Wellcome Trust Centre for the History of Medicine at UCL, London

Methods of outbreak investigation in the "Era of Bacteriology" 1880–1920

Summary

The advent of bacteriological methods in the later 19th century has been seen, on the examples of America and Germany, to have been followed by a new laboratory-based, contact-tracing method of investigating outbreaks of epidemic disease. In Britain, however, this new approach never took firm root, and practising epidemiologists continued to follow an observational and deductive tradition in field investigations, rejecting any primary dependence on bacteriological methods. Alongside this persistent observational practice, there emerged a new statistical approach, based in Pearsonian biometrics, which allied itself with experimental laboratory techniques to develop a more systematic, theoretical trajectory for explaining disease outbreaks in the years after World War I.

Key-Words: Epidemiology – Bacteriology – Typhoid – Salmonella – Statistics.

At the International Health Exhibition of 1884, the President of the London Epidemiological Society outlined his society's objectives as follows[1]:

"To watch pestilences to study their mysterious ways, movements and changes, which are so often quite inscrutable even to the most experienced and learned; to become acquainted with their natural history; to track them step by step, as the hunter tracks the tiger and the wolf in all their concealments and devious lurkings, and thus to anticipate their attacks and discover means for their avoidance."

The very phrasing and terminology of this statement reflect much of the robustness and sense of purpose of High Victorian epidemiology. The period 1880 to 1920 is often regarded as one of abeyance and transition in the history of epidemiology, when the high Victorian discipline became submerged in the minute concerns of the new bacteriology, while the years after 1915 saw the emergence of new styles of epidemiology which foreshadowed its modern post World War II flowering, the transition from "a qualitative, descriptive procedure into a quantitative and analytical modern science"[2]. This attitude is especially persistent among epidemiologists themselves.

For most practising epidemiologists, the Victorian contribution to their discipline is represented by John Snow and William Budd, who published their studies in the 1840s and 1850s, and history thereafter remains more or less of a vacuum until a more modern period. Yet a vigorous tradition of epidemiological study was established in the 1850s, in Britain at least, which produced a considerable body of literature in the years up to World War I. While there clearly were differences between England, Germany, and America in the pattern and timing of change in epidemiology after 1870, and it may well be that the English were notably slow in their responses to bacteriology, a closer examination of English epidemiology between 1880 and 1940 reveals not only a continuing emphasis on populations as opposed to individuals, but the development of new methods of outbreak investigation, a vigorous debate about the relationship between the different medical specialities of epidemiology, bacteriology and statistics, and a complex of professional, institutional and legislative developments which effected a substantial shift in the nature of the medical community involved with epidemiology. Moreover, it may be that different diseases provoked different epidemiological responses, taking the subject in new directions as it accommodated bacteriology and statistics in the first decades of the 20th century.

Soz.- Präventivmed. 46 (2001) 355–360
0303-8408/01/060355-06 $ 1.50 + 0.20/0

There are several factors external to the immediate history of the discipline which deserve consideration when we look at its neglected history between 1880 and 1914. First there is the continuing dominance in epidemiological mythology of Snow and Budd. Classic as their studies are, they have perhaps made it too easy to forget subsequent research which contributed to the shaping of epidemiology as a discipline, and to the establishing of its identity. Secondly, the impact of bacteriology on public health and epidemiology has rather been assumed than demonstrated – and recent research has indicated that it did not have a complete or immediate victory over older methods[3]. Finally, the period after 1880 saw a transformation in the kind of people who were interested and engaged in the practice of epidemiology. In the 19th century it was largely the concern of amateurs – of general practitioners like Snow and Budd, of medical officers of health responsible for controlling outbreaks of infectious disease, of military and naval physicians and surgeons interested in the wider context of their daily work. These men were not employed as epidemiologists; they practised it as part of their official duties. In England only a small and select group of men were professionally engaged in epidemiological investigation and research – the superintendents of statistics at the General Register Office, William Farr and his successors, and the staff of the central Medical Department[4]. Between its creation under John Simon in 1858 and its recreation as the Ministry of Health in 1919, the Medical Department investigated hundreds of disease outbreaks and occurrences in England and Wales, and sponsored a considerable programme of scientific research into the minute pathology of disease processes[5]. In this work, it was supported by the local medical officers of health, whose own concerns often provided the stimulus to investigation. From about 1900, however, the popular perception of England's most pressing public health concerns shifted from the infectious diseases to individual lives and their nature, nurture and management[6]. This shift of focus entailed increasing administrative responsibilities, for maternal and child health, tuberculosis and VD clinics, and eventually hospitals, and the medical officers' interest in epidemiology and medical research largely disappeared[7]. At the same time, new medical specialities emerged whose representatives had claims on epidemiology and whose achievement of personal professional niches and creation of career pathways was eventually to establish a dramatically different occupational profile for practising epidemiologists.

These reflections can, perhaps, best be substantiated by examining the epidemiological investigations associated with one particular disease, or group of diseases. The salmonellas provide a useful window, partly because the causes of typhoid, the severest in man, were well enough understood by the 1890s for epidemiologists to be engaged in an extension of understanding rather than a basic search for clues; partly because the decline of typhoid as a public health problem was paralleled by the rise of its less virulent cousins as a cause of concern; and finally because by the first decade of the 20th century food-borne typhoid was replacing waterborne typhoid as a subject of epidemiological interest. On the one hand bacteriology modified and challenged the traditional techniques of epidemiology; on the other it extended its environmental concerns.

The integration of bacteriology, and a little later of modernising statistical methods into epidemiology was not accomplished without resistance on the part of epidemiology's practitioners. High Victorian epidemiology was, as William Coleman has noted, environmentalist in its concerns, and it was observational in its techniques[8]. The Victorians were above all field epidemiologists whose investigations of disease outbreaks and occurrences performed the dual function of resolving public health problems and extending their understanding of how diseases behaved. At its best, this epidemiology expressed itself in reports of a richly literary character, which incorporated a vast range of contextual detail of a human, social, topographical, geological, and even meteorological character. The investigators employed by the Medical Department in the 1880s and 1890s were past-masters of this type of epidemiology, and they were conscious and proud of their skills. Many of their investigations were, of course, of limited significance, but others were classics of their kind. In this genre, the report furnished by William Frederick Barry on epidemic typhoid in the valley of the Tees river in 1891 is outstanding. At a time when there were still many who doubted the water transmission theory of typhoid, or who held that defective sanitary arrangements were more significant, Barry's Teesdale report reaffirmed and established the importance of unpolluted water supplies for public health[3].

The report generated a renewed interest in typhoid incidence at the Medical Department, and right up until World War I its investigators reported on a long series of local typhoid outbreaks, which repeatedly emphasised the fragility of the new water distribution systems and their vulnerability to pollution, as well as drawing attention to the links between rural agricultural practices and urban disease, and the environmental hazards posed by dry conservancy systems. In these investigations the Victorian tradition was still very much to the fore, with the field investigations slowly building up a fuller long-term picture of the relationship between man, environment, and disease. In the earlier investigations of this series, bacteriology featured only occasionally as a handmaid to epidemiology.

Soz.- Präventivmed. 46 (2001) 355–360

Early in the 20th century, however, bacteriology began to assert itself, while the epidemiologists began to incorporate it into a developed picture of preventive action. Failing to unravel the mysterious distribution of typhoid in the city of Chichester in the late 1890s, Theodore Thomson noted the need for comparative local environmental studies of typhoid-prone places with others not so affected. "Such investigation", he observed, "would need to be supplemented by skilled research on the part of the statistician, the geologist, the chemist and the bacteriologist". In other words, epidemiology alone was not enough[3].

In these years, as means of typhoid transmission other than through water became known, bacteriology began to assume a more significant role. In the early 1890s, it became apparent that certain foodstuffs played a regular part in causing sporadic cases and occasional outbreaks of typhoid. Shellfish, for example, became something of a *cause celebre*. In 1894 a sharp outbreak of typhoid in Connecticut was traced to oyster consumption, and the link was firmly established. In England, the association was confirmed by two major incidents in 1902, when participants in the annual mayoral banquets at Winchester and Southampton caught typhoid as a result of eating contaminated oysters. Here, the menu surveillance technique still used in food poisoning outbreaks today was first introduced[3]. These outbreaks provoked a spate of local epidemiological studies, which demonstrated, among other things, that the incidence of typhoid in the county of Essex was more than twice as great in the areas bordering the Thames, where polluted shellfish were freely gathered and consumed, as it was in the inland districts.

A very clear population concern was evident in these studies – medical officers were seeking to establish how far the continued prevalence of typhoid among populations in their districts was associated with the consumption of shellfish taken from polluted coastal waters. Bacteriology played little part in these assessments, since negative bacteriological evidence on the sewage pollution of waters carried a known possibility of being highly misleading, while there was no agreement among bacteriologists as to the precise significance of either the presence or numbers of *B.coli* and *B.enteritidis*; that is, no bacteriological standard existed or could in justice be applied[9]. Such standards became available within a few years, and the epidemiological investigation of shell-fish related typhoid outbreaks, which continued enthusiastically up to 1914, gave way after the War to an increasingly specialised branch of bacteriology.

Meanwhile, bacteriology was opening up a new field of hazard in respect of foodstuffs, which was to increase in importance as the century advanced. This was the discovery of the vast spectrum of salmonella bacteria less virulent than typhoid, and their association with animal populations, especially of domestic animals. First indications of this huge reservoir of hazard came in 1880, when Edward Ballard investigated an outbreak of food-poisoning originating on the Duke of Portland's Welbeck Abbey estate[10]. Eight years later Gaertner demonstrated the pathogenicity of the bacillus which he named *B.enteritidis*, and the recorded history of the lesser salmonellas began.

For some years, however, there was confusion over whether these organisms were natural inhabitants of the animal gut, or whether they were introduced by accidental contamination during preparation, or whether they were present in animals as the result of animal diseases. Each of these possibilities indicated different methods of prevention but traditional epidemiology did not prove competent to settle these questions. However, in a series of experiments conducted for the Medical Department between 1908 and 1910, the microbiologist William Savage showed that salmonellas are not normal inhabitants of the animal gut, but that the microorganisms are found in the muscle and internal organs of animals suffering from clinical or sub-clinical infections, and that such infections may also be introduced into foodstuffs externally, through unhygienic food-handling practices. This was epidemiology with a difference – but Savage's work both reflected and supported an interest in food-borne infections which had been building in the Medical Department since 1880. It was a public health interest that survived the War, and was continued by the Ministry of Health and the Medical Research Council in the inter-war period. Under the aegis of the latter, and with the assistance of another microbiologist, Bruce White, Savage was instrumental in the early 1920s in establishing the relationship between the various salmonella types and food poisoning, and in showing that domestic animals and vermin are important reservoirs of these organisms[11,12].

In the years immediately before the War, human reservoirs of typhoid, rather than animal reservoirs of salmonella, constituted the great public health issue; and provided the context for a series of English debates as to the relative merits and necessary relationships of epidemiology, bacteriology, statistics, and preventive medicine. The starting point for these debates was Robert Koch's theory that typhoid was due to an organism whose natural habitat was the human body, and the resulting campaign mounted in South-West Germany from 1903 to isolate typhoid sufferers, to search out all persons harbouring the bacillus, and to disinfect and destroy all infective material produced by these healthy carriers[13]. It was a policy which epitomised the bacteriological approach to epidemiology – the point of contact method[14]. In England, however, such methods proved widely

Soz.- Präventivmed. 46 (2001) 355–360

unacceptable when applied to typhoid at least until after the War. Indeed, several eminent British epidemiologists were sceptical about the significance of carriers in typhoid prevalence. William Hamer, in particular, set out to demonstrate that much of the German field evidence of the role of carriers in typhoid outbreaks was "unconvincing" when viewed from an epidemiological as opposed to a bacteriological standpoint. Five years later, when the final report on the South-West German anti-typhoid campaign was published, Hamer gave it a lengthy and destructive review, in which he argued from a traditional epidemiological and statistical standpoint the case against a significant role being played in typhoid endemicity by carriers[15].

Hamer's reactions to the German carrier theory of typhoid were possibly extreme. Although an able mathematician, he was hostile both to bacteriology and to the new biometry and the biometrical approach to epidemiology which emerged in these years. His own epidemiology was traditional and humanistic: social change, population movements, and the peculiarities of different diseases were continuous themes in his work. His critical attitude towards the carrier theory was nonetheless consistent with a more general English preventive attitude: if such a carrier is found, what is to be done with him?[16] Public health in Britain at this time still trod a fine line between the permissible and the impermissible in terms of the liberty of the subject, and even if treatment of the carrier himself fell to one side of that line, treatment of contacts most certainly would fall on the other. As Savage admitted, "the elaborate examination of excreta (on the German model) … certainly would not be tolerated"[17].

For a time, it seemed as if anti-typhoid inoculation, by a process developed by Sir Almwroth Wright, the "father of English bacteriology", might offer a solution. In practice, however, English mistrust of immunisation procedures combined with the consideration of personal liberty and very public disagreements among medical men as to the real value of the operation, ensured its virtual uselessness as a preventive measure. The debates over anti-typhoid inoculation illustrated, however, the encroaching into epidemiology of a new statistical methodology, that of biometry, which cast long shadows before it towards the later 20th century. On one trajectory, it was statistics rather than bacteriology that was to reshape the theory and practice of epidemiology in the long term. Several important figures in the bacteriology/epidemiology negotiation, like William Savage, were young bacteriologists carving out specialist careers; similarly, statistics were driven into English epidemiology by another striving young specialist, Major Greenwood. Greenwood has been a relatively neglected figure, but there is a case for arguing that he was one of its pivotal influences – less perhaps through his own original contributions than for the talents which he fostered as teacher and mentor.

It was Greenwood's own mentor, the biometrician Karl Pearson, who formalised the statistical attack on anti-typhoid inoculation. Almwroth Wright had sought to use statistical evidence in proof of the efficacy of the technique. Unfortunately, not only were his statistics very crude, but field experience seemed to demonstrate that the effectiveness of the technique was questionable[18]. At this point Pearson provided a destructive statistical analysis of Wright's data. The technique then went back to the laboratory where another bacteriologist, William Leishman, sorted it out and finally produced both laboratory and statistical evidence, based on field results, of efficiency. With the outbreak of World War I in 1914, the whole debate resurged over the issue of whether British troops going abroad should be compulsorily inoculated against typhoid. In an argument considerably complicated by political, ethical, and military considerations, the statisticians once again set out to try to develop a method of analysis which would validate preventive and curative procedures to the satisfaction of both the statistician and the epidemiologist. In 1915, Greenwood, in association with the Cambridge mathematician G. Udney Yule, published an essay on the interpretation of inoculation statistics in which they demonstrated the fundamental tensions between statistical modelling and biological reality, concluding "that mathematical difficulties of method must not absorb the whole energies of the statistician"[19]. If the new statistical methods were to be of value to epidemiology, biological reality must not be lost sight of.

Greenwood's campaign to bring new statistical methods into wider use and better repute in epidemiology and public health can be seen in part as an attempt to maintain and extend the population emphasis within epidemiology, and also as an active counterbalance to the ominous minutiae of the fashionable bacteriological model. Yet, as already indicated, point of contact epidemiology did not find extensive application in England; indeed, medical officers of health were reluctant even to use inoculation for fear that it would distract from the need to secure safe water supplies and proper sanitation. Between about 1900 and 1914. There was an ongoing debate within English epidemiology as to the uses and limitations of bacteriology and later of statistics, and these debates continued to some degree after the war.

After 1918, much of the dynamism of pre-war epidemiology in Britain disappeared. The Medical Department, for so long the central force of English epidemiology, was replaced by the Ministry of Health, and Arthur Newsholme, a

dedicated epidemiologist, was replaced as Chief Medical Officer by George Newman for whom epidemiology had never been much of an interest. These changes, combined with the extending administrative responsibilities of the local medical officers of health, effectively put an end to the old epidemiological community as it had existed before the War. In the 1920s, a new, professional community of epidemiologists gradually emerged under the aegis of Major Greenwood, and achieved an institutional focus with the creation in 1927 of the Department of Epidemiology and Vital Statistics at the new London School of Hygiene and Tropical Medicine (LSHTM).

Continuity with the pre-war world was represented by Major Greenwood, and to a lesser degree by men like Hamer [20]. Greenwood was perhaps the moving force in English epidemiology in these years, being appointed head of the Medical Research Council's Statistical Unit after the War, and first professor of the new department at the LSHTM in 1927. In particular, he joined William Whiteman Carlton Topley in the latter's attempt to develop the field of epidemiology along biological lines. Wartime experience of the great Serbian typhus epidemic focused Topley's attention on epidemiology. As a laboratory scientist, however, he found its lack of precision intellectually unsatisfying, and he began to explore it as a form of experimental biology [21].

Topley recognised two outstanding obstacles to the investigation of epidemic disease behaviour along bacteriological lines: that the diseases best suited to such inquiry were those in which the causal organisms were unknown (e.g., measles), and that it had proved impossible to reproduce in laboratory animals diseases as they occurred in man [22]. Building on the work of earlier bacteriologists like Savage, Topley resolved the problem by using naturally occurring infections of animals to elucidate the mechanisms of infection and epidemicity. Thus a series of studies developed the concepts of herd immunity and of unstable equilibrium between host and parasite, and incidentally reinforced recognition of overcrowding as a potent force in the generation of epidemics. At an early stage in these researches, Topley realised the need for a statistician to analyse the data he was accumulating, and recruited Greenwood's assistance. In the early 1920s, therefore, bacteriology and statistics went forward together, as the latest research tools of a broader, more theoretical epidemiology than had been practised in England before the War. In this development, it seems likely that Topley's experience of epidemic typhus in Serbia – the experience of observing a major epidemic in a human population at first hand – was central in arousing his interest in general, as against local, epidemiological problems.

The immediate post-war years saw a change in English epidemiology for both intellectual and institutional reasons. The period between 1880 and 1920, however, was not as devoid of epidemiological enterprise as is often assumed. The impact of bacteriology on the English epidemiological tradition was rather less impressive than has been generally accepted, and the practitioners of epidemiology continued actively to evolve new methods for the investigation of disease and disease outbreaks, some of which involved bacteriology, but in a constructive and exploratory rather than a reductionist, contact-tracing, mode. Reductionist bacteriological methods encountered criticism and resistance from an already well established tradition, which accepted as sensible certain modifications to its practice indicated by bacteriology, but which drew back from embracing a wholesale bacteriological perspective on problems of disease. Less historically obtrusive, more insidious in its gradual inroads into epidemiological method, was the statistical methodology introduced by Major Greenwood and creatively developed by Austin Bradford Hill, which drew its inspiration from Pearsonian biometry. Under Greenwood's guidance, this achieved a subtle and influential accommodation with the statistical and observational traditions of high Victorian epidemiology in the inter-war years; under Hill it contributed to the methodological revolution which transformed epidemiology after the Second World War [23, 24].

Zusammenfassung

Methoden zur Untersuchung von Krankheitsausbrüchen in der "Ära der Bakteriologie" 1880 – 1920

Mit dem Aufkommen bakteriologischer Methoden im späten 19. Jahrhundert wurde zum Beispiel in Amerika und Deutschland eine neue Methode zur Untersuchung epidemischer Erkrankungen eingeführt. Diese Methode beruhte auf Labordaten und kontrollierte das spezifische Umfeld. In Britannien fasste dieser neue Ansatz jedoch nie richtig Fuss. Praktizierende Epidemiologen verfolgten weiterhin die beobachtende und deduktive Tradition der Felduntersuchungen und lehnten jede Abhängigkeit von bakteriologischen Methoden ab. Seite an Seite mit dieser sich fortsetzenden Beobachtungspraxis entstand aber ein neuer statistischer Ansatz, der auf der Biometrie nach Paerson basierte und mit experimentellen Labortechniken verbunden war. Damit sollte ein systematischerer, theoretischer Ansatz entwickelt werden, der die Krankheitsausbrüche in den Jahren nach dem Ersten Weltkrieg erklärt.

Résumé

Méthode d'investigation des épidémies à l' «époque de la bactériologie» 1880–1920

L'avènement de méthodes bactériologiques à la fin du 19e siècle a été suivi, comme le montre les exemples de l'Amérique et de l'Allemagne, par le développement d'une nouvelle méthode d'investigation des épidémies basée sur le laboratoire et le contrôle d'entourage. En Angleterre, cependant, cette nouvelle approche n'a jamais pris solidement racine, et les épidémiologistes de terrain continuèrent à suivre la tradition observationnelle et déductive dans leurs enquêtes, rejetant toute dépendance par rapport aux méthodes bactériologiques. Parallèlement à cette pratique observationnelle persistante, émergea une nouvelle approche statistique, basée sur la biométrique Pearsonienne, qui, s'alliant aux techniques de laboratoire expérimentales, va développer une approche théorique plus systématique pour l'explication des épidémies dans les années qui suivirent la première guerre mondiale.

References

1 Epidemiological Society of London. Epidemic Diseases: International Health Exhibition Conferences. London: Executive Council of the International Health Exhibition, 1884: 1.

2 *Roth D*. The scientific basis of epidemiology: an historical and philosophical enquiry. [Thesis]. Berkeley: University of California, 1976: 91.

3 *Hardy A*. On the cusp: Epidemiology and bacteriology at the Local Government Board, 1890–1905. Med Hist 1998; *42*: 328–46.

4 *Eyler J*. Victorian social medicine: the ideas and methods of William Farr. Baltimore: John Hopkins University Press, 1979.

5 *Lambert R*. Sir John Simon, 1816–1904, and English Social Administration. Bristol: McGibbon and Kee, 1965: 400–4, 432, 568–9.

6 *Jones H*. Health and society in twentieth-century Britain. London: Longmans, 1994.

7 *Galbraith N*. A national epidemiological service. Public Health 1966–67, *81*: 224–5

8 *Coleman W*. Yellow Fever in the North: the methods of early epidemiology. Madison: University of Wisconsin Press, 1987: 173.

9 *Houston A*. The bacteriological examination of oysters and estuarial waters. J Hyg 1904; *4*: 173–200.

10 *Hardy A*. Food, hygiene and the laboratory: a short history of food poisoning in Britain, circa 1850–1950. Soc Hist Med 2000; *12*: 293–311.

11 *Savage W, Bruce White P.* An investigation of the salmonella group, with special reference to food poisoning. MRC Spec Rep Ser 1925: 91.

12 *Savage W, Bruce White P.* Food poisoning: a study of 100 recent outbreaks. MRC Spec Rep Ser 1925: 92.

13 *Klinger D*. Epidemiological observations on the antityphoid campaign in the south-west of the German empire. JRAMC 1910; *14:* 90–101.

14 *Leavitt J*. "Typhoid Mary" fights back. Bacteriological theory and practice in early twentieth-century public health. Isis 1992; *83*: 608–29.

15 London County Council. Medical Officer's Annual Report. London: London County Council, 1912: 35–40.

16 *Clegg S.* Notes on an outbreak of enteric fever in Newcastle-upon-Tyne, August-October 1913. Public Health 1913–14; *27*: 235–43.

17 *Savage W*. Recent work upon the bacteriology of typhoid fever in relation to preventive measures. Public Health 1907; *20:* 19.

18 *Mathews J*. Quantification and the quest for medical certainty. Princeton: Princeton University Press, 1996.

19 *Greenwood M, Yule G.* The statistics of antityphoid and anti-cholera inoculations, and the interpretation of such statistics in general. Proc Roy Soc Med 1914–15; *8:* 113–94.

20 *Mendelsohn J.* How epidemics became complex after World War I. In Lawrence C, Weisz G, eds. Greater than the parts. Holism in biomedicine 1920–1950. Oxford: Oxford University Press, 1998: 309–10.

21 *Greenwood M*. William Whiteman Carlton Topley. Biog Mem Fell Roy Soc 1944; *4*: 699–712.

22 *Topley W*. The spread of bacterial infections. Lancet 1919: *2*: 1–5, 45–9, 91–6.

23 *Doll R*. Austin Bradford Hill. Biog Mem Fell Roy Soc 1994; *40*: 129–40.

24 *Susser M*. Epidemiology in the United States after World War II: the evolution of technique. Epidemiol Rev 1985; *7*: 147–77.

Address for correspondence

Prof. Anne Hardy
Wellcome Trust Centre for the History of Medicine at UCL
Euston House
24 Eversholt Street
GB-London NW1 1AD

Soz.- Präventivmed. 46 (2001) 355–360