Early municipal bacteriology in Brighton, Aberdeen and Bristol: blessing or burden?

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ABSTRACT

In contrast to the idea that bacteriology was introduced as a tool for the diagnosis and management of the individual patient, this review highlights the work of the municipal bacteriological laboratory in the United Kingdom to illustrate how bacteriological laboratories were introduced as means to control community epidemic disease. Using the examples of municipal laboratories in Brighton, Bristol and Aberdeen, it shows how public health considerations of community infectious diseases such as diphtheria and typhoid dominated the early development and workload of the municipal laboratory, rather than examination of patients with pathological states of uncertain aetiology. It argues that this public health focus of the Medical Officer of Health limited the range of diagnostic tests carried out in such laboratories for over two decades. The growing number of pathogenic microbes being discovered in the late 19th century appears to have had little impact on the tests being carried out in the municipal laboratory. Municipal bacteriological facilities in three towns, a central municipal laboratory (in Brighton), a central university pathological department (Aberdeen) or a combination of both (Bristol) all provided the same limited set of tests. This restricted set of bacteriological examinations is likely to have diminished the value and status of bacteriology in what should have been a period of increasing scope.

KEY WORD: Bacteriology.
History.
Laboratory.

Introduction

As with any scientific discipline, historical considerations of bacteriology are concerned principally with concepts and their discovery. The function of the diagnostic bacteriology laboratory has, therefore, remained a backroom function, largely ignored in the literature. This is exemplified by the current media portrayal of methicillin-resistant *Staphylococcus aureus* as a scourge of hospitals staffed by doctors and nurses, with scant mention of the laboratory. This review seeks to draw attention to the early work of municipal bacteriology laboratory services established across the UK in the late 19th century.

The Scottish surgeons Alexander Ogston, Joseph Lister and William Watson Cheyne were all interested in the significance of germs in the wounds of their patients. As examples of early bacteriologists, they support the view that medical bacteriology in the UK occurred as a nascent branch of pathological anatomy.

A number of British diagnostic bacteriology laboratories originated within departments of pathology where many of the early important British bacteriologists originally held chairs of pathology and bacteriology.[1] It is less obvious that the public health concerns of the Medical Officer of Health (MOH) were responsible for the appearance of diagnostic bacteriology laboratories in many towns.

This review discusses some of the characteristics of municipal bacteriology services that were established and directed by an MOH (e.g., Brighton and Bristol) or made available within a university-based pathology laboratory run by the professor of pathology (Aberdeen).

Arthur Newsholme and the Municipal Laboratory, Brighton

Details of municipal bacteriological facilities in Brighton can be tracked through the local annual reports of the MOH written by Arthur (later Sir Arthur) Newsholme (1857–1943). Newsholme was responsible for establishing the local laboratory in 1897. The chronology of bacteriological tests carried out year by year illustrates the development of public health bacteriology. We have chosen, somewhat arbitrarily, to limit the period of study up to the outbreak of World War I to avoid the ensuing disruption.

Arthur Newsholme was appointed MOH for Brighton in 1888, reporting to the local government Sanitary Department. Newsholme was the first full-time MOH to Brighton and an industrious and prolific worker whose efforts in promoting public health in the town established his reputation such that he left Brighton in 1908 to become Principal Medical Officer for the Local Government Board, London. While Newsholme's attitudes and interests have been examined thoroughly by John Eyler,[2] the concern of this review is the work of the laboratory.

In addition to his function as an MOH (inspecting work places, farms and slum housing), Newsholme was also appointed medical officer for the local isolation hospital. His responsibilities for the control of infectious diseases became a central part of his workload. The isolation hospital was already in existence when Newsholme arrived in Brighton, but it was in a ramshackle state. Plans were in place for a

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new set of buildings (the 'Sanatorium'), which were erected over a period of years between 1897 and 1905. The buildings were ready to admit patients in 1898.

The patients were typical for the period, dominated by scarlet fever and diphtheria with some additional cases of typhoid. The term sanatorium was used as a synonym for the isolation hospital and not as a sole tuberculosis treatment facility. Tuberculosis (phthisis) cases were only admitted from 1905 onwards.

Although the International Congress on Hygiene and Demography in Budapest in 1894 proved significant, due to the announcement by Emile Roux of successful diphtheria antitoxin treatment, it was the work of Hermann M. Biggs in controlling diphtheria in New York through the use of the new bacteriology laboratory (established in 1892) that had the greatest impact on Arthur Newsholme.[3] Newsholme was at the Congress and presented his arguments for the extension of the Notification of Infectious Diseases Act to include tuberculosis.

On his return to Brighton, Newsholme wrote of the desirability of a laboratory for bacteriological diagnostic services in his quarterly report to the Council.[4] Newsholme heard again of the value of a diagnostic bacteriology facility for diphtheria at the summer British Medical Association meeting in London the following year in 1895. The speakers at the Public Medicine Session included both Hermann Biggs and Emanuel Klein, talking on the bacteriology of diphtheria.[5]

It took three years but eventually, in October 1897, Newsholme was able to open such a laboratory, initially in Brighton's Municipal Technical College, but within a few years it moved to the administration building of the new Brighton Sanatorium. The municipal laboratory was staffed by Newsholme and trainee MOsH studying for the Diploma in Public Health (DPH).

Laboratory tests

The laboratory opened in October 1897 and the numbers of samples received in the 17 years from 1898 to 1914 are shown in Figure 1 (including those from November 1897 to the end of December 1898). Initially, just three bacteriological tests were performed: culturing throat swabs for diphtheria (the Klebs-Loeffler bacillus [KLB]), staining sputum for the tubercle bacillus, and the serum Widal-Gruber test for typhoid.

The Brighton MOH annual reports show that scarlet fever was as important as diphtheria in terms of the number of cases admitted to the sanatorium, but they provide no evidence for attempts to culture streptococci. Figure 2A shows how the demand for KLB testing rose with a local epidemic and then remained a popular test. In contrast, the demand for Ziehl-Neelsen (ZN) testing of sputa appears to mirror the incidence of tuberculosis in the community.

Throat swabs for diphtheria

A year after Edwin Klebs observed (but not cultured) a short bacillus on the diphtheritic membrane, Friedrich Loeffler cultured the causative bacillus on solidified serum in 1884. Quite why the introduction of bacteriological diagnosis took over 10 years to develop in the UK is not immediately obvious. Certainly, a proportion of the medical community was either unaware or sceptical of the significance of the KLB in diphtheria in particular and bacteriology in general. For example, alongside Loeffler and Roux at the above

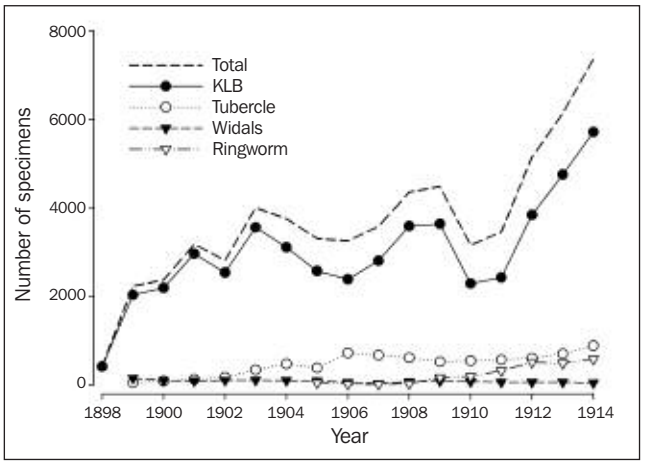

Fig. 1. Specimen numbers and types examined at the Brighton Municipal Laboratory between 1898 and 1914. Bacteriological examinations of water and food are not included. Compiled from the annual reports of the Medical Officer of Health for the town of Brighton.

mentioned 1894 International Congress in Budapest was Edward Seaton (MOH for Surrey), who represented Great Britain and spoke on the relationship between diphtheria and the movement of subsoil water (using data from 1891).[3]

It would be easy to draw unflattering comparisons between the bacteriological innovations in Europe and America of the period with British MOH concerns about damp and diphtheria, but such data were of great interest to public health officials. Newsholme devoted roughly 10 out of 30 pages to atmospheric influences in the definitive work on diphtheria in 1908.[6] Atmospheric influences on diphtheria were still deemed valid over 20 years later when J. G. Forbes, principal assistant MOH to the London County Council, devoted 11 sides to rainfall and diphtheria in his textbook published in 1932.[7]

In his annual reports for Brighton, Newsholme discloses his thinking on the value of bacteriological testing for KLB as shown from excerpts from the following yearly reports:

- Newsholme was ''...confident that a negative result of bacteriological diagnosis may be nearly always accepted as indicating that the case is not one of diphtheria'' (1898)
- ''...each patient is swabbed at least twice, once on admission and once on discharge'' (1899)
- with negative results of bacteriology ''...the final decision remains with the medical attendant'' (1900)
- each patient is ''tested at least four times before discharge'' (1903) – note the reversal in thinking to that of 1898
- ''many of the negative results were positive when second swabs were taken; the rule was to obtain three consecutive negative swabs from each patient before sending the patient home'' (1904) – in 1905, this was dropped to two swabs and back to three in 1906.

The impression is one of Newsholme adjusting laboratory practice according to his interpretation of the bacteriological results.

Throat swabs for diphtheria clearly dominated the workload in Newsholme's laboratory, and continued to do so after he left in 1908 (Fig. 1). On average, 67% of throat

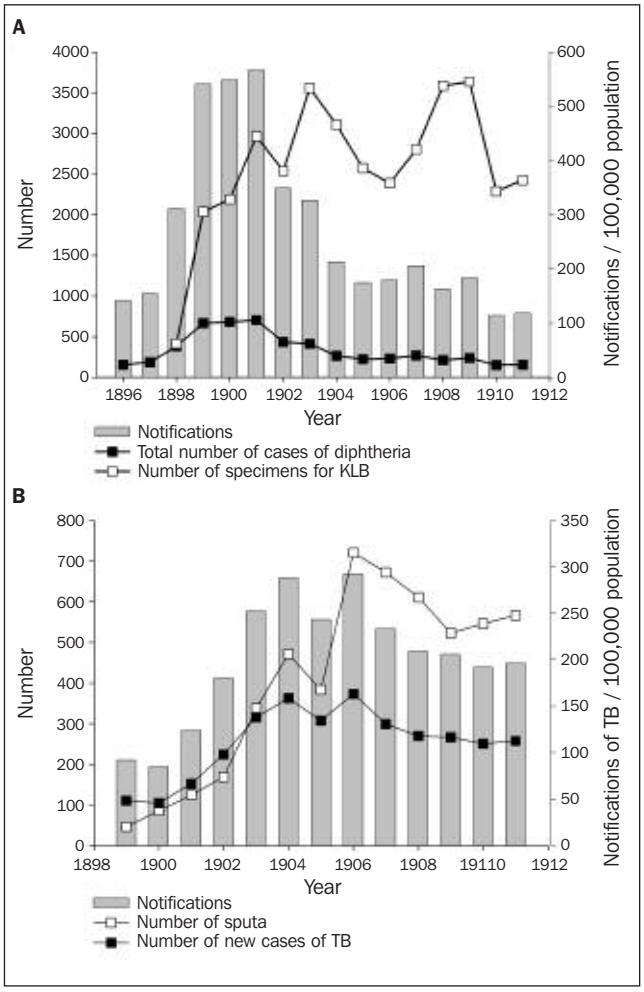

Fig. 2. Relationship between numbers of samples and numbers of cases (left axis) for (A) diphtheria and (B) tuberculosis at Brighton. To correct for possible population variations, the numbers of cases are also expressed as notifications per 100,000 population (right axis). Note how the numbers of cases of diphtheria and tuberculosis were similar but the respective samples diverge. Compiled from the annual reports of the Medical Officer of Health for the town of Brighton.

swabs were obtained from the isolation hospital (sanatorium), most cases being children. Between 1899 and 1914, the proportion of throat swabs that yielded KLB was 22% (ranging from 9% to 34%). Figure 2A shows the numbers of throat swabs and cases of diphtheria. The ratio between the two rose from 1:1 in 1898 to almost 16:1 by 1911, suggesting that the test was valued by the medical community despite the absence of any repeated epidemics following that of 1898–1901.

Tubercle in sputa

Staining for tubercle bacilli started in Newsholme's laboratory in 1897, with 10 sputa (four positives) in the first four months, rising to 883 by 1914 (Fig. 2B). The small number of sputa received prior to that originated from general practice, but increasingly the samples came from the sanatorium once it started to admit phthisis cases in 1905. Tubercle testing remained at around 12% of the workload from 1904 onwards, with roughly 35% of the samples positive for tubercle (Fig. 2B).

Widal-Gruber test

The incidence of typhoid locally and nationally was falling throughout the period, which would explain why the number of Widal-Gruber tests carried out continually represented the smallest of the three diagnostic tests offered by the laboratory. In the first four months, the laboratory examined sera from 74 patients out of a total of 301 (24%) specimens, but by 1913 the proportion of the total number of samples had fallen to less than 1% (Fig. 1). Newsholme made great efforts to reduce typhoid while in Brighton, perhaps most notably addressing the faecal contamination of the oyster beds in the seaside port of Shoreham, west of Brighton.[2]

Hair samples for ringworm

The examination of hair for ringworm arose out of an attempt to reduce its epidemic transmission between children at school. Newsholme explained that such a diagnosis would "…aid early recognition, ...secure exclusion of the affected scholar, …facilitate earlier treatment and the earlier return to school". The first samples were received in 1905 (Fig. 1) and grew steadily in number, reaching over 500 per year by 1914.

Other examinations

From 1899, around 100 water samples per year were analysed 'quantitatively'. This would have been chemical analysis, as was the widespread practice, and performed by the Public Analyst. In 1902, Newsholme's laboratory started to examine well water samples bacteriologically as well as chemically. Arrangements were made with the Waterworks Committee so that this could continue. It did continue but, unlike medical specimens, the numbers did not increase, remaining consistently below 100 per year between the years 1903 and 1914.

Nevertheless, Newsholme managed to obtain funding for an extra pair of hands to do the work and the Waterworks Committee agreed to fund a physician at the sanatorium to do the analyses, alongside his normal work at the sanatorium. Water analysis remained a small but consistent feature in Newsholme's annual reports even if it generated little comment.

In 1905, the use of the "opsonic index for phthisical patients" appears for the only time in the annual reports. Introduced by Almroth Wright in 1903, the opsonic index was an important demonstration of the role of serum opsonins in the engulfment of bacteria by neutrophils. The index was used as a guide to treating patients with autologous vaccines, and both procedures were carried out by many laboratories across the country.

Newsholme's laboratory chose to investigate the value of the test in its consumptive patients. Newsholme tested the opsonic index in 61 patients, making 149 counts of phagocytosis of tubercle bacilli. Newsholme states that the results "were not …a satisfactory means for estimating the prospect of each patient, as was first anticipated". The test did not reappear in the annual reports.

When Newsholme moved on to higher things in 1908, Duncan Forbes took over as MOH for Brighton. Forbes introduced a small number of newer investigations into the laboratory. In the 1909 annual report, 33 miscellaneous investigations appear (mostly examining urine and faeces for tubercle and typhoid), but by 1913 the numbers of such

tests had only risen to 60. It seems that the laboratory stuck to what it knew.

Aberdeen

It was not until 1920 that a permanent municipal bacteriology laboratory was established in Aberdeen, but over two decades earlier local authorities across the north-east of Scotland initiated a bacteriological service through the pathology department at the University of Aberdeen by special arrangement with David James Hamilton (1849–1909), the first professor of pathology at the university.[8] Hamilton had toured Europe between 1873 and 1875 to see first hand the new thinking in pathology, including bacteriology. He visited, among others, Virchow and Pasteur[9–11] (Burnett[8] lists Koch as well) before taking up the appointment at Aberdeen in 1882. However, Hamilton found himself with very limited support and resources with which to set up pathological and bacteriological facilities, and municipal bacteriology did not commence until 1894.[12]

The stimulus appears to have been the high death rate among diphtheria cases, which drove James Peter Watt (1856–1933), the Medical Officer for the County of Aberdeen, to seek help. In 1893, almost one-third of known cases had been fatal, and in some instances killed entire families. Dr. Watt negotiated an arrangement with Professor Hamilton, whereby testing and reporting could be performed at the rate of five shillings (25 pence) per case. In the space of several months, from November 1894 to April 1895, Watt approached five of the county's eight district committees, whose statutory responsibilities included public health, and asked them to bear the cost of bacteriological testing of doubtful cases of diphtheria submitted by local medical practitioners. All five districts agreed and testing began, using facilities Hamilton had established in the university's Marischal College.

Watt was pleased with the laboratory results for diphtheria cases, and in his 1896 annual report he highlighted the value of extending the service to include other infectious diseases such as earlier detection of pulmonary tuberculosis and the "simple method for the bacteriological diagnosis of typhoid fever", namely the Widal test. He suggested that a combination of the city, the county and other adjoining authorities would ensure that such a bacteriology service could be provided "at a comparatively trifling expense to each", Professor Hamilton having estimated the total cost of the work at £100.

Watt's report was completed in March 1897, and, barely a year later, in January 1898, the same arguments were put to Aberdeen Town Council by Matthew Hay (1855–1932), city MOH and professor of medical logic and jurisprudence between 1883 and 1926. Hay, who did much for public health in Aberdeen, including initiating the Diploma of Public Health,[13] maintained the desire to see the local authority set up its own bacteriology laboratory.

In a report to the Council's public health committee in 1898, Hay spoke of the scientific advances that had been made and the range of tests that were now available for diphtheria, typhoid and tuberculosis. He went a step further than Watt and suggested the possibility of a municipal laboratory, noting that several large urban local authorities had set up bacteriological laboratories of their own, or had made arrangements with existing laboratories. However, he recognised that "in the meantime" the cost involved in building, equipping and staffing a municipal laboratory in Aberdeen was outweighed by the advantage of having the work supervised by Professor of Bacteriology (*sic*).

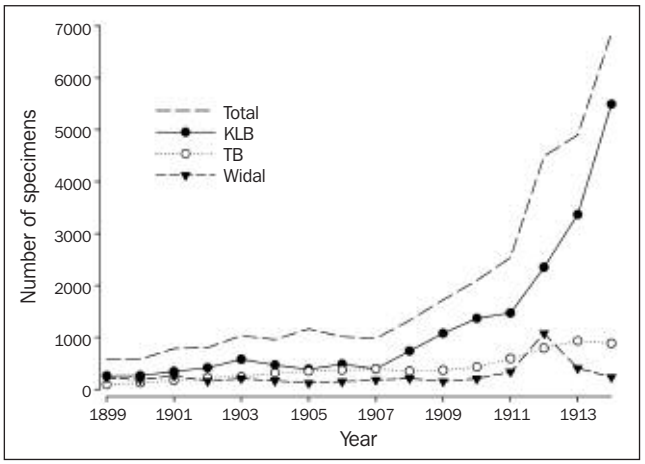

Fig.3. Specimen numbers and types examined at the Pathology Department, University of Aberdeen between 1899 and 1914. Bacteriological examinations of water and food are not included. Compiled from the annual reports of the Medical Officers of Health for the city and county of Aberdeen.

Hay therefore recommended that the Town Council enter into an arrangement with the university pathology department to provide a bacteriological service to the medical practitioners of the city of Aberdeen (as indeed it had been doing for the county practitioners in cases of diphtheria).

It was agreed that the professor would arrange for all bacteriological examinations required and report back. In return, the Town Council would pay £120 per annum (later raised to £150) to cover the salary of "a skilled assistant acting under the direction and supervision of the professor of pathology", as well as payment of laboratory and other expenses. The Council hoped to be able to recoup part of this sum by asking neighbouring local authorities to sign up to the service.

With the Town Council effectively promising to underwrite the scheme, the testing arrangements were quickly agreed by a range of smaller local authorities across the north-east of Scotland. Over the next 10 years, with only minor changes in the participating authorities, the service ran successfully.

The annual reports of the MOH for the city of Aberdeen and of the County Medical Officer contain details of the number and type of examinations carried out for these two authorities (Fig. 3). In the early years of the scheme, the three diseases that formed the bulk of the work were diphtheria, typhoid and tuberculosis. Hamilton started receiving specimens in 1894, first throat swabs for KLB and then, from 1898, Widal tests. Specimen numbers are recorded only from 1899 but Watt started submitting specimens in 1894 and Hay started in 1896.

As with the annual reports of the MOH for Brighton, those for the city of Aberdeen reflect the changing practice of testing. In 1901, bacteriological testing was undertaken in two-thirds of typhoid cases and four-fifths of diphtheria

cases occurring in the city of Aberdeen. By 1904, cases under hospital treatment were likely to be tested more than once, and in 1905, during an epidemic of typhus in the city, 307 serological tests were performed. Testing of spinal fluid for meningitis seems to have started in 1907, and, in typhoid cases, stools and urine were now also being examined.

For the first time, it was explicitly stated that testing was needed not only for diagnosis but also to ensure freedom from infection. By 1908, typhoid patients were discharged from hospital only after achieving two negative results.

Hamilton retired through ill health in September 1908, but the service continued under the supervision of his successor, Professor George Dean (1863–1914). Despite having been head of the bacteriological department at the Lister Institute, one of the leading bacteriological centres in Britain, Dean oversaw an increase in specimen numbers but no increase in the range of analyses offered. The laboratory work was still dominated by examinations for diphtheria bacilli (Fig. 3).

Writing in 1908, when Hamilton had recently retired but before Dean's appointment, Hay noted that "bacteriological work is likely to increase considerably in future. It is desirable to extend greatly the bacteriological examination of milk, especially for tubercle". A circular sent to the local authorities urged them to make greater use of the department's services "owing to the great development in quite recent years of the application of bacteriology to the investigation of problems in public health administration".

Given the development and discoveries in bacteriology over the previous decade, it became clear that the agreement should be re-negotiated between the university department and the local authorities of north-east Scotland, with proposals to widen the facilities for such bacteriological examinations. So confident was the Town Council (and its MOH) that this work would continue that in February 1909, when it received a circular letter from the Royal Institute of Public Health, offering to undertake chemical and bacteriological examinations in the Institute's laboratories, the Council's response was that no action was needed. It had an arrangement with the professor of pathology.

Thus, because of the increased work, both in quantity and in the range of tests, the pathology department would receive an annual sum of £300. Of this, £175 was needed to provide a better salary to attract a special assistant, £25 paid for a lab boy, and £50 was allocated for materials and postage. The remaining £50 formed an honorarium to the professor. The total cost would be divided among the participating authorities on the basis of population figures.

Most of the previous participants signed up to this new agreement. One major new partner in the arrangement was the County of Banff. Here, the MOH was Alexander Ledingham (1872–1944), and, given that his elder brother (J. C. G. Ledingham) was director of the Lister Institute, it is perhaps not surprising that he sought bacteriological support. Alexander had taken up the Banffshire post in 1907, having previously been assistant MOH and bacteriologist to the County of Lanark.

Other laboratory investigations

Although testing for the main infectious diseases formed the bulk of the public health bacteriology work undertaken by the university, some other investigations were also performed. From 1900 onwards, the city of Aberdeen annually sent a small number of samples of diseased meat for examination. In 1905 there is a brief reference to a number of examinations of milk for tubercle, and four years later this had become more systematic. Samples of milk were now being examined yearly for the tubercle bacillus by means of inoculation experiments. The County of Aberdeen regularly sent samples to test for carriers and occasionally also requested testing of water and milk. Certain other samples of food and animal products were also examined.

Special assistants

It has been possible to identify and to track the later careers of most of those who held the post of special assistant in the pathology department responsible for the public health bacteriology work. The first special assistant was Dr. James W. H. Walker, who, in addition to the bacteriological examinations of specimens, carried out experiments of disinfectants for county hospitals in 1898. Walker left to become bacteriologist to the Clinical Research Association in London by 1901 and was succeeded by Dr. David Albert Hutcheson for less than a year.

From 1901 Dr. Andrew Ross Laing took over and remained in post for the next eight or nine years. From 1910 onwards, assistants seemed to stay in post for about a year, and most were either studying for, or had recently obtained, the Diploma in Public Health. In 1914 a substantial rise in the number of diphtheria cases in the city of Aberdeen led to an increase in bacteriological examinations, and this resulted in the temporary employment of two student assistants in the laboratory, while several others helped to take swabs.

Although several of the special assistants subsequently also studied for an MD degree, few chose bacteriology as the topic of their thesis or took up bacteriology full-time despite many forging careers in the field of public health or in tuberculosis.

The municipal bacteriology continued to be sent to the University of Aberdeen pathology facilities after Dean's death in 1914, and this continued up until 1920 when the bacteriological work for all the north-east counties was transferred to the newly established regional municipal laboratory, much as Hay had wanted back in 1898.

Bristol

It was not just Newsholme who was inspired by the work of Hermann Biggs in New York. David Samuel Davies (1855–1933),[14] MOH at Bristol from 1886, heard Biggs speak at the British Medical Association meeting in Bristol in 1895 and promptly advised the Bristol Sanitary Committee to fund the bacteriological testing of suspected cases of diphtheria. Davies started examining throat swabs for diphtheria bacilli the same year in a disused room[15] (one obituarist says that Davies started bacteriological examinations in his office) and two years later (1897) started Widal tests. From 1895 to 1902, throat swabs for KLB predominated, representing 60–100% of the specimens, and the remainder comprised sera for Widal testing. From 1903, sputa for tubercle were submitted. The numbers of samples are shown in Figure 4, along with the data from other municipal laboratories across England. While the numbers examined at Bristol rose 10-fold (517 specimens in 1895 to

5578 specimens in 1906), they subsequently increased by just 1314 some seven years later (6892 specimens in 1913).

Like Newsholme in Brighton, the significance of bacteriological screening for KLB was evaluated after six months. By late 1895, Walter Dowson, the assistant MOH, had examined 49 cultures and found KLB in roughly 50%, both from suspected cases as well as those confidently diagnosed. These findings confirmed what Loeffler had found in 1884 and justified the value of bacteriological testing.

Davies continued the bacteriological analyses until 1902 when the work was transferred to Alfred Frank Stanley Kent, professor of physiology and bacteriologist to the Royal Infirmary, based at the bacteriological laboratory, University College, Bristol. When Kent left in 1906, Isaac Walker Hall (a former student of Delepine at Manchester) was appointed professor of pathology at University College with responsibility for bacteriology and also as director of the hospital clinical laboratory.

Municipal bacteriology was carried out in Walker Hall's laboratory at the Royal Infirmary, as Walker Hall did not obtain a university laboratory until 1910, a year after the university was formally established. From the annual reports, it seems (although it is not explicitly stated) that some bacteriology was also carried out at the local infectious diseases hospital and TB sanatoria, but it is not possible to determine the exact locations from the annual reports.

For example, results of throat swabs examined for KLB from the Ham Green Isolation Hospital appeared from 1903 (Ham Green Isolation Hospital opened in 1899) and were signed off by the resident medical officer, James Fletcher. In addition, corresponding with the opening of the Wisley Sanatorium in December 1904, separate results of examinations of sputa for tubercle bacilli appear and the numbers quickly rise (reaching 1102 examinations by 1913) that year. Milk to be examined for tubercle was sent to Delepine at Manchester.

While Davies was initiating a municipal bacteriological service for Bristol, a diagnostic bacteriological department was established at the Bristol Royal Infirmary in 1897, and John Odery Symes was appointed honorary bacteriologist to run the department. Two years later when Symes resigned it was Kent who took his position of bacteriologist at the hospital.[16]

Stephen Ralli Memorial Pathological Laboratory, (Royal) Sussex County Hospital, Brighton

An indication of the differences between Newsholme's municipal laboratory and local hospital bacteriology can be seen from the work of the diagnostic laboratory at the Sussex County Hospital, Brighton. The Stephen Ralli Memorial Clinical Research and Bacteriological Department was established in 1904 following an initial bequest by Mrs Stephen Ralli of £12,000. The laboratory was installed in the hospital's old museum building and consisted of five rooms over two floors, of which one was the 'bacteriological room'.[17,18] By the time of the official opening ceremony in June 1905, Frank George Bushnell (1868–1941) was the hospital pathologist who ran the laboratories from their inception until 1908, when Hugh Miller Galt (1866–1936) took over. Bushnell issued a summary of the work of the laboratory,[19] which detailed the numbers of requests made between July 1904 and January 1908.

Table 1. Comparison of bacteriological specimens received in the Stephen Ralli Memorial Laboratory and the Municipal Laboratory between July 1904 and January 1908.

	Stephen Ralli Laboratory		Municipal Laboratory*	
Sample	Number	% positive	Number	% positive
Nose/throat swabs for Klebs-Loeffler bacillus	65	18.5	9319	23.0
Sputum for TB	366	19.7	2011	38.7
Serum for Widal	79	25.3	229	23.0
Hair for ringworm	0	–	82	–
Inflammatory products	210	–	0	–
Blood	55	–	0	–
Urine	86	–	0	–
Miscellaneous	32	–	0	–
Water samples	0	–	227	–
TOTAL	893		11868	

*Values for the Municipal Laboratory are taken to the end of 1907 as the figures for the month of January 1908 alone are not available.

Table 1 lists the types of investigations carried out at the Ralli laboratory, including 893 out of 2447 specimens (36%) for bacteriology. The number of inflammatory products analysed reflects the nature of the in-patient population and contrasts with Newsholme's municipal laboratory where community infectious diseases such as diphtheria dominated. However, cases of diphtheria were seen at the County Hospital as well as at the local sanatorium, and the proportion that yielded KLB were broadly comparable.

In the pre-antibiotic era, Bushnell, like many others, took up preparing autologous vaccines. In the period reported, seven vaccines were produced for the treatment of staphylococcal infections. Bushnell had tested 100 sera between 1904 and 1908 for opsonic indices. In contrast to Newsholme, Bushnell seems to have been converted to the idea, and he sent a colleague to Hamburg to demonstrate the technique to Professor Unna.

Discussion

We assume that the laboratories in Brighton, Aberdeen and Bristol are representative of municipal bacteriology in the UK at the turn of the 19th century. The workload of the municipal laboratories in Glasgow, Edinburgh, Cardiff and Nottingham in the same period is very similar, dominated by diphtheria, tuberculosis and typhoid. Municipal bacteriology laboratories run by the local MOH were introduced in towns without medical schools, such as Brighton, Portsmouth and Cardiff (Fig. 4). We have seen similar results from laboratories in Blackburn, Glasgow and Hove, all established in 1899. In some of the larger cities,

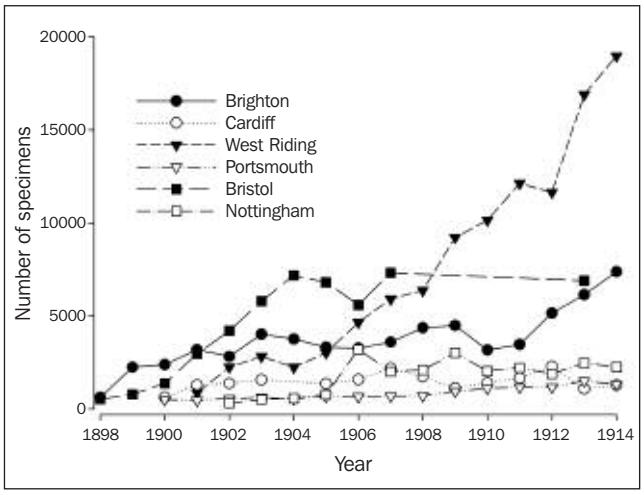

Fig. 4. Comparison of specimen numbers analysed by several municipal bacteriology laboratories in the United Kingdom. Bacteriological examinations of water and food are not included. Compiled from the appropriate annual reports of the Medical Officers of Health.

a specific 'city bacteriologist' was appointed, such as Rubert Boyce at Liverpool in 1898.

The impact of the work of Biggs in establishing the New York municipal bacteriology laboratory has probably been overshadowed by the success of the antitoxin. Worboys suggests that the need for diphtheria antitoxin was a major stimulus for the appearance of municipal laboratories in Britain in the 1890s.[20] In the three laboratories studied here, manufacture of the antiserum receives little comment in the annual reports. In contrast, the value of diagnostic testing in the management of community infectious disease receives regular comment. The reasons presented to the sanitary committees by Newsholme, Watt, Hay and Davies all speak (albeit in general terms) of the benefits of accurate bacteriological diagnosis over clinical diagnosis alone and its implications for spread both in the community and in the isolation hospital.

In 1932, when reviewing his work. Newsholme placed greater significance on bacteriological diagnosis of diphtheria than on the treatment of disease with antitoxin, as the latter had "done but little to prevent the spread of epidemic diphtheria".[21] Diphtheria was causing major epidemics throughout the 1890s, as seen in Brighton (Fig. 2) and London.[22] We suggest that the identification of KLB was the primary driver for the establishment of municipal bacteriology laboratories, with the diagnosis of typhoid and the detection of tubercle bacilli less so.

Municipal laboratories were built on such specimens, but other establishments were culturing KLB, too. In the late 1890s, these included the Lister Institute (British Institute of Preventive Medicine), which received samples from a substantial proportion of the London boroughs[23] and from private pathology services such as the Clinical Research Association.

German Sims Woodhead was superintendent of the laboratory of the Royal College of Physicians in Edinburgh between 1887 and 1890, and he directed the bacteriological work received from local medical practitioners. The diagnostic work increased such that by 1898 it comprised 70% of the workload.[24] Sims Woodhead left Edinburgh to take charge of the Royal College of Surgeon and Physicians conjoint laboratory on London's Victoria embankment, where examination for KLB from London's Metropolitan Asylum Board hospitals was started late in 1894.[25] Initially, some of this work was carried out by E. E. Klein, working from the pathology department at St. Bartholomew's Hospital.[26] From 1894, a total of 10,374 specimens in 12 months were examined from hospitals of the Metropolitan Asylum Board.[27]

Outside London, bacteriological examination of throat swabs in cases of suspected diphtheria was started in November 1893 at St. Helens, Liverpool, by the MOH, John (later Sir John) Robertson.[28] E. F. Trevelyan, professor of pathology and bacteriology at Yorkshire College, Leeds, started bacteriological examinations for diphtheria in 1895, and, in 1897, the MOH at Southend, J. T. C. Nash, did the same.

However, A. S. Delepine at Owen's College, Manchester, can be considered to have established the leading model of public health bacteriology in England.[20,29,30] Having arrived in Manchester in 1891 as professor of pathology and morbid anatomy, Delepine started to offer similar bacteriological examinations as were employed by Newsholme and Hamilton. Where Delepine's laboratory differed was the apparent lack of analysis of sputa for tubercle. In his review of "public health" bacteriology carried out in Manchester, Delepine outlines procedures for detecting tubercle in milk but not sputum.[31] Delepine had clear interests in tuberculosis and worked with the local sanatorium, but it is peculiar that analysis of sputum receives no mention in an article illustrating the role of the diagnostic laboratory.

In the decade when the UK Health Protection Agency has undergone major reshuffling,[32] and the terms MOH (1974) and PHLS (2003) are now obsolete, we wish to highlight the role of the MOH in introducing what would become the Public Health Laboratory Service. It might be expected that the introduction of bacteriological diagnoses into the work of the MOH would be something of which to be proud. Newsholme, who wrote two books on his work in public health, fails to mention such work, either in his laboratory or any other municipal laboratory. Likewise, medical historians seemingly have ignored this component. J. L. Brand, in an otherwise illuminating survey of the work of the MOH and public health in Britain, omits any reference to the municipal bacteriology laboratory.[33]

As numerous bacteriologists in the UK were pathologists (represented by Hamilton and Walker Hall in this study), the idea that bacteriology was introduced into medicine via pathological departments in university-linked medical schools overlooks the role of the municipal bacteriology laboratory. The scenario in Brighton shows that municipal laboratories established bacteriology in the town before the local hospital pathological department, and that there was a need for both. In Bristol, a municipal and a hospital diagnostic laboratory were established at the same time.

Eyler has documented the vigour with which Newsholme raised the state of public health services (particularly infectious diseases issues) in Brighton.[2] The number of samples received in Newsholme's laboratory may reflect the size of the local population, rather than any aggressive recruitment and publicity campaign by Newsholme on the value of such tests to the medical community. Table 2 shows

the workload expressed according to population size for the year 1901. Brighton comes top for that year but Bristol was processing more samples over the longer course (Fig. 3).

In 1900, Newsholme's laboratory tested 2372 samples for the three pathogens (plus an additional 111 water samples for bacteriological and chemical tests), which by 1914 had also risen to 7525 plus 390 additional tests (including water examinations). In terms of specimen numbers, Newsholme's municipal laboratory was analysing an equivalent number of samples to the laboratory of the Royal College of Surgeons, Edinburgh, which examined a total of 3000 specimens in the year 1900 (total number of samples for diphtheria, tubercle and typhoid), increasing to 10,639 by 1914.[34]

Table 3 lists a few of the more important human bacterial pathogens that had been cultured up to 1898. By comparison, the range of bacteriological examinations appears limited, given the number of pathogens that had been cultivated adequately *in vitro* by the time Newsholme opened his laboratory in Brighton. This contrast is again highlighted if one considers the range of organisms described in a contemporary textbook written for the MOH and public analysts. The public analysts Thomas Hames Pearmain and Cresacre George Moor published their *Applied bacteriology* in 1897,[35] in which a large number of pathogenic bacteria relevant to human disease and public health are described in 374 pages. Of the organisms in Table 3, only brucellosis, plague and *Haemophilus ducreyi* fail to get a mention in the book. Salmonellas are included but only as *Bacillus muriseptica* (*Salmonella typhimurium*) and not as an agent of human disease. Culture for enteric pathogens such as salmonellas was not carried out in the laboratories studied here. Such organism had been recognised for many years prior to the opening of municipal laboratories, but they failed to command attention it seems. Both the municipal and hospital laboratory in Brighton (at least until 1908) took little active interest in culturing anything but KLB, with just very occasional reference to examination of the typhoid bacillus in stools from suspected carriers.

Of the pathogens described at the time, it is likely that few were considered responsible for acute epidemics and thereby fall under the remit of the MOH. Alongside diphtheria, the biggest problem was probably scarlet fever. Isolation hospitals regularly admitted large numbers of such cases, but the acceptance of the role of the group A streptococcus was only adopted in the 1920s. The other pathogens in Table 3 did not have sufficient significance for the MOH and general practitioners such that they warranted bacteriological diagnosis.

We have been unsuccessful in finding the numbers of people employed in such laboratories and therefore cannot indicate to what extent the growth of the department was influenced by the number of people available to process the specimens. Equally, we have been unable to clarify the extent to which city public analysts carried out diagnostic bacteriology. It is certain that they did such work, mostly on food, milk and water samples rather than clinical specimens. In Bristol, Edward Russell carried out the chemical analysis of water, while Samuel Russell Trotman (city analyst from 1896) in Nottingham carried out the municipal bacteriology before Dr. F. Jacob was appointed as a medical bacteriologist in 1901.

Public analysts were often chemists (Trotman was a Fellow of the Institute of Chemistry) or pharmacists by training and were carrying out bacteriological laboratory examinations before physicians started such work. Consequently, *The Lancet* registered disquiet about the MOH carrying out public analyst laboratory work on food and water, and similarly disapproved of public analysts doing diagnostic bacteriology.[36,37]

Table 2. Bacteriological workload of municipal bacteriological service laboratories in the UK in 1901*.

Town	Population	Number of bacteriological examinations	Workload per 100,000 population
Brighton	123479	2809	2255
Bristol	338895	4191	1236
Hove	38443	387	1006
Hull	249639	240	962
Bradford	283412	150	533
Manchester	553486	2666	481
Sheffield	425528	2000	471
Cardiff	172598	748	433
Portsmouth	191909	537	280
Liverpool	716810	2000	279
Salford	226480	627	277
Aberdeen	345362	783	227
Birmingham	533039	683	128
Nottingham	245985	302	122
Newcastle	222241	98	44

*Modified from the Annual Report of the Medical Officer of Health for the City of Portsmouth for 1902, supplemented with data from the appropriate annual reports from Aberdeen, Brighton and Hove.

The influence of the Diploma of Public Health on the bacteriological interests of the MOH remains speculation. Bacteriology was part of the curriculum and the diploma was taken by MOsH who wished to work in the larger towns and cities. The University of Dublin first introduced the DPH in 1871, and bacteriology started to appear in the curriculum approximately 20 years before Newsholme or Hay thought about bacteriological diagnosis.

Despite the comprehensive bacteriological coverage given in Pearmain and Moor's standard textbook[35] the qualification would not have guaranteed bacteriological competence as the actual bacteriological content taught was highly variable, and depended on the host university.[38]

To what extent funding determined the appearance of bacteriology laboratories has not been addressed in this review. Davies and Dowson in Bristol carried out the work voluntarily in addition to their official duties. The municipal laboratories discussed here were supported by local authority funds, typically from a Sanitary Committee. However, Hamilton in Aberdeen struggled to obtain funds to run his university laboratory of pathology and was most grateful to obtain the money he received for municipal bacteriology work.[12]

Hospital-based pathological bacteriology may have fared worse financially. The appearance of the Stephen Ralli Memorial Laboratory seven years after Newsholme's

Table 3. Dates of first cultivation of some bacteria pathogenic to man.

Year	Organisms
1876	*B. anthracis*
1880	*S. aureus*
1882	*P. aeruginosa, M. tuberculosis, K. pneumoniae, P. mallei*
1883	*V. cholerae*
1884	*S. pyogenes, S. typhi, C. diphtheriae*
1885	*N. gonorrhoea*
1886	*S. pneumoniae, E. coli*
1887	*N. meningitidis, B. melitensis*
1888	*S. enteritidis*
1889	*C. tetani, H. ducreyi*
1894	*Y. pestis*
1896	*C. botulinum*

municipal laboratory only occurred because of a private bequest. Such circumstances were typical of many pathological departments established in the voluntary hospital sector. Before the formation of the National Health Service, hospitals had to work hard to raise funds and thus had serious constraints on money for funding new developments such as bacteriology. However, private benefaction was no guarantee of continued support. A municipal laboratory was established in Leicester in 1895, funded partly by a laboratory equipment manufacturer, but it closed down due to lack of funds shortly thereafter.

The Medical Research Council (MRC) quinquennial review of 1924 felt that bacteriology (and pathology) had failed to deliver significant breakthroughs, and it laid some of the blame on the burden of routine bacteriology, both diagnostic and municipal.[39] The issue was debated at the British Medical Association meeting in Bath in 1925, and it generated correspondence in the *British Medical Journal*.[40,41] The narrow focus of the laboratory examinations in the three examples studied here appear to support the MRC's opinion.

Conclusions

The municipal bacteriological laboratory in Brighton was only one of several such departments in the country at the end of the 19th century supplying a service to the MOH. From the workloads of the laboratories in Brighton and Bristol, run by the MOH, and the laboratory in Aberdeen under a professor of pathology, a remarkably uniform set of tests were established under the leadership of MOsH and university pathologists in England and Scotland. The numbers of samples examined by municipal laboratories could exceed those examined by hospital diagnostic laboratories. At Brighton, Newsholme's laboratory received more than 10 times the number of specimens received by the Stephen Ralli Memorial Laboratory between the years 1904 and 1908.

The fact that a county municipal laboratory was receiving numbers of samples equivalent to or greater than laboratories in cities with an established medical school shows how communicable diseases in the community was the predominant application of bacteriology, rather than improving diagnostic pathology. However, the limited range of bacteriological tests may actually have limited the scope and development of public health laboratory services in the subsequent decades. □

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