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Casting Light on

the Statistical Life of Florence Nightingale

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"Lo! in that house of misery,

A lady, with a lamp, I see

Pass thro' the glimmering gloom,

And flit from room to room."

H.W. Longfellow, Santa Filomena, 1857 [12]

This excerpt is from a poem by H. W. Longfellow, written shortly after an article was released describing the horrors of the Crimean war taking place in the Ukraine [1, p. 95]. The article described a nurse named Florence Nightingale making her way "alone, with a little lamp in her hand," through "those miles of prostrate sick." [2, p. 4] Santa Filomena, or Saint Philomena, whose name means "one who loves the moon", was about to be canonized as a Saint during the Crimean war and the comparison to Florence Nightingale's practice of caring for the sick all through the night would not have been missed among readers [1, p. 96]. Longfellow's poem greatly contributed to the iconic status of Florence Nightingale, or "Saint Nightingale" as he called her [1, p. 96]. Known as the founder of modern nursing and "The Lady with the Lamp", Florence Nightingale loved mathematics and "believed that statistics could be used to improve the condition of humanity." [3, p. 172] Her contributions to the world of numbers and her incredible determination in healthcare did just that.

While on a two year tour of Europe, a wealthy British couple gave birth to their second daughter Florence Nightingale in Florence, Italy on May 12, 1820 [3, p. 159]. During the 19th century, women didn't attend universities, so Nightingale was educated at home by her father, a man who understood the importance of education and had studied at Edinburgh, Scotland. He was well educated particularly in languages and philosophy. Nightingale had a great interest in numbers. On their family trip through Europe, "she kept a notebook to record the distance

traveled each day, the times of departure and arrival, and notes on the laws, the land systems, the social conditions and benevolent institutions of the regions they traveled through." [3, p. 159] Thus, it was no surprise that when she was 20 years old, she pleaded with her parents to "let her study mathematics instead of doing worsted work and practicing quadrilles." [9] The Quadrille was a type of French square dance that was very difficult yet extremely popular at that time. [11] According to her mother, a proper lady should be spending her time dancing and participating in social activities so as to one day be married and keep a home.

Eventually, after much prodding, her parents finally gave in to her desires and she began studying under a tutor. Nightingale's love for mathematics began to flourish and was expressed in several letters. In a letter to her sweetheart she wrote, "There is a most lovely character given of D'Alembert's the great mathematician's lightheartedness. It says that it is the exclusive privilege of the exact science [mathematics], to enjoy every day some new truth which comes to reward one's work." [9]

Her father, through his connections with many intellectuals of the time, created opportunities to be exposed to many leading scientific figures of their day which, in turn, allowed her to create relationships with numerous scholars from across Europe. Nightingale had no trouble making lasting impressions as she was very bright, well-mannered, and lovely in appearance. [4, p. 67] Her enthusiasm and determination in her work was often met with hostility from her family who had hoped she would soon be satisfied with her education and marry. After being presented to a suitor followed by a long courtship, Nightingale, to her parents' disappointment, decided that she wouldn't be satisfied by marrying and "making society and arranging domestic things." [2, p. 2] In fact, she wrote in her diary that marriage meant "to be nailed to a continuation and exaggeration" of her present life and like "suicide." Nightingale

knew that God had a different plan for her. She continued to worked tirelessly studying statistics, mainly on public health and hospitals, often during the night and morning hours so as to not neglect her family duties. [4, p. 67]

Nursing in the 1800's was not a profession of high regard. In fact, nurses were generally ill-bred women of questionable morals with little if any training that were known to partake in frequent drunkenness and promiscuity [3, p. 160]. Nightingale, however, was drawn to the profession and truly felt that she was being called by God "to help her fellow human beings" [3, p. 159]. She began to gather information on hospitals by sending out questionnaires "on health administration and duly tabulating and analyzing the returns in her bedroom" [4, p. 67-68]. She collected an impressive amount of statistical data on health and hospitals which essentially made her a professional in the field.

She accepted her first job in 1853 at 33 years old as an unpaid superintendent of an institution for the Care of Sick Gentlewomen in Distressed Circumstances, in Harley Street to which her mother "stormed, lamented and had to be given sal volatile [smelling salts]" and her sister "wept, raged, worked herself into a frenzy with hysterics, collapsed and had to be put to bed." [3, p. 161]

While she was only at Harley Street for about year, she made some incredible improvements throughout the facility. According to Bernard Cohen in his book *The Triumph of Numbers*, "She trained the nurses, saved money on supplies, straightened out the accounts, reorganized the housekeeping and cleaning, and improved the food." [3, p. 161] She also kept specific records of each patient noting their illness, treatments, outcomes, discharges and deaths. [3, p. 161] Nightingale recognized that, although keeping such detailed data of social statistics was uncommon at this time, reliable records were hard evidence that could be used to evoke

reform and also demonstrate the idea that "social phenomena could be objectively measured and subjected to mathematical analysis." [2, p. 1]

While Nightingale was exploring her call to nursing and statistics, a dispute was brewing between Russia and Turkey and British and French troops were sent to the Crimea, a peninsula of the Ukraine located on the northern coast of the Black Sea, to support Turkey. A War Office sent out a request in 1854 to take a party of nurses to Scutari Hospital. Scutari, located near the southwestern bank of the Black Sea on Bosphorus, the Istanbul Strait, was where the sick and wounded of the Crimean war were taken. Poor sanitation had become a serious issue among the patients.

During the first seven months of the Crimean war, a wounded soldier had a better chance of survival if left on the battlefield than being taken to an Army hospital. As Cohen states, "a goodly number of the expeditionary force came down with cholera, diarrhea, dysentery, and other disorders, and many died." [3, p. 162] Hospitals were absolutely unequipped, filthy, lacking in trained nurses, infested with vermin, and utterly incapable of providing successful healthcare whatsoever. The particular hospital in Scutari was built over sewers and the strong stench would rise into the rooms. [3, p. 162]

When Nightingale and her team of nurses arrived at Scutari Hospital, they first scrubbed clean the wards and used boilers to clean the laundry. They obtained goods such as furniture, clothing, and better food through donations or through Nightingale's own donations. Cleaning the latrines, removing a dead horse carcass from the water supply, and ventilating the wards, are just a few of the many tasks they did to improve Scutari Hospital, things we would call now "common sense".

On top of all of this administration work, Nightingale still found time to care for the sick patients, usually late at night carrying a lamp, hence the source of the name "Lady with a Lamp". She didn't allow other women into the wards at night, so she did her endless rounds alone which led to one of the several legends surrounding Nightingale, the "ministering angel" of the Crimea.

Nightingale, of course, kept detailed records of the patients. The first months of the Crimean campaign produced the morbidly high mortality rate of 60% from disease alone. This percentage is greater than that of the Great Plague of 1665 in London. As reported in Bernard Cohen's *Triumph of Numbers,* "In January 1855 the mortality in all British hospitals in Turkey and the Crimea (excluding men killed in action) reached an annual rate of 1,174 per 10,000, calculated on the average patient population. Of this number, 1,023 deaths per 10,000 were attributable to epidemic, endemic, and contagious disease." [3, p. 164] Therefore, if this rate had continued for a year without replacing those who died, "disease alone would have wiped out the entire British army in the Crimea." [2, p. 5] Cohen adds, "In February, 1855, the mortality rate at the hospital was 42.7 percent of the cases treated." [2, p. 4]

While people had been collecting statistical data for hundreds of years before Nightingale's time, analysis and presentation of such data was not a common practice. Nightingale used comparative tables, charts, colorful diagrams and graphs to show her results in a myriad of ways. The use of several methods to calculate and compare the numbers was extremely innovative and helped not only to promote the use of statistics but to illustrate the impact of disease, reform and the results of their efforts. We will see some examples of these methods later.

According to Nightingale's statistical data, once the new sanitation reforms were put into place, by the Spring of 1855 the mortality rate dramatically dropped from 42.7 percent to 2.2

percent. "By the end of the war, according to Nightingale, the death rate among sick British soldiers in Turkey was 'not much more' than it was among healthy soldiers in England; even more remarkable, the mortality among all British troops in the Crimea was 'two-thirds only of what it [was] among our troops at home.'" [2, p. 5]

Though in the 1800's not much was known about disease, how it spreads, or how to prevent it, Nightingale's numbers were clear evidence of the correlation between good health and clean air and proper sanitation, and she wasn't about to stop at the numbers. Nightingale was determined to use this information to change the face of nursing and health care. Eventually, with great determination, she finally was granted a formal investigation of military health care in May, 1857, which established the Royal Commission on the Health of the Army.

While this was a big advancement for Nightingale, she knew, as a woman (even an educated one), the difficulties of being heard; furthermore, she knew that in order for the government to reform, it had to base its decisions on significant fact. Thus, she gathered together a group of people, each in a special field, to collaborate and validate her information. She called upon the help of many leading statisticians in England, particularly Dr. William Farr, a doctor who had dedicated much of his studies to sanitation, a statistician, and a close friend of hers. [4, p. 68] Dr. Farr, as Diamond and Stone put it in their 1981 article *Nightingale on Quetelet*, "was able to advise FN [Florence Nightingale] on statistical procedure and, more importantly, to provide her with information from official statistical sources, sometimes before these statistics were made generally available... As a motto for their work, he suggested a line from Goethe: 'It has been held that the world is governed by numbers: (be that as it may) this I know that numbers teach us whether the world is well or ill-governed.'" [4, p. 69]

Nightingale's report "Notes on matters affecting the health, efficiency, and hospital administration of the British Army, founded chiefly on the experience of the late war," is a collaboration of her work on the health of the British army. She reviewed health services, addressed the health of the British soldiers in peace time, included her calculations, comparative tables and diagrams (seen on pages 8-10), even explained how to provide nourishing food for 1,000 soldiers with only 26 cooking pots.

One thing Dr. Farr and Nightingale did not agree on was the addition of the colorful diagrams and illustrations. Dr. Farr thought the presentation should be more of hard facts than impressions. Diamond and Stone relay his argument,

> "'We do not want impressions, We want facts' he wrote critically in 1861. 'Again I must repeat my objections to intermingling Causation with Statistics ... The statistician has nothing to do with causation; he is almost certain in the present state of knowledge to err ... You complain that your report would be dry. The dryer the better. Statistics should be the dryest of all reading. What I complain of is that on reading your report I am conscious of receiving a wrong impression, because your details are not sufficiently dry and sufficiently extensive.'" [4, p. 70]

On the contrary, in a letter to Sidney Herbert, the commission's chairman and longstanding friend of Nightingale's, she writes, "None but scientific men ever look into the appendices of a Report. And this is for the vulgar [common] public. ... Now, who is the vulgar public who is to have it? 1. The Queen. ..." [3, p. 174] For this reason, Nightingale thought the presentation would be better received with illustrations of soldiers in their barracks and diagrams, as she did for her "Observations on the Sanitary State of the Army in India" commenting that "the queen might look at her copy 'because it has pictures.'" [3, p. 174].

While Nightingale wasn't an inventor of the statistical diagram, she was certainly an innovator in creating a new design. [3, p. 173] She invented polar-area charts, a sort of pie chart with wedges complete with color-coated sections. "The statistic being represented [the colored section] is proportional to the area of a wedge in a circular diagram." [2, p. 6] The colors were not only to look nice, but to also emphasize the extent "to which deaths in the Crimea campaign has been preventable." [2, p. 6] She referred to these as "coxcombs" in her report, since their shape and colors resemble the crest on the head of a cock. Her original creation of the chart is represented in Figure 4, known as the "bat's wing" which she revised into the final product in Figure 5.

Nightingale's reports were submitted to the Royal Commission and became the leading authority on the medical administration of the armies. Charts from the Royal Commission's report submitted by Nightingale can be seen in Figure 1, Figure 2 and Figure 3. If you notice, she compares the death rate of the British army to that of the civilians which allows the reader of her reports to get an accurate idea of how poor the conditions were.

TABLE showing, of 10,000 Recruits, at the Age 20, the Numbers remaining at each successive year of Age, up to 40, and also the Numbers annually eliminated by Invaliding or by Death.—It has been constructed from the facts supplied by the Army Reports and by the Paper of Dr. Balfour, on Invaliding. The principle of construction is the same as that employed at the General Register Office, in constructing Life Tables. It is assumed that the Soldiers enter the Service at the age of 20 years.

Age.	English Soldiers.				Completed Years of Service.
	Living.	Dying and Invalided.	Dying.	Invalided.	
20	10,000	350	169	181	0
21	9,650	325	168	157	1
22	9,325	305	166	139	2
23	9,020	289	164	125	3
24	8,731	278	162	116	4
25	8,453	270	160	110	5
26	8,183	265	159	106	6
27	7,918	264	158	106	7
28	7,654	263	157	106	8
29	7,391	266	155	111	9
30	7,125	271	153	118	10
31	6,854	275	150	125	11
32	6,579	282	147	135	12
33	6,297	288	145	143	13
34	6,009	296	144	152	14
35	5,713	302	144	158	15
36	5,411	307	143	164	16
37	5,104	313	141	172	17
38	4,791	315	138	177	18
39	4,476	318	135	183	19
40	4,158				

Figure 1: As it says above the chart, "TABLE showing, of 10,000 recruits, at Age 20, the Numbers remaining at each successive year of Age, up to 40, and also the Numbers annually eliminated by Invaliding [illness] or by Death. -- It has been constructed by the facts supplied by the Army Reports and the paper by Dr. Balfour [the Army Doctor recruited onto Nightingale's team for research] on Invaliding. The principle of construction is the same of that employed at the General Register Office in constructing Life Tables. It is assumed that soldiers enter the service at the Age of 20 years. [10, table marked F --a]

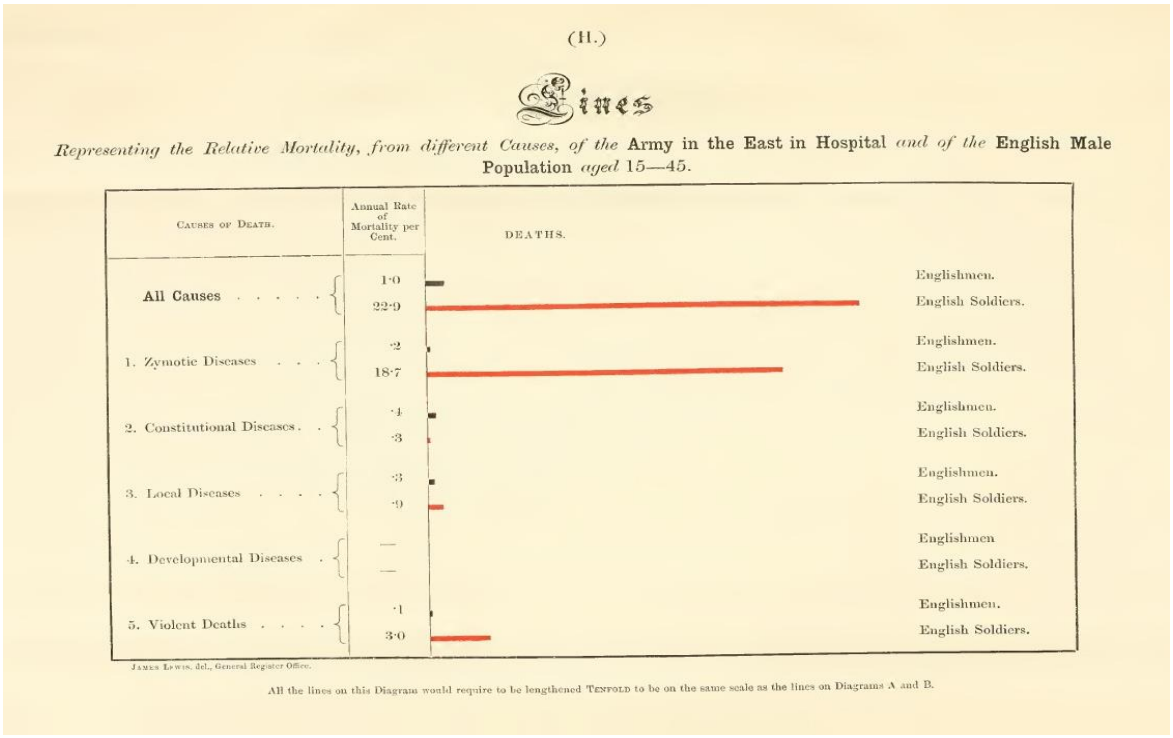

Figure 2: Relative Mortality of "Englishmen" (top bar of each category) and "Soldiers"(bottom bar of each category) from different causes for ages 15-45. From top to bottom, the causes are as follows: All Causes, Zymotic Diseases [Zymotic is an old name for a contagious disease, thought to have developed in the body after infection, similar to the process of fermentation and growth of yeast], Constitutional Diseases, Local Diseases, Developmental Diseases, and Violent deaths. [10, p. 11]

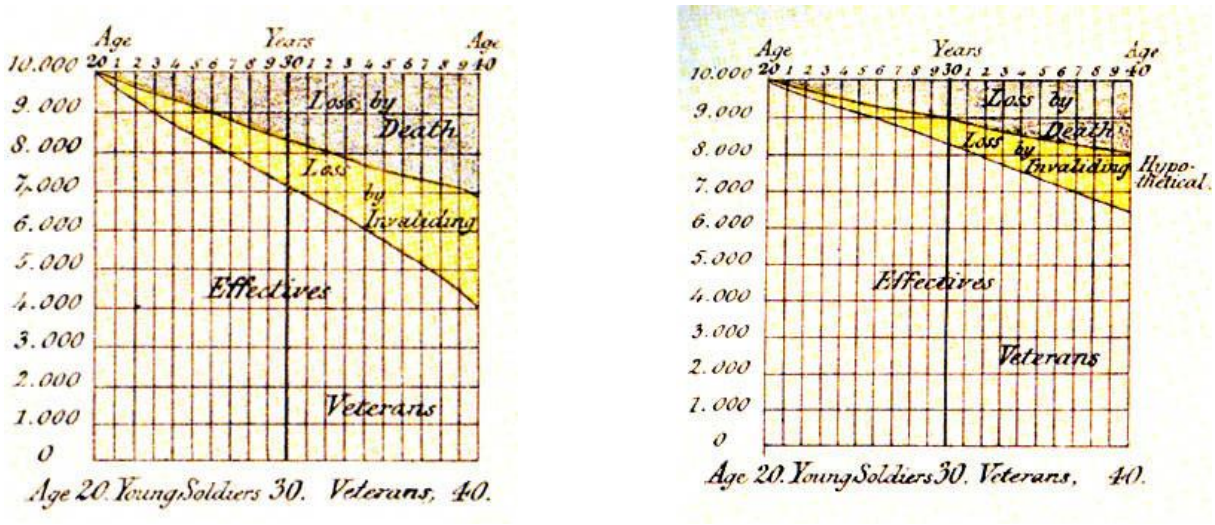

Figure 3: Displayed is the loss of manpower in the British army due to excess mortality or invalidity. These assume that 10,000 new 20 year old recruits enter into the force annually and that each soldier's career lasts 20 years. "Effectives" refers to the years that a soldier is ready and fit for service, which is between 20 years old and 40 years old. "Young Soldiers" refers to beginning soldiers from 1- 10 years of service or from 20 to 30 years old. "Veterans" refers to men that have had 10-20 years of experience in the army which is from 30 years old to 40 years old. Each rectangle represents 1,000 men. [2, p. 5] Left: Represents the Army at Home [British Army] at its present state. Right: Represents what the Army would be like if the mortality rate were the same as the Civilian mortality rate and if the Invalidating bore the same proportion to the Deaths as it does in the one on the left. The invalidating may be more but would probably be less than it is represented on the right. [10, p. F]

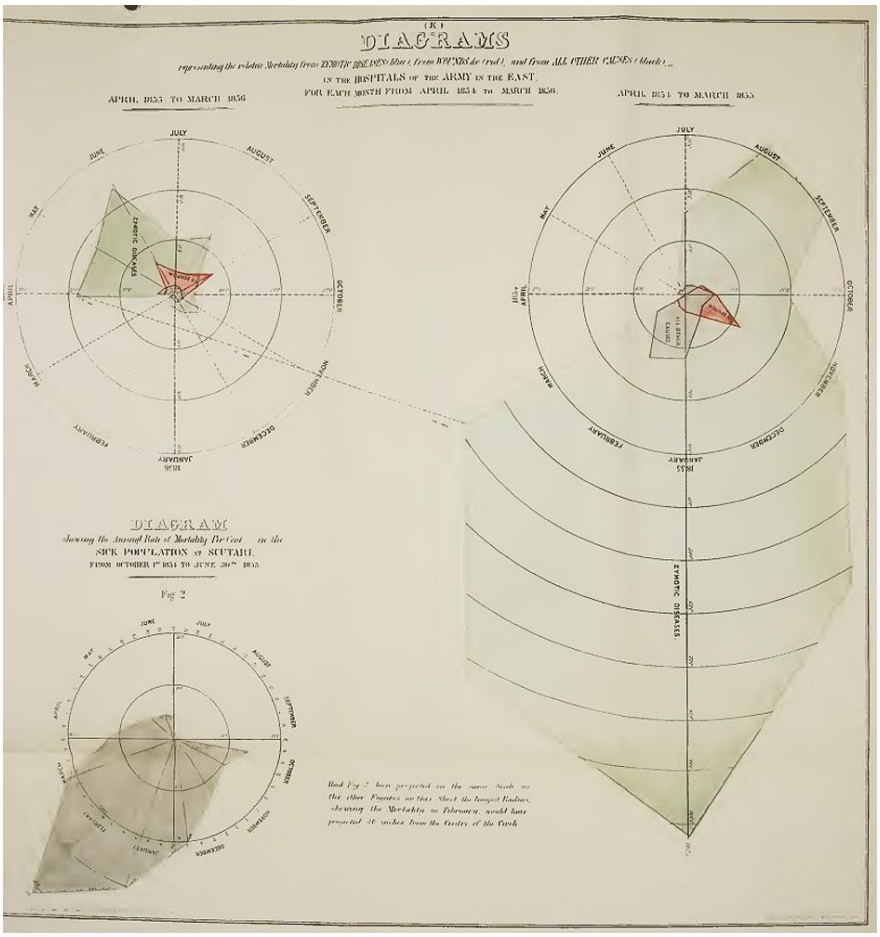

Figure 4: Nightingale's original coxcomb diagram. The green (largest lightly shaded outside region) represents deaths from disease. The red (inner darker shaded region) represents deaths from wounds. The following explanation appeared with the original: "The diagrams represent the ANNUAL RATE of Mortality per 1000 in the Hospitals of the Army in the East [British Army hospitals like Scutari] for each Month from April 1854 to March 1856.

"The inner circle shows the Mortality which the Army would have experienced if it had been subject to the same rate which prevailed in one of the unhealthiest Cities of England (Manchester). The distances between the Centre and the second, the second and the third circles &c. each represent 100 deaths to 1000 living. The Annual rate of Mortality in any particular Month is shown by the length of the radial line extending from the centre in the direction of the Month indicated on the outer circle.

"Thus: In January 1855 the Annual rate of Mortality per 1000 was 1174: a higher rate than that which prevailed during the Month (September) when the Mortality was highest in the year of the Great Plague, 1665." [10]

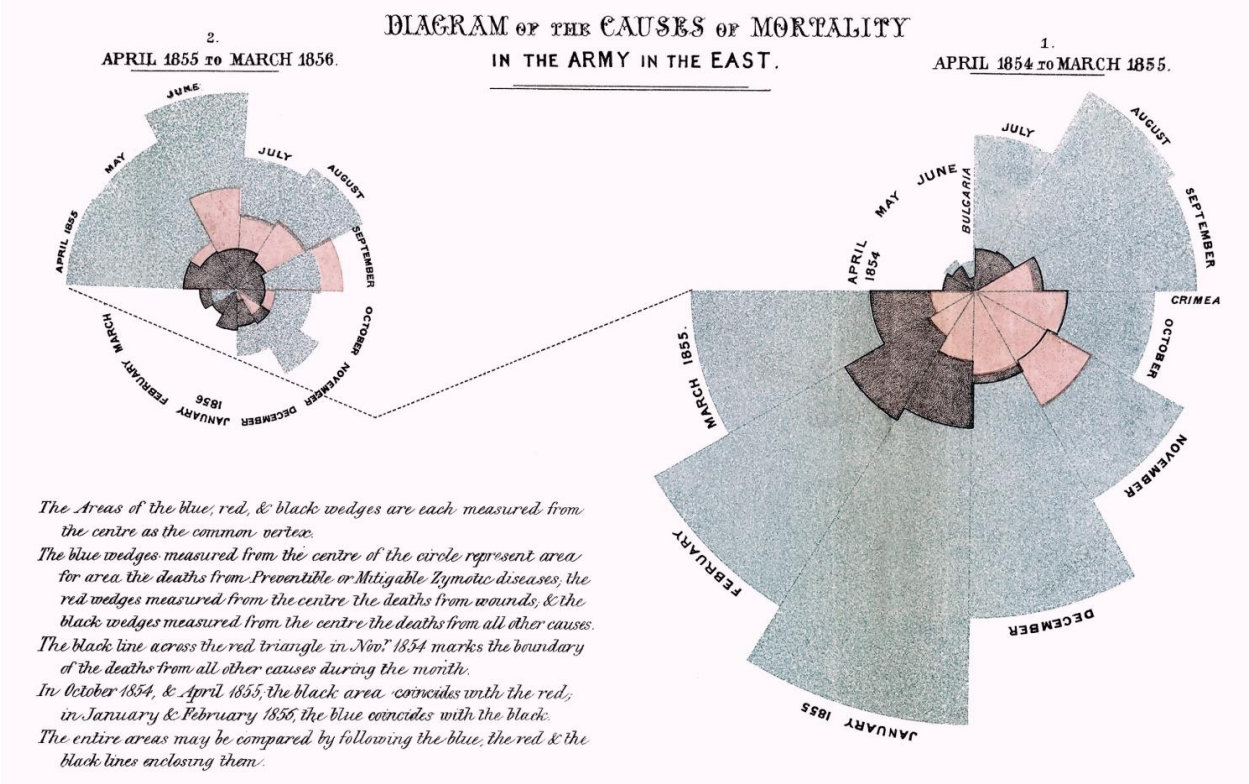

Figure 5: The "coxcomb" diagrams. As the chart says, "The Areas of the blue [outside gray], red [light gray], & black [darkest inside gray] wedges are each measured from the centre as the common vertex. The blue wedges measured from the centre of the circle represent area for area the deaths from Preventible or Mitigable [able to be alleviated] Zymotic diseases, the red wedges measured from the centre the deaths from wounds, & the black wedges measured from the centre the deaths from all other causes. The black line across the red triangle in Nov. 1854 marks the boundary of the deaths from all other causes during the month. In October 1854, & April 1855, the black area coincides with the red, in January & February 1856, the blue coincides with the black. The entire areas may be compared by following the blue, the red, & the black lines enclosing them." [10]

The Royal Commission established four sub-commissions for the purpose of carrying out certain reforms in its report, almost word-for-word from Nightingale's suggestions. A commission took control of physical alterations such as ventilation in military barracks and

hospitals, sewage disposal, water supply, heating, etc. Others worked on drafting a code for the army, setting up a medical school and revamped the system for collecting statistics. [2, p. 6]

Nightingale's work in the Crimean War led to countless improvements on the British home-front; however, that was not enough for Nightingale. She continued to push the Royal Commission to consider the conditions of health care and sanitation of the British stations in India. Along with her trusty partner Dr. Farr, she researched the mortality and sickness rates from the India Office, which included a death rate six times higher than the rate among civilians in England. They determined that several causes of this rate include, as stated in Bernard Cohen's article *Florence Nightingale*, "defective sewage systems, overcrowding in the barracks, lack of exercise and inadequate hospitals", causes very similar to those in the Scutari Hospital [2, p. 6]. After the submission of Nightingale's report of conditions in India and ten years of sanitary reform, she reported the decline of the death rate from 69 to 18 per 1,000 [2, p. 6].

Nightingale's knowledge of the impact of utilizing statistics was certainly way before her time. "Uniform and accurate hospital statistics, she wrote, would 'enable the value of particular methods of treatment and of special operations to be brought to statistical proof '; in short statistics would lead to improvement in medical and surgical practice." [2, p. 6] As Nightingale learned, hospitals during that time were not very organized and didn't keep detailed records; thus, Nightingale, Dr. Farr and other physicians came up with a Model Hospital Statistical Form. This new form set new standards on how to keep records in hospitals and, unfortunately, was never put into general practice due to its complexity.

Nightingale, having made quite the name for herself, became a consultant both to the United States during the American Civil War and the British war office in Canada on matters of army health. "Her mathematical activities included ascertaining 'the average speed of transport

by sledge' and calculating 'the time required to transport the sick over the immense distances of Canada.'" [9] In 1858, she was elected to membership in the Statistical Society of England based on her impressive work in statistics and advancements in healthcare.

In addition to her work improving military healthcare, Nightingale took statistics to a whole new level, believing that statistics can reveal truths about mankind, philosophy, even the laws of God. During the International Statistical Congress held in London in 1860, organized by Dr. Farr, Nightingale, who didn't get to attend due to invalidity after the Crimean War, was determined to meet a statistician named Adolphe Quetelet (1796-1874). She was quite familiar with Quetelet's book *Physique Sociale* (1835) and was utterly inspired by the work. She told Dr. Farr, "I never read Quetelet's *Physique Sociale* (which I have done over and over again) without being astounded at the force of genius and accurate observation which has produced such a work." [4, p. 71]

Nightingale knew the importance of informal interaction and offered her home to any delegates from the Congress, specifically Quetelet. [4, p. 71] Her meeting with Quetelet, like most of Nightingale's meetings, turned into a friendship, much to her delight. Nightingale sent Quetelet her book *Notes on Lying -- in Institutions* and in return Quetelet sent her two volumes of *Physique Sociale*, revamped in 1869, and another work of his, *L'Anthropometrie*, a work particularly of interest as it monitored the supposed decline of the average man which Nightingale, as well as other sanitarians, feared would occur if the environment didn't improve. [4, p. 72]

Quetelet's writings also touched on philosophy, a topic, as mentioned earlier, very dear to Nightingale. "Throughout her life, she was attracted by certain aspects of mysticism, and statistics became part of her search for God." [4, p. 72] Through Nightingale's study of Quetelet,

she believed he was truly "seeking the Laws of the Moral World" and "has done so much to discover the action or plan of Supreme Wisdom and Goodness". [4, p. 72] To Nightingale, this was the basis for practical application of statistics, as she explains to Quetelet,

> "On my part this passionate study is not in the least based on a love of science, a love I would not pretend I possessed. It comes uniquely from the fact that I have seen so much of the misery and sufferings of humanity, of the irrelevance of laws and of Governments, of the stupidity, dare I say it? of our political system, of the dark blindness of those who involve themselves in guiding our body social that ... frequently it comes to me as a flash of light across my spirit that the only study worthy of that name is that of which you have so firmly put forward the principles." [4, p. 72]

Nightingale wrote extensively over the margins in her copy of Quetelet's *Physique Sociale*. Her writings can be read in the article Diamond and Stone produced in 1981 called *Nightingale on Quetelet II: The Marginalia*. [5] Nightingale also wrote a critical essay of Quetelet's writings which she called *Essay in Memoriam*, dedicated to Quetelet shortly after his death in 1874. In this essay, she approaches the concept of Moral Law, discusses importance of learning these laws and how they are supported by solid numbers. She writes about ideas of "Original Sin", a "perfect God", and even quoting historic philosophers like Plato.

For example, she explores the correlation between criminals and education, bringing in Quetelet's work of course:

> "We have now the most exact numbers of how many thefts there will be *per annum:* always *pre-supposing* the present Social State to continue -- at precisely what ages these thefts will be committed -- how many of the thieves will be able to read & write, how many to read only, & how many neither to read nor write. ... There is also a

> most curious speculation as to how far education -- not diminishes crime but-- only increases the probability of a criminal 'getting off' -- i.e. of his not being committed or not being convicted -- so much so that Quetelet gives us a *Table* of what are our superior advantages for not being convicted." [6, p. 336]

She uses Quetelet's *Table* to show that one predictor for not being convicted is a superior education. The Essay continues on using the statistics provided in Quetelet's writings to dive into more issues regarding marriage, suicide, murder, and other social issues. One can read fully her philosophy on Moral Law as translated in Diamond and Stone's 1981 article, *Nightingale on Quetelet III: Essay in Memoriam.* [6]

Florence Nightingale was a woman of long-lasting determination and deep thought, and her love of statistics stemmed from a constant struggle for truth. Nightingale took her calling from God to be a nurse, an administrator and a mathematician whole-heartedly which meant battling her family, her superiors, political figures, and even societal norms concerning women. Through all of her efforts and with her statistical sword at her side, Nightingale succeeded in transforming hospitals around the world and ascertaining a deeper understanding of the Laws of Man. To conclude, the penultimate stanza of Longfellow's poem accurately illustrates Nightingale's legacy:

"A Lady with a Lamp shall stand
In the great history of the land,
A noble type of good,
Heroic womanhood." [11]

Appendix

Saint Filomena (1857) - Saint Nightingale -- a tribute to Florence, the saint of the Crimea

When'er a noble deed is wrought,
Whene'er is spoken a noble thought,
Our hearts, in glad surprise,
To higher levels rise.

The tidal wave of deeper souls
Into our inmost being rolls
And lifts us, unawares,
Out of all meaner cares.

Honor to those whose words or deeds
Thus help us in our daily needs,
And by their overflow,
Raise us from what is low!

Thus thought I, as by night I read
Of the great army of the dead--
The trenches cold and damp--
The stared and frozen camp--

The wounded from the battle-plain,
In dreary hospitals of pain--
The cheerless corridors--
The cold and stony floors.

Lo! in that house of misery,
A lady, with a lamp, I see
Pass thro' the glimmering gloom,
And flit from room to room.

And slow, as in a dream of bliss,
The speechless sufferer turns to kiss
Her shadow, as it falls
Upon the darkening walls.

As if a door in heaven should be
Opened, and then closed suddenly,
The vision came and went,
The light shone, and was spent.

On England's annals, thro' the long
Hereafter of her speech and song,
That light its rays shall cast

From portals of the past.

A Lady with a Lamp shall stand
In the great history of the land,
A noble type of good,
Heroic womanhood.

Nor even shall be wanting here
The palm, the lily, the spear--
The symbols that of yore
Saint Filomena bore.

H. W. Longfellow [11]

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