

# Florence Nightingale: using graphical statistical analysis to combat the spread of disease



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**Institute** of  
**mathematics**  
& its applications



UNIVERSITY  
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# Amateur in History of Mathematics



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- Council of the British Society for the History of Mathematics

| *b s h m* |

BRITISH SOCIETY FOR THE  
HISTORY OF MATHEMATICS

# Sources



- ❧ Mark Bostridge: Biography of Florence Nightingale
- ❧ Eileen Magnello: Article in BSHM Bulletin
- ❧ Wellcome Library for Nightingale's publications and letters



# Outline



- ∞ Introduction - myself and this research
- ∞ Early life
- ∞ Education
- ∞ Statistics and statistical diagrams of the day
- ∞ Politics and Crimea
- ∞ Florence's statistical writings
- ∞ Conclusion



# Who was Florence?



- ∞ Prolific letter writer
- ∞ Administrator / manager
- ∞ Nurse and hospital reformer
- ∞ Pioneer of women's rights
- ∞ Mathematician / statistician
- ∞ Populariser of maths / stats



# Early Life



- ❧ Born in Florence in 1820 to William and Fanny Nightingale
- ❧ Sister Parthenope (Pop)
- ❧ Came back to England in winter 1820/21
- ❧ Settled in Derbyshire – Lea Hurst – during the summer

292. Lea Hurst

"Home of Florence Nightingale"



W. & A. G. BOYD

# Home life



- ❧ Florence was raised in a very disciplined way
- ❧ An avid letter writer from an early age
- ❧ Proud of her studies
- ❧ Visited the poor and sick from a young age
- ❧ Brought up as a devout Christian
- ❧ Fanny was a stickler for discipline

# Letter to Mother - 1830



*I promise to take [a] run before breakfast to gate... ½ an hour's walk before dinner, long walk after, or if cold & damp long walk before & ½ an hour's after ... to do 20 arms [exercises] before I dress, 10 minutes before breakfast & 10 after exercises, if ill done 10 more ... to practice 1 hour a day ... to draw ½ an hour regularly ... not to lie in bed ... to go to bed in proper time ...*

# Letter to Mother - 1830



*To read the Bible & pray regularly before breakfast & at night ... to visit the poor people and take care of those who are sick ... to take medicine when I want it ... to go regularly after breakfast on Sundays to church when there is anyone to go with me ... to read my books you put out for me ...*

# Florence's character



- ❧ More solitary than her sister
- ❧ Retreated into own imaginary world
- ❧ Deeply religious
- ❧ Very close to her father
- ❧ Neat and methodical
- ❧ Wrote copious lists and instructions



# Letter to Grandmother

age 8



☞ Listed all the animals she saw on a visit to the zoo:

*‘2 leopards, 2 bears, 2 parrots, 2 emus (which are very large birds), 2 rabbits, 1 lion, 2 cockatoos, 3 squirrells, 4 kangaroos, 6 monkeys (3 in a cage, 3 chained to a pole with a little house on top).’*



PLAN OF THE GROUNDS OF THE ZOOLOGICAL SOCIETY OF LONDON

Tabulating  
 contents of fruit  
 and vegetable  
 larder age 10

copied  
 37a  
 1834  
 Feb 24<sup>th</sup> Wednesday. Fair-Soft

Dear Pop-

I have not put your Scrap Book any-where, but one day I saw it in a drawer in the Music room, next to the low window, and I think it very odd, you did not think of looking for it there!!! We have banked up the kitchen-door, (at our house) and made a new one. We have made a sofa of sand in the kitchen, covered with hay. Our mass-beds are so wet, we cannot sleep in them. We have filled up our potato-lands in the kitchen, and made a ladder. We have made a great addition to our provisions, viz.

Vegetable	Fruits
Little Lamb Potatoes	Small Potatoes
	Champney
	Small Apples
	Small Peas
Large Lamb Potatoes	Small Peas
	Small Currants
Small Peas	Small Currants

We intend to make <sup>after</sup> a ladder. We have made 3 other parts to different parts of our house. We have made a porch and a summer-house, and are making

# Education



- ✧ Taught at home under direction of William Nightingale.
- ✧ *'I do figures, music ... Latin, making maps of Palestine, ... & then we walk & play & do patchwork & we have such fun.'* (aged 8)
- ✧ Later Florence's education was to become more academic as she showed 'no taste' for drawing.

# Difference between sisters



- ❧ Parthe – irresponsible and childish
- ❧ Florence – neat, methodical and thoughtful
- ❧ Fanny: *'[Parthenope] has not shown any decided taste excepting for flowers and poetry ... [but Florence] is a shrewd little creature with a clear head which makes her thoroughly mistress of all she attempts by dint of thought and diligent application...'*

# William's influence



- At 16 her education included: chemistry, geography, physics and astronomy. She also studied mathematics, grammar, composition, philosophy and history. She was fluent in French and Italian and later German. She was also impressive in Latin and Greek
- Florence was often to be found reciting Latin / Greek translations to her Father. She would get up very early to prepare her work

# Fanny's influence



- ∞ Florence was much impressed by her mother's practical abilities as 'a most excellent manager'.
- ∞ Her own skills in this area employed in a more dramatic setting owed much to the example set by her mother



# Mathematics



- ❧ Developed a passion for mathematics around the age of 18-20 yrs.
- ❧ Knew Mary Somerville through acquaintances of her mother and was inspired by her dedication of pursuing an occupation in the face of parental opposition.
- ❧ Knew Lady Byron and her estranged daughter Ada Lovelace.



# Mathematics

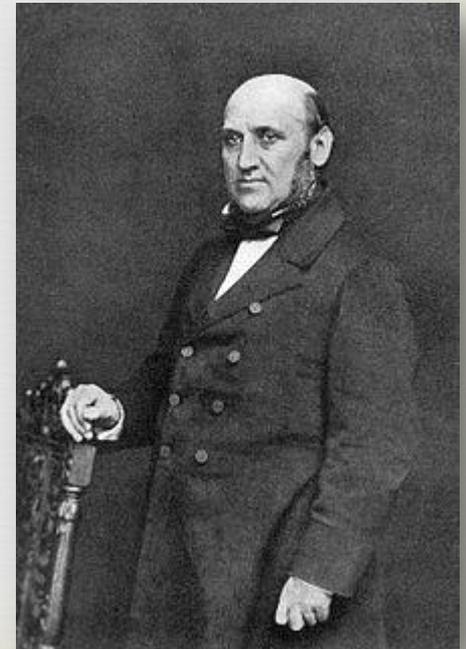


- ❧ Her sister wrote: *'Florence has taken to mathematics and like everything she undertakes she is deep in them and working very hard.'*
- ❧ Tutored her cousins, including William Nicholson, for his exam for Sandhurst. His father asked her to keep this secret saying William would be a laughing stock if it was found out he was tutored by a woman.

# Statistics of the Day



- ❧ Joseph Priestley
- ❧ William Playfair
- ❧ Andre-Michel Guerry
- ❧ Adolphe Quetelet
- ❧ William Farr

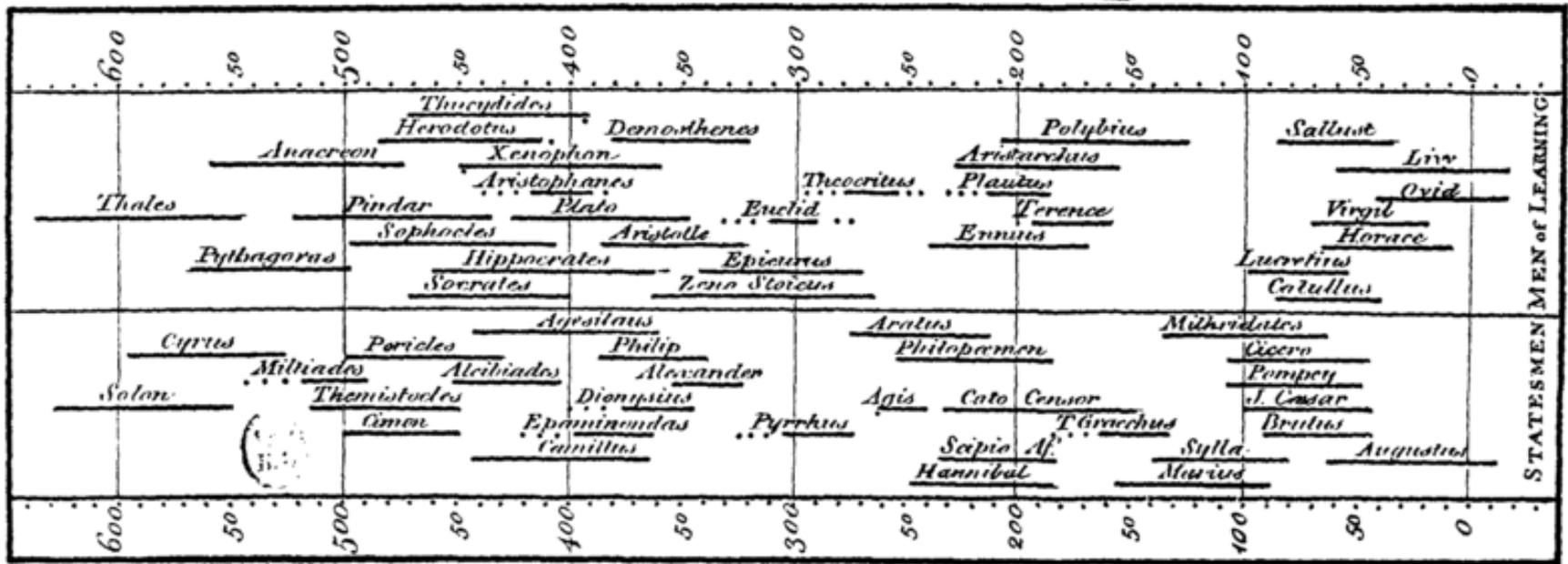


# Statistics of the day



Joseph Priestley (1765)

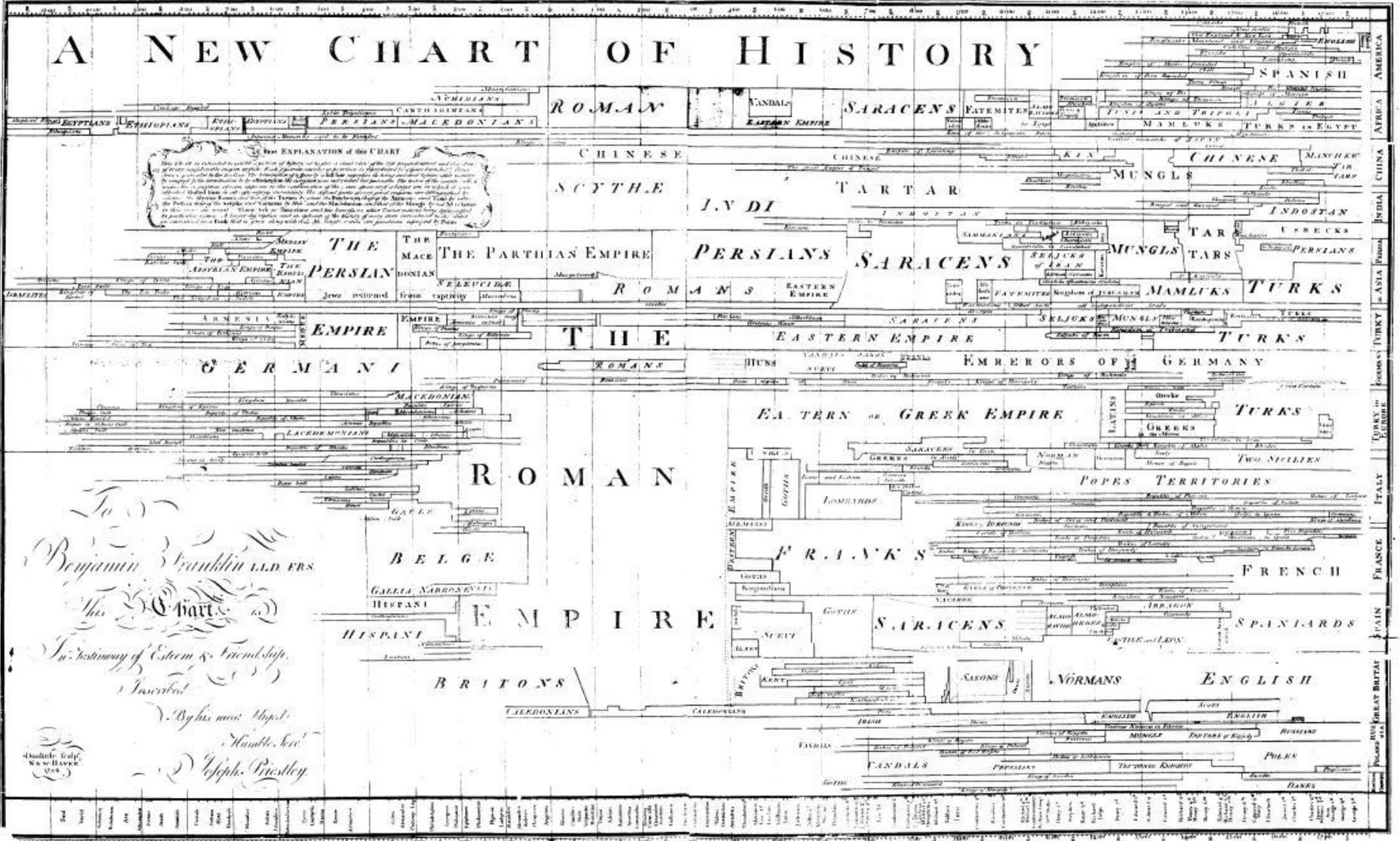
## A Specimen of a Chart of Biography.



# 1769

Historia in historiam antiquam scriptura  
a. Theodosius. HARTII

## A NEW CHART OF HISTORY

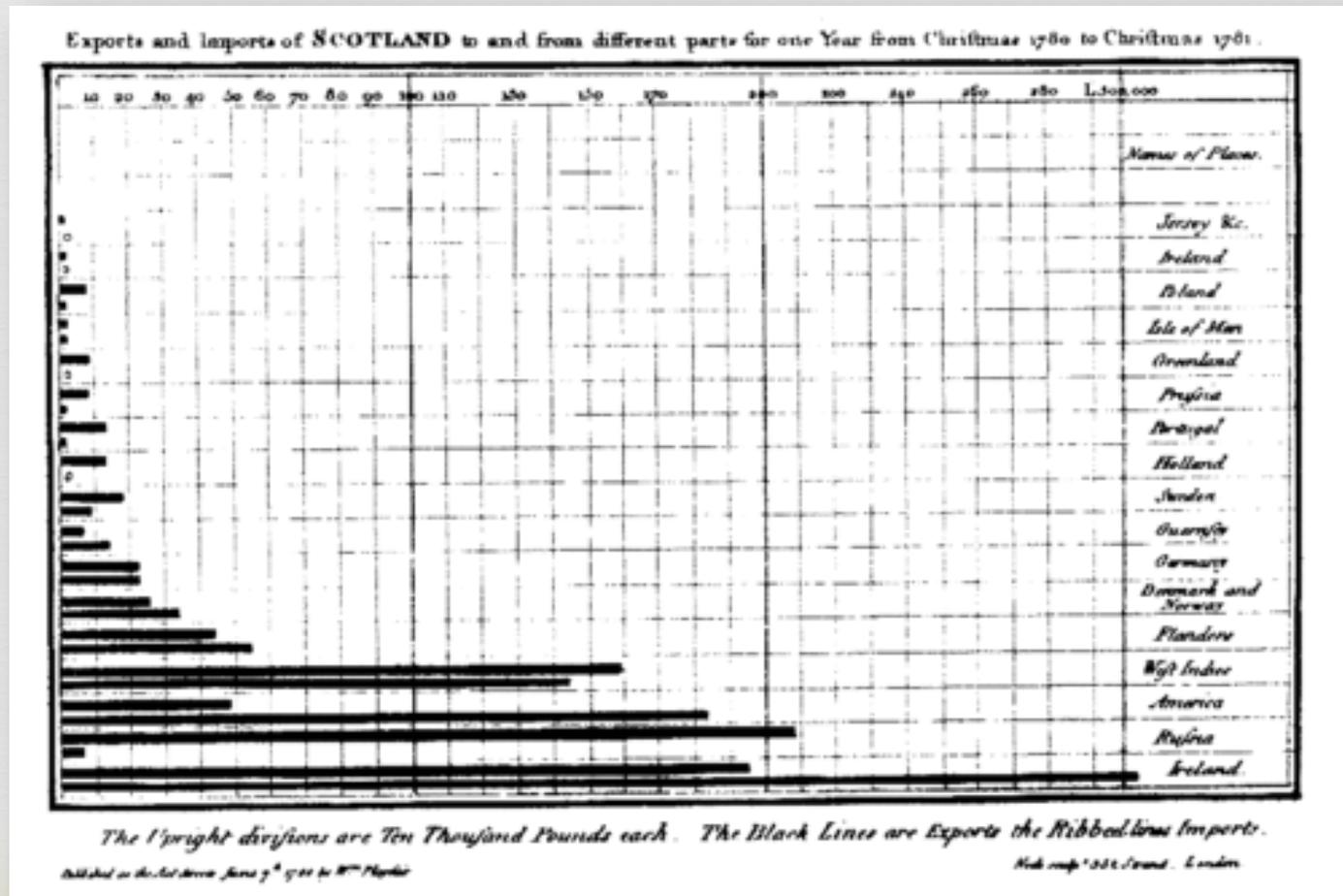


To Benjamin Franklin LL.D. FRS.  
The Chart  
In testimony of Esteem & Friendship  
Inscribed  
By his most Obedt.  
Humble Servt.  
J. Uph. Priestley

Printed by J. Uph. Priestley  
No. 1. in the Strand

# Use of charts by statisticians

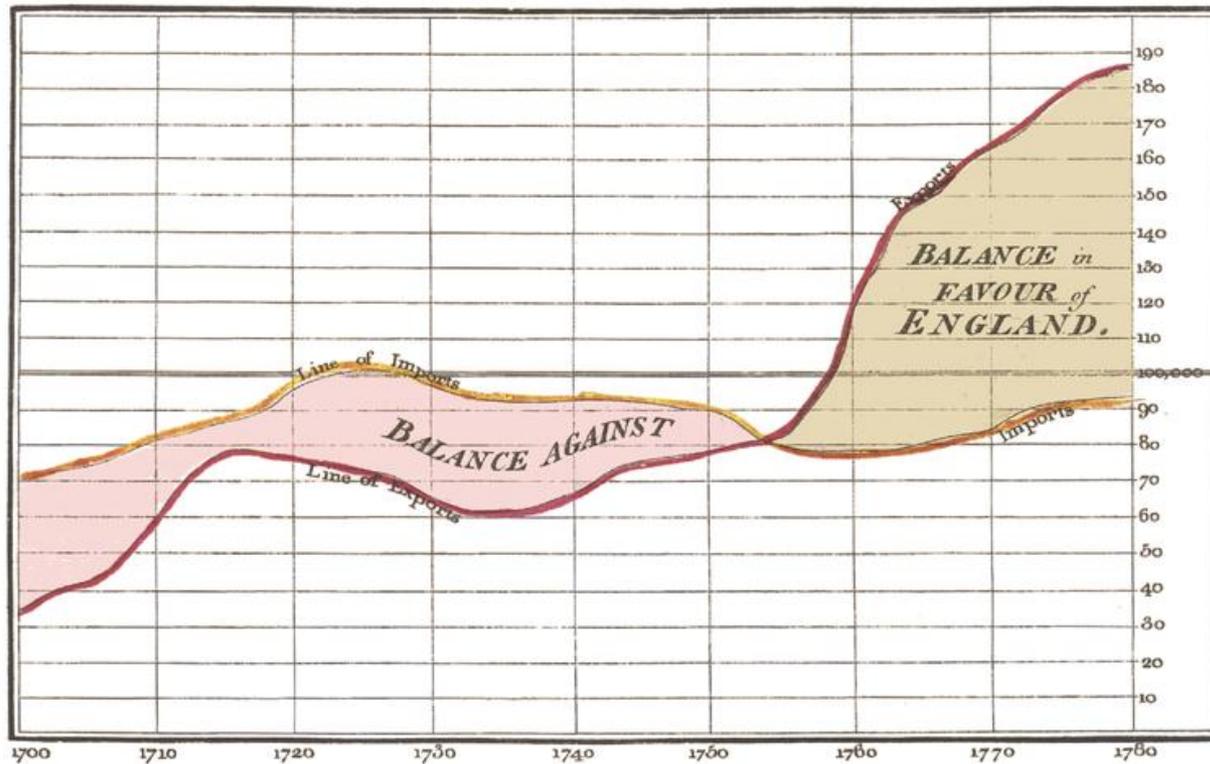
## - Playfair (1786)



# Use of charts etc by statisticians



Exports and Imports to and from DENMARK & NORWAY from 1700 to 1780.

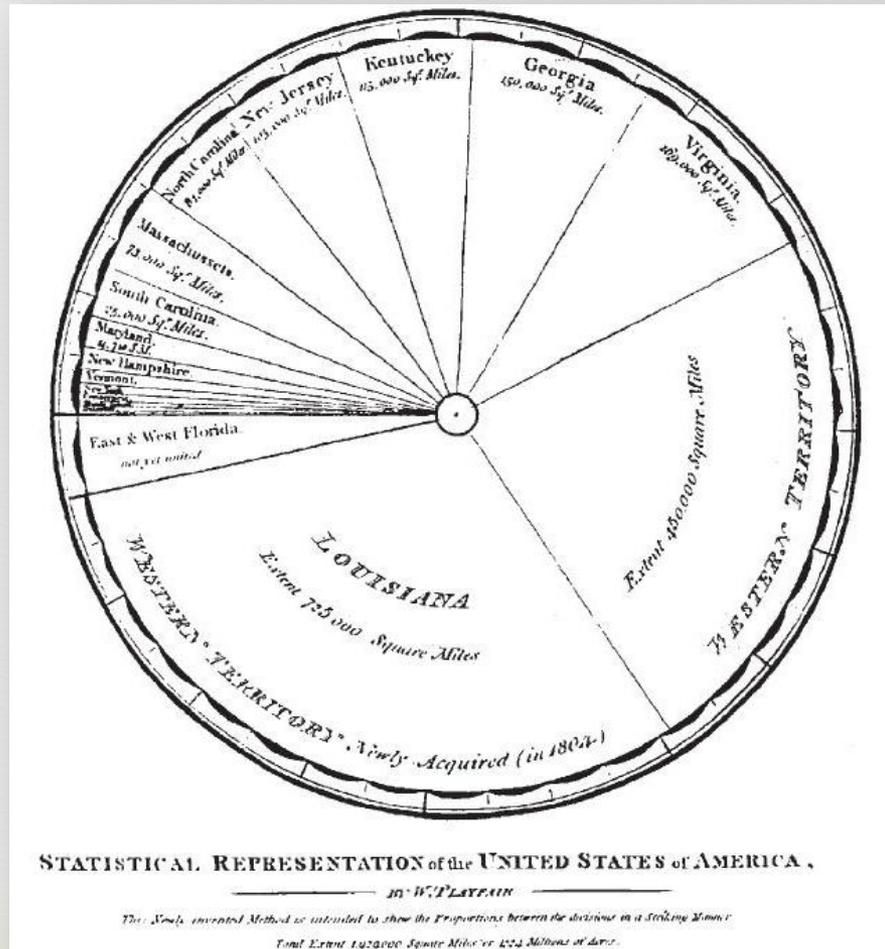


The Bottom line is divided into Years, the Right hand line into £10,000 each.

Published as the Act directs, 1<sup>st</sup> May 1786. by W<sup>m</sup> Playfair

Neale and Pelt 352, Strand, London.

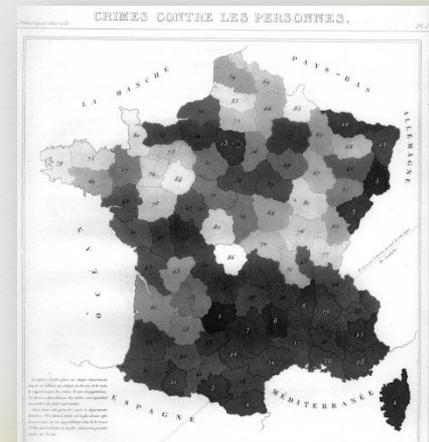
# Playfair's pie charts



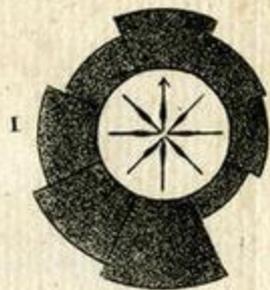
# Reception



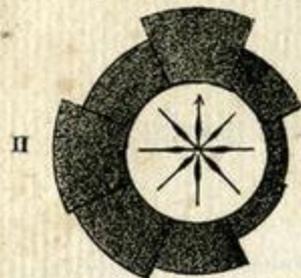
- ❧ These statistical diagrams were received with scepticism in England but welcomed in Europe.
- ❧ Polar Area Diagrams – Guerry (1829)
  - ❧ Diagram showing variation of weather in relation to mortality.
  - ❧ Guerry worked with Quetelet
- ❧ Quetelet had links with Britain



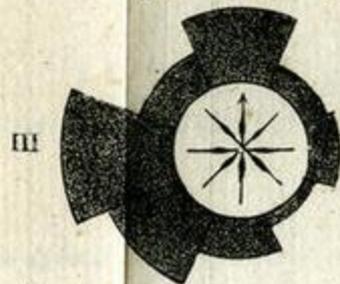
Dec. Janv. Fêv.



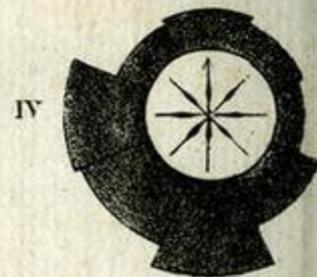
Mars Avril. Mai



Juin. Juill. Août.

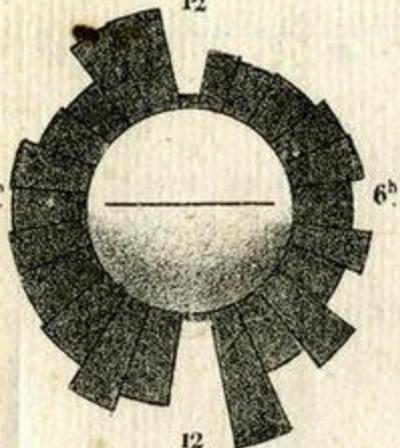


Sept. Oct. Nov.



Midi  
12

XXIX 6<sup>h</sup>

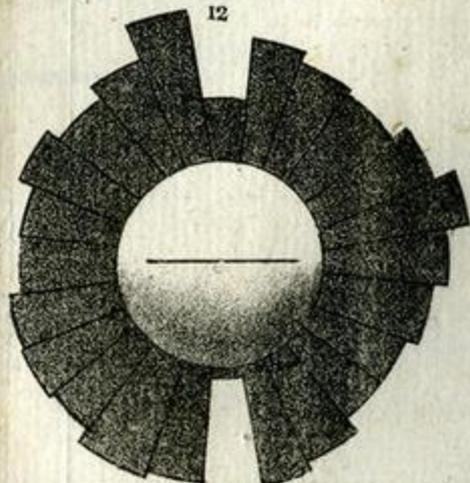


12  
Minuit.

Midi.

12

XXX 6<sup>h</sup>



12  
Minuit

# Politics and Statistics



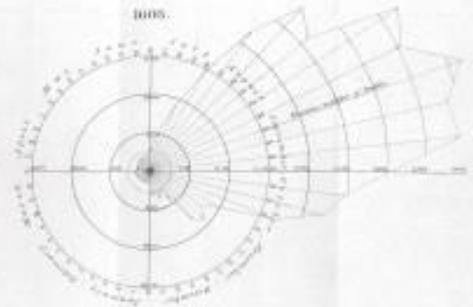
- ❧ Many early statisticians were involved in social reform but they were slow to adopt statistical diagrams
- ❧ William Farr began using them in the Journal of the Statistical Society of London (~1850)
- ❧ Became Superintendent of Statistics at General Register Office

### PLAGUES OF LONDON.

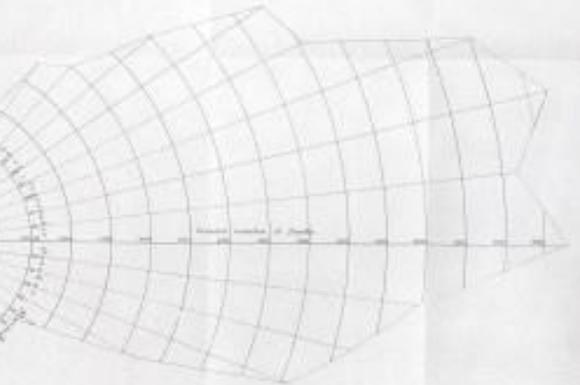
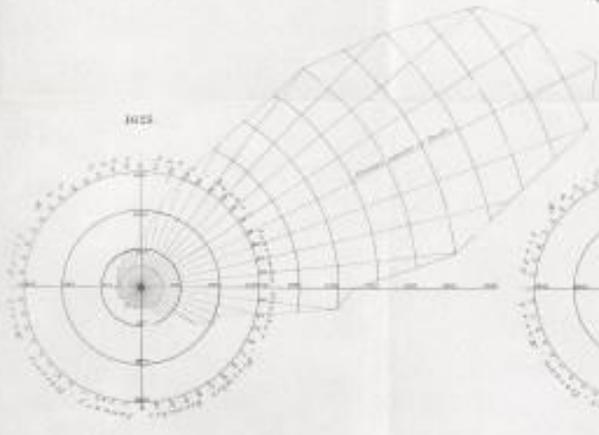
#### CHOLERA YEAR.

#### PLAGUE YEARS.

Average Mortality  
of 7 ordinary years



### PLAGUE YEARS.



These diagrams representing the weekly deaths in the years 1603, 1604, 1625, 1665, 1679, 1692, 1699, and the average weekly deaths of 1649-50.

The distance between the circles and the center, the number and the length of the lines represent the number of deaths in the various streets. The concentric circles represent the average weekly deaths of the period 1649-50. The diameter of 1625 is the average of the 27 years 1699-1725, and is the diameter of the several other years. The average is calculated from the 7 years 1665-72. The number of the scale is arranged round the outer circle. The number of deaths in any particular week is shown by the length of the radial line extending from the center to the diameter of the number of the week indicated on the outer circle.

There is the 22<sup>nd</sup> week of the year 1662 the number of deaths was 1200 which is shown by the length of the 22<sup>nd</sup> line. In order to make the circles on the different years agree in comparison with one another it was necessary to increase the number of deaths in the early years on the same scale as the population or to decrease the number of later years in the same proportion. But on the distant parts of a city, which have been made, other the diameter drawn, would have to be the same as in actual, the history was thought preferable.

Note in which the mortality of the Cholera Year (1849) was included.

Estimated population of London (Growth) 1603 = 212,000  
1625 = 210,000  
1665 = 210,000  
1679 = 210,000  
1692 = 210,000  
1699 = 210,000  
1720 = 210,000

Consequently the population in 1665 was the same as in 1603, and the number of deaths in 1665 was the same as in 1603. The population in 1679 was the same as in 1603, and the number of deaths in 1679 was the same as in 1603. The population in 1692 was the same as in 1603, and the number of deaths in 1692 was the same as in 1603. The population in 1699 was the same as in 1603, and the number of deaths in 1699 was the same as in 1603. The population in 1720 was the same as in 1603, and the number of deaths in 1720 was the same as in 1603.

Population of 17th Century (approx.) correspond to the 1603. There is the year 1720 (approx.) has shown the actual year, the 1665 correspond to the 1603, as shown in 1665, the population of which was also probably decreasing. It has been assumed that the population of the 1603, 1665, 1679, 1692, 1699, and 1720 was the same as in 1603. The total number of weekly deaths returned has therefore been divided into 1603, 1665, 1679, 1692, and 1720. It is believed that the mortality of these years is then understood, notwithstanding the addition of the cause.

TEMPERATURE AND MORTALITY OF LONDON For every week of 11 years (1840-50)



These figures show the relative mortality and the mean temperature in each week of the 11 years 1840-50. The distance between each week represents either 10 days or 10° of temperature, the red represents the weeks of the year the number of which are averaged round the mean of 50° in 24 hours, the white which were 40° or more above or below, the red, white, and black the mortality, the yellow the mean temperature.

The black and white the red, represent respectively the average weekly deaths of the 11 years 1840-50 corrected for increase of population, and the mean temperature of 1840-50. The grey represents the deaths, and the black represents 100. The mean temperature in each week of the year.

The red and white the average mortality, the black and the yellow which indicate the weeks in which the weekly deaths are above the average. The red and white indicate the weeks in which the mean temperature of the week is above the mean temperature of the year, and the black and white the weeks in which the mean weekly temperature is below the mean temperature of the year. The number of deaths represented by the 10° each was 100.

The average weekly number of the 11 years was 472, the deaths were 112, below the average, which difference is shown by the width of the yellow column. The mean temperature of the year was 50° 2, which the average mean of the 11 years was 50° 4, in that the mean temperature of 1840 was 49° 2, which the average mean, which excess is shown by the width of the red column.

# Statistics and Politics



- ❧ *'I can never be sufficiently thankful to Papa for having given me an interest in Statistical and Political matters.'* (1847)
- ❧ Studied the work of Quetelet.
- ❧ Became friendly with Sidney and Liz Herbert (Rome 1847)
- ❧ Became independent from her family in 1853.

# Nursing



- ❧ Taught in Ragged School in London
- ❧ Wanted to nurse from 1844
- ❧ Visited Kaiserwerth in 1850.
- ❧ Became Superintendent of the  
Establishment for Gentlewomen during  
Illness (1853)
- ❧ *'The Government has asked, I should say  
entreated, Flo to go out and help in the  
hospital in Scutari.'* Parthenope 1854

# Crimea and return



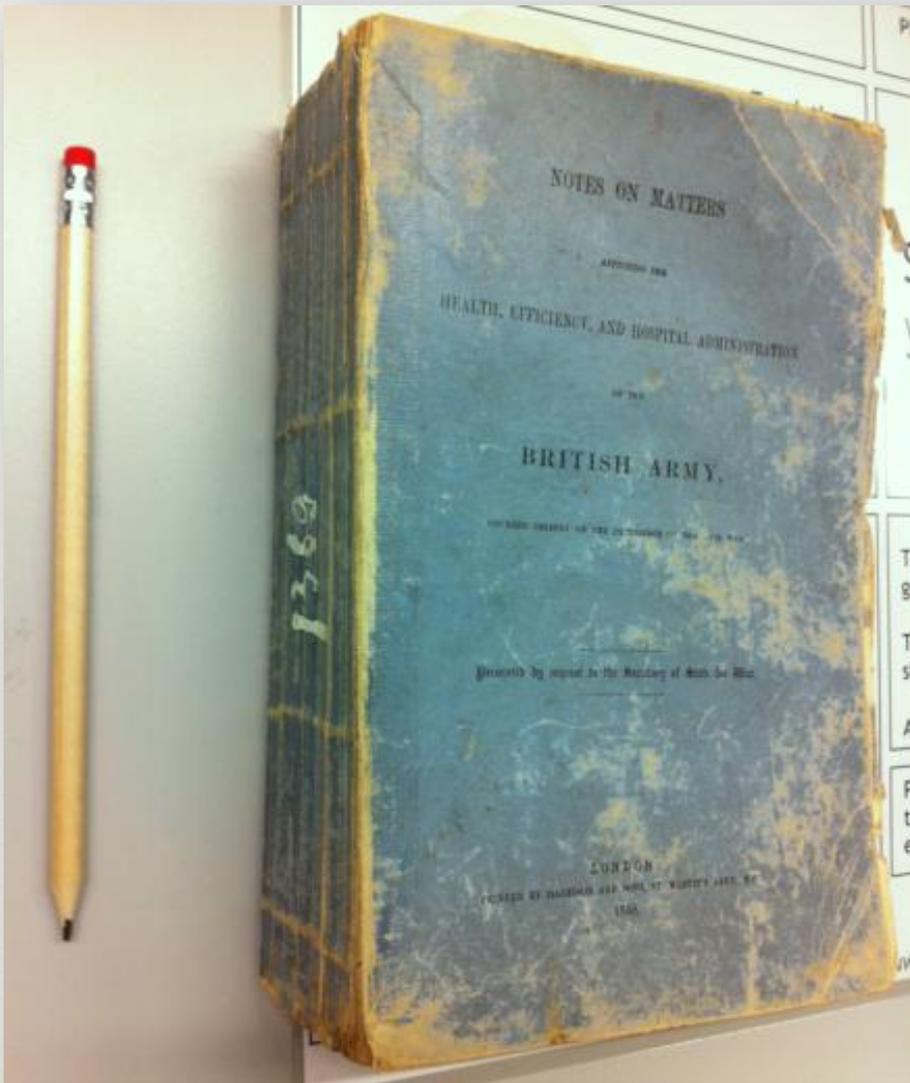
- ❧ Reports of her time in Turkey led to her becoming something of an icon in England.
- ❧ Contracted Cholera before her return home in 1856.
- ❧ On return met with Queen Victoria
- ❧ Panmure and PM agreed to Royal Commission
- ❧ Palmerston urged Florence to write a report.
- ❧ She did this aided by Farr.

# Johann Wolfgang Von Goethe



‘It has been said that figures rule the world. Maybe. But I am sure that figures show us whether it is being ruled well or badly.’

# Notes on Matters.....



Lancet:

*‘Terse phrases’  
providing a  
welcome change  
from the ‘brown-  
suited dullness’ of  
other books on  
the subject.*

# Contents



- ❧ Reads like a diary
- ❧ Copious lists
  - ❧ Stores
  - ❧ Conditions
  - ❧ Diseases
  - ❧ Correspondence
- ❧ Much description and discussion about the stock (or lack of stock) of lime juice.

# Mathematics and diagrams



- ∞ Florence doesn't just present the diagrams she discusses and challenges the maths of the day:

In constructing a Table of Mortality we take 100 men, eight die the first year, there are left 92—two die the second year, there are left 90. The usual method of stating this mortality would be to *take the hundred over again* and strike the difference, thus—

$$100 + 100 = 200 \quad 8 + 2 = 10$$

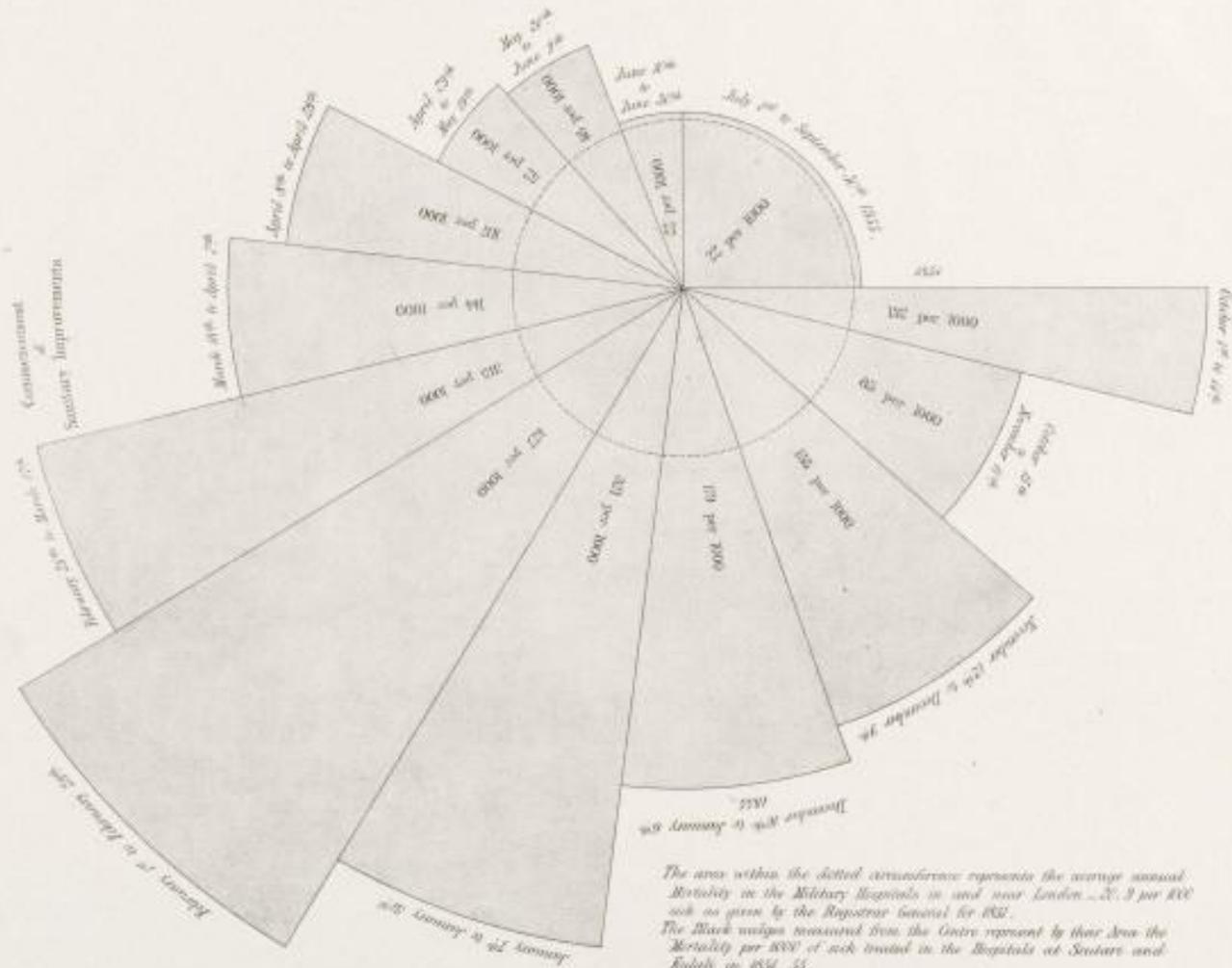
$$\begin{array}{r} - \\ 2)10(5 \end{array}$$

Therefore, it is a mortality of 5 per cent., per annum. Now, this is manifestly wrong, and gives the Secretary of State no idea of his *accumulated* loss.

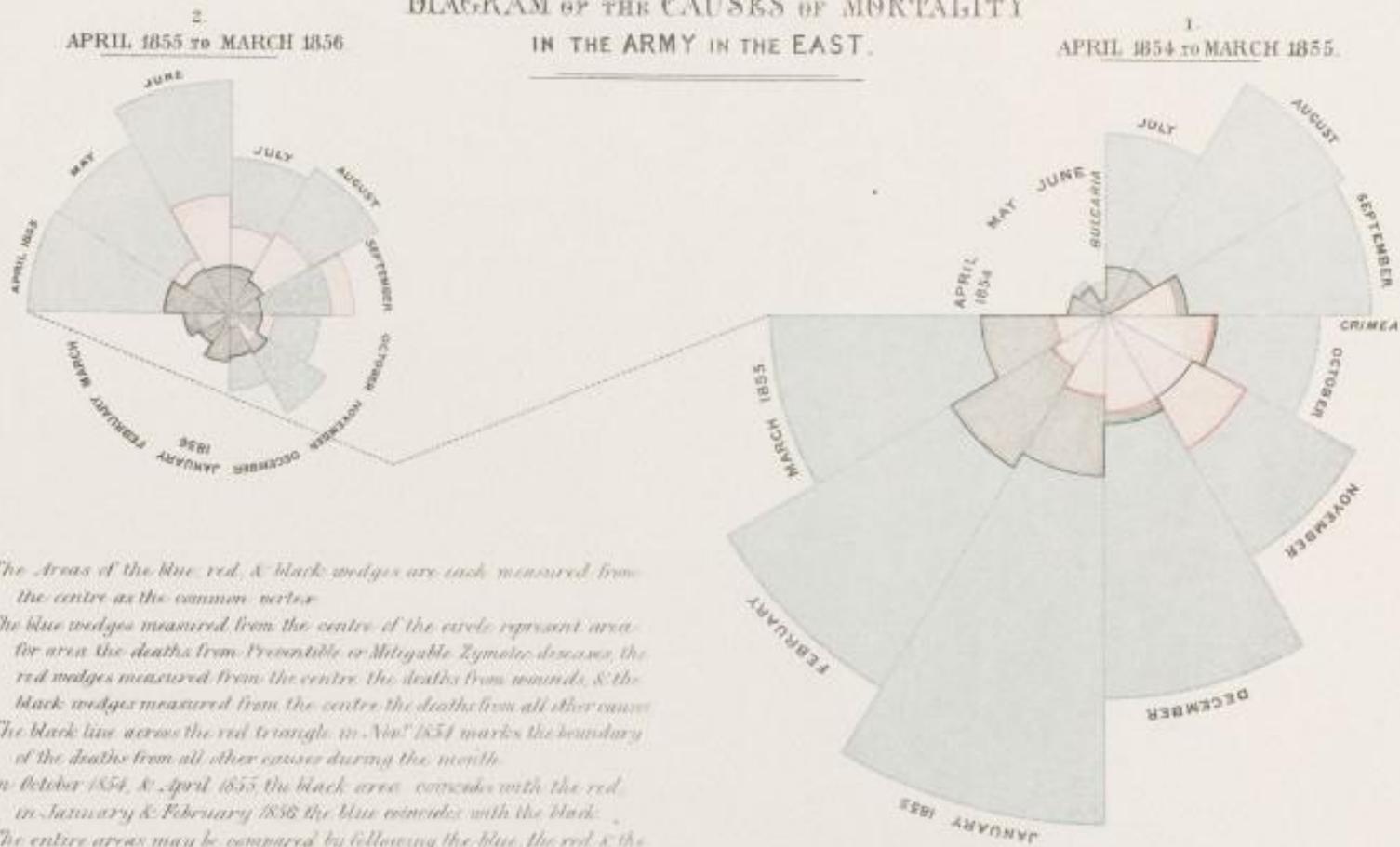
# A Statistical Problem

A singular Statistical problem is thus stated by the Com-mandant, for the official information of Her Majesty's Govern-ment, p. xi :—"Sickness has very much diminished and so has the Mortality. In January last the number of deaths was 1,480, in February, 1,254, and in March, 424, every month showing a steady decrease over the preceding one. The average mortality, at present, is  $5\frac{1}{2}$  per diem." This problem is much like the celebrated riddle, "Given the height of the mast, to tell the captain's name." *Not* given the numbers in Hospital, to tell whether there is a "steady decrease" in its mortality. The real fact, alas! stood thus,—there was an appalling *increase* of mor-tality, up to the end of February, reaching nearly 43 per cent., in that month, of cases treated, from 32 per cent., which it was in January. The numbers in Hospital had diminished. Up to March 17 the mortality was 43 per cent., on cases treated.

DIAGRAM REPRESENTING THE MORTALITY IN THE HOSPITALS,  
AT SCUTARI AND KULALI, FROM OCT<sup>R</sup> 1<sup>ST</sup> 1854. TO SEPT<sup>R</sup> 30<sup>TH</sup> 1855.



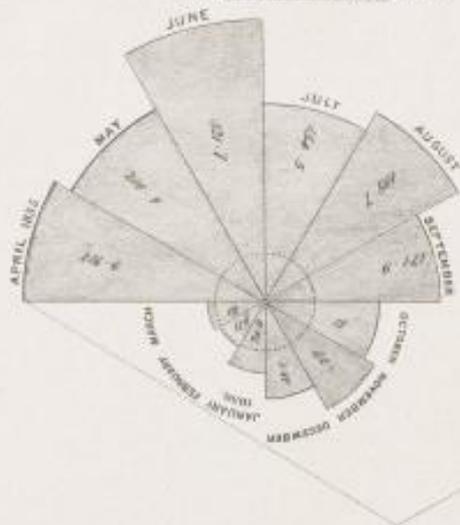
## DIAGRAM OF THE CAUSES OF MORTALITY IN THE ARMY IN THE EAST.



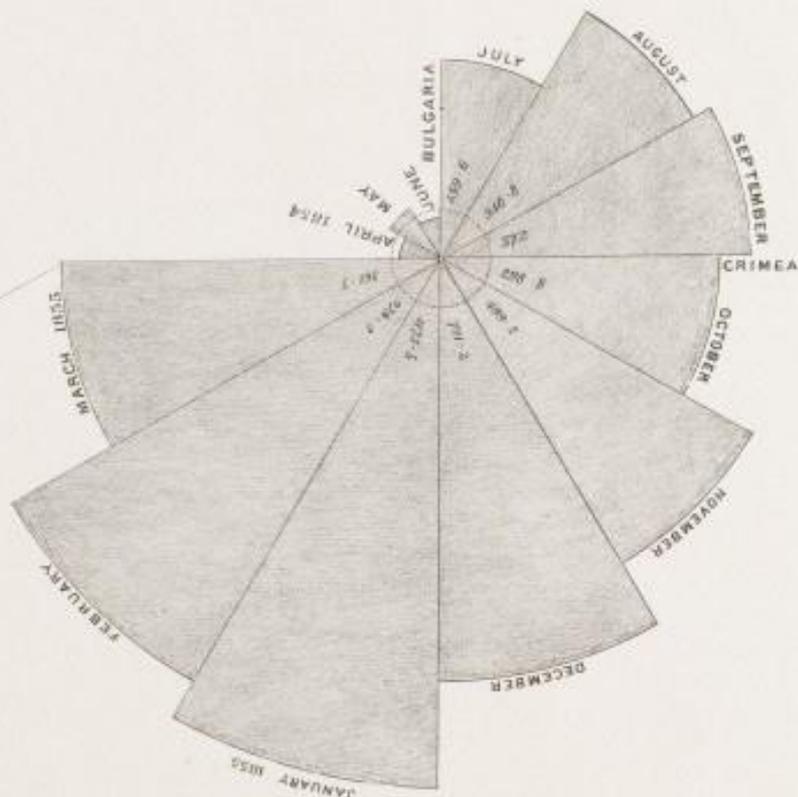
*James & Henry B. Baillie, London*

## DIAGRAMS OF THE MORTALITY IN THE ARMY IN THE EAST.

2.  
APRIL 1855 to MARCH 1856.



1.  
APRIL 1854 to MARCH 1855



The dotted circle represents what the Mortality would have been, had the Army been as healthy as Manchester - 4 per 1000 per Annum. The Area of each Monthly division exhibits the relative Mortality in the Army during the Month.

Each wedge admits of comparison, area for area, with every other wedge, and with the Manchester circle, and each wedge shows the Mortality per 1000 per Annum for the Month.

The dark Area outside the Manchester circle exhibits the excess of Mortality in the Army for the same year over that of one of the most unhealthy Towns in England. The figures show the Mortality per 1000 per Annum.

*Barrington's Army in the Crimea*

(1C)  
DIAGRAMS

representing the relative Mortality from ZYMOTIC DISEASES (blue), from WOUNDS &c (red), and from ALL OTHER CAUSES (black),—

IN THE HOSPITALS OF THE ARMY IN THE EAST,

FOR EACH MONTH FROM APRIL 1854 TO MARCH 1856.

APRIL 1855 TO MARCH 1856.

APRIL 1854 TO MARCH 1855.

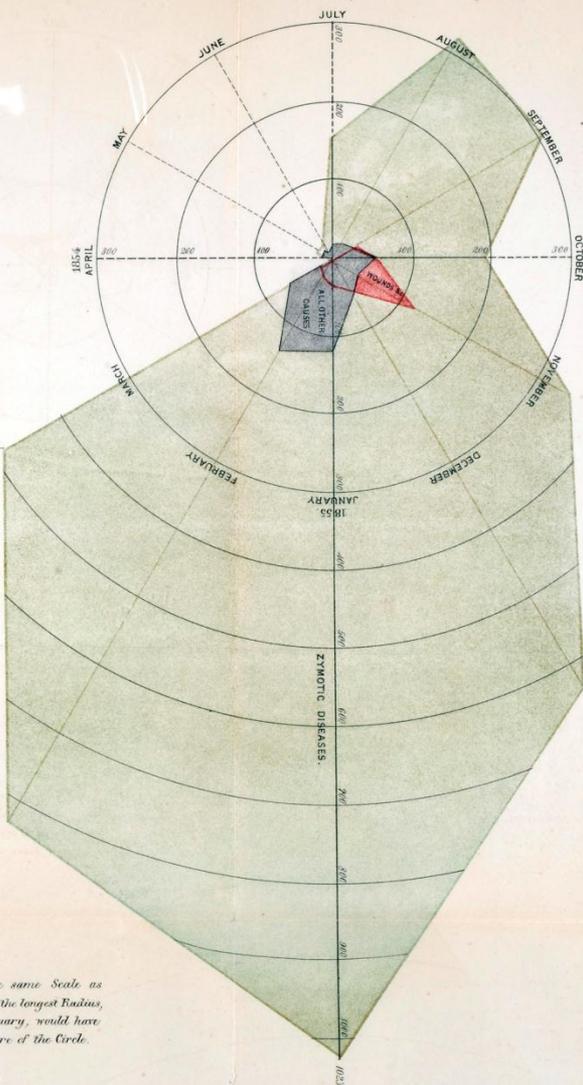
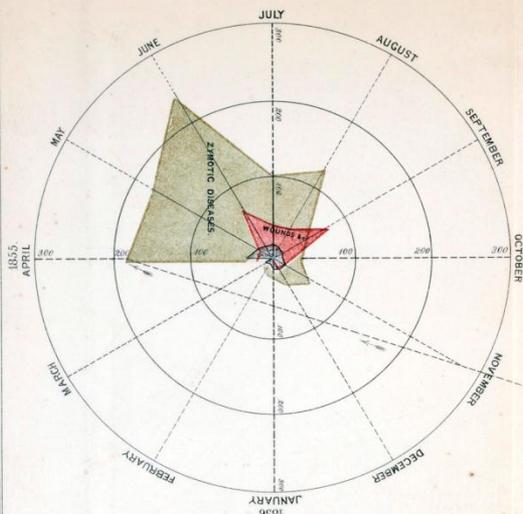
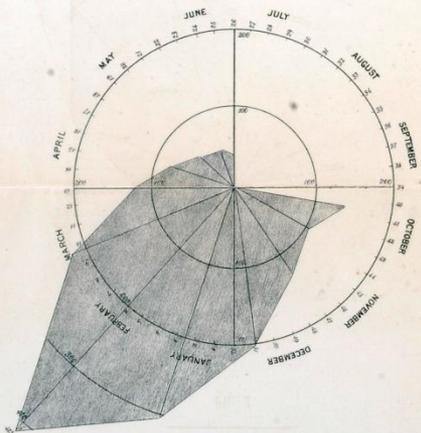


DIAGRAM  
showing the Annual Rate of Mortality Per-Cent, on the  
SICK POPULATION AT SCUTARI,  
FROM OCTOBER 1<sup>st</sup> 1854 TO JUNE 30<sup>th</sup> 1855.

Fig. 2.



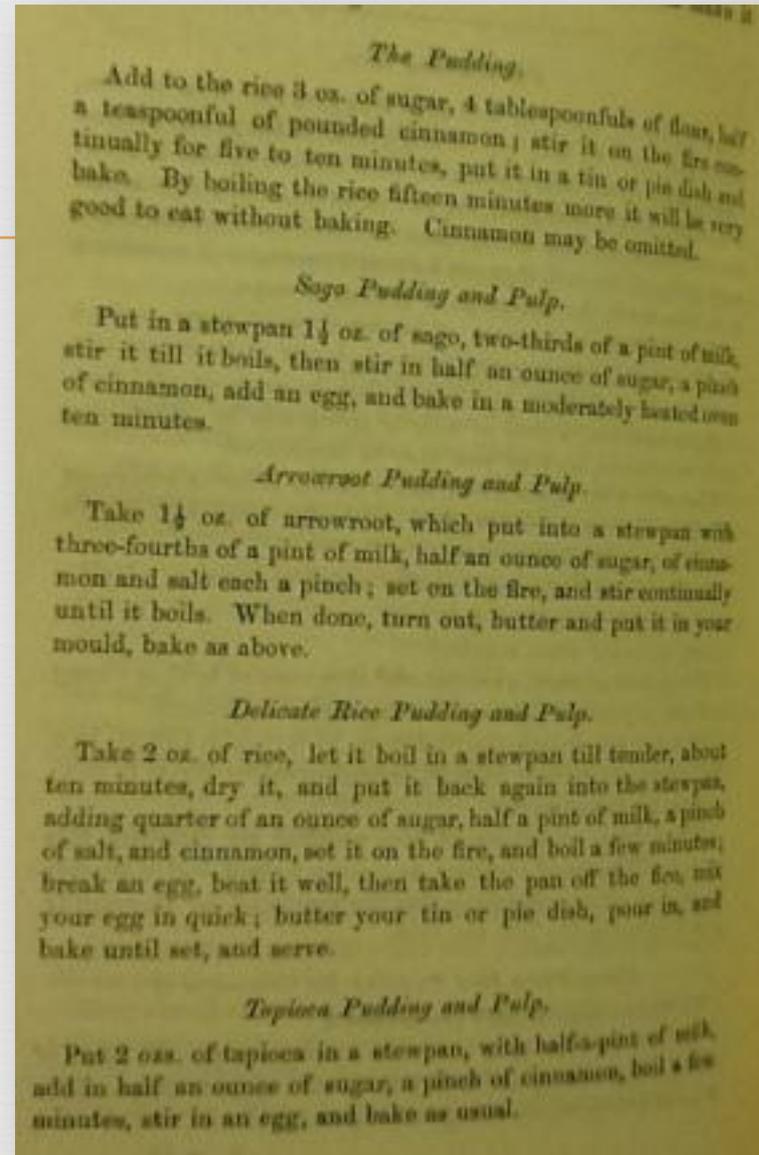
Had Fig. 2 been projected on the same Scale as the other Figures on this Sheet, the longest Radius, showing the Mortality in February, would have projected 40 inches from the Centre of the Circle.

# On zymotic disease



☞ ‘One has killed its thousands and others its tens of thousands’.

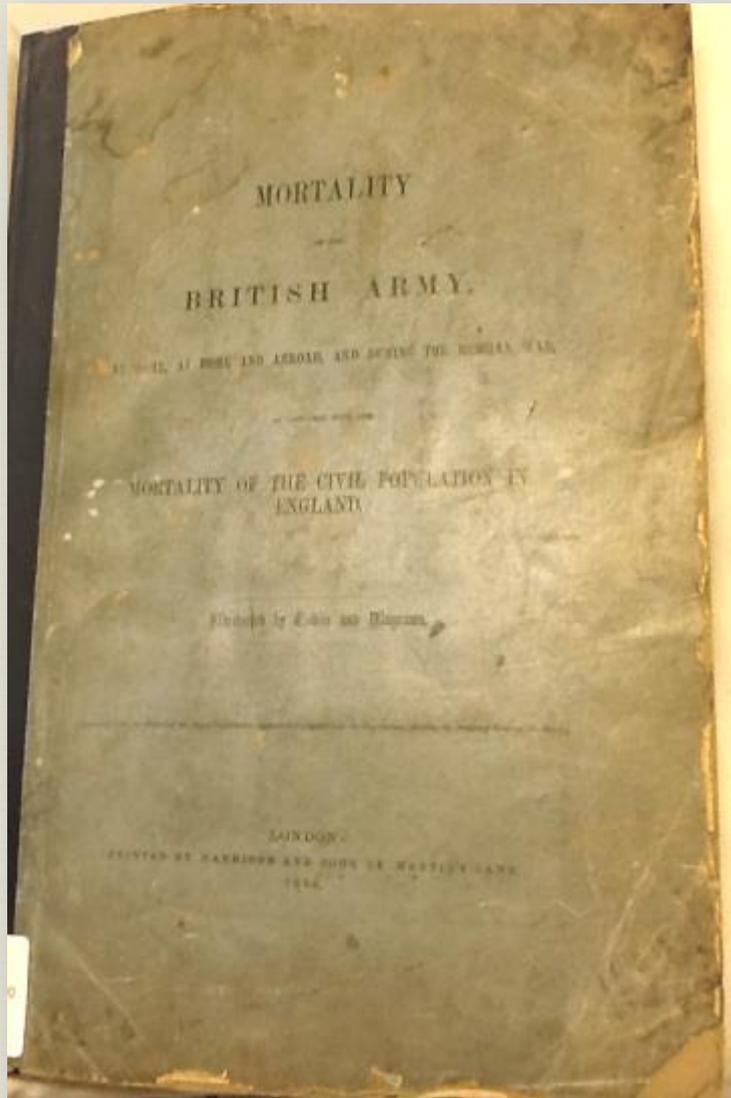
☞ The book continues with tables of nutrients, plans of hospitals and kitchens and many recipes!



# Mortality of the British Army

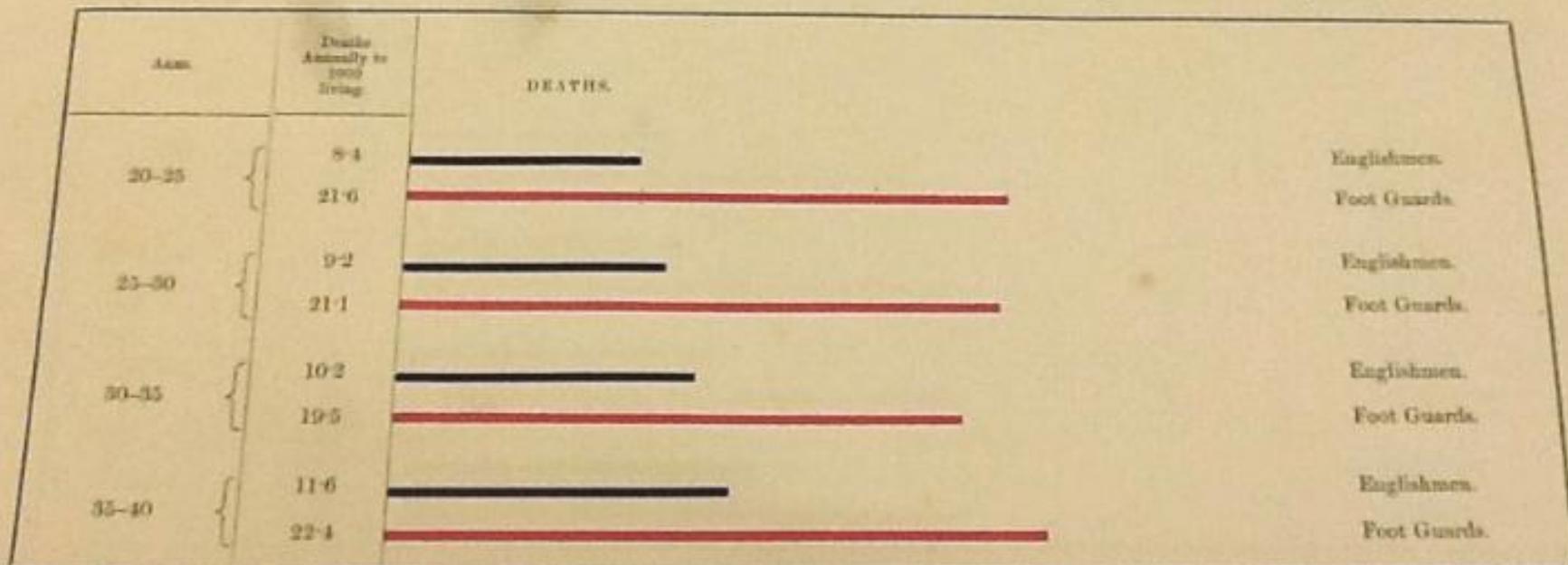


❧ *'Diagrams, one of the great utility for illustrating certain questions of vital statistics by converging ideas on the subject through the eye which cannot be so readily grasped when contained in figures.'*



# LINES

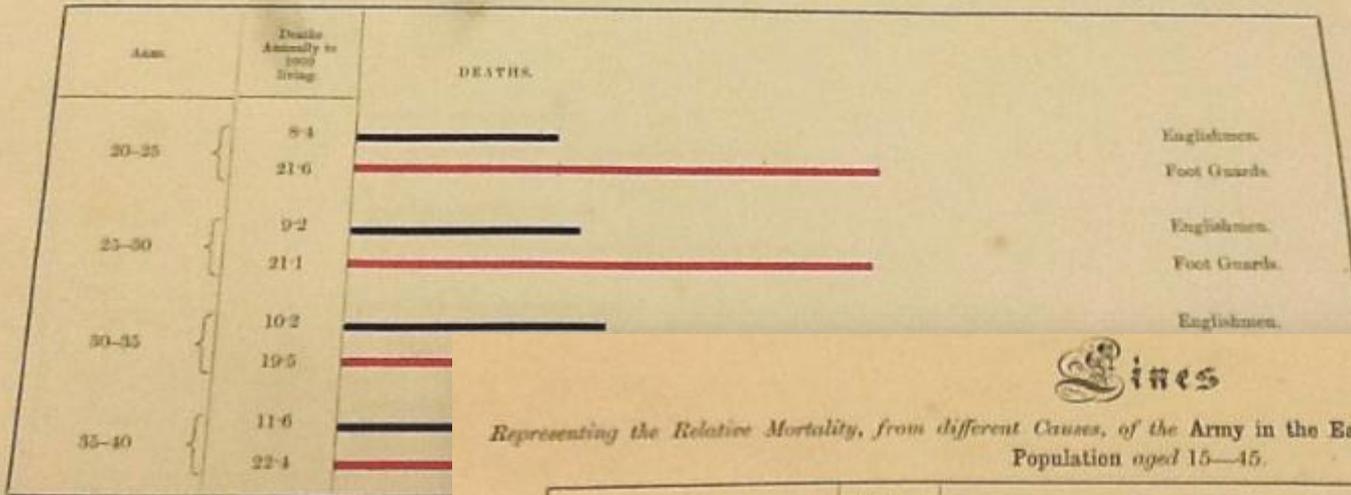
*Representing the Relative Mortality of the Foot Guards and of the English Male Population at corresponding Ages.*



JAMES LEWIS, Act., General Register Office, General House.

**NOTE.**—The Mortality of the English Male Population, at the above ages, is taken from English Life Table (1849-53).

Representing the Relative Mortality of the Foot Guards and of the English Male Population at corresponding Ages.

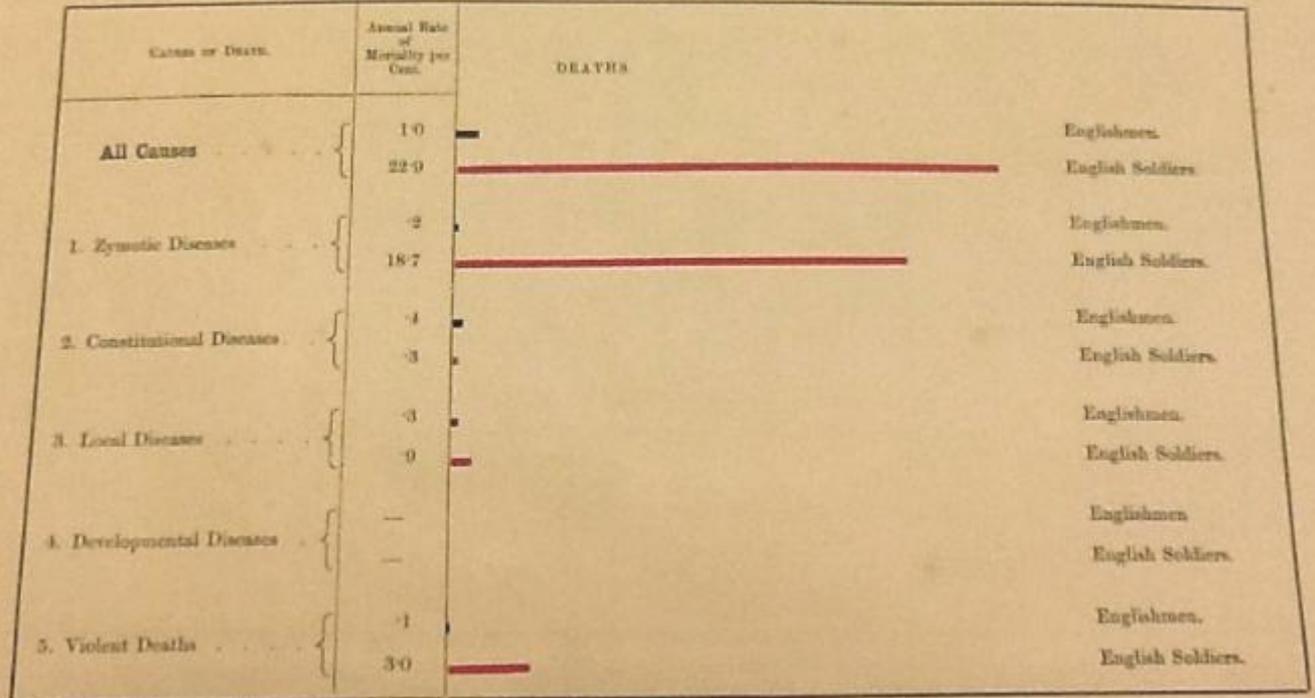


JAMES LEWIS, Esq., General Register Office, General Register House.

NOTE.—The Mortality of the

‘Guards are physically very select.... One could say... that a soldier.... was the most likely to enjoy perfect health and a long life.’

Representing the Relative Mortality, from different Causes, of the Army in the East in Hospital and of the English Male Population aged 15—45.



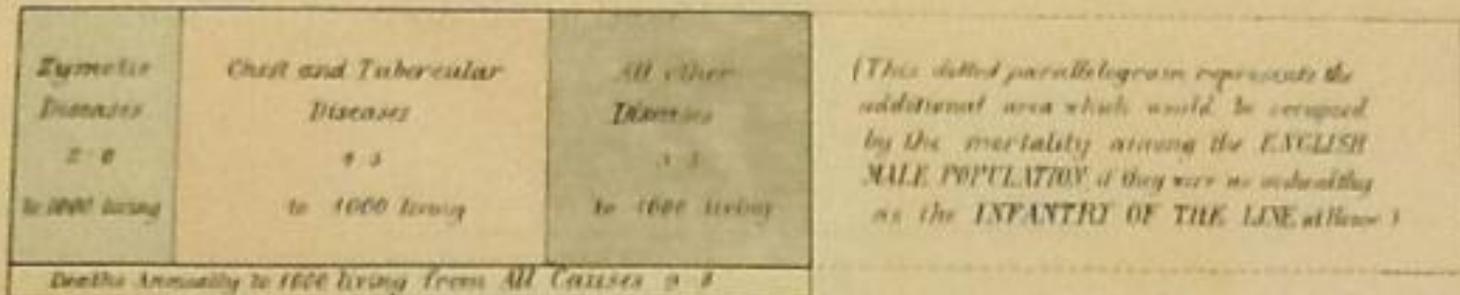
JAMES LEWIS, Esq., General Register Office.

All the lines on this Diagram would require to be lengthened upwards to be on the same scale as the lines on Diagrams A and B.

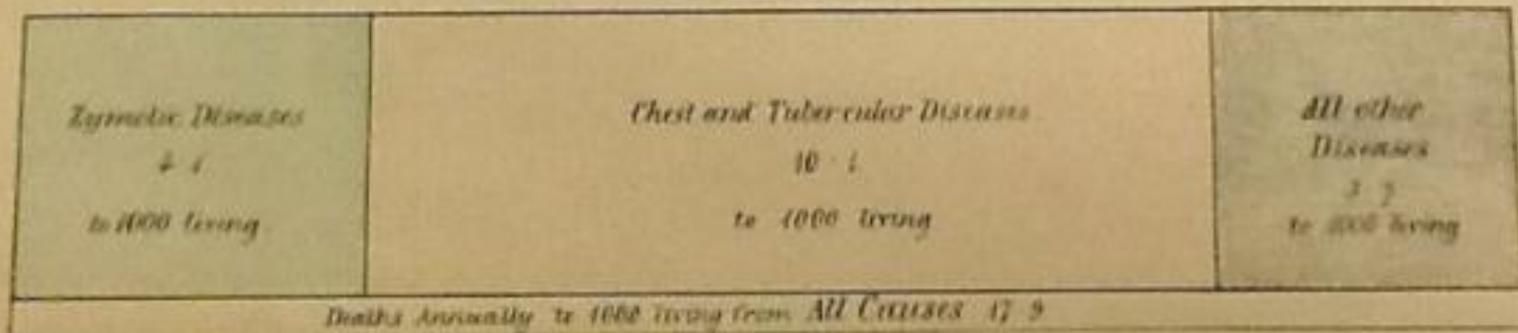
DIAGRAMS  
(for Illustrative Table C.)

representing the relative Annual Mortality from ALL CAUSES, ZYMOTIC DISEASES, CHEST and TUBERCULAR DISEASES and OTHER DISEASES in the ENGLISH MALE POPULATION aged 15-45, and in the INFANTRY OF THE LINE, serving at Home

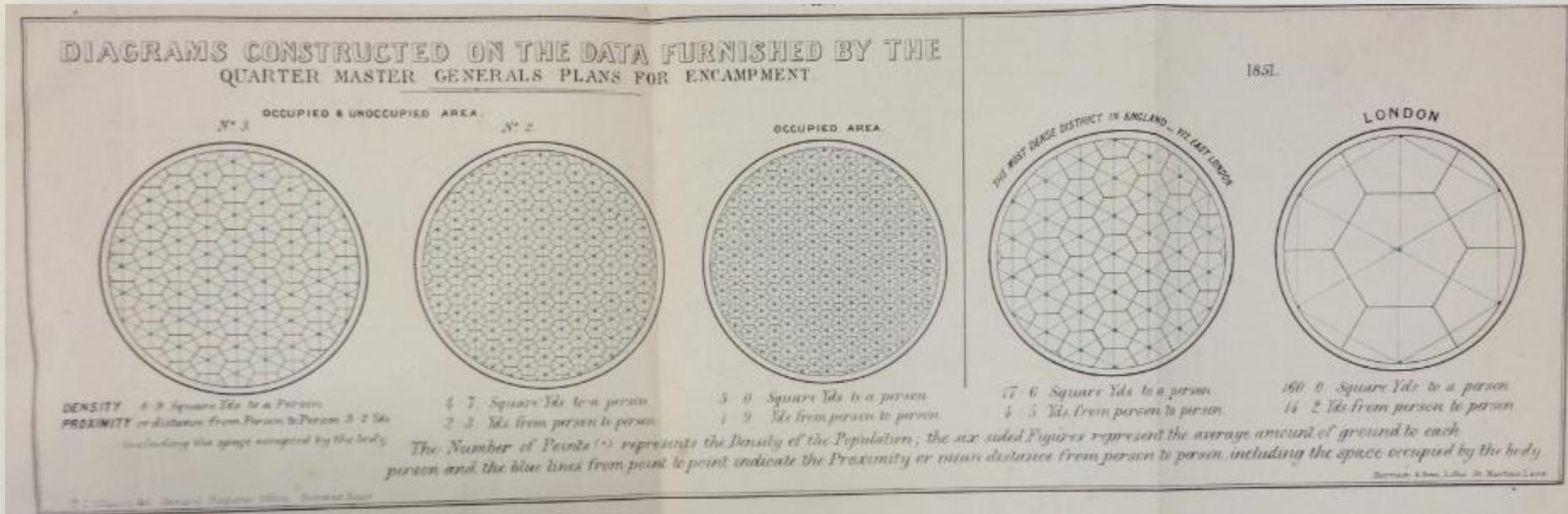
ENGLISH MALE POPULATION AGED 15-45 (1848-54)



INFANTRY OF THE LINE (SERVING AT HOME) (1837-46)



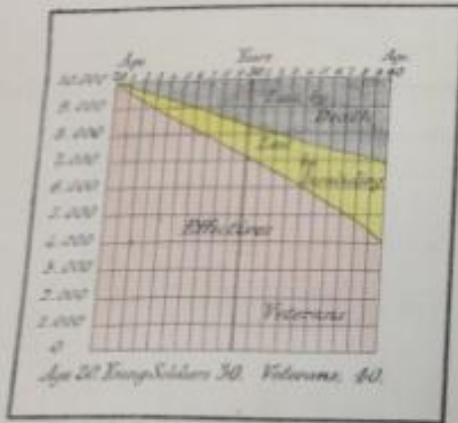
# Comparisons



‘It will be seen that the least crowded of the QMGs plans affords about a twentieth part of the area per man allotted to each inhabitant of the metropolis; that it is about half the amount of that in the most densely peopled part of London; and that the population on the occupied area of the camp is above 50 times more crowded than the population of London.’

# Forecasting

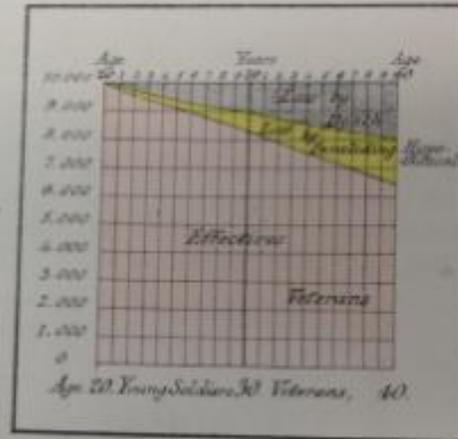
*I. DIAGRAM - representing the ARMY at Home in its present State.*



*I. This Diagram has been constructed to illustrate Table F.a.*

*Each of the 200 small Parallelograms represents 1000 Men.*

*II. DIAGRAM - representing the ARMY at Home in an improved State.*



*II. This Diagram is constructed so as to show what the State of the Army at Home would be if the Mortality were the same as it is in the Civil Population at corresponding Ages, and if the Invaliding bore the same proportion to the Deaths as it does in Diagram I. The Invaliding may be more, but it would probably be less than it is represented to be in Diagram II.*

## *TWO DIAGRAMS showing the loss of strength in the ARMY by INVALIDING and by DEATH.*

*The force 141,764 (represented by the RED Area,) is assumed to be maintained by 10,000 Annual Recruits, which if there were no loss by Death, or by Invaliding would sustain a force of 200,000 Men, represented by the Square figures. - The loss of strength shown in Diagram I is equal to 58,237 = 29 per Cent.*

*The DARK Area represents the loss of strength by DEATH.*

*The YELLOW Area represents the loss of strength by INVALIDING, and it will be borne in mind that many of the Invalided die soon after leaving the Army.*

*NOTE. 10,000 Annual Recruits under system N<sup>o</sup> 1, would sustain a force of 141,764; under System N<sup>o</sup> 2, 10,000 Annual Recruits would sustain a force of 166,910. ( See Table F.d.)*

*Owing to Service abroad in unhealthy Stations, the numbers are actually reduced much more rapidly than they are at home, as shown in Diagram I.*

# Achievements



- ❧ Significantly lowered the mortality rate of the British Army
- ❧ Reorganisation of Army Medical Statistics
- ❧ Commission to inquire into the state of the British Army in India
- ❧ Redesigning of hospitals
- ❧ Nursing training schools – especially district nursing

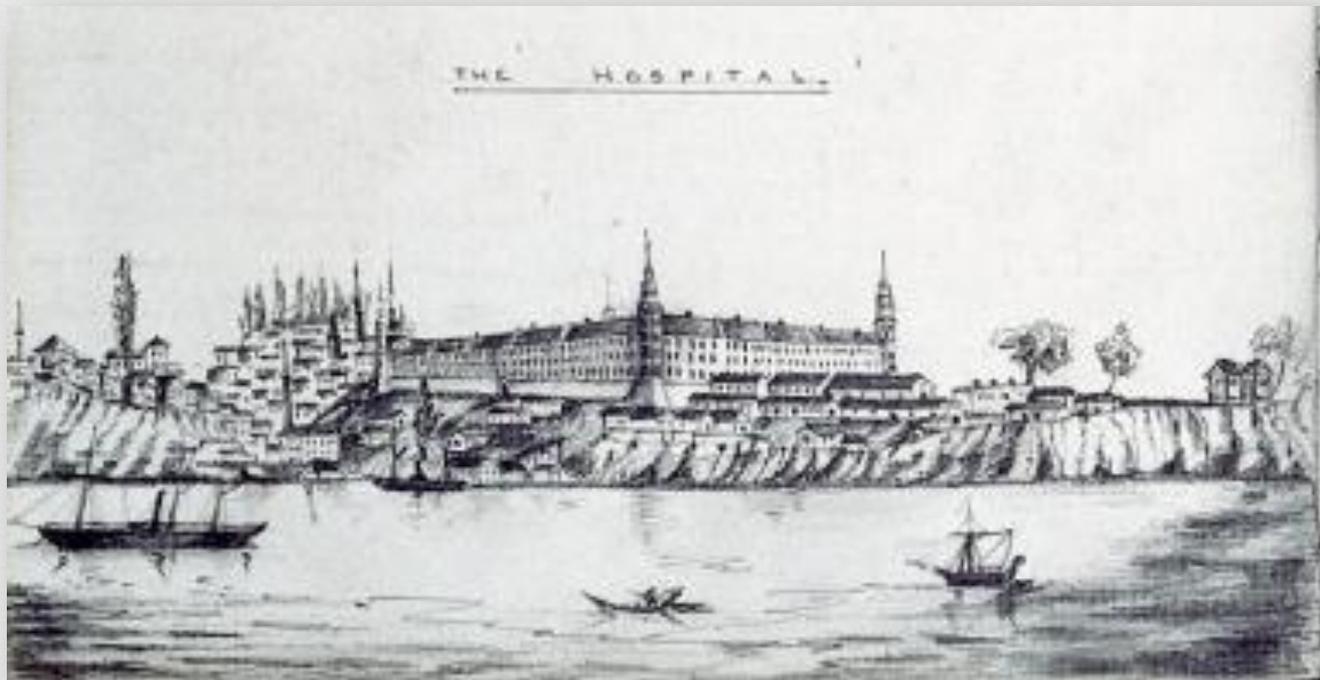


# Who was Florence Nightingale?



- ❧ Prolific letter writer
- ❧ Administrator / manager
- ❧ Nurse and hospital reformer
- ❧ Pioneer of women's rights
- ❧ Mathematician / statistician
- ❧ Populariser of maths / stats
  
- ❧ Used maths and statistics to change lives

# Operational Researcher?





Thank you for  
Listening  
Questions?

# References



- ❧ Bostridge, M., 2009 *Florence Nightingale* London: Penguin
- ❧ Magnello, E., 2012 Victorian statistical graphics and the iconography of Florence Nightingales's polar area graph in *BSHM Bulletin* 27 pp. 13-37
- ❧ Nightingale, F., 1858 *Notes on Matters on the health, efficiency and hospital administration of the British Army*, London: Harrison & sons
- ❧ Nightingale, F., 1858 *Mortality of the British Army compared with the mortality of the civil population*, London