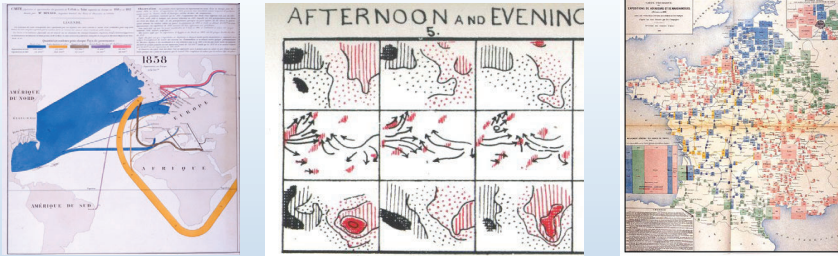
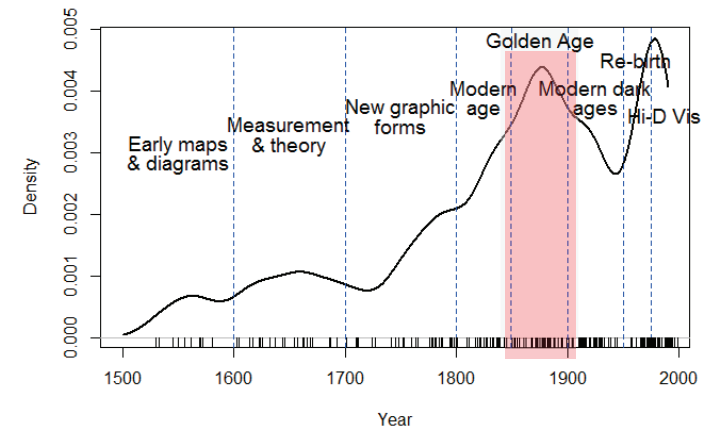


The Golden Age: ~ 1850 -- 1900

Why do I call this the “Golden Age of Statistical Graphics”?
The most obvious is as a **peak** in developments over the course of history.

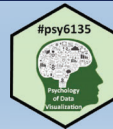
Milestones: Time course of development



The Golden Age of Statistical Graphics

Michael Friendly
Psych 6135

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



What makes an “Age”? What makes one “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)

Some Golden Ages

- **Athens** (Pericles): 448 BC—404 BC: growth & culture
- **Islam**: 750—1258 (sack of Baghdad): science, math ...
- **England**: Elizabeth I (1558-1603): literature, poetry, ...
- **Piracy**: 1690--1730
- **Radio**: 1920—1940
- **Animation**: 1928 (sound) – 1960s (TV)
- **Senior citizens**: 60+

Metaphors



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

Preludes to the Golden Age

Infrastructure required:

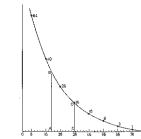
- **Data:** collection & dissemination
- **Statistical theory:** combining & summarizing quantitative information
- **Technology:** printing & reproduction of maps & diagrams
- **Visual language:** new graphic forms for maps and diagrams
- → a **perfect storm** for data graphics

What does this imply for today?

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!



Population data: keeping track of births, deaths, causes of mortality



1665.

A General BILL for this present Year,

Ending the 19th Day of December 1665.

According to the Report made to the King's most excellent Majesty,

By the Company of Parish Clerks of LONDON, &c.

DISEASES and CASUALTIES.

A Borne and Stillborn	617	Executed	21	Overhead and Stomach	45
Aged	1243	Flux and Small Pox	62	Quary	35
Ague and Fever	2147	Found dead in the Streets	4	Scourge	28590
Appoplexy and Sublety	110	French Pox	28	Shingles	15
Betred	10	Brightness	23	Splinter	1
Bleeding	10	Gout and Sciatica	27	Quarry	35
Bloody Flux, Scourging, and Flux	182	Griping in the Guts	1288	Riding of the Lights	357
Burnt and Scalded	8	Hang'd and mott away	3	Rupture	36
Cancer	3	Chenitides	3	Scoury	105
Cancer, Gangrene, and Ulcers	26	Headmoulding	3	Shingles and Swine Pox	3
Chanker and Thrush	111	Jaundice	110	Sores, Ulcers, broken	32
Children	624	Impottibune	217	Spleen	16
Christnes and Infants	1298	Kill'd by several Accidents	26	Spooned Fever and Purple	1939
Cold and Cough	68	King's Evil	27	Stopping of the Stomach	228
Colic and Wind	124	Leprosy	2	Stout and Strangury	38
Consumption and Tillick	4208	Lethargy	14	Surfit	21
Convulsion and Mother	1030	Livergrowne	20	Trench and Worms	2614
Dibbered	2	Megrima and Head-ach	13	Yawning	51
Droopy and Tympany	1478	Measles	3	Wen	1
Drowned	50	Murdered and Shot	51		

CHRISTENED {Males — 2114 } BURIED {Males — 48269 }
 {Females — 255 } {Females — 45727 }
 {In all — 2667 } {In all — 97296 }

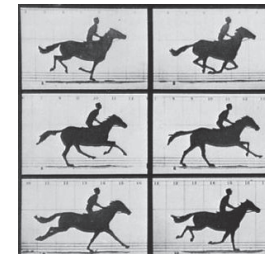
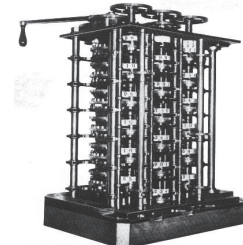
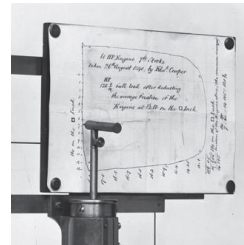
Increased in the Burials in the 130 Parishes and at the Pest-house this Year 70000
 Increased in the Burials in the 130 Parishes and at the Pest-house this Year 68290

Year	1662	1663	1664	1665	1666	1667	1668	1669	1670	1671	1672	1673	1674	1675	1676	1677	1678	1679	1680
Buried	1118	1007	758	2812	820	1678	1618	1418	1218	1018	1118	1218	1318	1418	1518	1618	1718	1818	1918
Born	1018	1118	1218	1318	1418	1518	1618	1718	1818	1918	2018	2118	2218	2318	2418	2518	2618	2718	2818

J. Graunt (1662) *Natural and Political Observations on the Bills of Mortality*

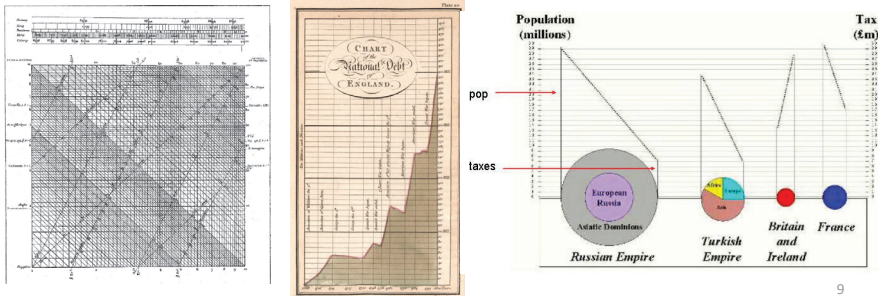
Preludes: technology

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



Preludes: visual language

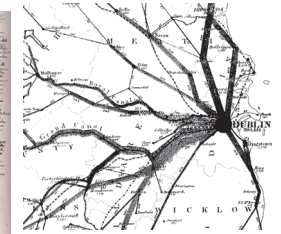
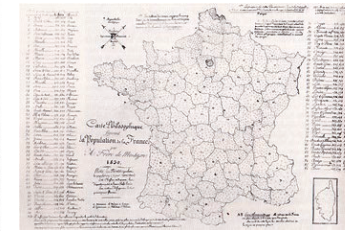
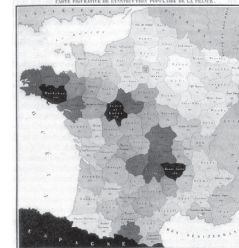
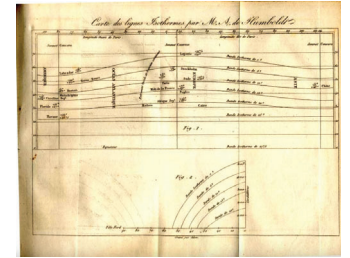
- Graphs & diagrams
 - Line, bar, pie charts– Playfair (1786, 1801)
 - Scatterplot– Herschel (1832)
 - Polar plots– Guerry (1829), Nightingale (1857)
 - Nomograms & graphical calculation– Lalanne (1846)



9

Preludes: visual language

- Thematic maps
 - Isoleth– Humboldt (1817)
 - Choropleth– Dupin (1826)
 - Dot– Frère de Montizon (1830)
 - Flow– Harness (1837)

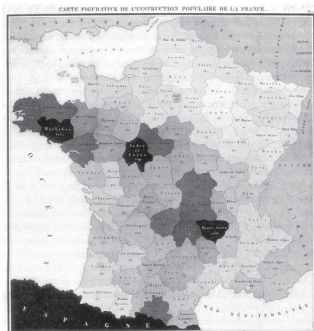


10

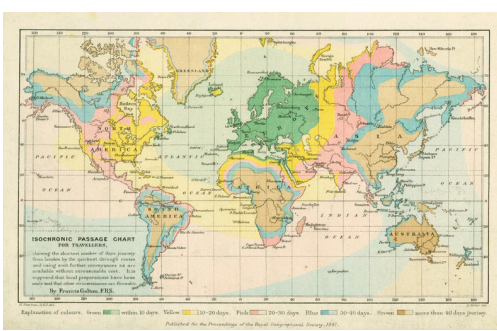
Data visualization: Diffusion of ideas

- Those who developed thematic maps often not cartographers

Dupin (1826): literacy in France



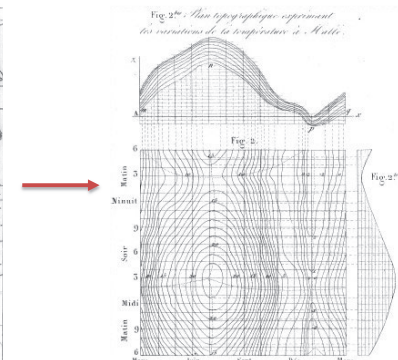
Galton (1881): travel time from London



12

Data visualization: Diffusion of ideas

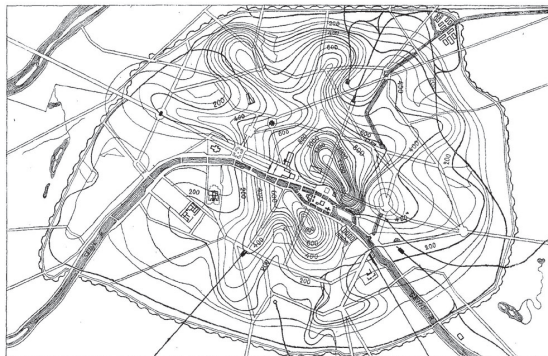
- Those who developed data graphics often borrowed from cartography
 - Halley (1701): contour map -> Lalanne (1843): contour diagrams of soil temperature



13

Data visualization: Diffusion of ideas

- ... and vice-versa
 - Lalanne → L.L. Vauthier (1874) contour map of population density of Paris, seen as mountains
 - Map-based data visualization was extended widely



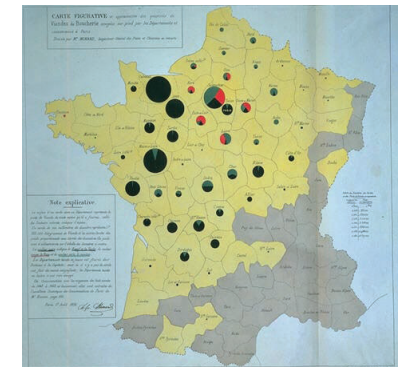
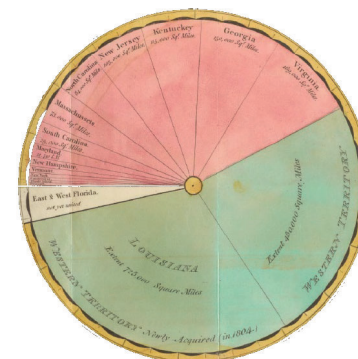
14

Data visualization: Diffusion of ideas

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

What are the sizes of US territories?

Where does meat sold in Paris come from?



15

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

16

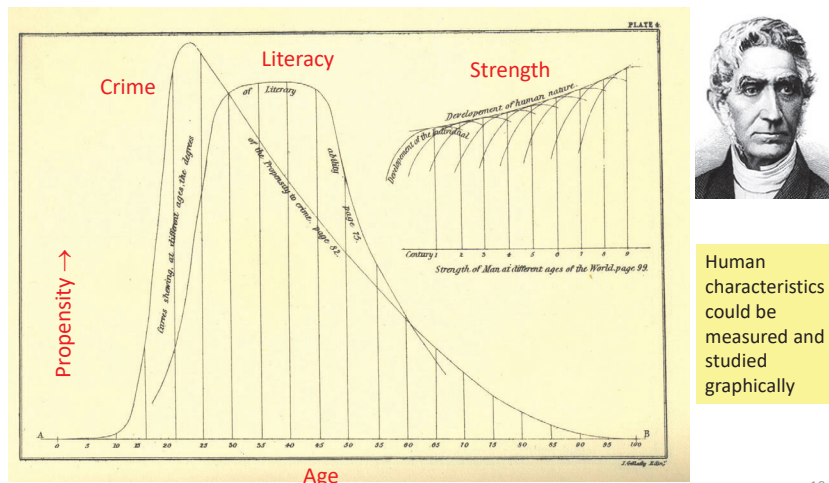
Big questions of the early 1800s

- 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 (Quetelet)
 - Mortality, suicide, propensity to crime
- Beginnings of statistical theory and application
 - Normal distⁿ (de Moivre, 1733)
 - *L'homme moyen* (Quetelet, 1835)

17

Quetelet: Anthropometry

Quetelet (1842), *A Treatise on Man and the Development of His Faculties*, uses graphs to illustrate various themes: measurement, graphical comparison, ...



Human characteristics could be measured and studied graphically

18

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**

19

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



21

Social context of crime in 1820s France

- Crime a serious concern:
 - Explosive growth in Paris after Napoleon’s defeat (Waterloo, 1815)
 - Widespread unemployment,
 - Emergence of perception of “dangerous classes”: what to do???
 - Victor Hugo (*Les Misérables*); Honoré de Balzac; Emile Zola
- Liberal (“philanthrope”) view:
 - Increase education
 - Better prison conditions, diet (bread **and** soup)
 - Religious instruction
- Conservative view:
 - Build more prisons; longer prison sentences
 - Harsher treatment of recidivists
- Now, there was finally some **DATA!**

22

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 systematically** 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	OMG! ~ constant → 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	OMG! ~ constant → 31	32	30	31	32	31
Crime	Committed in summer (%)					
Indecent assault	.	36	36	35	38	36
Assault & battery	.	28	27	27	27	28

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

The discovery of “social facts”

Social laws à la physical laws

Do crime and other moral variables represent:

- ▶ structural, lawful **characteristics of society**, or are they
- ▶ simply indicators of **individual behaviour**?

Guerry argued:

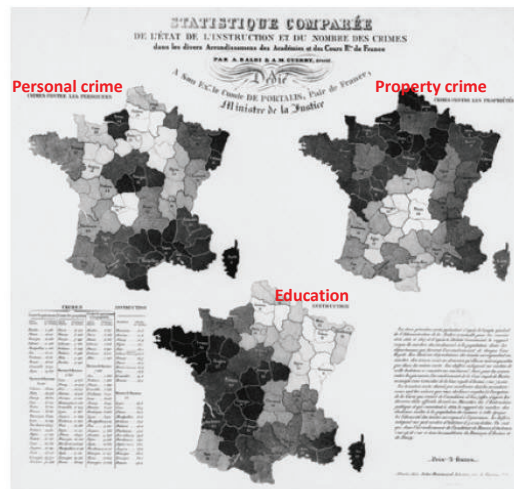
Each year sees the same number of crimes of the same degree reproduced in the same regions. (Guerry, 1833, p.10)

*... 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)

24

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

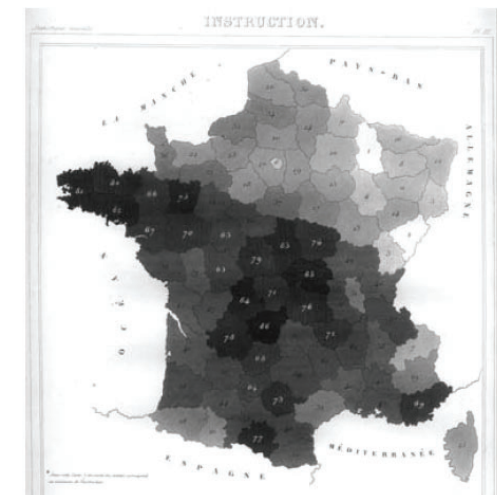
- ▶ First shaded thematic maps of **crime data**
- ▶ First **comparative** maps of social data
- ▶ ↳ crime against persons seemed **inversely related** to crime against property!
- ▶ Instruction: ↳ *France obscure* and *France éclairée* (Dupin, 1826)
- ▶ North of France highest in education, but also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



25

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

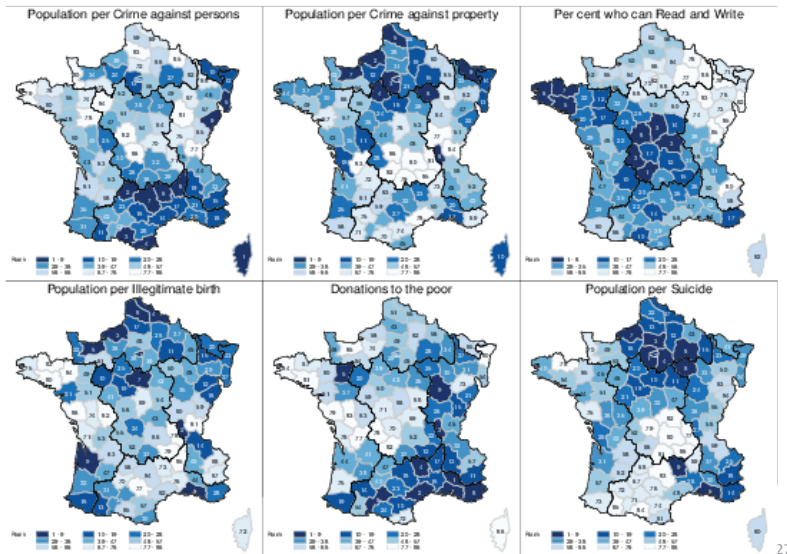
- ▶ Divided the 86 departments into 5 regions
- ▶ Supplemented data from the *Compte général* with:
 - ▶ Suicides in Paris, 1794–1832
 - ▶ Prostitutes in Paris (Parent-Duchâtelet)
 - ▶ Wealth (taxes per inhabitant)
 - ▶ Distribution of clergy
 - ▶ ...
- ▶ First study to use crime data to “test” hypotheses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



Guerry's 1833 map of literacy in France

26

Guerry's moral variables



1864: *Statistique morale de l'Angleterre comparée...*

Dayenul

- Proposes to replace simple "moral statistics" (tables) with "analytical statistics"
 - calculation, graphic display
 - general, abstract results
- 17 large color plates (56 × 39 cm):
 - data for France (1825–1855), England (1834–1855)
 - crimes against persons and property decomposed in various ways
 - first attempt to delineate **multivariate relations** among moral variables
- Voluminous data:
 - 85,564 suicide records (1836–1860), classified by motive
 - 226,224 accused of personal crime
 - numbers, in a line → 1170 meters!

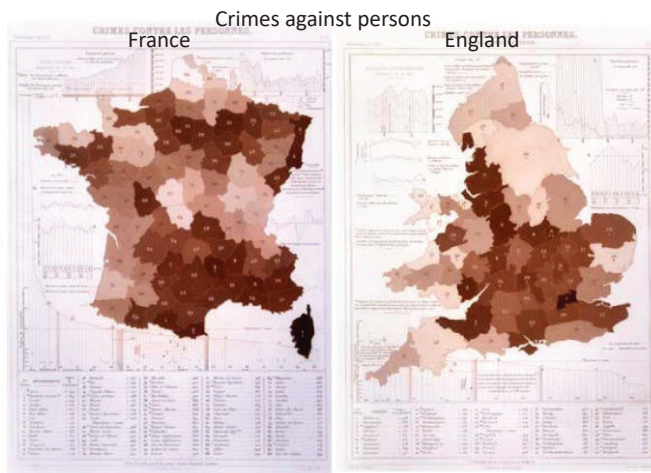


Further details: Friendly, M. (2007). A.-M. Guerry's *Moral Statistics of France*: Challenges for Multivariable Spatial Analysis, *Statistical Science*, 22, 368-399

29

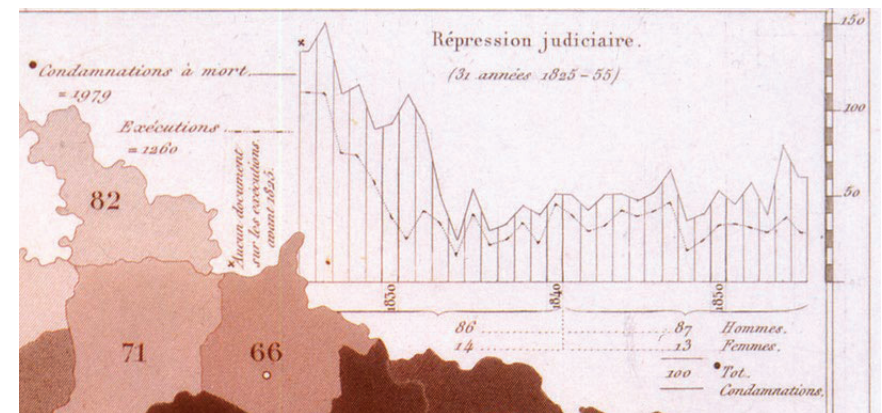
1864: *Statistique morale de l'Angleterre comparée...*

Comparing France and England



Graphs and tables around the outside give details: data, trends over time, or season, ...

30



Detail: Trends in death sentences and executions over 31 years

31

Statistique analytique: General causes of crime

Plate XVII: M. Guerry's magnum opus

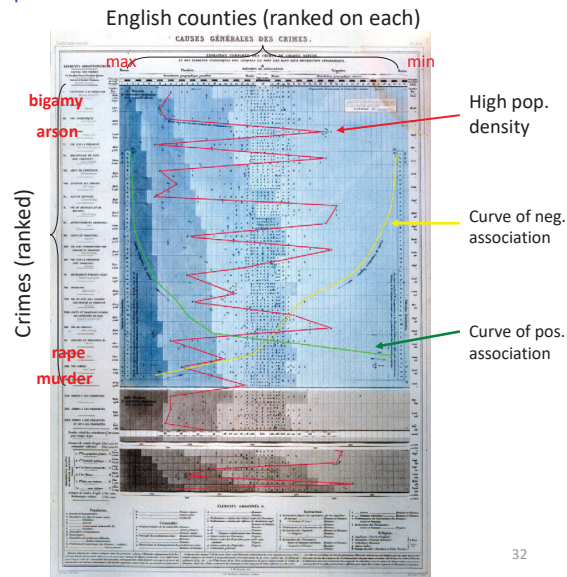
Goal:

- Show **multivariate** factors associated with distribution of crime
- Before invention of correlation

Entries: Codes for factors

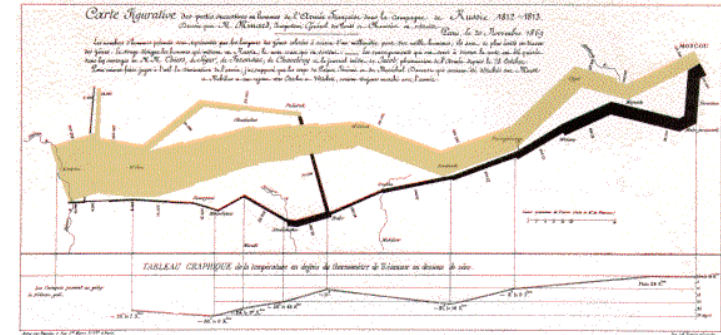
- Pop: (% Irish, domestics, ...)
- Criminality: (male, young, ...)
- Religion (Anglicans, dissenters, ...)

	g	h	o	v	z	ε	λ	δ
x	f	e	β	a	n	c	m	l
	a	e	j	k	q	p	θ	μ
	r	γ	ι	Δ	η	ε	h	ν
								o
								m



32

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"

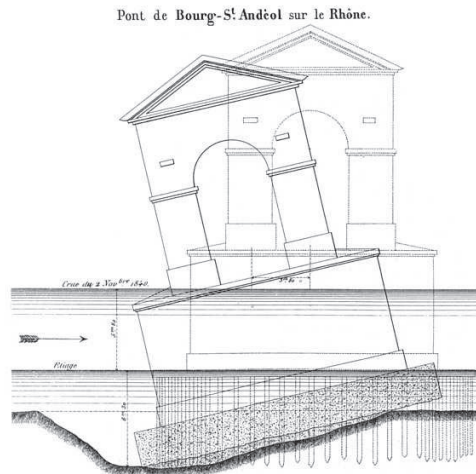
33

Visual thinking, visual explanation

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

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

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



Big questions of the mid 1800s

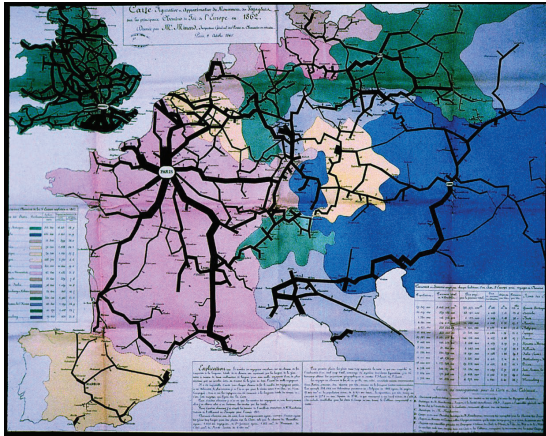
- 1830—1860: emergence of modern French state, dawn of globalization
- Trade, commerce, transportation:
 - Where to build railroads, canals?
 - How to compete with imports/exports?
 - Visualizing changes over time, differences over space
 - → Flow maps and other graphical innovations
- These questions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

See: Friendly, M. (2008). The Golden Age of Statistical Graphics, *Statistical Science*, 23, 502-535, <https://www.datavis.ca/papers/golden-age.pdf>

35

Flow maps as visual tools

Transport of passengers on the principal railroads in Europe in 1862

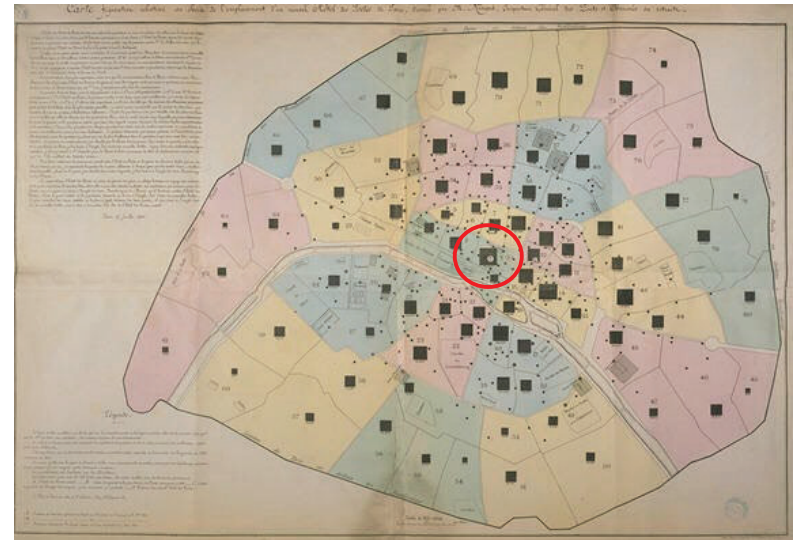


The dominant principle which characterizes my graphic tables and my figurative maps is to make immediately appreciable to the eye, as much as possible, the proportions of numeric results.

...Not only do my maps speak, but even more, they count, they calculate by the eye.
-- Minard (1862)

36

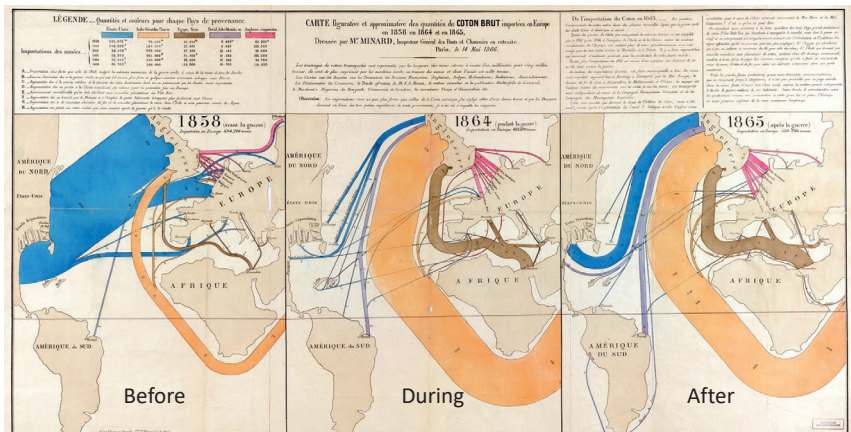
- Q: Where to build a new post office in Paris?
- Visual solution: at the center of gravity of population



37

Visual explanation

What was the effect of the US Civil War on trade in cotton?



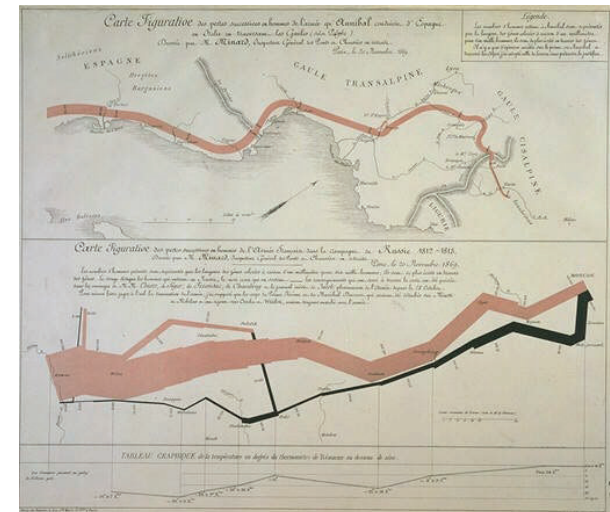
"Carte figurative et approximative des quantités de coton brut importées en Europe en 1858, en 1864 et en 1865" by Charles Joseph Minard (1866)

38

The March Re-Visited (1869)

Hannibal's retreat

Napoleon's 1812 campaign



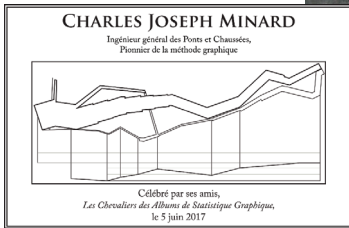
39

Les Chevaliers: Minard's Tomb

Jean-Pierre Airey-Jouglard Antoine de Falguerroles

Recent discovery of Minard's tomb in Montparnasse Cemetery, Paris.

Celebrated June 5, 2017



MF

Gilles Palsky

3. Galton's discovery of weather patterns- Perhaps the most notable purely graphic discovery ever!

METEOROGRAPHICA,

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

Galton's data collection form:

Contributors, according to the Conditions of my Circular Letter, are requested to enter their Observations in one of the blank forms, to enclose it in a stamped envelope, and to post it to my address on January 1st, 1862.

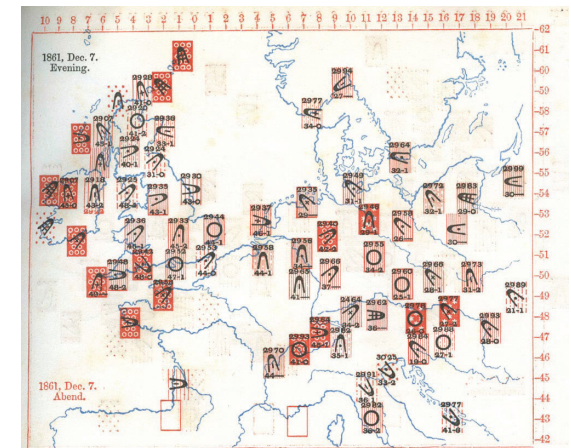
FRANCIS GALTON,
42, Rutland Gate, London.

Name of Station :		Name of Contributor :						
Its Latitude :		Full Address to which the Charts are to be forwarded when ready :						
Its Longitude from Greenwich :								
Its Height above Sea Level, in English Feet :								
Date, Either Local or Railway Time; state which.	Barometer corrected to Mean Sea Level, and reduced to English Inches, Tenths, and Hundredths.	Exposed Thermometer in Shade, Fahrenheit.	Moistened Bulb to nearest Degree, Fahrenheit, and Dew Point.	Direction of Wind, <i>from</i> not magnetic. Only 16 points of the Compass are used; as, N., N.E., E., S.E., S., S.W., W., W.S.W., &c.	Force of Wind: Calm, Gentle, Moderate, Strong, Gale.	Amount of Cloud: Clear blue sky, A few clouds, Half clouded, Entirely clouded, Entirely and heavily clouded.	Rain, Snow, or neither.	REMARKS.
December 1861.								
1	9 A.M.							
	3 P.M.							
	9 P.M.							
2	9 A.M.							
	3 P.M.							
	9 P.M.							
3	9 A.M.							
	3 P.M.							
	9 P.M.							

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



EXPLANATION OF THE SYMBOLS USED IN THE WEATHER CHARTS.

RAIN. Rain, Snow, Entirely and heavily clouded, Entirely clouded, Mostly clouded, Half clouded, A few clouds, Clear blue sky.

DIRECTION OF WIND. S, S.S.W, S.W, W.S.W, W, &c.

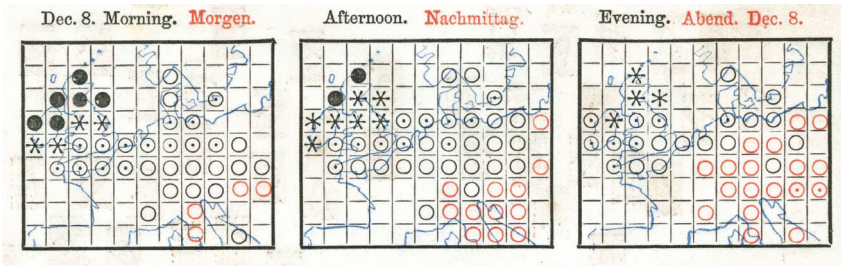
FORCE OF WIND. Gale, Strong, Moderate, Gentle, Almost calm, Calm.

- 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.

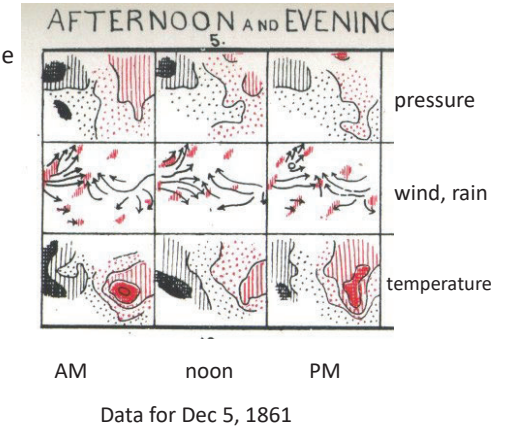
Black	Inches. 29.95 to 29.71	Inches. 29.70 to 29.46	Inches. 29.45 to 29.21	Inches. 29.20 and below.
Red	○ 29.96 to 30.20	⊙ 30.21 to 30.45	✱ 30.46 to 30.70	● 30.71 and above.

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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



EXPLANATION OF SYMBOLS.

Barometrical	29.95-29.70 In.	29.70-29.45 In.	29.45-29.20 In.	29.20 In. & below
WIND: -	33-37°F	38-42°F	43-47°F	48°F & above.
RAIN: -	32-28" In.	27-23" In.	22-18" In.	17" & below.

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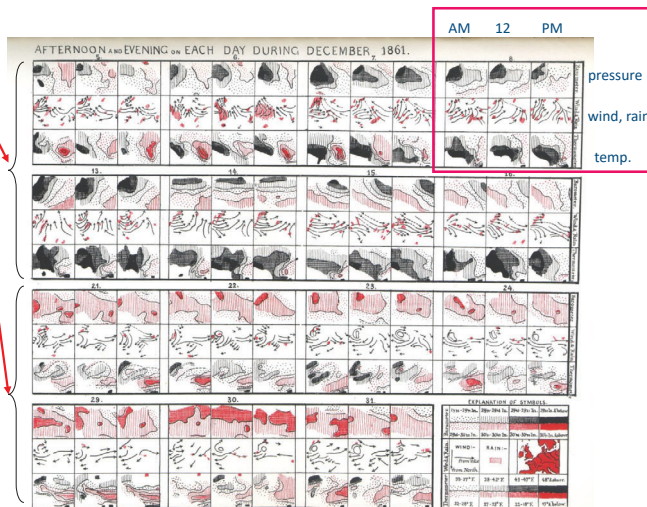
The large picture → Insight

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!)



A series of weather maps from the *Metéorographien*.

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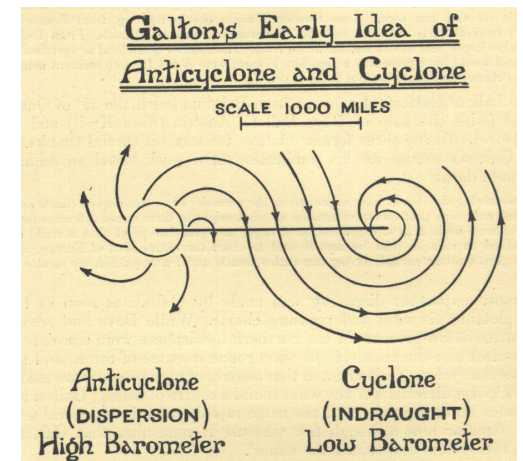
Visual insight → Theory

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—“anticyclone”

Theory:

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

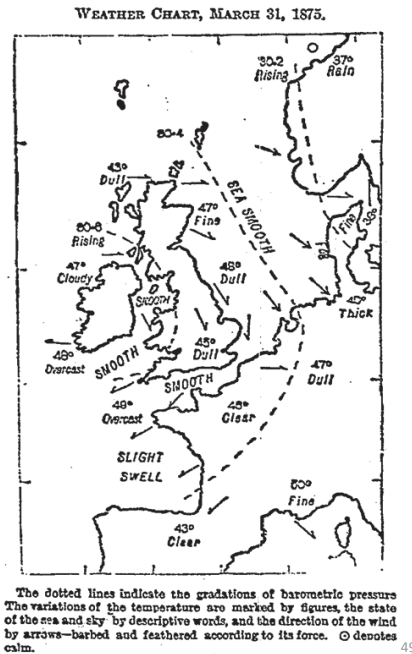


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Theory → Practice

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)



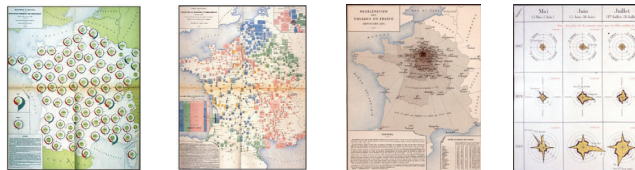
4. Statistical atlases: Data → practice, national identity & graphical excellence

- 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
 - Germany: 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"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!



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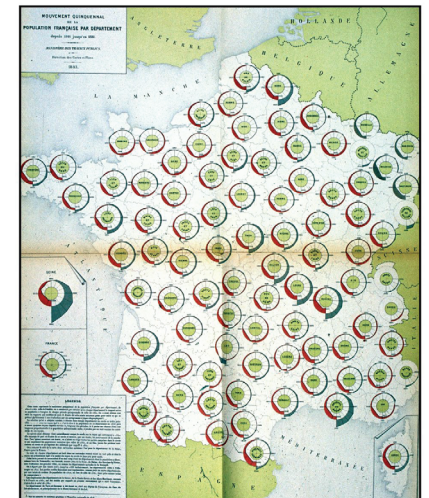
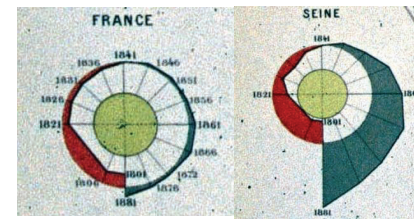
Album de statistique graphique

Spiral time-series on a map

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

Where is population growing most? least? declining?

Why use this graphic form?

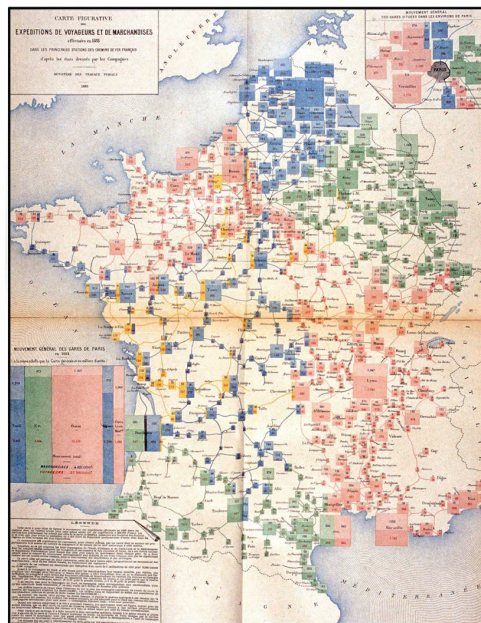
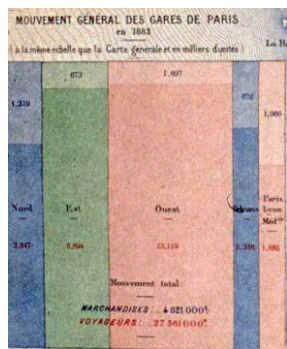


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Recursive multi-mosaic map

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

(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.	1789.	1814.	1834.	1854.	1887.
Caen	123	60	40	25	6	4
Lille	105	41	34	22	4	3
Mâcon	110	40	34	22	4	3
Forbach	171	93	55	38	10	6
Strasbourg	218	108	70	47	10	6
Belfort	182	98	59	39	17	10
Besançon	166	92	57	37	12	7
Genève	245	128	75	48	19	11
Nice	438	221	140	98	65	38
Marseille	359	184	118	80	38	23
Montpellier	356	193	114	77	40	25
Toulouse	330	169	104	70	31	19
Bayonne	258	130	106	64	27	16
La Rochelle	297	165	75	41	19	11
Nantes	179	90	56	37	9	5
Brest	270	125	67	41	20	12
Le Havre	97	52	31	17	5	3

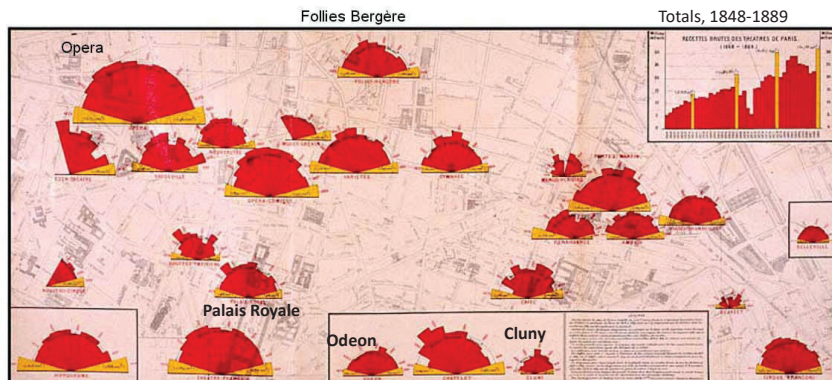


Album de statistique graphique

Q: How did Paris benefit from various int'l expos? How to show this visually?

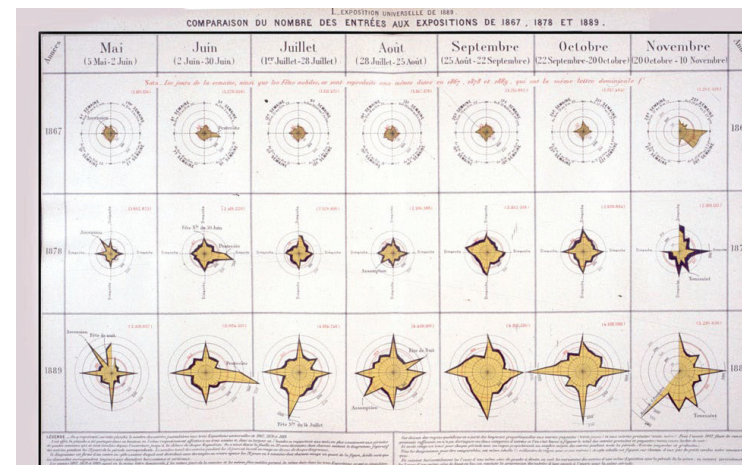
Polar area diagrams on Paris map

Gross receipts in theaters in Paris, 1878—1889, related to universal expositions [Album, 1889, plate 26]



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]

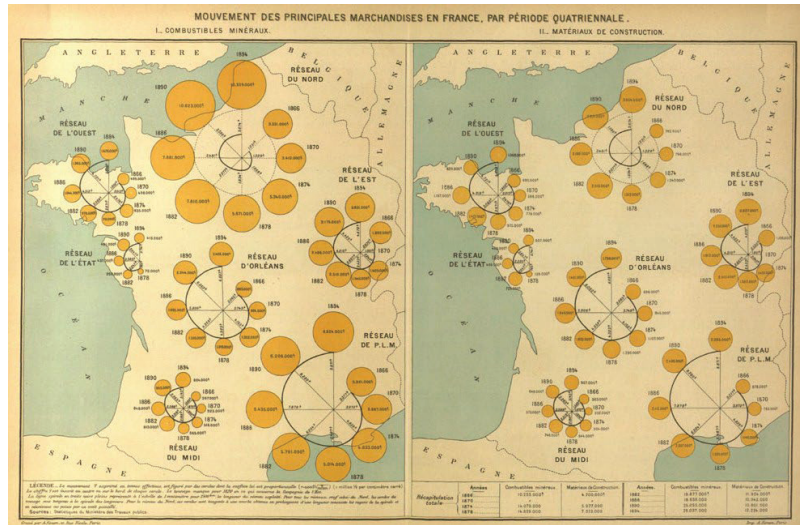


Planetary diagrams

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

Combustible minerals

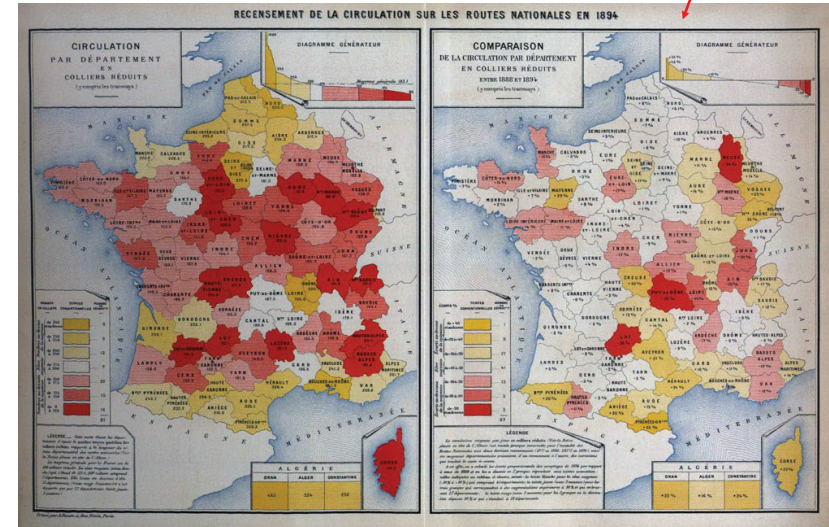
Construction materials



Classed choropleth maps,

- bipolar color scale
- visualizing change

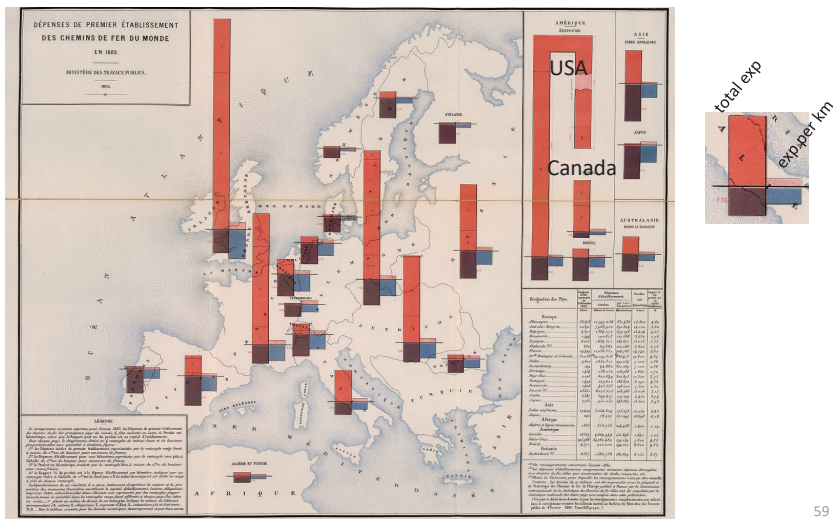
Circulation on the national roads in 'colliers réduits', a standard measure
Left: 1894; Right: % change, 88-94
[Album, 1895, plate 21]



2x2 graphic bar charts

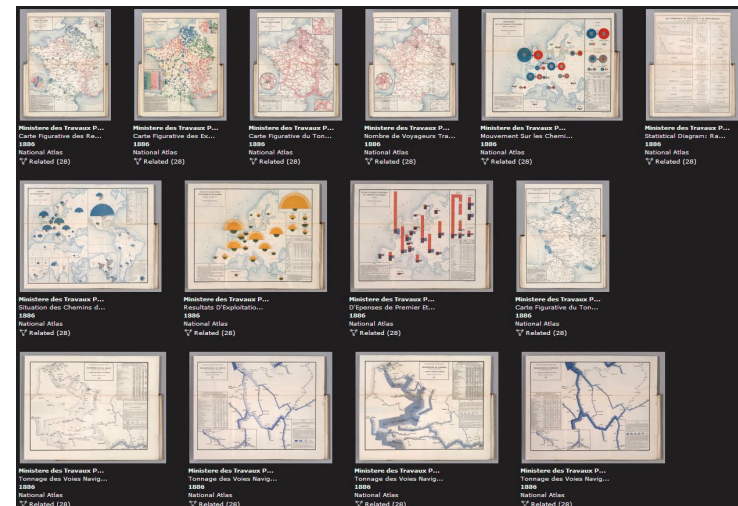
- 4 variables shown
- creative folding of long bars

Expenses of the first establishment
of railroads of the world as of 1883
[Album 1886, p. 11]



ASG now online: David Rumsey

All 18 volumes, <https://www.davidrumsey.com/luna/servlet/s/nl72bu>



Golden Lessons: Graphical Impact

- Impact: Early ideas
 - 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
- Graphical impact (Tukey, 1990)
 - **Interocularity**: the message hits you between the eyes
 - **Immediacy**: it hits you fast
 - **Inescapability**: it is hard to avoid the message
- **2nd lesson**: strive for visual impact in graphs and tables

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Golden Lessons: Expressive power

- Hand-made graphics were often beautiful but entailed much sweat and hard work.
- Today: software– ease of use vs. expressive power
- Theories of graphics → graphic “languages”
 - Bertin: *Semiology of graphics*
 - Wilkinson: *Grammar of Graphics*
 - Wickham: *ggplot2* R package
 - In all: the devil is in the details!
- **3rd lesson**: continue to reduce the distance between a graphic idea and appearance on screen or paper.



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Conclusions

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

- Data visualization has deep roots:
 - Cartography
 - Statistical theory
 - Data collection
 - Visual thinking
 - Technology

All combine to give insightful views of data

Each area fed from, and nourished the others
- The Golden Age:
 - Qualitatively distinct, deserves recognition
 - Works of unparalleled beauty & scope
 - Statistical graphics had a **purpose**: tell a story, inform decision
 - Provides lessons for today and tomorrow

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