Springer Series in the Data Sciences

Edited by:
Alicia L. Carriquiry
William F. Eddy
Judith M. Tanur
With Margaret L. Smykla

Statistics in the Public Interest

In Memory of Stephen E. Fienberg

Springer

Chapter 27
On the Origins of Data Visualization

Howard Wainer and Michael Friendly

27.1 Prelude

On December 24, 2018, we received an early Christmas gift from an old friend. Judy Tanur wrote to tell us that she had joined with two other friends to generate a memorial volume for Steve Fienberg, whose untimely passing in 2016 had saddened us all; this sadness exploded to tragedy with the murder of Steve's widow, Joyce, at her synagogue on October 27, 2018. We were honored to be included among the contributors to this volume and immediately set to work choosing an appropriate topic.

HW's history with Steve goes back to September of 1970 when we, as statisticians and new assistant professors at the University of Chicago, were both assigned to count votes in the faculty election. We became friends and continued to collaborate on various projects for almost 50 years. Two of those collaborations are relevant to today's topic, the use of data visualization both for data exploration and for the communication of quantitative phenomena.

1. In 1978, HW was in Washington, directing the NSF-sponsored Graphic Social Reporting Project, and as part of this project had convened a conference of interested scholars. Steve was one of the principal speakers. Al Biderman, HW's co-organizer of the conference, introduced Steve as "Holland's only Jewish Bishop." At that time, it was an insider's joke, but one that is not likely to be obscure to the audience of this volume. Steve's message in his talk, as nearly as we can remember it, was that a scientist's job was to speak truth – especially to

H. Wainer (✉)
Pennington, NJ, USA

M. Friendly
York University, Toronto, ON, Canada

A. L. Carriquiry et al. (eds.), *Statistics in the Public Interest*, Springer Series in the Data Sciences, https://doi.org/10.1007/978-3-030-75460-0_27

those who were in positions to make policy – and that the best way to convey quantitative truths was using pictures, not numbers.

2. In 1988, Steve and Bill Eddy began the statistics magazine *Chance*, which they had imagined as readable by the general public, a parallel to *Scientific American* that dealt with the field of statistics, principally its applications. In 1990, Steve asked HW to write a column for *Chance* called "Visual Revelations" that would focus specifically on statistical graphics. He felt strongly that this should be a topic of primary concern to quantitative scientists generally and the readers of *Chance* specifically. The case he made was so convincing that HW agreed to take on the column for at least a couple of years; as of this moment, 31 years later, he is still writing it.

A decade later Steve took a leave of absence from Carnegie Mellon to return to his native Toronto and ascended to the position of Vice President for Academic Affairs at York University. It was here that he made the acquaintance of MF, who was then chair of York's Academic Planning Computing Committee. Together they immediately set about developing a plan to modernize the university's computing facilities. They planned to shift from a mainframe environment to the modern approach of distributed computing using the exploding developments of personal computers, augmented, for heavier tasks, with work stations. They were especially attracted to those developed by Steve Jobs (MACs and NeXT machines) whose graphical user interfaces were obviously (to Steve and MF) the future of computing. Steve's administrative leadership was as inspiring as it was rare and, within 18 months York's computing environment, had moved from the trailing edge to the forefront.

The subject of this essay is the origin of data visualization, and we begin with an extended metaphor of a wedding between empiricism and visualization. Among the details of the wedding that were only recently unearthed was that Steve Fienberg was the guest of honor at the ceremony. In his toast, he offered his wishes for a rosy future in which the offspring of the union would provide wisdom in choosing important questions and guidance in finding solutions. Among those joining Steve at the dais was a distinguished sextet of our graphical heroes, each with his own special gift to the couple. To his left were:

William Playfair, who presented the couple with a beautiful, hand-colored plot of England's national debt indicating how wars contributed to its skyrocketing growth.

Andre-Michel Guerry, whose gift of a shaded map of crime provided suggestions of potential causes and possible remediation, marking the birth of modern criminology and social science. The renowned Belgian statistician Aldolphe Quetelet had also figured largely in this but sent his regrets and best wishes to Steve.

John Snow, who gave an innovative dot-map of a cholera epidemic in London that marked the start of modern epidemiology.

And to Steve's right were:

Charles Joseph Minard, who had adapted his visual stories of commerce to provide a heart-rending tale of the horrors of war

Francis Galton, who had set aside his fascination with regression to construct a map of weather patterns decorated with multivariate glyphs that would allow the honeymooners to only go where the sun was shining brightly

Emile Cheysson, director of the statistical bureau of the French Ministry of Public Works who produced the *Albums de Statistique Graphique*, the most ambitious effort to make data of the state ("statistics") accessible to public inspection

27.2 One Wedding, No Funeral

What follows is the saga of a family. It begins, as do all such stories, with a marriage. The marriage is a good one, and we will learn how it came to be as well as how it evolved in both richness and depth. Our tale then branches to the issue from that union, taking time to include both the geneses of the offspring and their accomplishments.

Let us begin.

The marriage represents the joining of the epistemological approach of empiricism, as a window to understanding the world, to visualization as a way of connecting evidence to human experience. It was a match made in heaven, for it facilitated the easy connection of the seat of the intellect to the seat of the pants.

Empiricism begins, as do so many things, with Aristotle, but it was a tough sell, for it meant that any proposal, no matter how convenient or how beautiful, could be dismissed with a single reliable fact. Aristotle got away with such a rigid outlook only because he had Alexander the Great watching his back. Thus anyone who crossed Aristotle had to contend with Alex. But even Aristotle didn't buy in fully – he proposed that women had but 28 teeth. This was a rational conclusion; after all women were smaller and more delicate. What need they for the extra chomping power? Of course, had Aristotle truly digested his own epistemology he would have counted – he did have two wives. But apparently, this particular application of empiricism never occurred to him.

After the passing of the perfect storm of Aristotle, Alexander, and the Golden Age of Greece, empiricism faded. It briefly reappeared with Roger Bacon (1214–1292), who told us that,

> Reasoning draws a conclusion, but does not make the conclusion certain, unless the mind discovers it by the path of experience. (Bacon, 1897 in the section on the scientific method, *De Scientia Experimentali*, *page 244*)

But once again it slipped away only to gain a firmer foothold with the work of Francis Bacon (1561–1626), the second of the two fabulous Bacon boys. Following on quickly were the British empiricists John Locke (1632–1704), George Berkeley (1685–1753), and David Hume (1711–1776). And so by the end of the eighteenth century, one spouse was ready.

27.3 Picture that

The history of visualization is much longer. Perhaps the best known of very early examples is found in the Lascaux caves near the French village of Montignac. On the walls are remarkable drawings of animals, which carbon dating has estimated to be more than 17,000 years old. But although the Lascaux cave drawings are remarkable, and a bit stylized, they represent straightforwardly just what was seen (Fig. 27.1).

Jumping forward in time (to about 1400 BCE) and southward in direction, we arrive in ancient Egypt. The lives of most of Egypt's inhabitants revolved around the Nile. The regular floods of the river would wash away all but the most stubborn of property markers; thus, maps were prepared to indicate whose land was whose after the waters receded. Maps were a brilliant solution to a very practical problem, but, like the cave drawings in ancient France, they represented space in spatial terms. Aside from their miniaturization (and a rudimentary coordinate system of intersecting horizontal and vertical lines to enable a more precise placement of data points), this hardly represented a huge conceptual breakthrough.[1] For that we would have to wait more than two millennia.

But developments in cartography were to presage some critical future developments in the communication of evidence. For example, Descartes (1596–1650) is typically credited with the establishment of his eponymous coordinate system. But Hipparchus (ca. 140 BC) had a reasonably refined system for locating points in the

Fig. 27.1 Four sample paintings from the Lascaux caves, courtesy of the Bradshaw Foundation

[1]Maps were developed independently in the Far East. During the Warring States period in China (about 227 BCE), we find the first mention of a Chinese map being drawn. It showed a portion of Dukang that the Yan State was to cede to the King of Qin in exchange for peace.

heavens; its axes were called (translated into Latin) *longitudo* and *latitudo*. Roman surveyors used a coordinate grid to lay out their towns on a plane that was defined by two axes; the *decimani* running from east to west and the *cardi* that ran north to south. Music notation (as early as the ninth century) used a horizontal axis to represent time and the vertical axis for pitch; and the chessboard (with its associated notation to locate pieces) was developed in seventh-century India.

All of these visualizations were of something real and specific in the world. We might capitalize them as we do proper nouns – I saw Sam yesterday; my land and Gamal's before the spring flood; our chess game as we left it today. But there was another branch of visualization developing too – the common noun part – in which what was being depicted was theoretical. One well-known early example was published in Padua in 1486 on the first page of Oresme's *Tractus de latitufunus forarum* (Wainer, 2005, P. 10). The common noun structure of scientific visualizations is not a surprise once we consider that the reigning epistemology in natural science grew out of natural philosophy that favored a rational rather than empirical approach to scientific inquiry.

By the middle of the eighteenth century, the empirical seeds sown by Locke, Berkeley, and, especially, Hume (whose 1738 *Treatise on Human Nature* and his 1741 *Essays*, *Moral and Political* had a profound influence on Adam Smith, Jeremy Bentham, and Immanuel Kant) had started to bear fruit. The Scottish enlightenment, a magical period in the eighteenth century, gave rise to a torrent of practical innovations in mathematics, science, and medicine. James Watt revolutionized manufacturing; Adam Smith's *The Wealth of Nations* started modern economics; and the mathematician/geologist John Playfair's advocacy of Hutton's evidence-based theories yielded an estimate of the age of the Earth that was very much at odds with the 6000-year biblical estimate. But the star of our story is not the very worthy John Playfair (1748–1819), but rather his ne'er-do-well younger brother William (1759–1823).

Early on in his working life, William Playfair was a draftsman for James Watt. He later went on to become a pamphleteer typically focusing on political arguments based on economic data conveyed in vivid, original graphical forms. Thus was consummated the union between empiricism and visualization begun long ago during the Golden Age of Greece and completed in the Scottish Enlightenment. William Playfair's 1786 *Atlas* filled with spectacular and beautiful graphs of mostly economic data was not a natural outgrowth of what came before. In fact, we view Descartes' 1637 development of a coordinate system as an intellectual impediment that took a century and a half and Playfair's eclectic genius to overcome.

A wonderful example of Playfair's genius is his plot of England's national debt (Fig. 27.2) which is the first "skyrocketing debt" plot and exhibits many of Playfair's unique characteristics:

(a) It displays copious data, in this case England's national debt from 1688 until 1800.
(b) It uses a higher-than-wide aspect ratio to emphasize the skyrocketing.

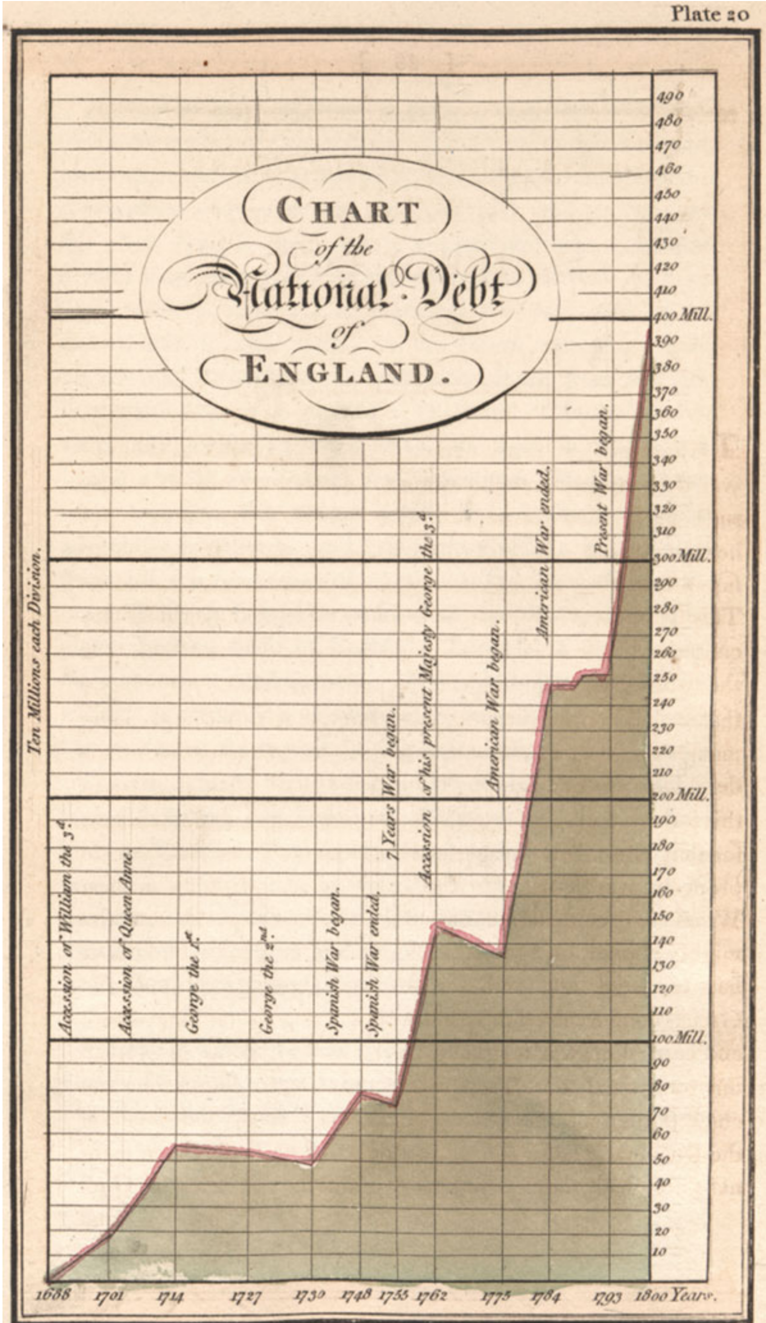

Fig. 27.2 Playfair's plot of England's national debt from 1688 to 1800 dramatically showing the adverse effect wars had on debt. Plate 20 (opposite page 85 in his 1801 Commercial Atlas)

(c) It has unevenly spaced years to be explicit about when events influential for the debt occurred.
(d) Those years are labeled with explanations (e.g., start of Seven Years' War).

27.4 Finding Unexpected Values

The plotting of real data had a remarkable, and largely unexpected, benefit. It forced the viewers to find what they hadn't expected. Thus was born the empirical modern approach to science that does not disdain the atheoretical plotting of data points with the goal of investigating suggestive patterns. Graphs that were in existence before Playfair (with some notable exceptions that we will discuss shortly) grew out of the same rationalist tradition that yielded Descartes' coordinate geometry – that is, the plotting of curves on the basis of an a priori mathematical expression (e.g., Orseme's "pipes" – discussed in Clagett, 1968).

Naked empiricism did not meet with universal approval. Luke Howard, a prolific grapher of data in the late eighteenth and early nineteenth century, as late as 1844, apologized for his methodology and referred to it as an "autograph of the curve . . . confessedly adapted rather to the use of the *dilettanti* in natural philosophy than that of regular students" (Howard, 1847, p. 38).

Now we can see the value of the grammatical metaphor that we introduced earlier, for it is accurate to think of early graphic displays as nouns, indeed common nouns that were used to depict some theoretical relationship. Thus we can conceive of the first major revolution in the use of graphic display in science as a shift from its use as a common noun (e.g., the theoretical relationship between supply and demand) to that of a proper noun (e.g., England's imports and exports from 1700 to 1800). This revolution seems to have begun in 1665 with the invention of the barometer, which inspired Robert Plot to record the barometric pressure in Oxford every day of 1684 and summarize his findings in a remarkably contemporary graph that he called a "History of the Weather" (Fig. 27.3) (Wainer, 2005, P. 14).

He sent a copy of this graph with a letter to Martin Lister in 1685 with a prophetic insight on the eventual use:

> For when once we have procured fit persons enough to make the same Observations in many foreign and remote parts, how the winds stood in each, at the same time, we shall then be enabled with some grounds to examine, not only the coastings, breadth, and bounds of the winds themselves, but of the weather they bring with them; and probably in time thereby learn, to be forewarned certainly, of divers emergencies (such as heats, colds, dearths, plague, and other epidemical distempers) which are not unaccountable to us; and by their causes be instructed for prevention, or remedies . . . we shall certainly obtain more real and useful knowledge in matters in a few years, then we have yet arrived to, in many centuries (Wainer, 2005, P. 15).[2]

[2]Plot's proposed method of crowd-sourcing weather data and his assessment of its potential value would later bear great fruit in Francis Galton's (1863) spectacular discovery of weather patterns in the northern hemisphere.

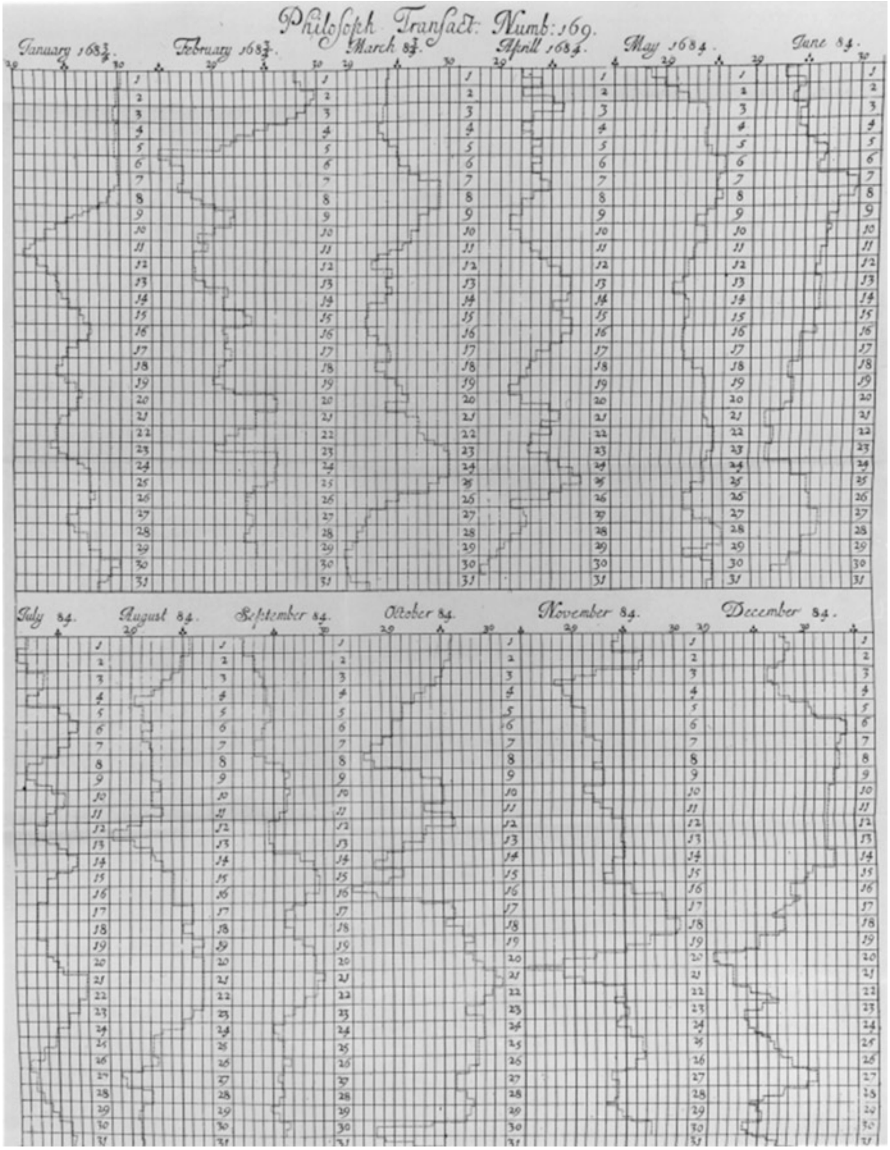

Fig. 27.3 Robert Plot's (1685) "History of the Weather" recording of the daily barometric pressure in Oxford for the year 1684

Plot and Lister's use of graphic display was scooped by the seventeenth century Dutch polymath Christiaan Huygens (1629–1693). On October 30, 1669, Christiaan's brother Lodewijk sent him a letter containing some interpolations of life expectancy data taken from John Graunt's 1662 book the *Natural and Political*

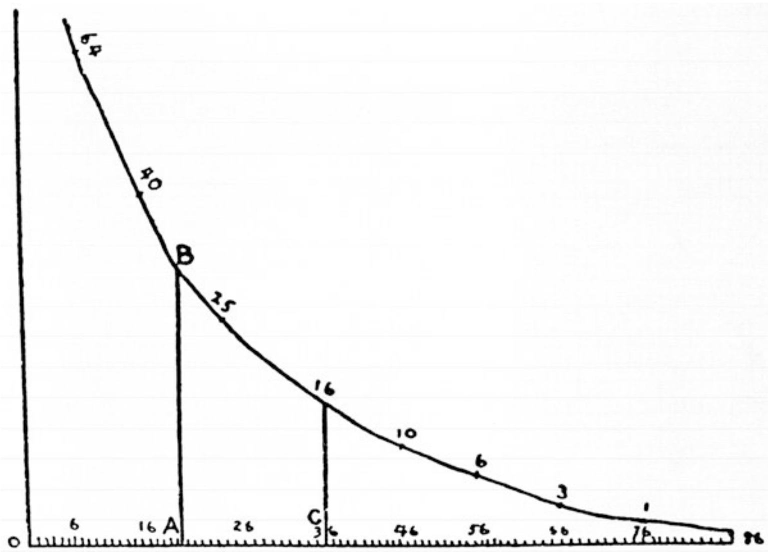

Fig. 27.4 Christian Huygens's 1669 curve showing how many people out of a 100 survive between the ages of infancy and 86. (The data are taken from John Graunt's *Natural and Political Observations on the Bills of Mortality, 1662*)

Observations on the London Bills of Mortality. Christiaan responded in letters dated November 21 and 28, 1669, with graphs of those interpolations. Figure 27.4 contains one of those graphs showing age on the horizontal axis and number of survivors of the original birth cohort on the vertical axis. The curve drawn was fitted to his brother's interpolations. The letters on the chart are related to an associated discussion on how to construct a life expectancy chart from this one – that is, analyzing a set of data to yield deeper insights into the subject. Christiaan constructed such a chart and indicated that it was more interesting from a scientific point of view; the alternative, he felt, was more helpful in wagering.

There were a smattering of other examples of empirically based graphs that appeared in the century between Huygen's letter and the 1786 publication of Playfair's *Commercial and Political Atlas*, for although some graphic forms were available before Playfair, they were rarely used to plot empirical information. In 1978, Albert Biderman argued that this was because there was an antipathy toward that as a scientific approach. This suggestion was supported by such statements as that made by Luke Howard. But at least sometimes, when data were available (e.g., Graunt's survival data, Plot's weather data, and several other admirable uses), they were plotted. Perhaps part of the exponential increase in the use of graphics since the beginning of the nineteenth century is merely concomitant to the exponential growth in the availability of data. Of course there might also be a symbiosis in that the availability of graphic devices for analyzing data encouraged data gathering. For whatever the reasons, Playfair was at the cusp of an explosion in data gathering, and his graphic efforts appear causal. He played an important role in that explosion.

The consensus of scholars, well phrased by Costigan-Eaves and Macdonald-Ross (in progress) (in their oft-cited, but as yet, unpublished manuscript), is that until Playfair "many of the graphic devices used were the result of a formal and highly deductive science . . . This world view was more comfortable with an arm-chair, rationalistic approach to problem-solving which usually culminated in elegant mathematical principles" often paired with elegant geometrical diagrams. The empirical approach to problem-solving, a critical driving force for data collection, was slow to get started. But the empirical approach began to demonstrate remarkable success in solving problems, and with improved communications, the news of these successes, and hence the popularity of the associated graphic tools, began to spread quickly.

We are accustomed to intellectual diffusion taking place from the natural and physical sciences into the social sciences; certainly that is the direction taken for both calculus and the scientific method. But statistical graphics in particular and statistics in general went the reverse route. Although, as we have seen, there were applications of databased graphics in the natural sciences, it was only after Playfair applied them within the social sciences that their popularity began to accelerate. Playfair should be credited with producing the first chart book of social statistics; indeed, publishing an *Atlas* that contained not a single map is one indication of his belief in the methodology (to say nothing of his chutzpah). Playfair's work was immediately admired, but emulation, at least in Britain, took a little longer (graphic use started up on the continent a bit sooner). Interestingly, one of Playfair's earliest emulators was the banker S. Tertius Galton (the father of Francis Galton, and hence the biological grandfather of modern statistics) who, in 1813, published a multiline time series chart of the money in circulation, rates of foreign exchange, and prices of bullion and of wheat.[3] The relatively slower diffusion of the graphical method back into the natural sciences provides additional support for the hypothesized bias against empiricism there. The newer social sciences, having no such tradition and faced with both problems to solve and relevant data, were quicker to see the potential of Playfair's methods.

The Prodigal Brother

Playfair's graphical inventions and adaptations look contemporary. He invented the line graph and the pie chart to suit particular purposes. He invented the statistical bar chart out of desperation, because he lacked the time series data required to draw a line showing the trade with Scotland and so used bars to symbolize the cross-sectional character of the data he did have. Playfair acknowledged Priestley's (1765,

[3] Ironically, had Galton paid close enough attention to his own graphs he would have been able to foresee the financial crisis of 1831 that created a ruinous run on his own bank.

1769) priority in this form, although Priestly used thin horizontal bars to symbolize the life spans of historical figures in a time line (Fig. 27.5).

Playfair's role was crucial for several reasons. It was not for his development of the graphic recording of data; others preceded him in that. Indeed, in 1805, he points out that as a child his brother John had him keep a graphic record of temperature readings. But Playfair was in a remarkable position. Because of his close relationship with his brother and his connections with Watt, he was on the periphery of applied science. He was close enough to know of the value of the graphical method, but sufficiently detached in his own interests to apply them in a very different arena – that of economics and finance. These areas, then as now, tend to attract a larger audience than matters of science, and Playfair was adept at self-promotion.[4]

In a review of his 1786 *Atlas* that appeared in *The Political Herald*, Dr. Gilbert Stuart wrote,

> The new method in which accounts are stated in this work, has attracted very general notice. The propriety and expediency of all men, who have any interest in the nation, being acquainted with the general outlines, and the great facts relating to our commerce are unquestionable; and this is the most commodious, as well as accurate mode of effecting this object, that has hitherto been thought of . . . To each of his charts the author has added observations (which . . . in general are just and shrewd; and sometimes profound . . . Very considerable applause is certainly due to his invention; as a new, distinct, and easy mode of conveying information to statesmen and merchants (Playfair 1801/2005, P. 31) . . .

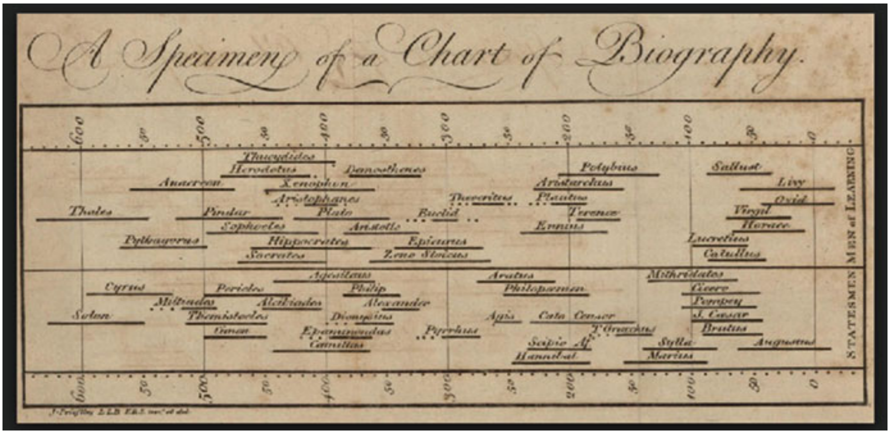

Fig. 27.5 Lifespans of 59 famous people in the 6 centuries before Christ (Wainer, 2005, P. 43)

[4]For more about the remarkable life and accomplishments of William Playfair (including the fascinating story of his attempted blackmail of Lord Archibald Douglas), the interested reader is referred to Spence and Wainer (1997, 2000), Wainer (1996), Wainer and Spence (1997), and, especially, Wainer and Spence's Introduction to Playfair (1801/2005).

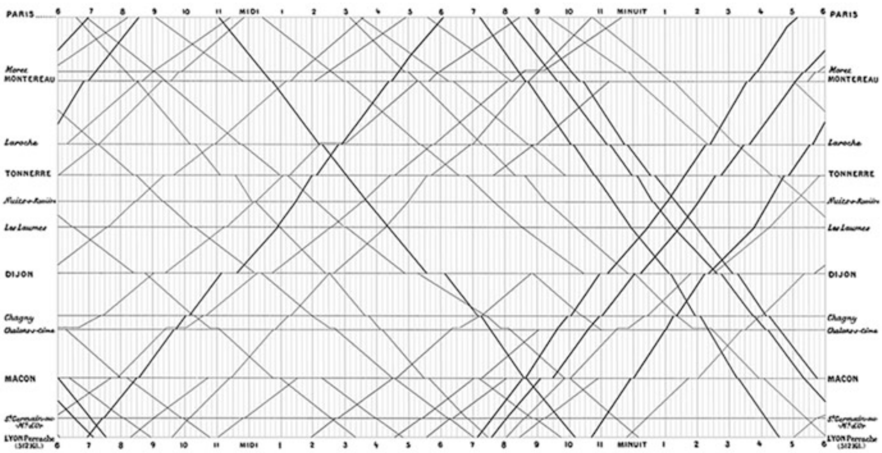

Fig. 27.6 Marey's graphical train schedule, showing all trains between Paris and Lyons each day (Wainer, 2005, P. 7)

Such wholehearted approval rarely greets any scientific development. Playfair's adaptation of graphic methods to matters of general interest provided an enormous boost to the popularity of statistical graphics.

The popularity of visualizations owes much to the almost religious fervor of scientists and epistemologists of the nineteenth century who sought to banish subjectivity from science. "The prophets, philosophers and preachers of objectivity drew on a number of techniques including inferential statistics, double-blind clinical trials, and self-registering instruments to hold subjectivity at bay."[5] But, as we have sketched, the oldest and most important of these was visualization.

By 1878, the French physiologist Etienne Marey, whose graphic schedule of all the trains between Paris and Lyons reproduced in Fig. 27.6 provides a powerful illustration of the breadth of value of this approach, expressed the feelings of most natural scientists of the value of graphical representation

> There is no doubt that graphical expression will soon replace all others whenever one has at hand a movement or change of state – in a word, any phenomenon. Born before science, language is often inappropriate to express exact measures or definite relations (Marey, 1878, p. iii).

Marey was also giving voice to the movement away from the sorts of subjectivity that had characterized prior science in support of the more modern drive toward objectivity. Although some cried out for the "insights of dialectic," "the power of arguments," and the "flowers of language" (All quotations on this page are drawn from Daston and Galison (1992), P. 86), their protestations were lost on Marey, who

[5]From page 17 in Lorraine J. Daston and Peter Galison's, marvelous 2007 book, *Objectivity* (Daston and Galison, 2007).

dreamed of a wordless science that spoke instead in high-speed photographs and mechanically generated curves – in images that were, as he put it, in the "language of the phenomena themselves."[6]

Historians have pointed out that "Let nature speak for itself" was the watchword of the new brand of scientific objectivity that emerged at the end of the nineteenth century. In their fascinating 1992 essay, Daston and Galison emphasize that "at issue was not only accuracy but morality as well: the all-too-human scientists must, as a matter of duty, restrain themselves from imposing their hopes, expectations, generalizations, aesthetics, and even their ordinary language on the image of nature" (p. 84). Mechanically produced graphic images would take over when human discipline failed. Marey and his contemporaries turned to mechanically produced images to eliminate human intervention between nature and representation. "They enlisted polygraphs, photographs, and a host of other devices in a near-fanatical effort to produce atlases – the bibles of the observational sciences" (p. 118) – documenting birds, fossils, human bodies, elementary particles, flowers, and economic and social trends that were certified free of human interference.

Daston and Galison conclude, "The problem for nineteenth-century atlas makers was not a mismatch between world and mind, as it had been for seventeenth-century epistemologists, but rather a struggle with inward temptation. The moral remedies sought were those of self-restraint: images mechanically reproduced and published, warts and all; texts so laconic that they threatened to disappear entirely. Seventeenth-century epistemology aspired to the viewpoint of angels; nineteenth-century objectivity aspired to the self-discipline of saints. The precise observations and measurements of nineteenth century science required taut concentration endlessly repeated. It was a vision of scientific work that glorifies the plodding reliability of the bourgeois rather than the moody brilliance of the genius[7]" (p. 118).

The graphic representation of scientific phenomena served two purposes. Their primary function was standardizing phenomena in visual form, but they also served the cause of publicity for the scientific community. They preserved what was ephemeral and distributed it to all who would purchase the volume, not just the lucky few who were in the right place at the right time with the right equipment. And, they served the cause of memory, for images are more vivid and indelible than words.

But the graphic display of natural phenomena was viewed as yet more. Marey, in an accompanying note to his design of a portable polygraph, which automatically registered a variety of measures, suggested that through the use of graphics scientists could reform the very essence of scientific research and scientific evidence. "The graphic method translates all these changes in activity of forces into an arresting

[6]Marey (1878, p. vi)

[7]Although with such contributors as Condorcet (1743–1794), von Humboldt (1769–1859), and Florence Nightingale (1820–1910), there was certainly room for genius in the eighteenth and nineteenth centuries. Indeed, Galton's weather maps, developed at the end of the nineteenth century, shows how plodding reliability when adjoined with moody brilliance can yield especially fruitful results, yet no one would doubt that Robert Plot was a plodding plotter.

form that one could call the language of the phenomena themselves, as it is superior to all other modes of expression" (Daston and Galison, 2007, p. iv). Such a language was, for Marey, universal in two senses. Graphical representation could cut across the artificial boundaries of natural languages to reveal nature to all people, and graphical representation could cut across disciplinary boundaries to capture phenomena as diverse as the pulse of a heart and the downturn of an economy. Pictures became more than merely helpful tools: they were the words of nature herself.[8]

The Wedding Banquet

Yet something even more remarkable occurred among the wedding planners in the latter part of the nineteenth century, as many forces combined to produce the perfect storm for data graphics we call the Golden Age. The table had been well set. Heaps of data on important societal issues (commerce, literacy, crime) had been ordered up; some statistical theory had been developed to allow the essential flavors to be extracted; technological advances in printing and reproduction now allowed serving a huge guest list. The guests were truly international, but they shared a common visual language and visual thinking.

Only one of the planners will be mentioned here: Charles Joseph Minard (1781—1870), a civil engineer in France and who later produced a now iconic[9] flow map depicting Napoleon's disastrous Russian campaign of 1812. Minard used the graphic method to design exquisitely beautiful thematic maps and diagrams showing all manners of topics of interest to the modern French state in the dawn of national concern for trade, commerce, and transportation: Where to build railroads? What happened to the production of cotton goods during the US Civil War (shown in Fig. 27.7)?

By the end of the nineteenth century, guests from the USA (Francis Walker in the Census Bureau), France (Émile Cheysson in the Ministry of Public Works), and others in Germany, Sweden, and elsewhere began to send their gifts to the happy couple – elaborate and detailed statistical albums tracing and celebrating their nation's achievements and aspirations – and decked out in the fancy colors and styles of what became the language of graphics.

We have gone beyond merely tracing the history of the bride and groom in the marriage of empiricism and visualization to also include some snapshots of the wedding, the honeymoon, and of a fair number of anniversaries attended by the

[8]This simple? Perhaps not. An alternative thesis to the one that characterizes science's task as capturing the glorious revelations by nature of her sublime design is one that sees humans imposing the order of their senses and their arts upon the unheavenly disorder they find themselves amidst.

[9]Marey (1878) first called attention to this work, saying it "defies the pen of the historian in its brutal eloquence." Tufte (1983) later bestowed the title of "the best statistical graphic ever drawn."

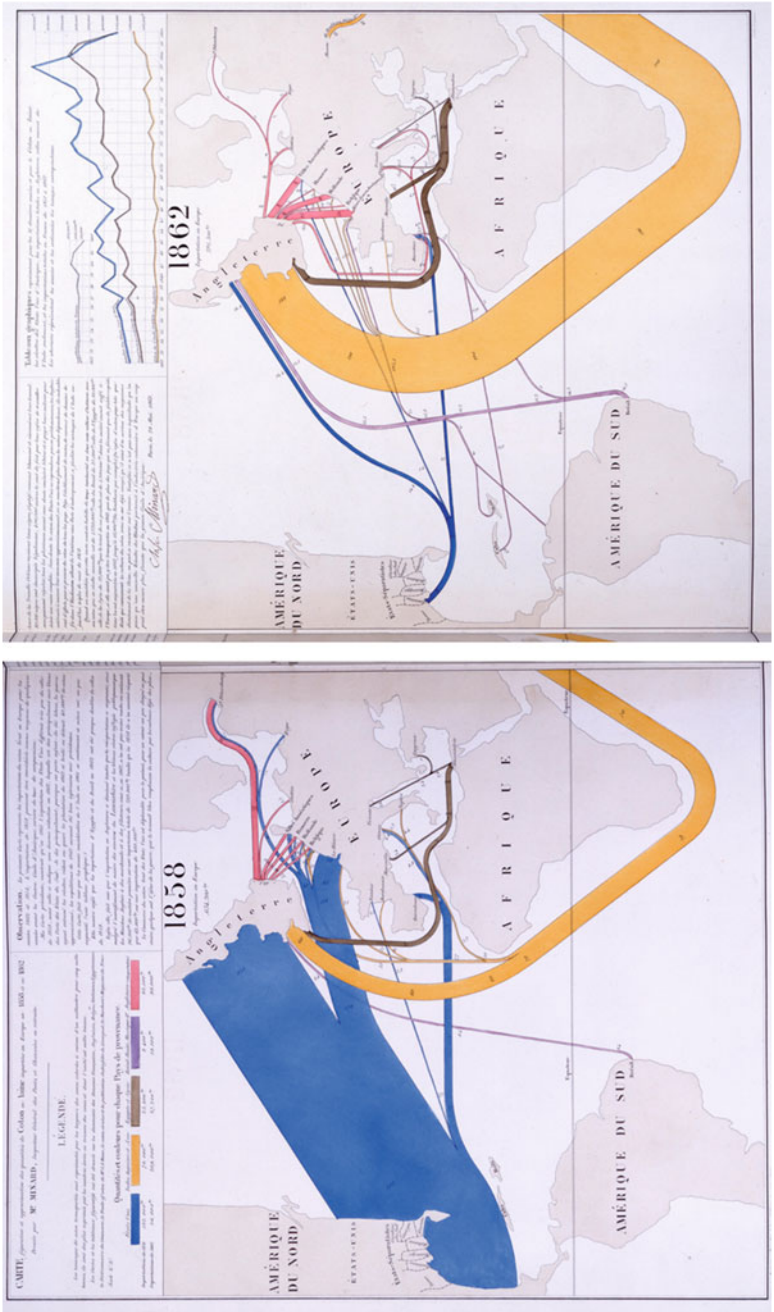

Fig. 27.7 Minard's before-after flow maps showing how the supply of cotton to English mills shifted dramatically from the southern states of the USA to India during the US Civil War, when the Union's naval blockades made reliable Confederate shipping problematic (Rendgen, 2019, P. 98–99)

many descendants of the initial pairing. Our goal was to provide a foreshadowing of the beauty and accomplishments that issued from this union.

For those who would value a fuller elaboration, we immodestly refer you to Friendly and Wainer (2021) from which this chapter has been abstracted.

References

Apel, W. (1944). The notation of polyphonic music. Cambridge, MA: The Mediaeval Academy of America.

Bacon, Roger (1897) Bridges, John Henry (ed.), The 'Opus Majus' of Roger Bacon: Edited, with Introduction and Analytical Table (in Latin and English), Vols. I & II, Oxford: Horace Hart for the Clarendon Press.

Beniger, J. R. & Robyn, D. L. (1978). Quantitative graphics in statistics: A brief history. *The American Statistician,* 32*,* 1–10.

Biderman, A.D. (1978) *Intellectual impediments to the development and diffusion of statistical graphics, 1637-1980*. Presented at 1st General Conference Social Graphics, Leesburg, VA.

Biderman, A. D. (1990). The Playfair enigma: Toward understanding the development of schematic representation of statistics from origins to the present day. *Information Design Journal, 6(*1*),* 3–25.

Clagett, M. (1968). Nicole Oresme and the Medieval Geometry of Qualities and Motions. Madison, WI: University of Wisconsin Press.

Costigan-Eaves, P., Macdonald-Ross, M. (in progress). The Method of Curves: a brief history to the early nineteenth century. Unpublished manuscript. Milton Keynes, England: The Open University.

Daston, L. & Galison, P. (1992). *Representations,* 40*,* 81–128.

Daston, L. & Galison, P. (2007). *Objectivity*. New York: Zone Books.

Friendly, M. (2002). Vision and re-visions of Charles Joseph Minard, *Journal of Educational and Behavioral Statistics*. 27 (1), 31–52.

Friendly, M. & Wainer, H. (2021). *A History of Data Visualization and Graphic Communication*, Cambridge: Harvard University Press.

Funkhouser, H. G. (1937). Historical development of the graphic representation of statistical data. *Osiris,* 3*,* 269–404.

Galton, F. (1863). *Meteorographica, or methods of mapping the weather*. London: Macmillan.

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

Gunther, R.T. (1968). *Early science in Oxford, Vol. XIII Dr. Plot and the correspondence of the Philosophical Society of Oxford*. London: Dawsons of Pall Mall.

Howard, L. (1847). *Barometrigraphia: twenty years' variation of the barometer in the climate of Britain, Exhibited in autographic curves, with the attendant winds and weather, and copious notes illustrative of the subject.* London: Richard & John E. Taylor.

Huygens, C. (1895). *Oeuvres completes, Tome Sixieme Correspondance*, 515–518, 526–539. Den Hague: Martinus Nijhoff.

Marey, E. J. (1878). *La Méthode graphique dans les sciences expérimentales et particuliérement en physiologie et en médecine.* Paris.

Marey, E. J. (1885), *La Méthode Graphique,* Paris: Boulevard Saint Germain et rue de l'Eperon.

McKie, D. (1972). "Scientific societies to the end of the eighteenth century." In A. Ferguson (Ed.) in *Natural philosophy through the 18th century and allied topics,* (p. 133–143). London: Taylor & Francis.

Playfair, W. (1786). *The Commercial and Political Atlas.* London: Corry.

Playfair, W.: *The Commercial and Political Atlas, Representing, by means of Stained Copper-Plate Charts, The Progress of the Commerce, Revenues, Expenditure, and Debts of England, during the whole of the Eighteenth Century.* Edited and introduced by Howard Wainer and Ian Spence. New York: Cambridge University Press, 2005 (1801/2005).

Priestley, J. (1769). *A New Chart of History*. London. Reprinted: 1792, New Haven: Amos Doolittle.

Rendgen, S. (2019). *The Minard System*. New York: Princeton Architectural Press.

Spence, I. & Wainer, H. (1997). William Playfair: A Daring Worthless Fellow, *Chance,* 10*(*1*),* 31–34.

Spence, I. & Wainer, H. (2000). William Playfair (1759-1823): An inventor and ardent advocate of statistical graphics. In *Statisticians of the Centuries* (C.C. Heyde, ed.). International Statistical Institute: Voorburg, Netherlands.

Tufte, E. R. (1983). *The visual display of quantitative information*. Cheshire, CT: Graphics Press.

Wainer, H. (1997). *Visual Revelations: Graphical Tales of Fate and Deception from Napoleon Bonaparte to Ross Perot.* New York: Copernicus Books.

Wainer, H. (1998). The graphical inventions of Dubourg and Ferguson: Two precursors to William Playfair. *Chance,* 11*(*4*)*, 39–41.

Wainer, H. (1996). Why Playfair? *Chance,* 9*(*2*),* 43–52.

Wainer, H. (2005). *Graphic Discovery*. Princeton: Princeton University Press.

Wainer, H. & Spence, I. (1997). Who was Playfair? *Chance,* 10(1), 35–37.