Playfair, William

Ian Spence
University of Toronto, Toronto, Ontario, Canada

Howard Wainer
National Board of Medical Examiners, Philadelphia, Pennsylvania, USA

Glossary

Biderman, Albert (1922–) American sociologist trained at the University of Chicago. He was instrumental in founding the National Science Foundation (NSF) working group on social graphics, and his NSF project on graphics can be credited with instigating the work of Edward Tufte and Howard Wainer in statistical graphics.

Euler, Leonhard (1707–1783) Swiss mathematician who trained under Jean Bernoulli. He published over 800 books and papers on every aspect of pure and applied mathematics, physics, and astronomy. In 1738, when he was professor of mathematics at St. Petersburg Academy, he lost sight in one eye. In 1741 he moved to Berlin, but returned to St. Petersburg in 1766, where he soon lost sight in the other eye; however, his prodigious memory allowed him to continue his work while totally blind. For the princess of Anhalt-Dessau he wrote *Lettres à Une Princesse D'Allemagne* (1768–1772) in which he gave a clear, non-technical outline of the principal physical theories of the time. His *Introductio in Analysin Infinitorum* (1748) and later treatises on calculus and algebra remained the standard texts for more than a century.

Funkhouser, Howard Gray (1898–1984) American mathematician and educator who was born in Winchester, Virginia. He was a 1921 graduate of Washington and Lee and received his Ph.D. from Columbia. He taught mathematics at Washington and Lee from 1924 to 1930 and spent 1931 on the mathematics faculty at Columbia. In 1932, he accepted a position on the faculty at Phillips Exeter Academy, where he remained until his retirement in 1966. His groundbreaking paper "Historical development of the graphical representation of statistical data," published in *Osiris* in 1937, joined two other papers, "Playfair and his charts" (1935) and "A note on a tenth century graph" (1936), as the jumping off point for subsequent researchers in the history of graphics.

Louis XVI (1754–1793) King of France (1774–1793), born in Versailles, France, the third son of the dauphin Louis and Maria Joseph of Saxony, and grandson of Louis XV, whom he succeeded. He was married in 1970 to Marie Antoinette, daughter of the Hapsburg Empress Maria Theresa. He made a number of unfortunate decisions (e.g., failing to support reform of financial and social structures, involvement in the American Revolution), which exacerbated the national debt. In August of 1792 the monarchy was abolished; he was then tried by the revolutionary government, and in 1793 he and his queen were guillotined in Paris.

Meikle, Andrew (1719–1811) Millwright and inventor who was born in East Lothian, Scotland. He inherited his father's mill, and to improve production invented the fantail (1750), a machine for dressing grain (1768), and the spring sail (1772). His most important invention was a drum threshing machine (patented in 1788) that could be driven by wind, water, horse, or (some years later) steam power.

Minard, Charles Joseph (1781–1870) He was first a civil engineer and then an instructor at the École Nationale des Ponts et Chaussées (ENPC). He later was an Inspector General of the Council des Ponts et Chaussées, but his lasting fame derived from his development of thematic maps in which he overlaid statistical information on a geographic background. The originality, quality and quantity of this work led some to call him "the Playfair of France." His intellectual leadership led to the publication of a series of graphic reports by the Bureau de la Statistique Graphique of France's Ministry of Public Works. The series (*l'Album de Statistique Graphique*) continued annually from 1879 until 1899 and contained important data on commerce that the Ministry was responsible for gathering.

In 1846, he developed a graphical metaphor of a river, whose width was proportional to the amount of materials being depicted (e.g., freight, immigrants), flowing from one geographic region to another. He used this almost exclusively to portray the transport of goods by water or land. This metaphor was employed to perfection in his 1869 graphic, through which, by using the substitution of soldiers for merchandise, he was able to show the catastrophic loss of life in Napoleon's ill-fated Russian campaign. The rushing river of 422,000 men that crossed into Russia when compared with the returning trickle of 10,000 "seemed to defy the pen of the historian by its brutal eloquence." This now-famous display has been called "the best graph ever produced."

Playfair, John (1748–1819) Minister, geologist, and mathematician. Born in Dundee, Scotland, he was the older brother of William Playfair. He studied at St. Andrews and became professor of mathematics (1785) and natural philosophy (1805) at Edinburgh University. In addition to influential writings on geometry, including a widely used textbook, he also investigated glaciation and the formation of river valleys. He was responsible for clarifying and amplifying the revolutionary geological theories of James Hutton, which anticipated modern scientific ideas such as evolution, natural selection, plate tectonics, and asteroid strikes.

Playfair, William (1759–1823) Scottish engineer, writer on political and economic topics, and the father of modern graphical methods.

Priestley, Joseph (1733–1804) Chemist and clergyman who was born in Fieldhead, West Yorkshire, England. He became a Presbyterian minister in Suffolk in 1755 but returned to Leeds in 1767 where he continued his scientific and philosophical studies. He is best known for his research on the chemistry of gases and for his discovery of oxygen. Some of his most productive scientific years were spent in Birmingham, where he also wrote books on education and politics. His political activities and his support of the French Revolution were controversial, making his continued presence in England more than uncomfortable, and in 1794 he emigrated to America, where he was well received.

Rennie, John (1761–1821) Born in East Linton, Scotland, he apprenticed with Andrew Meikle and later studied at Edinburgh University. He worked briefly at Boulton & Watt, and in 1791 started his own engineering company in London. He built docks at Hull, Liverpool, Greenock, Leith, Portsmouth, Chatham, and Plymouth. He is best known for his bridges, and his successes include Leeds Bridge, Southwark Bridge, Waterloo Bridge, and London Bridge, which was dismantled in 1967 and re-assembled in Arizona as a tourist attraction.

Tufte, Edward R. (1942–) American political scientist and graphics expert. He was born in California and trained at Yale and Stanford. His seven books include *The Visual Display of Quantitative Information*, *Envisioning Information*, and *Visual Explanations*, which have received unprecedented attention garnering among them more than 40 awards for content and design. They have sold, in aggregate, more than a half million copies and their author is in constant demand as an influential critic of graphical design.

Von Humboldt, Alexander (1769–1859) Naturalist and geographer who was born in Berlin and educated in Frankfurt, Berlin, Göttingen, and Freiberg. He spent 1799 through 1804 exploring South America with Aimé Bonpland (1773–1858). When he was 58, he spent three years traveling throughout central Asia. The Pacific current of the coast of South America is named for him. His principal book, *Kosmos,* tries to provide a comprehensive characterization of the universe.

Watt, James (1736–1819) Inventor. He was born in Greenock, Scotland, and in 1754, he apprenticed as an instrument maker in Glasgow, where he stayed and set up a business. As part of his trade he carried out surveys for canals and began to study the use of steam as an energy source. In 1763, he repaired a model Newcomen steam engine and found he could improve its efficiency through the use of a separate steam condenser. In 1774, he joined with Mathew Boulton in an enterprise to manufacture an improved steam engine in Birmingham. He subsequently made numerous other inventions, including the double-acting engine, parallel motion linkage, centrifugal governor for automatic speed control, and the pressure gauge. He is credited with coining the term "horse-power." The standard unit of electrical power is named for him.

A ubiquitous practice in modern science is the atheoretical plotting of data points with the goal of looking for suggestive patterns. This practice was initiated by William Playfair, an 18th century Scot, who not only invented most of the graphical forms used today but also showed in numerous publications how they could profitably be used.

Introduction

Today, with illustration at the heart of communication, we see pie, bar, and line charts everywhere—in the press, on television, on computer screens, on boardroom desks, on blackboards, whiteboards, and greenboards, in video presentations, handouts, flyers, and so forth. Aircraft control panels and nuclear power station monitors contain displays that look like bar charts in motion, and video games often keep track of players' scores in graphical form. It is difficult to determine how many graphs are created each day, but more than a decade ago, one noted commentator estimated the number at more than 5 million. However large the true number is, you can be sure it will be larger tomorrow, and the multitude of users of all these charts, graphs, and displays will grow apace. Statisticians employ graphs but so do scientists of every stripe, and unnumbered professionals in business and commerce make use of graphs every single day. Economists, sociologists, psychologists, social workers, medical professionals, and even historians are just a few of the occupations for which graphs are the stuff of everyday life.

Graphs convey comparative information in ways that no table or description ever could. Trends, differences, and associations are effortlessly seen in the literal blink of an eye. The eye discerns immediately what the mind would take seconds or minutes to deduce from a table of numbers. This, of course, is what makes graphs so appealing—they allow the numbers to speak clearly; they release them from their mute state. Graphs and charts not only show what numbers tell, they also help scientists—numerical detectives, if you will—tease out the critical clues from their data. Graphs transcend national boundaries—a Chinese can read the same graph that a Russian draws. There is no other form of communication that more appropriately deserves the description "universal language."

Who invented these ubiquitous and versatile objects? Have they been around for millennia, rather like the wheel or fire, the work of inventors unknown? The truth is that statistical graphs were not created in some distant past; their inventor lived only two centuries ago. He was a man of such unusual talents and background that had he not introduced his charts at the end of the 18th century, during the Age of Enlightenment, we might have waited until the 20th century for statistical graphs. The inventor was not a cloistered academic, although he was deeply knowledgeable on many subjects and wrote more prolifically than many in the ivory towers. He was a man of several careers and varied experience. He dearly wanted to be rich, but none of his many schemes realized this desire. He was something of a rogue, but oddly enough this rascally aspect may have helped bring his graphical inventions to the world.

Though born and raised in Scotland, he lived most of his life in London and Paris during turbulent times. William Playfair (1759–1823) was so convinced that he had found the best way to display economic data that he spent almost 40 years of his life trying to influence others to follow his example. He made notable converts, including the doomed Louis XVI of France, but he was unsuccessful in persuading the academic establishment and thus his inventions waited almost a century before widespread adoption.

William Playfair is the principal inventor of statistical graphs. Although one may point to isolated instances of rudimentary line graphs that precede Playfair's work,

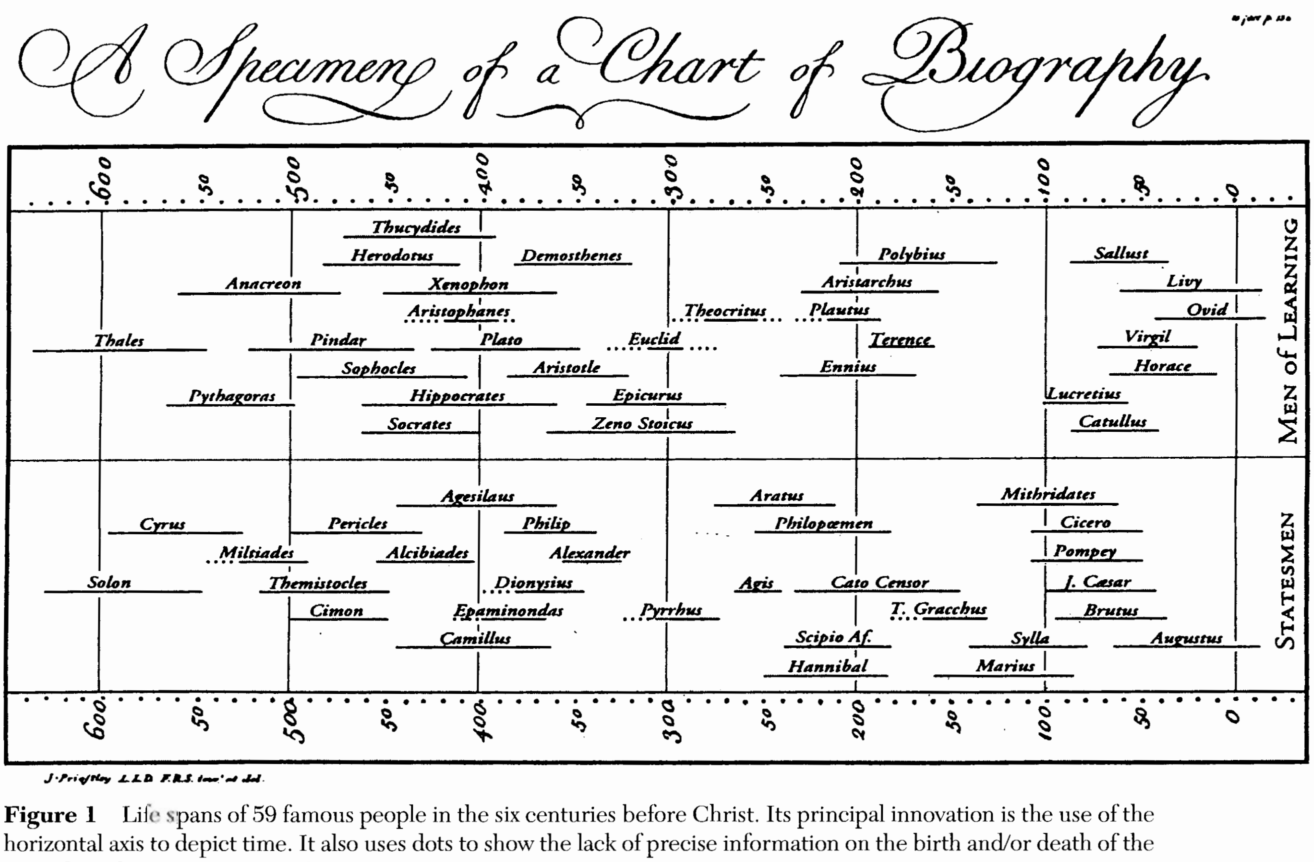

Figure 1 Life spans of 59 famous people in the six centuries before Christ. Its principal innovation is the use of the horizontal axis to depict time. It also uses dots to show the lack of precise information on the birth and/or death of the individual shown. From Priestley (1765).

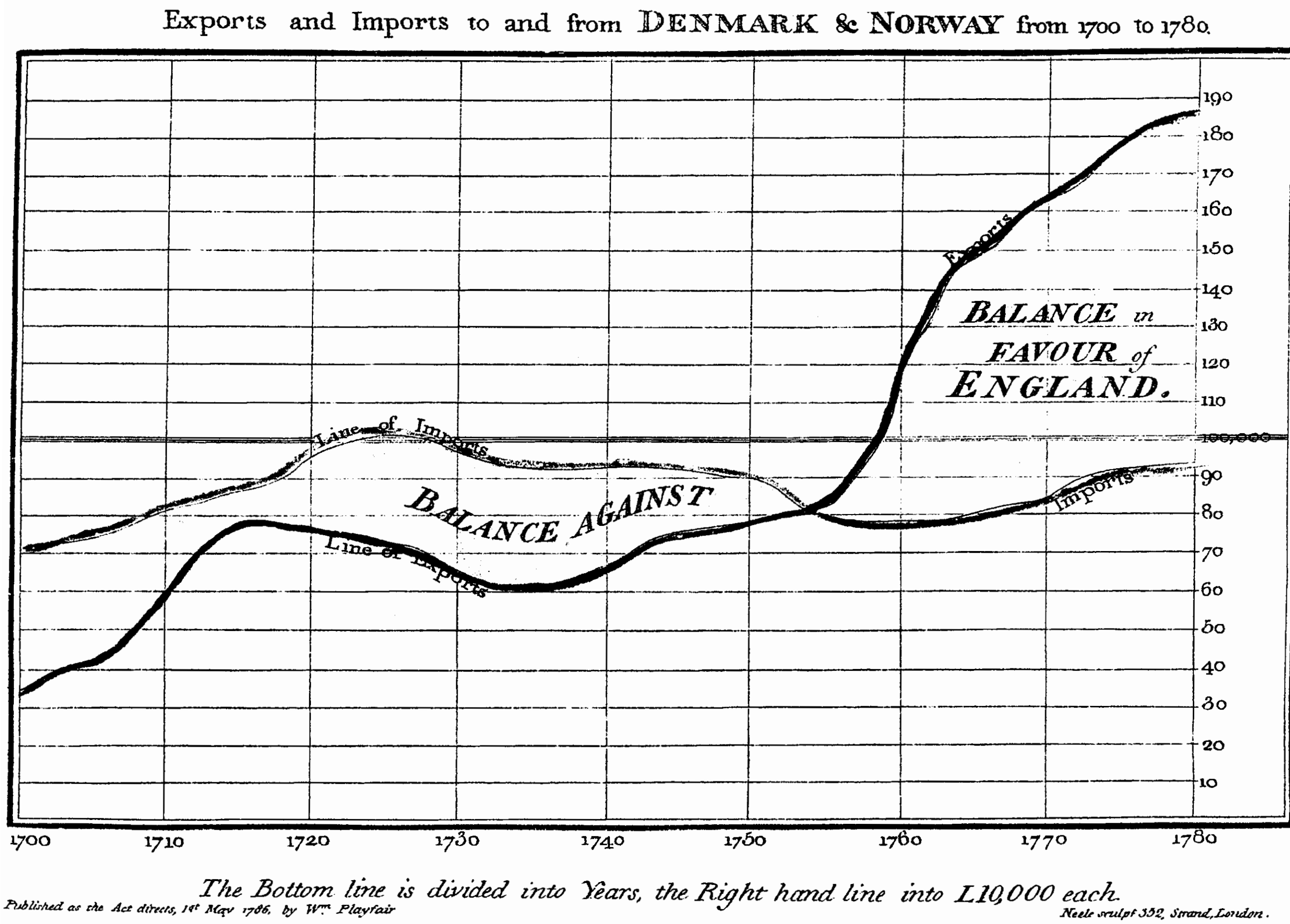

Figure 2 A typical line chart from Playfair's 1786 *Commercial and Political Atlas*, which uses one line to show imports and another for exports over the 80-year span from 1700 until 1780. The balance of trade between England and Denmark and Norway is the area between the two curves, which was shaded red (prior to 1765) when it was against England, and green thereafter when it was in England's favor.

such examples generally lack sophistication and, without exception, failed to influence others. In contrast, Playfair's graphs were elaborate and well constructed: they appeared regularly in several publications over a period of more than 30 years and they introduced a surprising variety of devices and techniques that are in use to this day. He invented three of the four basic forms; the statistical line graph, the bar chart, and the pie chart. The other important basic form—the scatter plot—did not appear until almost a century later. Playfair also invented other graphical elements that are still in use today, for example, the circle diagram and statistical Venn diagram, but these innovations were less effective and are less widely used.

William Playfair was born in 1759 in Scotland during the Enlightenment, on the cusp of the Industrial Revolution, to which he contributed as a young draftsman in the employ of Boulton & Watt. Upon his death in 1823—after a controversial and unconventional life—Playfair's obituaries were united in the conclusion that his talent had been squandered. But all published tributes missed the key achievement of his life, and a century would pass before the value of his work was fully recognized. As Funkhouser (1937) has noted, Playfair invented a universal language useful to science and commerce, and though his contemporaries had failed to grasp the significance, Playfair never doubted that he had changed the way we would look at data. Very few shared his enthusiasm for pictorial display, and it is a curiosity of history that one of those who did appreciate the inventions was the ill-fated King of France, Louis XVI. Playfair noted that, after receiving a copy of his pioneering volume *The Commercial and Political Atlas,* Louis XVI said, "[The charts] spoke all languages and were very clear and easily understood."

William Playfair was the fourth son of the Reverend James Playfair of the parish of Liff and Benvie near the city of Dundee, Scotland. His father died in 1772, leaving the eldest brother John to care for the family. John was subsequently to become one of Britain's foremost

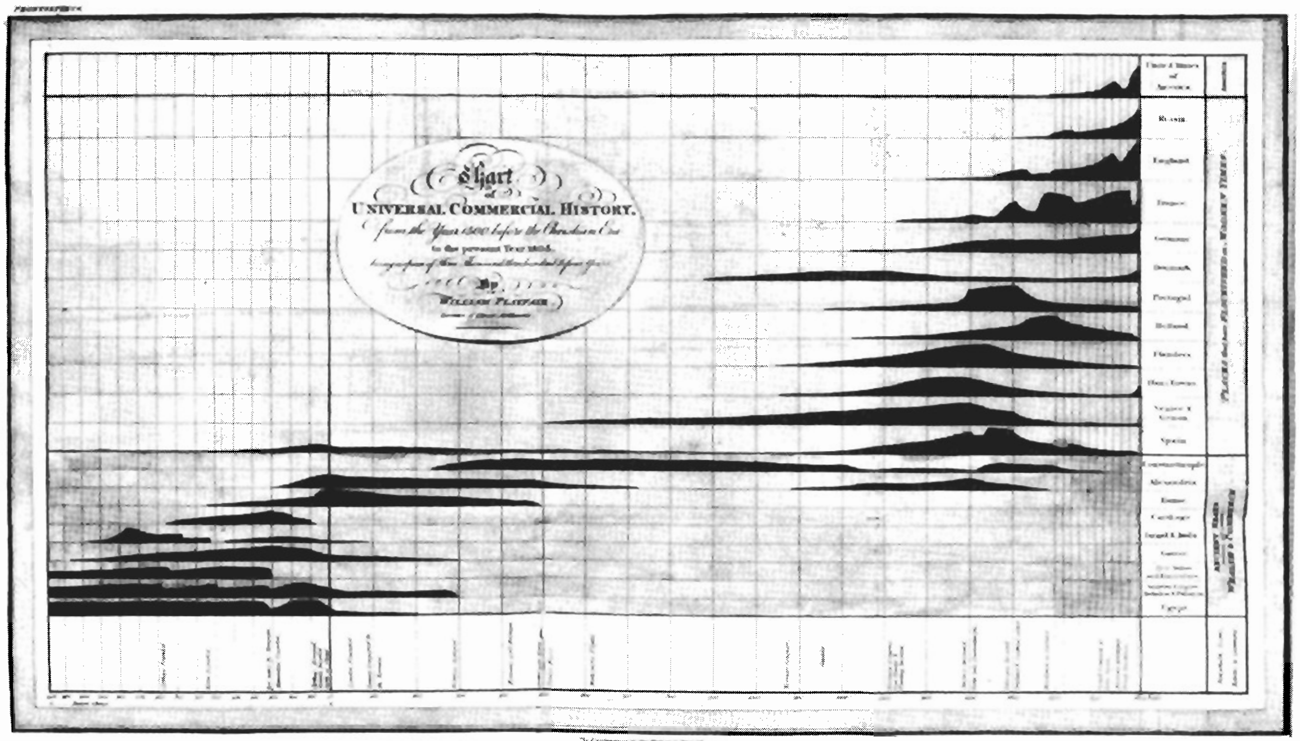

Figure 3 Playfair's only silhouette chart found as the frontispiece in *An Inquiry* (1805, 1807). This is a diagrammatic chart with no quantitative values represented. It depicts the rise and fall of 20 economies over a period of more than 3000 years. The original uses various colors in the background.

mathematicians and scientists as professor of natural philosophy, mathematics, and geology at Edinburgh University. After an apprenticeship with Andrew Meikle, the inventor of the threshing machine, William became draftsman and personal assistant to the great James Watt at the steam engine manufactory of Boulton & Watt at Birmingham in 1777. Thus, William's scientific and engineering training was at the hands of the leading figures of the Enlightenment and Industrial Revolution. On leaving Boulton & Watt in 1782, Playfair set up a silversmithing business and shop in London, but the venture failed. Seeking his fortune and hoping to apply his engineering skills to better effect in a developing French economy, Playfair moved to Paris in 1787.

It was about this time that Playfair developed most of his graphical formats and published several examples. He already had the mathematical training from his brother John, the engineering know-how from Meikle and Watt, knowledge of business and economics from men such as Boulton, and some hard practical experience of the world of affairs from his botched enterprises in London and Paris. But his charts were not readily accepted, especially in Britain, where concerns regarding accuracy were not eased by his occasional carelessness and his less than reputable personal standing. He was received more sympathetically in Germany and France, gaining approval from the geographer Alexander von Humboldt, among others. Nevertheless, there was still considerable opposition to his ideas and there was no general adoption of his methods until the second half of the 19th century, when Minard and Bertillon incorporated some of Playfair's devices in their cartographical work.

The Time-Series Line Graph

In 1786, shortly before he left for Paris, Playfair published his *Commercial and Political Atlas*, which contained 44 charts, but no maps; all of the charts, save one, were variants of the statistical time-series line graph. Playfair credits his brother for the inspiration that led to the line graph—John had made him keep daily records of temperature and chart these data in similar fashion. As Scotland's foremost mathematician of the day, John Playfair was certainly familiar with the use of Cartesian graphs to represent functions, and would also have been aware of the work of Lambert, who superimposed empirical data points on such functions. Another influence can be found, a decade beforehand, in the work of Joseph Priestley, who had conceived of representing time geometrically (see Fig. 1). The use of a grid with time on the horizontal axis was a revolutionary idea, and the

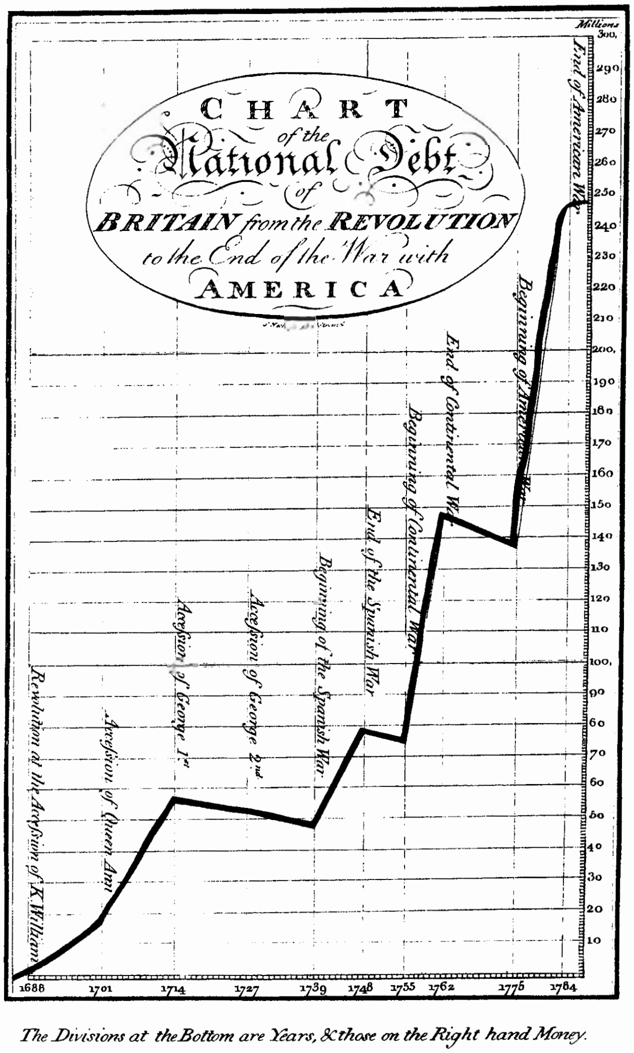

Figure 4 This remarkable "Chart of the National Debt of England" appeared as plate 20, opposite page 83 in the third edition of Playfair's *Commercial and Political Atlas* in 1801. Not only is it the first "skyrocketing government debt" chart, but it also uses the innovation of an irregularly spaced grid along the time axis to demark events of important economic consequence.

representation of the lengths of reigns of monarchs by bars of different lengths allowed immediate visual comparisons that would otherwise have required significant mental arithmetic. What is more, the relative differences in time periods and their relative position in the overall chronology could also be readily apprehended; no wonder that Priestley's device proved popular.

William Playfair was well acquainted with Priestley and his work, encountering the older man on a frequent basis in the Birmingham of the late 1770s. It was Playfair's genius to take the ideas implicit in Lambert and Priestley's charts and, with the stimulus of his brother's early instruction, to produce the first statistical time-series line graphs (see Figs. 2 and 3).

These charts introduced a large number of innovative features that remain part and parcel of the statistician's repertoire today: the use of an informative title; graduated and labeled axes; ruled gridlines, with greater line weight for major intervals; broken and solid lines, or different line colors, to distinguish time series of different kinds; hachure, solid fill, and color to indicate areas that represent accumulated amounts; the colors green and red to indicate positive and negative balances; appropriately placed labels to indicate historical events (Fig. 4); and so forth.

Playfair also introduced novelties that are still occasionally seen today: for example, in one chart, whose vertical dimension was insufficient to contain a particularly high peak in expenditures, Playfair extended the curve beyond the frame at the top and allowed it to repeat at the bottom of the graph. Although it is likely that this obvious peculiarity may have resulted from an error in planning, it turned out to be, in effect, an editorial comment. The reader is immediately drawn to the unusual nature of the sharp rise in cost—the implication is that the spike in prices is so egregious that the scope of the chart is unable to accommodate the excursion.

The Bar Chart

Playfair freely acknowledged Priestley's chronological diagrams as the source of the single bar chart that appeared in his atlas (Fig. 5). But he introduced this chart with apologies. He had insufficient data to be able to present the time-series chart that he had intended and so of necessity had to invent another form in which the horizontal axis did not represent the flow of time. He thought so little of this invention that he made no subsequent use of it, at least in its original form. He did, however, use bars in later graphs, but to display changing data over time.

The Pie Chart

Whereas both the line graph and bar chart used linear extent to represent quantity, Playfair's next inventions used area. The *Statistical Breviary* contained charts that were intended to show the areas, populations, and revenues of European states (Fig. 6). The charts also indicated which countries were maritime powers by coloring them green, while the others were stained red. The first chart of the *Breviary* shows the countries before the French Revolution of 1789, and the second chart displays the changes thereafter in 1801, the year of the Luneville peace.

Thus in two charts in a single volume, Playfair introduced three new forms of statistical graph: the circle diagram, the pie chart, and a Venn-like diagram, which is

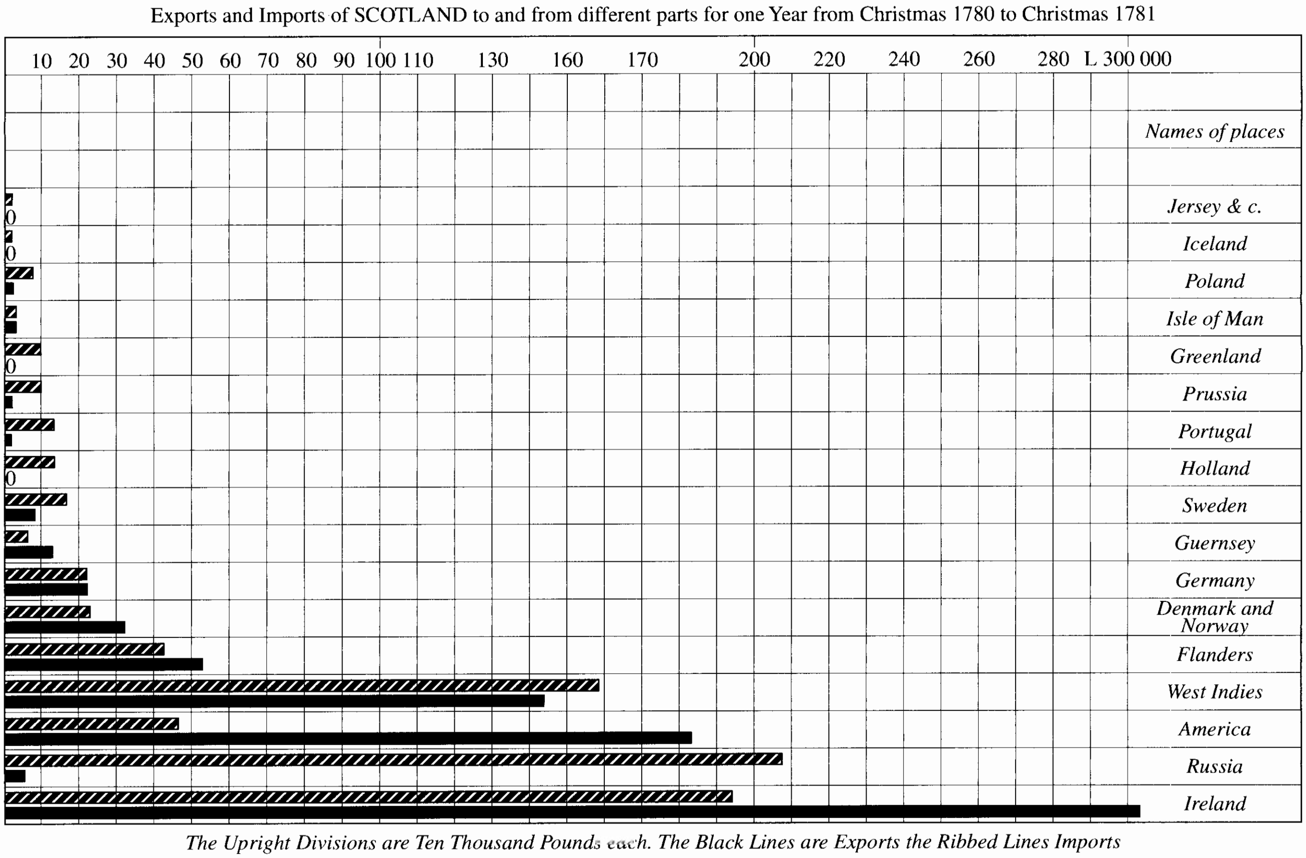

Figure 5 Imports from and exports to Scotland for 17 different places. After Playfair (1786), plate 23.

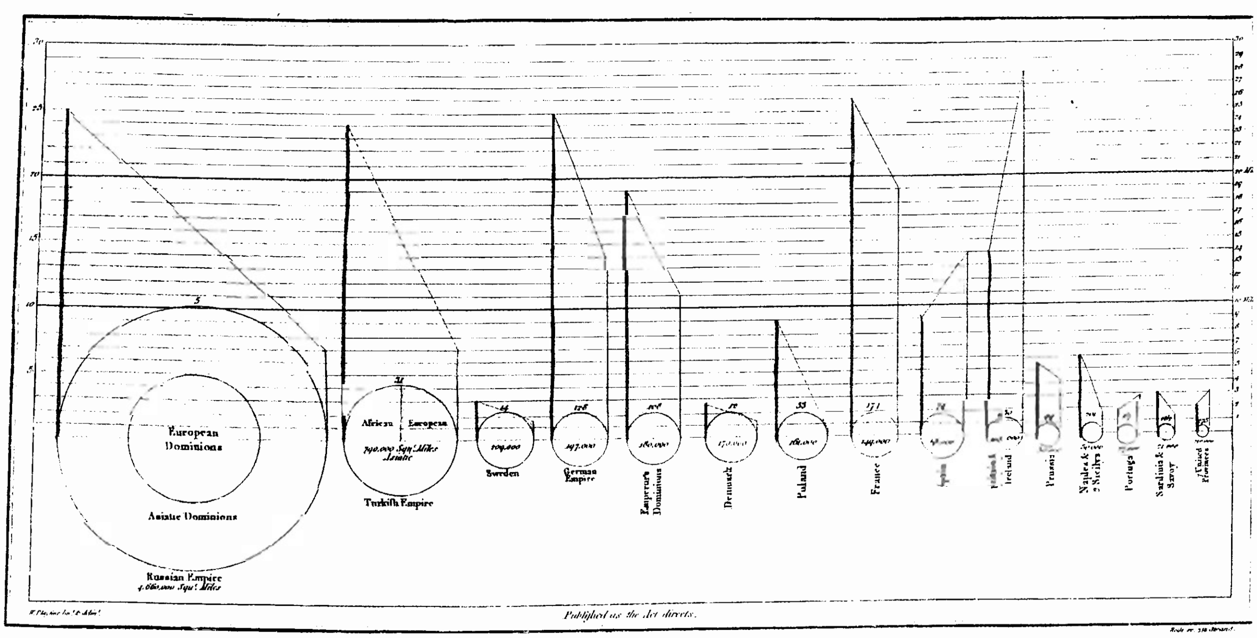

Figure 6 An innovative design from Playfair's *Statistical Breviary* (1801), which showed multivariate data using area to depict quantity for the first time. The circle represents the area of the country, the line on the left of each circle represents the size of the population, and the line at the right the tax revenues collected. The slope of the dotted line indicates the extent of the tax load. It is easy to see that the small populations of Britain and Ireland stand out as the most heavily taxed of all nations included.

used to show joint properties. As in the case of the line and bar charts that he had introduced 15 years before, his basic designs were sound and have scarcely been improved upon. The areas of circles are used to represent varying quantities, and the practice of using circles, or areas of other figures, persists to this day. In the pie chart, Playfair used angle to denote proportion, and used color and labeling to differentiate the segments that make up the whole (Fig. 7). The use of Venn-like diagrams to portray statistical quantities is less common, both today and two centuries ago, but the device is not unknown.

However, the pie chart remains a mystery—Playfair left us no indication of its inspiration. And yet it is likely that he was copying or adapting the ideas of others—his career is replete with instances of adaptation. Perhaps a clue is to be found in the intersecting and included circles. Such diagrams were used by Venn in his work on logic in 1880—but, of course, Playfair's diagrams precede Venn's. Venn (1834–1923), contrary to popular myth, was not the inventor of such logic diagrams. Euler (1707–1783) had used them for exactly the same purpose more than a century before. And before Euler, Leibniz (164–1716) devoted serious attention to the analysis of logical propositions by means of diagrams: he explored various means of representing Aristotelian syllogisms by means of geometric figures, including Venn-like diagrams as well as his own linear versions,

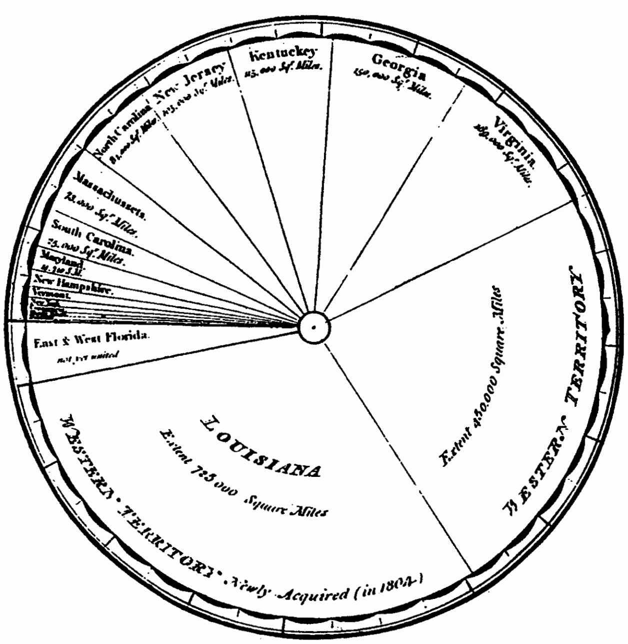

Figure 7 Playfair's pie chart using the segments of the pie to represent the relative size of each component of the United States at the beginning of the 19th century. Areas in the chart are proportional to the areas in square miles. From Donnant (1805).

which he considered superior. It was, however, Euler who popularized the use of circle diagrams, although he was quick to point out that the type of shape was unimportant. It is interesting to observe that the work of Euler and Leibniz was well known to John Playfair, the author of "Progress of Mathematical and Physical Science since the Revival of Letters in Europe" in the fourth edition of the *Encyclopedia Britannica*. This article has been described as the best short general history of science written during the first half of the 19th century. His concluding discourse on the genius of Leibniz and Newton was universally admired. Because of his intimate familiarity with the work of Leibniz and Euler, John Playfair could not have failed to make William aware of this work as he instructed his 12-year-old younger brother in mathematics, after the early death of their father.

After the great inventions of 1786 and 1801, Playfair introduced no further innovations of any consequence. He did, however, refine his graphs, and later publications include rather splendid examples that combined the time-series line graph, a seamless sequence of bars depicting quantities averaged over fixed time periods, and a chronological diagram in a single chart (Fig. 8).

Conclusion

Playfair's final two decades were not easy. He was in frequent financial difficulty, despite his involvement in a variety of schemes. These generally involved publishing, banking, and writing about economics. When he returned to London, Playfair and his partner Hartsinck opened the Security Bank, modeling its practices on schemes that he had seen in Paris during the Revolution. The London establishment, however, did not tolerate these unregulated innovations, and the venture collapsed after a conflict with the Bank of England. From the mid-1790s onward, he made his living as a writer and also as a gun carriage maker, developing the occasional new mechanical invention. He argued against the excesses of the French Revolution and commented extensively on British policy toward France. In his illustrated nine-volume *British Family Antiquity*, he catalogued the peerage and baronetage of the United Kingdom. He also edited more than one periodical, including the *Tomahawk*. After the restoration of the Bourbon monarchy, he returned to France and became editor of the periodical *Galignani's Messenger*, but his comments on a duel between a Colonel Duffay and the Comte de St. Morys were held to be libelous by the widow St. Morys and led to Playfair's prosecution. Sentenced to three months imprisonment, a fine, and damages, Playfair thought flight a better option, and he spent his remaining years in London writing. He constantly pushed the boundaries of legality and was convicted on more than one occasion.

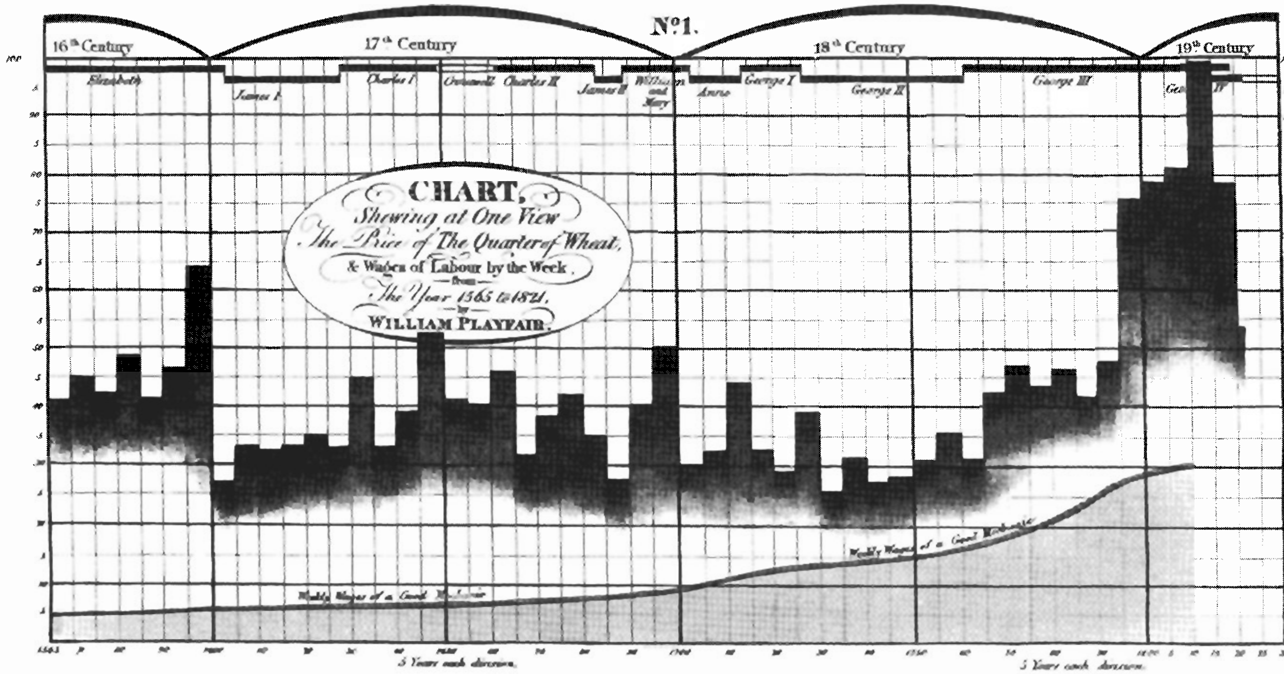

Figure 8 One of Playfair's most dramatic displays designed to show the unfair price of a quarter of wheat compared to the humble wages of a "good mechanic." In the original, the curve for the wages of the mechanic appeared in red and the area beneath was stained blue. This chart appeared in both editions of *Agricultural Distresses* (1821, 1822).

He even descended to a kind of genteel blackmail of acquaintances (for example, the famous engineer John Rennie) and more aggressively with strangers (Lord Archibald Douglas). Despite his considerable efforts, including a hopeful but brief return to France, his schemes failed to gain the fortune that he craved. He died in modest circumstances at the age of 63.

See Also the Following Articles

Graph Theory • Lazarsfeld, Paul • Time Series Analysis in Political Science

Further Reading

Biderman, A. D. (1990). The Playfair enigma: The development of the schematic representation of statistics. *Inform. Design J.* **6,** 3–25.

Donnant, D. F. (1805). *Statistical Account of the United States of America*. Translated from the French by William Playfair. Greenland & Norris, London.

Euler, L. (1761). *À une princesse d'Allemagne sur divers sujets de physique et de philosophie,* Vol. 2, Letters No. 102–108.

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

Lambert, J. H. (1779). *Pyrometrie.* Berlin.

Palsky, G. (1996). *Des chiffres et des cartes: Naissance et développement de la cartographie quantitative français au XIX^{eme} siécle.* Éditions de CTHS, Paris.

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

Playfair, W. (1801). *The Commercial and Political Atlas,* 3rd Ed. John Stockdale, London.

Playfair, W. (1801). *The Statistical Breviary.* T. Bensley, London.

Donnant, D. F. (1805) *Statistical Account of the United States of America.* Translated from the French by William Playfair. Greenland & Norris, London.

Playfair, W. (1807). *An Inquiry into the Permanent Causes of the Decline and Fall of Powerful and Wealthy Nations.* Greenland & Norris, London.

Playfair, W. (1821). *A Letter on Our Agricultural Distresses, Their Causes and Remedies.* London: W. Sams.

Playfair, W. (1822). *Can This Continue? A Question Addressed to Whom It May Concern.* W. Sams, London.

Priestley, J. (1765). *A Chart of Biography.* London.

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

Spence, I., and Wainer, H. (1997). William Playfair: A daring worthless fellow. *Chance* **10,** 31–34.

Wainer, H., and Velleman, P. (2001). Statistical graphics: Mapping the pathways of science. *Annu. Rev. Psychol.* **52,** 305–335.