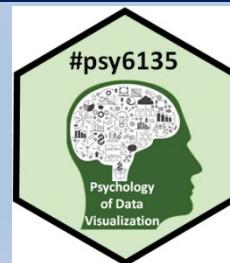
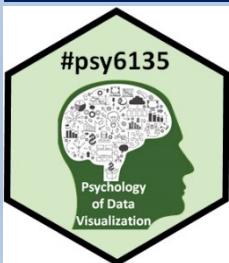


The Golden Age of Statistical Graphics

Michael Friendly
Psych 6135

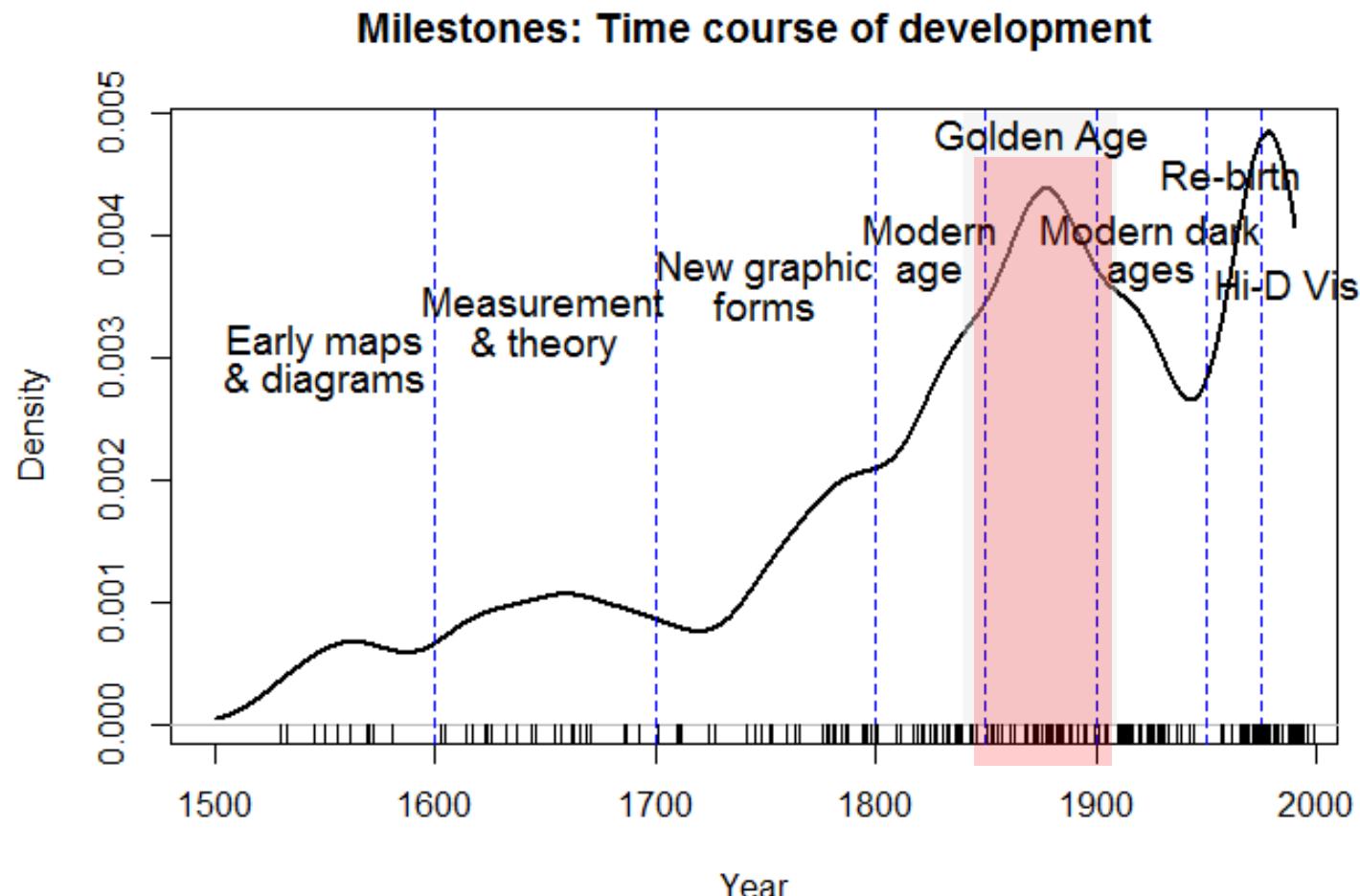
<https://friendly.github.io/6135>



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.





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+



Pietro Da Cortona, *The Golden Age* (Fresco, Sala della Stufa, Palazzo Pitti, Florence) 4



Preludes to the Golden Age

Infrastructure required:

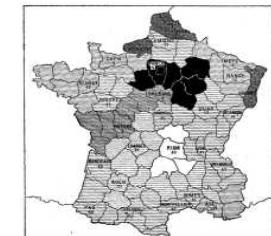
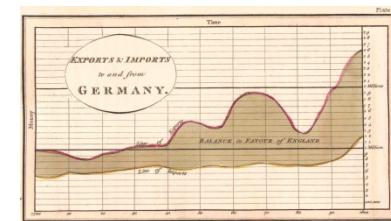
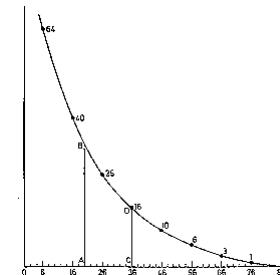
- **Data**: collection & dissemination
- **Statistical theory**: combining & summarizing quantitative information
- **Technology**: printing & reproduction of maps & diagrams
- **Visual language**: new graphic forms for maps and diagrams
- → a **perfect storm** for data graphics

What does this imply for today?

Preludes: data

- 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!

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



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



1665.

The Table of Burials and Christnings in London.							
Ann.	97. Dom.	16. Parish. fests.	Out- Parish. fests.	Buried in all.	Buried of the Plague.	Christ- ned.	
1660	1518	2007	708	4213	896	1618	
1661	1014	1974	968	5248	444	6104	
1662	1941	1910	935	5798	2114	6616	
1663	1879	2772	1619	5670	2374	6192	
1664	3291	3218	1149	6718	2162	8049	
1665	1495	3610	1441	7485	4540	6387	
1666	2316	3791	1369	7486	1803	6785	
1667	2151	3398	1166	6716	617	2014	
	16715	24780	8747	50142	14711	51190	
1668	1473	3843	1461	7778	64	8986	
1669	2406	3579	1418	7503	16	6816	
1670	2369	3504	1494	7167	21	7308	
1671	2446	3791	1613	7150	37	7621	
1672	1490	3576	1697	8063	9	7985	
1673	2397	4109	1774	8180	56	7747	
1674	2815	4215	2066	9596	18	2793	
1675	2339	3857	1804	7999	9	8117	
	19735	31374	13318	64436	171	60316	
1676	2726	4319	2146	9691	27	7845	
1677	2438	3759	1915	8112	37	8039	
1678	2811	4317	2392	8943	16	7894	
1679	3191	4711	2783	11095	17	7945	
1680	3385	5119	2805	11299	11	8199	
1681	5143	9819	3886	12848	35117	4983	
1682	2150	3285	1965	7491	134	6701	
1683	2325	3400	1988	7711	4	8408	
	24569	39940	1970	84000	35631	61114	

The Table of Burials, and Christnings, in London.							
Ann.	97. Dom.	16. Parish. fests.	Out- Parish. fests.	Buried in all.	Buried of the Plague.	Christ- ned.	
1628	2421	3311	2017	7740	—	3	8564
1629	2136	3994	3143	8771	117	6	9991
1630	2106	4101	3521	9137	7319	9315	
1631	2419	3697	3121	8128	374	8134	
1632	1704	4412	2411	9527	8	9184	
1633	2378	3916	3078	8393	10	9997	
1634	2917	4980	1982	10399	113	9315	
1635	2241	4986	2943	10451	10	10034	
	20694	33495	19327	73105	1603	75774	
1636	2815	6924	3210	13939	10600	9112	
1637	2188	4365	2118	8621	3082	9180	
1638	3584	1916	3711	13281	363	10311	
1639	2592	4344	2611	9548	314	10710	
1640	1919	5116	3246	11521	7450	10870	
1641	3148	5093	3417	11767	1375	10670	
1642	3126	5145	3578	11999	1174	10370	
1643	3397	5513	3169	11116	998	9410	
	23987	42544	25221	91751	19144	80443	
1644	1593	4274	4774	9461	1491	8106	
1645	2524	4639	2445	9108	1871	7966	
1646	3746	4872	3797	10415	2365	7143	
1647	2671	4749	3041	10461	3397	7332	
1648	2480	4288	2115	9123	611	6144	
1649	3865	4714	2910	10499	67	1015	
1650	2301	4138	2310	8749	15	1012	
1651	2845	5002	2197	10504	23	6071	
	21026	16676	11195	78895	10041	14617	

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

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.

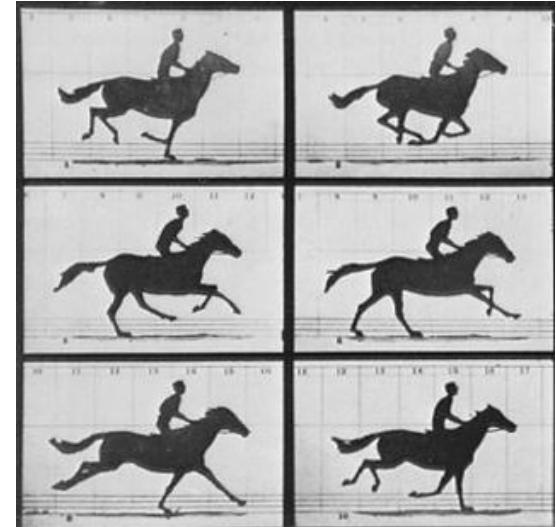
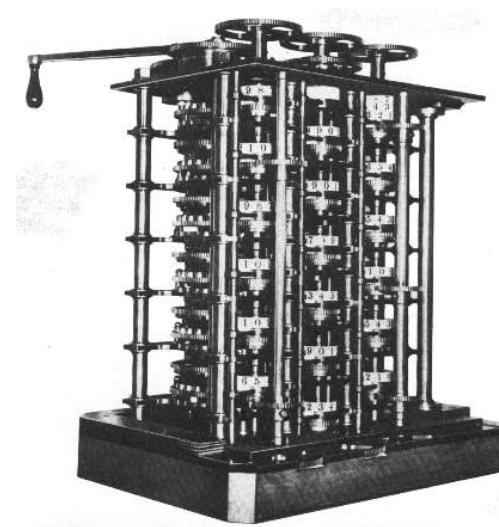
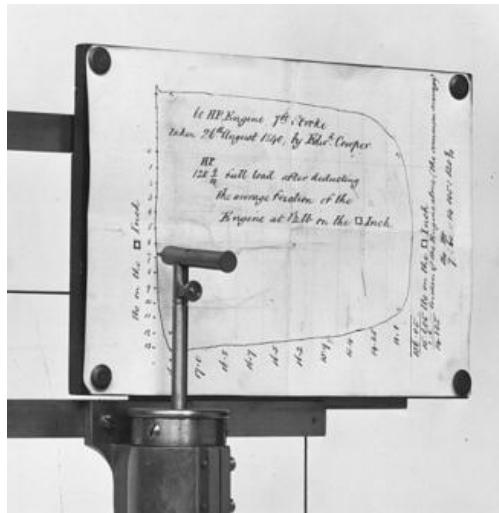
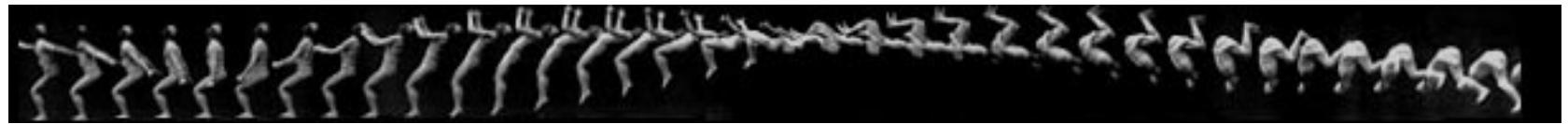
A Bortive and Stillborn	617	Executed	21	Overtake and Strangled	45
Aged	1545	Fox and Small Pox	655	Poony	30
Ague and Fever	5257	Found dead in the Streets,	7	Plague	68596
Apoplexy and Suddenly	116	Fields, &c.	1	Planet	5
Bedrid	10	French Pox	86	Plurisy	15
Blaſted	5	Gripped	23	Poisoned	1
Bleeding	16	Gout and Sciatica	27	Quinty	35
Bloody Flux, Scouring, & Flux.	185	Grief	46	Rickets	557
Burnt and Scalded	8	Gripping in the Guts	1238	Rising of the Lights	397
Caleſture	3	Hang'd and made away	8	Rupture	34
Cancer, Gangrene, and Fiftula	56	themſelves	7	Scurvy	105
Canker and Thrush	111	Headmouldhot	14	Shingles and Swine Pox	2
Childbed	625	Mouldfallen	1	Sores, Ulcers, broken and bruised Limbs	82
Chirſomes and Infants	1258	Jaundies	110	Spleen	14
Cold and Cough	68	Impoſthume	227	Spotted Fever and Purples	1929
Colick and Wind	134	Kill'd by several Accidents	46	Stoping of the Stomach	332
Consumption and Tifſick	4808	King's Evil	86	Stone and Strangury	98
Convulſion and Mother	2036	Leproly	2	Surfeiit	1251
Diftacted	5	Lethargy	14	Teeth and Worms	2614
Dropfy and Tympany	1478	Livergrown	20	Vomiting	51
Drowned	50	Megrims	7	Wen	1
		Murdered and Shot	91		

CHRISTENED { Males — 5114 Females — 4853 In all — 9967 BURIED { Males — 48569 Females — 49737 In all — 97306 } Of the Plague 68596

Increased in the Burials in the 130 Parishes and at the Pest-house this Year 79009
Increased of the Plague in the 130 Parishes and at the Pest-house this Year 68590

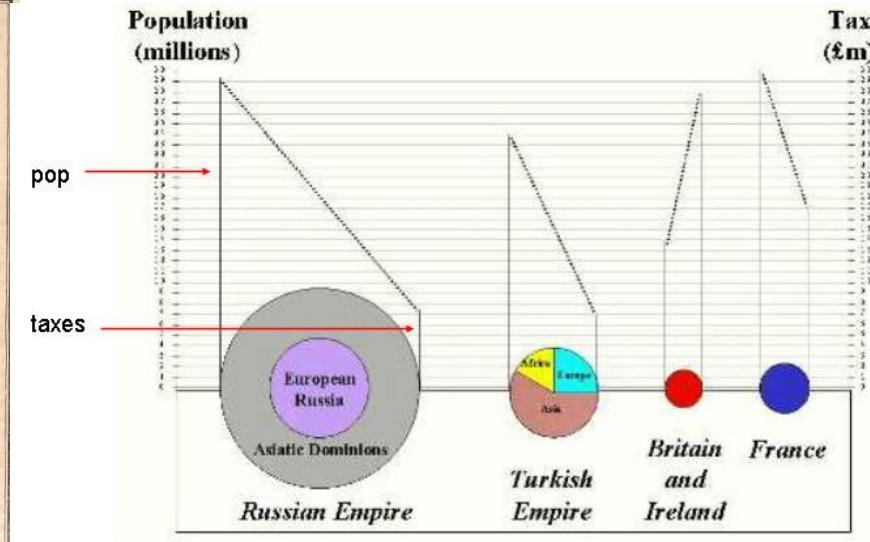
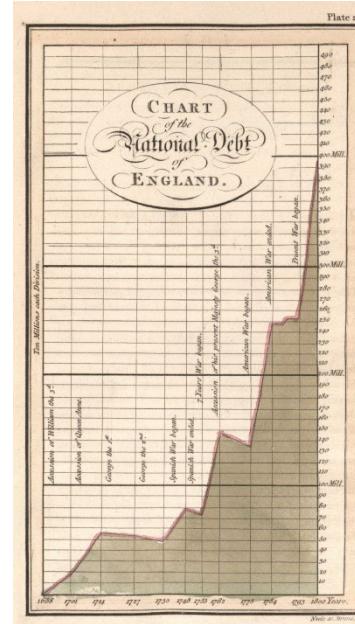
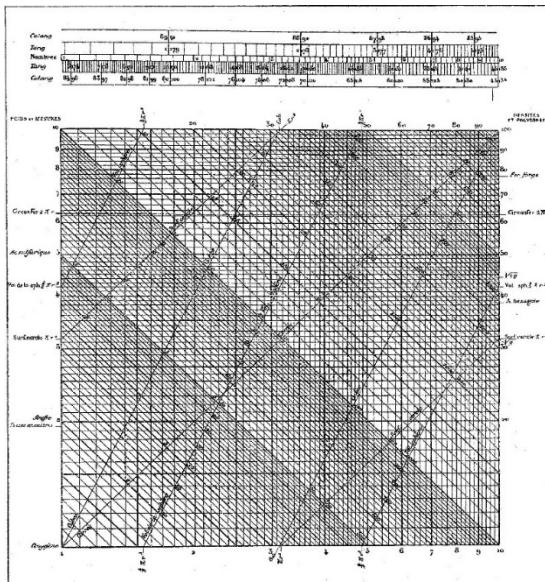
Preludes: technology

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



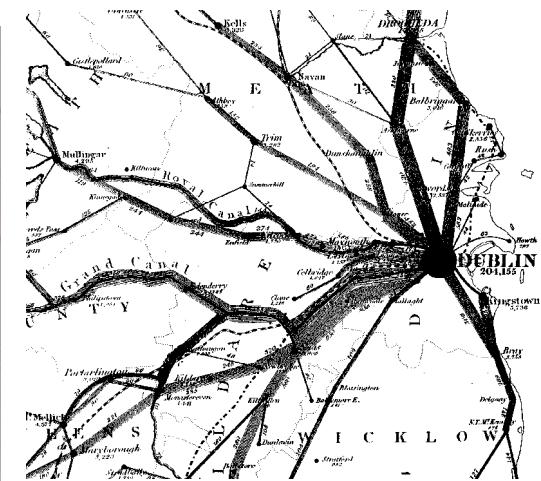
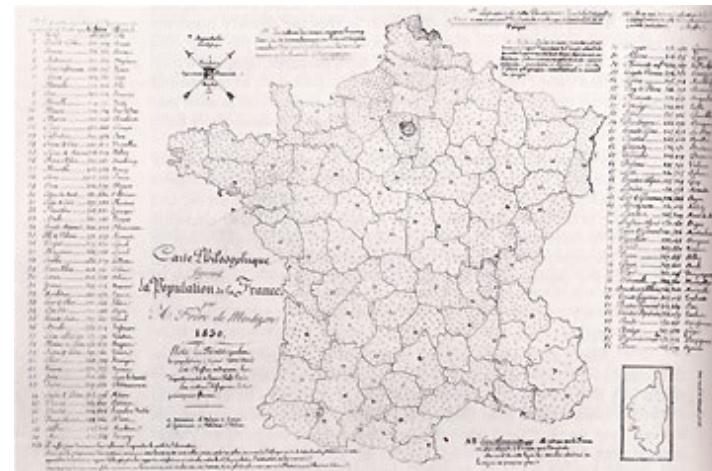
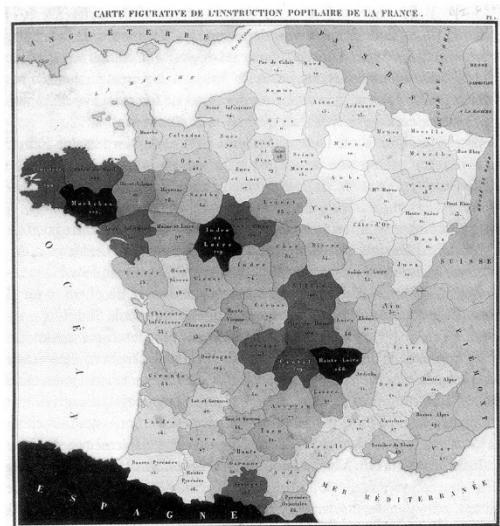
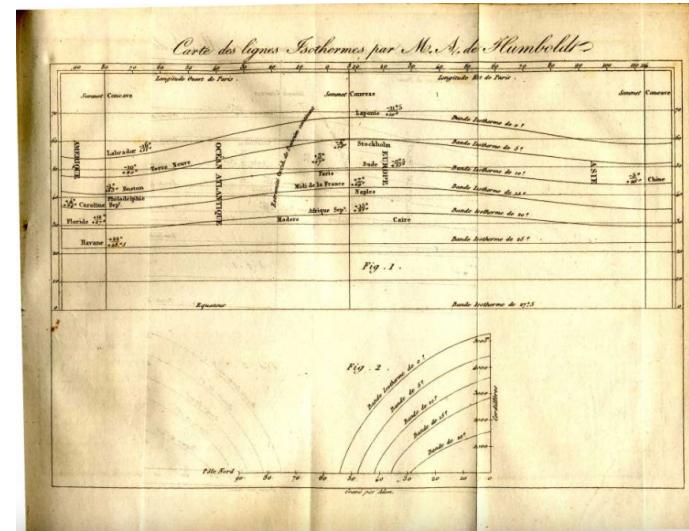
Preludes: visual language

- 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

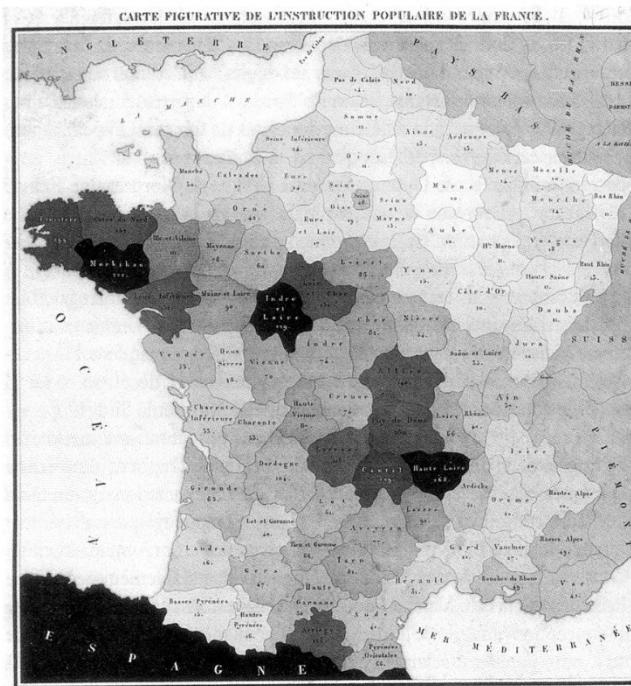
- Thematic maps
 - Isopleth– Humboldt (1817)
 - Choropleth– Dupin (1826)
 - Dot– Frère de Montizon (1830)
 - Flow– Harness (1837)



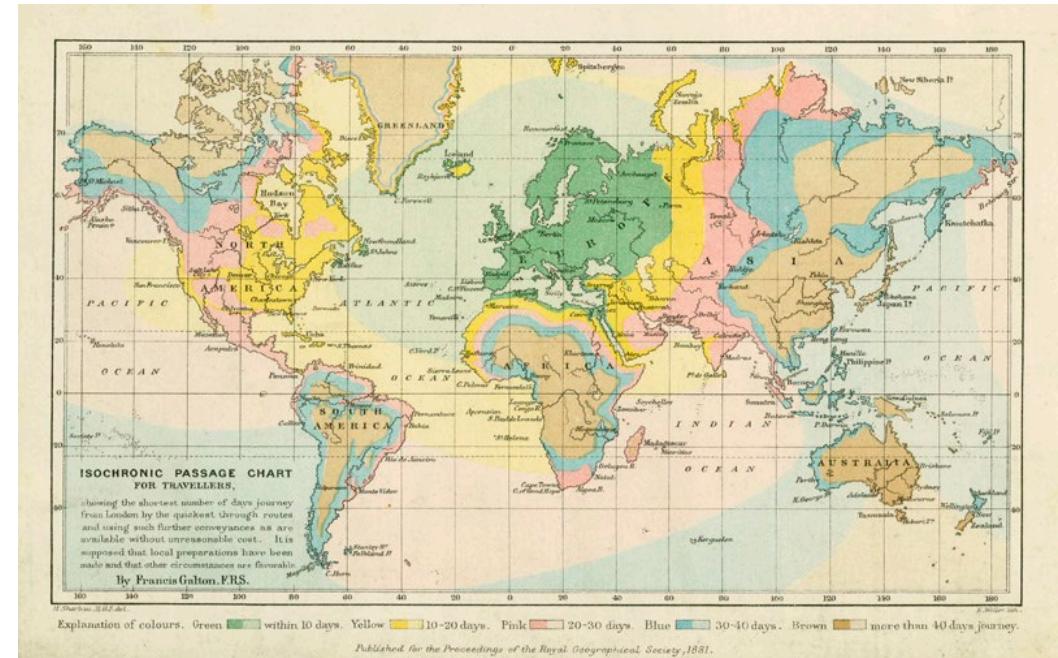
Data visualization: Diffusion of ideas

- Those who developed thematic maps often not cartographers

Dupin (1826): literacy in France

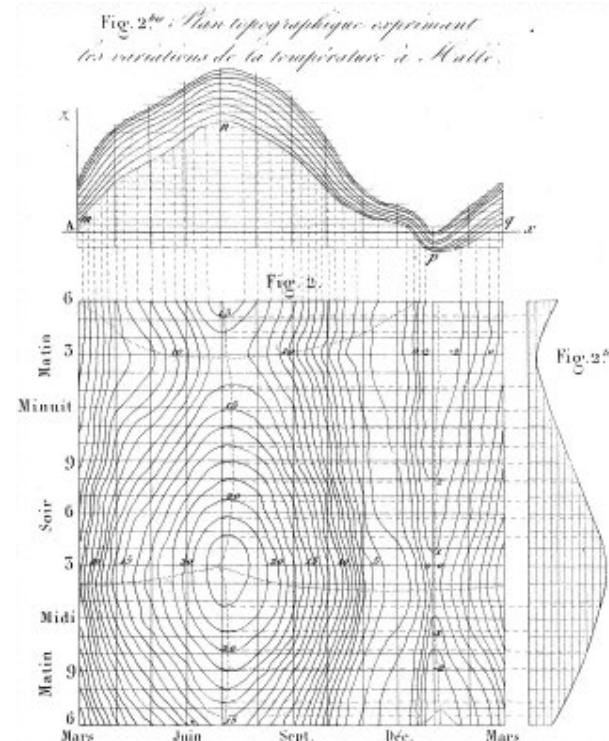


Galton (1881): travel time from London



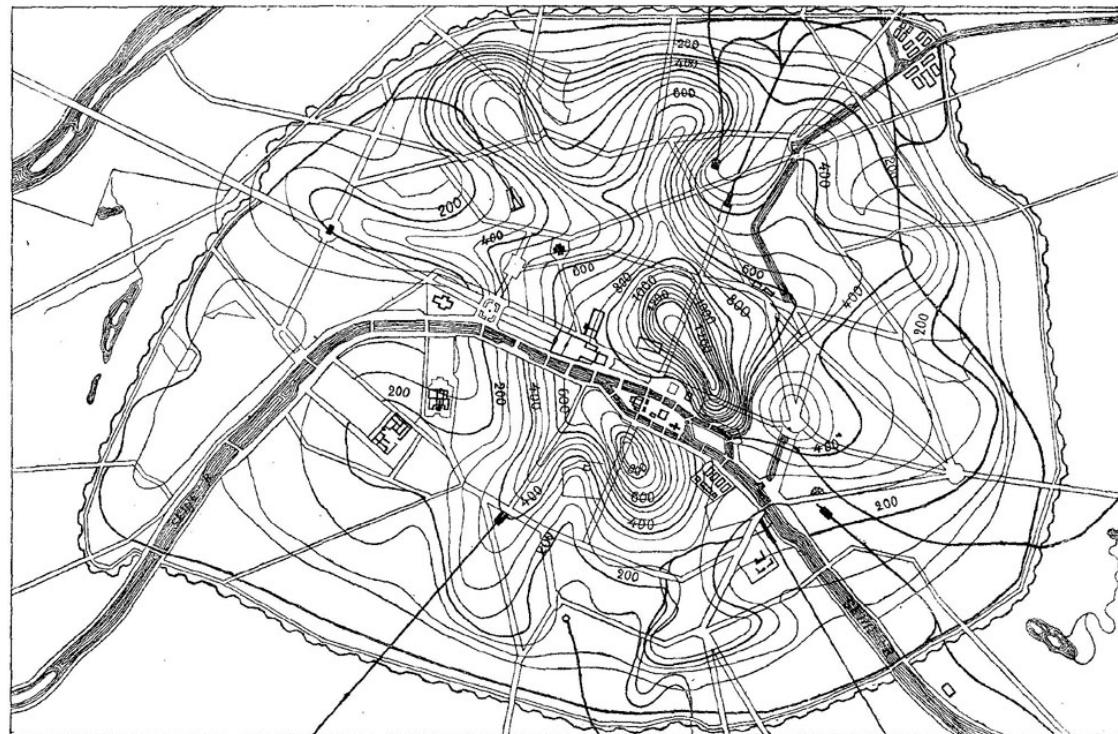
Data visualization: Diffusion of ideas

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



Data visualization: Diffusion of ideas

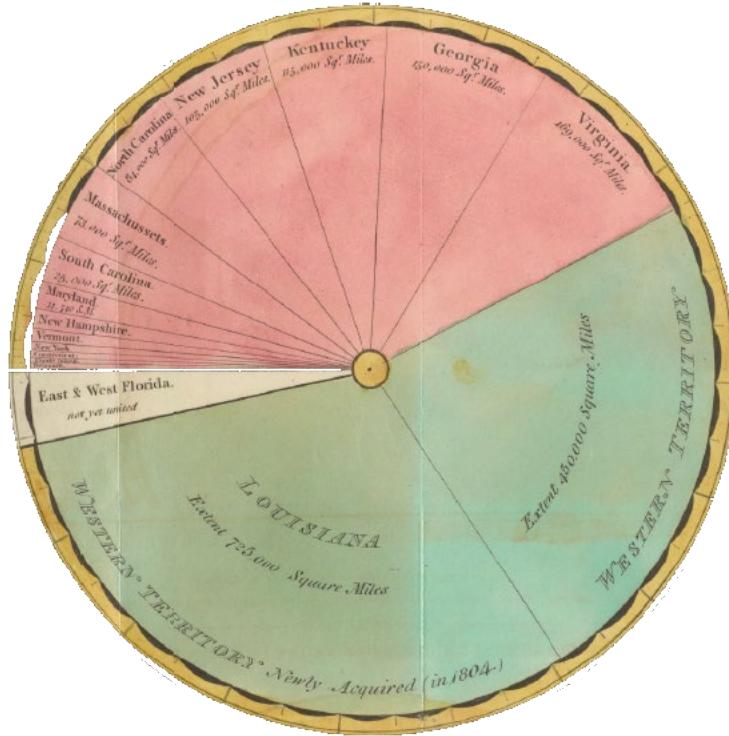
- ... and vice-versa
 - Lalanne → L.L. Vauthier (1874) contour map of population density of Paris, seen as mountains
 - Map-based data visualization was extended widely



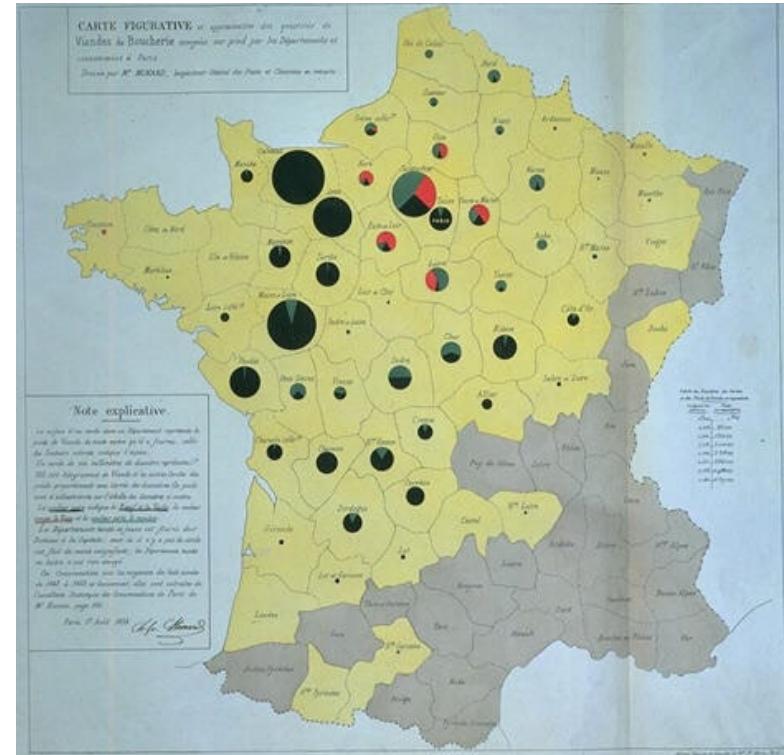
Data visualization: Diffusion of ideas

- 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?



Stories from the Golden Age (1850-1900)

Stories:

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

Themes:

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

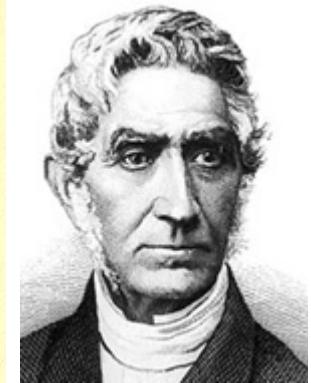
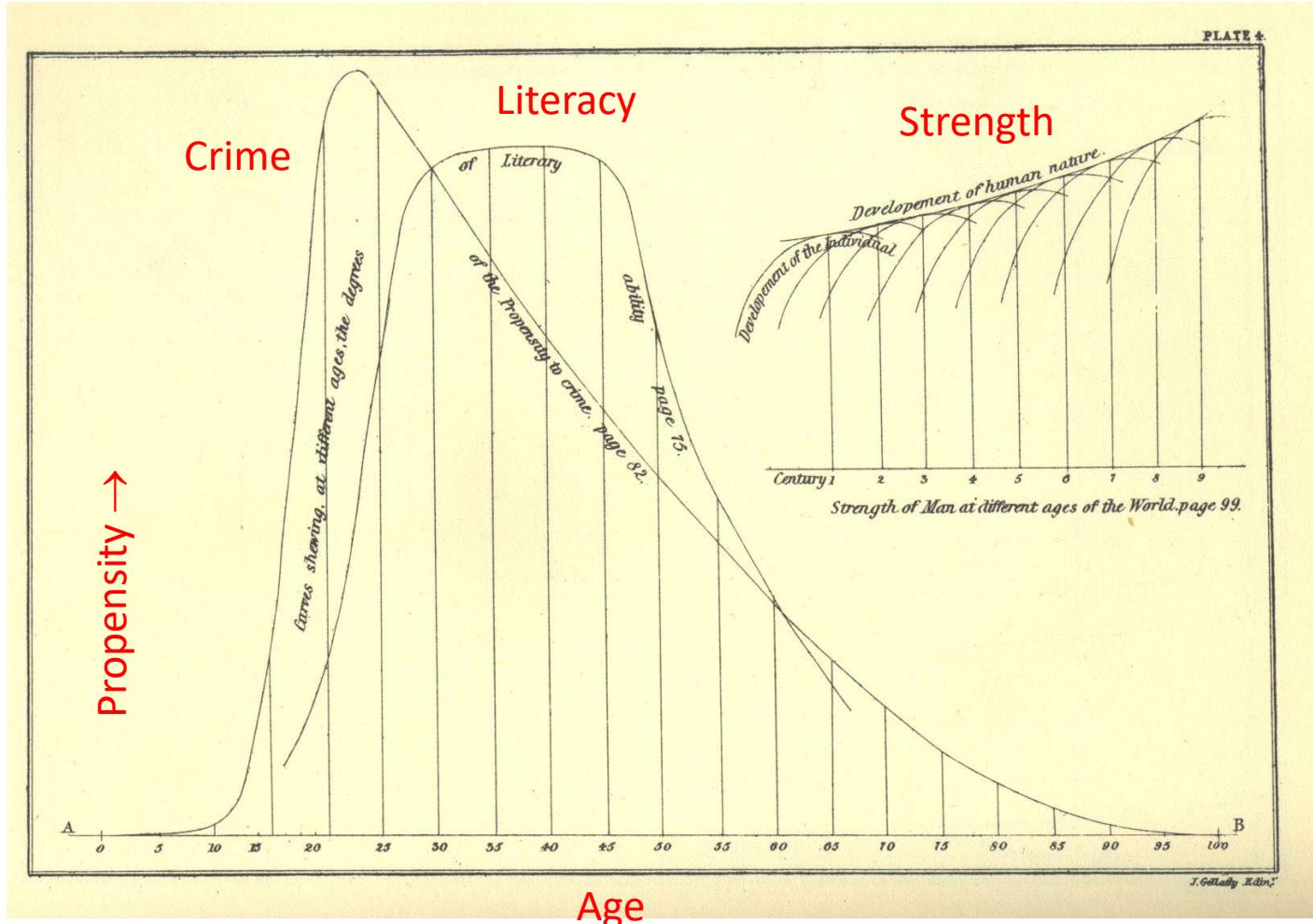


Big questions of the early 1800s

- Issues for European states
 - Demography: taxes, raising an army (Süssmilch, 1741)
 - “Statistik”: Numbers of the state (Achenwall, 1748)
 - Social problems: crime, suicide, literacy, etc.
 - Disease epidemics, e.g., cholera
- Anthropometry: the measure of Man
 - Distributions of human characteristics (Quetelet)
 - Mortality, suicide, propensity to crime
- Beginnings of statistical theory and application
 - Normal distⁿ (de Moivre, 1733)
 - *L'homme moyen* (Quetelet, 1835)

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

Big data of the early 1800s:

“An avalanche of social numbers”

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

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

Essai sur la statistique moral de la France

The launching pad of modern social science

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





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!

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 indicants of individual behaviour?

Guerry argued:

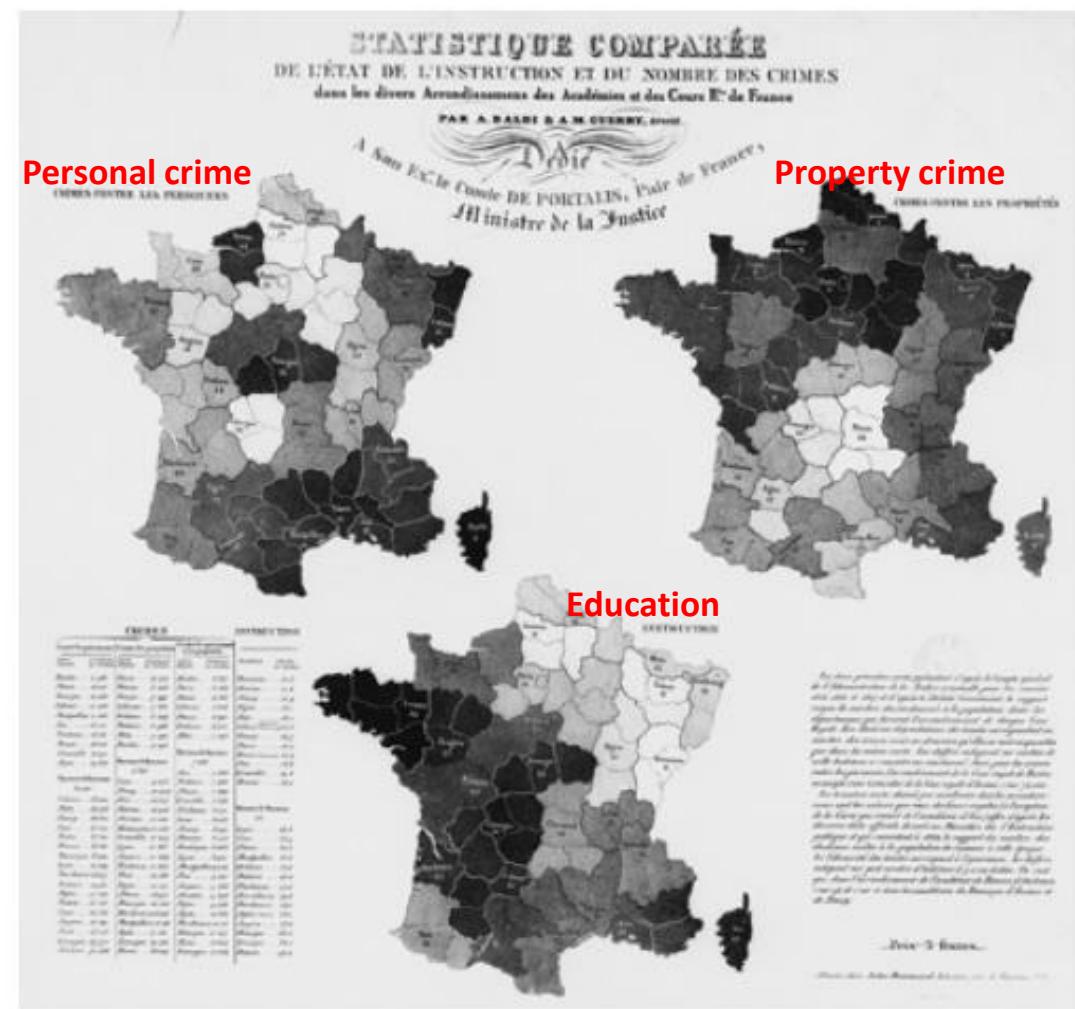
Each year sees the same number of crimes of the same degree reproduced in the same regions. (Guerry, 1833, p.10)

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



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

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



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

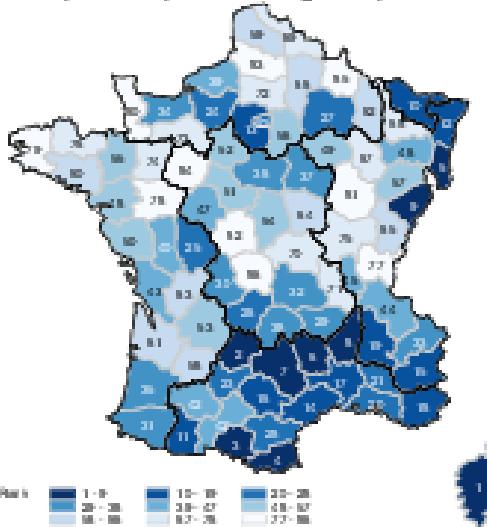
- ▶ Divided the 86 departments into 5 regions
- ▶ Supplemented data from the *Compte général* with:
 - ▶ Suicides in Paris, 1794–1832
 - ▶ Prostitutes in Paris (Parent-Duchâtelet)
 - ▶ Wealth (taxes per inhabitant)
 - ▶ Distribution of clergy
 - ▶ ...
- ▶ First study to use crime data to ‘test’ hypotheses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



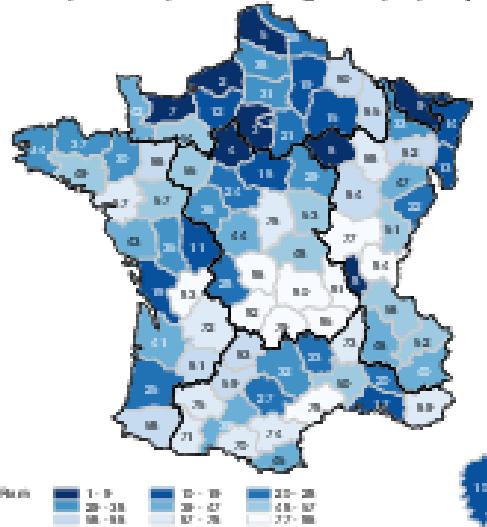
Guerry's 1833 map of literacy in France

Guerry's moral variables

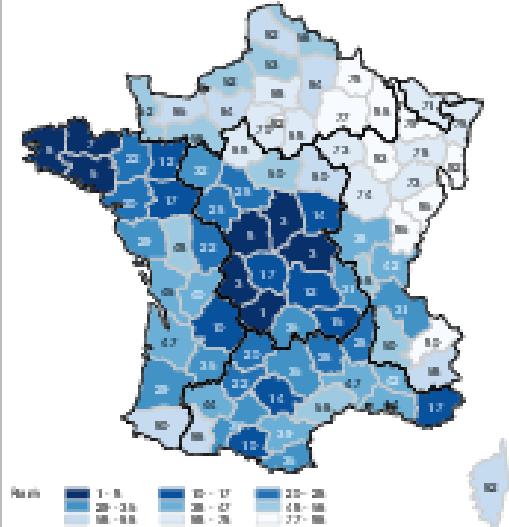
Population per Crime against persons



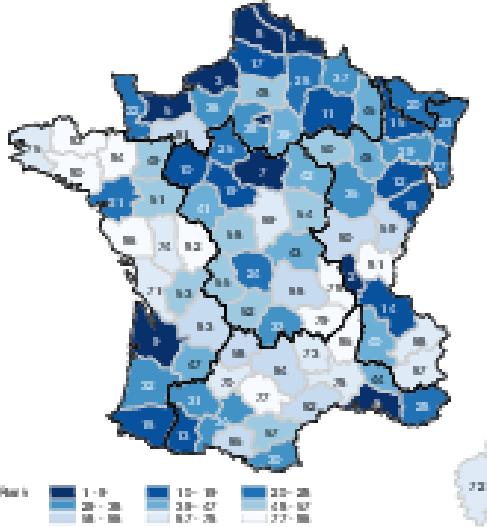
Population per Crime against property



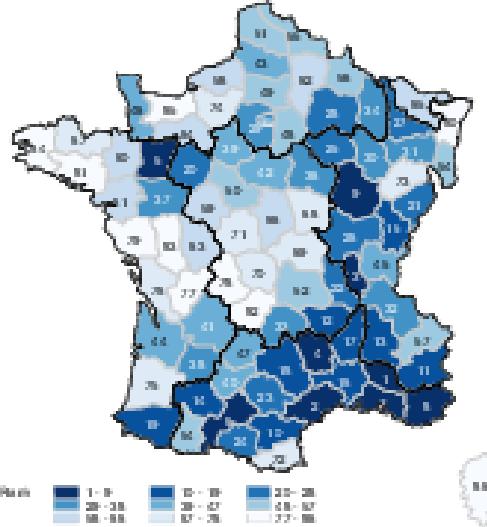
Per cent who can Read and Write



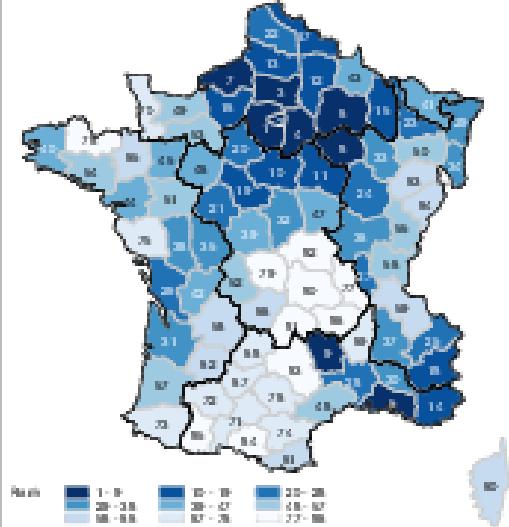
Population per Illegitimate birth



Donations to the poor



Population per Suicide





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

Dayenu!

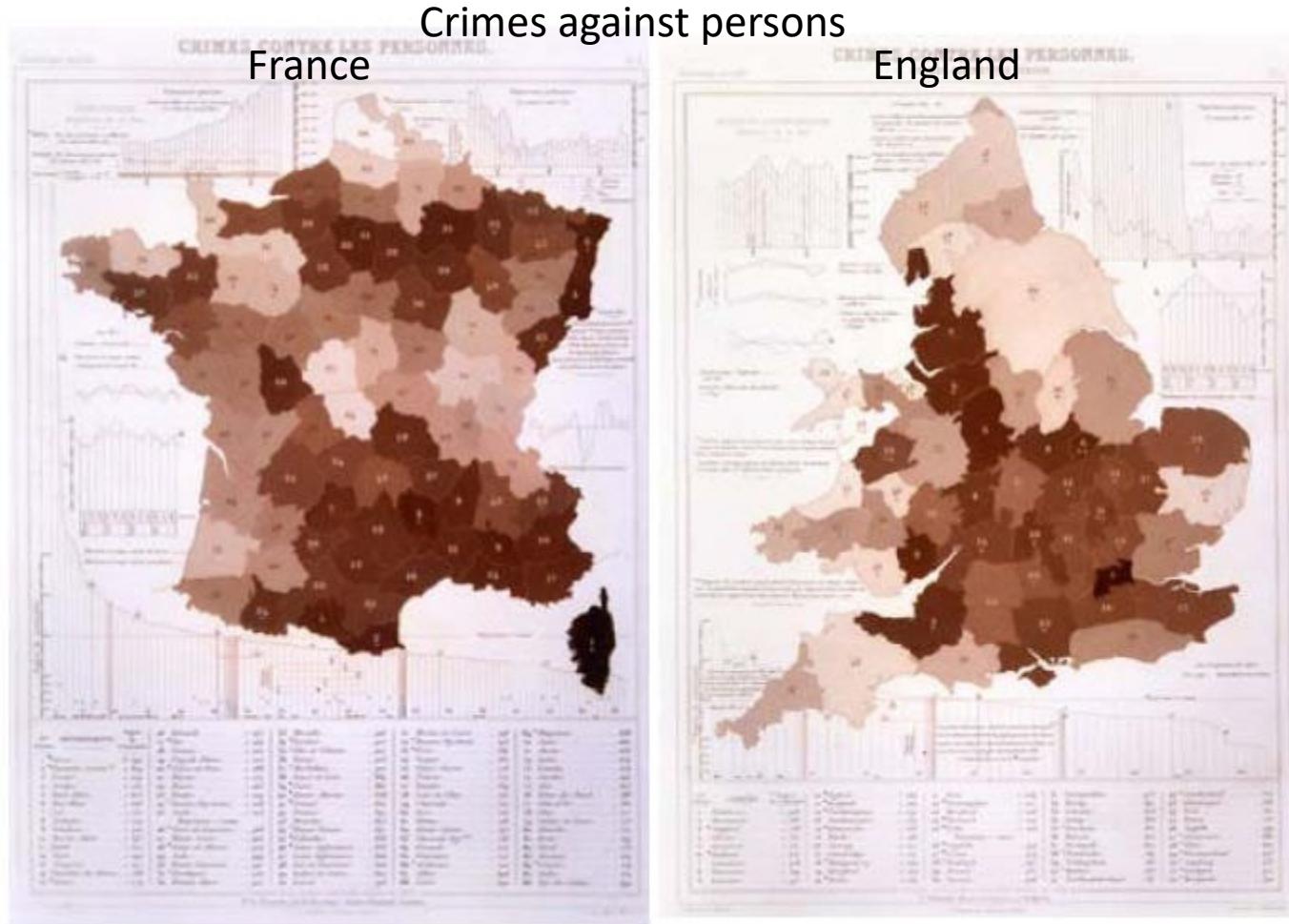
- ▶ Proposes to replace simple “moral statistics” (tables) with “analytical statistics”
 - ▶ calculation, graphic display
 - ▶ ↫ general, abstract results
- ▶ 17 large color plates (56×39 cm):
 - ▶ data for France (1825–1855), England (1834–1855)
 - ▶ crimes against persons and property decomposed in 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!



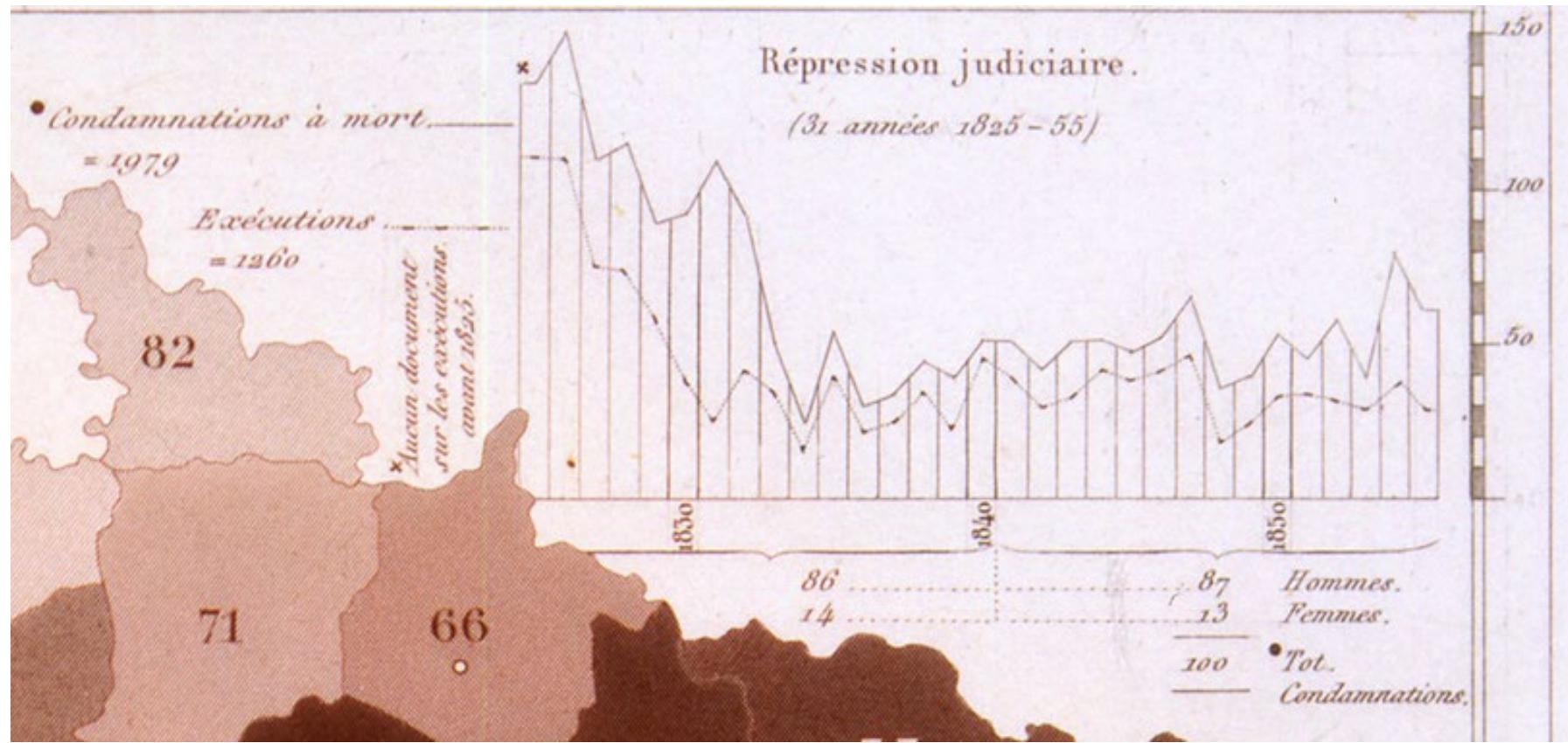
Further details: Friendly, M. (2007). A.-M. Guerry's *Moral Statistics of France*: Challenges for Multivariable Spatial Analysis, *Statistical Science*, 22, 368-399

1864: *Statistique morale de l'Angleterre comparée à celle de la France*

Comparing France and England



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



Detail: Trends in death sentences
and executions over 31 years

Statistique analytique: General causes of crime

Plate XVII: M. Guerry's magnum opus

Goal:

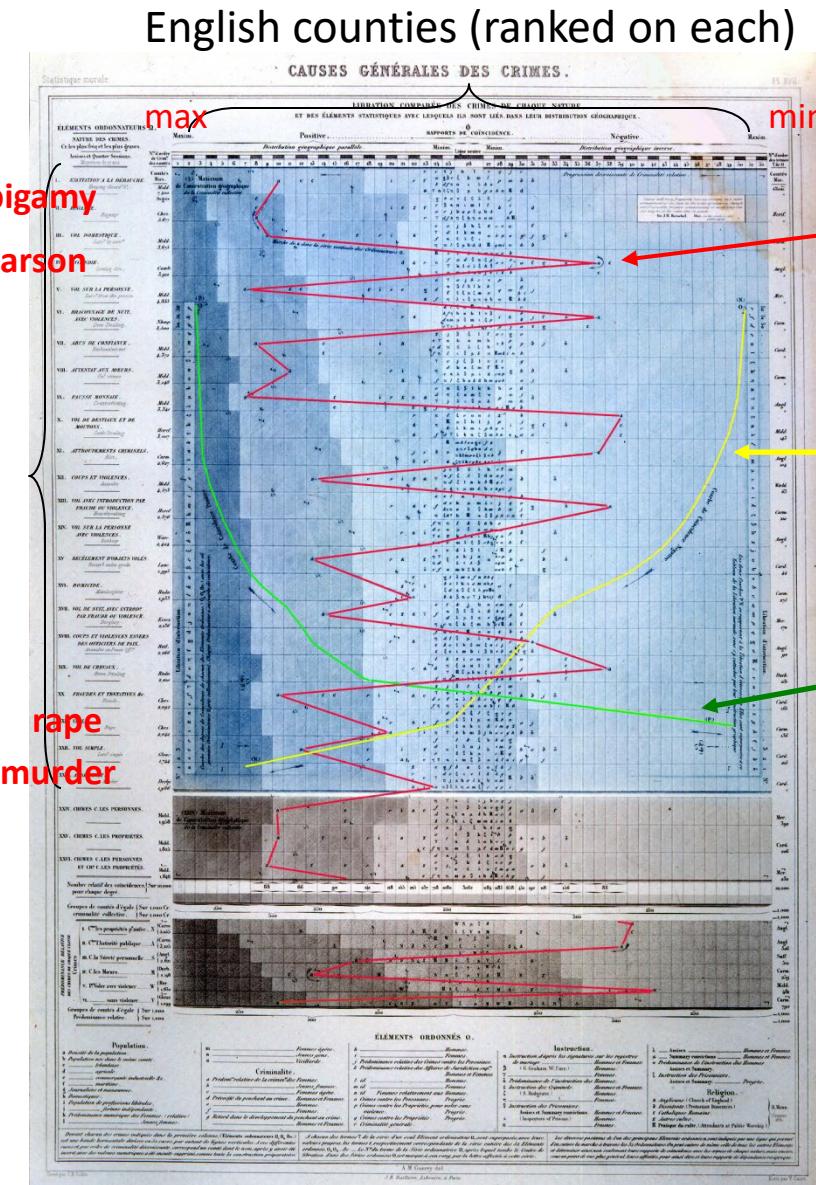
- Show multivariate factors associated with distribution of crime
- Before invention of correlation

Entries: Codes for factors

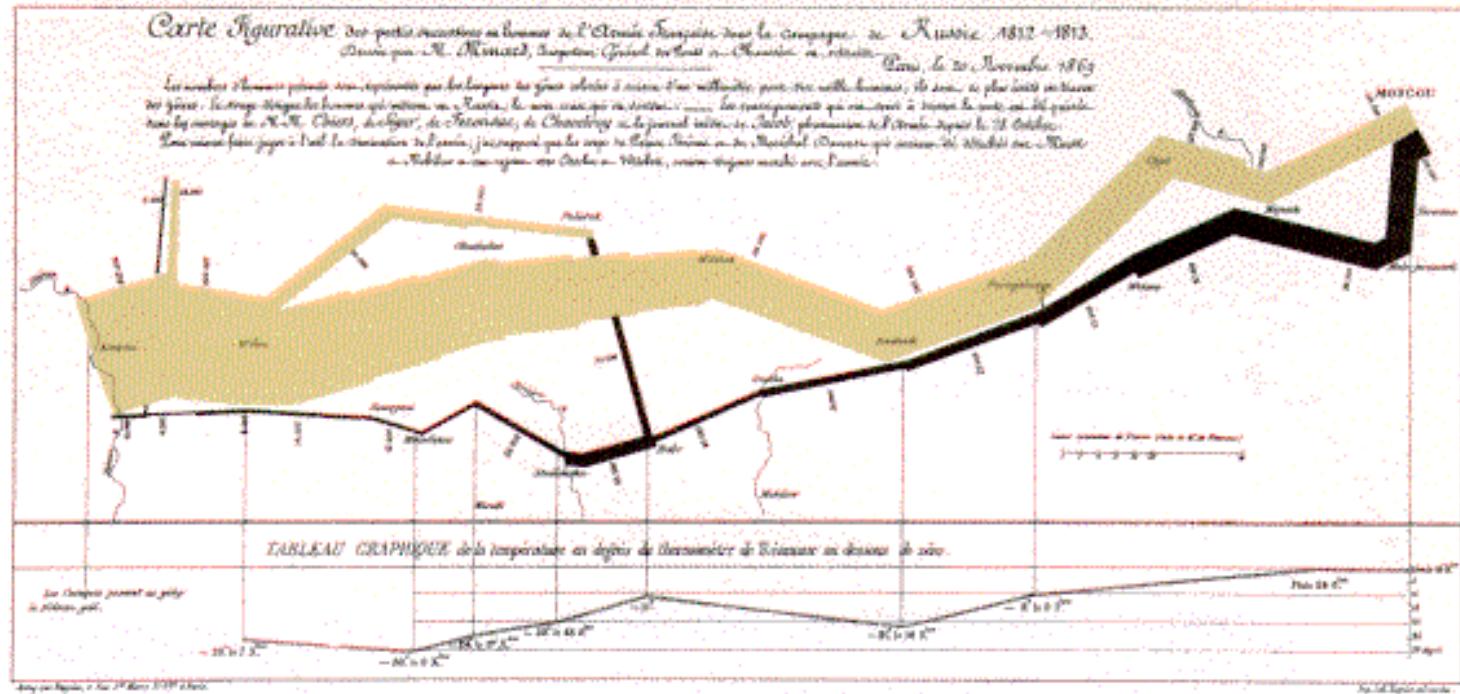
- Pop: (% Irish, domestics, ...)
- Criminality: (male, young, ...)
- Religion (Anglicans, dissenters, ...)

x	f	g	b	o	v	ζ	ε	λ	δ
c	β	a	n	i	m	l	t		
a	e	j	k	q	p	θ	μ	b	k
r	γ	d	f	α	η	ξ	h	ν	o

Crimes (ranked)



2. The graphic vision of C. J. Minard



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

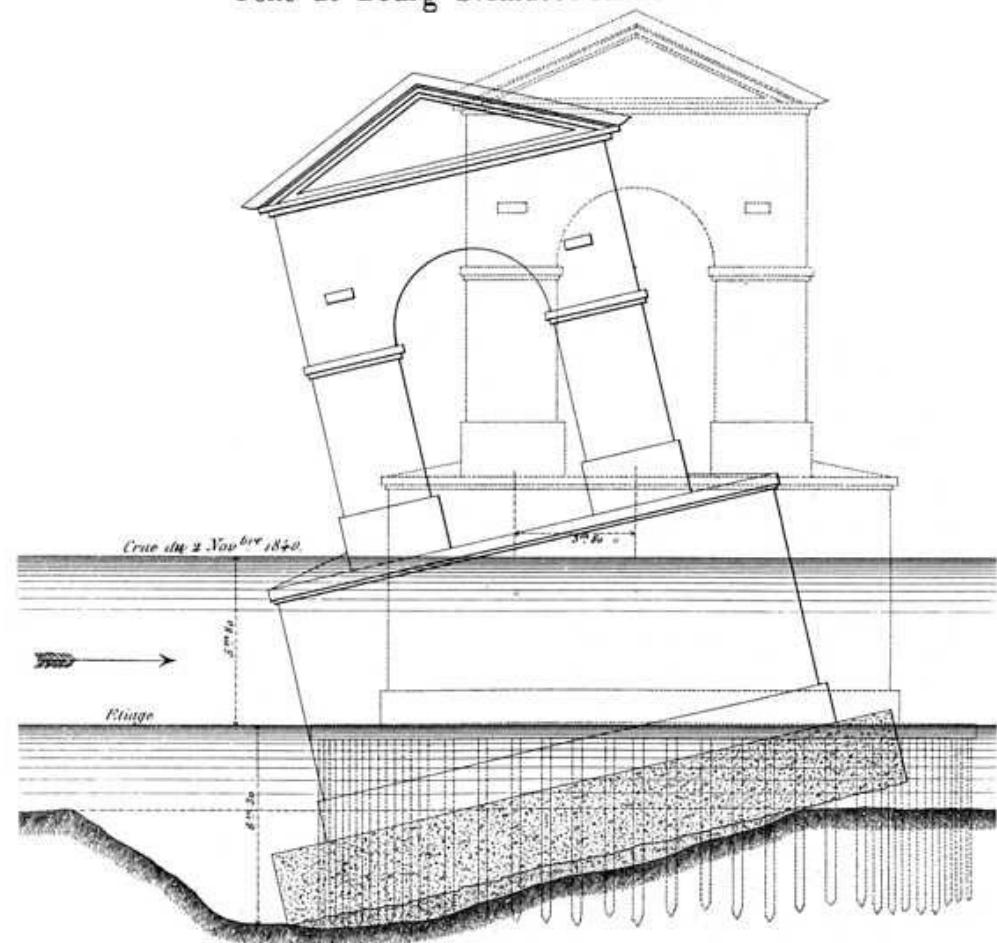
Visual thinking, visual explanation

Minard's main career was 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.

Pont de Bourg-S^t Andéol sur le Rhône.



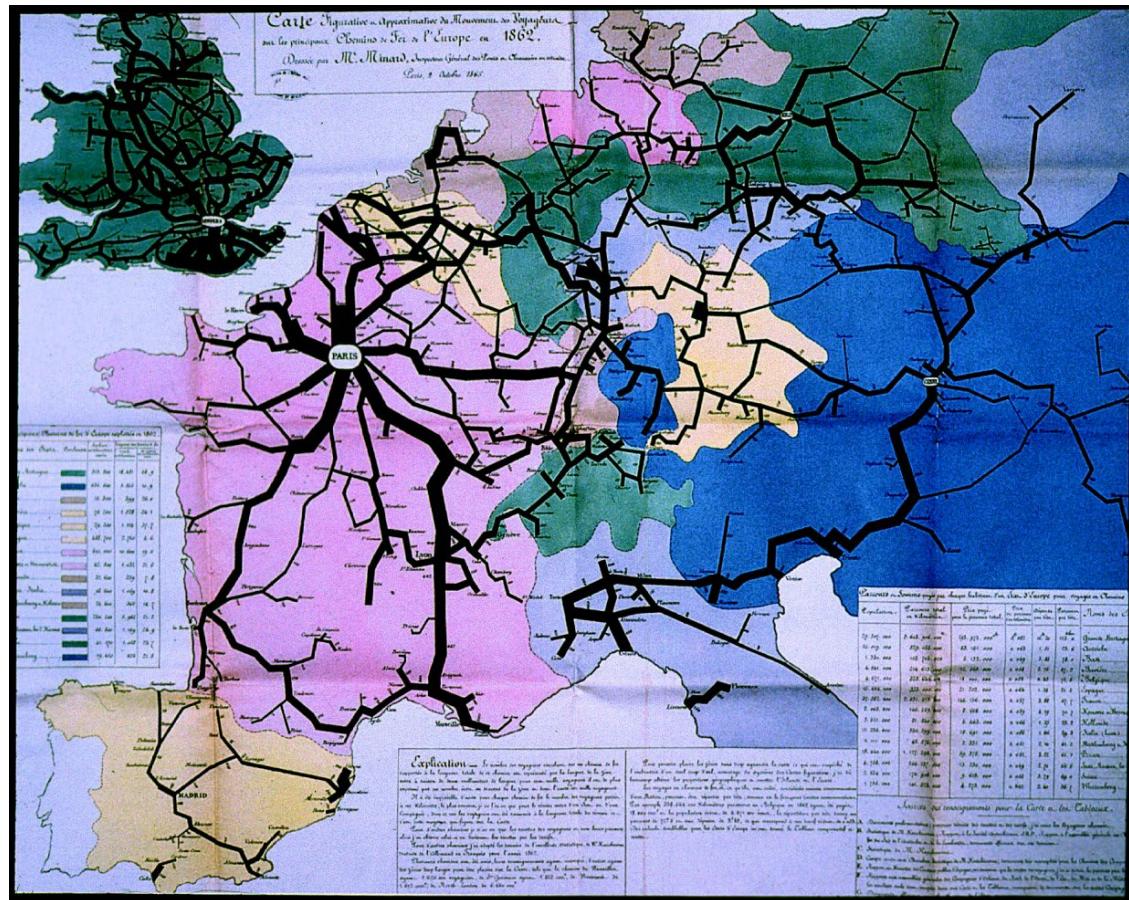
Big questions of the mid 1800s

- 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>

Flow maps as visual tools

Transport of passengers on the principal railroads in Europe in 1862



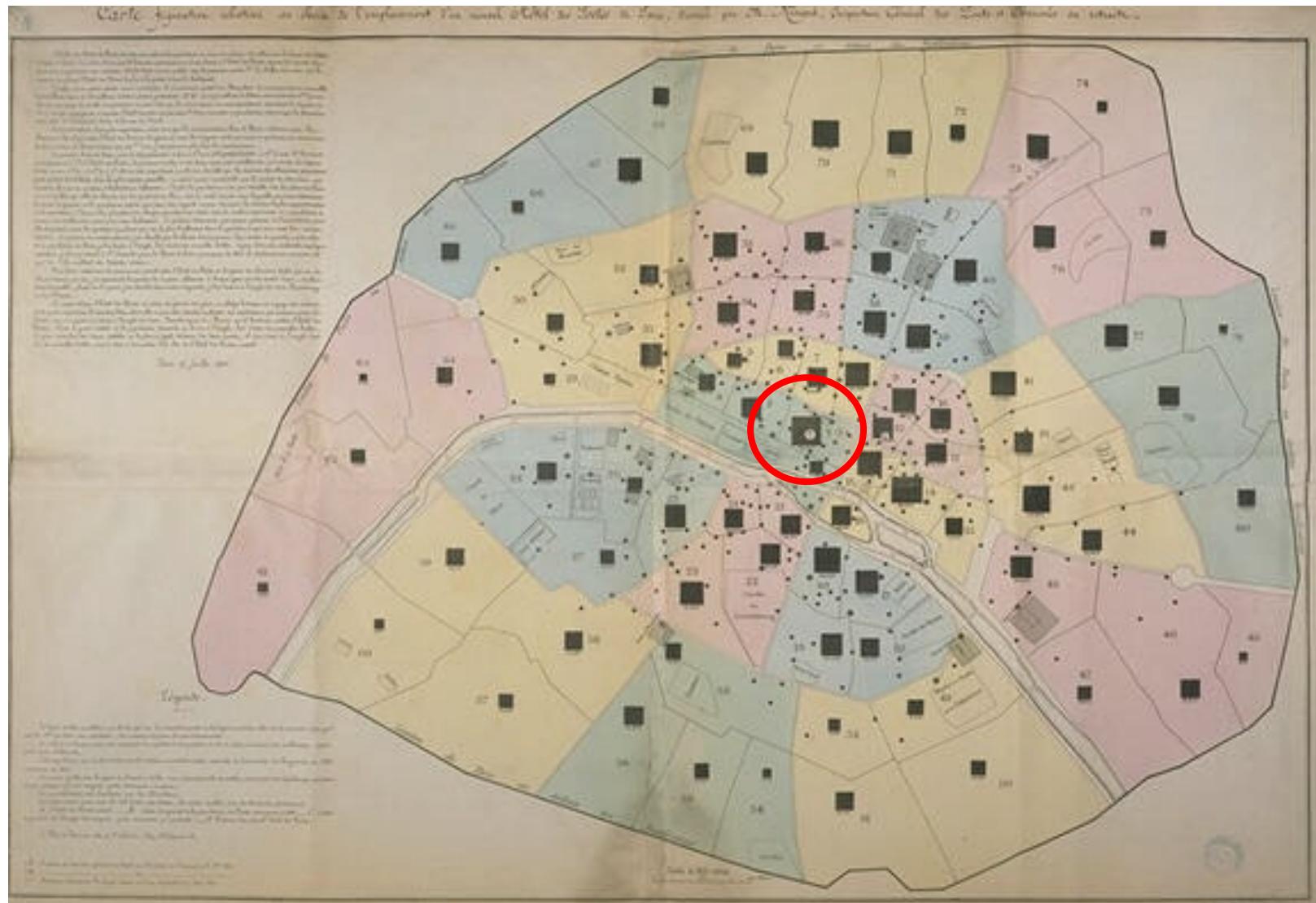
The dominant principle which characterizes my graphic tables and my figurative maps is to make immediately appreciable to the eye, as much as possible, the proportions of numeric results.

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

-- Minard (1862)

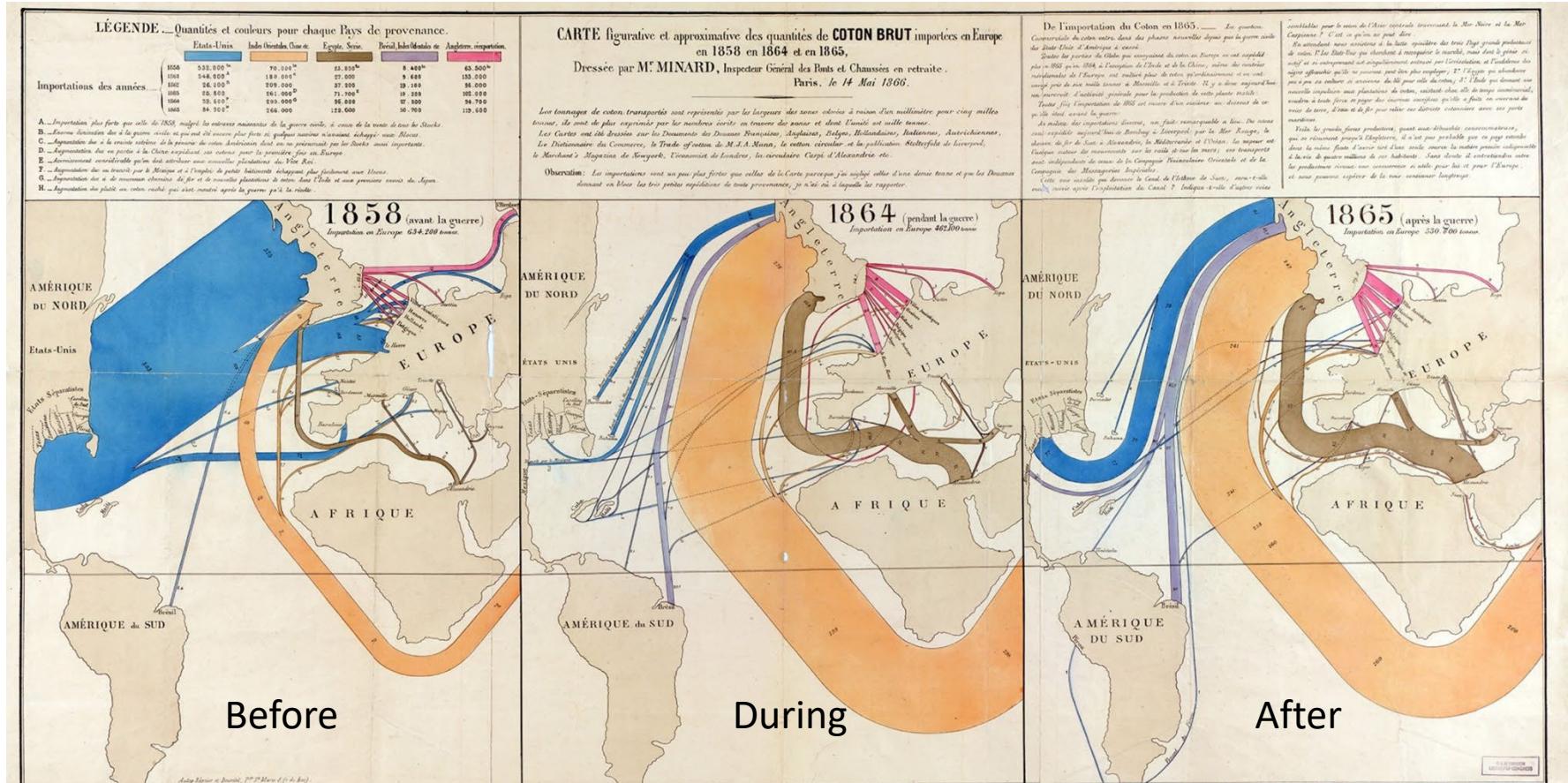
Where to build a new post office in Paris?

- Visual solution: at the center of gravity of population



Visual explanation

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

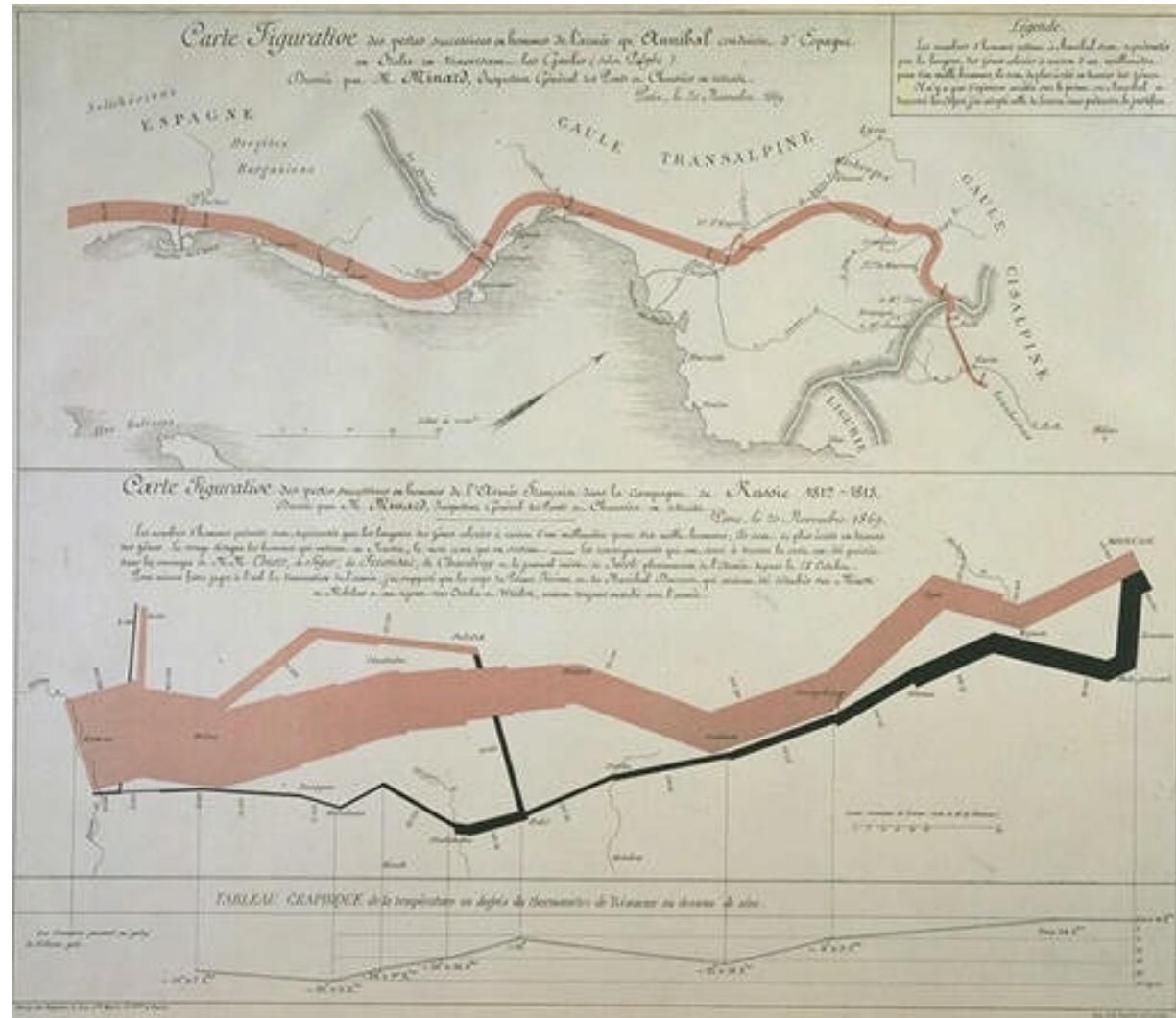


"Carte figurative et approximative des quantités de coton brut importées en Europe en 1858, en 1864 et en 1865" by Charles Joseph Minard (1866)

The March Re-Visited (1869)

Hannibal's
retreat

Napoleon's
1812
campaign



Les Chevaliers: Minard's Tomb

Jean-Pierre Airey-Jouglard

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

Celebrated June 5,
2017

Antoine de Falguerroles



MF

Gilles Palsky

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

METEOROGRAPHICA,

OR

METHODS OF MAPPING THE WEATHER;

ILLUSTRATED BY UPWARDS OF 600 PRINTED AND LITHOGRAPHED DIAGRAMS

REFERRING TO

THE WEATHER OF A LARGE PART OF EUROPE,

During the Month of December 1861.

BY FRANCIS GALTON, F.R.S.

(Galton, 1863)

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

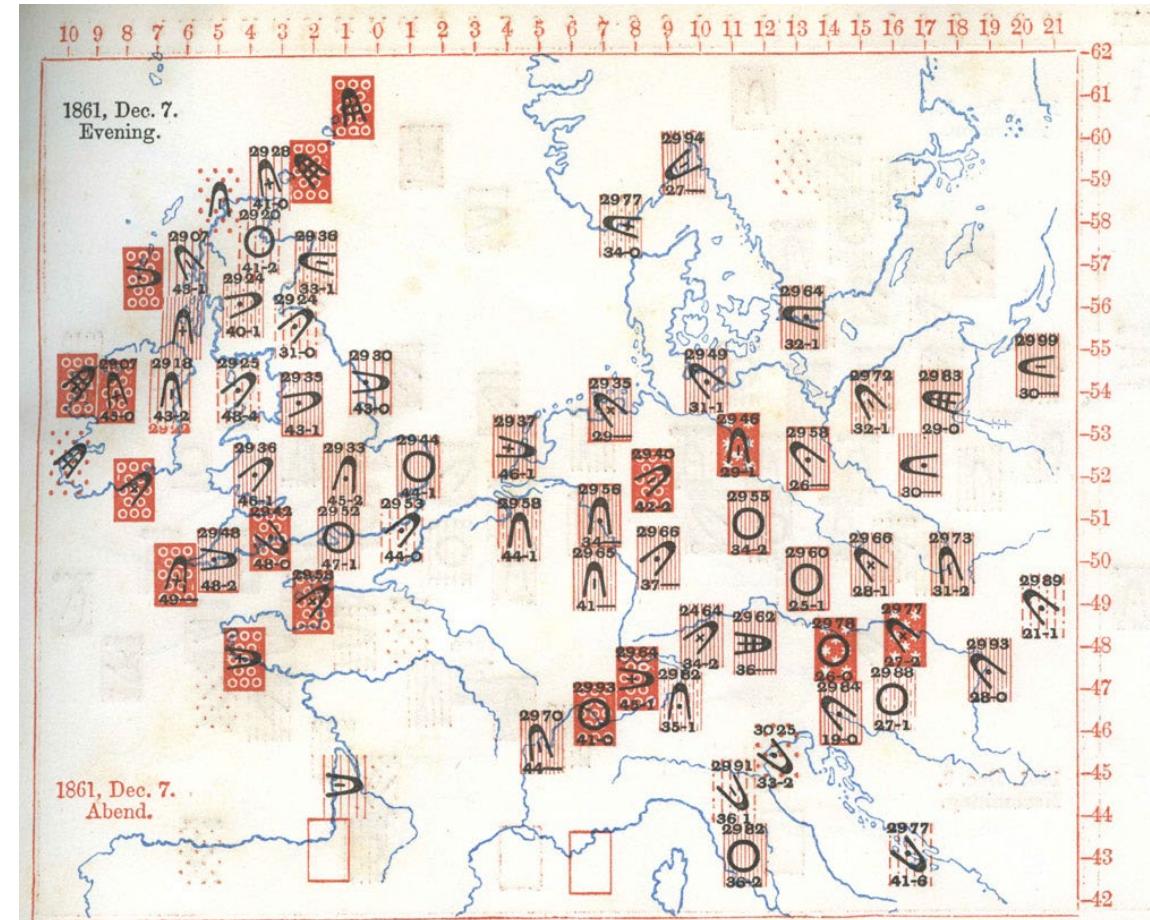
Galton's data collection form:

<p><i>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.</i></p>								
<p style="text-align: right;">FRANCIS GALTON, 42, Rutland Gate, London.</p>								
<p>Name of Station :</p> <p>Its Latitude :</p> <p>Its Longitude from Greenwich :</p> <p>Its Height above Sea Level, in English Feet :</p>				<p>Name of Contributor :</p> <p>Full Address to which the Charts are to be forwarded when ready :</p>				
Date. Either Local or Railway Time; state which.	Barometer corrected to Freezing Point at Mean Sea Level, and reduced to English Inches, Tenths, and Hundredths.	Exposed Thermometer in Shade, to nearest Degree, Fahrenheit.	Moistened Bulb to nearest Degree, Fahr- enheit, for Evaporation and Dew Point.	Direction of Wind, <i>true</i> not magnetic. Only 16 points of the Compass are used; as, N., N.N.E., N.E., E.N.E., E., &c.	Force of Wind: Calm, Gentle, Moderate, Strong, Gale.	Amount of Cloud: Clear blue sky, A few clouds, Half clouded, Mostly 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.
[Rain symbol: dots in a grid]	[Snow symbol: stars]	[Clouded symbol: vertical lines]	[Clouded symbol: horizontal lines]	[Clouded symbol: diagonal lines]	[Clouded symbol: vertical lines]	[Clouded symbol: horizontal lines]	[Clouded symbol: dots]

CLOUD.

Rain.	Snow.	Entirely and heavily clouded.	Entirely clouded.	Mostly clouded.	Half clouded.	A few clouds.	Clear blue sky.
[Rain symbol: dots in a grid]	[Snow symbol: stars]	[Clouded symbol: vertical lines]	[Clouded symbol: horizontal lines]	[Clouded symbol: diagonal lines]	[Clouded symbol: vertical lines]	[Clouded symbol: horizontal lines]	[Clouded symbol: dots]

DIRECTION OF WIND.

N	S	E	W	&c.
S.S.W.	S.W.	W.S.W.	W.	

FORCE OF WIND.

Gale.	Strong.	Moderate.	Gentle.	Almost calm.	Calm.
[Gale symbol: vertical lines]	[Strong symbol: diagonal lines]	[Moderate symbol: short lines]	[Gentle symbol: dot]	[Almost calm symbol: dot]	[Calm symbol: dot]

Visual ideas:

- Iconic symbols
- Multivariate glyphs (stamps!)

Visual abstraction → Patterns

How to see patterns of geographical variation over time?

- Iconic symbols on a geographical grid
- “Small multiples:” separate graphs laid out for direct comparison



Symbols in Barometrical Charts.

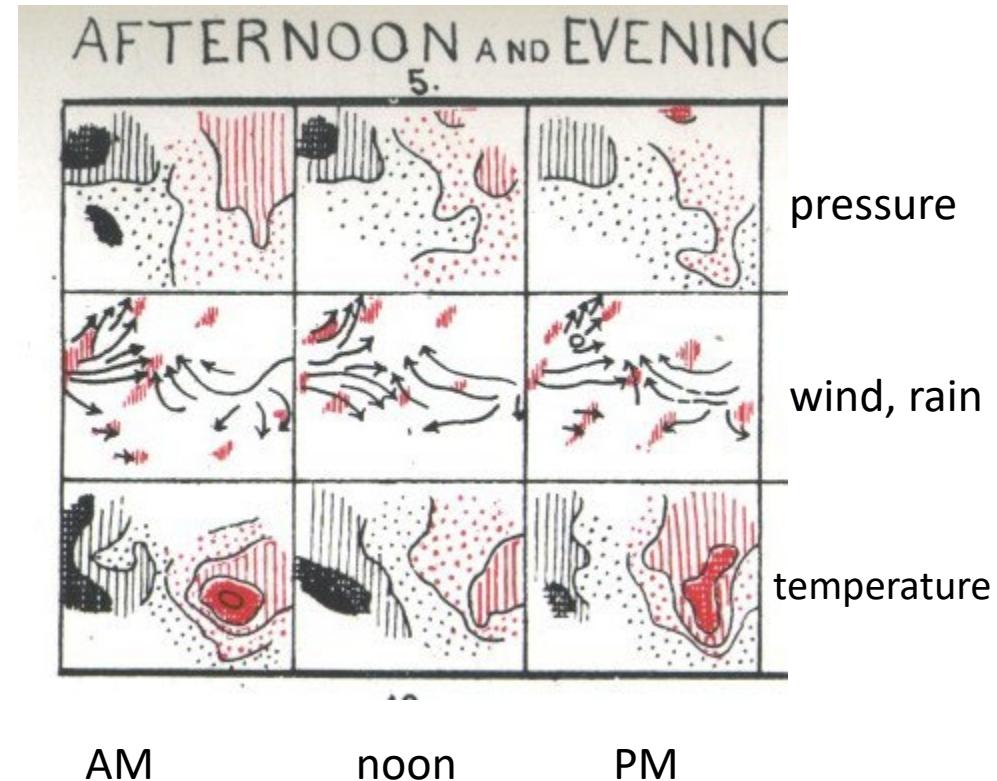
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
Black	- 29.95 to 29.71			- 29.70 to 29.46		- 29.45 to 29.21	
	○			○		*	
Red	- 29.96 to 30.20			- 30.21 to 30.45		- 30.46 to 30.70	
						●	- 30.71 and above.

Visual abstraction → Patterns

What varies with what, over time and space?

- mini, abstract maps: vars x TOD
- iso-contours, shading to show equivalence
- arrows to show wind direction

EXPLANATION OF SYMBOLS.			
Barometer	29 35-29 1/2 In.	29 1/2-29 1/4 In.	29 1/4-29 1/2 In.
	29 1/2-30 1/2 In.	30 1/2-30 1/4 In.	30 1/4-30 1/2 In.
Wind & Rain	WIND:- from West from North.	RAIN:-	
Thermometer	33-37° F.	38-42° F.	43-47° F.
	32-28° F.	27-23° F.	22-18° F.
			17° & below.



Data for Dec 5, 1861

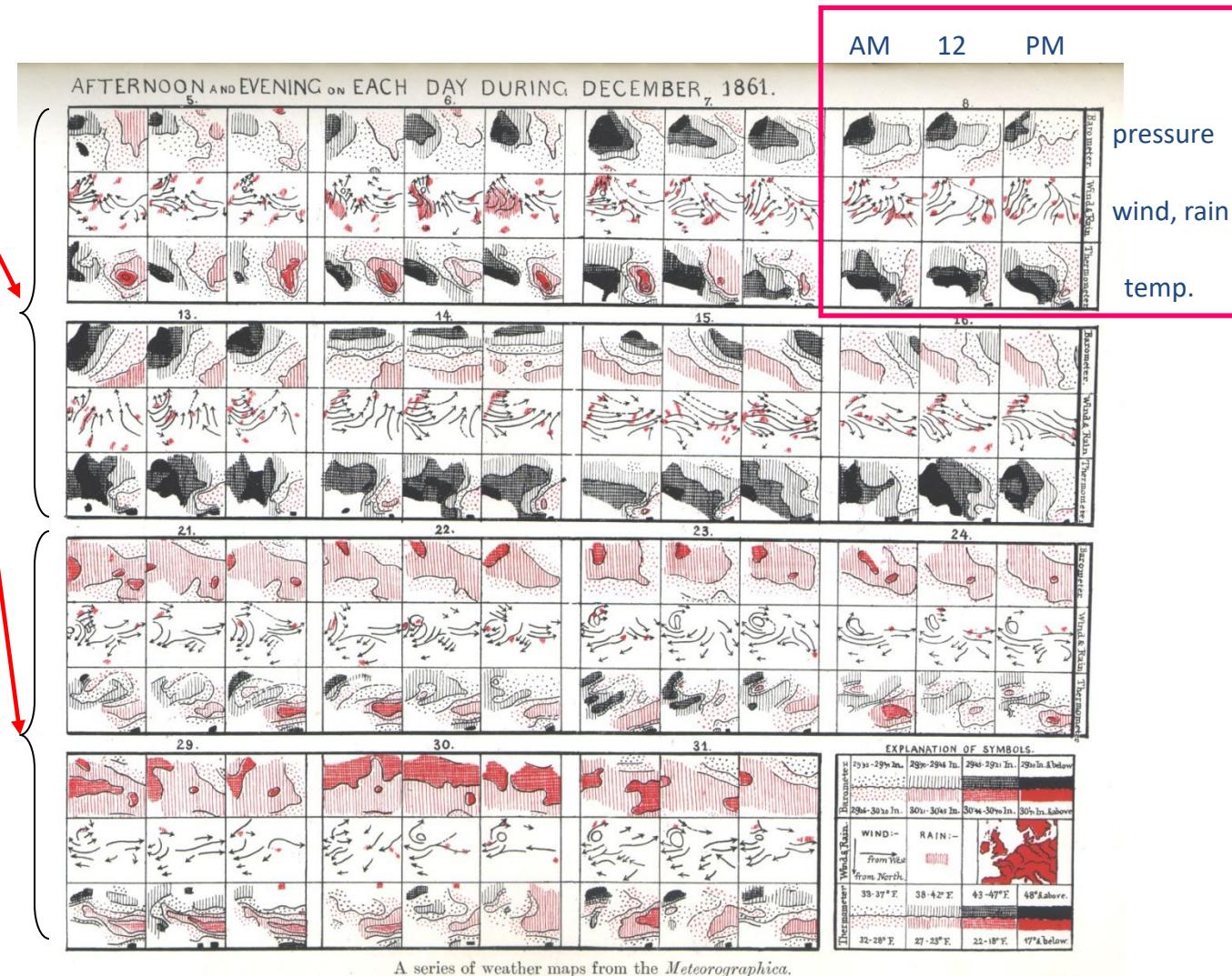
The large picture → Insight

Pattern:

Low pressure (black) in early Dec. → CCW wind
 High pressure (red) in late Dec. → CW wind

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

(try this with your software!)



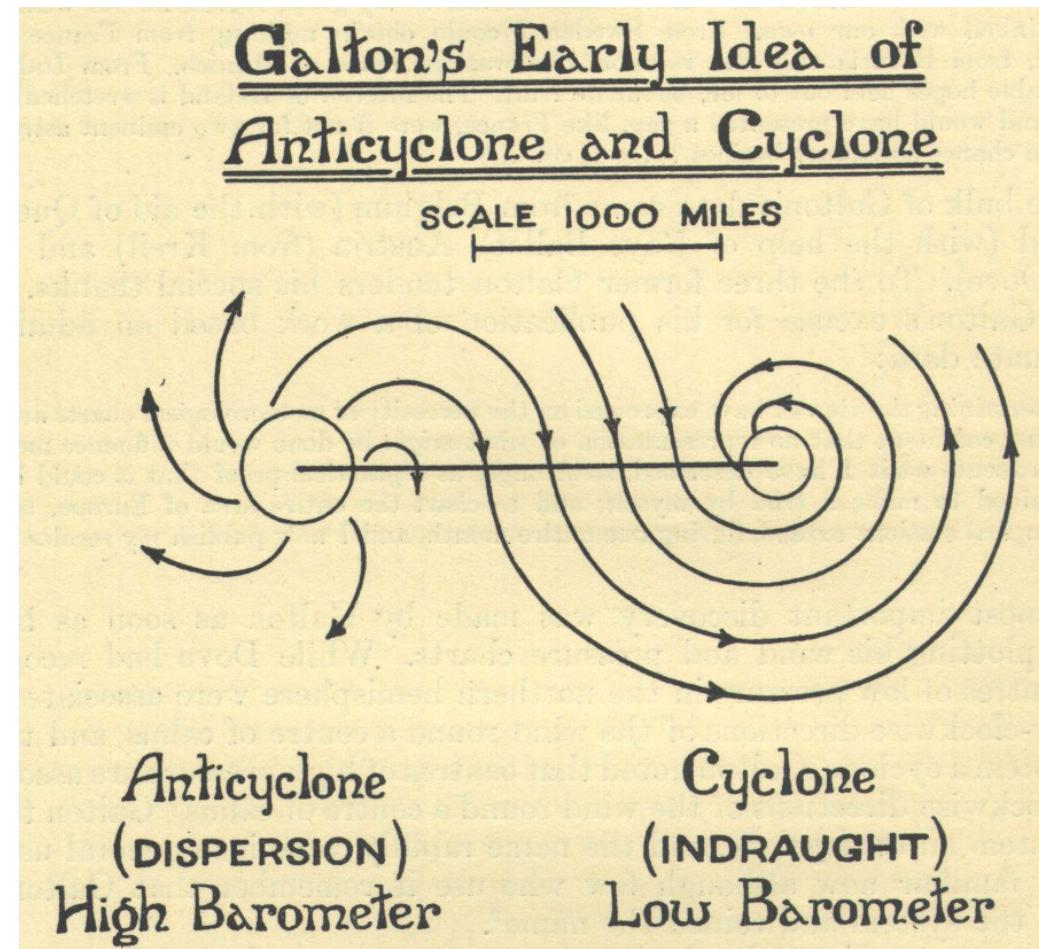
Visual insight → Theory

Visual insight from 93 (3x31) high-D graphs:

- Changes in wind dir w/ pressure over time
- → Winds revolve inwardly (CCW) in low pressure areas— as in a cyclone;
- → revolve outwardly (CW) in high pressure areas— “anti-cyclone”

Theory:

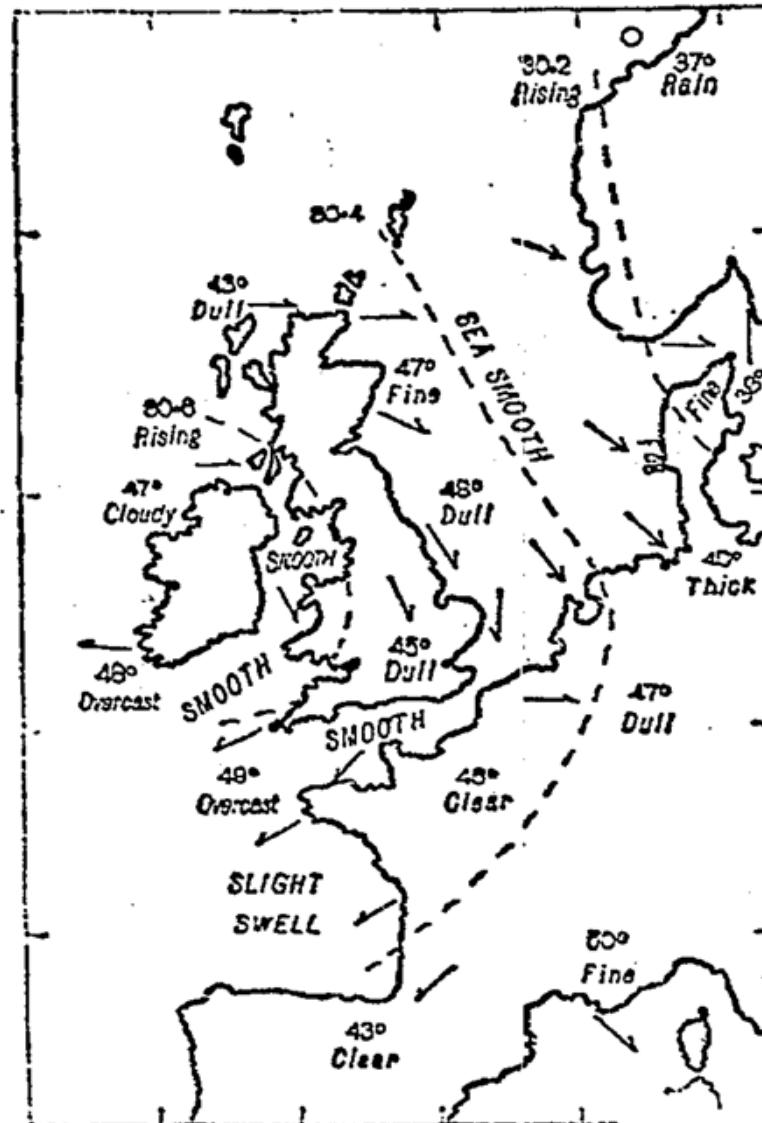
- Explained by Dove’s ‘Law of Gyration’
- Prediction: reversed pattern (CW/CCW) in southern hemisphere – confirmed!



Theory → Practice

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

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



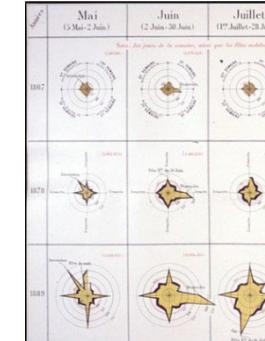
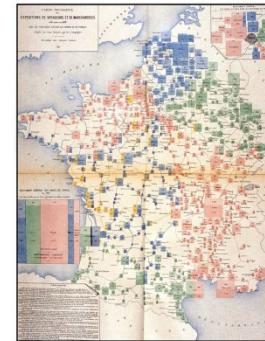
The dotted lines indicate the gradations of barometric pressure. The variations of the temperature are marked by figures, the state of the sea and sky by descriptive words, and the direction of the wind by arrows—barbed and feathered according to its force. ◎ denotes calm.

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.*

Album de statistique graphique

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



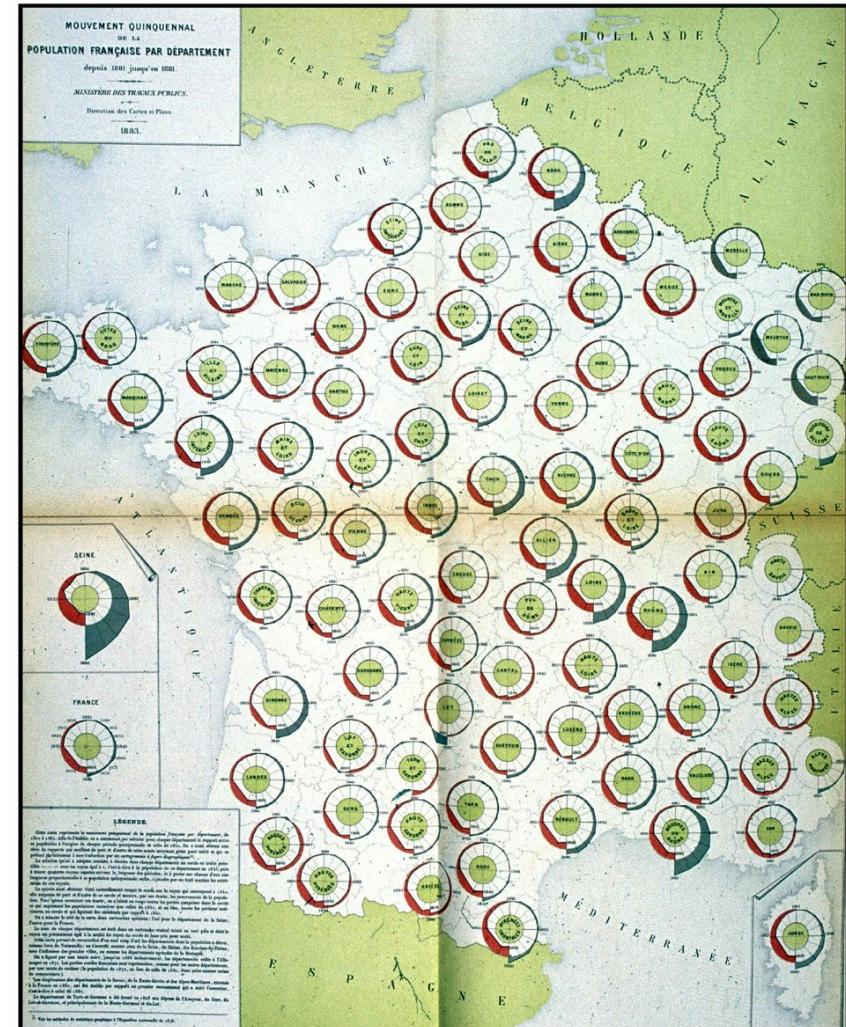
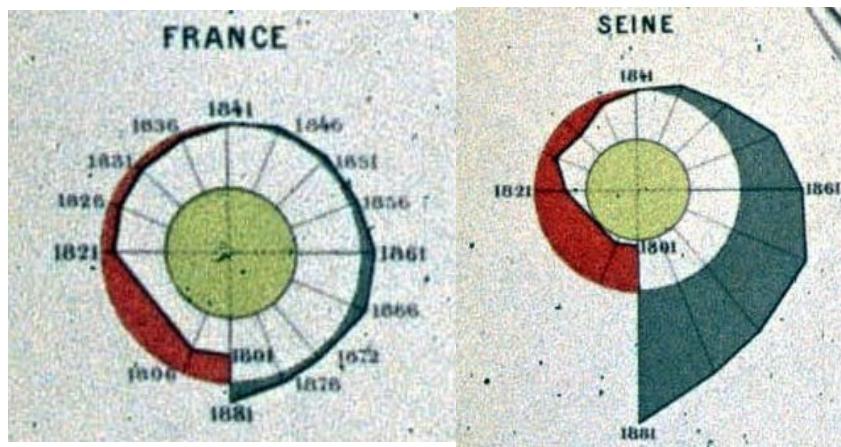
Album de statistique graphique

Spiral time-series on a map

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

Where is population growing most? least?
declining?

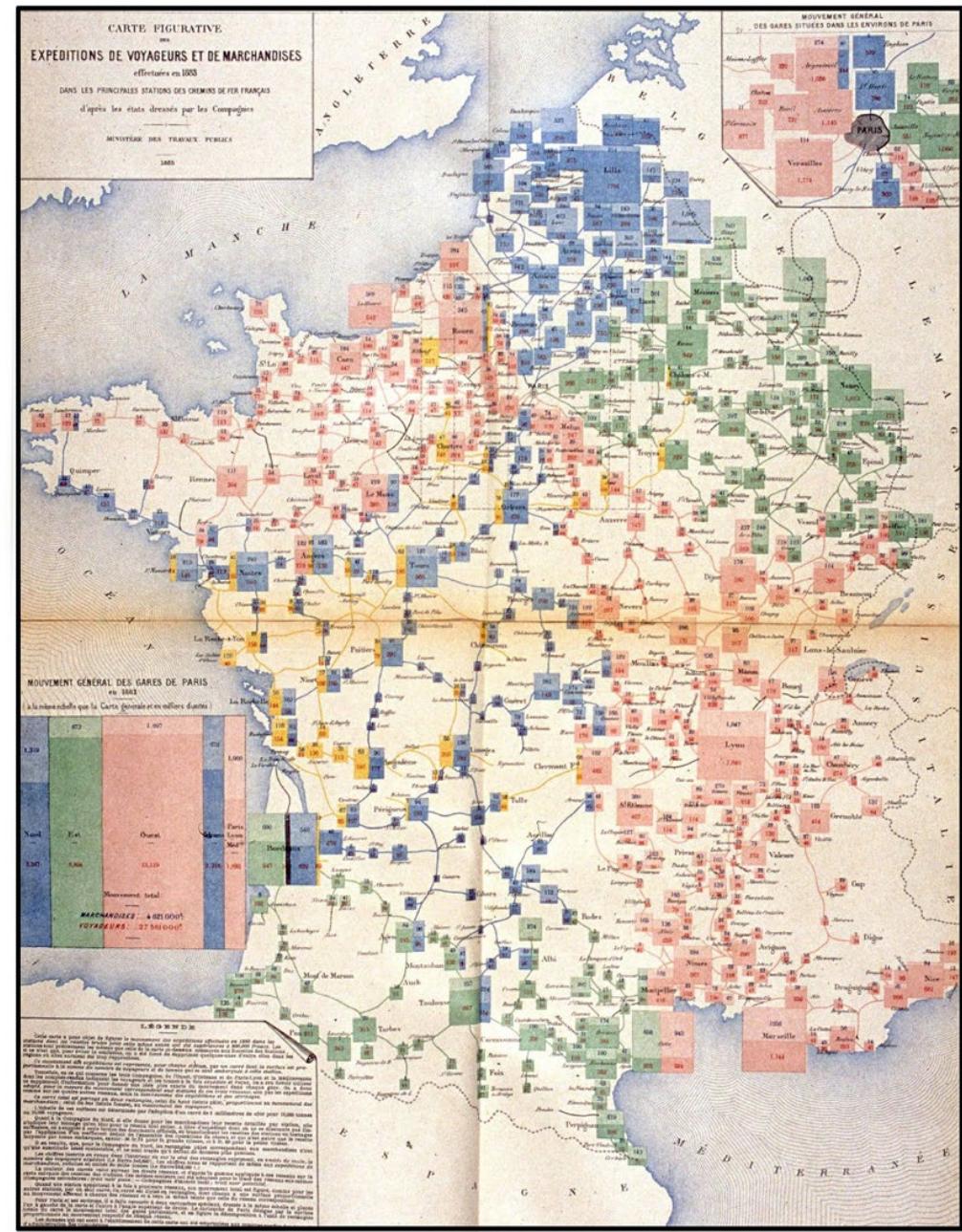
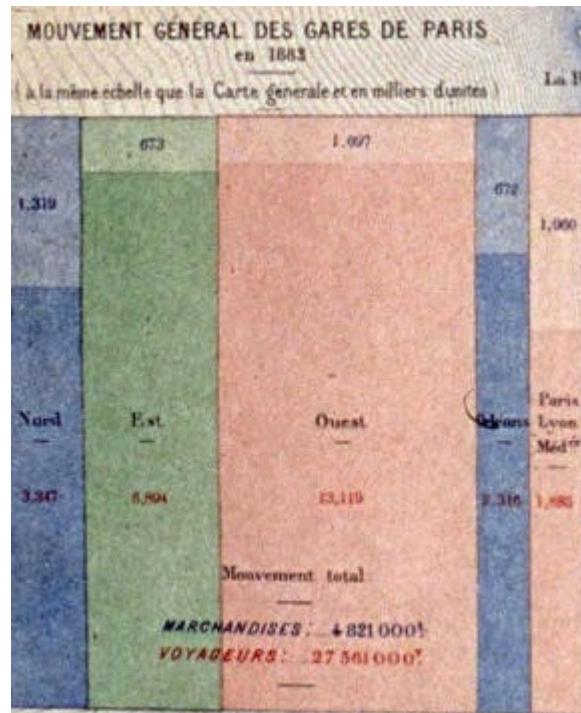
Why use this graphic form?



Recursive multi-mosaic map

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

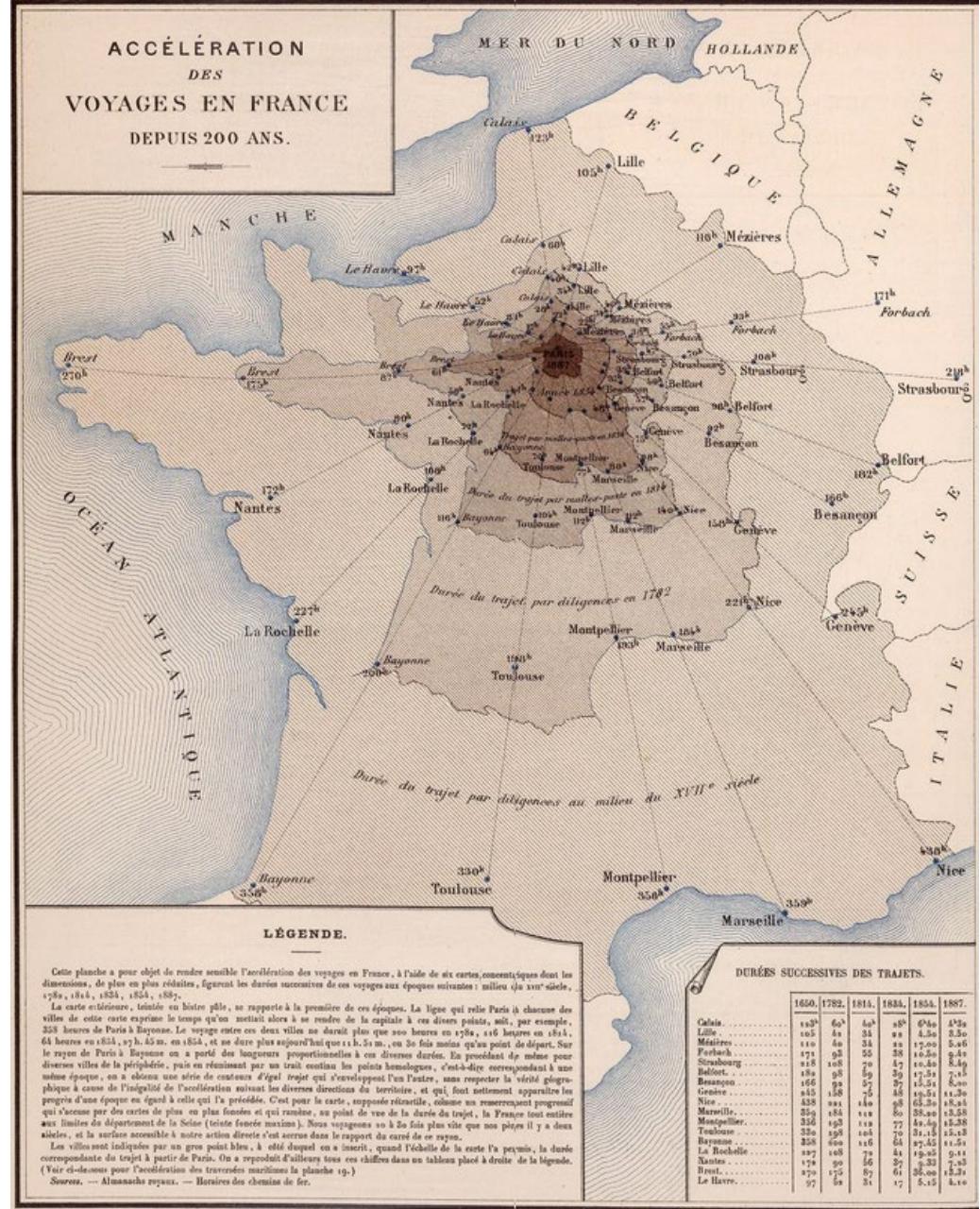
(The image that launched my interest in the history of data vis.)



Anamorphic map

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

DURÉES SUCCESSIVES DES TRAJETS.					
	1650.	1782.	1814.	1834.	1854.
Caen.	113 ^h	60 ^h	40 ^h	18 ^h	6 ^h 40 ^m
Lille.	105	41	34	22	4.50
Mézières.	110	60	34	22	5.40
Forbach.	171	93	55	38	10.50
Strasbourg.	118	108	70	47	16.40
Belfort.	182	98	59	39	17.51
Besançon.	166	91	57	37	12.51
Genève.	145	108	73	48	19.51
Nice.	138	91	100	98	25.30
Marseille.	35 ^h	18 ^h	11 ^h	8 ^h	38.20
Montpellier.	33 ^h	19 ^h	11 ^h	7 ^h	42.40
Toulouse.	33 ^h	19 ^h	104	70	31.15
Bayonne.	25 ^h	100	116	64	27.45
La Rochelle.	87	103	74	43	19.45
Nantes.	17 ^h	90	56	37	9.33
Brest.	70	175	87	61	36.00
Le Havre.	97	62	31	17	6.15

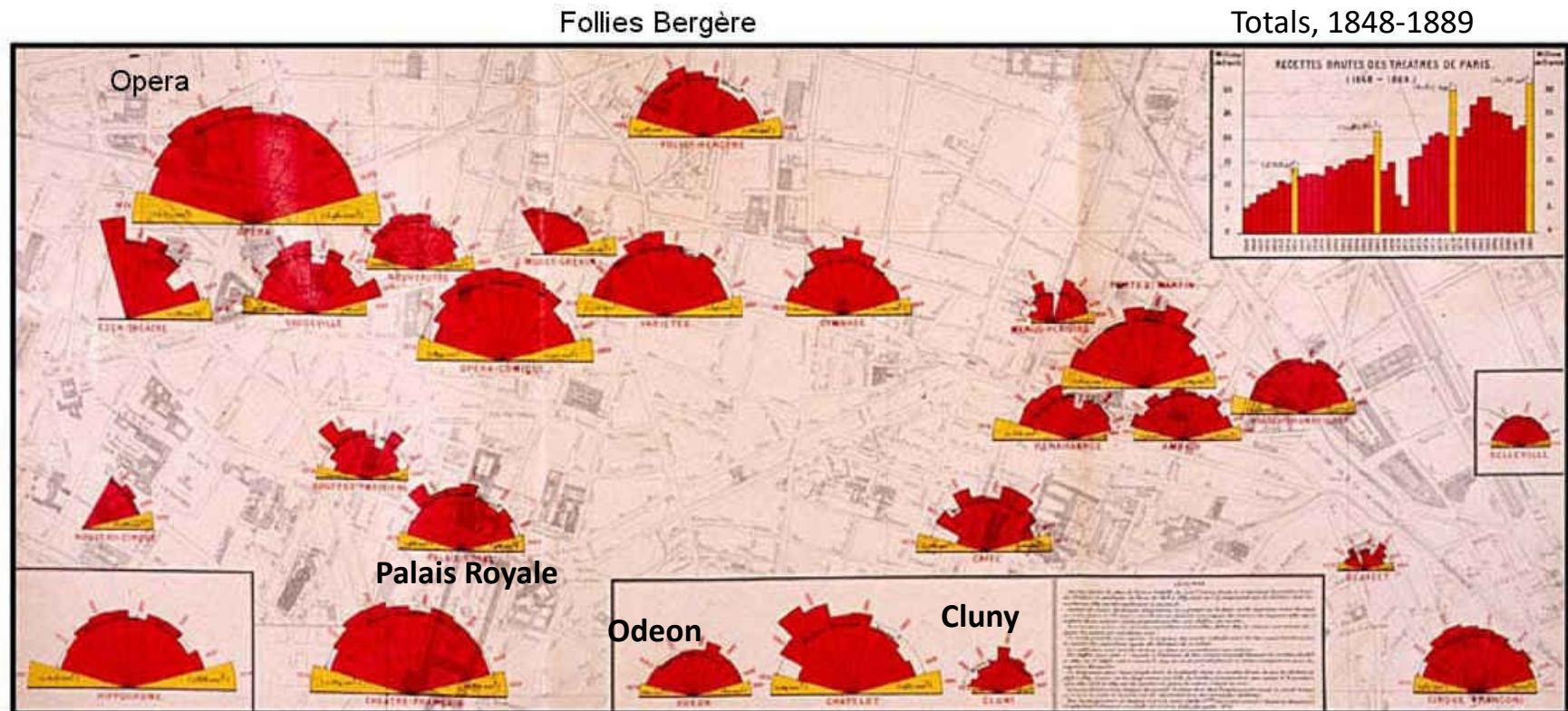


Album de statistique graphique

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

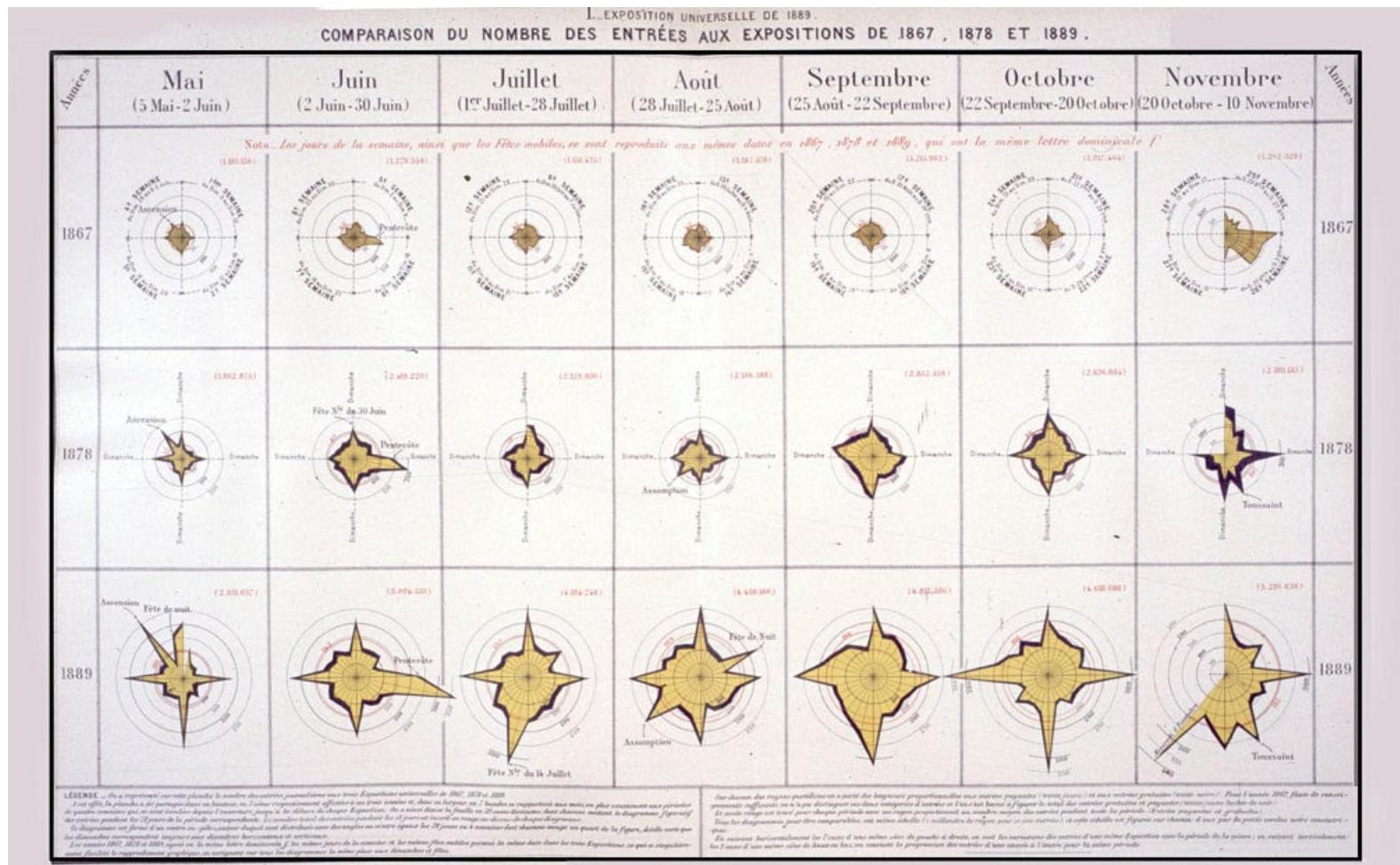
Polar area diagrams on Paris map

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]



1867

1878

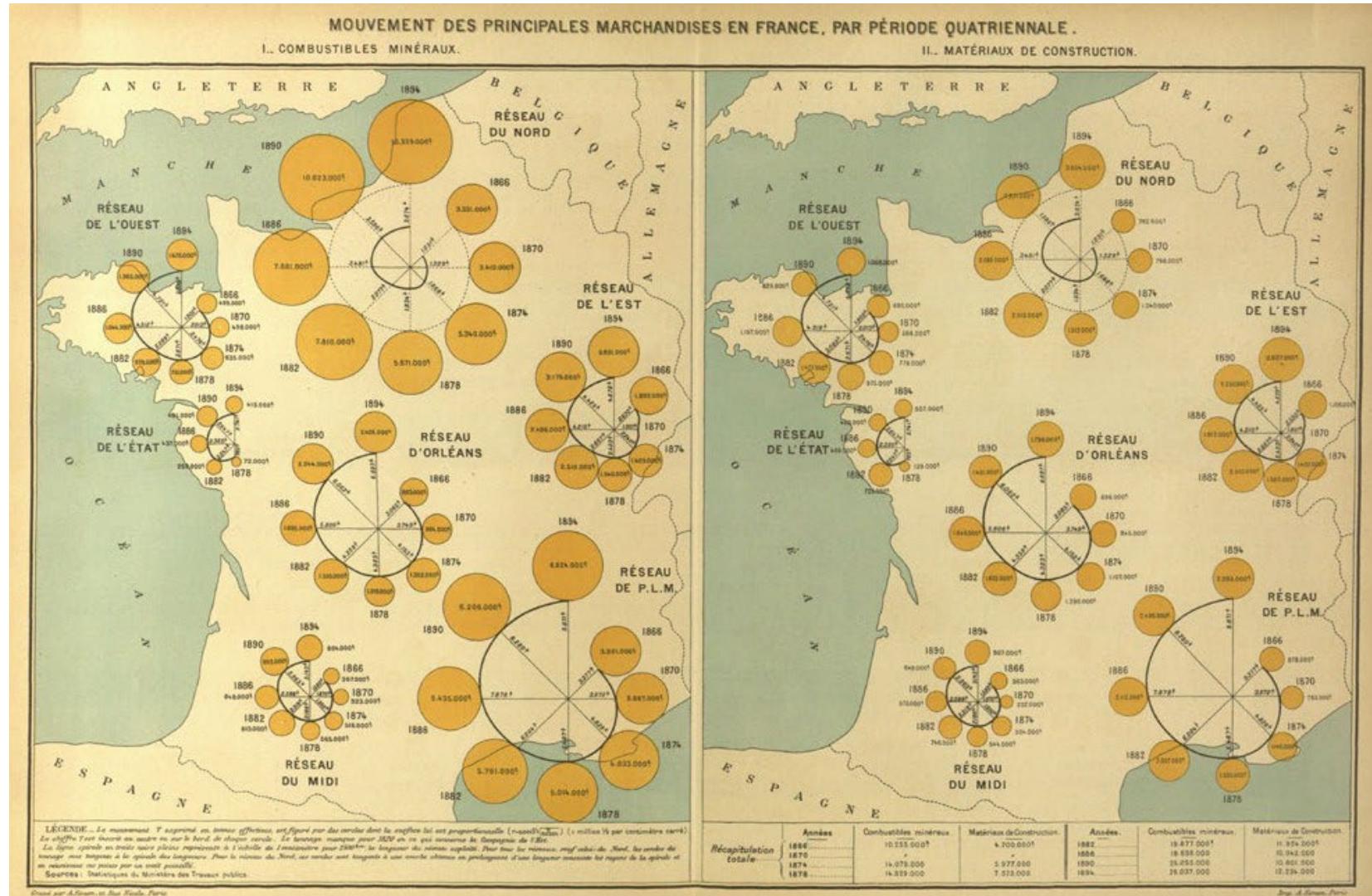
1889

Planetary diagrams

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

Combustible minerals

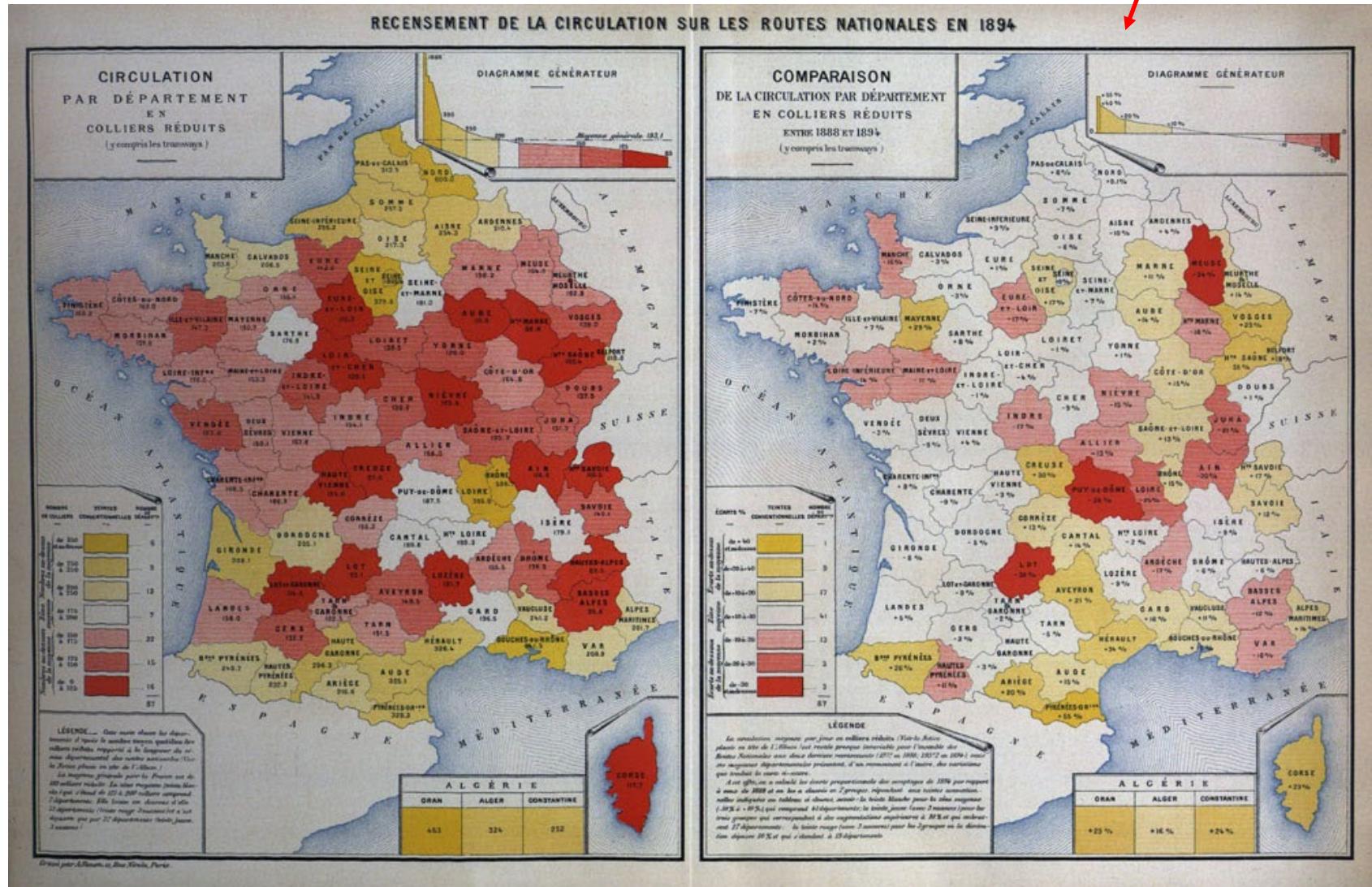
Construction materials



Classed choropleth maps,

- bipolar color scale
- visualizing change

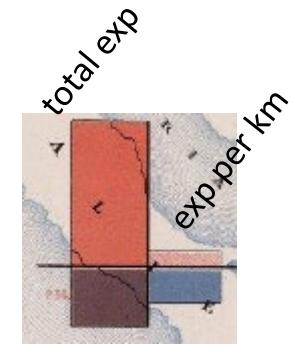
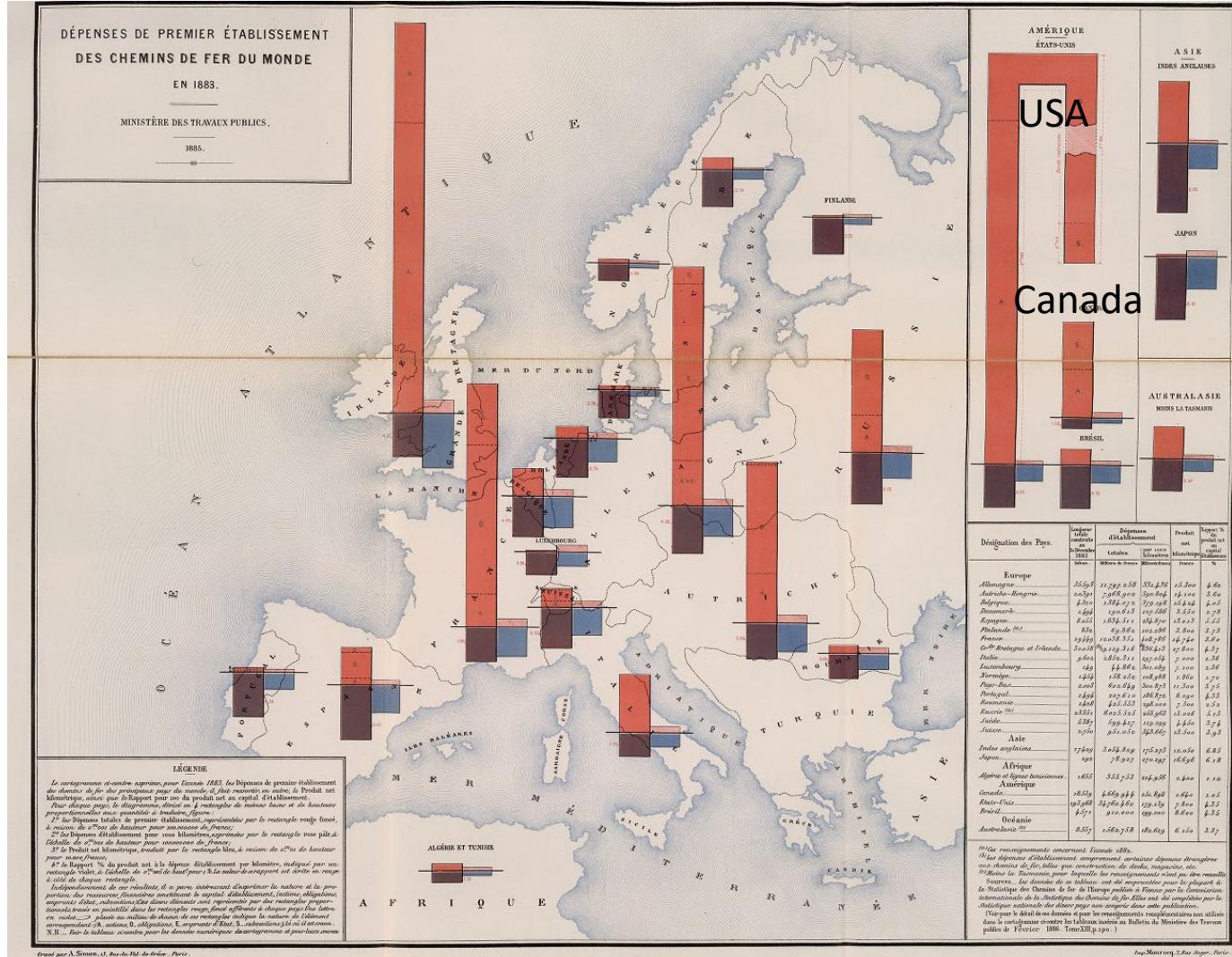
Circulation on the national roads in
'colliers réduits', a standard measure
Left: 1894; Right: % change, 88-94
[Album, 1895, plate 21]



2x2 graphic bar charts

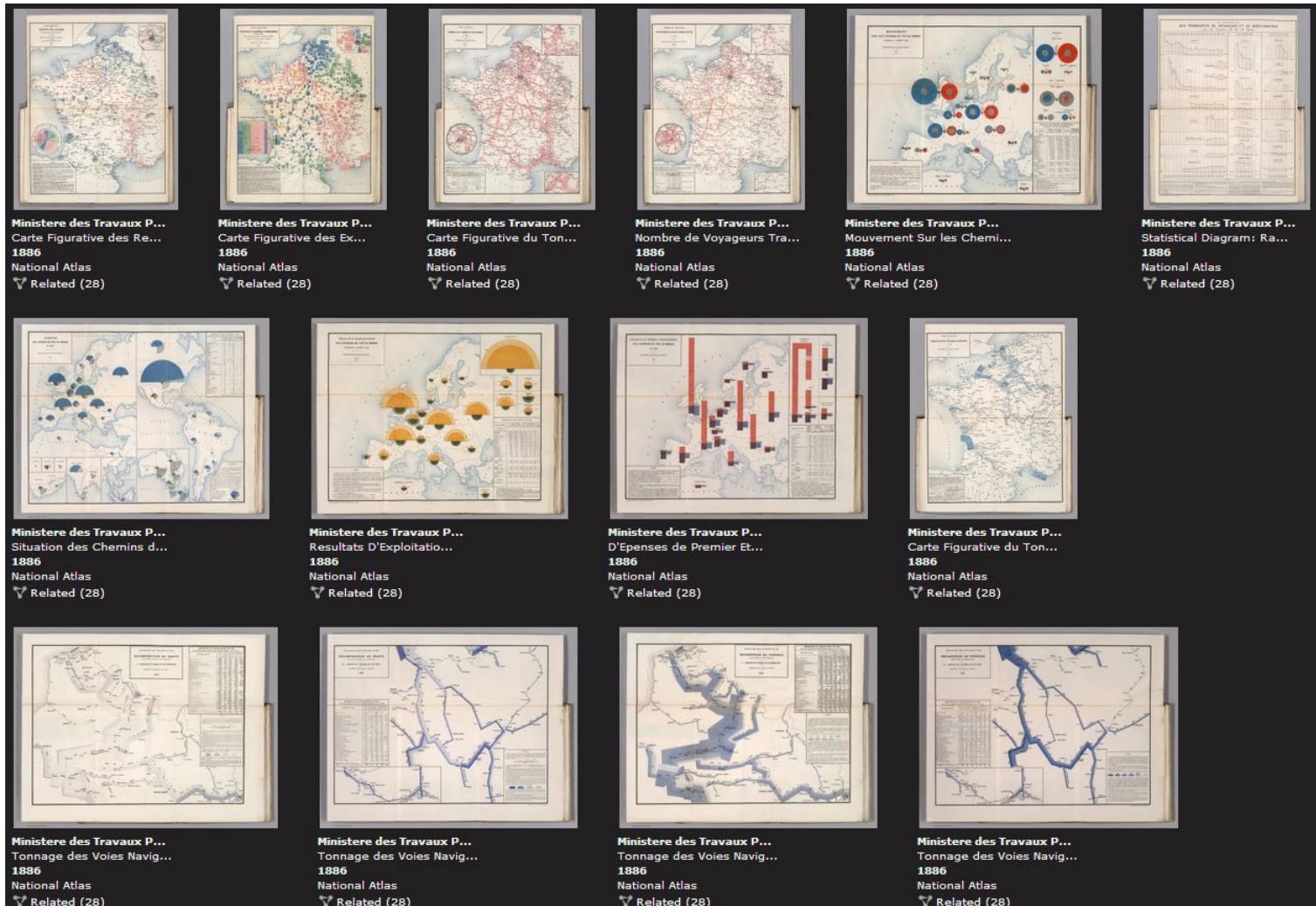
- 4 variables shown
- creative folding of long bars

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>



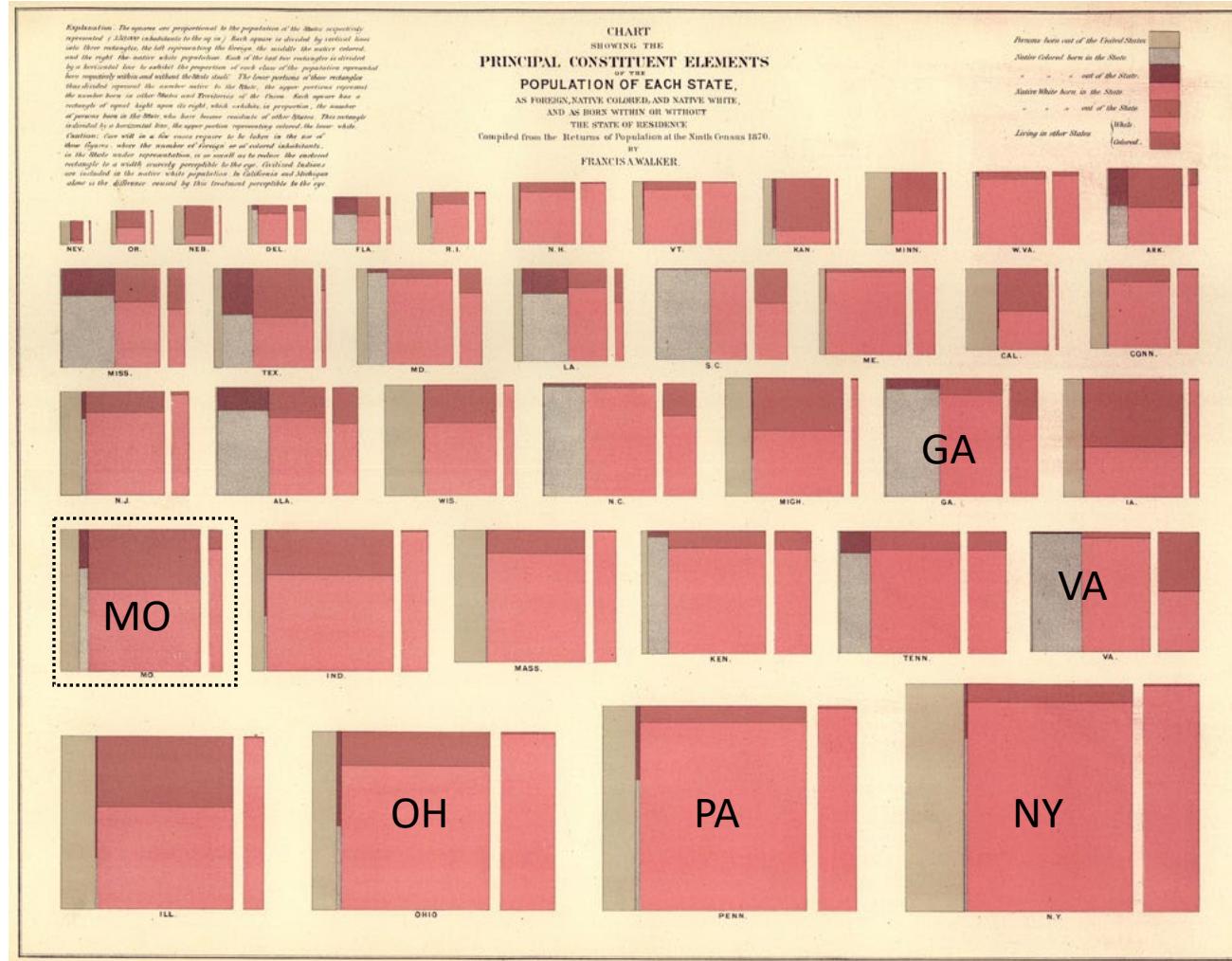
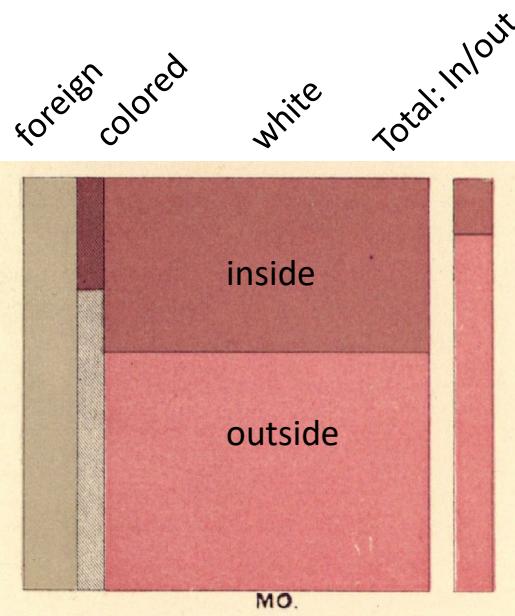


U.S. Census Atlases

- *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

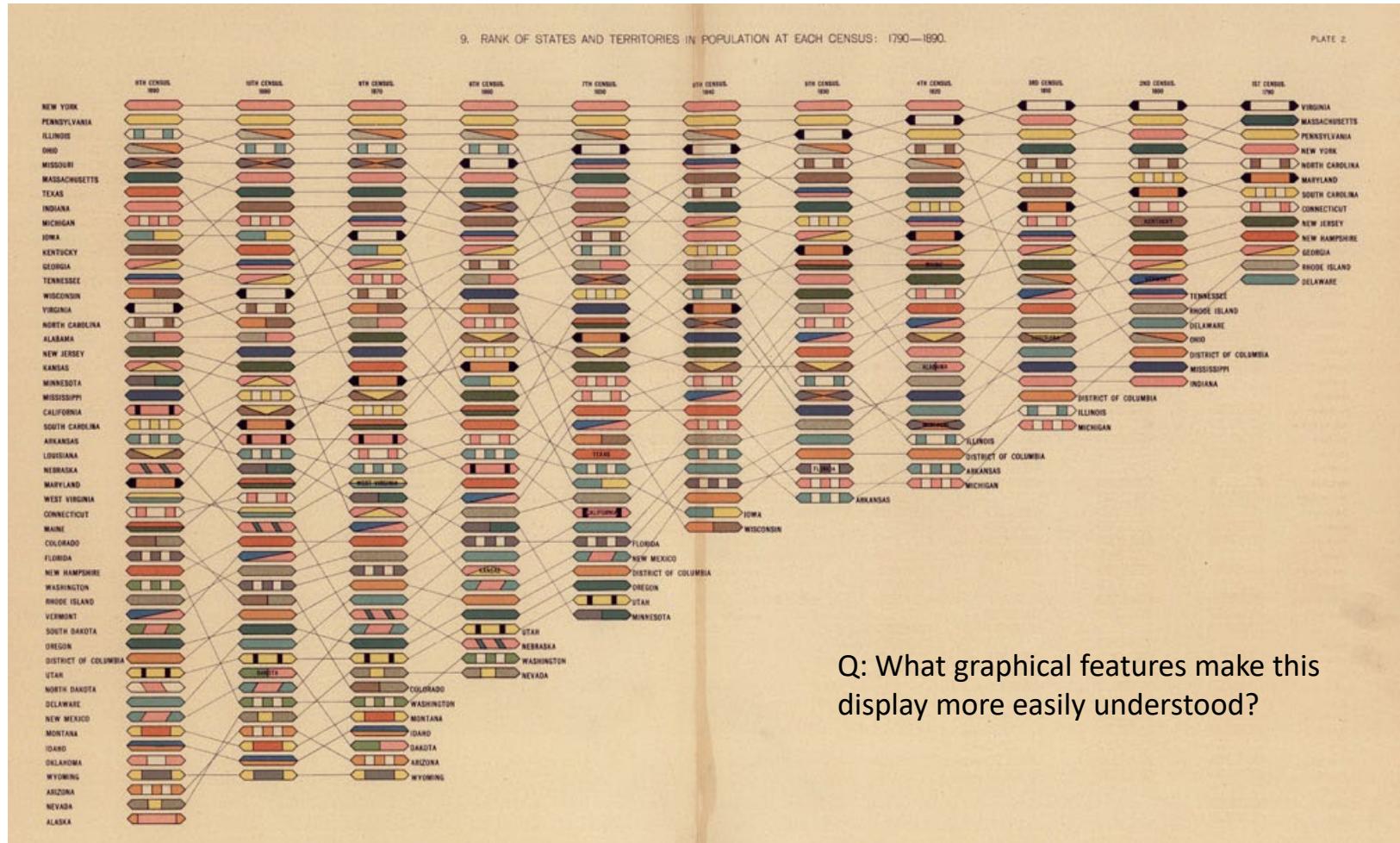
Mosaics/treemaps: Area ~ state population

State populations: Foreign born / Native colored / White + Born inside/outside [Atlas, 1870, plate 20]



Linked parallel-coordinates time-series diagram

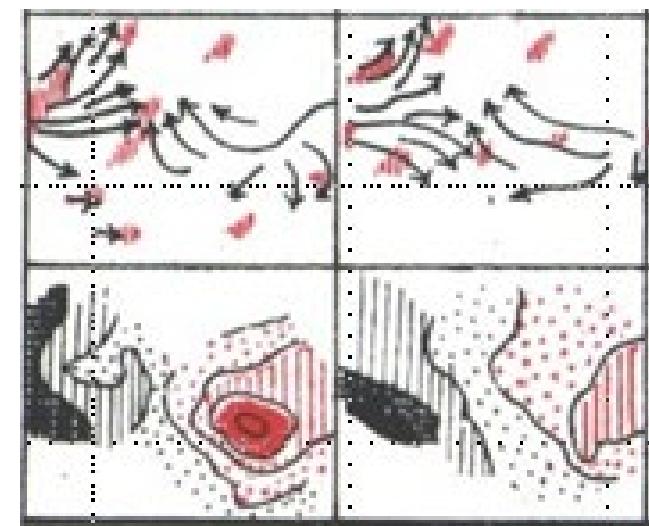
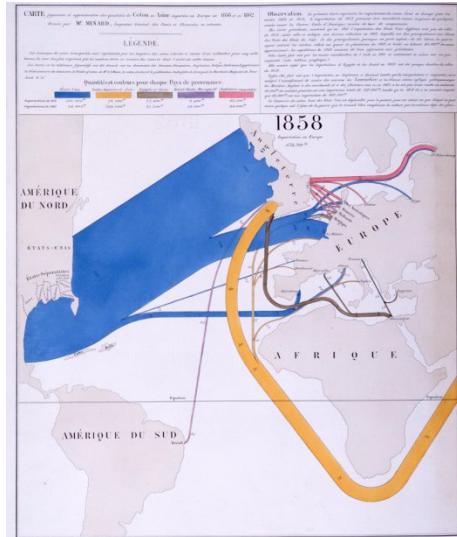
Rank of states & territories in each census, 1790—1890. [Atlas, 1898, plate 2]



Q: What graphical features make this display more easily understood?

Golden Lessons

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



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)
 - **Intercularity**: 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

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.



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