

RESEARCH ARTICLE

‘A remedy for this dread disease’: Achille Sclavo, anthrax and serum therapy in early twentieth-century Britain

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Abstract

In the years around 1900 one of the most significant practical consequences of new styles of bacteriological thought and practice was the development of preventive vaccines and therapeutic sera. Historical scholarship has highlighted how approaches rooted in the laboratory methods of Robert Koch, Louis Pasteur and their collaborators were transformed in local contexts and applied in diverse ways to enable more effective disease identification, prevention and treatment. Amongst these, the anti-anthrax serum developed by the Italian physician Achille Sclavo (1861–1930) has received little to no attention from historians. This article positions Sclavo’s serum as a neglected but significant presence in British microbiology, which achieved widespread uptake amidst a wave of optimism, despite prolonged uncertainty about its mechanism of action and dosage. After being introduced to Britain in 1904 by the enterprising first medical inspector of factories Thomas Morison Legge, within a matter of months the serum became regarded by medical practitioners as an effective treatment of cutaneous anthrax, though access to ‘fresh’ serum and the necessary speedy diagnosis remained problematic. Like the disease anthrax itself, discussion of ‘Sclavo’s serum’ was out of all proportion to the relatively low number of cases, reflecting a deep-seated fascination with the wider possibilities afforded by effective serum therapy.

Introduction

Sclavo’s serum has been almost solely employed. The results attending its administration appear to us to have been so good that the use of other serums seemed scarcely justifiable.¹

After the deaths of noted anthrax authorities Louis Pasteur in 1895 and Robert Koch in 1910, Frederick William Eurich – quoted above – was arguably the medical scientist most familiar with this rapidly fatal and much-feared disease as it manifested in humans. As bacteriologist to the Anthrax Investigation Board for Bradford and District from 1905 to 1918, Eurich encountered a large number of cases of the disease – principally in employees in the local wool and worsted trades. He analysed wool samples in an attempt to culture the causative agent of anthrax, *Bacillus anthracis*; tested the efficacy of various

¹ F. Eurich, ‘Some notes on industrial anthrax: its diagnosis and treatment’, *British Medical Journal*, 8 July 1933, pp. 50–3, 52.

disinfectants; and delivered monthly reports to the board and local employers.² Although he spent the bulk of his time in a small laboratory in Bradford Technical College, the German-born, Edinburgh-trained Eurich was also concerned with the clinical presentation of anthrax, and he worked closely with employers and workers to institute practical preventive measures. He identified which kinds of wool posed the greatest risk and collaborated at a national level with the Home Office to produce a poster, using his own artworks, showing the diverse ways in which anthrax could manifest on the skin.³ Eurich, working in Bradford where anthrax was more frequently seen than any other locality in Britain, was uniquely well placed, then, to commend the anti-anthrax serum developed by Italian physician Achille Sclavo above all other therapeutic approaches in cases of cutaneous anthrax.⁴ This he did most forcefully in his retrospective 1933 article in the *British Medical Journal*, nearly forty years after Sclavo had first announced his apparent success in creating an effective serum in 1895.⁵

The history of serum therapies, drawing on methods developed principally by Pasteurians, Koch and Paul Ehrlich in the late nineteenth century, has received little attention in comparison to the broader literature on bacteriology, especially in the British context. Amongst the great serum therapy researchers of this period Ehrlich stands almost alone as a focus of significant scholarship, notwithstanding efforts to rehabilitate the work of others, such as Emil von Behring, whose fame in the medical world of the 1890s was arguably eclipsed only by that of Pasteur.⁶ One recent exception is Jonathan Simon's rich account of the diphtheria antitoxin as developed and implemented in France during the last years of the nineteenth century. Simon's narrative, with Emile Roux front and centre, ties this key episode in the application of Pasteurian methods to the transformations in French medical practice and broader national sociopolitical considerations; the serum was a source of both inter- and intranational tension, between France and neighbouring Germany, and between Paris and provinces over serum production and distribution.⁷ The case of Sclavo is far less prominent, and is invariably seen as a mere footnote to the bacteriological investigations of the late nineteenth century. However, considering this particular configuration of bacteriological methods reveals important features of how early twentieth-century microbiology was translated into

² 'Minutes of the Anthrax Investigation Board', 17 September 1906, 6 December 1906, 24 June 1907, 20 October 1910, 15 October 1914, WYB111/1/2/15, West Yorkshire Archive Service, Bradford.

³ James F. Stark, *The Making of Modern Anthrax, 1875–1920: Uniting Local, National and Global Histories of Disease*, London: Pickering and Chatto, 2013, Chapter 1; Stark, "'Classic, characteristic or typical': the skin and the visual properties of external anthrax lesions", in Jonathan Reinarz and Kevin Siena (eds.), *A Medical History of Skin: Scratching the Surface*, London: Pickering & Chatto, 2013, pp. 195–208; Stark, 'A poster of pustules: representations of early twentieth century industrial anthrax in Britain', *Endeavour* (2011) 35(1), pp. 23–30.

⁴ Given its appearance within the central local worsted trade, rapid and high mortality, and indiscriminate occurrence in young and old, fit and unhealthy alike, anthrax was a topic of huge local interest and concern, out of all proportion to its incidence. Between 1877 and 1890, for example, only thirty-one fatalities were recorded by Bradford medical officers of health. Annual reports of the medical officer of health for Bradford (1877–90), Bradford Central Library, B614 COR.

⁵ Pasteur's close collaborator and intellectual heir, Emile Roux, who was also intimately acquainted with the disease and the production of a much-hailed anti-diphtheria serum (antitoxin), died in 1933.

⁶ For examples of recent work exploring the contributions of Ehrlich and Behring see Deborah Neill, 'Paul Ehrlich's colonial connections: scientific networks and sleeping sickness drug therapy research, 1900–1914', *Social History of Medicine* (2009) 22(1), pp. 61–77; Jonathan Simon, 'Emil Behring's medical culture: from disinfection to serotherapy', *Medical History* (2007) 51(2), pp. 201–18; Derek S. Linton, *Emil von Behring: Infectious Disease, Immunology, Serum Therapy*, Philadelphia: American Philosophical Society, 2005; Jonathan Liebenau, 'Paul Ehrlich as commercial scientist and research administrator', *Medical History* (1990) 34(1), pp. 65–78.

⁷ Jonathan Simon, *Diphtheria Serum as a Technological Object: A Philosophical Analysis of Serotherapy in France 1894–1900*, Lanham, MD: Lexington Books, 2017.

clinical practice. This is especially notable in the context of Britain, where the methods of both Koch and Pasteur were adapted to create a distinctive bacteriology, typified institutionally by the hybrid approach visible most prominently at the Lister Institute, which was centrally involved in serum production and development from the mid-1890s, and the Brown Animal Sanatory Institution.⁸

In the context of a dynamic transnational network of serum development this article provides the first comprehensive account of the role played by Sclavo's serum in Britain, with a dual focus on the serum's framing in the context of medical science, and its clinical application. At the same time as Pasteurians and Kochians were developing an effective vaccine for animals and mastering the causative organism of anthrax, *Bacillus anthracis*, Sclavo devised a therapeutic anti-anthrax serum derived from immunized animals in the mid-1890s. Uncovering how the serum was introduced into medical practice is a crucial stepping stone for understanding what it reveals about bacteriology since discussion within the British medical and lay press was predicated on the importance of deploying the serum effectively in humans. In Britain, the high-profile medical inspector of factories, Thomas Morison Legge, brought this therapy first to the attention of medical practitioners in Bradford, a national anthrax hot spot, in 1904. Within a couple of years, Sclavo's serum had become embedded as a trusted, standard treatment for cases of both external and internal anthrax, supplementing rather than supplanting surgical excision of any visible pustule on the skin. The ascent of the serum is especially surprising given that Sclavo was singularly opaque about the precise mechanism of action, veering between claims that it acted as an antitoxic or antimicrobial preparation.

As the area in Britain with the most significant incidence of both cutaneous and pulmonary anthrax, Bradford, in the industrial area of West Yorkshire, became the initial testing ground for this new form of therapy before it was deployed in other locales affected by the disease such as Glasgow, Liverpool, Worcester and London.⁹ Despite being liable to rapid decay when stored, and the requirement to use extremely large volumes – up to eighty cubic centimetres in a single dose – Sclavo's serum became a cornerstone of therapy used to treat established cases of anthrax long before the Duckering process of disinfection rendered most potentially infection-carrying imported

⁸ Michael Worboys, *Spreading Germs: Disease Theories and Medical Practice in Britain, 1865–1900*, Cambridge: Cambridge University Press, 2000. The Lister Institute was established as the British Institute of Preventive Medicine in 1891, before being renamed to honour Edward Jenner in 1899 and then Joseph Lister in 1903. Early records show its role in the production of diphtheria antitoxin from 1894. 'Diphtheria anti-toxin', 1894, Wellcome Library, SA/LIS/I.1. It was pre-dated by the Brown Institution (from 1871), which undertook critical work in relation to infectious diseases in animals, including anthrax, particularly under the directorship of William Smith Greenfield between 1878 and 1881. R.J.M. Franklin, 'The Brown Animal Sanatory Institution: historical lessons for the present?', *Veterinary Journal* (2000) 159(3), pp. 231–7; Graham Wilson, 'The Brown Animal Sanatory Institution', *Journal of Hygiene* (1979) 82(3), pp. 501–21. In Nancy Tomes's authoritative account of germ theories and practices in the United States – where the so-called 'gospel of germs' transformed domestic spaces and reshaped public hygiene – serum therapies are noticeable by their absence. Indeed, on Tomes's interpretation, 'Robert Koch's isolation of tuberculin ... proved to be useful only as a diagnostic tool', an especially surprising perspective since the director of the New York City Department of Health, Hermann Biggs, was a keen advocate of the benefits of serum treatment of diphtheria prior to 1900. Nancy Tomes, *The Gospel of Germs: Men, Women, and the Microbe in American Life*, Cambridge, MA and London: Harvard University Press, 1998, p. 115; Daniel M. Fox, 'Social policy and city politics: tuberculosis reporting in New York, 1889–1900', *Bulletin of the History of Medicine* (1975) 49(2), pp. 169–95.

⁹ By the time an occupational-health poster about anthrax prevention was issued by the Home Office in 1919, Sclavo's serum was available at five sub-depots operated by the Jenner Institute for Calf Lymph Ltd, located in London (two), Glasgow, Liverpool and Leeds. The last was the chief supplier for neighbouring Bradford, though it is not clear why a base for distribution was not established in Bradford itself. 'Anthrax poster', 1927, CMAC PP/HUN/B.17, Papers of Dr Donald Hunter (1898–1977), Wellcome Collection.

animal hides and fleeces safe.¹⁰ It was also the most significant practical preventive or treatment for human cases of anthrax to emerge from bacteriological investigations of the late nineteenth century; the animal vaccine demonstrated so sensationally at Pouilly-le-Fort in 1881 was never successfully adapted for use beyond the veterinary context despite being produced on an industrial scale through the large international network of Pasteur Institutes, and locally adapted variants.¹¹

By examining the effect of Sclavo's serum on British anthrax practices we see not only the theoretical but also the practical changes which took place in the so-called golden age of bacteriology, when the discipline appeared to herald a new era of therapeutic promise. Of the three diseases for which Koch himself demonstrated the causative organism – anthrax, tuberculosis and cholera – all attracted significant efforts to develop a curative serum. Cholera remained stubbornly impervious to such attempts. For example, when reporting in the *British Medical Journal* in 1935 on experiments with a serum to treat cholera, the director of the Department of Bacteriology and the Indian Institute for Medical Research, H. Ghosh, noted, 'Since the introduction of saline transfusions by Sir Leonard Rogers [from 1914] little progress has been made in the treatment of cholera.'¹² At the same time, the production of diphtheria antitoxins resulted in a crowded market of sera, as has been noted especially in the French context. By the interwar period, pneumonia had become the subject of the most intensive efforts to create effective antisera.¹³ Indeed, given that serum-based approaches were applied to a huge range of infectious diseases, the case of Sclavo's serum represents a neglected but important example of the application of bacteriological techniques in a pre-antibiotic era. It was an attempt to combat a disease centrally involved in early cause-tracing of infectious diseases, which also represented the first specific therapy for a high-profile and deadly industrial disease. This is especially pronounced since it coexisted with dramatically different approaches to disease control, such as those pioneered by the Manchester-based Sheridan Delépine in an effort to fracture the purported causal connections between bovine tuberculosis and the infection in humans.¹⁴

The Siena-based pathologist at the heart of this account, Achille Sclavo, has been the subject of a small number of brief biographical studies in Italian, but is a peripheral figure

¹⁰ This was developed jointly by the factory inspector, G. Elmhirst Duckering, and bacteriologist Frederick William Eurich, and implemented on an industrial scale from 1921 at a wool disinfection station in Liverpool, the whole process mandated by the Anthrax Prevention Act (1919).

¹¹ A related vaccine, developed in New South Wales by John Gunn and John McGarvie Smith, was far more widely adopted in Australia than was the 'original' Pasteurian vaccine. See Jan Todd, 'From Paris to Narrandera: adaptation in the diffusion of anthrax vaccination in the Australian pastoral industry', *Prometheus: Critical Studies in Innovation* (1989) 7(1), pp. 32–48.

¹² H. Ghosh, 'Treatment of cholera with a new anti-cholera serum', *British Medical Journal*, 12 January 1935, pp. 56–7, 56. Ghosh and his colleagues carried out further research in this area, but without much success. See H. Ghosh, 'Further investigation of a new anti-cholera serum', *British Medical Journal*, 9 May 1936, pp. 936–8. For more on Leonard Rogers and his work on cholera see John Smith Knox Boyd, 'Leonard Rogers, 1868–1962', *Biographical Memoirs of Fellows of the Royal Society* (1963) 9, pp. 261–85, esp. 274–6.

¹³ In the interwar period, after the use of Sclavo's serum had become embedded, the most significant attention in terms of the development of antisera was reserved for pneumonia. See Scott H. Podolsky, *Pneumonia before Antibiotics: Therapeutic Evolution and Evaluation in Twentieth-Century America*, Baltimore: Johns Hopkins University Press, 2006; Podolsky, 'Jesse Bullowa, specific treatment for pneumonia, and the development of the controlled clinical trial', *Journal of the Royal Society of Medicine* (2009) 102(5), pp. 203–7. The search for sera was allied to the ongoing deployment of disinfection as a major method of disease prevention. Hannah Landecker, 'Antimicrobials before antibiotics: war, peace, and disinfectants', *Palgrave Communications* (2019) 5(5), doi:10.1057/s41599-019-0251-8.

¹⁴ Susan D. Jones, 'Mapping a zoonotic disease: Anglo-American efforts to control bovine tuberculosis before World War I', *Osiris* (2004) 19, pp. 133–48.

in English-language scholarship.¹⁵ Where he does appear in the literature, Sclavo and his work are discussed only superficially in the global history of anthrax, and do not feature in any broader accounts of serum therapy.¹⁶ In his historical overview of anthrax across the *longue durée* Swiderski characterizes the therapeutic serum made by Sclavo as a refined vaccine, and notes that it was ‘not especially effective’.¹⁷ Similarly, in a piece focused on transnational efforts to regulate industrial anthrax in Britain, Carter and Melling note only in passing, ‘Although an antiserum was developed by Sclavo at the turn of the [twentieth] century, treatment remained problematic and was often ineffective’.¹⁸ However, this sits at odds with the views of key historical actors such as Eurich and Legge, as well as the wide deployment of the serum over a long period: the anti-anthrax serum which Sclavo produced from around 1895 onwards had a major impact on the therapeutic approach to cutaneous anthrax in Britain as the first viable non-surgical treatment, and remained in use for at least fifty years. This is particularly significant given the very high reliance on sera of various kinds in this period to treat already established diseases. As one commentator noted in 1904, ‘Diseases treated by antitoxic sera were diphtheria, tetanus, snake-bite, hay fever, dysentery, plague, typhoid fever, and tuberculosis ... Diseases treated by antimicrobial sera were streptococcal and staphylococcal infection, plague, typhoid fever, dysentery, pneumonia, anthrax, tuberculosis, Malta fever, and relapsing fever.’¹⁹ By contextualizing the origins, application and adaptation of Sclavo’s serum we see more clearly how it became so centrally embedded as a key strategy in combating infectious disease, reinforcing the significance of serum-related bacteriological research and practice in the decades around 1900.

The birth of Sclavo’s serum

Achille Sclavo was born in Alexandria on 21 March 1861, and studied medicine at the University of Turin, from where he graduated in 1886. He did not enter general practice, but rather pursued a career in academic medicine, holding positions at his alma mater (as lecturer at the Institute of Pharmacology) and in Rome (working with the Directorate General of Health) before being appointed director of the Laboratory of Hygiene and Public Health at the University of Siena in 1896.²⁰ In 1921 he was the founding president of the Associazione nazionale degli igienisti italiani (National Association of Italian

¹⁵ For biographical details of Sclavo in Italian see F. Vannozi, ‘L’istituto Sieroterapico e Vaccinogeno Toscano “Sclavo”: una città laboratorio’, in F. Vannozi (ed.), *Siena, la città laboratorio: Dall’innesto del vajuolo ad Albert Sabin*, Siena: Protagon Editori Toscani, 1999, pp. 27–47. Sclavo’s work in so-called ‘hygienic education’ has also received some recent scholarly attention: Giambattista Bufalino, ‘School, hygienic care and education: the contribution of Achille Sclavo’, *Studi sulla Formazione* (2020) 23, pp. 157–73.

¹⁶ Susan D. Jones, *Death in a Small Package: A Short History of Anthrax*, Baltimore: Johns Hopkins University Press, 2010, pp. 117–18; Tim Carter’s short article characterizes Sclavo’s serum as ‘the most effective cure for the disease [anthrax]’, but he uses only sources in English authored by Legge. See Tim Carter, ‘Anthrax: a global problem with an Italian cure’, in Antonio Grieco, Sergio Iavicoli and Giovanni Berlinguer (eds.), *Contributions to the History of Occupational and Environmental Prevention*, Amsterdam: Elsevier, 1999, pp. 247–51.

¹⁷ Richard M. Swiderski, *Anthrax: A History*, Jefferson, NC: McFarland, 2004, p. 154.

¹⁸ Tim Carter and Joseph Melling, ‘Trade, spores, and the culture of disease: attempts to regulate anthrax in Britain and its international trade, 1875–1930’, in Christopher Sellers and Joseph Melling (eds.), *Dangerous Trade: Histories of Industrial Hazard across a Global World*, Philadelphia: Temple University Press, 2012, pp. 60–73, 62.

¹⁹ ‘The British Medical Association meeting at Oxford’, *The Lancet*, 13 August 1904, pp. 454–70, 454.

²⁰ [‘Reports of the University of Siena Council’], Sclavo Papers, uncatalogued, Università degli Studi di Siena, Siena; Saverio Battente and Stefano Maggi, ‘Salute e igiene pubblica tra impresa e ricerca: Achille Sclavo e l’Università di Siena’, *Rassegna Storica Toscana* (2005) 51, pp. 165–84. In Siena the non-profit Sclavo Vaccine Association still bears his name.

Hygienists), and he later held the position of chancellor at Siena (1924–6).²¹ Sclavo was working in a country which, like both France and Germany, experienced anthrax most frequently as a disease of animals, and it was in this veterinary context that he received a small grant from the Italian Home Office in 1893 to investigate possible means of prevention. According to data which he collected, between 1890 and 1900, there were some 24,032 cases of veterinary anthrax across Italy, of which 5,812 proved to be fatal.²² Although he is most often described as having carried out significant work into anthrax from his time in Siena (1896–1918), Sclavo had already begun to investigate the condition – known in Italy as either *antrace* (internal, when contracted through the lungs) or *carbonchio* (external, when infection was set up through an abrasion in the skin) – whilst in Rome as director of the Bacteriological Health Laboratory. It was from here that he published his first work on the subject in 1895.²³

Sclavo's brief 1895 text, entitled *Sulla preparazione del siero anticarbonchioso* (On the Preparation of an Anti-anthrax Serum), outlined his methodology in fairly basic terms. His approach was rooted in the experimental fundamentals of the Pasteurian programme which had led to the creation of the much-studied vaccine first demonstrated on sheep at Pouilly-le-Fort in May 1881.²⁴ This was supplemented by Sclavo's immersion in the work of Behring, and represented a conjunction of multiple bacteriological modes of thought.²⁵ This enabled him to adapt the origin vaccination method developed by Pasteur and Charles Chamberland in response to chicken cholera. The organism responsible had appeared to Pasteur and Chamberland to lose its virulence when exposed to oxygen during prolonged culturing, yet retained the capacity to produce effective immunization from the fully virulent strain. Although this work did not translate into a vaccine which transcended the boundary of the laboratory, the later two-dose anthrax vaccine – also heavily influenced by the work of Henry Toussaint – was based on the same close control of the *in vitro* attenuating culturing process through serial passages, working instead with the causative organism *Bacillus anthracis*.²⁶ Adopting a similar method, Sclavo inoculated progressively larger animals – starting with rabbits and sheep, but moving on to goats and finally asses – with a Pasteurian vaccine, and then proceeded to apply progressively higher doses of more virulent anthrax cultures over a period extending up to two years.²⁷ He then drew off fluid from the carotid artery of the affected animals, which 'produced a potent serum for use in human cases of the disease', with, he claimed, no

²¹ Achille Sclavo, *Autobiografia Scientifica del Prof. Dott. Achille Sclavo*, Siena: Meini, 1954.

²² Achille Sclavo, *Sullo Stato presente della Sieroterapia Anticarbonchiosa*, Turin, 1903.

²³ Vaccination Commission: *Sixth Report of the Royal Commission Appointed to Inquire into the Subject of Vaccination*, London: HMSO, 1896, p. 506.

²⁴ Louis Pasteur, 'Compte rendu sommaire des expériences faites a Pouilly-le-fort, près Melun, sur la vaccination charbonneuse', *Comptes rendus de l'Académie des sciences* (1881) 92, pp. 1378–83. This public display of vaccine efficiency was a significant step in developing preventive measures for animals, but the method was not applied to humans and remained purely within the veterinary realm. Amongst the extensive scholarship on Pasteur's Pouilly-le-Fort demonstration see Massimiano Bucchi, 'The public science of Louis Pasteur: the experiment on anthrax vaccine in the popular press of the time', *History and Philosophy of the Life Sciences* (1997) 19(2), pp. 181–209.

²⁵ 'Achille Sclavo precursore ed apostolo dell'odierna medicina sociale', in *Siena e Francoforte unite nel ricordo di von Behring, Ehrlich e Sclavo*, Rome: Luigi Pozzi, 1954; C.A. Ragzzi, 'Achille Sclavo, maestro e precursore dell'odierna medicina preventiva', *Annali della Sanità Pubblica* (1954) 15(3), pp. 453–61; Stefano Maggi, *Cittadella della scienza: L'Istituto Sclavo a Siena nei cento anni della sua storia (1904–2004)*, Milan: Francoangeli, 2004.

²⁶ Nadine Chevallier-Jussiau, 'Henry Toussaint et Louis Pasteur: Une rivalité pour un vaccin', *Histoire des sciences médicales* (2010) 44(1), pp. 55–64; Hervé Bazin, 'Pasteur and the birth of vaccines made in the laboratory', in Stanley A. Plotkin (ed.), *History of Vaccine Development*, London: Springer, 2011, pp. 33–47, 35–6.

²⁷ Achille Sclavo, *Sulla preparazione del siero anticarbonchioso*, Rome, 1895.

observable negative side effects.²⁸ Commentators described the serum variously as an antitoxin and an antiserum in subsequent years, whilst Sclavo himself vacillated, claiming in 1901 that ‘both man and animals can be saved by antitoxin after injection by anthrax bacilli’; in 1904 that ‘it quickly arrests the extension of the oedematous process’; and later, by 1911, that ‘by stimulating the leucocytes in their fight against the germs’, his preparation was ‘not an anti-toxic serum’, but an antiserum mirroring the action of the live, attenuated, Pasteurian vaccine.²⁹

The initial results were first reported rapidly in English in the *British Medical Journal* in 1895 and Sclavo stated ‘that there is ground for hope that anthrax both in man and in domestic animals may be combated by serum-therapy’, though with typically vague reference to any possible mechanism of action; the serum appeared to have ‘preventive and therapeutic properties’.³⁰ The timing was significant. Over the previous two years an increasing number of successful applications of diphtheria serum had been reported in the British medical press, ‘building up the sense of a modern medical miracle’ based on the significant reduction in mortality.³¹ In 1896 a copy of Sclavo’s publication arrived at the Royal Sanitary Institute of Great Britain, but it seemed to generate little interest, possibly owing to the relatively small incidence of anthrax, or perhaps the fact that cases were invariably limited to specific trades and therefore places, in profound contrast to the far more widely distributed disease of diphtheria.³² Whatever the reason behind this initial lack of attention, reports of successful use of the serum in Italy appeared sporadically in the British medical press over the following years. For example, a commentary in *The Lancet* published in 1899 described ‘the twenty-seventh case of anthrax which has been successfully treated with Professor Sclavo’s serum’, without noting or recommending its uptake in Britain.³³

Although Sclavo’s work was funded with the intention of devising a successful therapy for use primarily in herd animals, his research began to receive more widespread attention in Britain when the efficacy of its application to human cases began to come into focus. In a pamphlet published in 1903 Sclavo focused on the disease in humans and described 158 cases which he had encountered; in all of these the attending medical practitioners had used his serum. He detailed them in very similar fashion to the tables used by the early Bradford-based anthrax investigator and local medical practitioner John Henry Bell some twenty-five years earlier, by recording age, the location of any external pustule and, importantly, the occupation of the patient, as well as the outcome: either *guarito* (recovery) or *morto* (death). He recorded cases amongst *conciatores* (tanners), *contadinos* (peasants), *lavotantes in crini* (horsehair workers) and *pastores* (shepherds), amongst others, and used the relatively high proportion of recovery to advocate wider use of his own serum.³⁴ Sclavo was by this stage using bacteriological techniques as a matter of routine in order to confirm the diagnosis of suspected cases of anthrax, but it is telling that by no means all of those which he included were identified in this way. Indeed, out of the

²⁸ Joseph C. Regan, ‘The advantage of serum therapy as shown by a comparison of various methods of treatment of anthrax’, *American Journal of the Medical Sciences* (1921) 162(3), pp. 406–23, 411.

²⁹ J.S. Tew, ‘Notes on anthrax’, *Public Health*, October 1911, pp. 2–7, 6; ‘Therapeutics’, *British Medical Journal*, 29 June 1901, pp. 103–4, 103; F. Figari, ‘Experimentelluntersuchungen über die innerliche Darreichung eines Tubercularantitoxins’, *Berliner Klinische Wochenschrift*, 4 January 1904, pp. 56–7; ‘Verhandlungen ärztlicher Gesellschaften’, *Berliner Klinische Wochenschrift*, 2 May 1904, pp. 479–85; ‘Reports of societies’, *British Medical Journal*, 16 July 1904, p. 126.

³⁰ ‘Rome – the anti-anthrax serum – the policlinico’, *British Medical Journal*, 23 November 1895, p. 1323.

³¹ Worboys, op. cit. (8), p. 258.

³² ‘Contributions and additions to library’, *Journal of the Sanitary Institute* (1897) 17, pp. 103–7.

³³ ‘Serum treatment of anthrax’, *The Lancet*, 8 April 1899, p. 981.

³⁴ Sclavo, op. cit. (22), pp. 36–47.

158 cases, an equal number of patients were diagnosed using clinical methods alone as those confirmed by bacteriological tests: seventy-one in each instance. The remainder had blood taken and examined microscopically to ascertain the nature of their condition.³⁵ Sclavo thus employed a variety of diagnostic methods, almost certainly owing to a combination of the rapid progression of the disease and the desire to administer serum as soon as anthrax was suspected. These were allied to a broad range of serum therapy protocols, with dosage never standardized. As we shall see, this became routine practice in Britain: conventional wisdom dictated that even before confirmation that the practitioner was dealing with anthrax, they should administer a dose of serum as a precaution. Sclavo's initial recommendations for dosage appear to have been based on little more than extrapolation from his confirmatory studies in animals, in which he experimented with a variety of dosage sizes in sheep, ranging from ten to fifty cubic centimetres. Finding that the lowest dose was equally effective as higher ones in sheep which weighed no more than eighteen kilograms, Sclavo accordingly recommended proportionately larger doses in humans.³⁶

Despite the testimonies of the serum's efficacy, and the fact that Sclavo attempted to publicize his preparation, it was not until 1904 that British researchers took an especially active interest in his results.³⁷ It was in this year that Thomas Morison Legge visited the laboratory in Siena, and returned with a number of samples of the serum for trial in Britain.

Thomas Morison Legge as serum popularizer

Legge (1863–1932) completed his medical training at St Bartholomew's, London, in 1890 and, following work with the Royal Commission on Tuberculosis and the publication in 1896 of a comparative treatise addressing public-health regimes in various cities across continental Europe, was appointed the first full-time medical inspector of factories in 1898.³⁸ In this newly created post Legge had responsibilities not only for overseeing general working conditions, but also for leading efforts to reduce the incidence of specific industrial diseases.³⁹ Although his high-profile Milroy Lectures of 1905 have been credited by historians as being the point at which Legge started to advocate the use of Sclavo's serum, by then he had already presented a paper to the Epidemiological Society (on 15 April 1904) in which he reflected at length on the preparation and its use. During the course of this paper, Legge expressed his hope 'that the serum prepared by Professor Sclavo, and by which he [Sclavo] had treated 164 consecutive cases with a mortality of only 6.09 per cent., would be shortly used in this country'.⁴⁰

In the published version of the second of his Milroy Lectures, delivered at the Royal College of Physicians on 9 March 1905, Legge went into greater detail. He tabulated key information about sixty-seven cases of external anthrax – 'all the cases that I can find' – in which '[a]ll but two of those cases have been treated in Italy with Sclavo's serum'.⁴¹

³⁵ Sclavo, op. cit. (22), pp. 36–44.

³⁶ 'Therapeutics', *British Medical Journal*, 29 June 1901, p. 103.

³⁷ 'Therapeutics', op. cit. (36), p. 103.

³⁸ Peter W.J. Bartrip, 'Legge, Sir Thomas Morison (1863–1932)', in *Oxford Dictionary of National Biography* (2004), at www.oxforddnb.com/view/10.1093/ref:odnb/9780198614128.001.0001/odnb-9780198614128-e-49286 (accessed 18 September 2020).

³⁹ For biographical details of Legge see Tony Waldron, 'Thomas Morison Legge (1863–1932): the first medical factory inspector', *Journal of Medical Biography* (2004) 12(4), pp. 187–8.

⁴⁰ 'Reports of societies: Epidemiological Society', *British Medical Journal*, 7 May 1904, p. 1079. Mortality from external anthrax (so-called malignant pustule) was typically around 25 per cent, whilst internal anthrax (also known widely in Britain as woolsorters' disease) was fatal in nearly all cases.

⁴¹ T.M. Legge, 'The Milroy Lectures on industrial anthrax', *The Lancet*, 25 March 1905, pp. 765–76, 766.

Perhaps unsurprisingly, given that Legge was aggregating published cases treated by a range of practitioners, there was significant divergence of practice across these. Dosage of the serum ranged from a single injection of between twenty and fifty cubic centimetres on admission through to multiple applications of similar size across several days or in response to patients' deterioration. Almost all the cases involved lesions on the face or neck, and in all but eleven cases the application of serum was the only treatment used, with the others involving a combination of excision or cauterization of the pustule.⁴² Especially appealing to British readers was likely the fact that only a handful of the cases, according to Legge's report, involved any long-term scarring. He variously described the longer-term consequences of these – 'no trace of scar', 'completely cured', 'no deformity', 'scar hardly visible' and 'no visible scar' – whilst only three cases involved significant lasting physical consequences.⁴³

When Legge first presented on the serum in 1904, Sclavo had not been able to produce the serum on a sufficiently large scale to allow for export in significant quantities, and he had also encountered problems in maintaining the efficacy of the serum over time since it appeared to degrade rapidly.⁴⁴ British treatment of external anthrax thus largely remained limited to surgical excision of pustules and the application of carbolic acid; practitioners could not obtain sufficient quantities of Sclavo's serum and, even if they could, would face the prospect of it becoming rapidly ineffective if stored for a long period. Those who wanted to employ serum-based therapies had to either obtain the material directly from Sclavo's laboratory at the University of Siena, or else embark on a lengthy, unreliable and poorly understood series of inoculations in order to manufacture their own serum. An Italian colleague of Sclavo's – Professor Ivo Bandi, a lecturer on hygiene and bacteriology at the University of Bologna – did just the latter when on a research field trip in São Paolo between 1902 and 1904. Following Sclavo's method as closely as he was able, Bandi reported that he cured two cases of systemic (internal) anthrax following very large (150-cubic-centimetre) injections of his serum into the abdomen.⁴⁵ Bandi's conclusion, which he reported in the *Lancet* in 1904, was unequivocal:

The double action of the anti-anthrax serum, antibacterial and antitoxic, is plainly evident, its antibacterial power shown by the immediate arrest of the progressive invasion of the organism by the bacillus, and its antitoxic power by the sudden improvement in the general condition of the patients.⁴⁶

Despite this glowing testament the fact remained that there were considerable technical difficulties behind serum manufacture and distribution, and lack of clarity about the precise nature of the serum. Sclavo himself acknowledged these, though his approach was to retain close control over the production process, which remained both physically and intellectually close to him. In 1904 he established the Istituto Siero e Vaccino Produttore (Institute for Serum and Vaccine Manufacture) at his own country house on the outskirts of Siena. We can contrast this with Pasteurians, who expanded their network internationally whilst also retaining close control by establishing numerous satellite

⁴² Legge, *op. cit.* (41), pp. 768–71.

⁴³ Legge, *op. cit.* (41), pp. 768–71.

⁴⁴ When Legge attended the Bradford Medico-Chirurgical Society to present a further paper on Sclavo's serum on 21 June 1904, he noted that his attention had been first drawn to the treatment after a receiving a letter from a Mr A. Webb – a horsehair manufacturer from Worcester – and that he had received around sixty tubes of serum from Sclavo himself. 'Reports of Societies', *op. cit.* (29), p. 126.

⁴⁵ Ivo Bandi, 'Contribution to the sero-therapeutic treatment of anthrax: two cases of general anthrax infection in man cured with anti-anthrax serum', *The Lancet*, 6 August 1904, pp. 372–4.

⁴⁶ Bandi, *op. cit.* (45), p. 374.

institutions, each under the direction of a disciple. These quite different models, which nevertheless underpinned the creation of similarly imperial, biosocial enterprises, both relied on retaining ownership of production and successful demonstrations in the public arena.

By the time that Legge came to deliver his Milroy Lectures on industrial anthrax in the spring of 1905, distribution of the serum had increased to such an extent that it had been used (without concurrent excision of the pustule) in a number of cases of external anthrax in Britain, the first of which was reported in the *British Medical Journal* on 7 January. This particular case – not included in Legge’s compilation – was treated at St Bartholomew’s Hospital, London, by the surgeon Charles Barrett Lockwood and pathologist Frederick Andrewes, and the use of serum (which Legge had personally secured for the hospital) was in their view ‘completely successful, fully justifying the claim made for it by Professor Sclavo’.⁴⁷ A second case, seen at the same institution, was reported by Anthony Bowlby and Andrewes the following month, and was notable for the conjunction between the administration of serum and bacteriological culturing in order to determine whether the number of anthrax bacilli was diminishing as a result of the treatment.⁴⁸ Critically, even though this was only the second case to be treated with Sclavo’s serum in Britain, Bowlby and Andrewes were sufficiently confident in its efficacy that this was ‘the sole treatment adopted’, rendering the usual excision of the pustule unnecessary.⁴⁹

The strong endorsement of the serum through these early clinical applications was significant, the more so since it came from three eminent sources. Lockwood (1856–1914) had been instrumental in founding the Anatomical Society of Great Britain and Ireland in 1887, and was well established as a leading surgeon by the turn of the twentieth century, with particular specialism in the application of disinfection and aseptic techniques in surgery.⁵⁰ Andrewes (1859–1932), meanwhile, had succeeded Alfredo Kanthack as lecturer in pathology at St Bartholomew’s in 1897, and in 1906 delivered the prestigious Horace Dobell Lecture – two years after E.E. Klein – on the evolution of streptococci.⁵¹ Bowlby (1855–1929) was at the time surgeon to Edward VII in addition to his appointment at St Bartholomew’s, and collaborated closely with Andrewes throughout his career.⁵²

Early use of the serum was not limited to London, despite the fact that Legge’s presence there meant that acquiring doses of serum was easier for practitioners based in the capital. In December 1904, for example, J. Lionel Stretton, a local medical authority in Kidderminster, another town marked by a large number of anthrax cases, used the serum in conjunction with excision in the successful treatment of a case of external anthrax at Kidderminster Infirmary.⁵³ He remained to be convinced that the serum itself was responsible for the patient’s full recovery, but noted that it was ‘probable [that] future experience will prove this [use of Sclavo’s serum alone] to be justifiable’. Like the cases at

⁴⁷ C.B. Lockwood and F.W. Andrewes, ‘A case of cutaneous anthrax successfully treated by Sclavo’s serum’, *British Medical Journal*, 7 January 1905, p. 16.

⁴⁸ Anthony Bowlby and F.W. Andrewes, ‘A second case of cutaneous anthrax successfully treated by Sclavo’s serum without excision’, *British Medical Journal*, 11 February 1905, pp. 296–7.

⁴⁹ Bowlby and Andrewes, op. cit. (48), p. 296.

⁵⁰ C.B. Lockwood, ‘Report on aseptic and septic surgical cases, with special reference to the disinfection of skin, sponges, and towels’, *British Medical Journal*, 27 January 1894, pp. 175–8; ‘Charles Barrett Lockwood, F.R.C.S.’, *British Medical Journal*, 21 November 1914, pp. 903–4; ‘In memoriam: Charles Barrett Lockwood’, *Journal of Anatomy and Physiology* (1915) 49(2), pp. 240–2.

⁵¹ ‘Sir Frederick Andrewes, O.B.E., F.R.S.’, *Nature*, 12 March 1932, pp. 390–1; ‘Sir Frederick Andrewes, F.R.S., M.D., D.C.L., F.R.C.P.’, *British Medical Journal*, 5 March 1932, pp. 451–2; F.W. Andrewes, ‘The Horace Dobell Lecture on the evolution of the streptococci’, *The Lancet*, 24 November 1906, pp. 1415–20.

⁵² ‘Sir Anthony Alfred Bowlby, Bt., K.C.B., K.C.M.G., K.C.V.O.’, *British Medical Journal*, 20 April 1929, pp. 747–50.

⁵³ For more on the occurrence of anthrax in Kidderminster see Tim Carter, ‘Anthrax in Kidderminster, 1900–14’, PhD thesis, University of Birmingham, 2005.

St Bartholomew's, Stretton also noted that '[f]or the supply of serum I am indebted to Dr. T.M. Legge, His Majesty's Medical Inspector of Factories, who has spared no pains in bringing this method of treatment before us.'⁵⁴ As Legge himself remarked in the second of his Milroy Lectures,

Since July, 1904, serum treatment has been tried in England, either alone or in connexion with excision, in 12 cases of external anthrax ... In 4 of these serum alone was used ... No.3 was treated by Dr Mitchell of Bradford ... [and] Case 4 was treated at the Royal Infirmary, Bradford.⁵⁵

This lecture concentrated on the treatment of external anthrax, and almost the entire talk was given over to a discussion of serum therapies. Legge paid particular attention to the high regard in which Sclavo's serum was held in Italy. Indeed, he was very favourably impressed by the manner in which workers had welcomed the introduction of this treatment:

In Santa Croce, a small town of about 5,000 inhabitants with 36 tanneries employing 350 workers, and where Dr Cicognani has adopted the serum treatment exclusively since 1899, the workers now insist on having this treatment to the exclusion of every other, and, since operative treatment [excision] is uncalled for, present themselves when there appears the smallest pimple or boil suggesting anthrax.⁵⁶

In marked contrast to the incessant worry surrounding the disease in the British wool, hide and tanning trades, Legge noted that the head of a horsehair firm in Milan had 'no fear whatever of the disease amongst his workpeople, as he had seen so many successes in dealing with it by this method [treatment with Sclavo's serum]'.⁵⁷ Legge was thus a strong advocate for the use of serum in British cases of external anthrax. His enthusiasm for leaving excision by the wayside was, at least initially, not shared by individuals such as Stretton, who had reservations about attributing healing power directly to the action of serum. However, further endorsements by Lockwood, Andrewes and Bowlby contributed to increasing interest in the serum and its therapeutic potential.⁵⁸ Amongst others, Bradford-based practitioners displayed particularly great enthusiasm for the serum, and engaged in transnational dialogue with Sclavo to try and standardize the mode of delivery.

Sclavo's serum becomes embedded

From the mid-nineteenth century, Bradford – an industrializing northern English town which was the global centre of the worsted trade – became gradually and indelibly

⁵⁴ J. Lionel Stretton, 'A case of anthrax (malignant pustule) treated with Professor Sclavo's serum', *The Lancet*, 4 February 1905, pp. 292–3, 293. Stretton would go on to treat further cases in this manner during the course of 1905. See J. Lionel Stretton, 'A case of anthrax successfully treated with Sclavo's serum', *The Lancet*, 27 May 1905, pp. 1420–1.

⁵⁵ Thomas M. Legge, 'The Milroy Lectures on industrial anthrax', *British Medical Journal*, 18 March 1905, pp. 589–93.

⁵⁶ Legge, op. cit. (55) p. 591. Legge also referred to this case, and the prospects of serum use generally, in his official capacity as medical inspector of factories through his annual report.

⁵⁷ Legge, op. cit. (55), p. 591.

⁵⁸ The *British Medical Journal* was particularly enthusiastic about this form of treatment, noting that they 'had faith in the efficacy of the very valuable remedy which medical men now have in the serum introduced by Professor Sclavo of Siena for the treatment of anthrax'. 'Annual report of the chief inspector of factories and workshops for the year 1904', *British Medical Journal*, 22 July 1905, p. 207.

associated with anthrax. Workers and, latterly, medical practitioners began to associate fleeces arriving from across the world, channelled mainly through the port of Liverpool, with a mysterious and rapidly fatal condition: woolsorters' disease, later reframed as anthrax. When Sclavo's serum first came to prominence in Britain, Bradford's best-known anthrax investigator was the retired, but still active, John Henry Bell. Drawing on testimony from factory workers as well as bacteriological techniques, Bell had been instrumental in connecting the seemingly new and distinctively local condition of woolsorters' disease with the causative organism of anthrax, *Bacillus anthracis*, in 1880. Legge gave Bell a sample of the serum, as Bell noted in his records, most likely in June 1904, when he visited Bradford.⁵⁹ Legge recognized the potential significance of the serum to Bradford as a whole, and delivered a paper to the local Medico-Chirurgical Society on the subject on 21 June 1904, very shortly after his return from Italy and just two months after his presentation to the Epidemiological Society in London.⁶⁰ In his talk, entitled 'Sclavo's serum treatment of anthrax in man' (which also pre-dated his more widely publicized Milroy Lectures), Legge revealed that his association with Sclavo was not limited to his visit to Siena; he was still in active correspondence with his Italian colleague. Legge listed the perceived benefits, given to him by Sclavo, as follows:

(1) The serum was innocuous even in large doses; (2) it could be well borne even when introduced into the veins; (3) no case taken in an early stage and of moderate severity would be fatal if treated with the serum; (4) by its means some cases might be saved when the condition was most critical ... (5) when injected into the veins it quickly arrested the extension of the oedematous process so as to reduce notably the danger of suffocation ... (6) if used early enough it reduced to a minimum destruction of the tissues ... and (7) persons attacked appeared to become convalescent almost at once.⁶¹

In addition to exhorting the benefits of the serum, Legge informed those present that Sclavo recommended a dose 'in ordinary cases ... [of] 30 to 40 cubic centimetres subdivided into three or four injections subcutaneously into different parts of the abdomen', representing a quite different approach from the many modes of administration used up to that point.⁶² Over the following years, however, there was significant debate amongst British medical practitioners as to the correct dosage, particularly in more advanced or severe cases. As was also the case with regulations designed to safeguard workers' health developed during the 1880s and 1890s, methods implemented and endorsed in Bradford became the national standard.⁶³ Bell's status as both anthrax authority and serum advocate is best illustrated by his involvement with a case of the disease in early 1905, reported later that year in the *British Medical Journal*.⁶⁴

⁵⁹ 'Dr J.H. Bell – Notebook Concerning Anthrax Epidemic in Bradford', WYAS, DB15/C5, unpaginated, n.d.

⁶⁰ 'The Bradford Medico-Chirurgical Society – Records', 21 June 1904, WYAS, 40D89.

⁶¹ 'Bradford Medico-Chirurgical Society', *The Lancet*, 9 July 1904, pp. 89–90, 89.

⁶² 'Bradford Medico-Chirurgical Society', op. cit. (61), p. 90.

⁶³ Stark, *The Making of Modern Anthrax*, op. cit. (3), Chapter 4.

⁶⁴ It seems that Bell had been unaware of the possibility of serum treatment as late as 1902, when his article on the etiology, treatment and prevention of anthrax did not refer to the work of Sclavo or the use of serum. See John Henry Bell, 'Anthrax: its relation to the wool industry', in Thomas Oliver (ed.), *Dangerous Trades: The Historical, Social, and Legal Aspects of Industrial Occupations as Affecting Health, by a Number of Experts*, London, John Murray, 1902, pp. 634–43. Although Legge and other London-based practitioners were major supporter of widespread serum use in Britain, Bell (who was present at Legge's paper in 1904) was ultimately also an

On 31 January of that year, William Mitchell, an Edinburgh-educated practitioner from Bradford, was called to attend a twenty-five-year-old wool carder, who had been working some days previously with 'mohair [a fleece taken from the Angora goat, notorious for its association with woolsorters' disease] of a very short and dirty character'.⁶⁵ Upon observing the very large pustule around her left eye, Mitchell suspected anthrax at once, and sought the advice of Bell:

I at once suspected anthrax and asked Dr. J.H. Bell if he would see the case with me. This he did the same day, and kindly brought three tubes of Sclavo's serum. He agreed with me that the case was one of local anthrax and advised me to inject sub-cutaneously 20 c.cm of the antianthrax serum, which I did at once.⁶⁶

Mitchell injected the remaining ten cubic centimetres of serum (which was all he had) the following day owing to the worsening condition of his patient, but also applied various other methods of treatment with which he was more familiar, including the administration of mercury perchloride and regular doses of sodium salicylate. In the afternoon, however, Mitchell received a visit from Thomas Morison Legge, who brought with him 'a further supply of 70 c.cm of serum, of which I [Mitchell] injected 40 c.cm at once'.⁶⁷ By the time Mitchell halted this mode of treatment, a hundred cubic centimetres of Sclavo's serum had been injected into the tissues around the patient's left eye. The case resulted in recovery, but there was significant and permanent scarring from the disease.

Mitchell reported the details of this particular case at a meeting of the Bradford Medico-Chirurgical Society in 1905; both Bell and Frederick William Eurich – later bacteriologist to the Anthrax Investigation Board – were present, and this marked a significant step in familiarizing local practitioners with the use of Sclavo's serum in individual cases. Mitchell was cautious about the efficacy of the serum as an active agent of treatment, however, and was of the opinion that 'it does not seem justifiable to treat a case of cutaneous anthrax with serum alone and without excision'.⁶⁸ There were good reasons for Mitchell to adopt this view. Surgical treatment for cutaneous anthrax had proven to be a relatively reliable method up to this point, and the general agreement amongst members of the Bradford medical network that serum therapy should be used on its own only when excision was practically impossible owing to the location of the pustule is not greatly surprising.

The creation of the Anthrax Investigation Board for Bradford and District – a collaborative enterprise between medical practitioners and employers – later in 1905 changed the dynamic of anthrax management in the town. Thereafter almost all of the cases in the area were under the observation of Eurich, who was able to determine under more accurate test conditions the efficacy of Sclavo's serum. Prior to this, it was difficult to assess whether the serum itself played an active role in assisting recovery, or whether improvement in patients' conditions was simply due to spontaneous recovery (which was already a well-documented phenomenon, particularly in the case of external anthrax). Following the death of Bell in 1906, Eurich became the strongest advocate for the use of serum therapy in the locality. Within a few short years, the use of serum without surgery in these

important figure in establishing the preference amongst local physicians for the use of the serum in cases of external anthrax.

⁶⁵ William Mitchell, 'Case of cutaneous anthrax treated without excision with Sclavo's anti-anthrax serum: recovery', *British Medical Journal*, 15 July 1905, pp. 118–20, 119.

⁶⁶ Mitchell, *op. cit.* (65), p. 119.

⁶⁷ Mitchell, *op. cit.* (65), p. 119.

⁶⁸ Mitchell, *op. cit.* (65), p. 120.

cases when they occurred in the Bradford area had become more commonplace and practitioners reported cases of recovery without incident.⁶⁹ The problem of dosage, however, remained. Although large quantities of serum were typically used, it was an expensive treatment which could only be acquired directly through Sclavo, and the administration of such volumes of fluid was painful for patients, particularly when serum was administered locally in cases where pustules appeared on the face and neck.⁷⁰ In addition, the serum was by no means a magic bullet, and a number of fatalities continued to occur, even when very large doses of serum were used. Fatal cases often involved attempts to excise the pustule and the injection of carbolic as a further antiseptic agent when the serum appeared to have been ineffective.⁷¹

Eurich entered into correspondence with Sclavo in 1909, largely in response to claims from fellow practitioners that the serum being supplied was so old that it had lost its potency. Sclavo himself claimed that the shelf life of his serum was two years, but experiences of this differed widely.⁷² Ultimately, the Anthrax Investigation Board 'made an agreement with Messrs F.M. Rimmington and Sons Limited [a local pharmaceutical firm, and stockists of Sclavo's serum] whereby no old stock of Dr Sclavo's serum should be used'. In addition, Sclavo recommended to Eurich that the initial dosage should be 'from 40 to 80 cc', twice as large as the quantities which Sclavo had suggested to Legge in 1904, with additional daily applications of between twenty and forty cubic centimetres as required.⁷³ This provided a possible explanation for the occurrence of fatalities despite the use of the serum; on several occasions previously a much smaller dose had been used with negative results.⁷⁴ Eurich also noted that the quicker a diagnosis of anthrax was achieved and serum therapy begun, the greater the chances of recovery.⁷⁵ As one of the stated aims of the board was to allow for quicker diagnosis, this became a still more pressing matter, as the efficacy of treatment depended yet more on speedy identification of the disease (even if the diagnosis remained unconfirmed, cases of suspected anthrax could be readily treated). This was recognized in a brief article in *The Lancet* from 1913, which remarked, 'In recent years the earlier recognition of the pustules and prompt treatment in hospital by excision and administration of Sclavo's serum have materially diminished the number of fatal cases.'⁷⁶ On 23 May that same year, Eurich noted in a major lecture to the Section of Epidemiology and State Medicine of the Royal Society of Medicine that he 'had at home some samples of Sobernheim's serum, but he had had good results with Sclavo's serum, so good that he hesitated to try a fresh kind'.⁷⁷

⁶⁹ Randal Herley, 'Eight cases of external anthrax', *The Lancet*, 4 December 1909, pp. 1662–5. Herley, a surgeon at Dewsbury General Infirmary, had been a pioneer of the use of Sclavo's serum in West Yorkshire, having overseen an early successful case in 1905. Herley, 'On a case of malignant pustule treated by excision and Sclavo's serum: recovery', *The Lancet*, 4 November 1905, p. 1329.

⁷⁰ Jones, op. cit. (16), p. 117, suggests that the cost of treatment using Sclavo's serum was prohibitive to a large extent in the United States.

⁷¹ Herley, op. cit. (69), p. 1664, for example, noted that a patient under his care died from 'malignant pustule' despite the injection of large doses of Sclavo's serum and a last-minute attempt to excise the pustule.

⁷² Bradford and District Anthrax Investigation Board, 'Fifth Annual Report: Bradford and District Anthrax Investigation Board', 1910, available at Bradford Central Library.

⁷³ Bradford and District Anthrax Investigation Board, op. cit. (72). Doses for other forms of serum therapy were far smaller. In the case of antituberculosis sera, for example, the daily application of five cubic centimetres was typical. 'Marmorek's antituberculosis serum', *British Medical Journal*, 9 April 1904, pp. 857–8.

⁷⁴ 'The increase in anthrax', *The Lancet*, 7 September 1907, pp. 715–16; Thomas M. Legge, 'The increase in anthrax', *The Lancet*, 12 October 1907, p. 1048.

⁷⁵ 'Anthrax at Bradford', *The Lancet*, 14 November 1908, pp. 1453–4.

⁷⁶ 'Industrial anthrax in Liverpool', *The Lancet*, 11 October 1913, p. 1076.

⁷⁷ Frederick W. Eurich, 'Anthrax in the woollen industry, with special reference to Bradford', *Proceedings of the Royal Society of Medicine* (1913) 6, pp. 219–40, 239. The German bacteriologist Georg Sobernheim, who had studied

As well as local practices in districts which saw significant incidence of anthrax, Sclavo's serum was also incorporated as a standard therapy in medical textbooks throughout Europe. Whilst the noted Glasgow-based pathologist and physician Robert Muir questioned the efficacy of the Pasteurian vaccine in animals and its widespread use, he used a lengthy section on anthrax in his 1907 *Manual of Bacteriology* to praise the positive results reported by both Sclavo and American serum pioneer Sobernheim.⁷⁸ In his large 1910 treatise, *Physiological Principles in Treatment*, Walter Langdon-Brown noted that whilst excision of the external pustule was 'the method of treatment which most often averts a fatal issue', it was often an impossible approach owing to the frequent location of the pustule on the neck or face and the necessity of removing a relatively large amount of surrounding tissue.⁷⁹ Despite recognizing significant and common side effects of serum therapy – including a high fever, rigour, headache, malaise and nausea, many of which were not referenced in published case histories – Langdon-Brown also highlighted its therapeutic superiority, with excision only recommended 'in the more severe lesions', and even then in conjunction with Sclavo's preparation.⁸⁰

The localization of anthrax in a few specific places – principally the port cities of Liverpool, Glasgow and London, and the specific manufacturing centres of Bradford and Kidderminster – gave rise necessarily to geographical restrictions on the storage and availability of Sclavo's serum. This was especially pertinent since 'early recognition and ... active treatment are of importance if life is to be saved', as remarked an anonymous contributor to *The Hospital* in the summer of 1910.⁸¹ Reporting on a case which occurred in Liverpool in 1910, the writer noted that 'Sclavo's anti-anthrax serum ... has come into vogue, and although it may be safest to excise the pustule as well as to use the serum, there have been not a few patients in whom successful treatment has resulted from the use of the serum alone.'⁸² The upscaling and transformation of local procedures to a national level were further enabled by the former Bradford medical officer of health, Sir Arthur Whitelegge, who from 1896 held the critical post of chief inspector of factories at the Home Office. In his earlier public-health career, Whitelegge, who qualified after study at University College London and Cambridge, had become intimately acquainted with anthrax in its earlier form as woollsorters' disease in Bradford.⁸³ In collaboration with the bacteriologist and former high-profile public-health official Sir George Newman, in 1890 Whitelegge published *Hygiene and Public Health*, the standard text in public health and disease management in the decades around 1900. By the time of the tenth

under Koch, developed a serum similar to Sclavo's, though derived ultimately from sheep, while working at a branch of the Merck research unit at the Halle Institute for Hygiene. Though it lagged behind other German firms and, especially, the research and development capacity of Burroughs Wellcome, Merck had engaged in bacteriological research since at least as early as 1895, including work on antitoxins and antisera. Sobernheim, meanwhile, was already well acquainted with anthrax when he moved to Merck in 1901, and ultimately achieved an international market for his serum. The positive reports of the earlier Sclavo serum, coupled with backing from key figures in British surgery and bacteriology, likely account for the relatively low uptake of Sobernheim's alternative. Carsten Burhop, 'Pharmaceutical research in Wilhelmine Germany: the case of E. Merck', *Business History Review* (2009) 83(3), pp. 475–503, esp. 498; 'Contract between Georg Sobernheim and Merck', 10 December 1901, Merck-Archiv, R 1/42, MERCK KGAA, Frankfurt; 'Annual Report of the Bacteriology Research Department, 1903/4', Merck-Archiv, F 3/32.

⁷⁸ Sobernheim found a more significant market in the United States, reflecting the inability of the serum to travel long distances owing to its rapid degradation. US Department of Agriculture, *Experiment Station Record*, vol. 15: 1903–1904, Washington, DC: Government Printing Office, 1904, p. 920.

⁷⁹ Walter Langdon-Brown, *Physiological Principles in Treatment*, London: Baillière, Tindall and Cox, 1910, p. 112.

⁸⁰ Langdon-Brown, *op. cit.* (79), p. 113.

⁸¹ 'Medicine: Sclavo's serum in the cure of anthrax without operation', *The Hospital*, 2 July 1910, p. 409.

⁸² 'Medicine: Sclavo's serum', *op. cit.* (81), p. 409.

⁸³ 'Obituary: Sir Arthur Whitelegge, K.C.B., M.D., F.R.C.P.', *British Medical Journal*, 6 May 1933, p. 806.

edition, issued in 1905, Whitelegge and Newman noted that ‘Sclavo of Siena has prepared an anti-anthrax serum from which excellent results have been obtained, reducing case mortality from 24 to 6 per cent’, reinforcing the same message in the twelfth edition, published in 1911.⁸⁴

Local press in Bradford and its environs also reflected a medical community increasingly confident in the efficacy of Sclavo’s preparation. Basil Hughes, a resident surgeon at Bradford Royal Infirmary, confirmed to the local *Shipley Times and Express* in 1913 that ‘sclavo [sic] serum [is] injected [directly by syringe] into the veins in large doses, and it neutralises the poison that the anthrax germs are making in the blood’. As a consequence, according to Hughes, anthrax was ‘not the fatal disease it was once thought to be’, and it was ‘rare that death does follow’ after that course of treatment.⁸⁵ Hughes argued that the serum’s efficacy was due to the fact that it targeted the toxin – ‘poison’ – circulating in the patient, though he did not provide any evidence to support this claim. This affirmed the uncertainty about the nature of the serum’s action as either antitoxic or antimicrobial.⁸⁶ The confusion about the possible modes of action was a hallmark of the debate in both the medical and the lay press, though there is no evidence that this represented a source of anxiety for practitioners or patients, nor did it seem to inspire hesitation in using the treatment.

By 1915, the practice of using the serum had become sufficiently embedded as the primary treatment for cases of cutaneous anthrax within spheres of British influence for the president of the Assam branch of the British Medical Association, T.C. McCombie Young, to remark in his article on the subject of anthrax in the *Indian Medical Gazette* simply that ‘Sclavo’s serum with or without excision is strongly recommended at home’.⁸⁷ By then, Sclavo himself had further revised the recommended dosage size over subsequent years, and by 1912 he argued that ‘smaller doses than 60 to 80 c.cm are useless’.⁸⁸ These practices became deeply embedded, and the Anthrax Investigation Board reaffirmed in 1916 ‘the use of his serum in doses of from 60 to 80 c.c. injected intravenously – smaller doses being practically useless in serious cases’.⁸⁹ The board also took a far firmer grip over the supply of serum, ensuring that ‘an adequate supply of Anti-Anthrax serum with a notice as to the latest date on which the Board recommend that it can be used with full confidence as to its undiminished strength, is always to be obtained from Messrs. F.M. Rimmington’.⁹⁰ The ready supply of fresh serum was therefore a key consideration, especially as it was imported from Italy, and the board was able to secure this through negotiation with a local pharmaceutical firm.

The *Yorkshire Observer* and the *Bradford Daily Telegraph*, both of which had been campaigning on the subject of anthrax prevention and treatment since the 1850s, advocated the widespread adoption of Sclavo’s therapy from 1905 onwards. These papers were clear that this method of treatment offered the best prospects for recovery, and encouraged greater access for patients with suspected anthrax.⁹¹ Despite these calls, there was little

⁸⁴ Arthur Whitelegge and George Newman, *Hygiene and Public Health*, 10th edn, London: Cassell, 1905, p. 421; Arthur Whitelegge and George Newman, *Hygiene and Public Health*, 12th edn, London: Cassell, 1911, p. 474.

⁸⁵ ‘Deaths from anthrax’, *Shipley Times and Express*, 25 April 1913, p. 10.

⁸⁶ ‘Deaths from anthrax’, op. cit. (85).

⁸⁷ C.T. McCombie, ‘An outbreak of anthrax’, *Indian Medical Gazette*, August 1915, pp. 288–91, 290.

⁸⁸ ‘England and Wales: West Yorkshire: the Anthrax Investigation Board’, *British Medical Journal*, 20 April 1912, p. 920.

⁸⁹ Bradford and District Anthrax Investigation Board, ‘Eleventh Annual Report – Bradford and District Anthrax Investigation Board’, 1916, p. 4.

⁹⁰ Bradford and District Anthrax Investigation Board, op. cit. (89), p. 4.

⁹¹ ‘The suspected case of anthrax in Bradford: serum injection at the infirmary’, *Yorkshire Daily Observer*, 19 April 1905; ‘Saltaire anthrax case’, *Bradford Daily Telegraph*, 28 April 1905, p. 3; ‘Success of anthrax serum’, *London Daily News*, 28 April 1905, p. 7; ‘An injection of serum in Dewsbury’, *Yorkshire Daily Observer*, 2 October 1905.

discussion in Bradford of the financial difficulties attending the use of serum, which have been posited by Susan D. Jones as an explanation for why the United States did not see such a ready uptake of the treatment (patients and practitioners also had access to an alternative in the form of the Philadelphia-produced but less specific Mulford's serum, originally developed to treat diphtheria).⁹² However, Kidderminster experienced some controversy when the medical officer of health tried to persuade the town council to provide the serum free of charge to those who might need such treatment. This was considered acceptable, but the workhouse infirmary was 'excluded from such benefit on the grounds that payment for the serum would be payment for medicine, which is illegal and ... [could] only be permitted after special sanction by the Local Government Board'.⁹³ Unproblematic and universal access to Sclavo's serum was therefore not achieved in the early years of its introduction.

By the end of the 1920s, the license to import Sclavo's serum had been taken over by the Jenner Institute for Calf Lymph, which also had a large share of the British vaccine production market, most notably in relation to smallpox.⁹⁴ Individual pharmacists, as well as medical practitioners and hospitals, were therefore able to access fresh serum through the Jenner Institute's extensive national network of sub-depots, which included locations in Liverpool, Glasgow and Leeds; the Jenner Institute was also responsible for testing the incoming serum, though this capacity came only after the therapy had been in routine use for over fifteen years. In addition, Evans, Sons, Lescher and Webb Ltd, based in London, were also able to 'supply a similar Serum' which was produced in Britain.⁹⁵ By this time, however, the popularity of Sclavo's serum, established through over two decades of use, and aided by the forceful advocacy of Legge, Eurich and others, had become firmly established, and practitioners in anthrax-affected areas were reluctant to abandon such a trusted therapy.⁹⁶

A case from 1927 serves to reinforce the dominance of this mode of treatment. After the death of two elephants at the London Zoological Gardens, four men associated with their care began to develop anthrax-like symptoms over the following week. In a collated case report, R.H. Boggon – surgical registrar at St Thomas's Hospital – noted that surgery was not even considered 'since all these cases reacted so well to serum'.⁹⁷ The serum, sourced by Boggon from the Jenner Institute, was still produced at Sclavo's premises near Siena, and was effective in the treatment of all four cases.

⁹² Mulford's serum was also employed in cases of cerebro-spinal fever and dysentery, amongst other conditions. F.W. Andrewes, 'Notes on the bacteriological examination of eleven cases of cerebrospinal fever treated in St. Bartholomew's Hospital during the first three months of the year 1916', *Proceedings of the Royal Society of Medicine* (1916) 9, pp. 1–8; G.A. Finlayson, 'On the treatment of dysentery', *British Medical Journal*, 13 January 1917, pp. 46–8, 46. For more on the origins of the serum see Louis Galambos and Jane Eliot Sewell, *Networks of Innovation: Vaccine Development at Merck, Sharp and Dohme, and Mulford, 1895–1995*, Cambridge: Cambridge University Press, 1995, p. 20. Mulford's serum was originally developed and marketed as a diphtheria antitoxin. See H.K. Mulford Co., *The Antitoxin Treatment of Diphtheria, with Bibliography, Official Reports and Clinical Notes*, Philadelphia and Chicago: H.K. Mulford Company, 1898.

⁹³ 'Kidderminster and anti-anthrax serum', *The Lancet*, 20 January 1906, p. 189.

⁹⁴ 'Anthrax poster', op. cit. (9).

⁹⁵ 'Anthrax poster', op. cit. (9).

⁹⁶ In addition to the role of these key figures, regular if infrequent cases of external anthrax, treated successfully with Sclavo's serum, were reported in the British medical press. See, for examples, W. Manson Fergusson, 'A case of anthrax treated by Sclavo's serum', *British Medical Journal*, 15 July 1911, pp. 103–4; 'Sclavo's serum in the cure of anthrax without operation', *The Hospital*, 2 July 1920, p. 409.

⁹⁷ R.H. Boggon, 'Four cases of anthrax treated with Sclavo's serum', *The Lancet*, 26 February 1927, pp. 435–6, 436. In all cases a positive anthrax diagnosis was made by analysing samples taken from an external pustule prior to the commencement of any serum treatment.

On the wane: Salvarsan, sulphonamides and antibiotics

Despite the widespread uptake of Sclavo's serum, the concurrent practice of excision and the use of antiseptic chemicals such as carbolic acid continued for some years, and other treatments gained popularity alongside the Italian preparation. Eurich himself, for example, used the then much-hailed Salvarsan from the early 1910s as well as Sclavo's serum in the treatment of cutaneous anthrax, and was careful to note the difficulty in ascribing success to either of these treatments.⁹⁸ It was not until 1933 that Eurich could note with some satisfaction that excision had ceased to be standard practice at Bradford Royal Infirmary.⁹⁹ This did not mean that the pathways to treatment with Sclavo's serum ran smooth. In postmortem notes for a fatal case of external anthrax which occurred in a female 'worker in a wool-combing factory in Bradford' in January 1930, Eurich remarked that the thirty-year-old patient 'was seen by four [medical practitioners], none of whom suspected the nature of the lesion'. A firm diagnosis came four days after the earliest signs of the disease appeared in the form of a pimple on the end of the chin, and although 'Sclavo's serum was administered' immediately after admission to hospital, the patient died eight hours afterwards on 25 January. A specimen from the patient, preserved in the pathology specimen collections at the University of Leeds, reveals large anthrax lesions in the jejunum and ileum.¹⁰⁰ A rapid diagnosis remained an essential first step to successful serum treatment.

Although treatment with serum alone was usual in Italy from the turn of the twentieth century (and insisted upon by patients), British practitioners therefore continued to employ a variety of approaches, fearing that serum-only treatment was not effectual. Indeed, such an approach was necessary during the First World War when supplies of the serum were cut off. In its place, Mulford's more general serum, developed by the H.K. Mulford Company of Philadelphia, was used, with apparently only marginally less satisfactory results than its Italian counterpart.¹⁰¹ Tellingly, the restoration of supply chains after 1918 saw the rapid reintroduction of Sclavo's serum.

In an age of additional treatments, Sclavo's serum was therefore not supplanted by, but supplemented with, other substances, with seemingly improved outcomes. In 1943, in a series of ninety-three cases, A.E. Hodgson, physician at the City Hospital in Fazakerley, Liverpool, found that out of the fifty-two patients who were treated only with serum there were six fatalities, whilst all of the forty-one who received a combination of serum therapy and 'full doses of neoarsphenamine ("Neo-kharsivan")' survived.¹⁰² Neoarsphenamine was a popular treatment for a number of conditions, especially syphilis, having been introduced in 1912 as a less toxic version of Salvarsan. Both originated in the laboratory of Paul Ehrlich, and the use of combined treatment with Sclavo's serum in cases of anthrax in the early 1940s demonstrates that new therapeutic value was hailed for these substances even as penicillin supposedly revolutionized the treatment of infectious diseases. Instead, the serum continued to be a mainstay of combined anthrax therapies with existing and new preparations until the 1940s when widespread use of

⁹⁸ J.C. Cruickshank, 'Chemotherapy of experimental anthrax infection', *The Lancet*, 23 September 1939, pp. 681–4. For more details of the manner in which Salvarsan was taken up in Britain during this period see J.E. Ross and S.M. Tomkins, 'The British reception of salvarsan', *Journal of the History of Medicine and Allied Sciences* (1997) 52(4), pp. 398–423.

⁹⁹ Eurich, op. cit. (1).

¹⁰⁰ 'Jejunum & ileum, with anthrax lesions', 27 January 1930, Pathology Specimen Collection, University of Leeds, MedChi 1931.

¹⁰¹ Galambos and Sewell, op. cit. (92), pp. 18–20.

¹⁰² A.E. Hodgson, 'Cutaneous anthrax' (letter), *The Lancet*, 29 July 1944, p. 161.

antibiotics and sulphonamides appeared to render it superfluous.¹⁰³ As the officer in charge of the surgical division in the Indian Military Hospital in Ferozepore, S. Ahmed, remarked in 1945, ‘there would appear to be no indication now to employ the Sclavo serum, a treatment I found expensive, troublesome to the patient, and not so satisfactory [as penicillin and sulphapyridine] as regards immediate response as well as the cosmetic result’.¹⁰⁴ In 1951 an editorial in *The Lancet* went further, remarking with confidence that ‘Sclavo’s antiserum appears more often in textbooks than in wards ... with at least four antibiotics effective against cutaneous anthrax, Sclavo’s white asses can graze in peace.’¹⁰⁵

Conclusion

Sclavo’s serum was a hybrid product of the bacteriological traditions of Pasteur and Koch. It was deployed in Britain where anthrax was primarily a problem of humans, not live-stock, and where the threshold for success was of a different kind from Pasteurian anthrax vaccines. In Britain, faith in the efficacy of Sclavo’s serum was constructed largely on the basis of anecdotal evidence and case histories, and within a tightly knit network of medical scientists and clinicians. It was never systematically tested in humans – perhaps unsurprising given the small number of cases in which it was used – and there remained long-standing and unresolved uncertainty about how the serum actually worked. British medical scientists did not voice public concerns about standardization, despite the informal nature of international networks of serum supply, nor did prolonged confusion about effective dosage stymie medical confidence. Neither, too, was there any suggestion that a reputable institute – either in Britain or overseas – was involved in ensuring standardization of the serum. Nevertheless, the serum was recommended wholeheartedly by almost all major medical figures connected with anthrax research in Britain. This came even amidst a growing landscape of serum options, with at least three alternative sera available for use in animals by 1911, and a British-developed alternative produced by the medical manufacturing firm Evans, Sons, Lescher and Webb on the market from at least 1927, albeit only available in Liverpool and London.¹⁰⁶

Debates about the possible modes of action of Sclavo’s serum were largely confined to a limited subset of clinically disinclined bacteriologists. It is especially revealing that the precise nature of the serum – antitoxic or antimicrobial – had seemingly no bearing on its clinical uptake. Sclavo himself was apparently similarly uncertain on this point. At the time when Sclavo first formulated his serum the vast majority of bacteriologists were of the view that all pathogenic bacilli generated and emitted toxins and that this was the root cause of disease. The failure of many antitoxins to live up to their early promise as universal treatments ultimately compelled researchers like Ehrlich to reconsider this view and turn to other approaches, such as chemotherapy.

At the same time, the production of Sclavo’s serum also offers a counterpoint to the most prominent race in early serum production, between the groups led by Emil Behring in Berlin and Marburg and Emile Roux in Paris. As Volker Hess has argued, both groups developed a standardized serum, though in Germany it was framed within the context of the private sector – a ‘prototype of industrial medications’ – whilst in

¹⁰³ Practitioners in the early 1930s were not confident in abandoning the serum, and it was often used in conjunction with other emerging therapeutic agents, such as novarsenobenzol. ‘Treatment of anthrax by N.A.B.’, *British Medical Journal*, 14 November 1931, p. 921.

¹⁰⁴ S. Ahmad, ‘Treatment of human anthrax with penicillin’, *Indian Medical Gazette* (1945) 80(12), p. 623.

¹⁰⁵ ‘Cutaneous anthrax’, *The Lancet*, 5 May 1951, p. 1004.

¹⁰⁶ These were manufactured throughout Europe by the Serum Institute in Milan, the Therapeutic Institute in Dresden and Detre-Deutsch in Budapest. Martin Klimmer and Alfred Wolff-Eisner, *Handbuch der Serumtherapie und Serundiagnostik in der Veterinär-mezizin unter Mitwirkung*, Leipzig: W. Klinkhardt, 1911; ‘Anthrax poster’, op. cit. (9).

France the serum was distributed freely within a national healthcare context.¹⁰⁷ Sclavo's serum arguably sat between these two regulatory positions, with the serum widely available in Britain but deployed selectively to districts where anthrax was most frequently observed.

In those areas where the serum was widely employed the desire for uptake and integration with surgical methods was rapid. Subsequent discussions focused on aligning other factors required to make serum use effective: rapid diagnosis, access to fresh serum, and determination of a safe, effective dose. The allure of an effective treatment for a disease as rapidly and surely fatal as anthrax doubtless functioned to focus the attention of British bacteriologists. After all, if anthrax succumbed to the advances of serum science, what might follow? This reveals the serum as an important and illustrative practical manifestation of bacteriological optimism, which characterized the search for effective therapeutics around the turn of the twentieth century. Much recent scholarship has sought to further erode any lingering impression of 'bacteriological revolution' around this time.¹⁰⁸ The case of Sclavo's serum adds another layer to this narrative, highlighting the importance of bacteriological promise – even in the face of limited or inconsistent evidence – for medical science, whilst also recognizing bacteriology as the successor to physiology as the principal locus of expectation within British biomedical science.¹⁰⁹ The continued presence of Sclavo's serum across a significant time period also encourages historians to look further beyond the dominant Franco-German axis of bacteriological thought to focus on important local adaptations, applications and modifications of these models elsewhere.

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¹⁰⁷ Volker Hess, 'The administrative stabilization of vaccines: regulating the diphtheria antitoxin in France and Germany, 1894–1900', *Science in Context* (2008) 21(2), pp. 201–27.

¹⁰⁸ A thorough articulation of this can be found in Michael Worboys, 'Was there a Bacteriological Revolution in late nineteenth-century medicine?' *Studies in History & Philosophy of Biological and Biomedical Sciences* (2007) 38(1), pp. 20–42.

¹⁰⁹ As Jennifer Wallis has noted for the earlier period, even the constraints of 'religio-philosophical concerns and the anti-vivisection movement' did not dampen physiologists' 'optimism about new modes and methods of scientific enquiry'. Jennifer Wallis, *Investigating the Body in the Victorian Asylum: Doctors, Patients, and Practices*, Basingstoke: Palgrave Macmillan, 2017, p. 62.

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