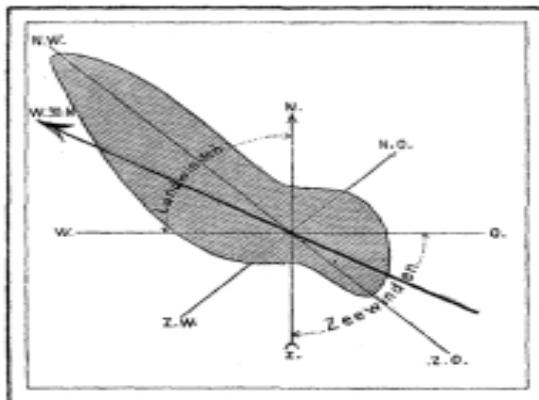
**1801:** Pie chart, circle graph invented- William Playfair



**1826:** First modern statistical map (illiteracy in France)- Charles Dupin



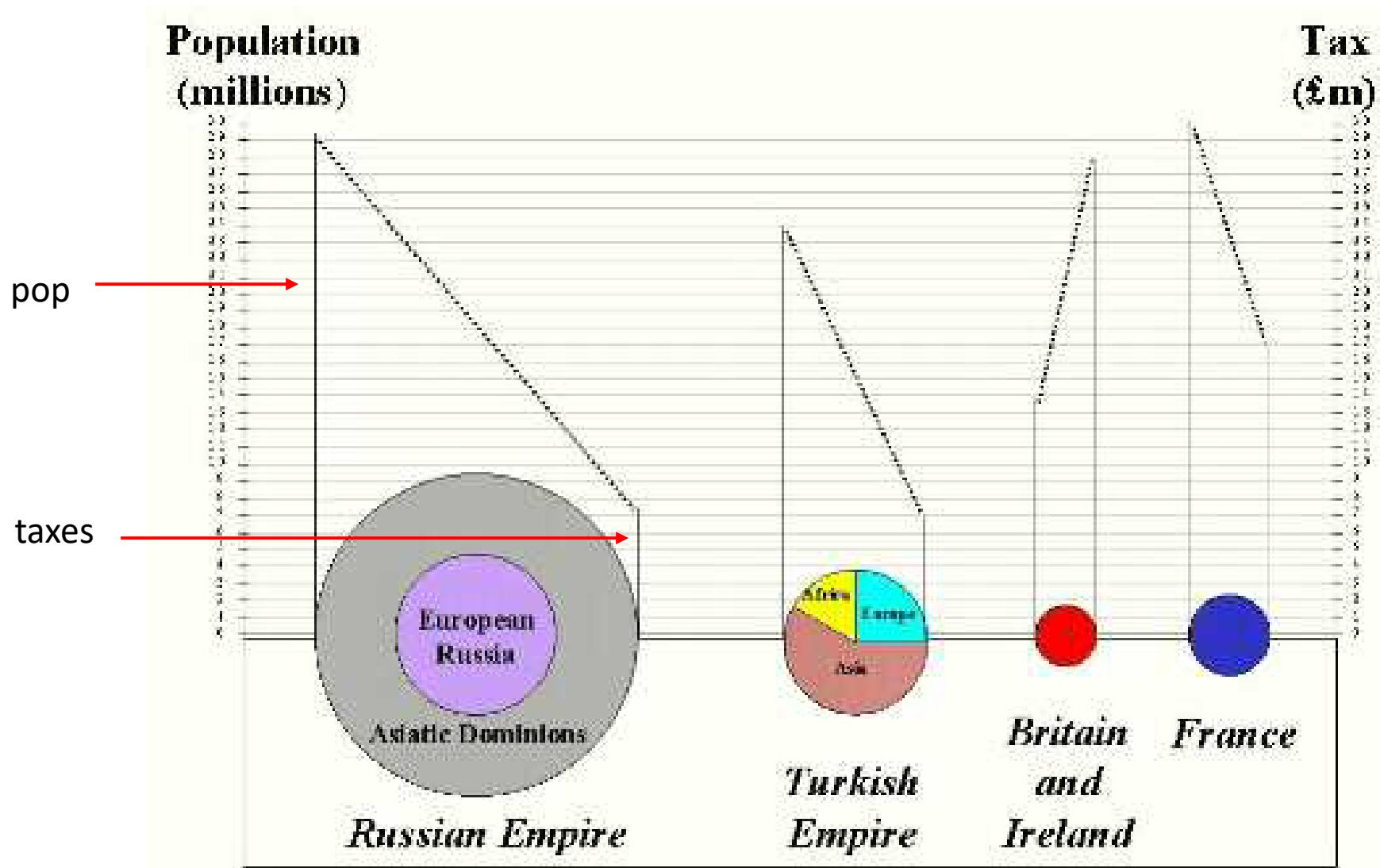
**1843:** Wind-rose (polar coordinates)- L. Lalanne



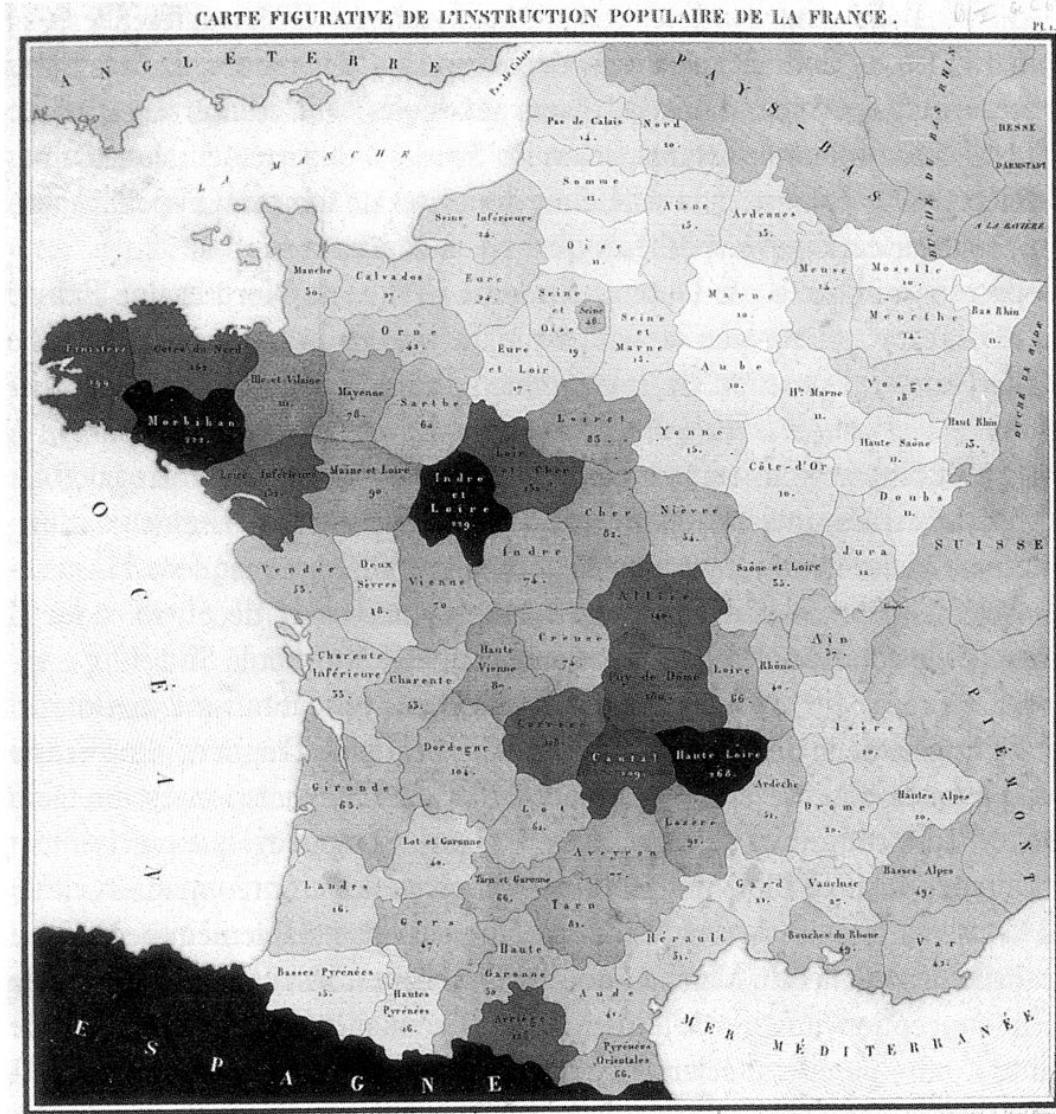
**1844:** variable-width, divided bars, area ~ cost of transport- C. J. Minard



# 1801: Pie chart, circle graph invented- William Playfair



# 1826: The 1<sup>st</sup> choropleth map, showing the distribution of literacy in France – Baron Charles Dupin



Social variables became:

- visual
- subject to scientific discussion

# 1844: Tableau-graphique: variable-width, divided bars, area ~ cost of transport- Charles Joseph Minard

## Tableau figuratif du mouvement commercial du Canal du Centre en 1844

dressé par M<sup>e</sup> Minard sur les renseignements de M<sup>e</sup> Comoy. <sup>6<sup>e</sup></sup> - 1845 Ch. J. Minard

Le mouvement total équivaut à 131,000 tonnes parcourant la longueur du Canal ou 117 kilomètres.

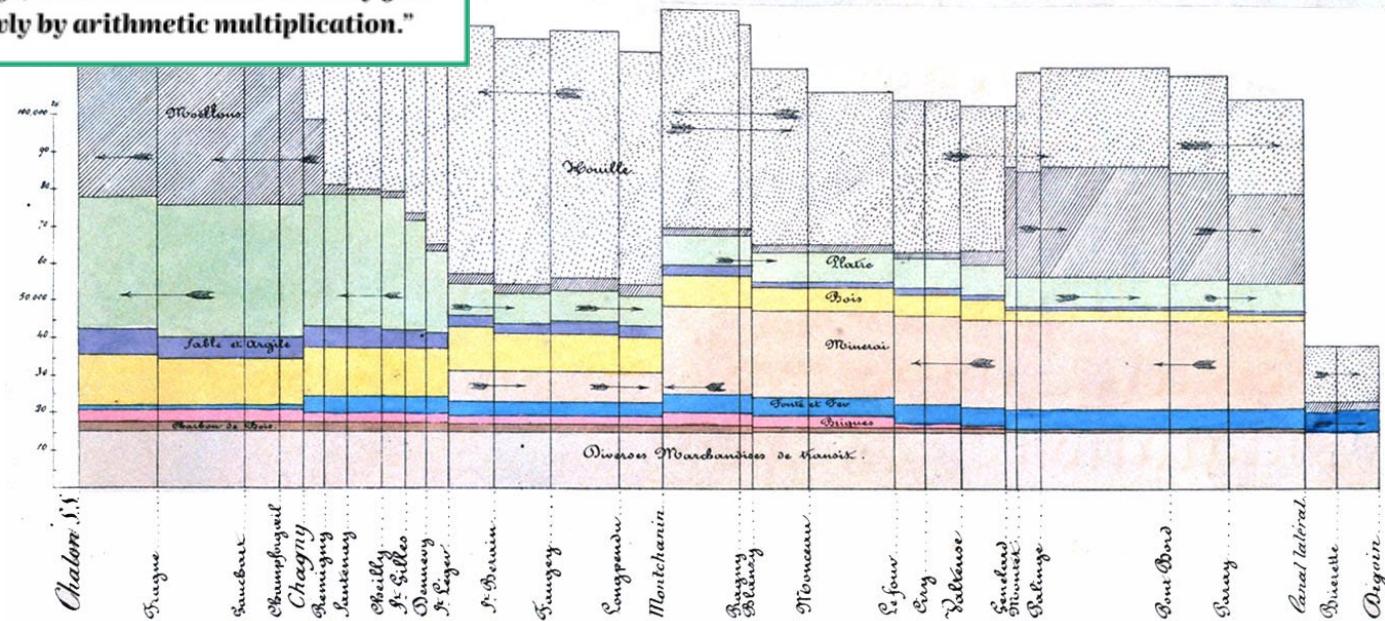
Le transit y est compris pour 16,000 tonnes.

"the total areas of each rectangle being proportional to the number of passengers carried at 1 kilometer [...], the comparison of these surfaces gives promptly, by the image, what written numbers only give slowly by arithmetic multiplication."

Extrait des Rappports... à l'Exposition internationale de l'Exposition Universelle de 1855.  
(page 436) Mention pour Ordre.

Ministère de l'Agriculture, du Commerce et des travaux publics.

A côté des bons modèles exposés par l'Ministère des travaux publics se trouvent deux publications importantes qui sont du résultat de la VIII classe : 1<sup>er</sup> l'Atlas de la carte de la Loire et ingénierie du Compte 2<sup>me</sup> le tableau graphique de la circulation sur le canal du Centre en 1842 et 1853 dressé par M<sup>e</sup> Comoy, l'après le système que M<sup>e</sup> Minard a introduit généralement dans les tableaux en traitant avec l'imagination appliquée à la représentation de la circulation sur les chemins de fer en 1841, et sur le canal du Centre en 1845. Signé M. Wertheim rapporteur.



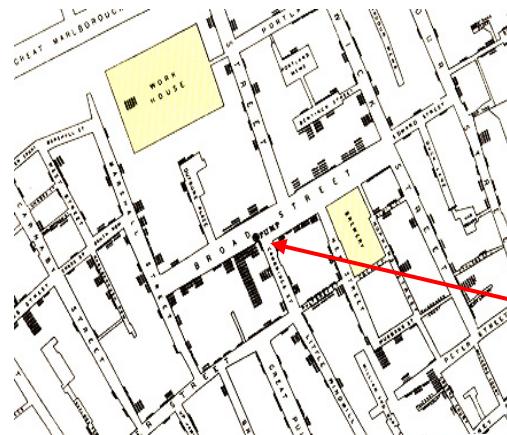
On a compris dans le transit les marchandises allant du Chalon au canal latéral à la Loire se reciprocement.

# 1850-1900: Golden Age

- By the last half of the 19<sup>th</sup> century the conditions for rapid growth of visualization had been established:
  - widespread data collection for planning, commerce, social theory
  - the beginnings of statistical theory and visual thinking
  - a wide range of graphic forms, reasonably well understood
  - technology:
    - lithography and color printing
    - automatic recording devices
    - calculation: machines & graphical calculators
- The result was a perfect storm-- among the most exquisite graphics ever produced.

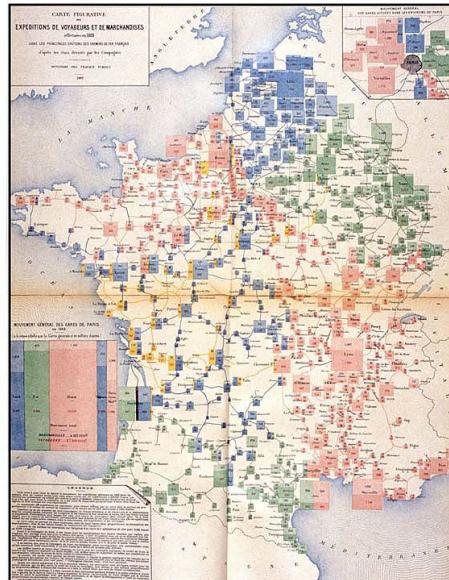


# 1850-1900: Golden Age



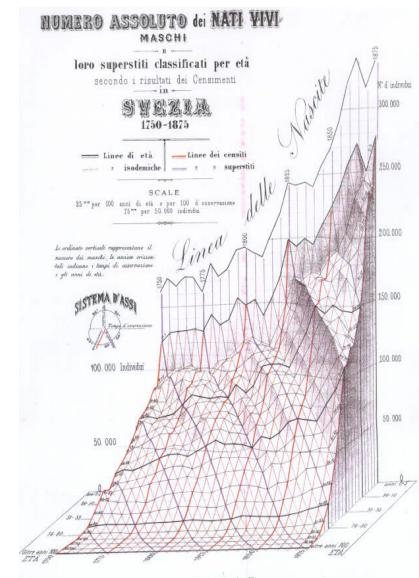
**1855:** Dot map of disease data (cholera)- John Snow

Broad St. pump

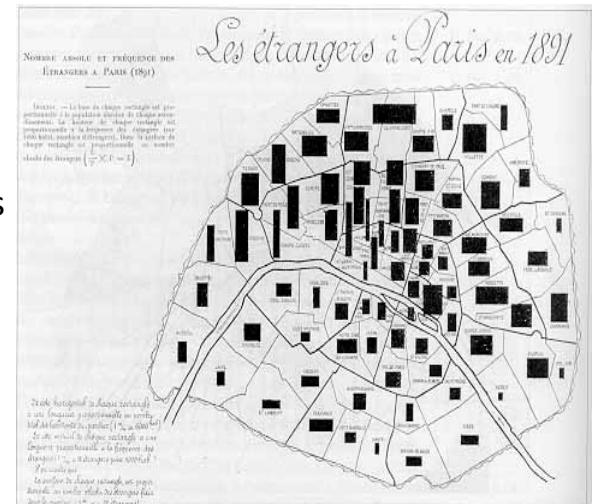


**1884:** Recursive multi-mosaic on a map- Emile Cheysson

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



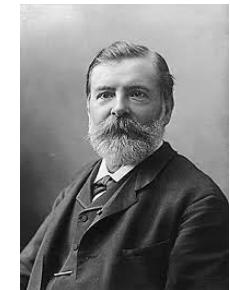
**1896:** Area rectangles on a map to display two variables and their product- Jacques Bertillon



| BC | AD | 1000 | 1600 | 1700 | 17th C | 18th C | 19th Century | 20th Century | 2000 |
|----|----|------|------|------|--------|--------|--------------|--------------|------|
|----|----|------|------|------|--------|--------|--------------|--------------|------|

# E.-J. Marey: *La Méthode Graphique*

- How to make human and animal motion subject to precise scientific study?
- e.g., aerial locomotion of flying insects & birds
  - What is the frequency of wings of different species?
  - What are the mechanisms of wings to produce lift and forward motion?



A harness, designed to register the trajectory, force and speed of a bird's wing in flight

Marey (1870) *Animal Mechanism*

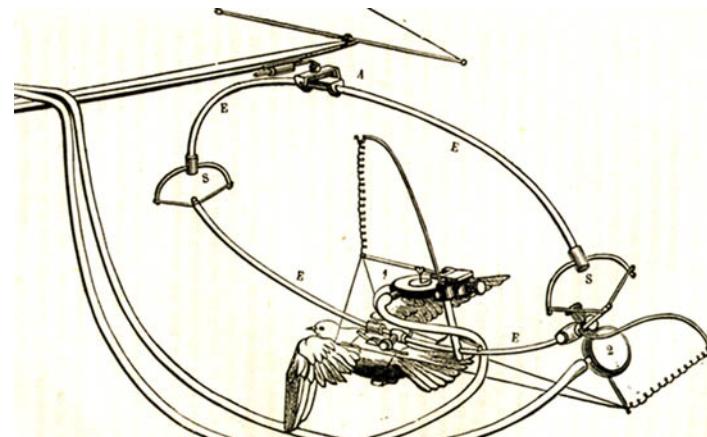


FIG. 104.—Suspension of the bird in the instrument. E E E E, an ellipse of metal capable of oscillating freely in every direction, by means of the double suspension A. S S, india-rubber supports allowing the lower part of the ellipse to oscillate in the vertical direction. The suspensory apparatus is fixed on the back of the pigeon. The lever-drum (1) receives the movements executed by the wing in a vertical direction. The lever-drum (2) receives those of the horizontal movements.

# E.-J. Marey: Chronophotography



Fig. 1. Fusil d'emploi de fusil photographique.

Rather than separate frames, Marey's "fusil photographique" allowed one to see motion continuously in a single static image.

This provides a visual analysis of a sprint:

- The runner takes about  $\frac{1}{2}$  second (7 frames) to make it to an upright position
- Successive frames alternate between power push from the hind leg to landing on the opposite leg

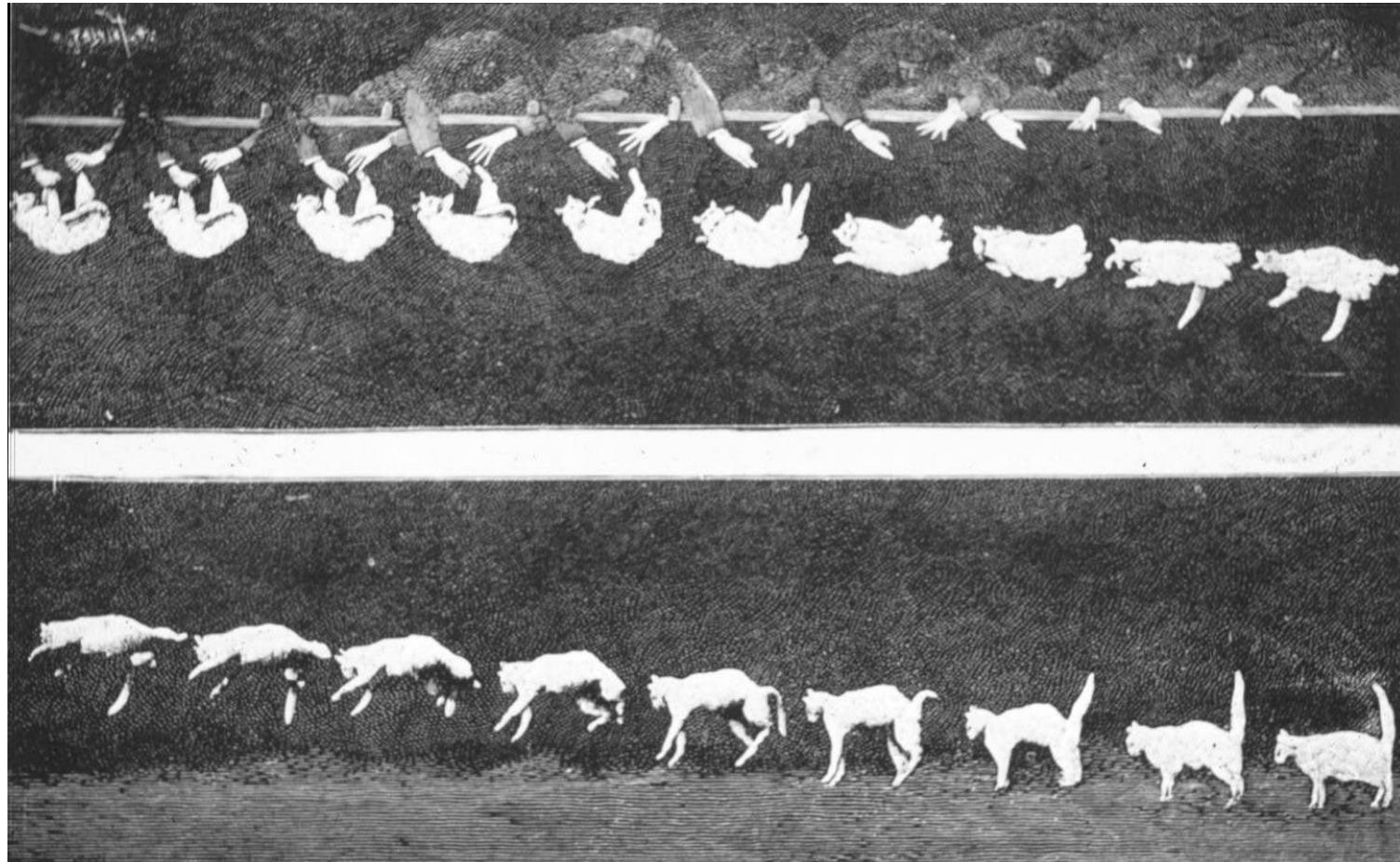


Source: <https://lightsmellscloud.wordpress.com/tag/etienne-jules-marey/>

# The Falling Cat Problem

Another fundamental problem answered by chronophotography:

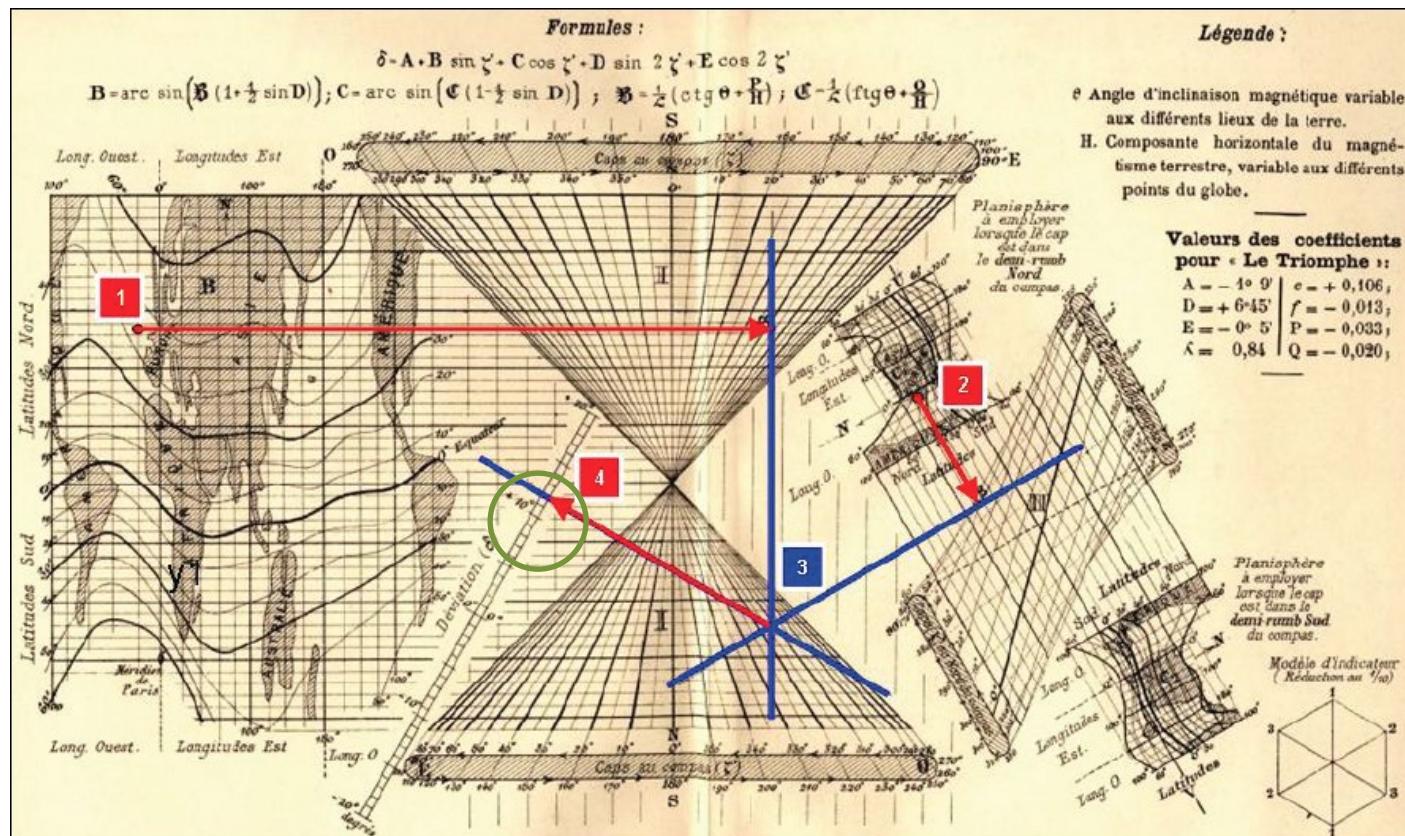
- How does a falling cat usually land on her feet? An OMG moment!



# Nomography

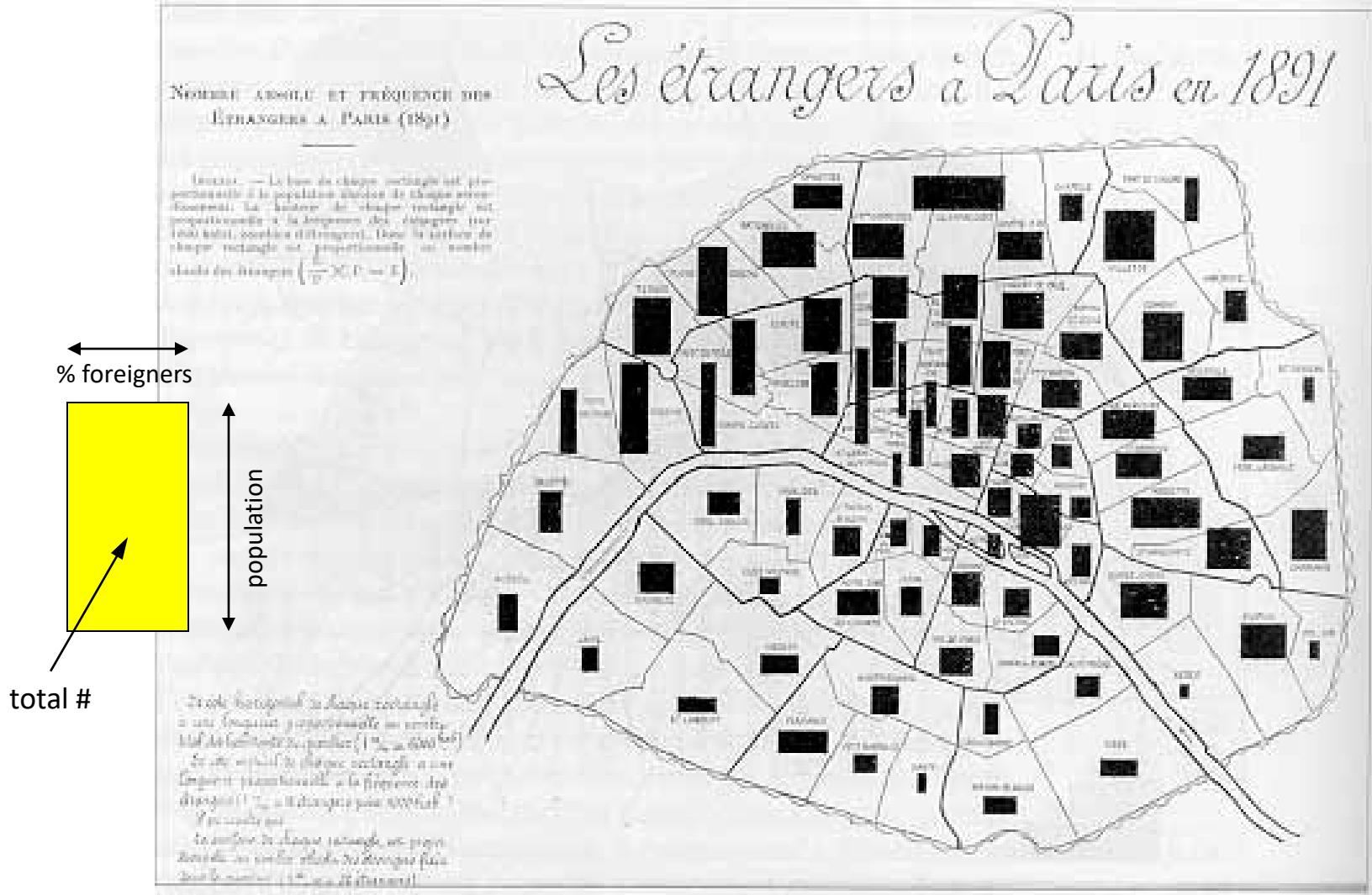
1885: Charles Lallemand, graphical calculator for compass course corrections of a ship at sea

Combines: anamorphic maps, hexagonal coordinates, trigonometric scales (5 eqns)



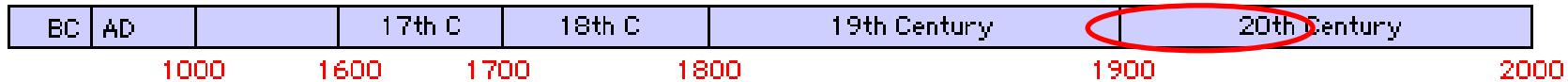


# 1896: Area rectangles on a map to display two variables and their product- Jacques Bertillon



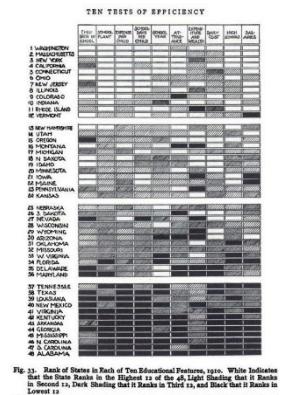
# 1900-1949: The Modern Dark Ages

- By the 1930s, the growth of statistical methods supplanted enthusiasm for graphics
  - There were few graphic innovations
  - In statistics: numbers were precise; graphs were just “pretty pictures”
- But graphical methods had entered the mainstream & were popularized
  - Text books, college courses
- There were several graphic-based scientific discoveries
- Electronic computers were born

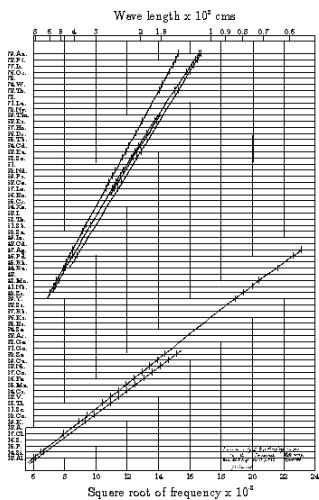


# 1900-1949: The Modern Dark Ages

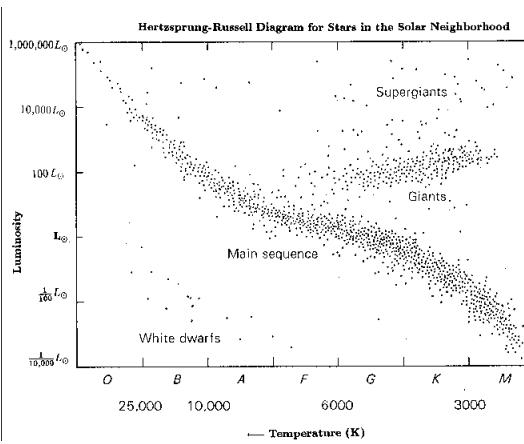
**1914:** Brinton: *Graphic Methods for Presenting Facts*



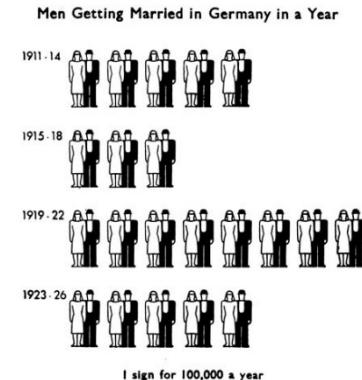
**1913:** Discovery of atomic number, based on graphical analysis- H. Moseley



**1911-1913:** The Hertzsprung-Russell diagram & evolution of stars



**1924:** ISOTYPE method of pictorial graphics—Otto Neurath



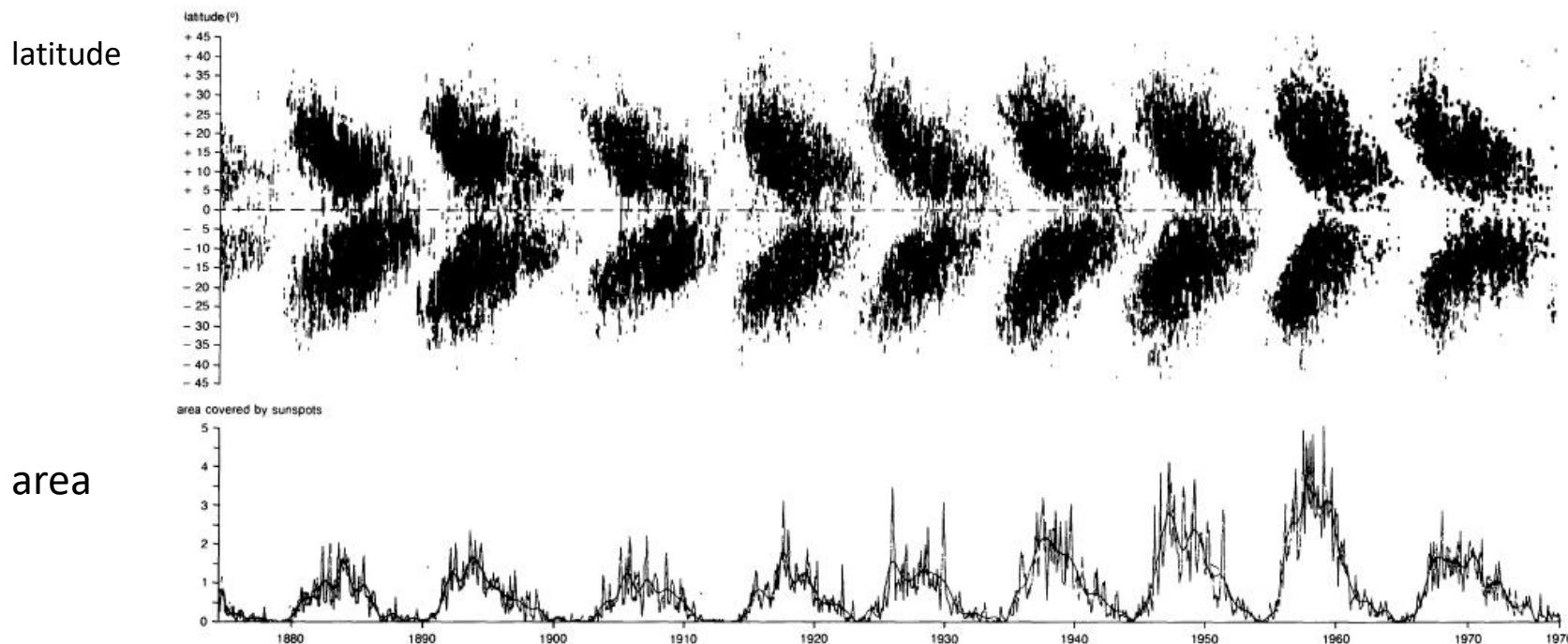
**1944:** Harvard's Mark I, the first digital computer- Howard Aiken, Grace Hopper



# Maunder: Butterfly diagram

1904: E.W. Maunder plots distribution of sunspots in sun's latitude by time

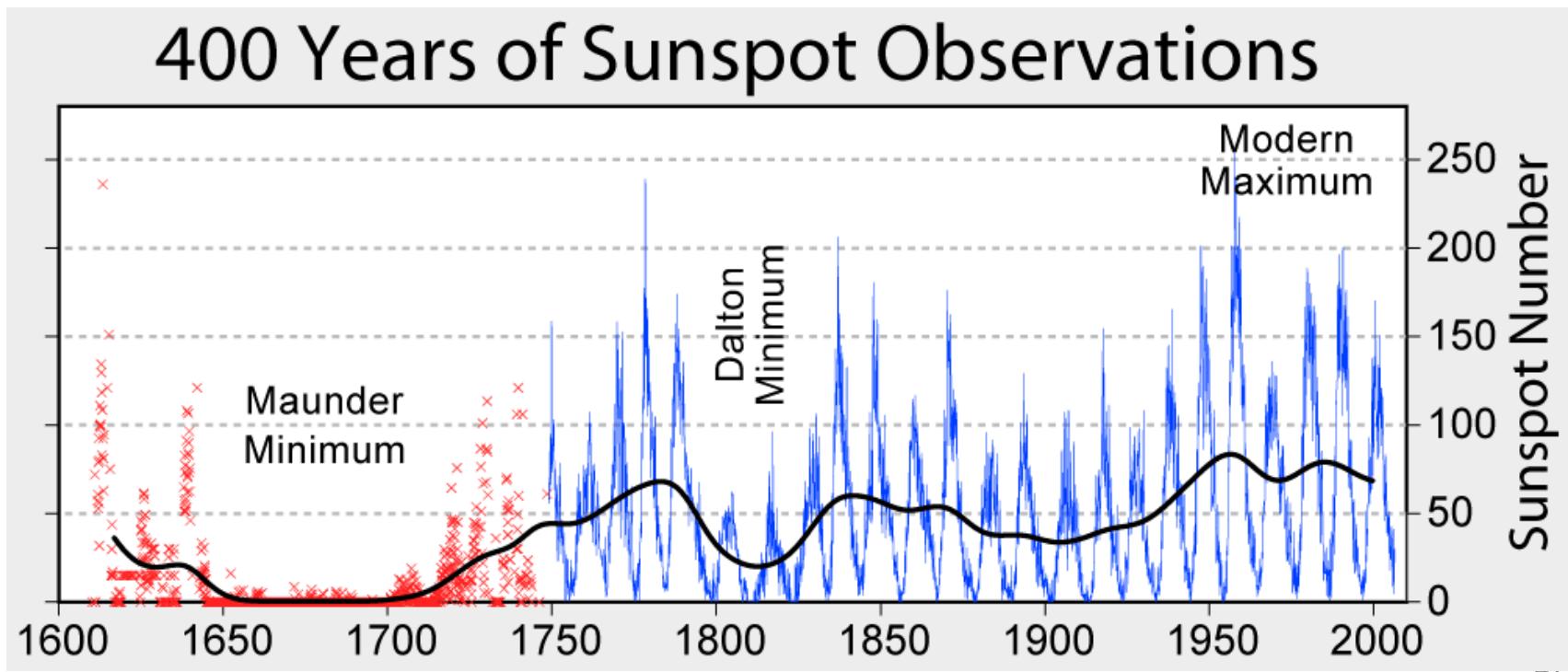
- Discovery of 11-year sunspot cycles (& 22-yr: reversal of sun's magnetic field)



# Maunder: Butterfly diagram

1904: E.W. Maunder plots distribution of sunspots in sun's latitude by time

- Discovery of “Maunder minimum” (1645-1715): “Little Ice Age”
- Smoothing reveals other extrema



**1914:** Willard C. Brinton publishes *Graphic Methods for Presenting Facts*, the 1<sup>st</sup> popular book on the topic



heatmap

TEN TESTS OF EFFICIENCY

|                  | CHILDREN IN SCHOOL | SCHOOL-PLANT | EXPENSE PER CHILD | SCHOOL-DAYS PER CHILD | SCHOOL-YEAR | ATTENDANCE | EXPENDITURE AND WEALTH | DAILY COST | HIGH SCHOOLS | SALARIES |
|------------------|--------------------|--------------|-------------------|-----------------------|-------------|------------|------------------------|------------|--------------|----------|
| 1 WASHINGTON     |                    |              |                   |                       |             |            |                        |            |              |          |
| 2 MASSACHUSETTS  |                    |              |                   |                       |             |            |                        |            |              |          |
| 3 NEW YORK       |                    |              |                   |                       |             |            |                        |            |              |          |
| 4 CALIFORNIA     |                    |              |                   |                       |             |            |                        |            |              |          |
| 5 CONNECTICUT    |                    |              |                   |                       |             |            |                        |            |              |          |
| 6 OHIO           |                    |              |                   |                       |             |            |                        |            |              |          |
| 7 NEW JERSEY     |                    |              |                   |                       |             |            |                        |            |              |          |
| 8 ILLINOIS       |                    |              |                   |                       |             |            |                        |            |              |          |
| 9 COLORADO       |                    |              |                   |                       |             |            |                        |            |              |          |
| 10 INDIANA       |                    |              |                   |                       |             |            |                        |            |              |          |
| 11 RHODE ISLAND  |                    |              |                   |                       |             |            |                        |            |              |          |
| 12 VERMONT       |                    |              |                   |                       |             |            |                        |            |              |          |
| 13 NEW HAMPSHIRE |                    |              |                   |                       |             |            |                        |            |              |          |
| 14 UTAH          |                    |              |                   |                       |             |            |                        |            |              |          |
| 15 OREGON        |                    |              |                   |                       |             |            |                        |            |              |          |
| 16 MONTANA       |                    |              |                   |                       |             |            |                        |            |              |          |
| 17 MICHIGAN      |                    |              |                   |                       |             |            |                        |            |              |          |
| 18 N DAKOTA      |                    |              |                   |                       |             |            |                        |            |              |          |
| 19 IDAHO         |                    |              |                   |                       |             |            |                        |            |              |          |
| 20 MINNESOTA     |                    |              |                   |                       |             |            |                        |            |              |          |
| 21 IOWA          |                    |              |                   |                       |             |            |                        |            |              |          |
| 22 MAINE         |                    |              |                   |                       |             |            |                        |            |              |          |
| 23 PENNSYLVANIA  |                    |              |                   |                       |             |            |                        |            |              |          |
| 24 KANSAS        |                    |              |                   |                       |             |            |                        |            |              |          |
| 25 NEBRASKA      |                    |              |                   |                       |             |            |                        |            |              |          |
| 26 S. DAKOTA     |                    |              |                   |                       |             |            |                        |            |              |          |
| 27 NEVADA        |                    |              |                   |                       |             |            |                        |            |              |          |
| 28 WISCONSIN     |                    |              |                   |                       |             |            |                        |            |              |          |
| 29 WYOMING       |                    |              |                   |                       |             |            |                        |            |              |          |
| 30 ARIZONA       |                    |              |                   |                       |             |            |                        |            |              |          |
| 31 OKLAHOMA      |                    |              |                   |                       |             |            |                        |            |              |          |
| 32 MISSOURI      |                    |              |                   |                       |             |            |                        |            |              |          |
| 33 W. VIRGINIA   |                    |              |                   |                       |             |            |                        |            |              |          |
| 34 FLORIDA       |                    |              |                   |                       |             |            |                        |            |              |          |
| 35 DELAWARE      |                    |              |                   |                       |             |            |                        |            |              |          |
| 36 MARYLAND      |                    |              |                   |                       |             |            |                        |            |              |          |
| 37 TENNESSEE     |                    |              |                   |                       |             |            |                        |            |              |          |
| 38 TEXAS         |                    |              |                   |                       |             |            |                        |            |              |          |
| 39 LOUISIANA     |                    |              |                   |                       |             |            |                        |            |              |          |
| 40 NEW MEXICO    |                    |              |                   |                       |             |            |                        |            |              |          |
| 41 VIRGINIA      |                    |              |                   |                       |             |            |                        |            |              |          |
| 42 KENTUCKY      |                    |              |                   |                       |             |            |                        |            |              |          |
| 43 ARKANSAS      |                    |              |                   |                       |             |            |                        |            |              |          |
| 44 GEORGIA       |                    |              |                   |                       |             |            |                        |            |              |          |
| 45 MISSISSIPPI   |                    |              |                   |                       |             |            |                        |            |              |          |
| 46 N. CAROLINA   |                    |              |                   |                       |             |            |                        |            |              |          |
| 47 S. CAROLINA   |                    |              |                   |                       |             |            |                        |            |              |          |
| 48 ALABAMA       |                    |              |                   |                       |             |            |                        |            |              |          |

Fig. 33. Rank of States in Each of Ten Educational Features, 1910. White Indicates that the State Ranks in the Highest 12 of the 48, Light Shading that it Ranks in Second 12, Dark Shading that it Ranks in Third 12, and Black that it Ranks in Lowest 12

pictogram

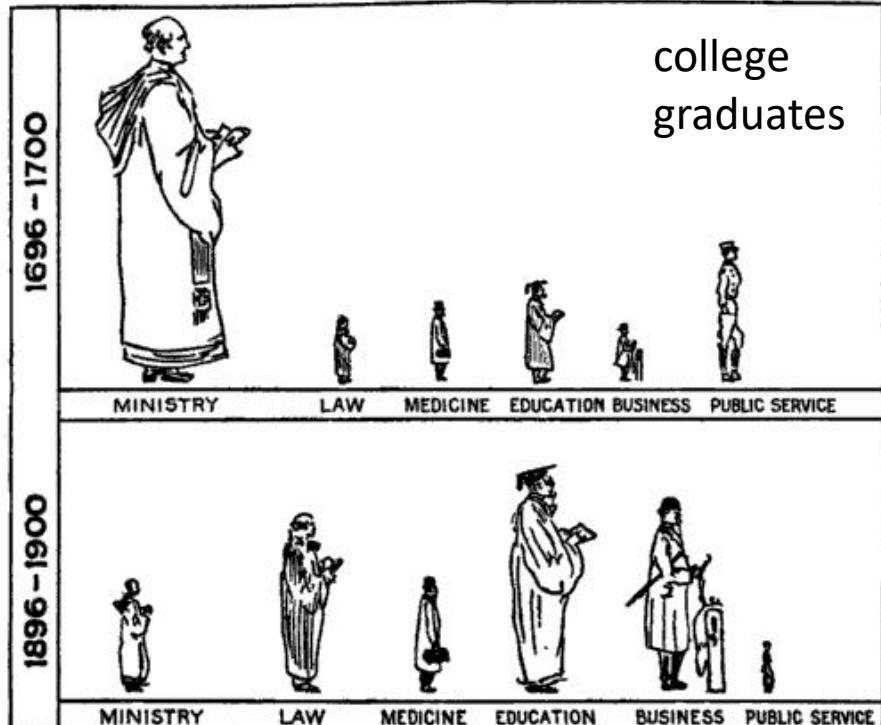
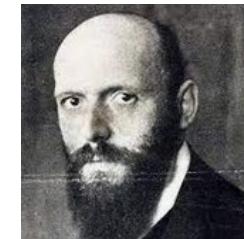


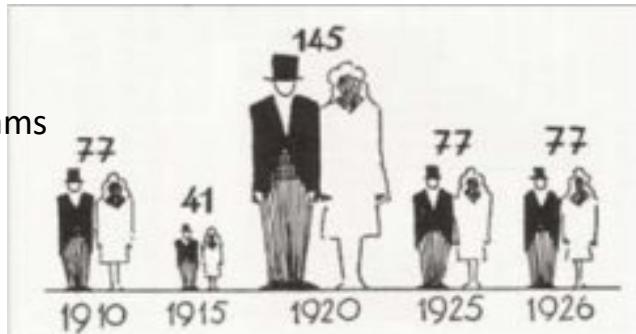
Fig. 39. Proportion of College Graduates in Different Professions in 1696-1700 and in 1896-1900

Charts of this kind with men represented in different sizes are usually so drawn that the data are represented by the height of the man. Such charts are misleading because the area of the pictured man increases more rapidly than his height. Considering the years 1696-1700, the pictured minister has about two and one-half times the height of the man representing public service. The minister looks over-important because he has an area of more than six times that of the man drawn to represent public service. This kind of graphic work has little real value.

**1924:** Otto Neurath developed the **Isotype** (International System of Typographic Picture Education) method to communicate statistical information to the broad public in an intuitive, pictorial way.



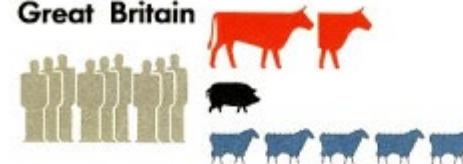
NOT  
pictograms



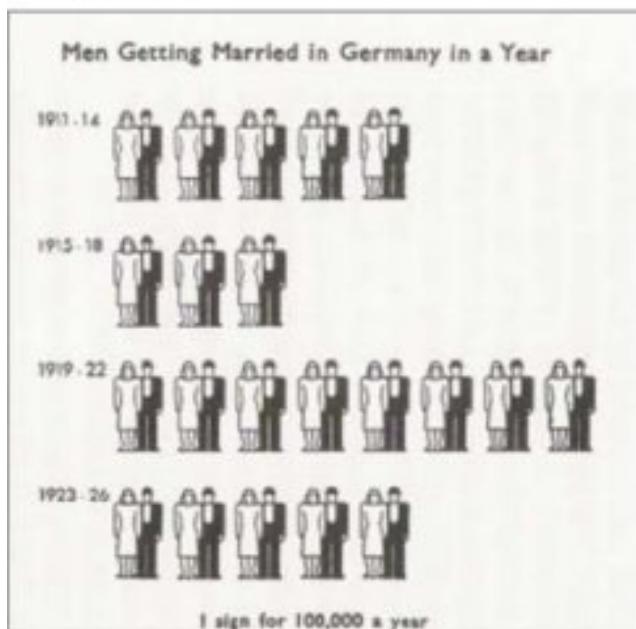
### Population and Live Stock



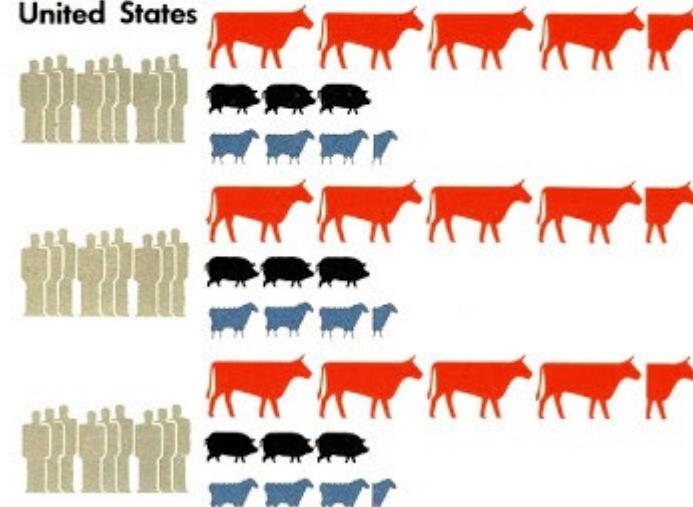
#### Great Britain



even complex,  
multivariate data



#### United States



Average for 1935 - 1939

Each grey figure represents 5 million population  
Each complete red symbol represents 5 million cattle  
Each complete black symbol represents 5 million pigs  
Each complete blue symbol represents 5 million sheep

## EXPLORATORY DATA ANALYSIS



# 1950-1974: Re-birth of graphics

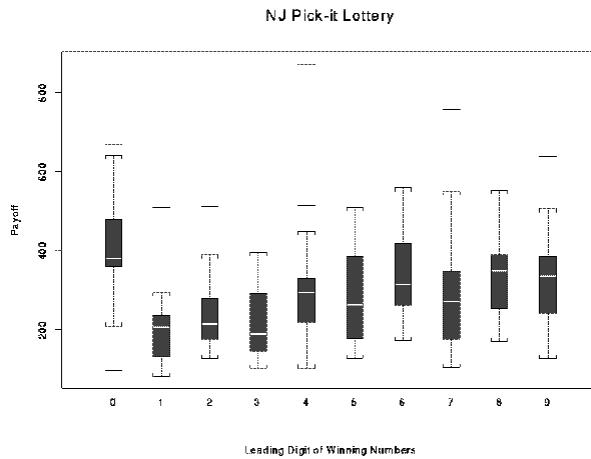
- Visualization began to rise from dormancy in the mid 1960s, spurred largely by:
  - J. W. Tukey's *Exploratory Data Analysis*: The power of graphics to show the unexpected in data analysis
  - Jacques Bertin's *Semiologie Graphique*: A general theory of composing graphs and maps
  - computer hardware for computation and display
  - the advent of statistical and graphics software

| VISUAL VARIABLES | LEVEL OF ORGANIZATION |        | DEPLOYMENT MODE |       |       |
|------------------|-----------------------|--------|-----------------|-------|-------|
|                  | PUNCTUAL              | LINEAR | ZONAL           |       |       |
| SIZE             | Q O ≠                 | • ● ●  | —               | ■ ■ ■ | ● ● ● |
| VALUE INTENSITY  | O ≠                   | ○ ○ ○  | —               | ■ ■ ■ | ● ● ● |
| GRANULATION      | O ≠ ≡                 | ■ ■ ■  | —               | —     | —     |
| ORIENTATION      | ≠ ≡                   | /   -  | —               | —     | —     |
| COLOR            | ≠ ≡                   | ● ● ●  | —               | —     | —     |
| FORM             | ≠ ≡                   | △ ● ■  | —               | ■ ■ ■ | ● ● ● |

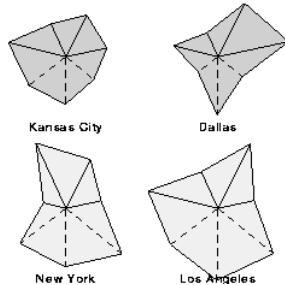


# 1950-1974: Re-birth of graphics

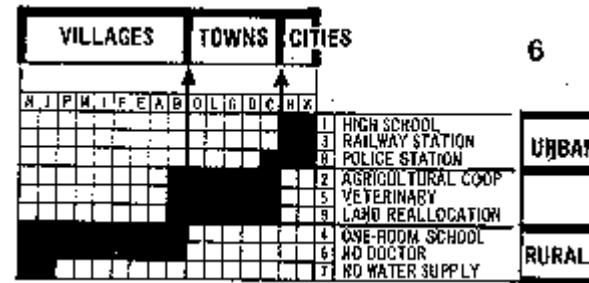
1969: Graphical innovations for EDA (stem-and-leaf, box-plots, etc.)- J.W. Tukey



## Multivariate glyphs

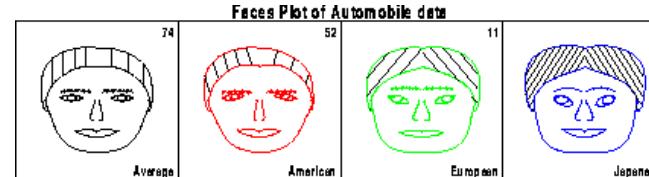


1971: Star plots- J. H. Siegel et al



1967: Reorderable matrix- Jacques Bertin

1973: Face plots- Herman Chernoff



# Digital display devices

The biggest limitation in the early development of dynamic and interactive graphics was in graphics display devices.



Only B/W, but for the first time, **dynamic** displays became possible.

By the late 1950s, pen-like input devices allowed rudimentary direct **interaction**

# 1975-present

## Technology:

- Progressively more powerful computation & graphics
  - Mainframes → PCs → workstations → servers → cloud computing
  - pen plotters → CRTs → graphics hardware & firmware
  - stand-alone → client-server architecture
- Internet
  - email → bitnet -> file sharing (FTP) → www (HTML) → Java → javascript
  - data: open data initiatives (~1995) → APIs (census, health, ...)
  - eCommerce: Amazon, Netflix, ... → BIG data, recommender systems
- Software
  - Graphics packages: SYSTAT, Data Desk, XGobi, ViSta
  - Statistical packages: SAS, SPSS
  - Statistical programming environments: R, matlab, Stata
  - Contributed package archives: CTAN (latex), CPAN (perl), CRAN (R)
  - Collaborative development sites: github, bitbucket, ...

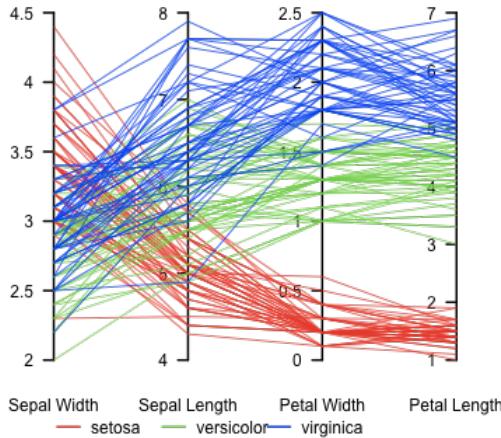
# 1975-present

Themes in data visualization:

- high-D problems of progressively higher dimensions
  - grand tour: n-D → 2D projections
  - Dimension reduction methods (PCA, MDS, biplots)
- graphics & methods for other data types:
  - categorical, frequency data,
  - networks, trees, ...
  - text (word clouds, ...)
  - spatial data & models
- interactive data vis
  - linked views
  - direct manipulation: select, zoom, filter
  - dynamic graphics & animation

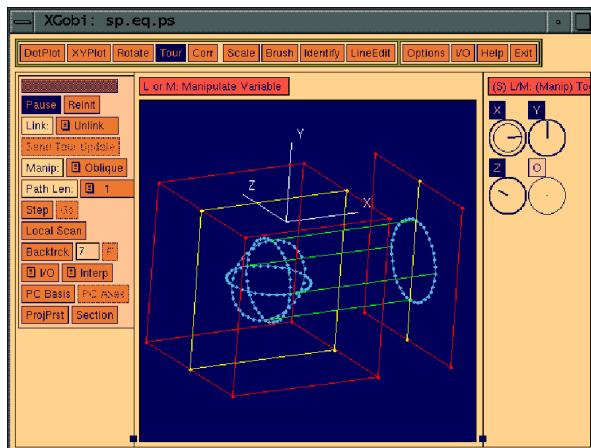
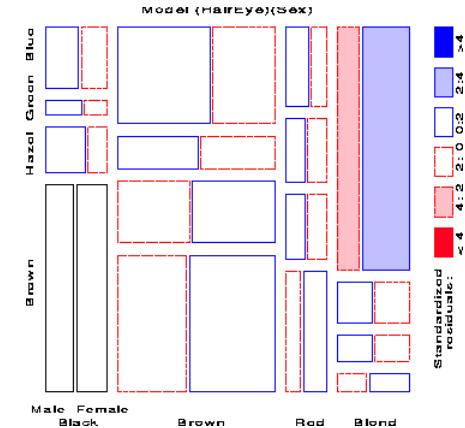
# 1975-present

Parallel coordinate plot, Fisher's Iris data



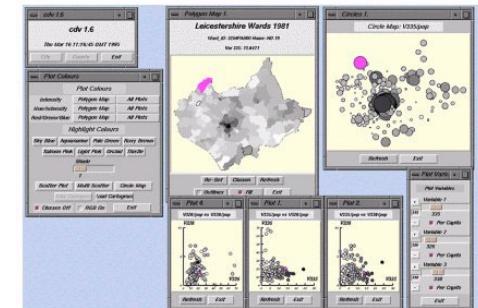
**1985:** Parallel coordinates plots for high-D data- Alfred Inselberg

**1991:** Mosaic display for visual analysis of log-linear models- Michael Friendly



**1991-1996:** High-interaction systems for data analysis and visualization, e.g., *XGobi*, *ViSta*

**1996:** Cartographic Data Visualiser – Jason Dykes



# Tukey: PRIM-9

1973: a group at the Stanford Linear Accelerator developed PRIM-9

- Picturing, Rotating, Isolation, Masking in up to 9 dimensions
- \$400K graphic display & keypad; computations on a mainframe, \$500/hr



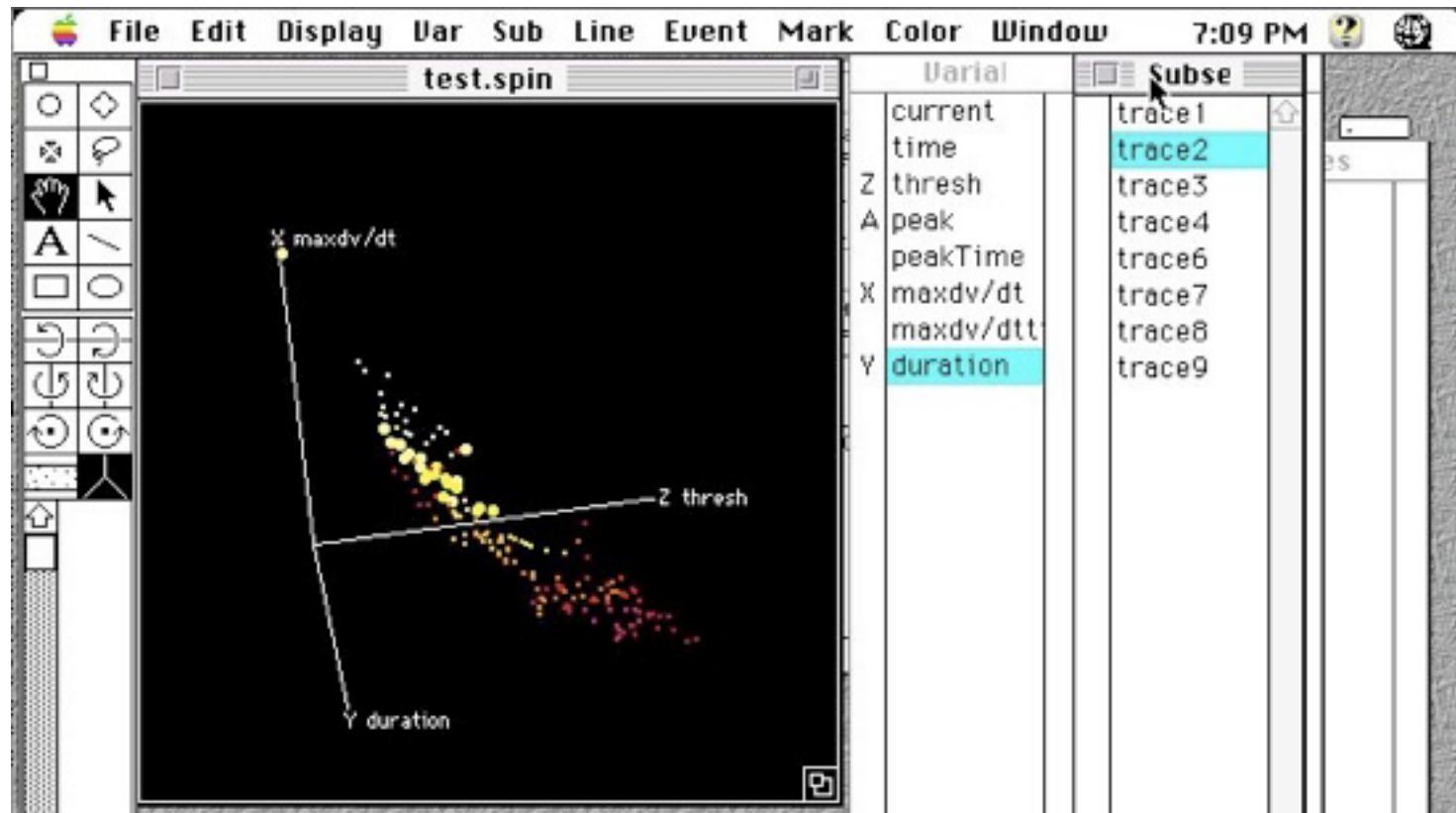
# Next steps: Hardware

- Dynamic 3D graphics was painfully slow for larger data sets.
- Specialized 3D graphics hardware:
  - Early 1970s: Simple LSI graphics chips for video games
  - 70s—80s: Graphics co-processors (GPUs) with increasing graphics capabilities
  - 80s—90s: Silicon Graphics develops high-performance 3D graphics workstations



# Software

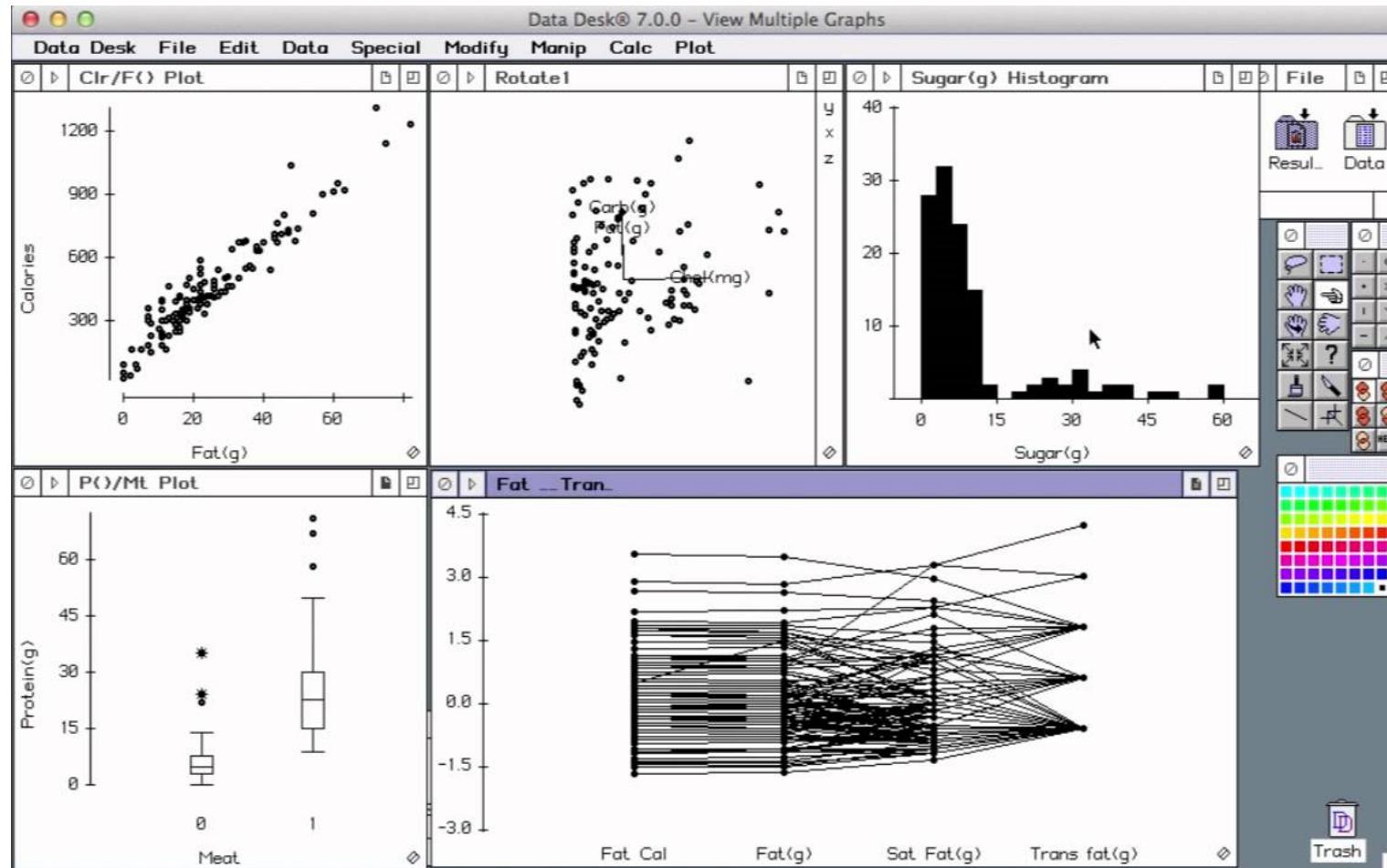
- MacSpin – Andrew & David Donoho (1984—85). At ASA meetings 1986, “dynamic graphics became as portable as a 25-lb Macintosh”



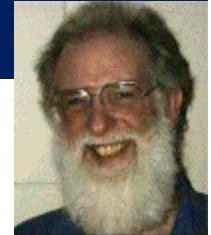
# Linking, brushing, 3D rotation

Paul Velleman (~1985): Data Desk provided multiple 1D, 2D, 3D views

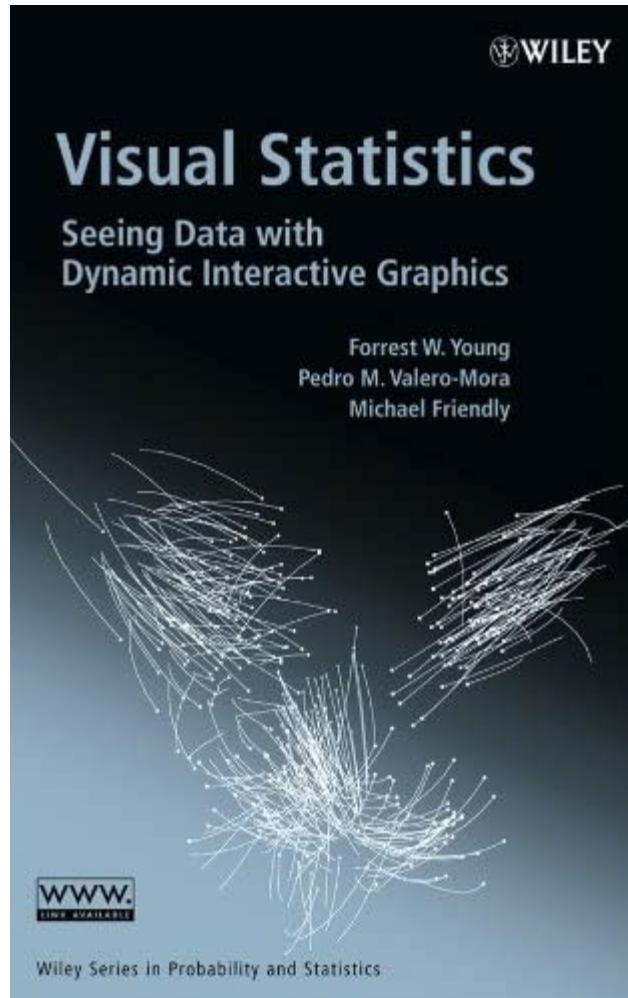
- **Brushing:** selection of points, regions, ... via mouse
- **Linking:** Any action in one plot reflected in all others



# Visual Statistics



Young, Valero-Mora & Friendly (2006)



A philosophy & pedagogy for statistics based on dynamic interactive graphics

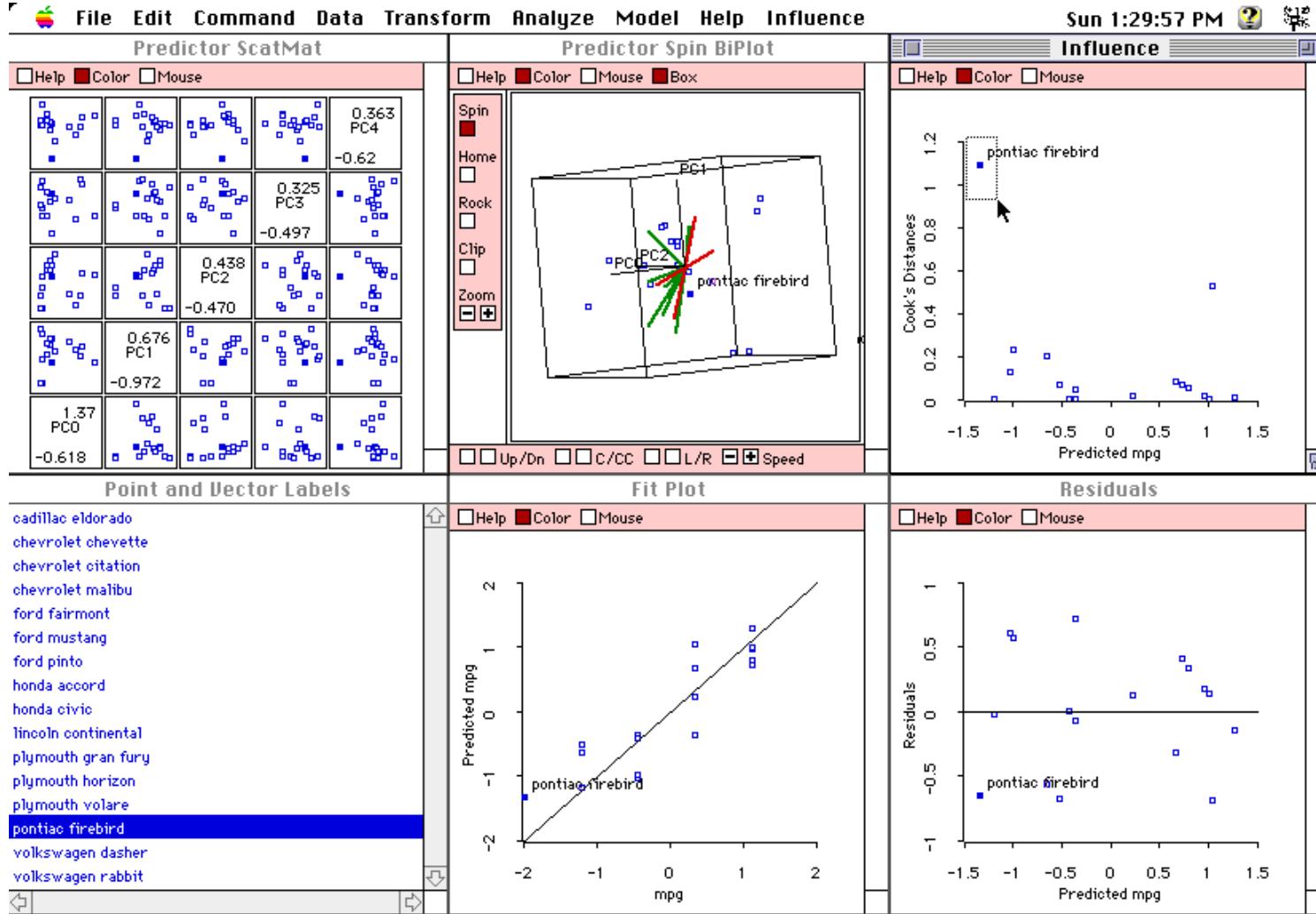
A theory of #datavis software:

- objects (data, model, ...)
- methods (print, plot, )
- manipulating plot objects & dimensions
- spin plots: rotating 3D plots
- spreadplots: dynamically linked views
- workmaps: visual record of analysis steps

Details: <https://www.uv.es/visualstats/>

See: The History of ViSta: The Visual Statistics System,  
<https://onlinelibrary.wiley.com/doi/full/10.1002/wics.1203>

# ViSta: Visual Statistics





# Summary

- Data Visualization has deep & wide roots:
  - **Cartography:** map-making, geo-measurement, thematic cartography, GIS, geo-visualization
  - **Statistics:** probability theory, distributions, estimation, models, stat-graphics, stat-visualization
  - **Data:** population, economic, social, moral, medical, ...
  - **Visual thinking:** geometry, functions, mechanical diagrams, EDA, ...
  - **Technology:** printing, lithography, computing...
- **Problem driven:** developments often driven by practical and theoretical problems of the day
- **Communication driven:** developments often arose from a desire to communicate better

# Conclusions

- Why study the history of data visualization?
  - “The only new thing in the world is the history you don’t know” – Harry S. Truman
  - “Those who cannot remember the past are condemned to repeat it.” – George Santayana (*The Life of Reason*, 1905)
  - “No scientific discovery is named after its original discoverer” – Stigler’s Law of Eponomy (1980). But: originally due to Merton!
- Today:
  - Narrow, specialized work in many fields
  - New methods “invented” and re-named w/o knowing history.
    - mosaic displays: Georg von Mayr (1877)
    - heatmaps: Loua (1873); Brinton (1914), Bertin (1967)
    - Nightingale (1859) rose diagram: polar diagrams by Guerry (1829), Lalanne (1843)