The Golden Age of Statistical Maps & Diagrams

Michael Friendly

York University
Chicago Maps Society, Dec. 12, 2007
Slides: www.math.yorku.ca/SCS/Papers/maps/

Acknowledgements: Thanks!

Plug: Palsky (1996), Paris: CTHS

- Bob Karrow, Jim Akerman: *Maps* book
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- *Chevaliers des Album de Statistique Graphique:*
  - Antoine de Falguerolles, Ian Spence, Howard Wainer, Ruddy Osterman, Tom Koch, Stephen Stigler, …
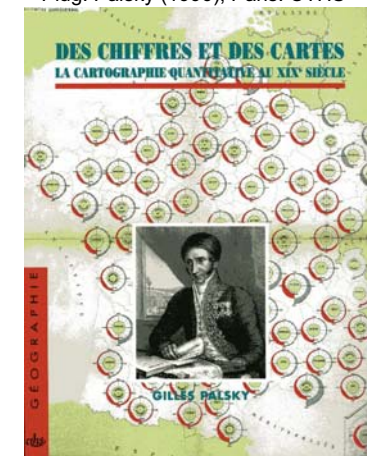

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Outline

- Introduction
  - Data visualization: thematic maps & diagrams
  - Context: Milestones Project
  - What is an Age? Why is it Golden?
- Preludes to the Golden Age
  - Statistics: Numbers of the state
  - Statistical theory, technology
  - Inventions in statistical graphics & cartography
- Exemplars of the Golden Age
  - Graphic vision of Charles Joseph Minard
  - Francis Galton's graphic discoveries
  - Statistical atlases

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Data visualization: thematic maps & diagrams

- Different 'visual language', but common goals:
  - **Exploration**: show trends, reveal patterns in quantitative or qualitative info
  - **Analysis**: aid in synthesizing, generalizing or testing patterns
  - **Presentation**: stimulate thought, convey conclusions, argue a point
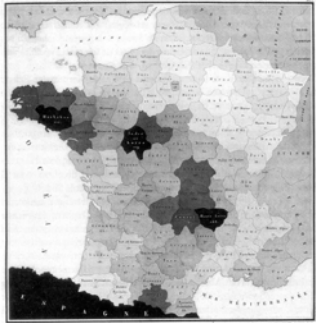
Snow (1855)   Galton (1863)   Minard (1869)
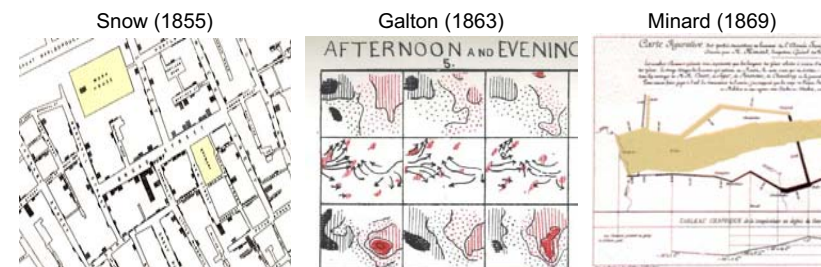
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Data visualization: Diffusion of ideas
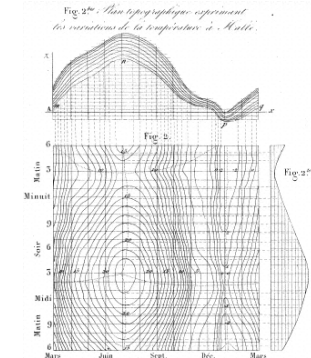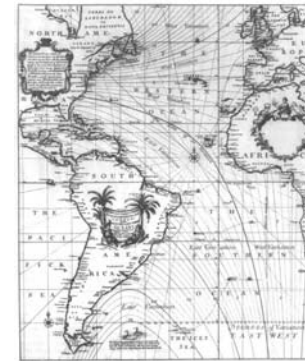
- Men who developed thematic maps often not cartographers

Dupin (1826): literacy in France   Galton (1881): travel time from London
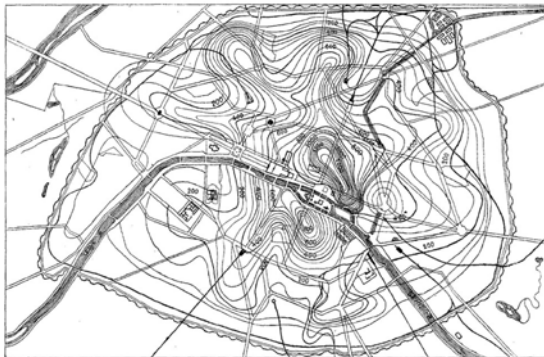

Data visualization: Diffusion of ideas

- Men who developed data graphics often borrowed from cartography
  - Halley (1701): contour map -> Lalanne (1843): contour diagrams of soil temp

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Data visualization: Diffusion of ideas

- … and vice-versa
  - Lalanne → L.L. Vauthier (1874) contour map of population density of Paris

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Data visualization: Diffusion of ideas

- Graphical inventions often applied to maps
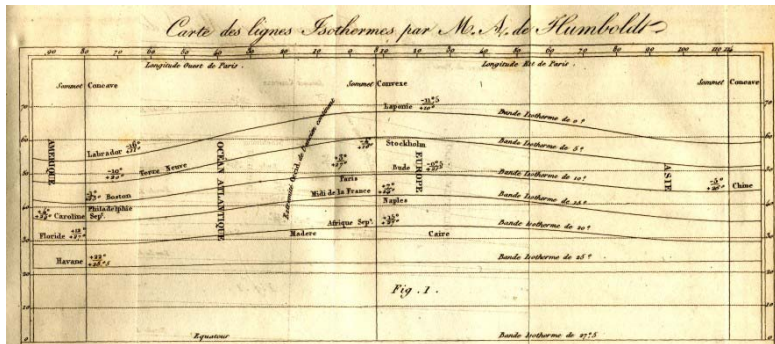 - Playfair (1805): pie chart -> Minard (1858): pie map

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Data visualization: Diffusion of ideas

- In map-based graphics, the map was often secondary: background, or deformed to fit the data

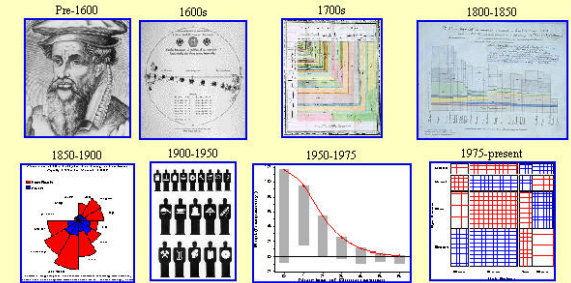A. von Humboldt (1817): Lines of isotherms

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Context: Milestones Project

www.math.yorku.ca/SCS/Gallery/milestone

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

An illustrated chronology of innovations by Michael Friendly and Daniel J. Denis
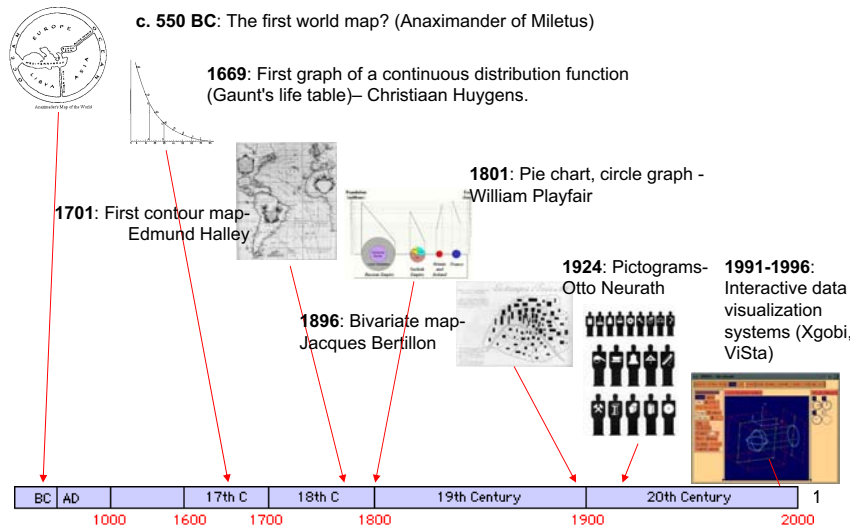
Project goals:
- Comprehensive catalog of developments in history of data visualization
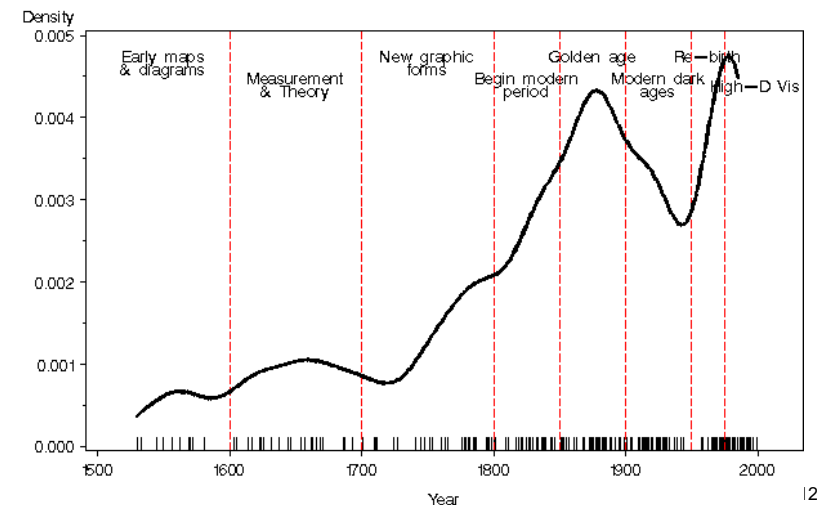- Tool to study themes, antecedents, influences, patterns, trends, etc.

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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: Pictograms- Otto Neurath

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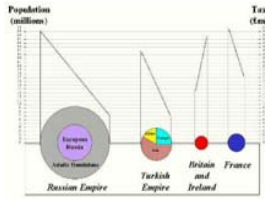

1

Milestones as a graph

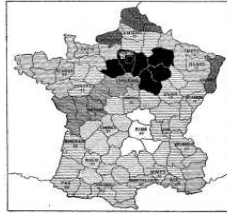Milestones: Time course of developments

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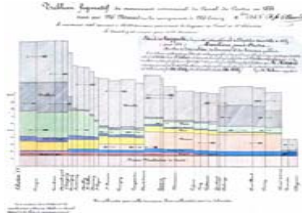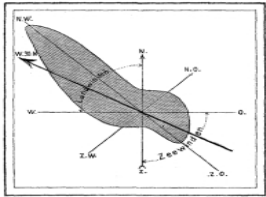## 1800-1849: Beginning of modern data graphics

1801: Pie chart, circle graph invented- William Playfair

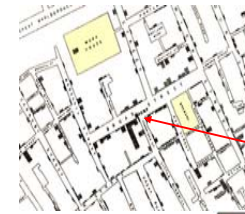**1819**: First modern statistical map (illiteracy in France)- Charles Dupin

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

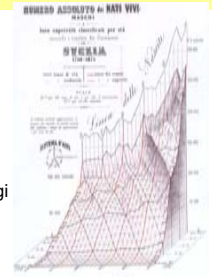**1844**: variable-width, divided bars, area ~ cost of transport- C. J. Minard

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

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

BC	AD		17th C	18th C	19th Century	20th Century
1000	1600	1700	1800	1900		2000
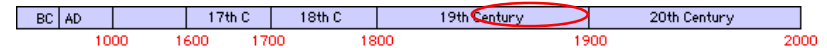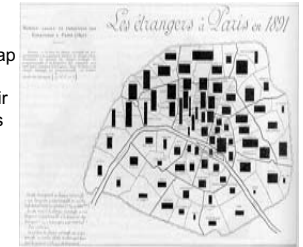
What makes an "Age"? Why is it "Golden"?

- Age:
  - Qualitatively distinct from before & after
- Golden age:
  - Recognizable period in a field where great tasks were accomplished
  - Years following some innovations
  - Artists apply skills to new areas
  - New ideas expressed, art forms flourish
  - Often ends with some turning point event(s)

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Some Golden Ages

- Athens (Pericles): 448 BC—404 BC
- Islam: 622—1258 (sack of Baghdad)
- England: Elizabeth I
- Piracy: 1690--1730
- Radio: 1920—1940
- Animation: 1928 (sound) – 1960s (TV)
- Senior citizens: 60+

Pietro Da Cortona, *The Golden Age* (Fresco Sala della Stufa, Palazzo Pitti, Florence)
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Preludes to the Golden Age

- Data: collection & dissemination
- Statistical theory: combining & summarizing quantitative information
- Technology: printing & reproduction of maps & diagrams
- Visual language: new graphic forms for maps and diagrams
- → a perfect storm for data graphics

Preludes: data

"Data! Data! I can't make bricks without clay." – Sherlock Holmes, Copper Beeches

- Population: ~ 1660--
  - Bills of mortality: Graunt (1662)
  - Political arithmetic: Petty (1665)
  - Demography: Süssmilch (1741)
- Economic data: ~ 1770--
  - Revenue, expenditures, taxes
  - Imports, exports
  - Transport
- Social data: ~ 1820--
  - Literacy, education
  - Crime, suicides, illegitimate births, prostitution
  - Poverty, debtors, disease
- → An avalanche of data, waiting to be visualized!

Preludes: technology

- Copperplate → Lithography (1800+) → color printing (1850+)
- Automatic recording: James Watt (1822)
- Calculation: Babbage (1822/33)
- Photography: Niépce (1827), Deguerre (1839), trichromatic process (1861)
- Motion: Muybridge (1872), Marey (1882)
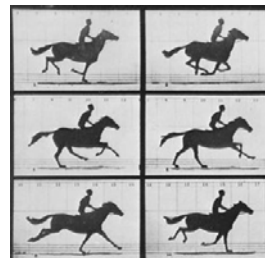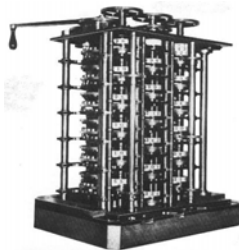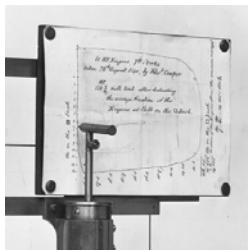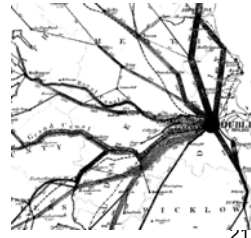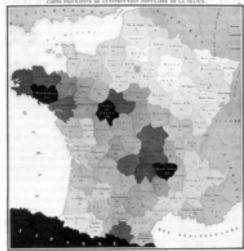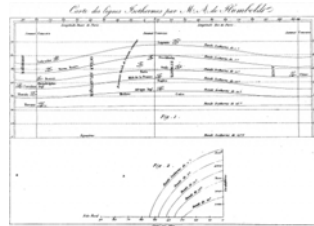

Preludes: visual language

- Graphs & diagrams
  - Line, bar, pie charts– Playfair (1786, 1801)
  - Scatterplot– Herschel (1832)
  - Polar plots– Guerry (1829), Nightingale (1857)
  - Nomograms & graphical calculation– Lalanne (1846)
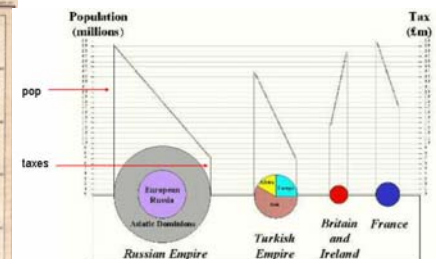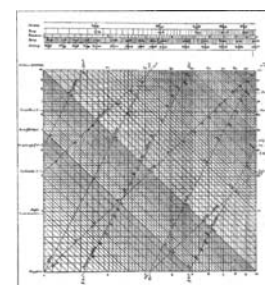
Preludes: visual language

- Maps
  - Isopleth– Humboldt (1817)
  - Choropleth– Dupin (1826)
  - Dot– Frère de Montizon (1830)
  - Flow– Harness (1837)

- Comparative & analytic maps (Balbi & Guerry, 1829)

First comparative maps of social data (crime, education)

- personal crime inversely related to property crime!
- neither directly related to education!
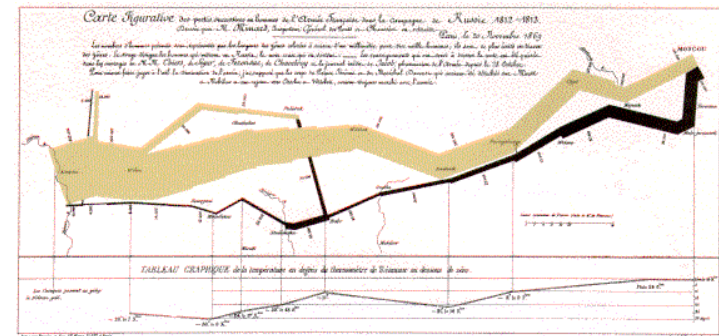- Education: *France obscure* vs. *France éclairée*

Personal crime   **Property crime**

Education
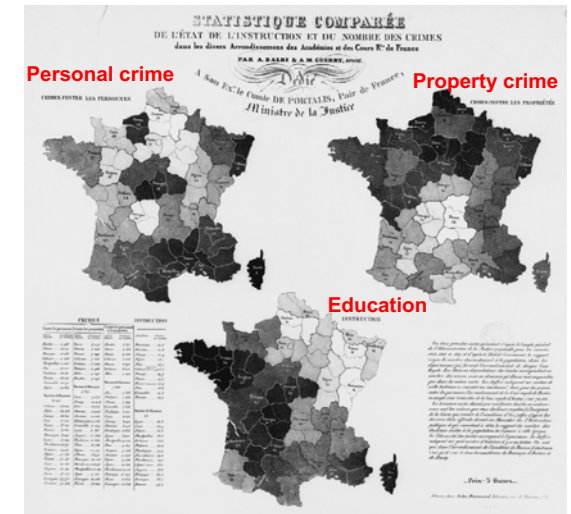
Exemplars of the Golden Age

- The graphic vision of C. J. Minard
- Galton's graphic discoveries
- State statistical albums
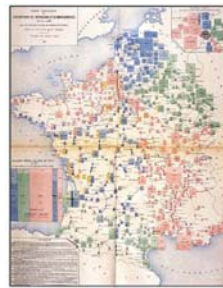
The graphic vision of C. J. Minard

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

Why Minard?

- Study breadth and depth of his work
  - How related to work in his time?
  - How related to modern statistical graphics?
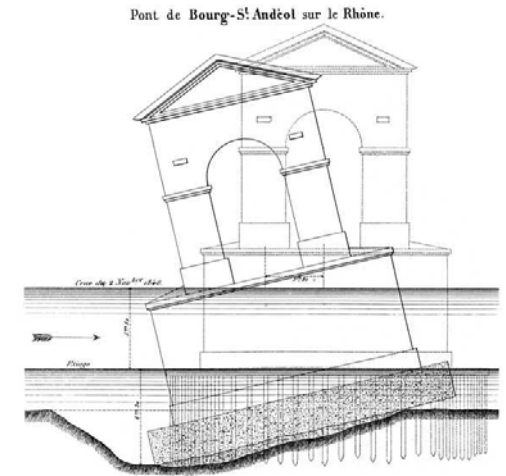 - How related to his personal history?

Civil Engineer for ENPC (1810-1842)

Visual Engineer for France (1843-1869)
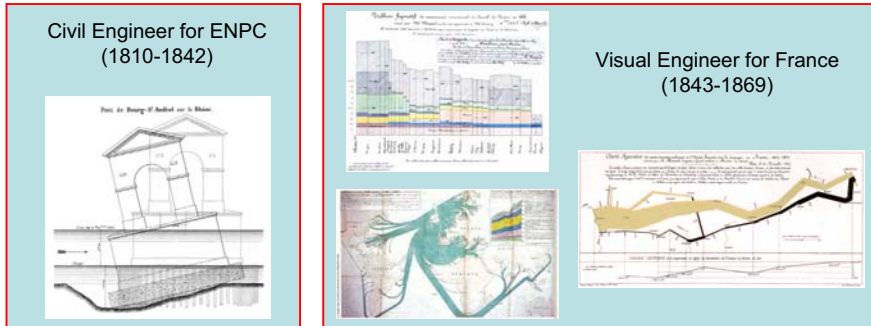
Visual thinking, visual explanation

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

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

Pont de Bourg-St Andèol sur le Rhône.

Visual tools for state planning

- 1830—1860: emergence of modern French state, dawn of globalization
- Trade, commerce, transportation:
  - Where to build railroads, canals?
  - Visualizing changes over time, differences over space
  - → Flow maps and other graphical innovations
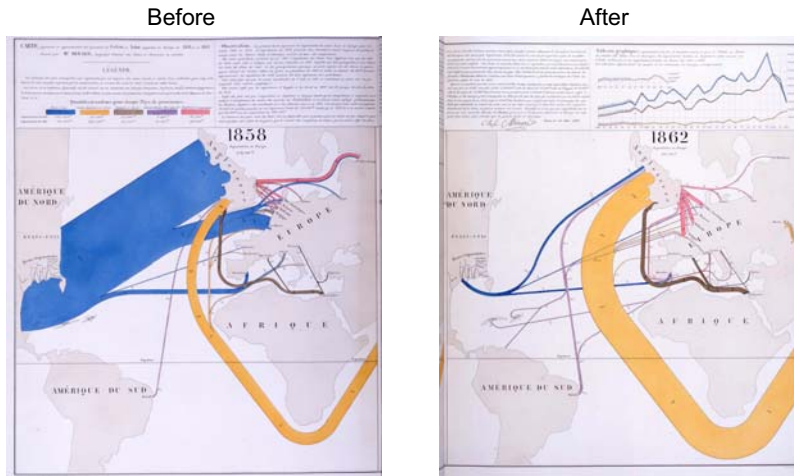
Flow maps as visual tools

Transport of passengers on the principal railroads in Europe in 1862
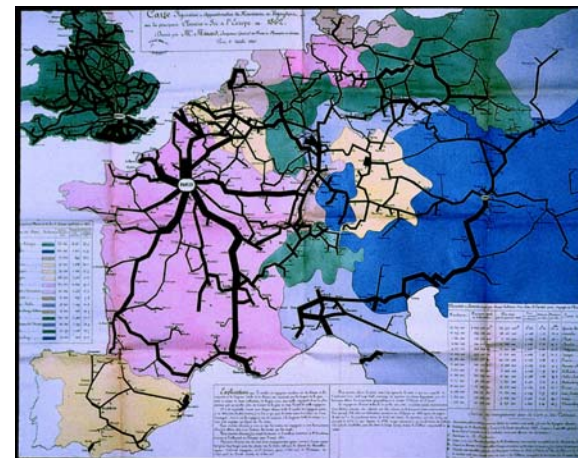
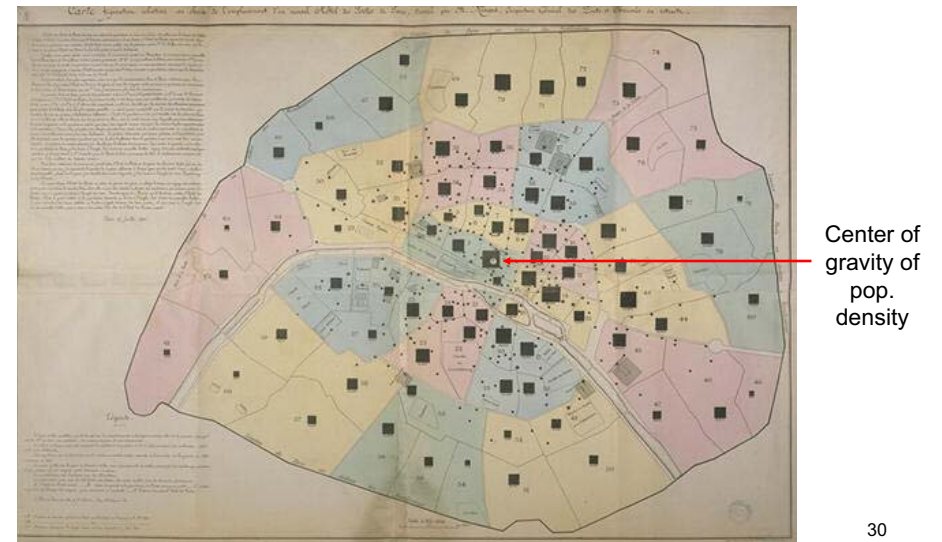*Carte figurative*: give precedence to the data over the map

Effect of US civil war on cotton trade

Before

After

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Where to build a new post office?(1867)

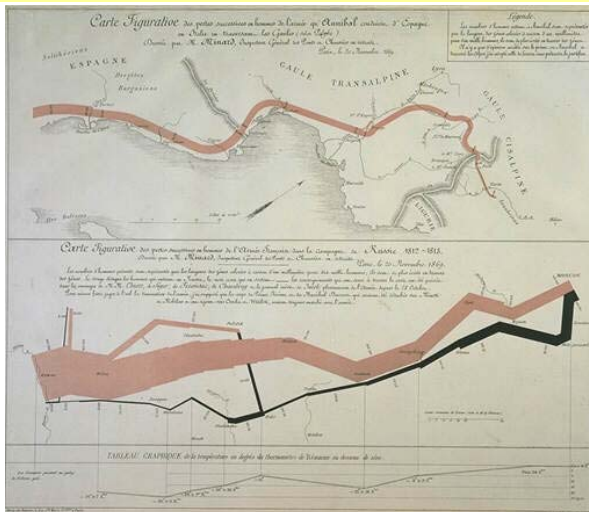Center of gravity of pop. density

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The March Re-Visited (1869)

Hannibal's retreat

Napoleon's 1812 campaign

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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)

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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!)

EXPLANATION OF THE SYMBOLS USED IN THE WEATHER CHARTS.
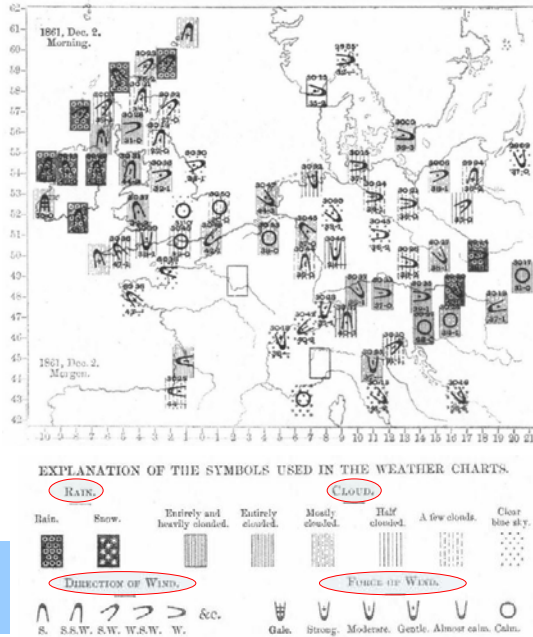
Visual abstraction → Patterns

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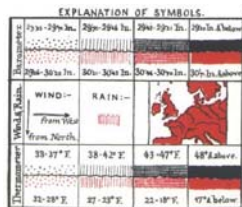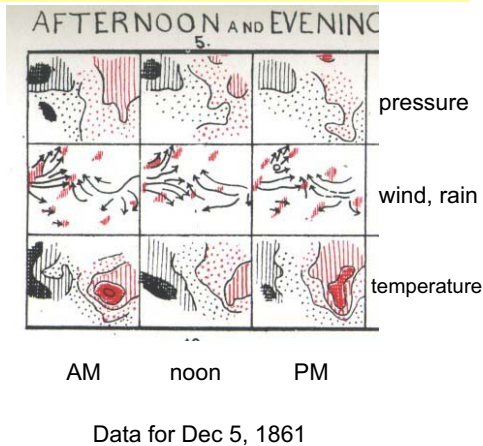• Iconic symbols on a geographical grid
• "Small multiples:" separate graphs laid out for direct comparison

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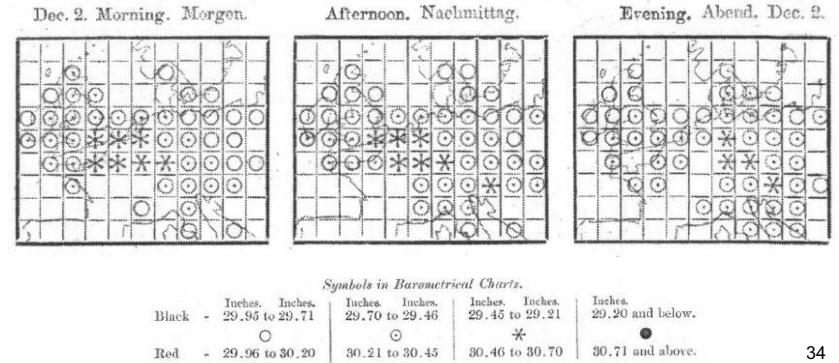
Visual abstraction → Patterns

What varies with what, over time and space?

• mini, abstract maps: vars x TOD

• iso-contours, shading to show equivalence
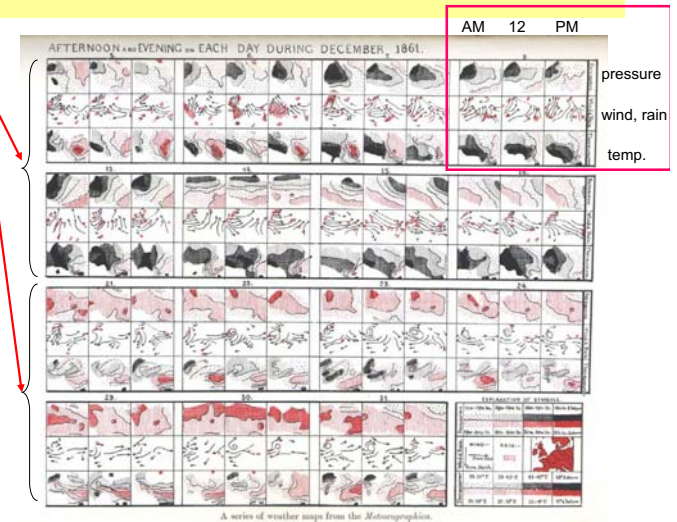
• arrows to show wind direction

pressure

wind, rain

temperature

AM   noon   PM

Data for Dec 5, 1861

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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!)

AM   12   PM

pressure

wind, rain

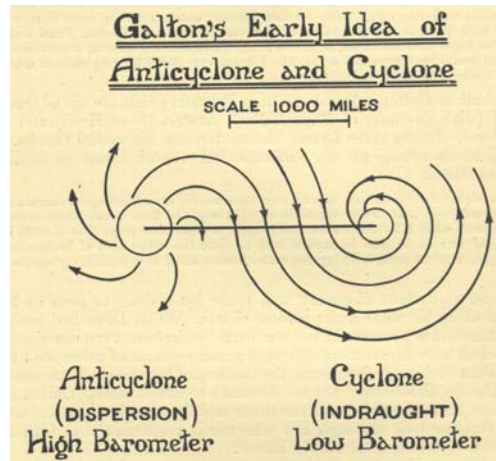temp.

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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!

Galton's Early Idea of Anticyclone and Cyclone

SCALE 1000 MILES

Anticyclone (DISPERSION) High Barometer

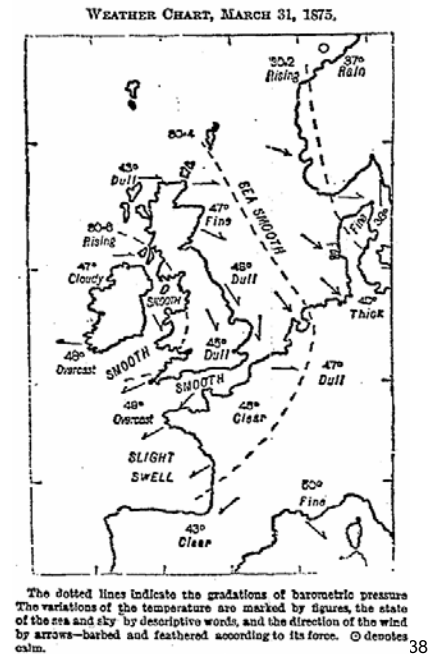Cyclone (INDRAUGHT) Low Barometer

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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)

WEATHER CHART, MARCH 31, 1875.

The dotted lines indicate the gradations of barometric pressure. The variations of the temperature are marked by figures, the state of the sea and sky by descriptive words, and the direction of the wind by arrows—barbed and feathered according to its force. ⊙ denotes calm.

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

• Collection of gov't statistics on pop., trade, moral & political issues widespread in Europe & US, starting ~ 1820

• Statistical albums ~ 1870—1910
  ▪ France: *Album de Statistique Graphique*: 1879-1899
  ▪ USA: Census atlases: 1870/80/90
  ▪ Gemany: local albums (Berlin, Frankfurt, etc.)
  ▪ Switzerland: *Atlas graphique de la Suisse:1897, 1914*
 ▪ *Others: Latvia, Romania, Bulgaria, etc.*

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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"x17" 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
• Formats: 1x1, 2x1, 2x2, 3x2, …
• Themes:
  ▪ Recurrent: railroads, navigation, transport (B&B)
  ▪ Occasional: agriculture, Paris, expositions, …
• Pinnacle of the Golden Age: exquisite sampler of all known graphic forms!
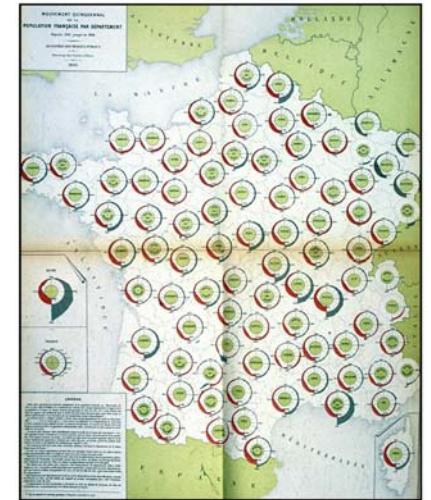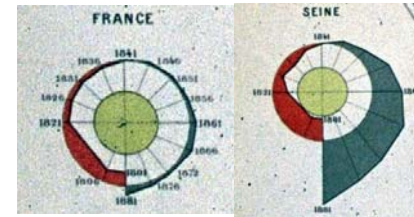
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Recursive multi-mosaic map

Distribution of passengers and goods from the Paris railways to the rest of France [Album, 1884, pl. 11]
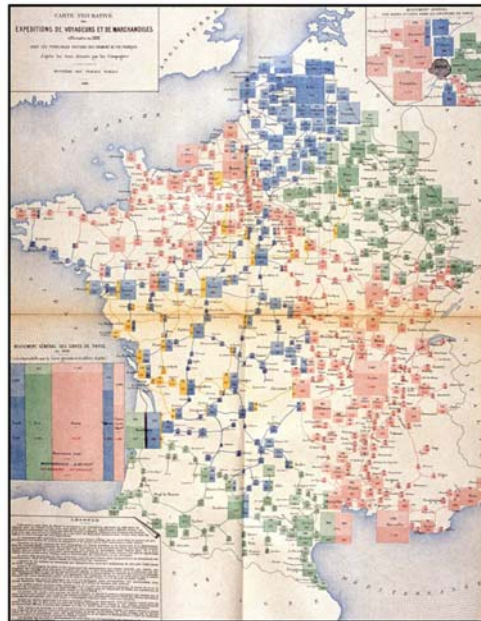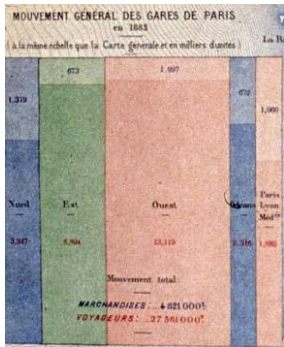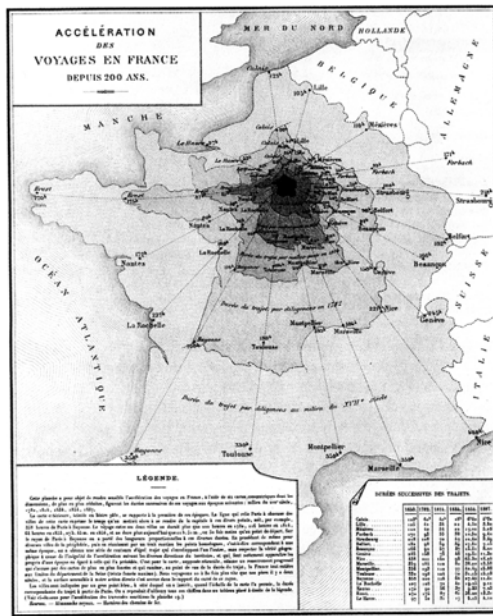
Spiral time-series on a map

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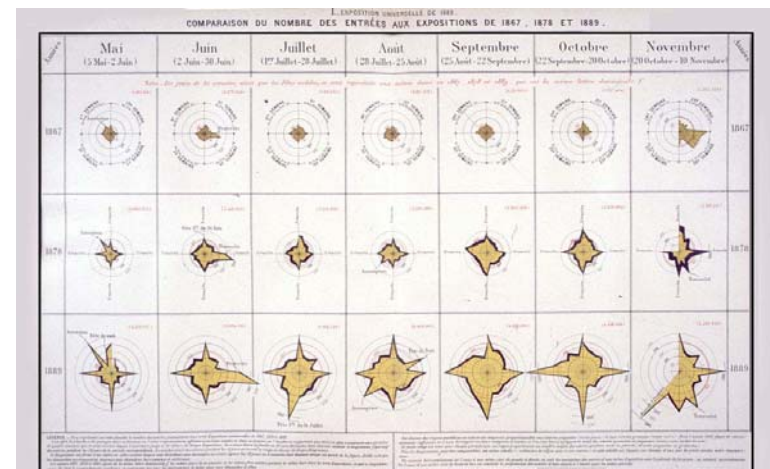

Anamorphic map

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

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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]
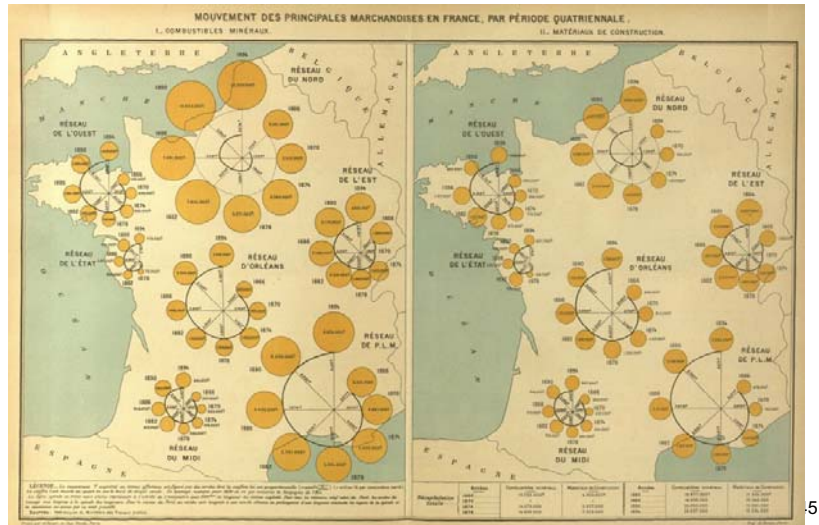

1867

1878

1889

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Planetary diagrams

Movement of principal merchandise by region. Spiral ~ distance; circles ~ tonnage [Album, 1895, plate 9]
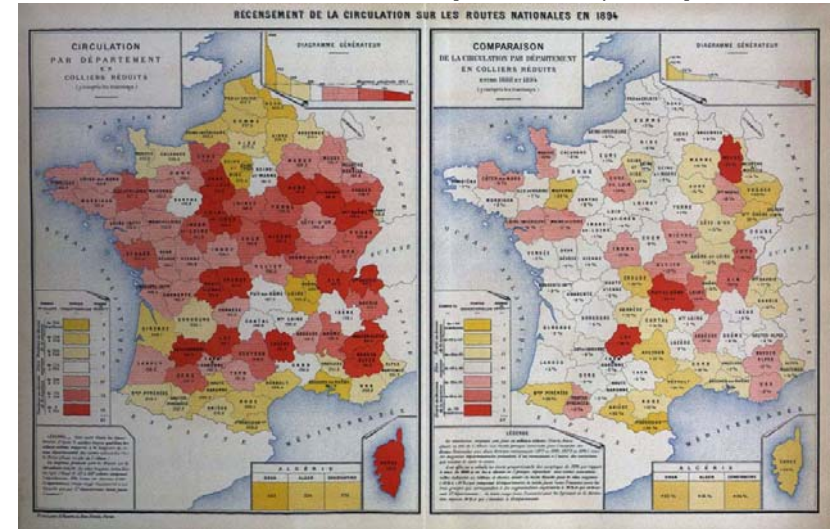
Combustible minerals   Construction materials

Classed choropleth maps, bipolar color scale

Circulation on the national roads in 'colliers réduits'
Left: 1894; Right: % change, 88-94
[Album, 1895, plate 21]

U.S. Census Atlases

- *Statistical Atlas of the Ninth Census* (1872) – Francis Walker
  - 60 plates: First graphic portrait of the nation
  - Topics: geology, minerals, weather, pop. by ethnicity, wealth, literacy, death rates by age, sex, cause, rates of blindness, insanity, etc.
- *Tenth Census* (1880) – Henry Gannett
  - 151 plates
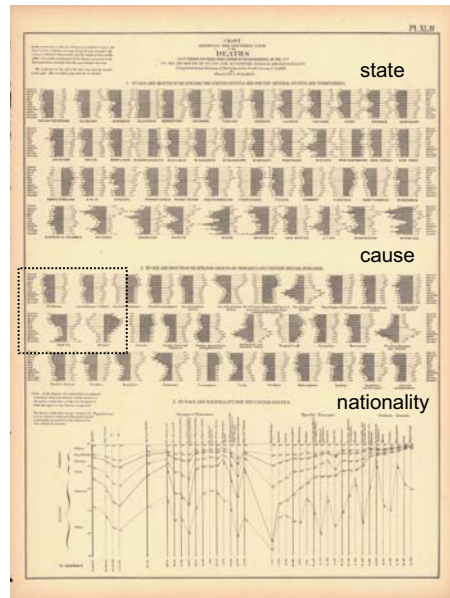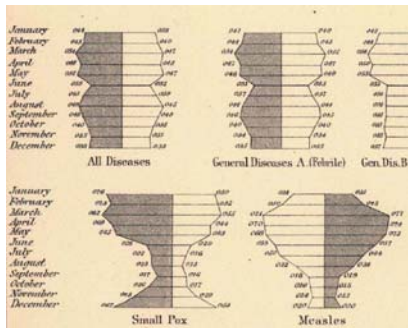- *Eleventh Census* (1890) – Henry Gannett
  - 126 plates

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Mosaics/treemaps: Area ~ state population

State populations: Foreign born / Native colored / White + Born inside/outside
[Atlas, 1870, plate 20]
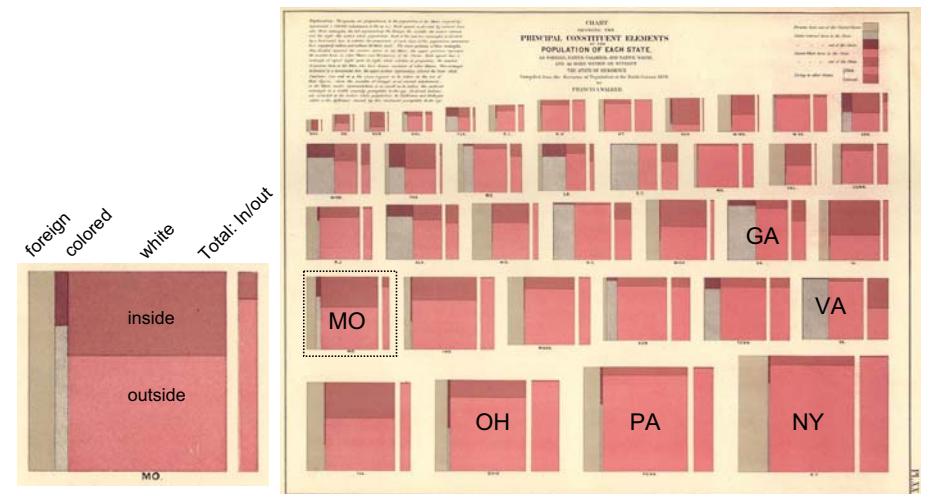
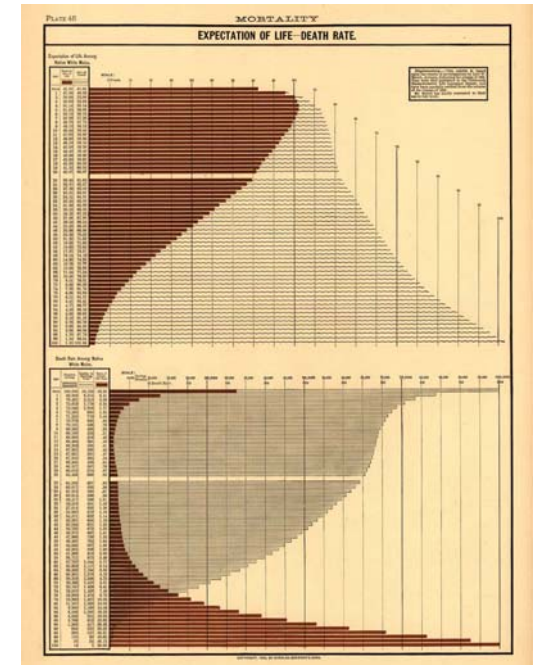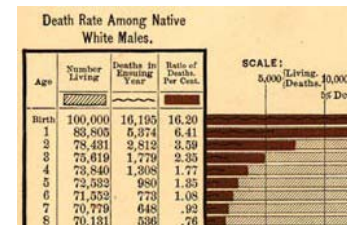## Bilateral histograms: deaths (sex by month) ~ state, cause, nationality

[Atlas, 1870, plate 44]

state

cause

nationality

Multi-function bar & line graphs

Mortality: Life expectancy & death rates by age, native white males
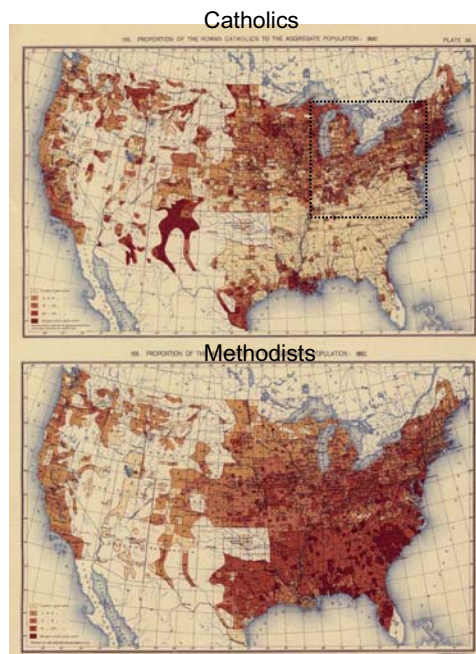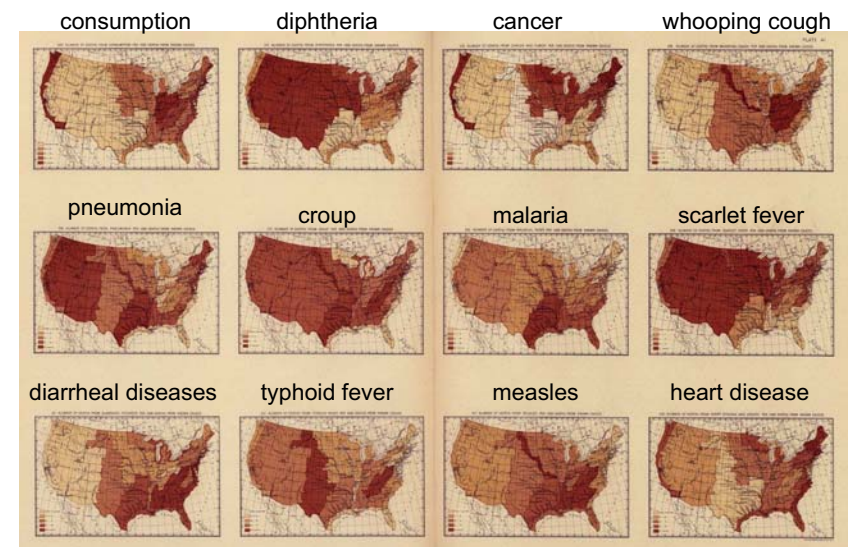[Atlas, 1880, plate 40]

Comparative density maps

Proportions of Catholics and Methodists in the total population [Atlas, 1890, plate 36]

Detail (Catholics)
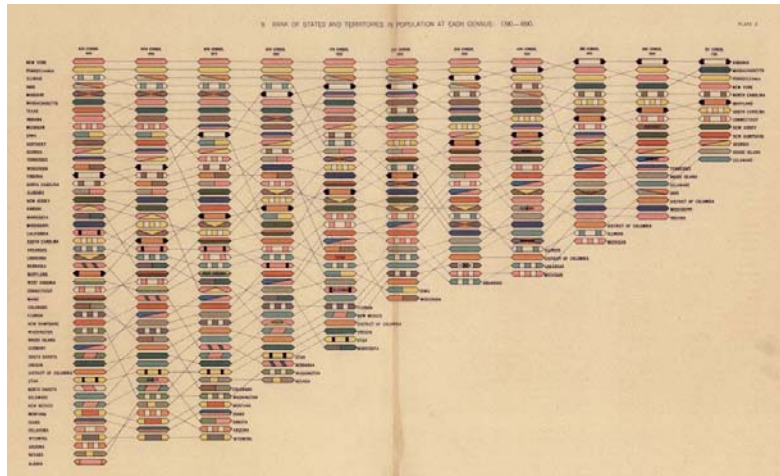
Catholics

Methodists

Comparative density maps

Deaths from diseases/1000
[Atlas, 1890, plate 41]

consumption diphtheria cancer whooping cough

pneumonia croup malaria scarlet fever

diarrheal diseases typhoid fever measles heart disease

Linked parallel-coordinates time-series diagram

Rank of states & territories in each census, 1790—1890. [Atlas, 1898, plate 2]

- 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
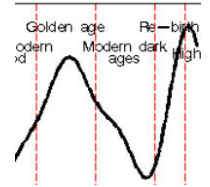
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Conclusions

The only new thing… is the history you don't know – **Harry Truman**

- Modern data visualization has deep roots:
  - Cartography
  - Statistics
  - Data collection
  - Visual thinking
  - Technology
- The Golden Age
  - Qualitatively distinct, deserves recognition
  - Works of unparalleled beauty & scope
  - Thematic maps & diagrams often aided each other

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