Major Greenwood’s early career and the first departments of medical statistics

Vern Farewell\textsuperscript{a}\textsuperscript{*} and Tony Johnson\textsuperscript{b}

Major Greenwood was the foremost medical statistician of the first half of the 20th century in the UK and is often credited with founding the first department of medical statistics at the Lister Institute in London in 1910. Here, we examine in detail his career prior to this appointment, including his association with Karl Pearson. We also examine the remit of the Department of Medical Statistics at the London Hospital of which he was the founding Director in 1908, some 2 years earlier than his appointment at the Lister Institute. Supporting information consisting of further details about Major Greenwood’s early career, biographical articles and obituaries for him, and a list of his publications to 1910 by year, is also provided. © 2014 The Authors. Statistics in Medicine published by John Wiley & Sons, Ltd.

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1. Introduction

In 1910, Major Greenwood was appointed medical statistician and head of the Statistical Department in the Lister Institute, London, a post that is generally described as the first such appointment; see, for example, [1, 2]. Seventeen years later, he became the first professor of Epidemiology and Vital Statistics in the London School of Hygiene and Tropical Medicine, and by the time of his death in 1949, he was widely recognized as the leading medical statistician of the first half of the 20th century in the UK. Although biographical articles have been written about his work and several obituaries were published soon after his death (Supporting information, Appendix 2), all of which mention the Lister Institute, none of them comment but briefly upon his work as a medical statistician prior to 1910. Here, we examine Greenwood’s early career that provided the basis for his prestigious appointment at the Lister Institute. Figure 1 is a portrait of Major Greenwood taken during the period 1900–1910.

2. Greenwood at the London Hospital

2.1. Early training

Greenwood was enrolled as a permanent medical student at the London Hospital Medical College in 1898. His career record while there is reproduced in Figure 2; it covers the period until he left in 1910. Although not evident in this document, Hogben [2] reports that a diagnosis of possible epilepsy ‘proved to be an auspicious excuse’ to work in Leonard Hill’s laboratory for 1 year during his medical training. He graduated in 1904 after which he went into family practice, albeit part-time, with his father, also called Major Greenwood, and possibly at his father’s request to satisfy family expectations. Figure 3 provides a family group photograph from 1897, the year before Greenwood enrolled as a medical student. Greenwood’s grandfather, another Major, had joined the practice (at 1 Queen’s Road, Dalston, London)
in 1855, and it had been located at several addresses on the Queen’s Road in north-east central London ever since. However, general practice was not to Greenwood’s liking, and he soon abandoned it by joining Leonard Hill’s Department of Physiology at the London Hospital as a British Medical Association (BMA) Scholar in October 1905. His official appointment was as a demonstrator in the Physiological Department.
This may have been the ‘chance in science’ which Hill, whose family lived close to the Greenwoods in East London, is reported to have said he must offer Greenwood because ‘the boy has brains, he’ll never be any use as a doctor’ [3].

The scholarship was initially for 1 year and worth a total of £150; it was extended later to a second year. These research scholarships, usually held for 1 year but extendable to 3 years at most, were for the encouragement of research in anatomy, physiology, pathology, bacteriology, state medicine, clinical medicine, and clinical surgery; scholars were appointed by the Council of the BMA on a recommendation from its Science Committee, and the applicant needed a recommendation from the head of the laboratory in which the work was to be carried out ‘setting out the fitness of the candidate to conduct such work and the probable value of the work to be undertaken’. In June 1906, the report to the BMA stated

Mr Greenwood is engaged with Mr L Hill FRS in a research on the influence of compressed air on the animal organism. Mr Hill informs me that his work is in every way satisfactory.

However, Greenwood’s first research paper was not in this area but arose instead from his earlier contact with Karl Pearson.

2.2. First paper

Greenwood’s first paper was published in *Biometrika* in 1904 with Greenwood as sole author and no affiliation (Table I) [4]. Given the publication date, it seems sensible to conjecture that the work for this paper was initiated prior to Greenwood’s qualification in medicine, likely during Greenwood’s year working with Leonard Hill [2], and finished then or in the subsequent period when he was in general practice. Certainly, Greenwood had proposed the study to Pearson in 1902 [5] and would study under him in the academic year 1904–1905, while in general practice part-time [2], presumably by attending his course on statistics at University College, London. The paper presented an analysis of data on the weight of human viscera, derived from the post-mortem records of the London Hospital and reported on variability and correlation, topics that would have been prominent in Pearson’s course. Indeed, Pearson’s early influence on Greenwood is clearly shown in the closing acknowledgement

I desire to take this opportunity of expressing my gratitude to Prof Karl Pearson, to whose staff, among other acts of kindness, I owe the correction of many arithmetical slips in the above results. Anything of interest in this essay is due, either directly or indirectly, to him.
Table I. Greenwood’s early career as gleaned from his publications from 1904 to 1910.

| Year | Designation and location |
|------|--------------------------|
| 1904 | No location stated though uses pathological data from the London Hospital and acknowledges with gratitude help of Karl Pearson and his staff |
| 1905 | No publications |
| 1906 | BMA Research Scholar; Physiological Department, London Hospital Medical College |
| 1907 | BMA Research Scholar; Loughton; Demonstrator of Physiology, London Hospital Medical College; Examiner in Physiology, St Andrews University |
| 1908 | Senior Demonstrator of Physiology in the London Hospital Medical College; Director of the London Hospital Statistical Department |
| 1909 | London Hospital Statistical Laboratory |
| 1910 | Statistical Laboratories of the London Hospital and the Lister Institute of Preventive Medicine |

More details of this paper, and of a selection of other papers mentioned subsequently, can be found in the Supporting information. As noted there, there is no information on how Greenwood performed the calculations for this paper, calculations which would have taken a considerable time with or without a mechanical calculator.

2.3. BMA research scholar

Greenwood had no publications in 1905, the year he was appointed to Leonard Hill’s physiology department at the London Hospital Medical College. During the next 2 years, his research focussed mainly on the effects of increased barometric pressure on man but was supported by experiments on animals. For example, Greenwood gave two oral presentations on the effects of rapid decompression on larvae, one at the Physiological Society (20 October 1906) and one at the Entomological Society (21 November 1906) [6]. The experiments showed that larvae suffered no ill effects from exposure to greater than 10 atmospheres for an extended period followed by rapid decompression unless they fed or were exposed to pure oxygen while under pressure, when they died.

Hill and Greenwood’s research was published briefly in several supplements to the BMJ in 1906 and 1907, and more substantially in a sequence of four papers (in the *Proceedings of the Royal Society* with Hill as first author) [7–12]; it culminated in Greenwood’s presentation of the Arris and Gale Lectures in 1908.

It is notable that the first three papers [7, 9, 11] contain very little statistical analysis. By contrast, the fourth paper [12] uses Pearson’s \( \chi^2 \) goodness-of-fit statistic to establish an association between age and decompression effects in previously published results from 545 caisson workers at the Blackwall tunnel (under the River Thames and completed in 1897), and 143 workers from the Nussdorf Works in Austria. In addition, it applies two of Pearson’s coefficients, the correlation ratio and the mean square contingency, to establish an association between body weight and decompression effects in rats.

2.4. Arris and Gale Lectures

These lectures mark the separation of the Surgeons of London from the Barbers and have been presented in the Royal College of Surgeons almost every year since 1810 (see Supporting information, Appendix 1, for more details). Greenwood’s lectures [13] were presented on 18 and 20 March 1908; he was described as senior demonstrator of physiology in the London Hospital Medical College, *Director of the London Hospital Statistical Department* (our italics), and late research scholar of the BMA. We cannot be certain but we think it is likely that his departmental head, Leonard Hill, may have been influential in his receiving the invitation. Greenwood was just 27 years of age, the only Arris and Gale lecturer under 30 years old during the surrounding years from 1901 to 1915 when 19 others would share this honour; of these, at least three were subsequently knighted, nine became FRS (or FRSE), six became professors, and 14 became fellows of a Royal College.

Greenwood used the occasion to give an overview of his work with Hill on exposure to increased barometric pressure but with an underlying theme of the importance of experimentation [13]. The latter provided an opportunity to make public criticism of some entrenched views with which he did not agree. For example, shortly into the first lecture, he remarks that
If it be concluded that the early history of caisson disease reflects but small credit upon the logical powers of our profession, certain extenuating circumstances may fairly be pleaded. It is easy to make merry over these physical crudities, but we have to remember that the divorce of experimental science from clinical medicine was then nearly as complete as certain educational authorities desire to make it now. The victory of error over truth is attributable to that divorce.

He repeats this caution at the close of the second lecture, remarking

To me the history of the whole subject seems to throw light upon the mutual obligations of the clinician and the experimenter, to show that each is powerless without his fellow.

As would be expected, Greenwood pays generous tribute to Hill commenting that with regard to caisson disease, ‘the most valuable and extensive researches are those of Dr Leonard Hill’, and continuing, that although he adopts

the conventional ‘we,’ no one acquainted with modern physiological literature can fail to recognize the sagacity in devising experimental methods, at once simple and effective, which characterizes all Dr Hill’s contributions to biological science.

Greenwood was also an admirer of the work of Paul Bert, a student of Claude Bernard, to whom alone ‘is due the credit of making this great advance, of patiently and accurately employing the experimental method’, indeed,

Paul Bert first placed the question (the true pathology of caisson disease) on the firm basis of experiment, and all subsequent advances are, in comparison with his work, trifles. His book has been exposed to searching and, in at least one instance, malicious criticism, yet not one important statement contained in it has been shown to be incorrect.

(Further biographical information on Bert is in the Supporting information, Appendix 1).

Thus, Greenwood’s work with Hill as a BMA scholar was to investigate physiologically the processes of compression and decompression, and the practical consequences for caisson workers and divers of varying the rate of decompression. This experimentation included Hill and Greenwood subjecting themselves to increased barometric pressure and the possible dangers therefrom. Greenwood admitted, ‘of course, even under such favourable conditions some degree of anxiety, especially in the earlier experiments, could not be avoided’. The pioneering spirit of Hill and Greenwood is clear!

2.5. The opsonic index

From 1908 to 1910, Greenwood published four papers on the opsonic index [14–17], all as first author and the first two as sole author. The first paper was from the London Hospital Statistical Department, the second and third from the London Hospital Statistical Laboratory, and the last from the Statistical Laboratories of both the London Hospital and the Lister Institute. All these papers have a statistical objective (‘statistical considerations’, ‘statistical view’, and ‘biometric study’) focussing particularly on the skewness of frequency distributions of the index.

The index is a measure of opsonic activity determined by the ratio of the number of microorganisms phagocytized by normal leukocytes in the presence of serum from an individual infected by the microorganism, to the number phagocytized in serum from a normal individual (Supporting information, Appendix 1). The phagocytic index is the average number of bacteria ingested per leukocyte of the patient’s blood.

Discovery of ‘opsonins’ in blood serum was announced in 1903 by Wright and Douglas [18, 19]; however, the experimental procedure for measuring the opsonic index was complicated (Supporting information, Appendix 1), and its interpretation was not entirely clear. Wright (for whom biographical details are also in the Supporting information, Appendix 1) maintained that values of the index below 0.8 or above 1.2 indicated the presence of the microbe under investigation, and thereby hoped to detect infection before any clinical symptoms of disease could be detected.

Greenwood’s involvement in this research resulted from his experience in laboratory techniques but also, as evidenced by the focus of the work, on his identification with the British Biometric School headed by Karl Pearson. One aspect of the background to these papers is that for some years Pearson had debated with Sir Almroth Wright concerning the efficacy of anti-typhoid vaccinations and the interpretation of the opsonic index and, thus, may have found it useful eventually to turn for support to his medically qualified colleague. The high profile of these debates is reflected by Wright (and his opsonin theory) featuring as Sir Colenso Ridgeon in Shaw’s play The Doctor’s Dilemma (1906), as well as in
Arrowsmith (1925) by Sinclair Lewis [20]. Karl Pearson also attracts the attention of Shaw with a section of the Preface to The Doctor’s Dilemma bearing the title Biometrika.

Succinct and detailed accounts of the controversies that arose from Wright’s research have been written by Matthews [5, 21, 22] and by Hardy and Magnello [23]. Readers are referred to these for the historical context, in-depth discussion, and references to personal communications between Pearson and Greenwood. Briefly, the controversies centred on three different schools of thought and their approaches to medical problems: clinical practice based on long-established procedures of careful observation and experience, the comparatively new laboratory-based discipline of bacteriology, and the new discipline of statistical analysis and interpretation developed mainly by the Biometric school. According to Matthews [22],

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while the advent of medical statistics through the Biometric School was ‘regarded with suspicion by the non-mathematically minded, and medically speaking of parvenu status’ [23]. The nature of the acerbic disagreements that could arise with the Biometric school is illustrated by the exchanges discussed later over Dr William Hunter’s statistics (see later discussions). Of the three main protagonists, Wright had experience in both clinical and laboratory medicine, Pearson had only statistical experience, while Greenwood had some experience in all three disciplines, ‘making him uniquely qualified to respond to Wright’s assertions on the relative merits of each approach’ [22]. Indeed, for Greenwood, ‘we learn anything by one of three branches of inquiry: clinical, pathological and epidemiological-statistical’ [24], a view he maintained throughout his life [3]. However, Greenwood, and indeed his later colleague John Brownlee, ‘needed to tread warily with the epidemiological and public health community, associated as they were with Pearson’ [23]. This may have been difficult for Greenwood for whom, following his early contact, Pearson became a lifetime idol [3]. As Hogben [2] states,

Pearson’s teaching was the inspiration of his life work, and it was also, and in more than one sense, a lifelong handicap. Only after Pearson’s death did he reach the fullest stature of his own manhood.

The debate between Pearson and Wright concerning immunization (see Supporting information, Appendix 1, for further details) set the stage for the dispute about the opsonic index, which involved both Pearson and Greenwood among others. Up until 1910, the period in which we are interested, Greenwood’s contributions appear to be his four published papers, some presented publicly, and exchanges of letters with Pearson [21]. Neither appeared to contribute to a major meeting at the Royal Society of Medicine held on 23 May 1910 [25]. Later on, the criticisms of both were to become more hostile [26, 27].

3. Other publications from 1907 to 1910

In addition to the papers described earlier, Greenwood had at least 13 other publications between 1907 and 1910: six papers, one letter in BMJ, two further papers and a note in BMJ, all of which we have attributed to him as discussed subsequently, an appendix to a report, a book chapter, and his first book.

3.1. Anonymous papers

In 1907, two anonymous papers appeared in the British Medical Journal, which we believe were written by Greenwood. In the first titled Recent advances in statistical methods [28], the author credits Pearson and his pupils with making sufficient progress in statistics as to transform it ‘into a branch of exact science’. The paper continues,

as it is probable that these methods will soon be applied on a large scale to medical problems, it seems desirable to give a sketch of the subject as free from technicalities as possible, so that readers of memoirs and reviews in which modern statistical notation is employed may at least have some idea of the meaning of the various terms used.

He then discusses and illustrates standard deviation (SD), coefficient of variation, frequency curve, arithmetic mean, skewness (defined as mean minus mode divided by SD), classification of frequency distributions (Pearson’s seven types), correlation coefficient, $2 \times 2$ tables, coefficient of contingency, and finally, probable error; the illustrative data are from several sources including Greenwood [4]. The final
paragraph is worthy of quotation in full because it expresses fears that have been recurrent throughout the century following:

It is especially necessary that medical men should use these methods of research, because often they, and they alone, can estimate rightly the nature of the material to be analysed, and so avoid the loss of time which results from the application of elaborate processes to unreliable data. It is undesirable that we should have in the future two classes of investigators, statisticians who know little of medicine and medical men who know nothing of statistics.

The references to the article form a bibliography with two textbooks (Davenport’s *Statistical Methods, with Special Reference to Biological Variation* and Elderton’s *Frequency Curves and Correlation*) and eight papers of which six have Pearson as an author. It is unclear why this paper was published in isolation in *BMJ* and without a named author; its content suitably expanded could be a template for the series of papers by Austin Bradford Hill (Leonard Hill’s son) published 30 years later in *The Lancet*, although we have no evidence that it was ever used for such purpose.

The second anonymous paper also published in *BMJ* is titled *Infantile mortality* [29] and clearly evinces Greenwood’s literary style. It is centred on two statistical publications, one by Prinzing (*Handbuch der Medicinischen Statistik*), the other by Saltet and Falkenburg (*Kindersterblichkeit, besonders in den Niederlander*), and their investigations of conditions associated with high or low death rates among young children. The author epitomizes four aspects (influence of diet, influence of prosperity, general and infantile death rate, and relationship between summer and autumnal maxima and meteorological conditions) of the information communicated and strongly advises those interested to consult the originals. There is a link to Greenwood in the reference to his paper with Thompson [30], and certainly in the style of the final paragraph:

we have said enough to make clear the interest and importance of these recent works; we only wish we could think that the numerous politicians and popular writers who pose as authorities on questions of this sort will make themselves acquainted with the books under review.

Finally, there is a brief note, in 1908, on the ‘probable error of a mean’ [31], which highlights Student’s paper on the distribution of the SD in small samples drawn from a normal distribution. The author (we assume Greenwood) comments that ‘the whole investigation is an amusing illustration of the refined analysis and intellectual delicacy necessary for the interpretation of statistical material’. The last two sentences of the note may appear a little obscure today because Greenwood contrasts Student’s paper with ‘the farrago of nonsense submitted to the Royal Commission on Vivisection by Mr Stephen Smith and dignified by the title of “statistical evidence”’, but he then refers to the statistical exploits of Mr Stephen Coleridge. Greenwood did carry out experiments on animals, whereas Stephen Coleridge, a barrister, was opposed to them, and his remarks may have some association with the episode of the ‘little brown dog’, which led to public clamour in 1903. The brown dog affair (see Supporting information, Appendix 1, for further details) was a political controversy about vivisection that raged in Edwardian England from 1903 until 1910. It involved the infiltration of University of London medical lectures by Swedish women anti-vivisection activists, pitched battles between medical students and the police, police protection for the statue of a dog, a libel trial at the Royal Courts of Justice, and the establishment of a Royal Commission to investigate the use of animals in experiments (see, for example, Baron [32]).

### 3.2. **Dr William Hunter**

A further named publication of Greenwood in 1907 [33] was a letter in *BMJ* commenting on the statistics of Dr William Hunter who published four linked articles [34] on the policy of London University in educating medical students. However unlikely at first glance, these articles became another source of controversy involving the Biometric School. Hunter used the numbers of students registered in each year from 1865 to 1906 at the universities of London, Cambridge, Oxford, Edinburgh, Glasgow, and others, to demonstrate changes in the student populations and express concern about the decline in the numbers of students in the great medical schools in London. In the same issue in which the third article appeared a correspondent [35], who signed anonymously as ‘statistician’, expressed concern that assumptions underlying Hunter’s analysis had not been checked and ironically praised the statistics commenting that ‘Dr Hunter has not only freed us from the necessity of carrying out a most tedious investigation, but has also shown us how to arrive at conclusions with intuitive rapidity’. He continues ‘I dare say some few statisticians will feel a little temporary irritation at being so far outdistanced by one who has never stooped to the drudgery of biometric methods’. He then advises statisticians to ‘write on pathology, to
which science they may perhaps make contributions as original as, although less important than, those of Dr Hunter to statistics’. Hunter responded [36] that he had made no attempt to contribute to the science of ‘biometric methods’ but welcomed the help of the statistician if by such methods—

by much arithmetic and the calculation of the probable errors of the constants obtained from subsamples he can show that university medical education in London is in a satisfactory and prosperous condition, he will earn the gratitude of all London teachers.

Clearly not impressed by biometric methods, Hunter suggests

they must be fearsome things to live with, sort of statistical ‘Fat Boys’ whose only pleasure in life it is to make your flesh creep. And yet, on closer acquaintance, not so fearsome, but carrying wonderful comfort to the distressed bosom, whether educational or financial.

The gauntlet had been thrown down, although why it should have been and in such a fashion by an anonymous ‘statistician’ is quite unclear. Pearson did not react (perhaps he was in on the ‘joke’) but Greenwood did [33], revealing that he was the ‘statistician’ author of the anonymous letter. He declares that in spite of Hunter’s recent research, ‘he is more at home in the role of humorist than in that of statistician’ and continues ‘his intentional pleasantries are capital, but only biometricians will appreciate the rich vein of unconscious humour running through his remarks on statistical methods’. Greenwood then engages in more serious statistical criticism of Hunter’s analysis, finishing with the comment that

Hunter has tackled a peculiarly complex problem in statistics, a problem requiring specially cautious treatment. Without even a semblance of analysis, he has published deductions intended to serve as a basis for immediate action and likely to be accepted without question by the many who have no leisure to examine the data.

Leonard Hill, Greenwood’s mentor, also contributed a letter commenting on the heterogeneity of the data [37]. There was just one other correspondent [38] who declared that ‘the majority of the teachers in London have, I venture to think, read Dr Hunter’s statistics without much interest’. In the last of his four linked articles [33], Hunter replied to his critics

the conclusion to which the figures point is the one known to every one acquainted with London medical education, namely, that students are more and more being attracted to other university centres than London. And if, as my severe critics admit, ‘nobody doubts this,’ I am at a loss to understand why I should be gravely called on to test the accuracy of the registration figures by ‘biometric tests,’ and by head-splitting mathematical formulae, the mere reading of which makes one giddy. Now that I have supplied the figures, it is open to any one to apply any test—biometric or mathematical—which he may think fit, or put any interpretation upon them that they appear to him to justify.”

These exchanges took place against a broader controversy surrounding election to the Senate and the threatened disintegration of the University of London, a new institution created in 1900. It is unfortunate that legitimate criticism of the assumptions underpinning Hunter’s conclusions, and of the lack of statistical analysis, should have resulted in an inelegant and unscientific squabble centred on the Biometric School. While neither Greenwood nor Hill states that Hunter’s conclusions were wrong, the correspondence may be a reflection of Greenwood’s commitment to Pearsonian methods.

3.3. Tuberculosis

In 1909, Greenwood published a paper [39] on marital infection in pulmonary tuberculosis (the disease that killed his two younger siblings and his mother). This was the second of two papers presented to the Epidemiological Section of the Royal Society of Medicine on 21 May 1909 with Dr (later Sir) Arthur Newsholme in the Chair. The first paper presented was on the causation and course of epidemics and was by John Brownlee [40] who would be appointed head of the Medical Research Committee’s statistical department 5 years later, and who from 1920 headed the MRC’s department while Greenwood chaired the MRC’s Statistical Committee [41]. The two men shared accommodation at Hampstead for several years, and there is no evidence of rivalry, dissent, or rancour between the two; indeed, Greenwood dedicated the published version of his MD thesis to Brownlee following his sudden death in 1927 [42]. Between them, they governed the MRC’s statistical programme for over 30 years, from its inception in 1914 to 1946 when Greenwood retired.
3.4. Physiology of the special senses

In 1910, just 6 years after graduation, Greenwood demonstrated the breadth of his knowledge of physiology by publishing his first textbook, *Physiology of the Special Senses* [43], with 236 pages devoted to general physiology, taste and smell, sense of position and movement, hearing, vision, and the physiology of space. The book marks a transition for Greenwood for although it is firmly rooted in Hill’s department, the frontispiece credits him as statistician to the Lister Institute of Preventive Medicine, Director of the London Hospital Statistical Department, late senior demonstrator of physiology in the London Hospital Medical College, and examiner in physiology to the University of St Andrews.

As outlined in the Supporting information (Appendix 1), reviews of this book were polarized, and while we will never know Greenwood’s views of this very mixed reaction, we do know that it never deterred him from writing books, for by the end of his career, he had published a further seven; for all except one, he was sole author. Perhaps he was reminded of this situation some 20 years later when his assistant lecturer, Hilda Woods, together with William Russell, published their only book *An Introduction to Medical Statistics*, which was met with a similar mixed reception from two reviewers. On that occasion, Greenwood, with confidence and conviction, wrote a very robust response [44].

3.5. Plague in India

In 1905, the Secretary of State for India was persuaded by the Lister Institute to undertake (further) investigations of some of the problems concerning plague in India, and accordingly, he set up a Commission with members appointed by his own department, the Royal Society, and the Lister Institute. The Commission would eventually be a source of work for Greenwood once he transferred to the Lister Institute in 1910. However, his first contact with it was in 1907 while he was at the London Hospital, and it therefore serves as a link between the two appointments. The work of the Commission was published in a series of reports in *Journal of Hygiene*, and Greenwood wrote an Appendix to the 22nd report [45].

Greenwood had one further publication on plague, which comprised Part II of the 35th report, *On the spread of epidemic plague through districts with scattered villages* [46]. He appears as statistician to the Lister Institute alone, although he maintained part of his position at the London Hospital.

4. The Statistical Department at the London Hospital

4.1. Establishment of department

The various aspects of Greenwood’s research in the years from 1904 to 1910, as outlined earlier, would have brought him to the attention of the limited number of individuals who were involved with medical statistics in one way or another. His career also demonstrably shifted over this period from clinical and laboratory investigations *per se* to having an emphasis on statistical investigations and methods. The most obvious indication of this is the affiliations given on his papers, which in the latter part of this period began to include The Statistical Department of the London Hospital (Table I).

The first mention of this Department appears in the minutes of a meeting of the College Board dated Monday, 19 February 1908. It stated simply that two letters (dated 7 and 14 February) with reference to the formation of a Statistical Department were read, but it is not known by whom these letters were written. As at that time the matter was under discussion by the London Hospital Medical Council (Minutes, 1 May 1908 to 19 March 1909 [Royal London Hospital Archives ref: RLHLM/1/8]), further consideration was postponed pending its decision. A decision was made by the Council before 16 June 1908 as by then the Statistical Department was advertised as ‘a new attraction at the Hospital’; the Minutes of the Meeting of the College Board held on 26 October 1908 record that the Council had decided that it should be left to each member of the staff to recommend his Clerks or Dressers to fill up the forms supplied by the Statistical Department. By the end of November, the rules for the Statistical Department had been set out (letters dated 21 and 29 November as reported in the College Board Minutes for the meeting on 21 December 1908: College Board: minutes, 17 June 1907 to 20 December 1909 [Royal London Hospital Archives ref: RLHMC/A/2/8]).

These rules, suggested by the Secretary of the Hospital, were set out in a letter from the Secretary of the Medical Council dated 29 November 1908; they are shown in Figure 4 after slight modification by the Council.

The Annual Report of the College Board dated March 1909 confirms the founding of the Statistical Department by the Hospital and that it will be under the College Board. It continues.
Clinical Clerks and Dressers will, subject to the approval of the Physicians and Surgeons under whom they are working, assist in the work of this department, and others desiring to work in the department will be permitted to do so.

Further progress was reported in the Minute of the College Board meeting on 21 June 1909 when two letters from Greenwood (3 and 9 June) were read, and it was resolved that Mr Douglas Owen, a member of the House Committee, be requested to act with the Statistical Committee at its meetings, that notice be given that the Department is now open to students desirous of preparing theses, and that a research assistant be advertised for, for a period of 6 months in the first instance and at a salary at the rate of £60 a year.

Five months later, the College Board meeting of 15 November 1909 accepted with regret Greenwood’s resignation as Senior Demonstrator in Physiology on his appointment as statistician to the Lister Institute, but allowed him to continue the Directorship of the Statistical Department (our italics).

4.2. London hospital prospectuses (1908 and 1909)

The Statistical Department was described in the Prospectus for the academic year starting in 1908, and this is reproduced in Figure 5. The extract also appears in the prospectus for the academic year starting in 1909 but with ‘Committee of the College Board’ replaced by ‘Committee composed of members of the House Committee and the Visiting Staff’.

Major Greenwood was depicted as ‘Junior’ since his father was still alive. Dr John Douglas Campbell White was a colleague of Greenwood who had trained at the London Hospital at the same time as Greenwood and was co-author of two of the four papers on the opsonic index [16, 17]. It is possible that he was a member of the opsonic department at the London Hospital because his record shows that
in 1908, he was an opsonic assistant. However, he does not appear to be a member of the Opsonic committee at the London Hospital, and neither was Greenwood.

A remarkable feature of the extract from the prospective first written in 1908 is that it could, with a few small changes, advertise the work of any medical statistics or biostatistical department at any time during the 20th century. A number of features are apparent:

1. An immediate need to improve statistical methods as applied to medicine. The reference to accumulation and reduction of medical statistics we interpret as the collection of data and its summary. At this time, there were no texts on practical aspects of medical statistics—Pearl was nearly 14 years away, Woods and Russell around 24 years, and Bradford Hill about 30 years. General practical texts on statistics had been around for several years but were perhaps not sufficiently subject based to enthuse medical students or medical researchers. Greenwood’s involvement in multiple areas as discussed in detail earlier had already made him aware of the need for better education in the application of statistical methods.

2. The instruction on elementary statistical methods as applied to medicine is both theoretical and practical. The practical application is easy to understand with the need to calculate means and SDs for example. Exactly what the theoretical methods were is more difficult to identify, although Greenwood was trained in the Biometric School, was much influenced by Pearsonian methods, and wanted to apply them.

3. The basis of much statistical analysis is the use of methods that require extensive and laborious computation. Mechanical calculators had been around since the 1890s but required some instruction to use efficiently as Woods was later to discover [44]. Greenwood was certainly familiar with the Borrough adding machines and the Brunsviga machines, and the former were available at the London Hospital (Figure 6). It is unlikely that they would be available for use outside the department partly because of expense and partly because they were heavy.

4. Biometric constants are those that characterize distributions such as mean, mode, SD, and correlation.

5. Even in those early days, the magnitude of the load on the department was appreciated especially if it was to reach out to all departments and students within the medical school. In 1908, the number of new medical students was 65. Greenwood obviously realized that the demand from preparation of theses could be overwhelming, although what the ‘exceptional facilities’ were we do not know. Certainly, Greenwood identified methods for channelling inquiries by using the network of departmental clinical clerks and dressers as the first point of contact. These are likely to have

Figure 6. A Burrough desktop adding machine from ca. 1910. Photograph reproduced from Wikipedia Commons and used in http://en.wikipedia.org/wiki/Burroughs_Corporation.
been medical students responsible for composing patients’ clinical notes and for bandaging and dressing wounds.

4.3. Further comments

There are two items that warrant further comment, the Statistical Committee and Forms to be completed by Clerks and Dressers. The Statistical Committee was set up in May 1909 by the College Board, after the responsibility for the Statistical Department was transferred from the House Committee. It consisted of Dr Leonard Hill (Greenwood’s head of department), Dr Theodore Thompson, and Mr Douglas Owen (a member of the House Committee). Its function presumably was to oversee the work of the department, and in October 1909, Greenwood as Director submitted a brief report of its activities. The report mentioned (i) papers already published, or in preparation, (ii) the extraction of family histories from bound volumes of medical notes with the object of throwing further light on the hereditary factor in disease, (iii) a systematic search of the hospital admission books from 1751 in the hope of ascertaining the changes that have taken place in the case mortality of common accidents and diseases, (iv) the award of a generous grant from the Research Fund to purchase an adding machine and some necessary books, (v) ancillary staff, and (vi) a course of lectures given by him, in connection with the department, on medical statistics during the summer session of 1909. We do not know the content of the course, although Greenwood makes a revealing comment that ‘although the audience was small it included some well-known men of science, viz. Dr CJ Martin FRS, Dr Harden FRS, and Dr JO Barratt’. The report ends on an upbeat with Greenwood proclaiming that

it may, I think, fairly be claimed that substantial results have been achieved and that the statistical department has established a right to be classed among the permanent institutions of the hospital and medical school.

The second item is the forms that were to be completed by the clerks and dressers in each department; these are referred to in several of the minutes. Certainly, Greenwood trained them to extract and record information, and this training may have been partly responsible for the improvement in post-mortem records noted in his two papers on human viscera [4, 47]. However, the minutes of the Statistical Committee (18 May 1909: [College Board: Statistical Committee, minutes, 18 October 1909 to 3 December 1911: Royal London Hospital Archives ref: RLHMC/A/4/61]) refer specifically to improving the family history records, and for this purpose, Greenwood had produced both a form and instructions (Figure 7). The Committee wanted more and, conscious of motivation, recommended that the objects of the scheme be explained to each new set of clinical clerks. Greenwood suggested that the new clerks be requested to attend in the statistical department.

Presumably, Pearson was aware of this project for the Schedule was a simplified version of one he devised (letter from Greenwood to Thompson dated 30 June 1908), and following the meeting of the House Committee on 18 May 1908, Greenwood received a letter from him ‘asking for aid in the collection of statistics bearing on the frequency of cousin-marriages among the class from which hospital patients are drawn’, and it is likely that the final item was added to the Schedule as a consequence.

The Council was not fully supportive for, while it thinks ‘very highly of the proposed work of the Statistical Committee’, it ‘does not see its way to impose the duty of collecting statistics upon the Clerks and Dressers’. Greenwood appealed (30 June 1908) in the strongest terms, and the Council relented, deciding, as mentioned earlier, that

it be left to the discretion of each member of the staff as to whether he should allow his clerks or dressers to fill in the forms provided by Mr Greenwood.

5. Leaving the London Hospital for the Lister Institute

Dr (later Sir) Charles James Martin, FRS (1866–1955), was appointed Director of the Lister Institute in 1903, a post he retained until retirement in 1930. Some background on the Lister Institute of Preventative Medicine is given in the Supporting information, Appendix 1. Martin was a physiologist, like Hill and Greenwood, and had attended the latter’s lectures on medical statistics at the London Hospital in 1909. Clearly, the two men knew each other well and shared a common background in physiology and experimental medicine, and in addition an interest in medical statistics. Martin may have been impressed by
Figure 7. Greenwood’s Notice to the Clinical Clerks and Dressers for recording family histories and the contents of the Schedule to be completed.

Greenwood’s skills in teaching, his presentation of a comparatively new and difficult subject, his position and tactical skill in the opsonic index dispute (Martin was an opponent of Wright), and also in Greenwood’s initiative and insight in establishing the Statistical Department at the London Hospital.

Also, staff at the Lister sometimes took considerable risks in early research. For example, when investigating plague in India, the method of transmission was established when a female worker put her hand into a flea cage and saw how high the fleas jumped, and Joseph Arkwright studied typhus by allowing himself to be bitten by infected lice (he survived but two others did not). Maybe Greenwood’s pioneering and to some extent risky experiments with Leonard Hill on the consequences of exposure to increased barometric pressure served as an additional recommendation in itself.

Mr Jonathan Evans, Archivist, Bart’s Health NHS Trust, has made the intriguing suggestion that Martin may also have been influenced by Professor William Bulloch (1868–1941) who was at the London Hospital at this time, having previously been employed in the Lister Institute until 1897 (Supporting information).

For whatever reasons, Martin was convinced that he needed a statistical department at the Lister Institute and must have persuaded the Governors as well, for at their meeting on 13 October 1909, Lord Iveagh proposed and W. J. Luard Pattison seconded a motion that ‘it is desirable that a medical statistician be added to the Staff of the Institute’; the motion was carried unanimously (the other members being Sir Henry Roscoe (chair) and Professor EH Starling) (Minute Book 2, Wellcome Library, London, ref: SA/LIS/A6). The Director (Martin) was empowered to approuch Greenwood and did so, clearly making a formal offer of appointment in the course of their conversation 6 days later on Tuesday, 19 October 1909. Whether the full details were discussed at the meeting or during the 3 days that followed we cannot be sure, but on Saturday, 23 October, Greenwood responded in writing (Wellcome Library, London, SA/LIS/H9), stating that

I shall be pleased to join the Staff of the Lister Institute as Statistician, or Medical Statistician, at a salary of £400 per annum. I should consider myself to be a whole time officer of the Lister Institute and only at liberty to undertake outside work with the permission of the Governing Body and on such terms as they might sanction. I should further consider myself bound by the general rules and conditions of service laid down in the existing regulations of the Institute as applicable to heads of departments or special laboratories.

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### Family Histories

**Notice to Clinical Clerks and Dressers**

It is the desire of the House Committee and Visiting Staff that some attempt should be made to tabulate data bearing on the hereditary transmission of disease. With this object a schedule has been prepared which will in future be issued with the history sheets and the attention of Clinical Clerks and Dressers is directed to the following points.

1. In order to arrive at conclusions as to the hereditability of disease it is not sufficient to record the fact that relatives of a patient suffering from a given disease have also suffered from the disease, it is equally important to record the members of the family who have not been affected.
2. It is essential to take family histories in all cases. Information respecting the relatives of persons suffering from tuberculosis do not enable us to form a judgment as to the inheritance of that disease, unless we have similar information relating to persons admitted for non-tubercular infections. This of course applies to all diseases.
3. In a very large percentage of cases, it will be found that the patient is not sufficiently acquainted with his family history to enable the observer to fill up the whole Schedule. In such cases, the words “no information” should be entered under the appropriate heading. This will save much waste of time on the part of subsequent investigators.

### Content of Schedule

- **Subject** – sex and age – registered number, living or dead, present age or age at death, cause of death, usual health.
- **Subject’s relatives** - father, mother, grandparents, uncles and aunts, siblings, cousins, wife, children – for each whether living or dead, present age or age at death, cause of death, usual health.
- **Subject’s father and mother** – state whether blood relatives (cousins).
However, Greenwood did not entirely vacate his current post or abandon his staff, for he asked to retain his Directorship of the London Hospital Statistical Department arguing that the utility of the Lister Institute’s own department ‘will be greatly increased if I and my assistants or pupils have free access to the statistical records of a large general hospital’. He considered that, as long as he retained the post, his access to the records would be assured, but his resignation would result either in the department being closed and his assistants discharged or in the appointment of a stranger; both would result in inability ‘to get the data for my own purposes’.

Perhaps wary that he might be perceived to have a lack of total commitment to the Lister, he declared that the formal duties attaching to the post at the London ‘are practically non-existent’ and that ‘one afternoon visit of a couple of hours per week would be more than sufficient’. He also declares that while no distinct salary is attached to the post, small grants amounting to about £50 have been made to him personally, and these will be placed at the disposal of the Governing Body of the Lister Institute if they sanction his continuance at the London.

Greenwood concluded by suggesting 1 January 1910 as a starting date and declared ‘I should do my utmost to render the new department in every way worthy of the Lister Institute and believe that the chance of success is great’. On 18 November 1909, Charles Martin informed him that the Governing Body had met on 10 November and appointed him on the terms he had requested.

Even before his arrival, Greenwood was in demand, the Governing Body being asked by the secretary to the Advisory Committee for Plague Investigation in India (1 November 1909) if they would lend his services either in whole or in part, during next year, to undertake a further statistical investigation of certain facts collected by the Plague Commission and if so whether they would make any suggestions as to the terms under which Mr Greenwood would work.

The Governing Body agreed the proposal but postponed the consideration of any financial adjustment until he had actually joined their staff!

Greenwood’s department was set up quickly for in his Director’s report, presented to the Governors on 11 May 1910, were listed four lines of investigation: statistics of plague incidence in the Punjab (Greenwood), statistical analysis of the opsonic index (Greenwood and Douglas White), case mortality of pneumonia and other hospital statistics (Greenwood and RH Candy), and application of frequency curves to economic data (Douglas White).

As stated earlier, we cannot be sure of the content of Greenwood’s lectures on medical statistics at the London Hospital, but they must have served as a basis for a course at the Lister Institute in early 1911. The Governors’ Minute Book provides a snapshot:

1. elementary—eight classes (lectures and practical work) suitable for medical men taking up public health or administrative work, commencing third week of January;
2. problems of applied statistics (four lectures on work carried out in the Institute’s department) in February; and
3. advanced lectures on special problems in the mathematical theory of statistics, which are of importance in medical inquiries (four lectures in March).

No fee was charged.

Both this course and the earlier one at the London Hospital deserve special mention, for they must be recognized as the first such courses ever given on the subject of medical statistics, certainly in the UK. It is clear that the course at the Lister Institute was highly developed and substantial in content, being some 16 lectures in extent. Its foundation must have been the earlier, probably shorter course at the London. Thus, Greenwood not only established the first departments of medical statistics but also introduced an essential part of their remit in setting up educational courses on the subject. The next such course in the UK was in March 1914 at the University of Glasgow and given by Greenwood’s future colleague John Brownlee [41]; the two knew of each other by this stage but had not as yet collaborated as far as we are aware. Perhaps it is surprising that, given his facility for developing textbooks from his lectures, Greenwood did not do the same with these lecture courses to produce the first textbook of medical statistics.

Within 6 months of starting, Greenwood was appointed Secretary to the Governing Body of the Lister Institute. He had already made his mark!

There followed two further reports of his Department at the London Hospital, the first annual report in March 1910 and another for 1910–1911. In the first, Greenwood reports that
he attends regularly once a week in the department and is available on the telephone at other times. Mr Candy attends for three hours daily. In the event of students requiring constant supervision and assistance, Mr Greenwood will arrange for them to work in his laboratory at the Lister Institute as well as in the Hospital Department which will prevent any waste of time.

Clearly at this point, there is no shortage of work, and there is also evident collaboration between the two institutes but,

no doubt, if the work of the department continues to increase, it may become necessary to appoint a whole-time officer, but the present arrangement is working satisfactorily and no immediate change seems necessary or desirable.

At the meeting of the Statistical Committee held on 10 March 1910, Leonard Hill was proposing that it be part of the work of the Statistical Department to collect and arrange the records of blood pressures taken in the Wards with a view to the obtaining of statistics of blood pressures in various important diseases.

The situation changed rapidly, and a year later on 14 March 1911, Greenwood was painting a very different picture in what appears a disappointing report. Mr Candy had vacated his appointment as assistant in September 1910 (and was now based at the Lister), Greenwood himself had received only one statistical inquiry from the London Hospital since his move to the Lister, and pressure on hospital space had necessitated the eviction of the statistical department.

I am personally willing and anxious to undertake any statistical inquiry based on the hospital records which may be suggested, provided that such an inquiry is statistically possible. Any such work can be undertaken in my laboratory at the Lister Institute and would be credited jointly to the London Hospital Statistical Department and the Lister Institute or to the former alone. I am not, however, able to attend the hospital regularly on the chance (experience has shown a very small chance) of my services being required. In my judgment, the most satisfactory or, perhaps least unsatisfactory course to adopt, is to allow me to retain my present nominal connection with the hospital as Director of the Stats department. I have had a number of pupils in my statistical classes at the Lister institute, although no old London student has ever put in an attendance.

His report ends by drawing attention to the very serious defects of the present system of hospital records, ‘that they are not only worthless as records but further that they have little value as scientific training for those who compile them’. Further, he regards the family histories as ‘slovenly in the extreme’ and recommends ‘that much of the present routine history-taking should be discontinued thereby appreciably diminishing the stationery bill of the hospital’. Given Greenwood’s involvement in setting up the family history records, it is difficult to understand why he does not admit some responsibility for the state of the records; we are unaware that they were ever used by Greenwood. Despite the pessimism, the loss of staff, loss of accommodation, lack of need for the adding machines, and poor quality of the basic records, the Statistical Committee at its meeting on 14 March 1911 optimistically agreed that ‘the department be continued for the purpose of undertaking any statistical work which may arise’.

6. Conclusion

Major Greenwood was the founder of the first Department of Medical Statistics (as we understand the discipline in the modern sense), but, as we have shown, it was not at the Lister Institute but at the London Hospital. In addition, he was the founder of the second such department, the one at the Lister Institute, as well as the first, and indeed, was Director of both simultaneously.

Thus, Greenwood was influential not just in establishing the modern discipline of medical statistics but also in creating the first departments devoted to it. In addition, he was the first to set out the remit of such departments in terms that are readily recognizable today.

The third Department of (medical) Statistics was established in 1914 by the Medical Research Committee, again in London, and although this was headed initially by John Brownlee, Greenwood was to become associated with it from 1920 and ultimately to be its Director from 1927. Unlike the departments at the London Hospital and the Lister Institute, which closed after only a few years in 1911 and 1919, respectively, this Department continues today as the Medical Research Council Biostatistics Unit in Cambridge and celebrates its centenary in 2014. In the USA, the Department of Biometry and Vital Statistics was founded in 1918 as part of the establishment of the Johns Hopkins School of Public Health. Raymond Pearl, who studied with Karl Pearson at University College London in the period 1905–1906 and became a close personal friend of Greenwood after they first met in 1917 or 1918 when
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**Supporting information**

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