William Farr on the Cholera: The Sanitarian's Disease Theory and the Statistician's Method

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IN 1852 the British medical press heralded a major work on England's second epidemic of cholera. The *Lancet* called it 'one of the most remarkable productions of type and pen in any age or country,' a credit to the profession.[1] Even in the vastly different medical world of 1890, Sir John Simon would remember the report as 'a classic in medical statistics: admirable for the skill with which the then recent ravages of the disease in England were quantitatively analyzed . . . and for the literary power with which the story of the disease, so far as then known, was told.'[2] The work was William Farr's *Report on the Mortality of Cholera in England, 1848–49*,[3] which had been prepared in England's great center for vital statistics, the General Register Office. In reading the report and its sequels for the 1853–54[4] and the 1866 epidemics[5] one is struck by their comprehensiveness and exhaustive numerical analysis, but even more by the realization that the reports are intimately bound up with a theory of communicable disease and an attitude toward epidemiological research

1. *Lancet*, 1852, *1*, 268.

2. John Simon, *English sanitary institutions, reviewed in their course of development, and in some of their political and social relations* (London, Paris, New York, and Melbourne, 1890), p. 240.

3. [William Farr], *Report on the mortality of cholera in England, 1848–49* (London, 1852).

4. William Farr, 'Letter to the Registrar General on the causes of death in England,' *Seventeenth annual report of the Registrar-General of births, deaths, and marriages in England*, Appendix (pp. 74–99). The title of this series will hereafter be abbreviated *Ann. Rep. Reg.-Gen.* These annual reports were usually reprinted in the British parliamentary papers as they appeared in their separate volumes. There are two exceptions: for the tenth to the seventeenth reports only a very brief abstract was included in the parliamentary papers, and for the earlier reports the text, although the same, is differently paginated in the two published forms. I have chosen to cite the form in the parliamentary papers first whenever possible giving: the parliamentary session, the report's command number, the volume number in the sessional sequence, and the page number within that volume. The numbers in parentheses are page numbers of the separately published volumes and are given whenever the paging in the two versions did not agree or when the portion of the report cited was not included in the parliamentary sessional papers.

5. [William Farr], *Report on the cholera epidemic of 1866 in England, Suppl. 29th Ann. Rep. Reg.-Gen.*, 1867–68 [4072], *xxxvii.*

quite foreign to twentieth-century medicine. The former is a social theory of disease of a reformer who was convinced that disease, and especially epidemic mortality, was not only a medical but also a social phenomenon and that the elimination of much human suffering was immediately possible by the physical improvement of the urban environment. The approach to epidemiological research involved the use of national mortality statistics to weigh environmental influences on health, a technique of great influence in the decades before the general acceptance of the germ theory of disease. Farr's cholera reports are unusual in their continuity of approach and data, and together they are an excellent example of the use in the nineteenth century of national vital statistics in assessing disease phenomena in a complex social setting. More germane to the present topic is the way these reports illustrate the relation of Farr's empirical methods to his eclectic notions of disease causation.

William Farr[6] (1807–83) received a varied medical education: private study and apprenticeship in Shrewsbury, two years at the Paris Medical School, and several terms at University College, London. He passed the examination for an Apothecaries' License in 1832, but failed to establish a successful medical practice. He made a meager living in medical journalism and meanwhile began privately to study vital statistics, a subject receiving renewed interest in Britain.[7] His chapter in McCulloch's *Statistical Account of The British Empire*[8] in 1837 established him as an authority on statistics and was instrumental in gaining for him the post of compiler of abstracts, later superintendent of the statistical department, in the newly

6. There are few published sources on Farr's life and work. A collection of excerpts of his writings and a short biographical introduction are found in William Farr, *Vital statistics: A memorial volume of selections from the reports and writings of William Farr, M.D., D.C.L., C.B., F.R.S.*, ed. Noel A. Humphreys (London, 1885). One aspect of Farr's thought is treated in Victor L. Hilts, 'William Farr (1807–1883) and the "human unit",' *Victorian Stud.*, 1970, *14*, 143–150. An attempt at a more comprehensive treatment is found in John M. Eyler, 'William Farr (1807–1883): An intellectual biography of a social pathologist' (unpublished Ph.D. dissertation, Dept. History of Science, University of Wisconsin, 1971). Older treatments emphasizing Farr's contributions to public health include: Major Greenwood, *The medical dictator and other biographical studies* (London, 1936), pp. 91–120, and *Some pioneers of social medicine* (London, New York, and Toronto, 1948), pp. 61–80; and Arthur Newsholme, *Fifty years in public health: A personal narrative with comments* (London, 1935), pp. 98–101, and 'The measurement of progress in public health with special reference to the life and work of William Farr,' *Economica*, 1923, *3*, 186–202.

7. In the mid-1830s Farr had editorial responsibility of *The British Medical Almanack* and for the *British Annals of Medicine, Pharmacy, Vital Statistics, and General Science.* Farr's growing familiarity with vital statistics and his concern to discover statistical laws of health and disease are revealed in his attempt to derive a law for recovery and death in smallpox over time, *British annals of medicine, pharmacy, vital statistics, and general science*, 1837, *1*, 72–79 and 134–143.

8. William Farr, 'Vital statistics; or, the statistics of health, sickness, diseases, and death,' in J. R. McCulloch, ed., *A statistical account of the British Empire* (London, 1937), 2 vols., II, 567–601.

created General Register Office. He served in that office from 1839 to 1880, his performance exceeding all reasonable expectations for the modest position. Farr became the architect of England's national system of vital statistics and a world authority on the subject. He provided the statistical and medical expertise for the office he served, making many technical innovations and compiling standard statistical sources.[9] Characteristically he showed how national mortality statistics could be used to illustrate the magnitude of human suffering and premature death caused by ignorance, mismanagement, and neglect.[10] Farr was a respected member of the medical community and an outspoken advocate of public health and social medicine.

I

Farr was not primarily an etiologist. His resort to disease theory was to bring the weight of medical opinion to the aid of sanitary reform and to provide a theoretical basis for statistical investigations of disease mortality. He was highly eclectic and drew heavily on the medical literature of his day. He first published his views around 1840 and constantly revised them for the next forty years.[11] His intended audience was only partially a medical one. It is significant that his comments on etiology occur not in medical or scientific journals, but in publications wherein he might reasonably expect to influence men of public affairs: the *Annual Reports of the Registrar-General*, an official government report, and the *Transactions* of the Social Science Association, the annual report of that body of liberal political figures, professional men, and other public-minded men and women dedicated to a variety of social reforms. Farr did not contribute directly to the elucidation of the etiology of cholera, although his statistics did, ultimately, help to promote John Snow's views. Rather, Farr articulated an attitude toward the causes of communicable disease quite typical of a large

9. He devised statistical nosologies for domestic and international use. See for example: *1st Ann. Rep. Reg.-Gen.*, Appdx. (P), 1839 [187], *xvi*, pp. 66–72 (pp. 92–101); *4th Ann. Rep. Reg.-Gen.*, Appdx. 1842 [423], *xix*, pp. 93–127 (pp. 147–216); *16th Ann. Rep. Reg.-Gen.*, Appdx., (pp. 71–105). Farr also constructed life tables for England and for smaller geographical regions or for separate social groups. Of these the most famous are his three national life tables: No. 1, *6th Ann. Rep. Reg.-Gen.*, Appdx. II, 1844 [540], *xix*, pp. 290–358 (pp. 517–666); No. 2, *12th Ann. Rep. Reg.-Gen.*, Appdx., (pp. 73–108), and *20th Ann. Rep. Reg.-Gen.*, Appdx., 1859 sess. 2 [2559], *xii*, pp. 177–204; and No. 3, *English life table: Tables of lifetimes, annuities, and premiums, with an introduction by William Farr, M.D., F.R.S., D.C.L.* (London, 1864).

10. Eyler (n. 6), pp. 229–239.

11. For the first systematic statements of Farr's theory of disease see: [William Farr], 'Statistical nosology,' *4th Ann. Rep. Reg.-Gen.*, Appdx., 1842 [423], *xix*, pp. 119–122 (pp. 199–205); and [William Farr], 'Causes of the high mortality in town districts,' *5th Ann. Rep. Reg.-Gen.*, Appdx., 1843 [515], *xxi*, pp. 203–207 (pp. 411–419).

section of the British medical profession in the 1850s and 1860s.[12] The statistical studies he undertook on the cholera epidemics were intimately related to this disease theory.

Of greatest interest is Farr's understanding of what he called the zymotic diseases: the epidemic, endemic, and contagious diseases. These diseases came first in his nosologies, and it was to them he and most advocates of preventive medicine devoted their attention. Among the zymotic diseases were the major epidemics: smallpox, cholera, typhus, plague, and influenza, as well as other diseases such as cow pox, glanders, hydrophobia, syphilis, 'infection in dissecting' [*sic*], erysipelas, puerperal fever, measles, scarlet fever, whooping cough, dysentery, and diarrhoea.[13] The blood, he reasoned, was probably the seat of these ailments, but their most distinctive feature was that they seemed to be caused by the introduction into the body of a nonliving organic substance specific for each disease. The nature of these materials was of course unknown, but several of their properties could be inferred from observations of disease processes. The most important property was the ability to reproduce in healthy blood and bring about disease symptoms. A drop of fluid from a smallpox pustule could not only cause the disease when 'mixed in the blood' of a susceptible child, but in the process was multiplied many times, producing enough new smallpox material to inoculate scores of other children.[14] Farr believed that the disease process, which he called zymosis, resembled but was not identical to fermentation. The analogy and the observation underlying it were hardly original. In first summarizing his theory, Farr freely used examples and excerpted passages from Liebig's *Animal Chemistry*, which had just appeared.[15]

Farr originally conceived of the disease-producing zymotic materials simply as nonliving organic poisons having in the body a peculiar reproductive property.[16] Smallpox, syphilis, typhus, and cholera, for example, were caused by the introduction of specific zymotic materials: varioline,

12. Farr's emphasis in disease theory in the 1860s should be compared with the views described in J. K. Crellin, 'The dawn of the germ theory: Particles, infection and biology,' in *Medicine and science in the 1860s: Proceedings of the sixth British congress on the history of medicine*, ed. F. N. L. Poynter (London, 1968), pp. 57–76.

13. For the following information see [William Farr], 'Statistical nosology,' *4th Ann. Rep. Reg.-Gen.*, Appdx., 1842 [423], *xix*, pp. 119–122 (pp. 199–205), which was reprinted in a long footnote in Farr (n. 3), pp. lxxx–lxxxiii.

14. W[illiam] Farr, 'Address on public health,' *Trans.*, NAPSS (Manchester, 1866), p. 75.

15. Farr (n. 13), pp. 119–122 (pp. 199–202 and 204–205).

16. His understanding in these terms is most apparent in his first presentation of the zymotic theory where he moved directly from cases of poisoning by known chemicals to poisoning by the zymotic materials, *ibid.*, pp. 118–120 (pp. 196–200).

syphiline, typhine, and cholerine, respectively.[17] As in the case of ordinary poisoning the dosage and the susceptibility of the victims were important to the outcome of the case. By the 1860s, however, Farr was sharing the interest of contemporary biologists and doctors in the elementary particulate units in biological, including disease, processes.[18] Although he retained the same names for the zymotic materials, his attention was drawn increasingly by ongoing microscopic and chemical investigations and especially by the scientific investigations of the cholera to the elementary units of zymotic material which he named zymads.[19] Following the 1866 cholera epidemic Farr was not content to explain zymotic diseases as the result of the introduction into the body of an undifferentiated organic material, but spoke rather of the generation, reproduction, and death of specific organic molecules, zymads or biads, in the victim's body.[20] This change of emphasis foreshadowed the method by which men of Farr's persuasion could accept the germ theory and still remain adherents of the older sanitary reform program. Farr at first assigned the zymads a place on the border of the three kingdoms of nature, but quite quickly he granted these elementary units additional properties of life, first corpuscular, not independent existence, and then by the early 1870s, the identity of independent living disease germs.[21]

Epidemic and endemic diseases were particularly troublesome to medical theoreticians of the second quarter of the nineteenth century. The spread of smallpox and syphilis by inoculation provided a strong example of contagion. Furthermore, the geographical movement of epidemic diseases suggested their communicability. However, there were serious obstacles to the use of the concept of contagion to explain epidemic and endemic diseases.[22] Among these must be counted the social behavior of such

17. Farr used the spelling 'cholrine' in later writings. For consistency I have chosen to use the form 'cholerine' throughout the text of this article.

18. Crellin (n. 12), pp. 58–66.

19. Farr (n. 5), pp. lxvi–lxx.

20. Farr so argued after summarizing the results of Pasteur's researches on fermentation and diseases of the silkworm, William Farr, 'Letter to the Registrar General on the causes of death in England,' *30th Ann. Rep. Reg.-Gen.*, Appdx., 1868–69 [4146], *xvi*, pp. 217–218. See also William Farr, 'Letter to the Registrar General on the causes of death in England,' *31st Ann. Rep. Reg.-Gen.*, Appdx. A, 1870 [C. 97], *xvi*, p. 198, and William Farr, 'Letter to the Registrar-General on the mortality in the registration districts of England during the years 1861–70,' *Suppl. 35th Ann. Rep. Reg.-Gen.*, 1875 [C. 1155-I], *xviii Pt. 2*, pp. iv and lxv.

21. Compare for example his statements on their nature in Farr (n. 5), p. lxvi; *31st Ann. Rep. Reg.-Gen.*, Appdx. A, 1870 [C. 97], *xvi*, p. 198; *34th Ann. Rep. Reg.-Gen.*, Appdx., 1873 [C. 806], *xx*, p. 221; and *Suppl. 35th. Ann. Rep. Reg.-Gen.*, 1875 [C. 1155–I], *xviii Pt. 2*, p. lix.

22. The most famous explanation of this issue is probably Erwin H. Ackerknecht, 'Anticontagionism between 1821 and 1867,' *Bull. Hist. Med.*, 1948, *22*, 562–593. For nineteenth-century summar-

ailments, especially their temporal fluctuations and geographical favoritism. So great had these problems become that it was common to differentiate contagious from epidemic diseases.[23]

Farr asserted repeatedly that simple contagion failed to explain the epidemics of even the most obviously contagious diseases such as smallpox.[24] Like others of his age he turned to notions of contingent contagion to assign important modifying influences to the environment. In his solution Farr affirmed contagion in the archetypal case of inoculation, normally introducing his etiological views with the examples of smallpox, syphilis, or rabies, which were acknowledged to be spread by the transmission of a material substance.[25] He asserted, however, that the more common mode of transmission for most zymotic diseases involved the atmosphere, not some body fluid as medium, with the lungs as the point of entry into the animal system. Zymotic material could become airborne, and in this state was subject to the fluctuating conditions of its medium. Atmospheric conditions therefore, as well as the susceptibility of individuals, played a role in determining the course of zymotic diseases. Temperature, humidity, wind, precipitation, and barometric pressure all had a hand in determining an epidemic's behavior, but most important were the locally produced organic pollutants called miasmata.[26] Miasmatic theories were of course ancient and had become recently favorite explanatory devices of contemporary doctors and lay sanitarians. The zymotic theory as originally envisaged by Farr relied heavily on miasmatic notions for its explanatory success. Only very slowly was the reliance on miasmata diminished in Farr's thought.[27] In this change his experience with the study of cholera had a large part.

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ies of widely accepted etiological views see William Henry, 'Report on the state of our knowledge of the laws of contagion,' *Rept. Br. Ass. Advmt. Sci.*, 1834, *4*, 67–94, or the writings of Thomas Southwood Smith such as *The common nature of epidemics and their relation to climate and civilization*, ed. T. Baker (London, 1866).

23. Henry (n. 22), p. 88.

24. William Farr, 'Letter to the Registrar-General,' *Appdx. 2nd Ann. Rep. Reg.-Gen.*, 1840 [276], *xvii*, p. 18 (pp. 93–95).

25. Farr (n. 13), pp. 119–120 (p. 200); Farr (n. 14), p. 75; and William Farr, 'Letter to the Registrar-General on the mortality in the registration districts of England during the years 1861–70,' *Suppl. 35th Ann. Rep. Reg.-Gen.*, 1875 [C. 1155-I], *xviii Pt. 2*, p. lxv.

26. This view is implied in many of Farr's reports. Perhaps the most explicit assertion is found in William Farr, 'Causes of the high mortality in town districts,' *5th Ann. Rep. Reg.-Gen.*, Appdx., 1843 [515], *xxi*, pp. 205–207 (pp. 416–419).

27. The beginning of this change is first noted in his later nosologies by the division of the zymotic class into four orders of which only one was miasmatic. Cholera was as yet in the miasmatic order. William Farr, 'Report on the nomenclature and statistical classification of diseases for statistical returns,' *16th Ann. Rep. Reg.-Gen.*, Appdx. (pp. 82–85).

Miasmata, Farr believed in the 1840s and 50s, were heavy, airborne, organic particles, given off by living bodies, or the products of organic decomposition. They were themselves in a state of rapid decomposition, and, until decomposed, hung over cities in light clouds.[28] Unlike gaseous additions to the air, which Farr believed pneumatic chemists had shown were dispersed too quickly to represent any danger to health, the miasmata, as heavy suspended particles, could easily reach hazardous concentrations.[29] In such circumstances zymotic material was especially virulent, and moreover the body was weakened and made more susceptible to its action.[30]

What is more, Farr suggested an intimate connection between miasmata and zymotic material; both were, after all, nonliving organic particles capable of suspension in the air. Under extremely unhealthy environmental conditions zymotic material could be formed from nonlethal organic substances by ordinary chemical means without the introduction of preexisting disease matter.[31] In this case for all practical purposes squalor might be said to cause disease. Hygienic attention was therefore quite properly directed, Farr insisted, to measures which would prevent the formation of heavy mists or clouds of miasmatic material: the removal of decomposing organic matter by proper drainage and sewage disposal, the strict regulation of burial practices and of industries dealing in animal products such as slaughtering or tanning, and the reform of municipalities to provide adequate ventilation through building of parks, the widening of city streets, and the prohibition of extremely dense living arrangements.[32]

The relation between ordinary miasmatic material and zymotic material remained somewhat ambivalent throughout Farr's career. When describing disease processes or the act of contagion, he maintained that the zymotic materials were distinct from any other organic substances. However, in grappling with the phenomenon of epidemics in a broad social setting, he allowed the division between the miasmata and the zymotic substances to

28. Farr (n. 26), pp. 206–207 (p. 418).
29. *Ibid.*, pp. 203–205 (pp. 411–416).
30. Farr (n. 3), p. iv.
31. Farr (n. 13), pp. 119–120 (p. 200); Farr (n. 14), p. 75; and [William Farr], 'Vital statistics,' in J. R. McCulloch, ed., *A descriptive and statistical account of the British Empire*, 4th ed. (London, 1854), 2 vols., II, 569.
32. William Farr, 'Letter to the Registrar-General,' *1st Ann. Rep. Reg.-Gen.*, Appdx. (P), 1839 [187], *xvi*, p. 78 (pp. 111–112); Farr (n. 24), p. 12 (pp. 84–85); and Farr (n. 26), pp. 211–213 (pp. 426–430).

blurr, at times even conjoining their action, allowing miasmata to modify or even to generate zymotic material.[33]

The zymotic theory with its miasmatic elements could offer explanations for epidemic diseases which simple contagion seemed helpless to solve. The action of airborne zymotic disease material could explain how epidemic diseases were able to move from place to place when no direct contact of sick and well could be discovered, and why the quarantine had not been effective against cholera. The modification of the power of zymotic material through meteorological variance, changes in its concentration, and the presence of other airborne organic material offered very plausible explanations for the great changes in time of the mortality of epidemic diseases and for the bizarre nature of the geographical distribution of their attack. Furthermore, the possibility of generating zymotic material from ordinary airborne filth provided an explanation for endemic disease phenomena and for the extraordinarily high mortality of the poorest, most crowded sections of industrial cities.

In all cases Farr's attention was directed principally to the state of the atmosphere, and the removal from the air of organic waste was therefore vindicated as the cardinal preoccupation of sanitary reform and preventive medicine. Well before the 1848–49 cholera Farr had worked out the essential features of his disease theory, and nowhere in that formulation had he seriously considered the possibility of the ingestion of zymotic disease-causing material in water or food. With the exception of the few causes of inoculation, the route of zymotic infection was assumed to be from the air to the lungs and on to the bloodstream, which was the principal site of disease activity. The use of social statistics was justified by the alleged role of the social environment in influencing the nature of the disease attack by determining the strength or concentration of disease material in the air or the susceptibility of human victims. The use of statistics was all the more appropriate in view of Farr's belief in the law-abiding nature of disease phenomena.

Farr began his study of the cholera with the goal of discovering statistical laws of the disease which would relate some natural influence such as age, sex, or time, or an aspect of social condition—for example, income or housing density—to disease mortality. A statistical law of disease, as he understood it, described concisely the order underlying massed statistics of death. Reduced to its essence, the law was a simple numerical relationship

33. Compare for example two passages written a quarter century apart, Farr (n. 24), p. 14 (p. 88); and Farr (n. 14), pp. 75–76.

which would permit one to generate from a series of measurements of one bio-social factor a series of mortality figures closely approximating the observed mortality values under regularly changing conditions.[34] As statistical laws, these relationships applied only to large populations, not to individuals. The almost exclusive use of mortality figures in Farr's studies of disease was dictated by the absence of national sickness statistics throughout his career.[35] Both the idea of such a law and the summation methods used to arrive at it were among Farr's standard techniques and were probably inspired by the actuarial methods used to derive the 'law of mortality' in the construction of life tables.[36]

The quest for statistical laws of disease presumed that disease phenomena exhibited a high degree of regularity and order. Farr made his belief in this regularity very explicit, claiming that the phenomena of life were no less ordered and only a little less accessible to human understanding than the subject matter of astronomy, physics, and chemistry.[37] Farr considered the demonstration of a statistical law an invaluable means of verifying theories or of ascertaining unexpected relations in medicine, and a crucial empirical test for the statistician. He frequently compared the series of mortality figures from the registration records to those generated by his statistical laws as if they were the observed and the theoretical values of a laboratory science. A medical theory supported by such a statistical law had therefore a unique claim to Farr's belief.

II

The *Report on the Mortality of Cholera in England, 1848–49* consists of a one-hundred-page introduction and general report by Farr himself, introduc-

34. For a treatment of Farr's idea of statistical law and the belief in biological and social regularity that underlay it see Eyler (n. 6), pp. 113–124.

35. This omission was frequently noticed in criticisms of the registration system. It was noted by the Social Science Association, 'Resolutions of the special committee on registration and sanitary police,' *Trans.*, NAPSS (Glasgow, 1960), p. xxviii; by the British Medical Association, *Brit, med. J.*, 1866, *ii*, 228–229; and by numerous private individuals the most outspoken of which was probably Henry Wyldbore Rumsey, *Essays on state medicine* (London, 1856), pp. 105–107; and 'On certain deficiences in our public records of mortality and sickness, with suggestions for an improved and extended national system of registration,' *Trans.*, NAPSS (Bradford, 1859), pp. 574–577.

36. Farr's general application of life table methods cannot be adequately demonstrated here with detailed references to his writings. The interested reader should see my dissertation, Eyler (n. 6), pp. 125–156, esp. pp. 137–149. Illustrations of nineteenth-century life table technique may be found in Joshua Milne, *A treatise on the valuation of annuities and assurances* (London, 1815), 2 vols. in 1, I, 80–112; and T. R. Edmonds, *Life tables, founded upon the discovery of a numerical law regulating the existence of every human being* (London, 1832). Farr provided several descriptions of the construction of life tables. Of these the most sophisticated is W[illiam] Farr, 'On the construction of life-tables, illustrated by a new life-table of the healthy districts of England,' *Phil. Trans. Roy. Soc. Lond.*, 1859, *149*, 837–878.

37. Compare William Farr, 'Inaugural address,' *J. statist. Soc.*, 1872, *35*, 417; and Farr (n. 8), p. 567.

ing almost four hundred pages of tables, maps, and diagrams prepared in the General Register Office. In the precomputer age of statistics the report was the fruit of a herculean effort. The general report consists of five sections: the first describing the registration of deaths, past experience with epidemics, and local differences in general mortality rates; the second providing a survey and history of the cholera epidemic; the third analyzing possible influences on cholera mortality; the fourth reviewing contemporary theories of the cholera in light of the analysis of the epidemic-caused mortality; and the fifth suggesting practical measures for cholera prevention. Farr paid particular attention to the geographical distribution of cholera deaths, identifying nine 'cholera fields,' geographical areas sustaining intense cholera losses, each centering on a large port city. In the case of each he reviewed the number of deaths in each field, the times of their occurrence, and some of the local characteristics of the field. He also illustrated for the nation at large the differences in cholera mortality between the sexes and calculated age-group cholera mortality rates during the epidemic. Using his mortality figures for the epidemic, he then constructed sickness tables to permit the calculation of the chances of recovery or of death for each period of illness or of the future duration of fatal attacks.[38]

Of greatest interest is Farr's analysis of environmental influences, for it was in this section that he revealed the discovery he prized most highly, that the mortality of cholera varied inversely with the elevation of the soil.[39] In his treatment of the environment's role in cholera mortality Farr gave a survey of the state of the atmosphere.[40] With the aid of the Greenwich observatory he plotted daily mean values for temperature, barometric pressure, rainfall, and wind against deaths by cholera and diarrhoea throughout 1849. No significant relation appeared. This daily tabulation did show that most cholera deaths occurred on Sunday, Monday, Tuesday, and Wednesday, a finding which Farr chose to regard as reflecting the pay periods and the drinking habits of the working class. The key to the cholera problem seemed to lie with the geographical distribution of the attack.[41] More than 80% of the registered 53,000 cholera deaths in 1849 occurred among four-tenths of the population on one-seventh of the land area. Coastal districts had on the average three times the cholera mortality

38. These topics are treated consecutively in Farr (n. 3), pp. xxiii–xliv.

39. Farr thought highly of this discovery and had sections of the report dealing with it reprinted as 'Influence of elevation on the fatality of cholera,' *J. statist. Soc.*, 1852, *15*, 155–183.

40. Farr (n. 3), pp. xlvi–xlix and Plate No. 2.

41. *Ibid.*, pp. l–liii.

of inland districts. What is more, records of the previous epidemic indicated the same pattern had been followed in 1832. It seemed then that some quite permanent feature of certain environments was responsible for the local excesses.

Farr had frequently used the thirty-six registration districts of London as a means of assessing the influence of local environment on mortality. He turned to London again.[42] He showed that the order of districts by mortality rates from all causes in nonepidemic years was followed closely by the ordering of districts based on their epidemic cholera mortality. Surprisingly, however, cholera mortality did not seem to vary directly with population density as he had shown some years earlier general mortality did.[43] On the other hand cholera mortality did exhibit an inverse relation to income as measured by taxable property value. None of these relations seemed entirely satisfying to Farr. When, however, he began to group the registration districts by mean elevation above the high-water mark of the Thames, the corresponding average cholera mortality rates displayed promising order. He found, for example, that if the districts were arranged by mean elevation into terraces, each with a twenty-foot range in elevation, i.e., 0–20, 20–40, etc., that the ratios of the corresponding mortality rates per 10,000 inhabitants of each terrace (102, 65, 34, 27, 22, 17) were fairly closely approximated by the series 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$. The relation Farr discovered could be more precisely expressed by the formula $C = C' \cdot \frac{e' + a}{e + a}$ where 'C' and 'C′' are cholera mortality rates per 10,000 living in two districts having mean elevations 'e' and 'e′' in feet above the high water mark of the Thames and 'a' is a constant: approximately 13.[44] This was Farr's law for the influence of elevation on cholera in London, which he demonstrated in tabular form by comparing the observed and the calculated mortality values for 0, 10, 30, 50, 70, 90, 100, and 350 feet. They were 177, 102, 65, 34, 27, 22, 17, 7, and 174, 99, 53, 34, 27, 22, 20, 6, respectively.

We can imagine Farr's delight. The result was just the sort he was looking for; moreover it seemed to confirm his disease theory. In fact the whole idea of looking at the influence of elevation was in keeping with his understanding of cholera's causation. The alluvial soil and stagnant water along the margins of the river contained abundant organic material for the production of miasmata. As one ascended the Thames basin the concentration

42. *Ibid.*, pp. lviii–lxviii.
43. Farr (n. 26), pp. 207–209 (pp. 420–423).
44. Farr (n. 3), p. lxiii.

of miasmata in the atmosphere dropped quite quickly, producing a regular and predictable change in cholera mortality.[45] Elevation was therefore not itself the cause of high cholera mortality but an indirect influence favoring the production and dissemination of the disease-producing material. Such explanations were not uncommon among British medical topographers. As late as 1877 Alfred Haviland, in suggesting how land form influences microclimate and therefore health, gave a physical explanation of the formation in steep valleys of heavy mists capable of holding 'malarious particles.'[46]

From a twentieth-century perspective the crux of the problem is that the same peculiarities of geographical distribution of the 1849 cholera that originally puzzled Farr had been used by John Snow in support of his waterborne theory of the cholera, the confirmation of which discovery would also rely on statistical studies of mortality. Farr obviously knew of Snow's theory, which had been published just before his own report, because he summarized Snow's ideas and gave brief treatment to some of the implications of the theory.[47] In view of his disease theory and his newly found cholera law, it is not surprising that Farr remained at first dubious of Snow's innovation. Farr calculated cholera mortality rates for the districts served by each of London's water companies and recognized that the districts with the highest cholera mortality were not only those of lowest elevation, but were almost all served by the Southwark and Lambeth water companies which drew their water far downstream in the tidal water of the Thames. He nevertheless chose to regard drinking water as he did income—simply as a modifying influence on the elevation law. Farr realized that of two major cities on the same river, the one downstream invariably had the higher cholera mortality. Farr admitted also that the second city inherited the sewage of the first. Whereas Snow's theory claimed the material cause of the cholera was transmitted from the intestines of cholera victims through the river water which residents of the second city consumed, Farr regarded the polluted river water as but another source of miasmata. The important factor was not the drinking of the water but the amount of organic material entering the air with the evaporation from the vast Thames surface in London.[48]

45. *Ibid.*, p. lxix–lxx.
46. Alfred Haviland, *Physical geography in relation to sanitary science* [London, 1877], pp. 206–207.
47. Farr (n. 3), pp. lxxvi–lxxviii, lviii–lxii, lii, and lxix–lxx.
48. Revealing of this attitude is Farr's summary of Glaisher's estimate of the amount of water evaporated from the Thames in London, *ibid.*, pp. lix–lx.

III

Although his theory had not yet achieved general acceptance, Snow had succeeded in forcing the issue of water purity into studies of the cholera. Medical reformers such as Farr did not flatly deny the possibility of impure water exerting a pernicious effect in cholera epidemics, but they denied Snow's explanation of the mechanism of such influence. Once Snow's theory had been raised, its implications could not be ignored in subsequent cholera epidemics. The opportunity for verification was not long delayed. Asiatic cholera became epidemic in England again in 1853, just one year after the appearance of Farr's report of the previous epidemic, and the new visitation continued in 1854.

Since the former epidemic the condition of the London water supply had changed so as to provide a unique opportunity for the vital statistician. Among the various new regulations to take effect by August 1855, the Metropolis Water Act of 1852 required that all river water supplied by water companies for domestic use be drawn from the Thames above Teddington Lock or from its tributaries above tidal influence.[49] At the time of the 1853–54 epidemic, only one company, the Lambeth Waterworks Company, had complied with the new regulations, thereby suddenly changing its source from one of the most to one of the least contaminated by sewage.[50] The change was of utmost importance since the districts the company had served were among those southern districts most severely affected in the previous epidemic. Most important of all, however, was the fact that in a number of districts the Lambeth company competed directly, street by street, house by house, with the Southwark and Vauxhall company, which continued to draw its water supply from a highly polluted area. In other respects the social and sanitary condition of the patrons of the two companies were as identical as it was imaginable to obtain. By considering the cholera mortality of the patrons of the two companies during the 1848–49 and 1853–54 epidemics, a vast experiment was obtained concern-

49. Great Britain, *Statutes at large*, 15 and 16 Vic., c. 84 (1852), 'An act to make better provision respecting the supply of water to the metropolis.'

50. For details of the Lambeth company's change of supply and its competition with the Southwark and Vauxhall company see John Simon, *Report on the last two cholera-epidemics of London, as affected by the consumption of impure water; addressed to the Rt. Hon. The President of the General Board of Health by the Medical Officer of the Board*, 1856 [2103], *lii*, pp. 4–5; and John Snow, *On the mode of communication of cholera*, 2nd ed. (London, 1855), in Wade Hampton Frost, ed., *Snow on cholera: Being a reprint of two papers by John Snow, M.D.* (New York and London, 1936), pp. 68–69.

ing 500,000 human beings in which only drinking water differed among all social and environmental conditions.[51]

The fate of the patrons of these two south London water companies in the 1853–54 epidemic is perhaps the most famous episode in the scientific investigation of cholera. The case attracted the attention of medical contemporaries, including William Farr of the General Register Office, John Simon for the General Board of Health, and of course, John Snow.[52] The results suggested overwhelmingly an important role for water in the epidemic. The population using the more impure water had three and one-half times the mortality rate of the population using water relatively free from sewage and tidal influence. Whereas the cholera mortality among the population served by the Southwark and Vauxhall company had increased from 11.8 to 13.0 per thousand over the two epidemics, the rate for the Lambeth company patrons had dropped from 12.5 to 3.7 per thousand following the procurement of cleaner water.[53] Faced with such striking results, most students of the epidemic now accepted the water supply as a major contributor to excessive cholera mortality, but Snow's explanation for the role of the water supply in the epidemic was as yet unacceptable to most medical sanitarians. In general, water was simply added to air as a medium for the diffusion of cholera-producing material.[54]

By 1854 Farr was an acknowledged cholera authority whose investigations served as models for those of other men.[55] He was one of five members of the Committee of Scientific Inquiry for the General Board of Health during the 1854 epidemic. The statistical section of its report clearly evidences his hand.[56] What is most revealing about the strength of Farr's statistical approach in the British medical profession and the current state of the theory of cholera causation is that although the committee readily accepted and relied on the results of its statistical investigations, it showed

51. Simon (n. 50), p. 9.
52. For summaries of the research see Snow (n. 50), pp. 76–91, and Simon (no. 50), pp. 1–35.
53. Simon (n. 50), pp. 6 and 19.
54. The Committee for Scientific Inquiries for the Medical Council of the General Board of Health concluded that the 'exciting cause' of cholera brews poison from air or water containing ample organic impurities, N[eil] Arnott et al., *Report of the committee for scientific inquiries in relation to the cholera-epidemic of 1854*, 1854–55 [1980], *xxi*, p. 48. John Simon blamed fecalized air and fecalized water equally, Simon (n. 50), p. 15. Other medical men were less sympathetic to Snow's theory: John Sutherland's report in Benjamin Hall, *Letter of the President of the General Board of Health, to the Right Honourable the Viscount Palmerston . . . accompanying a report from Dr. Sutherland on epidemic cholera in the metropolis in 1854*, 1854–55 [1893], *xlv*, pp. 45–46; and William Baly, 'Report on the cause and mode of diffusion of epidemic cholera,' in William Baly and William W. Gull, *Reports on epidemic cholera drawn up at the desire of the cholera committee of The Royal College of Physicians* (London, 1854), pp. 195–207.
55. See Farr's influence in Baly (n. 54), pp. v–vii, 9–18, 58–62, and 205–207.
56. Arnott et al. (n. 54), pp. 6–23.

great caution in making use of the chemical and microscopic investigations it had sponsored of London air and water during the epidemic.[57]

Farr did not publish a special report for the 1853–54 epidemic, and his interest in the epidemic seems to have been primarily that of verifying the results of the study he had just published. Besides compiling the statistics for the cholera report of the General Board of Health, Farr published observations on the epidemic in the Registrar-General's weekly reports, which he summarized in his seventeenth annual letter to the Registrar-General.[58] The organization of that summary is much like that of the 1848–49 report. Special attention was drawn to the comparison of the mortalities of the two epidemics, using the cholera fields he had identified in the previous epidemic and the registration districts of London. The geographical distribution of the deaths caused by the epidemic, the fact that no registration district escaped death by either cholera or diarrhoea, and that the cholera mortality could vary from 2 to 211 deaths per thousand within the districts of London, suggested to Farr that the cause of cholera was widely diffused but that the 'cause of the intense form of cholera is local, and circumscribed in its action.'[59] A statistical survey of the distribution of mortality by time, age, sex, and especially place, was once again his underlying tool, and he seemed convinced that the epidemic conformed to the general behavior of its predecessor.

What is new in this study was the increased attention he paid to the cholera deaths within the area served by each of London's eight private water companies. Farr had apparently directed his efforts toward investigating the effect of the water supply before Snow began his special study in South London, because on 13 October 1853 the General Register Office addressed a letter to each water company, asking information on the source of the water, the area of the metropolis served, and any changes they had made in water quality or service since 1849.[60]

Farr's statistics convinced him not only that polluted water had a large share in determining the character of London's cholera epidemic, but also that the zymotic theory needed modification. He ended the report saying, 'the cholera matter or *cholerine*, where it is most fatal, is largely diffused

57. *Ibid.*, pp. 34–38, esp. 36, and 46–48.
58. Farr (n. 4), pp. 74–99.
59. *Ibid.*, pp. 82 and 88.
60. *Ibid.*, pp. 91–94. John Simon recalled that Farr had suggested the investigation of the relation of water to cholera mortality in South London by the Committee of Scientific Inquiries for the General Board of Health as a sequel to his and Snow's studies, Simon (n. 2), pp. 259–260.

through *water*, as well as through other channels.'[61] Yet the acceptance of water as a medium for the diffusion of disease material did not deal a death-blow to airborne explanations of cholera; neither did it require a complete acceptance of Snow's cholera theory. As late as September 1854 Farr still regarded the air-lung route as the primary avenue of cholera infection. In the case of cholerine diffused in water, it seemed likely that most of the material first entered the air by evaporation from cisterns, taps, drains, and local reservoirs. The water 'comes into contact with the body in many ways and it gives off incessantly at its temperature, ranging from the freezing point to summer heat, vapors and effluvia into the atmosphere that is breathed in every room. . . .'[62]

IV

Farr's transition to a predominantly waterborne explanation of cholera epidemics was completed by the time he wrote his second major cholera report, that for the 1866 epidemic.[63] By that time John Simon was dead, the General Board of Health had been disbanded, and the character of etiological and epidemiological research sanctioned by the central health agency substantially altered. The role of John Simon's activity as medical officer to the Privy Council in encouraging and institutionalizing pathological research in public health is well known.[64] The changes in the theoretical basis of epidemiology in Europe are reflected in Farr's last cholera report. Whereas in the report for 1848–49 chemists were called upon to explain the cholera action in zymotic terms, by 1866 Farr was relying primarily on the pathologists and microscopists, especially those who had studied the digestive tracts and intestinal discharges of cholera patients.[65] Authorities like Liebig, Dumas, and Thomas Graham were replaced by John Burdon Sanderson, Filippo Pacini, Lionel S. Beale, and Louis Pasteur, whose work was interpreted in zymotic terms. We have already suggested that Farr's conversion to the germ theory of disease was foreshadowed by his growing interest in the elementary particles of zymotic material. In his report for the 1866 cholera epidemic Farr first gave serious

61. Farr (n. 4), p. 99.
62. *Ibid.*, p. 95.
63. Farr (n. 5).
64. Royston Lambeth, *Sir John Simon 1816–1904 and English social administration* (London, 1963); C. Fraser Brockington, *Public health in the nineteenth century* (Edinburgh and London, 1965), pp. 192–237; and Roy M. MacLeod, 'The anatomy of state medicine: Concept and application,' in *Medicine and science in the 1860s: Proceedings of the sixth British congress on the history of medicine*, ed. F. N. L. Poynter (London, 1968), pp. 206–209.
65. Farr (n. 5), pp. xiii–xv and lxv–lxxii.

attention to the results of microscopic investigations and identified the elementary disease particles, zymads, with particles such as 'cholera molecules' observed by Pacini in the discharges of cholera victims.[66]

The report on the 1866 epidemic was, like that for 1848–49, a book-length work and was in some ways statistically more sophisticated.[67] Like its predecessors this report was designed to illustrate the cholera epidemic as a complex socio-medical phenomenon, and to use the government's mortality statistics to test contemporary theories of its activity and to evaluate proposals for its prevention. The causal analysis in this report, however, was directed primarily against one agent, sewage-contaminated water. The old factors of income, occupation, population density, age, and sex were all considered but dispensed with brief regard, and graphs were constructed once again for the temporal distribution of the cholera fatalities and their coincidence with meteorological conditions.[68] The bulk of the explanation of the epidemic relied upon demonstrating the effects of the water supply of London on a special cholera outbreak in East London.[69] The General Register Office began a study of cholera mortality by waterfields, the geographical areas served by the water companies. It became clear early in the epidemic that the mortality in the East London Waterworks Company's waterfield was excessive. The disclosure of this discovery led to the appointment of a parliamentary commission, a select committee, and a royal commission, and a special inquiry by the Board of Trade, the collective results of which showed that through illegal operation the East London Waterworks Company was supplying from its reservoir at Old Ford, water contaminated by the discharge from the recently completed sewage system of West Ham.[70]

Farr's waterfield study was based upon a division of the 135 subdistricts of the metropolis into fifteen groups, eight receiving their water exclusively from one of London's water companies, seven having mixed supplies. A comparison of the groups pointed unambiguously to East London. For the entire epidemic the cholera deaths per 10,000 living in each of the other waterfields were 3, 4, 4, 6, 7, 8, and 15, while in the East London water-

66. Significantly Farr now took the microscopic investigations the General Board of Health had sponsored during the 1854 epidemic more seriously than at the time of their appearance, *ibid.*, pp. lxvi–lxvii.

67. Farr had now for example a section dealing with practical problems of statistical inference lacking in the previous cholera reports, *ibid.*, pp. xxiv–xxix.

68. *Ibid.*, pp. lv–lxi and diagrams 4 and 5.

69. *Ibid.*, pp. xv–xxxiii.

70. For Farr's summary of the committees' findings see *ibid.*, pp. xii and xvii–xx.

field they were 72.[71] In the subdistricts supplied wholly or in part from the suspect Old Ford reservoir of the East London Waterworks Company, the mortality rate was even more excessive than in the area supplied by the company's Lea Bridge reservoir. Furthermore, although the water supply of London had been improved substantially since the last epidemic, cholera mortality falling in South London, for example, from 121 to 94 to 8 over the three epidemics, the mortality in East London had gone from 59 to 34 to 72. The pollution of the River Lea between 1854 and 1866 explained the turnabout in the downward trend of East London's mortality rate.

An additional bit of statistical evidence against the East London Waterworks Company was provided by Farr's calculation of the rate of increase and decrease of cholera fatalities over time. He compared the rates of rise and fall of the 1866 epidemic for all of London and of its waterfields to the rates for 1849 and 1854.[72] The mortality experience revealed a different type of law at work between the two epidemic years 1848 and 1854 and the year 1866 which Farr believed was to be accounted for in the greatly reduced distribution of cholera material in the improved water system. As great a difference existed however between the rates for the waterfield of the East London Waterworks Company and the combined rates for the other waterfields of London in 1866. While the number of weekly deaths in the period 5 August to 3 November was four times that in the period 27 May to 4 August in all other waterfields, for the East London waterfield the deaths in the second period were only three-quarters those in the first. East London's cholera fatalities therefore dropped suddenly from an extremely high rate at the time when the fatalities in the rest of London were quadrupling. Farr traced this sudden decrease to changes the East London Waterworks Company made in its supply when attention was drawn to the cholera toll among its patrons.

By this time Farr accepted water as the primary medium for dissemination of cholera and was accepted by contemporaries as a spokesman for the waterborne theory of cholera contagion. The *Lancet* commented that Farr's report made the waterborne theory 'irresistible.'[73] Farr declared that it was clearly established that cholera was transmitted by the intestinal discharges, cholera flux, of cholera patients. There were principally four means of disseminating the cholerine from cholera flux: (1) personal contact, (2) air, (3) sewer vapor, and (4) water. Whereas the first three modes

71. *Ibid.*, pp. xxi–xxiii.
72. *Ibid.*, pp. xxxi–xxxii.
73. *Lancet*, 1868, *2*, 223.

exerted some influence, estimated for London at a rate of 5 per 10,000 over the entire metropolis, and while in certain less developed societies they might have a prominent influence, in London with its waterclosets and sewers the influence of cholerine diffused in the air was insignificant compared to that of waterborne cholerine.[74] It was to the latter means that the characteristic features of London cholera epidemics were due.

V

This substantial change in Farr's ideas on the communication of cholera, the tempering of the miasmatic elements in the zymotic theory, the admission of water as a disease-transmitting medium, and the growing interest in the results of bacteriological research all portend the new era in epidemiology soon to achieve spectacular success. But what became, we might ask, of the faith placed in social and mortality statistics as a tool of the epidemiologist? The clever use of such methods had done much to establish the new cholera etiology before the disease organism was discovered. His experience with cholera had not altered Farr's trust in statistical approaches in medicine. He retained a belief in the power of numerical empiricism to cut through the apparent complexity of socio-medical phenomena to discover fundamental laws governing human existence. One of his last publications gave a concise numerical law expressing the dependency of life expectancy on proximity of population.[75] His last great cholera report, like the first, was dedicated to the discovery of laws of the disease to explain, for example, the mean duration of cholera cases or the rate at which the body loses with age the power to resist cholera.[76] Here as before the law was a numerical relation permitting one to construct a series of numbers approximating closely the registered cholera mortalities under regularly changing conditions.

The most interesting test of Farr's position as a student of epidemic diseases is the fate of the elevation law for cholera mortality. We might expect to see the elevation law gracefully abandoned when he affirmed the primacy of water over air for cholera contagion. But such was not the case. An elevation relationship appears in all three cholera reports. Farr may have felt obliged to affirm the influence of elevation in subsequent reports,

74. Farr (n. 5), pp. xv–xvii and lxxx.

75. William Farr, 'Density or proximity of population: Its advantages and disadvantages,' *Trans.*, NAPSS (Cheltenham, 1878), pp. 530–535. A more complete version is found in William Farr, 'Letter to the Registrar General on the causes of death in England and Wales,' *40th Ann. Rep. Reg.-Gen.*, Appdx., 1878–79 [C. 2276], *xix*, pp. 231–246.

76. Farr (n. 5), pp. lx–lxiii.

having pronounced it the primary environmental influence in the first. It seems likely, however, that he believed a law as clearly set forth as the elevation law in 1849 revealed something fundamental in disease behavior which could not be overlooked, even though the etiological explanation for it might change. Nowhere does Farr accept John Simon's view that the order revealed in the elevation law was simply coincidental.[77]

Farr must have been disappointed to find that the cholera mortalities in London of 1854 did not follow exactly the pattern of the previous epidemic. He recalled the cholera law in the 1854 report, affirmed that it revealed a fundamental aspect of cholera's behavior, and had to content himself by showing that when the fatalities for both epidemics were combined, a similar but not identical series was produced as in 1849.[78] In 1866 the task was more difficult. Once again a simple grouping of fatalities by London terraces did not preserve the elevation law. In fact the rationale for seeking that type of relationship had been removed with his acceptance of water's ascendancy over air. All London shared the same atmosphere, but its people used different water supplies. Farr believed he had found that the fatalities from the cholera distributed themselves by elevation of residence within a waterfield, and that this distribution followed that predicted by his elevation law more exactly as the water became more polluted.[79]

His change in understanding of the mode of cholera diffusion permitted Farr to explain both the new observation and why the elevation law had not been preserved in its earlier form in subsequent epidemics. As in 1849 the explanation lay with the distribution of cholerine in its appropriate medium. By 1866 the primary medium was water not air. Farr made a point early in the 1866 report of including among the scientific observations of cholera that of Professor Frankland on the behavior of cholera flux suspended in a glass tube of distilled water. The water pipes of London's water companies could by analogy be thought of as Frankland's tubes in which the flux settled to the lower end of the column of water.[80] It seemed entirely plausible to Farr then that households drawing their water from the mains at lower elevations would receive more suspended cholera material than those whose taps were at higher elevations.[81] As the water com-

77. Snow (n. 50), pp. 97–98.
78. Farr (n. 4), pp. 88–90, and Arnott et al. (n. 54), pp. 13–16.
79. Farr (n. 5), pp. liii–lv.
80. *Ibid.*, pp. xiv and xx.
81. *Ibid.*, pp. lii–lv. This explanation was more plausible at a time when water was distributed on an intermittent basis rather than under constant pressure. This and other conditions of the water supply are summarized in Sutherland (n. 54), pp. 40–45.

panies pumped water of different degrees of purity, the regularity of mortality and elevation could be observed only within waterfields. The influence of elevation was more obvious the more polluted the source, since the differences in the relative density of cholerine in suspension in the pipes at different elevations would then be more pronounced.

Since the water of all the London companies was highly contaminated with sewage in 1848–49, the influence of elevation could be observed over the metropolis at large. By 1854 the condition of certain water supplies had been improved, causing a disturbance in the elevation law for the entire area. Finally by 1866 the amount of cholera material in the water of most companies had been drastically reduced, making it necessary to consider the effect of elevation only within a waterfield. When this was done and when elevation was measured at the level from which water had been pumped, the decrease in mortality with elevation was of the sort predicted by the elevation law.

William Farr began his study of cholera with a theory of disease imbued with miasmatic elements and with a commitment to the discovery of numerical laws of disease. He ended his investigations of cholera a quarter century later by helping to undermine the miasmatic theories of the sanitary reformers but still advocating the search for statistical laws of epidemics. While it would be rash to assert that Farr's cholera reports are typical of the efforts of most Victorian medical statisticians, the work of so few having been historically studied, it seems likely that some of Farr's problems in this venture were shared by his fellow workers in numerical research of kindred topics. We have tried to suggest how it was possible in the middle of the last century for the miasmatic theories of the sanitary reformers and the techniques of reform-minded vital statisticians to coexist and in fact to constitute a fairly unified attitude toward epidemic disease. The reliance on the medium of air and the effect of changes in its condition on suspended zymotic and miasmatic material permitted students of epidemics to explain the complex nature of such disease visitations. The very complexity of the chain of environmental influences determining the state of the air and the susceptibility of the human frame added support to the belief that mortality statistics would prove the most useful tool of epidemiological research. Farr's cholera reports suggest that nineteenth-century mortality statistics were most useful in providing a comprehensive description of epidemics and were particularly valuable in determining the geographical distribution of an epidemic attack. Farr's studies established that there was no simple connection between such meteorological conditions as temperature or barometric pressure and cholera deaths. While the condition of society was presumed to have a hand in determining the course of an epidemic, the usually suspect elements—income, occupation, or housing density—were shown to be comparatively minor influences on cholera.

An attempt to find causal factors in massed statistics is, of course, risky. Unexpected coincidences can exert an enormous influence, as is seen in the case of Farr's elevation law for cholera. As might have been expected, Farr's statistics proved most useful when directed to the demonstration of some relationship predicted by disease theory. In spite of Farr's claims of theoretical impartiality,[82] his discovery of the elevation law was made possible by the miasmatic twist which he gave his zymotic theory at the time. His belief in the power of statistics encouraged him to find ways to preserve a role for elevation in determining the behavior of cholera even after the theory of disease propagation underlying the original elevation law had been substantially modified. Farr's cholera statistics proved most useful in bringing an overwhelming mass of evidence in favor of Snow's theory. His conversion to Snow's theory was probably occasioned by the waterfield mortality studies and by the results of pathological research brought to his attention by the changed emphasis in disease research of the health authorities within the British government.

In spite of its successes and contributions to medical theory, Farr's dearest hopes for mortality statistics proved untimely. The socio-medical phenomena proved more complex than he realized, and the immediate future of epidemiological research lay with bacteriology rather than with attempts to study the exceedingly complex events of disease in human communities. But as elsewhere, the narrowing perspective which allowed extraordinary successes in one area was bought at the cost of ignoring other issues equally interesting. As a twentieth-century editor of John Snow's writings on cholera noticed, much of Farr's purpose in his statistical studies of cholera was to elucidate aspects of the behavior of disease which are still unexplained.[83]

82. Farr (n. 3), p. lxxx.
83. Wade Hampton Frost, 'Introduction,' in Snow (n. 50), pp. xiii–xiv.