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Life of Pie: William Playfair and the Impact of the Visual

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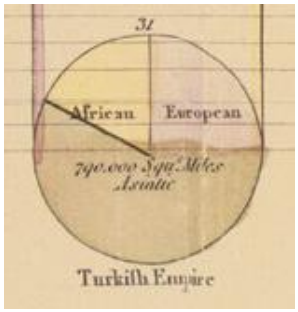
Introduction

At the dawn of the nineteenth century, a Scotsman published a circular diagram divided into three parts from the unlikely setting of the Fleet, a debtor's prison just north of Ludgate Hill in central London. It purported to represent the land mass of the Turkish Empire, with sectors of appropriate sizes indicating the fractions of the empire lying in Europe, Asia and Africa, and rather sloppily coloured by hand. This was the first pie chart and the man was William Playfair.



William Playfair's life: Part 1

The Mathematical Association was born out of a need to teach geometry unshackled from the suffocating constraints of Euclid's *Elements* and the associated pedantic pedagogy. In this regard some progress had been made over the century to 1871, including by John Playfair (1748–1818), whose 1795 edition of the *Elements* included algebraic notation for the first time (as well as a restatement of the troublesome fifth postulate, since known as Playfair's Axiom). At the time of the book's publication he had been Professor of Mathematics at the University of Edinburgh for a decade, his earlier career in the ministry set aside, and he was a key figure in the Scottish Enlightenment, brushing shoulders with the likes of Adam Smith, Joseph Black, Robert Adam and especially James Hutton, whose uniformitarian theory of geology he promoted.

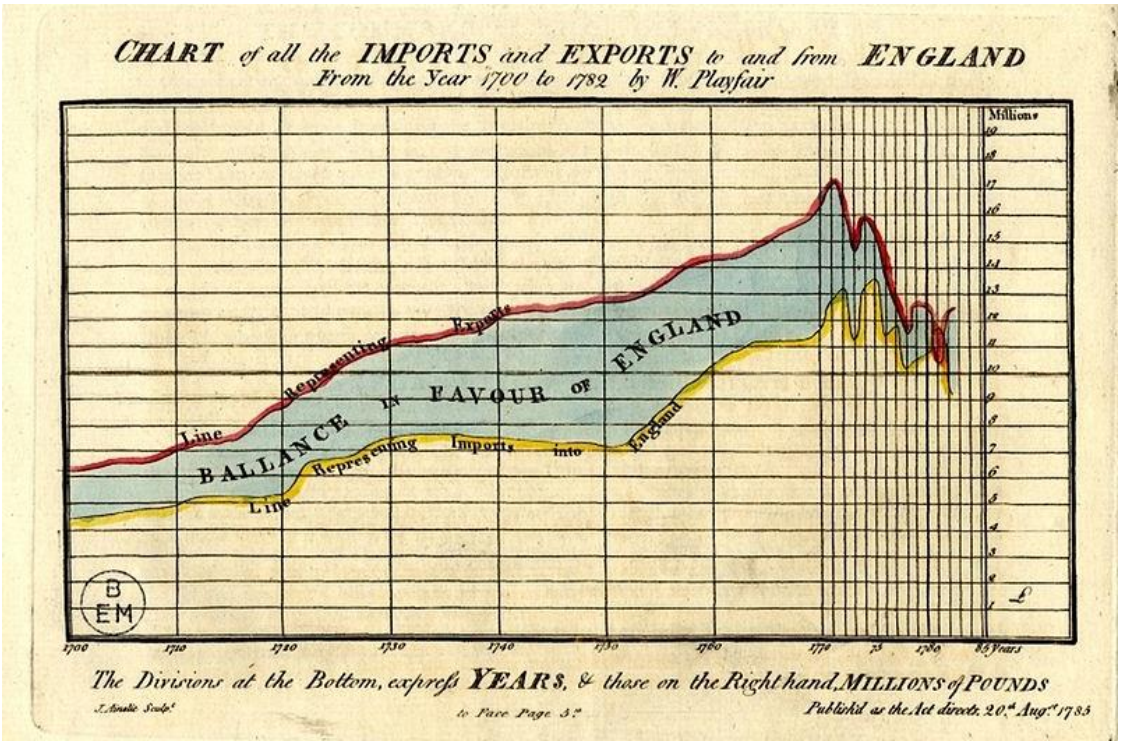
John Playfair was raised in a tiny settlement outside Dundee, the eldest but by no means the only talented member of his family. There were his younger brothers, the lawyer Robert Playfair and the architect James Playfair, as well as James's son, William Henry Playfair, whose architectural legacy is seen in many of the fine buildings in Edinburgh's New Town. And then there was another of John's brothers, William Playfair, engineer, businessman, political economist, spy and scoundrel, but also a visionary when it came to explaining things through diagrams. William Playfair, the subject of this article, is the father of the statistical diagram and hence a beacon for those who believe that understanding in mathematics and science is often enhanced by the visual.

William Playfair (1759–1823) was taught at home by his father until he was twelve (when his father died) and then by his brother John. He showed an early flair for things mechanical, for draughtsmanship and for model construction, and so it was that he became apprenticed to a local millwright. He was still in his teens when he was introduced to Matthew Boulton, co-owner with James Watt of the Soho Manufactory in Birmingham. Playfair was soon engaged as Watt's draftsman and clerk, working on improved designs for steam-powered machinery, and then in the onsite assembly and installation of steam pumping engines. But although this was a very effective way to further his education, he found the conservatism of the company stifling: there was little 'research and development', as we would call it now. So he left the Soho company and struck out on his own, taking out four patents and starting two companies. And then, out of the blue, he switched interests altogether, and moved towards international business, economics and visual statistics. Prompted by the loss of the American states, he argued that Britain's apparently waning power could be restored by focussing on manufacturing, banking and trade, rather than on the traditional land-grab. His view was that money should flow, usury should be allowed, and investment and speculation would surely follow.

The first time-series chart and bar chart

In the early twentieth century, the phrase 'a picture is worth a thousand words' caught the public imagination. It was invoked in journalism and advertising. In fact, similar sentiments had been expressed widely and over a long period of time, including, for example, by Ivan Turgenev who wrote in 1861 that 'the drawing shows me at one glance what might be spread over ten pages in a book'. Back in 1785, William Playfair recognised the possibility not of reducing words to a drawing but of condensing a multitude of numbers into a graph or chart designed to have maximum visual impact on the reader. Essential information could be conveyed more quickly, complex information could be understood by a wider audience and at greater speed. *The Commercial and Political Atlas* was published in 1786 as a quarto book of 158 pages in landscape orientation. Such was its success, that it was reprinted the following year, with a third edition following in 1801 (Playfair, 1786, 1787, 1801b). The last of the three piggy-backed another major publication of 1801, the *Statistical Breviary* (Playfair, 1801a). From here on in we will use the shortened titles, *Atlas* and *Breviary*.

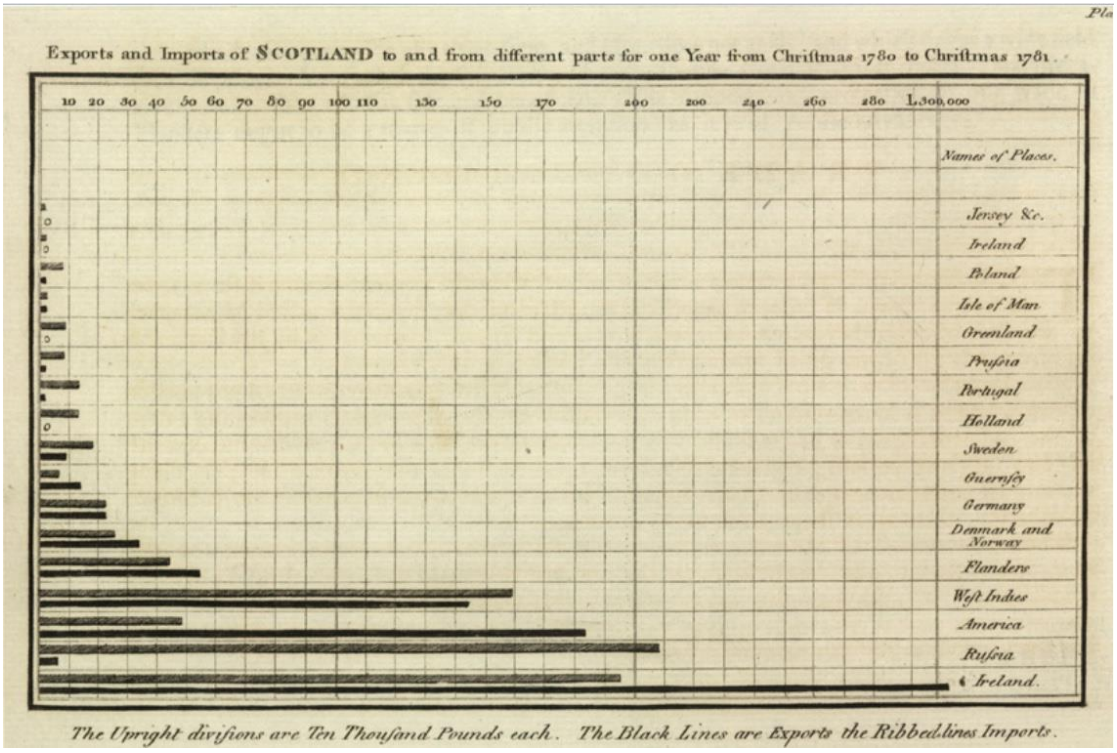
In the *Atlas*, Playfair's diagram of choice was what we now call the time-series chart; in fact, of the 44 charts the book contains, all but one are time-series charts. They include the first depictions of a fluctuating balance of trade (i.e. the differences between imports and exports) between England and its trading partners both collectively and individually. There are charts comparing the revenues of England and France from 1550 onwards, one showing the national debt since the English Revolution, and changes in the expenditure on the army and navy and on ordnance back to 1720. Importantly, these are not depictions of a functional relationship. The heights of the lines (the value of imports and exports) are not a function of time but a trace of empirical data over time. This is the very first of those time-series charts in Playfair's book of 1786:



Notice that all the good features of a statistical graph are in place – title, frame, labelling of the axes, uniform graduation of the scales, grid lines for ease in estimating values and the use of colour to embolden salient features. We wouldn't teach it any differently today. This is how statistical graphs should be drawn and this is how they were drawn from the very first example. Further finessing was never needed because William Playfair had incorporated all the necessary elements from the outset.

This was all very well when it came to picturing England's economic position over time, but the figures for Scotland's trade were not so comprehensive and so, unable to depict changes from year to year, Playfair decided to focus on a single year, and rather than pooling the amounts

for different countries he chunked the information country by country. In a sense Playfair had stumbled across the bar chart because his data were incomplete. He commented that 'this chart … does not comprehend any portion of time, and is much inferior in utility to those that do (Playfair, 1786, p.101). Today, we would typically call the diagram a dual bar chart because it compares imports and exports in a pair of horizontal bars, country by country. Note that Playfair also took the trouble to order the countries by the volume of trade for ease of comparison. Particularly striking is the volume of imports from Catherine the Great's Russia.



Another book, *Lineal Arithmetic*, appeared in 1798. Privately published and printed by Alexander Paris in London, it contained 35 engraved charts depicting the economic performance of England in the eighteenth century and is very rare. (A copy sold at Christie's in 2010 for $7500.) Among the conclusions that could be drawn from the charts was the likely military capability of a nation and the nature of that capability. Who could put men into the field and who could afford to produce military equipment became clear in a few glances. If charts were to be prepared displaying data of a different nature, they too should make understanding simpler. Playfair thought for example that they would be excellent for youngsters in terms of the ease and the attraction of learning.

William Playfair's life: Part 2

While the new statistical diagrams would make for ease of understanding, they could also be used to change perceptions and to influence policy, and having dipped his toe in the water with his earlier monograph, Playfair knew this well. The 'Eden Treaty' of 1786 had reduced tariffs between Britain and France, and there was an immediate opportunity for trade to flourish between the countries. So Playfair took himself off to Paris and through his contacts there a copy of the *Atlas* was passed on to the king, Louis XVI, who, as Playfair later recalled

> at once understood the charts and was highly pleased. He said they spoke all languages and were very clear and easily understood.

Apparently, he was so impressed that when Playfair saw an opportunity to build a rolling mill in Paris, the king intimated that he would be prepared to provide some of the capital. And with such royal favour, it is no surprise that when Playfair attended the Académie Royale des Sciences he was warmly welcomed.

When the Bastille was stormed in July 1789, Playfair was living close-by and is known to have attended a meeting to organise a local militia the day before. He witnessed much of the action and

reported on it in detail later. He also wrote a history of Jacobinism, a movement for which he had no sympathy, though he did see its emergence as an opportunity for a bit of adventure, with the possibility of making some money. As tensions rose in the build-up to revolution, the prospect of quitting France for safer shores including America seemed a wise option to some, and so it was that Playfair became involved in a scam to sell tracts of land on the banks of the Ohio River, land to which he and his cronies had only tenuous claim. French emigrants arrived in the United States by the boatload only to find their title deeds were invalid; the American government got involved right through to President George Washington and Playfair came out of the scandal badly. (For a comprehensive account, see Berkowitz, 2018, chapters 4 and 5.)

Meanwhile in Paris Playfair was running up debts and his creditors were on his tail. Yet he stayed there right through the Revolution, becoming more and more disenchanted with developments. In 1791 he bravely intervened when a friend was slashed repeatedly with sabres by a mob intent on killing him. By 1792 his concerns about Jacobinism were so great, including the growth of a similar movement back home, that he alerted his countrymen to the dangers in *A Letter to the People of England on the Revolution in France.* It included his analysis of the weaknesses in France's finances, noting in particular the use of *assignats*, paper money printed by the revolutionary government in huge quantities in order to maintain liquidity but at the cost of inflation. Words soon turned to deeds when some of his ideas found favour in London; he was eased into the role of agent for the British in France, at a time when spying was unorganised and ad hoc.

Two of Playfair's clandestine activities stand out. The first was the hijacking of the novel semaphore telegraph system of communication devised by the French. Following the execution of the king in January 1793, the French declared war on Britain, so when they found a way to pass messages to their army via a line of towers in a matter of minutes, it was of huge concern. Playfair, learnt of the system on one of his forays into France and actually built two such towers to see how they worked, passing on his findings to the Duke of York (remembered as 'The Grand Old Duke of York'), George III's second son, then in command of British troops in Flanders.

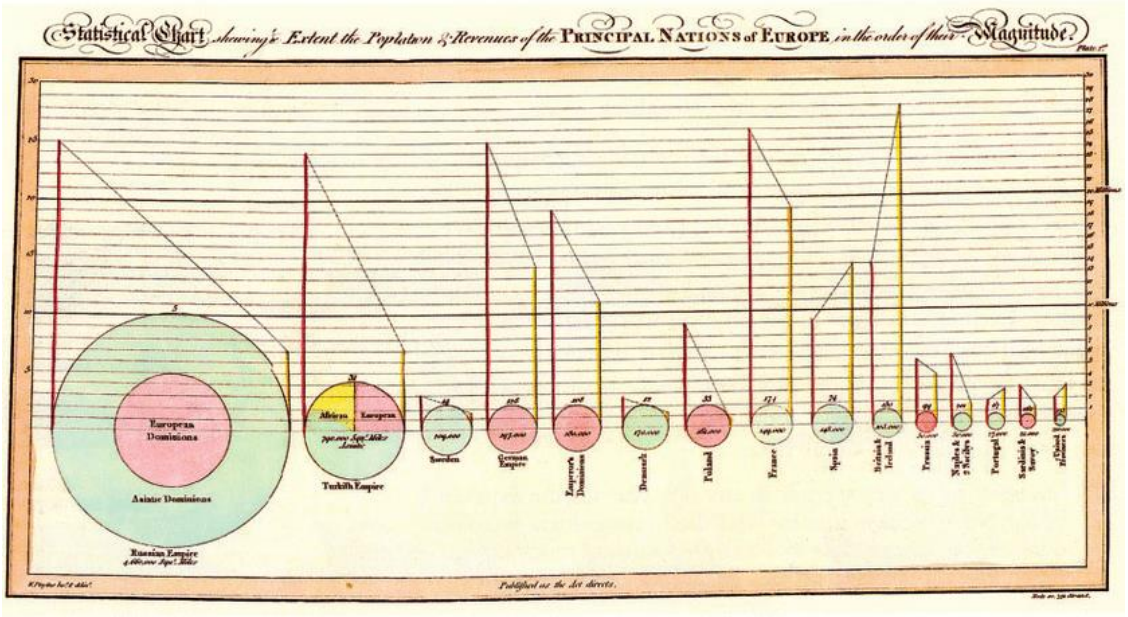
The second was a scheme Playfair sold to the British Government to produce counterfeit assignats in order to further destabilise the French economy. If the French currency were to become worthless, he argued, France could not prosecute a war against Britain. No fewer than seventeen outfits in London turned to counterfeit assignat production. Sure enough, the assignat collapsed completely, though the extent to which Playfair's scheme played a part it is hard to tell, as is the extent to which the currency's failure led to Napoleon's coup later that decade.

Counterfeiting was a serious problem in many countries at the end of the eighteenth century. Up to two-thirds of the coins in circulation in Britain were fake. And so it was that the Bank of England stopped minting copper coins altogether in 1773 leaving a vacuum that was initially taken up by the Parys Mines company on Angelsey which minted tokens directly from their own copper. But it was Boulton & Watt that took on the venture in more earnest, establishing the Soho Mint within the Soho Manufactory in the 1780s. Playfair had left the company by this point but he would have been aware of the problem with the coinage, and the opportunities that the production of token coins and indeed token notes provided, opportunities to turn a profit on a personal level but also to flip an economy given the right circumstances. Accordingly, in the late 1790s, Playfair returned to business and specifically to banking, setting up the Original Security Bank and an assignat scheme to print low denomination banknotes ostensibly backed by the Bank of England. But the Bank of England cried foul, and this, combined with considerable mismanagement, led to the bank going bust. Playfair found himself in Fleet Prison but, unbroken by his situation, he had a notion to write *The Statistical Breviary*. As his biographer, Bruce Berkowitz commented (p. 247), 'Playfair was trying to write his way out of debt. The result: some of the most important works in statistics, economics, and strategic analysis were written in London's Fleet Prison'.

The first circle area chart and pie chart

The *Breviary* arose out of a friend's project to gather together and publish descriptive, cartographic and statistical material about a number of European countries. The author, John Stockdale, also printed and sold books, and he

invited Playfair to update a wealth of statistical information compiled by Jakob Boetticher (1754–1792) in Königsberg. The outcome was a series of tables, inauspiciously arrayed. Having already produced the *Atlas*, Playfair realised that data of this sort could be presented much more effectively in visual form. One of the keys was deciding which information should be presented in this way and which should be omitted altogether. The new book was published in 1801; Playfair did not regain his freedom until a few months later following an appeal to a fund established to support struggling writers. The book consisted of 64 pages, most of them displaying tables of data, country by country, but with four plates, of which the most famous is that showing the first pie chart, 'Statistical chart showing the extent, the population and revenues of the principal nations of Europe in the order of their magnitude'.



What are the chart's innovative features?

1. Circles with areas that are proportional to the areas of the countries, drawn in descending order. Playfair wrote on page 15 that 'where the forms are not similar, the eye cannot compare them easily nor accurately', effectively arguing that the areas of two or more countries on a map cannot be compared as easily as if those areas are reduced to circles (which are necessarily similar).

2. Subdivision of two of the circles, those for Russia and Turkey, to indicate the extent to which they straddle two or more continents. Note here that Playfair uses two different approaches, and this begs the question, 'Why?' For the Russian Empire, its European territories appear as a circle while its Asian territories form an annulus wrapped around. But for the Turkish (Ottoman) Empire, which encompassed not just modern-day Turkey but Greece, Syria, Iraq and the Caucasus, as well as most of Mediterranean Africa, there is a single circle, proportional in area to the outer circle for Russia but subdivided into sectors for Europe, Asia and Africa; what we now call a pie chart. (Whilst the radius separating the last two is marked clearly, that separating the first two is not because the sector for Europe is a quadrant and the horizontal grid line is there anyway.) As to why Playfair offers two different ways of dividing the circle, one possibility (contained in an anonymous blog by a company called Geolytix) concerns the practicalities of drawing the diagrams. The circles are small; apparently just big enough in the case of Russia that the annulus approach works but too small in the case of the Turkish Empire for three bounding concentric circles to be drawn and the spaces between them coloured. If this theory is correct, then Playfair favoured the concentric circles approach and adopted the radial division method only when it broke down, in exactly the same way as the bar chart emerging from a failure to produce a time-series chart.

3. Vertical sticks are used to show two quantities: the population in millions represented by a stick to the left of a circle and read using the scale on the left; the budget in millions of pounds sterling represented by a stick to the right of a circle

and measured using the right-hand scale. The tops of the pair of sticks for each country are joined with a sloping line. Playfair mistakenly thought that the gradients of these lines would give a measure of the burden of taxation on the individual, the steep positive gradient for Britain for example highlighting just how heavily the British were taxed. In fact, a direct comparison of these lines, one country to another, is not possible because each gradient is affected by the radius (and hence the area of the country), so there is some fudging of the issue here.

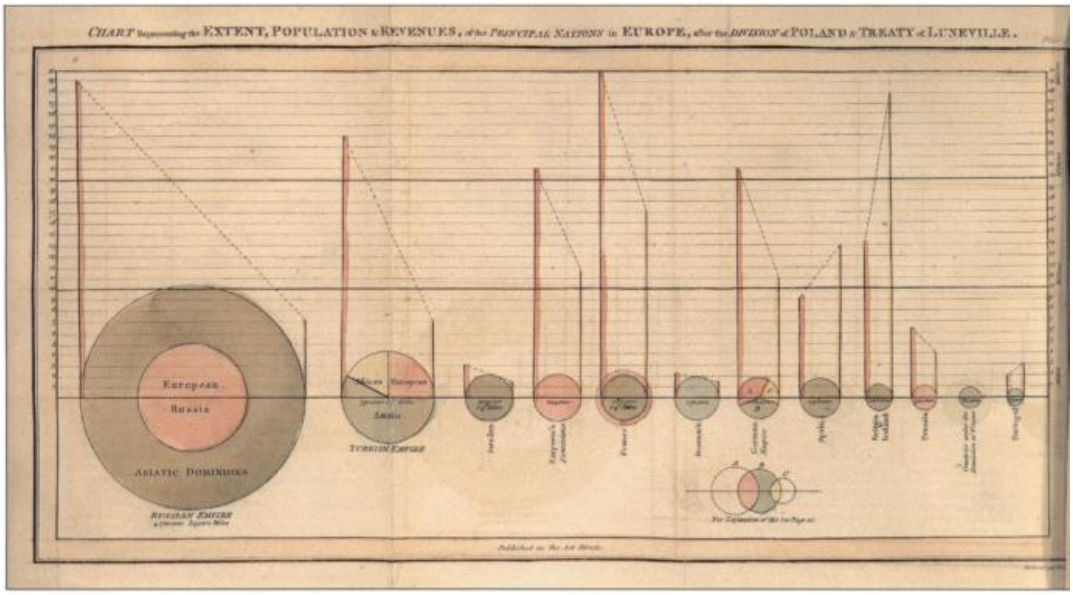
The first 48 pages of the book survey the historical picture of fourteen states in detail and allude to another twelve. But in the years since the publication of the *Atlas*, Europe had been in turmoil, the French Revolution itself spilling out into neighbouring countries, the rise of Napoleon and the prosecution of a pan-European war. So while it is possible that it was always Playfair's intention to finish the study at that point, changing circumstances made that impossible. The book was simply brought up-to-date with a further five pages and one plate on the changed state of Europe and an addendum on India (termed Hindustan, Persian for the 'lands of the Indus') and more specifically, British India.

Anticipating Venn diagrams

While Playfair was writing the *Breviary*, the fighting in Europe was still in progress. Napoleon continued to conduct the Revolutionary Wars (specifically, the War of the Second Coalition) against Austria, Russia, Turkey, Britain and other countries. But the Austrians, defeated at the Battle of Marengo, sued for peace and so whilst the British fought on, under the Treaty of Lunéville in February 1801, the Austrians were stripped of territory in Germany and Italy, and the Holy Roman Empire (bounded by the red outline in the French map below) withered towards secularisation.

By Tinodela - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=4611703

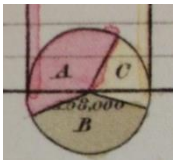
So Playfair included an updated chart on page 48 towards the end of the main section of the *Breviary* to include the Lunéville settlement.

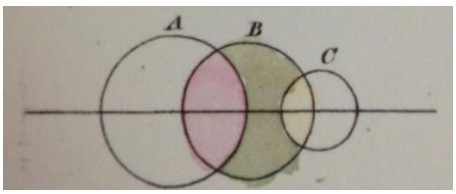


Here there is an additional pie chart for Germany. Playfair wrote (p. 50):

> … the most interesting situation exhibited is that of the German empire; for in the first place it is diminished in extent; it is in the next place so situated politically that all its internal unanimity is destroyed from the necessary and natural operation of opposite interests.
>
> That empire may be considered as divided into three parts, Austria, Prussia and Other German Princes, which make three bodies with different rather opposite interests. To illustrate this, the three circles A, B, and C, are

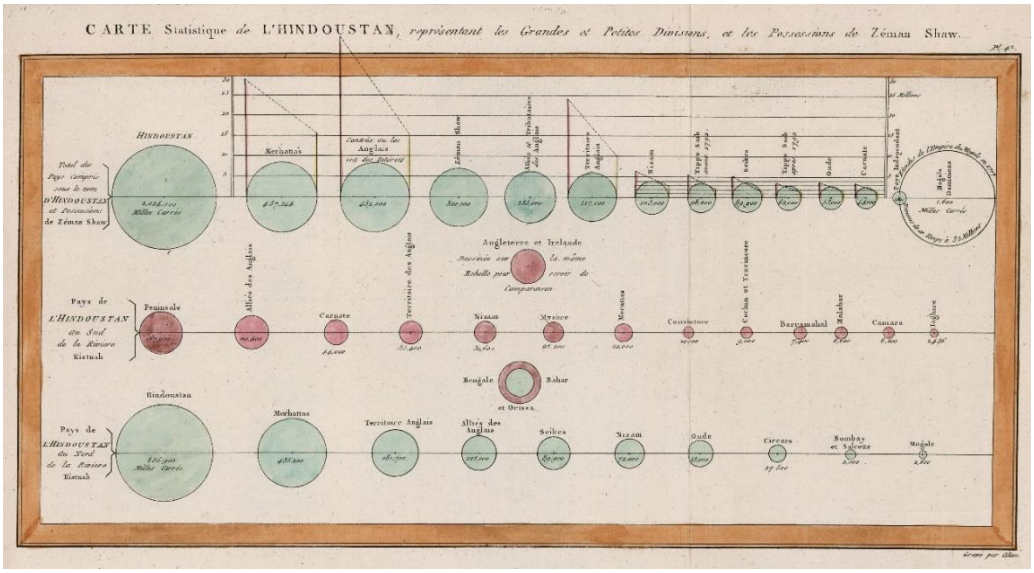
drawn intersecting each other. The circle A represents the German empire as it now is in its full extent. B represents the dominions of the emperor, and C the dominions of Prussia. The red part shows how much of the empire belongs to the house of Austria; the yellow portion represents what belongs to Prussia, and consequently the green, which is all that remains to the other princes, is what may alone truly be called the German empire.





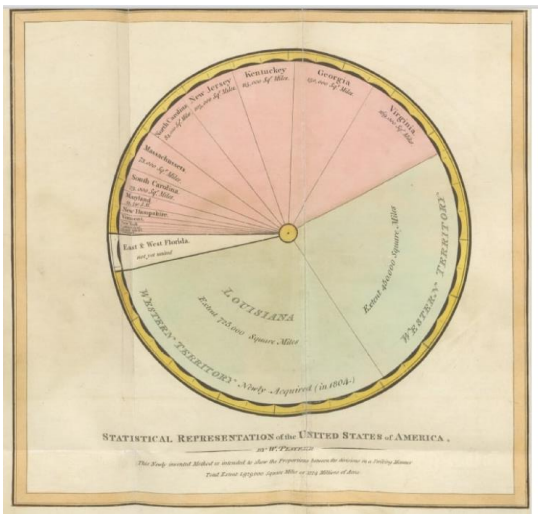
The figure above shows the relevant parts of the chart in greater detail. So while the three land areas in the pie chart are by necessity disjoint, the interests of the three parts overlap, so that A and B have shared interests, B and C have different shared interests and A and C have no shared interests at all. The intersecting circles figure has been likened to the later Venn diagram and perhaps not unreasonable because it shows relationships with carefree attention to scale; they are simply representational. Notice that the sloppiness of the shading here supports the hypothesis about the need to abandon concentric circles for subdivision into three or more parts.

The *Breviary* was quickly translated into French by Denis-François Donnant, Secretary of the Société Académique des Sciences. This 1802 volume includes a statistical chart of Hindustan, with no pie chart but another annulus diagram and another intersecting circles diagram.



(David Rumsey Map Collection, Stanford Libraries; Creative Commons License 3.0)

Donnant had enhanced what Playfair had done by including data relating to the USA, and so Playfair translated Donnant's work back into English as *The Statistical Account of the United States of America* (1805). Its full title finished with 'illustrated by a divided circle … by a new method, engraved and illuminated'. This was Playfair's pie chart, drawn to show the areas of the states in relation to each other and to the country as a whole, and making plain the effect of the Louisiana Purchase from France just two years earlier. The book was dedicated by Playfair to Thomas Jefferson whom he'd met in Paris years before and who had just begun his second term as the third US President. He sent him 25 copies, one of which was passed on to Humboldt.



Going beyond Adam Smith, anticipating David Riccardo, promoting education for women

Playfair's book of 1805, *An Inquiry into the Permanent Causes of the Decline and Fall of Powerful and Wealthy Nations*, was the culmination of his most ambitious project. In his review of Playfair's works, Jonathan Sachs explains how the book is linked to Adam Smith's *Wealth of Nations* (1776) and Edward Gibbon's *Decline and Fall of the Roman Empire* (1776–1788), the title obviously nodding in those directions. Essentially he analysed how countries become poor, rather than how they become rich. Playfair argued that if economic data were gathered and suitably displayed so that trends were apparent, any signs of decline in a nation could be measured and corrective measures taken. The policy of extending a country's territories through conquest should be abandoned in favour of developing its commercial strengths. Sachs believes the book constitutes the 'first attempt at a general and comparative theory of the rise and fall of nations'. It contains the idea of 'comparative advantage', a concept in economics to which David Riccardo's name is attached despite Playfair's priority. It also emphasised the need for entrepreneurs, that they would emerge only through education, and since the education of the young was largely in the hands of women they themselves must be educated to a good standard. Playfair argued that girls should be educated to the age of thirteen or fourteen. A selection of quotes from the *Inquiry* (pp. 99-101) will give a flavour of his views:

> When they become wives and mothers, when the economy of the family, and the education of the younger children depend chiefly on them, they are then of very great importance to society. Their conduct in that important situation must be greatly influenced by their education.
>
> Female education ought then … to be attended to in the same manner as the education of youth of the other sex.
>
> There is too much pains taken with adorning the person, and too little with instructing the mind.
>
> If the women of a nation are badly educated, it must have a great effect on the education of their sons.
>
> The great general error consists in considering the woman merely in her identical self, without thinking of her influence on others.

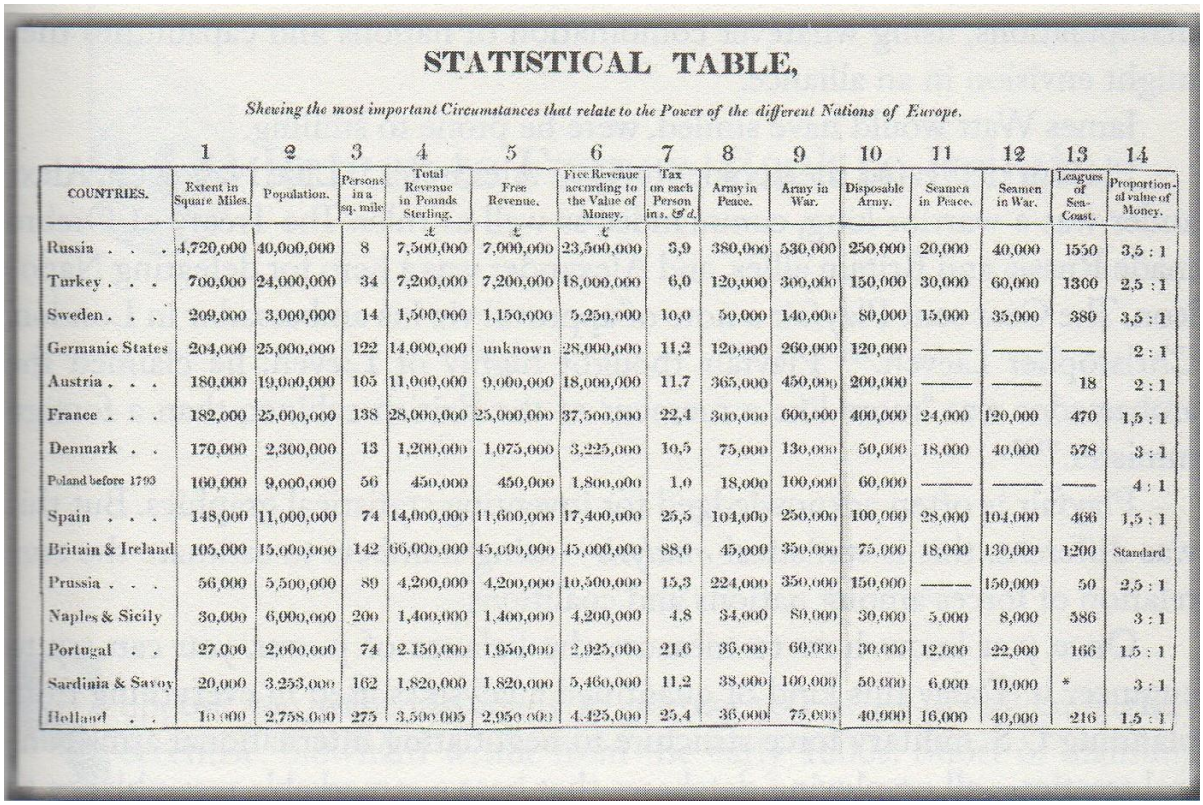
To Playfair, this was economics, not emancipation, though it perhaps had a small role in what was to become a movement later in the nineteenth century.

Invention of strategic studies and a missed opportunity

Playfair lived in times of huge social and political upheaval, of countries moving from war to war, of boundaries drawn and redrawn. Attracted by David Hume's concept of a 'balance of power' amongst nations, in 1813 Playfair tried to establish whether such a balance could be elicited from statistics. He saw an imbalance of power such as that which led to Napoleon's exploits to be like water in turmoil and a balance of power as a calmer and hence desirable equilibrium. Here, he appears to have been let down by his approach for, strangely, instead of displaying his data in a suitable chart, he provided the data without a supporting diagram. The table (shown on the next page) is in his *Outlines of a Plan for a New and Solid Balance of Power in Europe* (another incredibly rare book, a copy of which was sold at Christie's for $4750 in 2010). It gives key statistics for each of 15 countries (rows) arranged under fourteen headings (columns) — area, population, population density, various revenues, the strengths of armies and so on. A series of sectional bar charts might have displayed these data well and allowed interested parties to play with the bars to find suitable balances but Playfair already had his part-part, part-whole diagram of choice, the pie chart. And among the faults of the pie chart are its failure when there are many subdivisions and also when two or more of the subdivisions have similar magnitude, partly because length is easier than angle both to measure accurately and to judge by eye.

Let's take an example: here are Playfair's data from his 'Army in war' column, showing the numbers of soldiers each country could put in the field. The data have been reduced by a factor of 10000 and ordered:

France	60	Prussia	35	Poland	10
Russia	53	Germanic States	26	Sardinia, Savoy	10
Austria	45	Spain	25	Naples, Sicily	8
Turkey	30	Sweden	14	Holland	8
Britain, Ireland	35	Denmark	13	Portugal	6



STATISTICAL TABLE,

Shewing the most important Circumstances that relate to the Power of the different Nations of Europe.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
COUNTRIES.	Extent in Square Miles.	Population.	Persons in a sq. mile	Total Revenue in Pounds Sterling.	Free Revenue.	Free Revenue according to the Value of Money.	Tax on each Person in s. & d.	Army in Peace.	Army in War.	Disposable Army.	Seamen in Peace.	Seamen in War.	Leagues of Sea-Coast.	Proportional value of Money.
				£	£	£								
Russia . . .	4,720,000	40,000,000	8	7,500,000	7,000,000	23,500,000	3,9	380,000	530,000	250,000	20,000	40,000	1550	3,5 : 1
Turkey . . .	700,000	24,000,000	34	7,200,000	7,200,000	18,000,000	6,0	120,000	300,000	150,000	30,000	60,000	1300	2,5 : 1
Sweden . . .	209,000	3,000,000	14	1,500,000	1,150,000	5,250,000	10,0	50,000	140,000	80,000	15,000	35,000	380	3,5 : 1
Germanic States	204,000	25,000,000	122	14,000,000	unknown	28,000,000	11,2	120,000	260,000	120,000	———	———	———	2 : 1
Austria . . .	180,000	19,000,000	105	11,000,000	9,000,000	18,000,000	11,7	365,000	450,000	200,000	———	———	18	2 : 1
France . . .	182,000	25,000,000	138	28,000,000	25,000,000	37,500,000	22,4	300,000	600,000	400,000	24,000	120,000	470	1,5 : 1
Denmark . .	170,000	2,300,000	13	1,200,000	1,075,000	3,225,000	10,5	75,000	130,000	50,000	18,000	40,000	578	3 : 1
Poland before 1793	160,000	9,000,000	56	450,000	450,000	1,800,000	1,0	18,000	100,000	60,000	———	———	———	4 : 1
Spain . . .	148,000	11,000,000	74	14,000,000	11,600,000	17,400,000	25,5	104,000	250,000	100,000	28,000	104,000	466	1,5 : 1
Britain & Ireland	105,000	15,000,000	142	66,000,000	45,000,000	45,000,000	88,0	45,000	350,000	75,000	18,000	130,000	1200	Standard
Prussia . . .	56,000	5,500,000	89	4,200,000	4,200,000	10,500,000	15,3	224,000	350,000	150,000	———	150,000	50	2,5 : 1
Naples & Sicily	30,000	6,000,000	200	1,400,000	1,400,000	4,200,000	4,8	34,000	80,000	30,000	5,000	8,000	386	3 : 1
Portugal . .	27,000	2,000,000	74	2,150,000	1,950,000	2,925,000	21,6	36,000	60,000	30,000	12,000	22,000	166	1,5 : 1
Sardinia & Savoy	20,000	3,253,000	162	1,820,000	1,820,000	5,460,000	11,2	38,000	100,000	50,000	6,000	10,000	*	3 : 1
Holland . .	10,000	2,758,000	275	3,500,005	2,950,000	4,425,000	25,4	36,000	75,000	40,000	16,000	40,000	216	1,5 : 1

Playfair (1813): image taken from Berkowitz, p. 281

Could we create an approximate balance of power if there were two coalition armies, or three coalition armies? Playfair favoured a Britain-Russia alliance against France with the other countries moving from time to time as their interests changed. The Russian Tsar, Alexander I, to whom the book was dedicated, was much taken with Playfair's approach to these early strategic studies.

William Playfair's life: Part 3

Having returned to France in 1814 following the restoration of the monarchy Playfair edited an English-language newspaper but fled following a conviction for libellous, disparaging remarks resulting in a heavy fine and a three-month jail sentence that he did not serve. He also got wind of a plan for Napoleon to make an escape from exile on Elba, depose Louis XVIII and seize power once more and though he took the information directly to ministers he was not believed. Had he been taken seriously, the perilously close battle of Waterloo would not have been necessary and tens of thousands would have been saved from death or severe injury.

Playfair was also a minor figure in the Douglas Cause, a battle between Archibald Douglas and the seventh Duke of Hamilton. Actually the legal shenanigans took place in the 1760s and revolved around whether or not Douglas's sister and heir, Lady Jane Stewart, had given birth to twins at the age of 50 while in France. The matter proved of major public interest with many of the notable figures of the day expressing their opinion and the verdict led to rioting in Edinburgh. So it was that in 1816, almost fifty years later, William Playfair, once more strapped for cash, attempted to blackmail the Douglas family with the threat to publish papers purporting to prove the illegitimacy of the twins and hence of the inheritance. It was a scheme that failed, though its very existence was not revealed until 1997 (see Spence and Wainer). Clearly, Playfair was just as content to bend or even break the law towards the end of his life as he was to do so as a young man. It is no surprise therefore that in 1822 Playfair again spent several months in the Fleet. Leaving the prison with a gangrenous leg, there was little alternative to amputation but the surgery proved ineffective and he survived only a few weeks into 1823.

There are still two matters to be considered in greater detail:

- How a lad from a tiny community outside Dundee came to produce statistical diagrams. Where did the ideas come from?
- What did Playfair himself consider to be the merits of his diagrams?

Playfair's inspiration

So where did William Playfair's ideas come from and why did he call his approach 'lineal arithmetic'? Some have argued that they came from his employment at Boulton & Watt and certainly there were design features and automated pressure recordings attached to Watt's machines that could have made an impression. But if Playfair's own words are our guide on this matter, then the hand of his elder brother, the mathematician John Playfair, comes into focus, and this takes us back to where we began. The most overt reference is to be found in a footnote on page xvi of the *Inquiry* (1805):

> I think it well to embrace this opportunity … of making some return, (as far as acknowledgement is a return) for an obligation, of a nature never to be repaid, by acknowledging publicly that, to the best and most affectionate of brothers, I owe the invention of those Charts.
>
> At a very early period of my life, my brother, who, in a most exemplary manner, maintained and educated the family his father left, made me keep a register of a thermometer, expressing the variations by lines on a divided scale. He taught me to know that, whatever can be expressed in numbers, may be represented by lines. The Chart of the thermometer was on the same principle with those given here; the application only is different. The brother to whom I owe this, now fills the Natural Philosophy Chair in the University of Edinburgh.

John Playfair's research in meteorology did indeed generate a huge body of data, which was published in the *Transactions of the Royal Society of Edinburgh*; they were later quoted by Humboldt in his *Isothermal Lines and the Distribution of Heat on the Earth* (1817). And it is not at all surprising that William called it 'lineal arithmetic'.

We know that John Playfair was conversant with the writing of Richard Price, a writer on actuarial science, who was also responsible for bringing Thomas Bayes's essay of 1763 to publication. In the main part of the essay Bayes gave us Bayes's Theorem (for finding the probability of a cause from an effect) and Price appended twenty pages of examples (Stigler, 2018). John Playfair also knew of David Hartley's *Observations on Man* which alluded to Bayes's thinking prior to the publication of his ideas and he was familiar with Roger Boscovich's work, a precursor to Karl Pearson's on fitting a straight line to data (Stigler, 2018 and 1986). In short, it appears that William's elder brother had some understanding of developments in probability and statistics in the middle of the eighteenth century. William's claim that he was much influenced by his brother therefore seems completely plausible.

The advantages of statistical diagrams

Playfair's statistical diagrams, some 177 of them, were published in three clusters over 36 years (Costigan-Eves and Macdonald-Ross, p.319). From 1786 to 1801, the focus is on time-series charts to display financial information over time; from 1801 to 1805, his attention turns to novel forms, circles and parts of circles; from 1821 onwards, a return to line graphs.

The comparisons that Playfair asked his readers to make were comparisons of areas. This is obviously the case with circle charts and pie charts but not so obvious when it comes to time-series charts. But his use of colour or other shading (stippling or hatching) between lines is designed to draw the eye to those regions of the graphs rather than to the lines themselves. It is the shape of the region which impresses on the eye; as we scan from left to right (the passage of time) is the region narrowing or widening.

Playfair gave a number of advantages of using statistical diagrams and by and large, here, we are following the research findings of Costigan-Eaves and Macdonald-Ross (1990). The main four are shown below with examples:

1. Speed of interpretation and attractiveness of learning

   > '… no study is less alluring or more dry and tedious than statistics, unless the mind and imagination are set free to work' (*Breviary*, p. 16).
   >
   > 'Men of great rank, or active business, can only pay attention to general outlines, nor is attention to particulars of use, any farther than they give a general information … with the assistance of these Charts, such information will be got, without the fatigue and trouble of studying the particulars of which it is composed' (*Atlas*, 1786, p. 4).

2. Ease of interpretation

   > 'Information, that is imperfectly acquired, is generally as imperfectly retained; and a man who has carefully investigated a printed table, finds, when done, that he has only a very faint and partial idea of what he has read; and that like a figure imprinted

on sand, is soon totally erased and defaced. The amount of mercantile transactions in money, and of profit or loss, are capable of being as easily represented in drawing, as any part of space, or as the face of a country; though, till now, it has not been attempted. Upon that principle these Charts were made; and while they give a simple and distinct idea, they are as near perfect accuracy as is any way useful. On inspecting any one of these Charts attentively, a sufficiently distinct impression will, be made, to remain unimpaired for a considerable time, and the idea which does remain will be simple and complete, at once including the duration and amount' (*Atlas*, 1786, pp. 3-4).

'… tables are by no means a good form for conveying such information … I can see no kind of advantage in that sort of representation …' (*Breviary*, Preface).

3. Appeal to the eye

'As the eye is the best judge of proportion, being able to estimate it with more quickness and accuracy than any other of our organs, it follows, that wherever relative quantities are in question, a gradual increase or decrease of any revenue, receipt or expenditure, of money, or other value, is to be stated, this mode of representing it is peculiarly applicable; it gives a simple, accurate, and permanent idea, by giving form and shape to a number of separate ideas, which are otherwise abstract and unconnected' (*Atlas*, 3rd edition, p. x.).

'… making an appeal to the eye when proportion and magnitude are concerned, is the best and readiest method of conveying a distinct idea' (*Breviary*, p. 4).

In the expanded introduction to the third edition of the *Atlas* Playfair explains on p. xi his 'lineal arithmetic' by invoking an imaginary merchant who is paid exclusively in guineas, the standard gold coin until 1816. If he were to stack his guineas for one day, then append stacks on subsequent days until there was a straight line of such stacks shoulder to shoulder, then, he wrote, 'lineal arithmetic … is nothing more than those piles of guineas represented on paper, and on a small scale, in which an inch (suppose) represents the thickness of five millions of guineas'.

4. Increased efficiency of learning

'Whatever presents itself quickly and clearly to the mind, sets it to work, to reason and think; whereas, it often happens, that in learning a number of detached facts, the mind is merely passive, and makes no effort further than an attempt to retain such knowledge' (*Breviary*, 1801, p.7).

'The advantages proposed by this mode of representation, are to facilitate the attainment of information, and aid the memory in retaining it: which two points form the principal business in what we call learning, or the acquisition of knowledge' (*Breviary*, 1801, p.14).

Playfair was also aware of how statistical diagrams could be designed to mislead. In the first edition of the *Atlas* he wrote 'As to the propriety and justness of representing sums of money, and time, by parts of space, tho' very readily agreed to by most men, yet a few seem to apprehend there may possibly be some deception in it, of which they are not aware ...' (*Atlas*, 1786, iii). Written in this way it is difficult to know whether he is saying that some people have seen his graphs and are wary of their veracity or that he knows how to tweak a scale for example to bring out, even exaggerate, a particular feature.

Remembering William Playfair

After his death, Playfair's rather colourful life was repainted uniformly black, starting with the journalist John Goldworth Alger (1836–1907). In a number of publications, including the *Dictionary of National Biography*, Alger dismissed Playfair as a complete rogue and critically for our story made no mention of statistical diagrams. This judgement and this omission went largely unchallenged until 1983 when Edward Tufte propelled Playfair's reputation upwards. The biographer, Bruce Berkowitz, believes that Playfair's reputation as a rogue is exaggerated, his work as an agent of the British government understated (secrecy is central to tradecraft, after all) and his contribution to statistical and economic graphics without par. He notes that there is no image of William Playfair, either in portrait or statue, that he lived a most interesting life never far from penury, and it was that financial insecurity that drove him forward.

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