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The radiant diagrams of Florence Nightingale

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Abstract

This article is a tribute to the contributions of Florence Nightingale to statistics and statistical graphics on her bicentennial. We start with her most famous "rose" diagram and describe how she came to this graphic, designed to influence medical practice in the British army. But this study takes us backward in time to consider where and when the ideas of radial diagrams arose, why they were useful, and why we call these her "radiant diagrams."

MSC: 62-03, 62-09.

Keywords: Data visualization, polar area diagram, radial diagram, nursing, sanitation.

Introduction

This article is a celebration of Florence Nightingale (FN), on the slightly belated occasion of the 200th anniversary of her birth on May 12, 1820, but in time for the *International Year of Women in Statistics and Data Science: A Tribute to Florence Nightingale*, being promoted by many statistical societies worldwide. In her time, she achieved prominence as a reformer of hygiene in hospitals and medical practice, motivated by her experience in the Crimean War. She became known as the "Lady with the Lamp"[1] and is today considered the mother of modern nursing. Mobile Army Surgical Hospitals (MASH units) are part of her legacy, recounted in the eponymous TV series.

However, it is her pen rather than her lamp we pay tribute to here. Following her time in the Crimea, she launched a campaign to further the cause of army hospital reform and wielded impressively detailed data and radiant diagrams to convince those with influence in the merit of her cause. The lady with the lamp became a "passionate statistician."[2]

In the popular appreciation of FN's statistical work, she is most well-known for the singular *Diagram of the Causes of Mortality in the Army of the East* that appeared in 1859 (Figure 1).

1. This phrase comes from an 1857 poem by H. W. Longfellow: "Lo! In that house of misery / A lady with a lamp I see".

2. This phrase is attributed to Edward T. Cook's 1913 biography, *The Life of Florence Nightingale*. Her biography as a statistician is told by Kopf (1916).

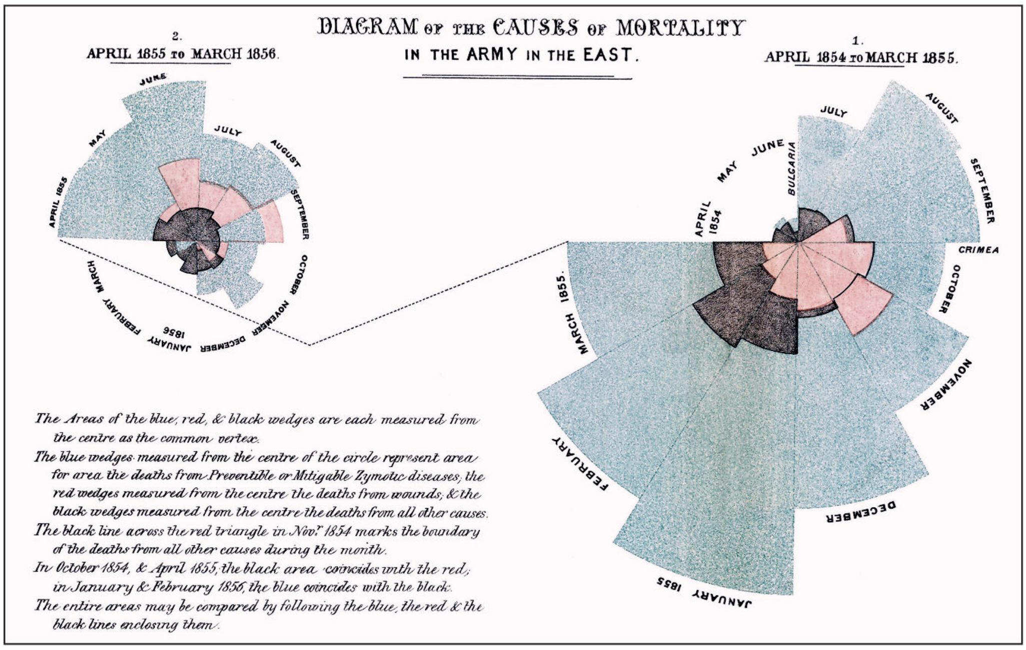

Figure 1: *Nightingale's radial diagram of mortality, showing the number of deaths from preventable zymotic diseases (outer, blue wedges), compared wtih deaths from wounds (pink), and from all other causes (dark gray). Source: Nightingale (1859, p. 19).*

The full story of her contributions to visual design and graphic rhetoric is fascinating (Andrews, 2019; Brasseur, 2005) but would take us too far afield from this brief tribute. Rather, we focus on the historical antecedents of her radiant radial diagram, some steps that led her to this, and other diagrams that followed her inspiration.

Life and career

Nightingale was born to a wealthy, landed British family. As a young girl, she exhibited an interest in and flair for mathematics, encouraged by her father, William. One of her mathematics tutors was the renowned James Joseph Sylvester [1814–1897], a contributor to the theory of matrices. Later, she was profoundly influenced by reading Adolphe Quetelet's 1835 *Sur L'Homme et le Developpement de ses Facultés*, in which he outlined his conception of statistical method as applied to the life of man. She also felt a strong religious calling to the service of others, and against her mother's strenuous objections, she decided that nursing would be her vocation.

The Crimean War

The Crimean War was fought by Russia against the forces of France, Britain, and the remnants of the Ottoman Empire. It began in October 1853, over disputed claims of the rights of Roman Catholics vs. the Eastern Orthodox Church, and lasted until February 1856. Press reports from the war zone soon enraged the British public. These accounts listed high death tolls and descriptions of dying patients crowded on floors of blood-soaked straw, with vermin-infested laundry. In short, the field hospitals were killing British soldiers faster than the enemy. Blame was placed on the government and the military.

The British government knew it had to react. In October 1854, Nightingale appealed to her friend Sidney Herbert, secretary of state for war, to send her and a team of nurses to the Crimea. She soon recognized that most of the deaths occurred, not from battle, but from preventable causes: zymotic diseases (mainly cholera) and insufficient sanitary policy in the hospitals that treated the soldiers.

The Sanitary Commission

Nightingale was more appalled by what she witnessed in the Crimea than what she had read in the newspapers. She developed a system to keep meticulous records of the causes of mortality among the British troops. Her initial attempts to understand these data through tables and charts led to shocking comparisons: deaths in the first seven months of the Crimean campaign amounted to an annual 60% mortality from disease alone. This exceeded that of the Great Plague in London (1665-1666) and that of cholera epidemics in 1848 and 1854. Following her persistent requests to the War Office, a Sanitary Commission was formed around April 1855 to investigate the causes of high mortality of the British Army in the Crimea.

The Royal Commission

After her return to England in July 1856, Nightingale pressed the government (with some support from Queen Victoria) to establish a Royal Commission to examine the causes of mortality in the army. She submitted a report with many tables and concrete proposals for reform, but little was done. How could she turn her insight from experience and data into a powerful call for action?

She met and was befriended by William Farr, the chief statistician of the General Register Office (G.R.O.) established by Parliament to track births and deaths. Farr had become influential in reporting on deaths due to cholera (Farr, 1852), and became an advocate for the careful use of data toward the goal of improving the health of the nation. Farr and Nightingale worked together to access and organize data from the Crimea, systematically analyze it with the help of Farr's team of G.R.O. clerks, and produce persuasive arguments in the form of a series of publications with corresponding text, tables, and diagrams. Farr was an accomplished presenter of statistical "reports." Nightingale elevated their collaborative craft to new heights with her infectious motivation to persuade the British government to adopt sweeping reforms to the entire treatment of soldiers. She said, "The main end of Statistics should not be to inform the Government as to how many men have died, but to enable immediate steps to be taken to prevent the extension of disease and mortality." (Nightingale, 1858a, p. 329).

Compared to what?

Nightingale's most celebrated diagram (Figure 1) was just one of several attempts by her and others to portray the deaths among British soldiers in the Crimea in a way that would capture attention of her readers and provide motivation for a call to action. To understand her graphic design, one key rhetorical question that permeates this work is "compared to what?"[3] She broke new ground here in several interesting ways.

Initially, she had just total mortality data, month by month in selected field hospitals of the East. But, how could she make these results most dramatic? For reasons we describe below, she employed what we would now classify as a "radial, polar area chart". Unlike a pie chart, which uses sectors of varying angle and equal radius to show amounts, FN's diagram in Figure 1 uses wedges of equal angle (for the months) and varying radius to portray deaths. Nightingale had no particular name for this chart form, but it is common and acceptable to call them "rose diagrams"

Perhaps the most striking feature of her design of this diagram was the separation of the months into two charts, one (on the right) for the period April 1854-March 1855 and the other for April 1855-March 1856. She could have placed the data for all 24 months in one chart, but her design makes a direct comparison of the deaths before the arrival of the Sanitary Commission with those after. Just a pre-attentive, millisecond glance shows the great difference in size (deaths) between the two portions.

A small puzzle is the arrangement of these two pieces. Normally, one would draw the before/after portions left to right, and in each piece, the initial month would be drawn at 12:00 or 3:00. But this made it more difficult to connect the data for March 1855 with that for April, the following month. Her right-to-left design, starting each diagram at 9:00, made it easier to connect these adjacent months with a dotted line.

FN's earlier attempts

We now consider how Nightingale arrived at the well-known diagram of mortality shown in Figure 1. She had seen a polar diagram in William Farr's 1852 report on potential causes of mortality due to cholera and was much impressed. In this (Figure 2) he drew circular diagrams showing weekly temperature and cholera deaths in London over the period 1840-1849, as if to establish some link between the two. This kind of chart is sometimes called a *radar chart* today. It uses annular rings with radii proportional to the a given measure; alternatively: a time-series line graph in polar coordinates, where the radial lines serve as axes for the 52 weeks of the year.

3. JW Tukey quote: "The purpose of [data] display is comparison (recognition of phenomena), not numbers. . . "

Figure 2: *Farr's radial diagram of temperature and mortality in London by week for the years 1840-1850. The yearly charts are arranged row-wise from 1840 at the top left. The chart at the bottom right corner shows the average over the years 1840-1849. Outer circles show weekly deaths; inner circles show weekly temperature. Source: Farr (1852), plate IV.*

The outer charts show average weekly deaths, relative to the mean over all years, shaded black when they exceed the average (excess mortality), and yellow otherwise. It was immediately apparent that something horrible had happened with cholera deaths in London in the summer of 1849 (row 3, column 2). But cholera deaths had also spiked in the winter months in 1847 (row 2, column 3).

Farr was searching for easily found associations with cholera mortality here. No direct link to temperature or other factors that he tried (e.g., elevation above the Thames) could be found, until John Snow (1855) argued for a water-born causative agent. But for FN, this radial diagram form seemed exciting and novel; something she could use to make her case.

The Bat-Wing Diagram

Nightingale was impressed enough with Farr's use of a radial diagram to adopt this form for her own data. In her first version (Figure 3), printed privately for the Secretary of War

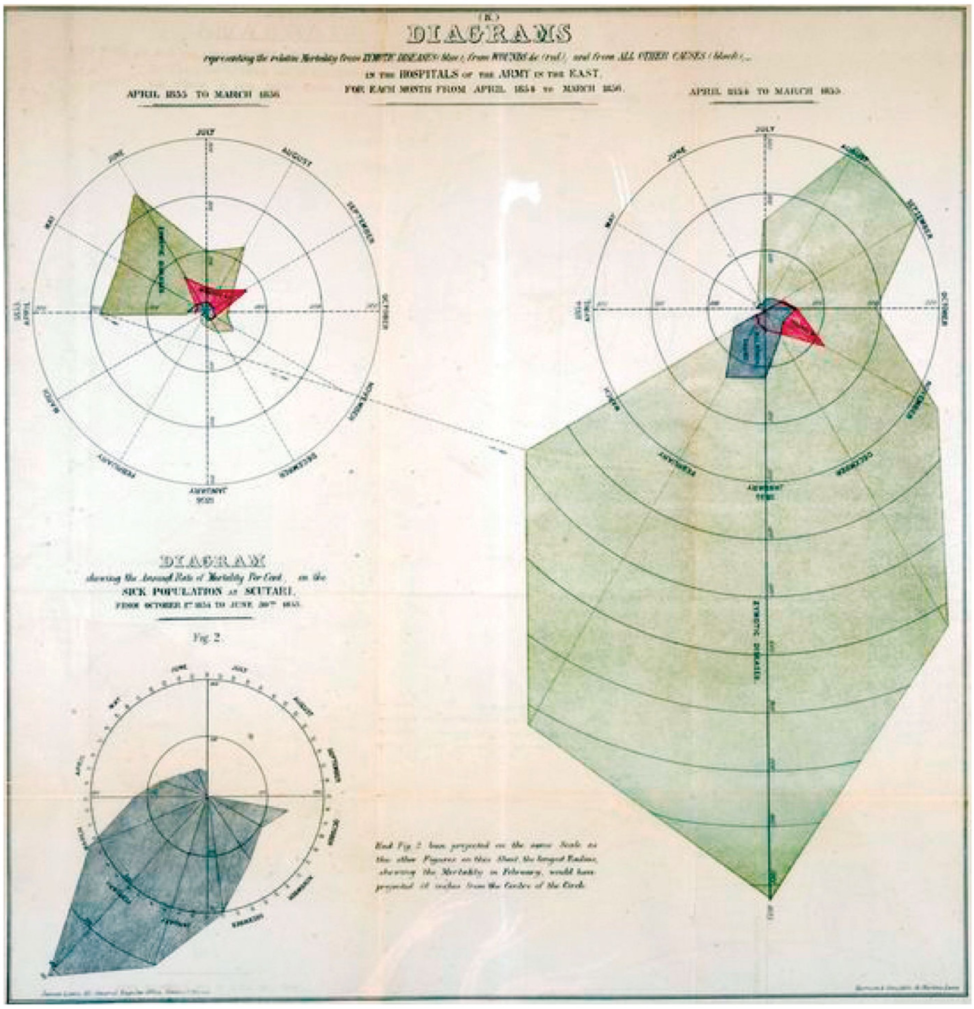

Figure 3: *Initial design of Nightingale's diagram, using a linear scale. The two diagrams at the top show relative deaths from zymotic diseases, wounds (red) and other causes (black). The bottom left diagram shows the annual rate of mortality at Scutari from October 1854 to June 1855. Source: Nightingale (1858b, Diagram K, p. 47).*

in 1858, she followed Farr's design, which plotted deaths on a linear scale (of deaths per 1000) as distances from the origin, with radial axes corresponding to 100, 200, 300, ...

What she saw here was beyond astounding. The deaths from preventable causes (zymotic diseases) totally swamped those from battle wounds or other causes, and totally dominated the scale. In her Fig. 2 at the bottom left in our Figure 3, she shows the annual rate of mortality in the sick population of Scutari, where the fraction reached 415% in February by her calculations. Here she notes, "Had Fig. 2 been projected on the same scale as the other figures on this sheet, the longest radius, showing the mortality in February, would have projected 40 inches from the centre" (Nightingale, 1858b).

She quickly realized that although the data were correct, this graph was deceptive, because the eye tends to perceive the area rather than length in such displays: doubling the death rate would give a perceived area four times as large. In her subsequent versions, Nightingale plotted deaths in each month as the square roots of distance from the center, so the **area** of each wedge reflected the number of deaths. It is easily seen that deaths from preventable diseases (the outer blue wedges in Figure 1) totally dominate those from battlefield wounds and other causes. This was yet another aspect of her graphical insight that "compared to what" meant that meaningful comparisons had to be on a reasonable scale.

The Manchester Rose

In other earlier versions, Nightingale tried different definitions of "compared to what," to make her argument salient. Figure 4 is stylistically similar to Figure 1, except that the smaller dotted circles represent "what the mortality would have been for the whole year if the army had been as healthy as men of army age are in Manchester, which is one of the most unhealthy towns in England" (Nightingale, 1859). Her goal here, as in other versions, was to shock the viewer: compared to even Manchester, the army in the East was suffering unfathomable losses.

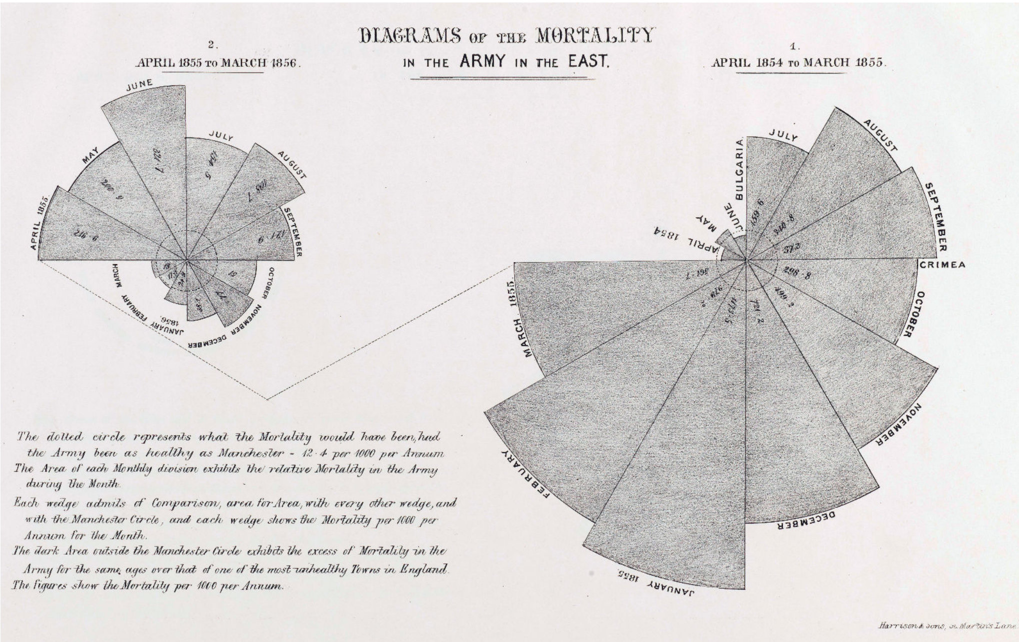

***Figure 4**: Diagram of the mortality in the British Army in the east during April 1854 to March 1855 (right) and April 1855 to March 1856 (left) in comparison to that of Manchester, represented by the circular dotted line. Source: Nightingale (1859), p. 320.*

Radial diagrams before FN

We described earlier how the immediate stimulus for Nightingale's use of radial diagrams developed from what she learned from Farr (Figure 2) and how she discovered that such diagrams were more perceptually accurate when counts of deaths were presented on a square root scale, so that wedges had areas proportional to the count (Figure 4). But while Nightingale is often credited as the inventor of such charts, it is useful to consider earlier origins.

Guerry's Cycles

As we have argued elsewhere (Friendly, 2007, 2007b), the earliest direct precursor of Nightingale's rose diagram appeared in an 1829 publication by André-Michel Guerry. His goal here was to try to determine if relationships among meteorological variation and physiological phenomena could be found by graphical means; but particularly to show how these could be represented as cyclical phenomena, over months of the year, hours of the day, days of the week and so forth.

Weather phenomena included wind direction, temperature, days of thunder, frost, rain, snow, etc. Physiological phenomena were comprised of various causes of admission to hospital. He also included data on weddings, mortality, suicides by month, and hourly data on births and deaths.

Figure 5 shows the portion of his diagram using the radial wedge form to show average trends for some periodic phenomena at different scales; he called these "courbes circulaires," meaning he saw them as curves wrapped around a circle. The top row here shows average wind directions for four quarters of the year, using the conventional compass orientations. He says:

> *We have represented by these circular areas, and from the observations of 9 years, the number of days that the various winds blow in Paris during a three-month period... According to popular opinion, the south winds prevail especially in summer, northerly winds in winter. We see that the exact opposite is happening.*

This establishes his idea that diagrams of cyclical phenomena can reveal consistencies not easily seen in tables. Graphical methods were still on the rise in 1829. To cite an authority, and frame his study in a wider context, he quotes von Humboldt's (1813) memoir on finding lines of isotherms.

> *The use of graphic means will throw a lot of light on phenomena of the highest interest. If, instead of geographical maps, we had only latitude, longitude and height coordinates, a large number of curious relationships offered by*

the configuration and inequality of the continents would have remained forever unknown.

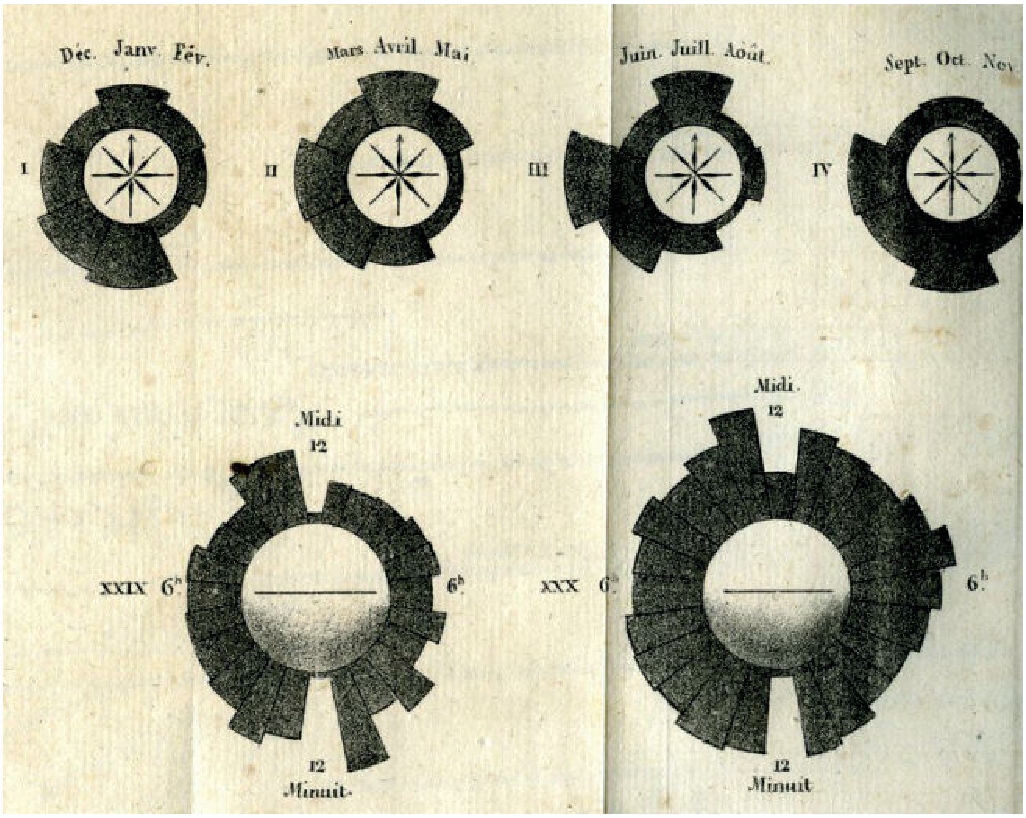

Figure 5: *Guerry's radial charts of cyclical phenomena. The top row, charts I.-IV. Show the averages of prevailing wind direction by circular area over 9 years according to compass directions. The bottom row, charts XXIX and XXX show, respectively the number of births and deaths over hours of the day. Source: Guerry (1829).*

The bottom row in Figure 5 illustrates how he thought that circular diagrams of compass directions could be generalized to other domains. These charts (XXIX and XXX) show variations in births and deaths. He says:

Since the diurnal period represents in some respects the annual period, we have sought if, as with the seasons, there would not be, for some hours, greater ease of births or deaths.

As far as we are aware, this is the first general statement of the graphical principle of radial diagrams for cyclical phenomena, using wedges of constant angle and varying radius.

The French Connection: Guerry → Farr

The link from Farr to Nightingale is clear, but the question arises whether Farr had gotten inspiration for radial diagrams from Guerry. The historical evidence suggests that this is highly likely, though uncertain. What follows is a reasonable account based on our knowledge.

In the early 1800s, following the societal chaos after Napoleon's 1815 defeat, a new idea of "social medicine" or "social epidemiology" began in France (Pinell, 2011). Some leading proponents were Alexandre Parent du Châtelet, Louis-René Villermé and Benoiston de Chateauneuf. In 1829, they launched a new journal, *Les Annales d'Hygiène Publique et de Médecine Légale,* and Guerry published his study in their first volume.

This journal soon became a hub of professional exchange for anyone in the country interested in what was called social hygiene but had a broader scope. It is known that Farr received a bequest in 1828, studied medicine in France and Switzerland, and most likely struck up a friendship with Guerry through the network of the *Annales d'Hygiène Publique.*

Guerry (1833) published his *Essai sur La Statistique Morale de la France,* for which he won the prestigious Moynton Prize upon the recommendation of the Académie Française. In this, Guerry argued that the relations among social and moral variables (literacy, crime rates, suicide, etc.) could be understood using graphs and shaded (choropleth) maps. More importantly he asserted that lawful relations among moral variables could be found, analogous to those of physics. Within a short period of time, this work attracted considerable attention in European statistical circles and Farr was among his admirers.

Guerry's final and most ambitious work was a comparative study of moral variables in England and France which appeared in 1864. Farr is acknowledged for having helped him in obtaining access to court records and other documents in England. In the 30 years between these two works, Guerry displayed his maps and charts in several expositions in Europe. In 1851, he had two exhibitions –an honored public one in the Crystal Palace at the London Exhibition and a second one at the British Association for the Advancement of Science (BAAS) in Bath, England. By October, 1864, Guerry had been made an honorary member of the Statistical Society of London, and was invited again by Farr to attend the BAAS meetings. The *Statistique Morale de l'Angleterre...* (Guerry, 1864) and its splendid plates were put on public display for the nearly 2800 members who attended, and became the subject of a public commentary by W. Heywood, vice-president of the Society.

Farr was not a graphic innovator, but he was tuned-in enough to recognize useful graphical methods and apply them in his work. It is quite likely that his radial diagrams (Figure 2) were inspired by Guerry, and perhaps Léon Lalanne, considered next.

Lalanne's Winds

Another French connection was Léon Lalanne, an engineer of the École Nationale des Ponts et Chaussées (along with Charles-Joseph Minard). Lalanne made several innovations in graphical methods, but the one of interest here is his polar area plot of wind directions (Figure 6). This figure shows the average relative frequency of wind directions recorded at Aigue-Mortes in Occitanie, France over some period of time.

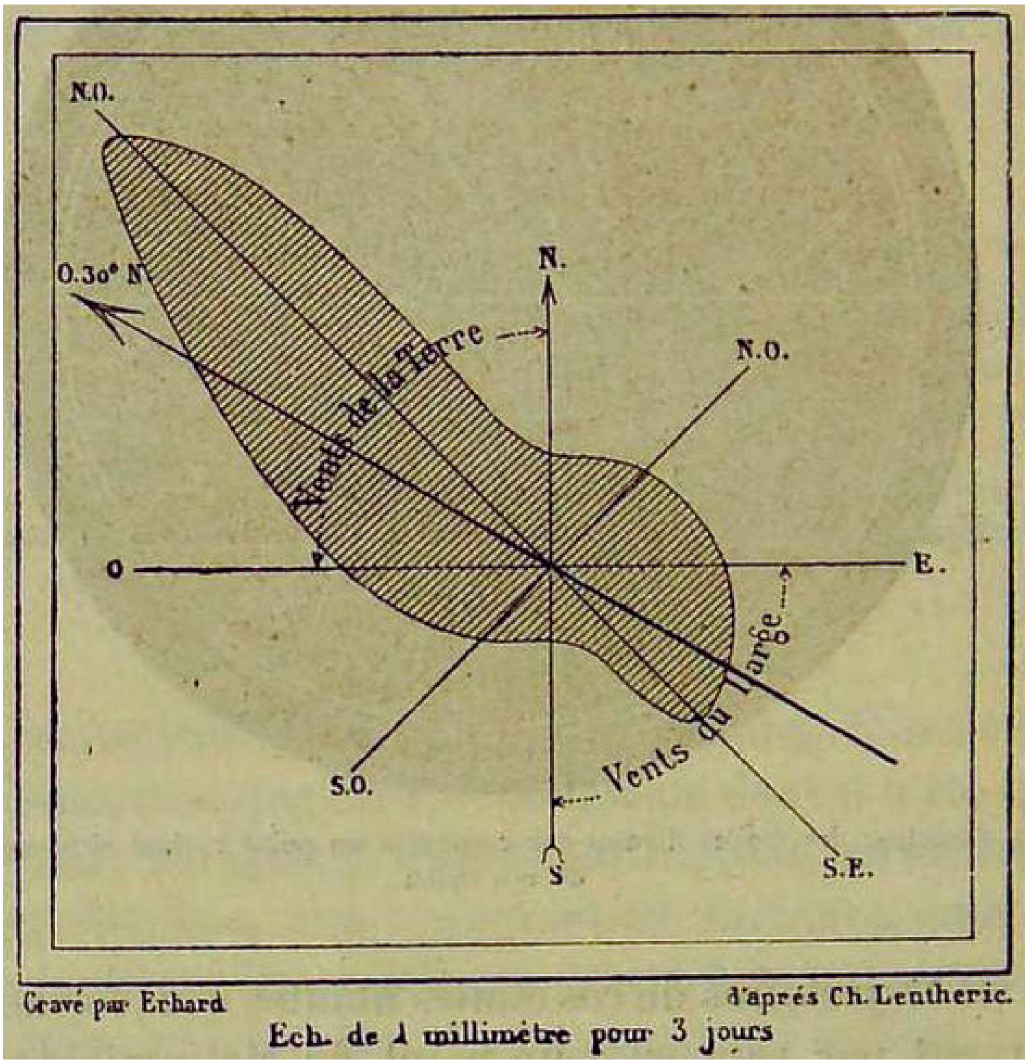

Figure 6: *Average prevailing wind directions at Aigue Mortes. The NW quadrant is considered land winds; the SE quadrant, sea winds. An arrow labeled 0.30° N is apparently the average overall wind direction. Source: originally from Lalanne (1843); this rendition from Marey (1885, Fig. 31, p. 68).*

He draws attention to compass directions with primary N-S, E-W axes, and adds secondary axes, NW-SE and NE-SW. But the main message is what he has discovered from this diagram: Winds that blow primarily in the NE quadrant he considers land winds (in the direction toward land). Winds that blow toward the SE quadrant are sea winds. An overall average is shown by a large arrow labeled 0.30° N.

What is remarkable here is that the shaded contour is really a smoothed representation of the data and represents another level of sophistication in radial diagrams: a level-curve (iso-contour) of circular data. Earlier, Lalanne had used polar diagrams to display the frequency, duration, and direction of winds over the months of the year near Calcutta, India. The data for individual years were quite variable, but he recognized (following von Humbodlt's (1813) isothermal diagrams) a more general principle, that such level curves could be found for other coordinate systems.

> *The difference consists merely in that the isothermals are applied to points, the existence of which on the surface of the terrestrial globe is real; whilst the curves of the equal duration of the winds in the same place, during the different seasons of the year, are applied to points, whose position on a plane, or a sphere, or a cone, has been determined by pure convention, by a particular choice of co-ordinates to represent two variable elements [p. 514].*

Antecedents of polar diagrams

Circular diagrams go back to antiquity, first with spatial directions for an observer of the sun and stars, and later for compass charts, based on a circle of 360°. Fractions of (0:3) * 1/4 easily corresponded to N, E, S, W. Intermediate fractions of 1/8 gave NE, SE, SW, NW. Half-way between these gave NNE, NNW, etc. A navigator could always use direct degrees for a compass heading. Wind directions could be referenced in the same coordinates.

Similarly, the idea of a 24-hour day goes back at least 4000 years, with 12 sections for the night marked by stars that rose and fell, and an equal number of sections for the day. As mechanical clocks developed after the 13^{th} Century, a double 12-hour clock face evolved, synchronized with noon or midday as AM (ante meridiem) and PM (post meridiem). A 12-hour clock face could be divided into 1/4 fractions (3, 6, 9, 12) or thirds (4, 8, 12).

The origin of pie charts (Spence, 2005) showing parts of a whole is usually traced to Playfair (1801), but there are earlier examples based on clock faces. Among these, the engraving by Nicolas Guérard (undated, but ca. 1700) shown in Figure 7 captures the style and intent in a graphic story illustrated by clock faces.[4]

4. We are grateful to Antoine de Falguerolles for discovering and translating this image.

Figure 7: *Clock-face drawing by Nicolas Guérard (1648?-1719) showing a circular (pie chart) representation for compositional data, namely time-budgets. The two clock shields are supposed to represent the paradise for women, and purgatory for men, with the horse in Hell. Source: https://gallica.bnf.fr/ark:/12148/btv1b8407520q.item*

A hermaphrodite rider (left: woman; right: man) rides a horse, each holding a 24-hour clock representing the way she/he spends a typical day. The content is a totally sexist, deplorable depiction of the daily life of women (left shield) vs. men (right) showing the supposed fractional composition of activities in a day by hours on a clock. Segments are labeled for women (dressing, church, promenade, . . .) and for men (different forms of work), but the main visual message is shown by the shaded sectors: 10 hours of repose for women compared with 4 hours for men. Perhaps the title: *Aujourd'hui d'une façon demain de l'autre* (today one way, tomorrow the other) can be read as a call to greater gender equality.

More radiant diagrams

Following Nightingale, the graphical idea of radial diagrams took off, but nowhere in as impressive a form as used by Émile Cheysson, in various volumes of the *Albums de Statistique Graphique*. As Charles-Joseph Minard had demonstrated earlier (Minard, 1858) in his use of pie charts as proportional symbols on a map, Cheysson saw the potential to illustrate time-varying phenomena in a spatial context to make many aspects of the data visually apparent. If we can think of Minard's pie-chart map of consumption of meat in Paris as Playfair 2.0, then surely Cheysson's wedge maps in the *Albums* can be considered Nightingale 2.0.

Paris theaters

Figure 8 is just one example, designed to show the gross receipts in theaters in Paris from 1878 to 1889, but to highlight the influence of the Universal Expositions in 1878 and 1889. Each diagram is positioned on a map of Paris, with a size proportional to the total receipts over all years. This places the diagrams for the theaters in spatial context and allows the eye to easily compare them in size and shape. Clearly, the Opéra was most popular overall, followed by the Opéra-Comique.

Within each diagram, the wedges are area-proportional to receipts in each year, highlighting the exposition years in yellow. The immediate impression is that in both Expo years, more people attended the theaters than in other years.

A rose by any other name

The history of Florence Nightingale and her radial diagrams has many stems and buds. These charts at the time were so novel for her audience that they demanded attention to her essential point: mortality in the army could be decimated by simple medical hygiene measures, just as we all wear masks today to prevent the spread of COVID.

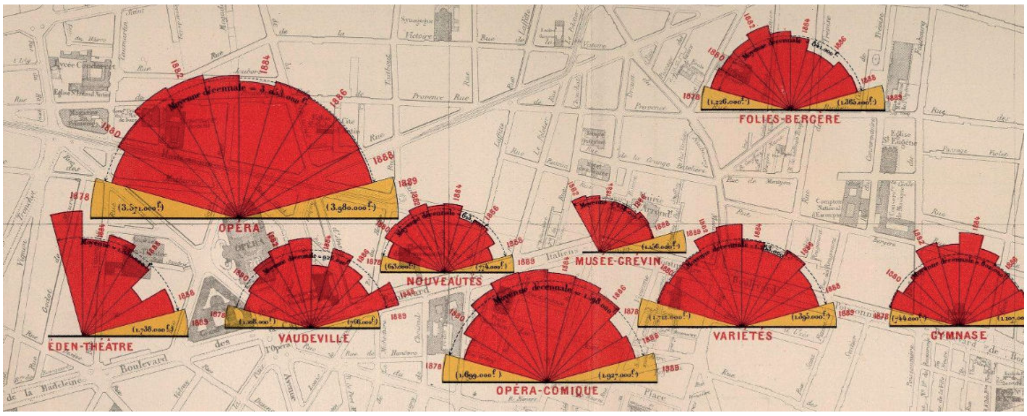

Figure 8: *A portion of "Gross receipts of theaters in Paris from 1878 to 1889" (Recettes brutes des théatres et spectacles de Paris 1878 à 1889), highlighting those in the exposition years. Source: Album de Statistique Graphique, 1889, Plate 26. https://www.davidrumsey.com/luna/servlet/detail/RUMSEY 8 1 309502 900 79343:Statistical-Diagram–VI–Exposition*

But they also seem to demand an equally iconic name. Nomenclature is one stem with multiple buds: "rose", "coxcomb", "wedge" diagram are all terms used to refer to these. None of these names have evidence in her writing that she called is such. All of these are somewhat fanciful but attest to a desire to nominate these as a new graphic form.

Here, we announce a new name: **Radiant Diagram** to celebrate FN's bicentennial and the graphic joy following her footsteps.

In case you were wondering,

- there is indeed a variety of rose called a Nightingale Rose,
- there is also a nightingale bird (*Luscinia megarhynchos*)
- in 1888, Oscar Wilde wrote *The Nightingale and the Rose*, having little to do with our subject, except for its' lovely alternative title. We might have used this, if it had not already been taken.

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