Science, Technology and Culture 1700–1945

William Crookes (1832–1919) and the Commercialization of Science

WILLIAM H. BROCK

Ubi Crux Ibi Lux

Ubi Crookes Ibi Spookes

Iconic cartoon of Sir William Crookes from Vanity Fair, 1905. Courtesy Wellcome Medical Library.

WILLIAM CROOKES (1832–1919) AND THE COMMERCIALIZATION OF SCIENCE

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Abbreviations

ADB	*American Dictionary of Biography* (1928–)
BL	British Library
CN	*Chemical News* (1859–1932)
CUL	Cambridge University Library
DL	Dibner Library, Smithsonian Institution Libraries, Washington, DC
DSB	*Dictionary of Scientific Biography*, 16 vols (Charles Scribner's Sons: New York, 1970–1980)
IC	Imperial College London
IEE	Institution of Electrical Engineers, London
ODNB	*Oxford Dictionary of National Biography* (OUP: Oxford, 2004)
PRS	*Proceedings of the Royal Society of London*
PT	*Philosophical Transactions of the Royal Society of London*
QJS	*Quarterly Journal of Science* (1864–78); continued as (*Monthly*) *Journal of Science* (1879–85)
RAS	Royal Astronomical Society
RI	Royal Institution of Great Britain
RCC	Royal College of Chemistry
RPS	Royal Photographic Society
SML	Science Museum Library, London
Wellcome	Wellcome Library for the History and Understanding of Medicine

Note on Possessives

Like Crookes himself, I have preferred to use the simpler possessive form *Crookes'*, rather than *Crookes's*, when using the genitive form. This form is also used when referring to Crookes and his wife collectively, rather than the cumbersome *Crookeses*. I have done the same with George Stokes.

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Introduction

> In all work of a biographic character it is important to make copious reference to as many as possible of the generally-recognized virtues, vices, good points, foibles, peculiarities, tricks, characteristics, little weaknesses, traits, imperfections, fads, idiosyncrasies, singularities, morbid symptoms, oddities, faults, and regrettable propensities.
>
> E. Clerihew, *Biography for Beginners* (1905)

Given his international fame at the beginning of the twentieth century it is surprising that William Crookes was not the recipient of a 'clerihew' that alighted on one of his perceived foibles or characteristics such as the well-waxed moustache that gave him a somewhat foreign appearance.[1] Most scientists are specialists and are remembered and commemorated for one singular achievement or area of investigation. There are notable exceptions. William Crookes, like Albert Einstein, was one of these. He is remembered chiefly for five things: the discovery of thallium in 1861, the invention of the eye-catching and puzzling radiometer in 1875, his brilliant experimental work on cathode rays using the eponymous Crookes tube in the 1870s, his dire prediction in 1898 that mankind would starve unless chemists worked out how to 'fix' the abundant supplies of nitrogen in the atmosphere, and for his seemingly unorthodox interest in spiritualism in the 1870s. This biography will demonstrate that he had many other interests that deserve commemoration, including work on the rare earth elements and radioactivity, a strong commitment to improvements in public health, the invention of new glass mixtures that when made into spectacles prevented glare, and the weekly production of a digest of chemical news and information that was read by chemists all over the world. All this was combined with an active business career.

Sir William Crookes (1832–1919), the 'most flamboyant character in British science',[2] was virtually unique among Victorian scientists in combining a business career with scientific research. To be sure, many chemists, like Frankland, Ramsay and Roscoe, took out patents and earned additional income through consultancies, but this was very much a part-time avocation to their principal positions as university teachers. Others, like Huggins, Joule and Rayleigh, had incomes from family businesses that were run largely by others. But Crookes had to earn his living daily as a working journalist, analyst, consultant, expert witness, gold-mine owner, director and speculative investor in stocks and shares. He was always alive to the possibility that his current investigation might solve a practical or economic problem. His work in a laboratory in his own house and not in an academic institution, like Lavoisier's

1 J.J. Thomson (1936), 377. Crookes adopted the moustache after returning from South Africa in 1896.

2 Keller (1983), 12.

in the eighteenth century, was part-time – though from the mid-1860s onwards he had a series of permanent assistants to ensure the continuity of his research and that routine manipulations and readings were conducted during his absences from home earning a living. That living was made principally as a science journalist and editor and by business enterprises ranging from water analysis, sewerage schemes and gold mining to the design of electric light bulbs.

Much of his research involved what has been termed 'commercial science'. It was this that paid for the 'professional science' he conducted in his spare time. He founded and edited the weekly *Chemical News* in 1859, and he was also closely involved in the editing of the popular *Quarterly Journal of Science* between 1864 and 1879. Both these journals were a commercial success, unlike *The Electrical News*, a journal he modelled on *Chemical News* in 1875 that collapsed after only 20 weekly issues. Crookes' long life was one of unbroken scientific and business activity. These interests collectively made him a well-known Victorian and Edwardian personality. He received many public and academic honours, including a knighthood (1897), the Order of Merit (1910) and the presidency of the Royal Society (1913–15). Although by 1900 younger chemists and physicists obviously thought Crookes had sown his wild oats beyond his allotted years, he remained active in mind and body almost to the end. He would only feel old, he said, if his imagination failed. The imagination, he believed, was the wonderful endowment given to the trained scientist of being able glimpse the future. With this 'most exquisite faculty' in a human's mental equipment, one could peer beyond the veil and claim kinship with divinity.

Crookes was more eclectic in his interests than any other Victorian scientist and he ranged over pure and applied science, economic and practical problems, and psychic research, and this encouraged him to write for a variety of audiences. Crookes published his work in both 'high' and 'low' science and general journals. While his major experimental researches were almost exclusively published in the *Transactions* and *Proceedings* of the Royal Society (curiously, he published only two papers in the *Journal of the Chemical Society*, despite his chemical background), he regularly wrote popular science articles for other journals, such as *The [British] Popular Science Review* in the 1860s. His diverse interests collectively made him a well-known personality within the late-Victorian scientific community. Each of his brilliantly illustrated lectures to the Royal Institution and his presidential addresses to the Chemical Society (1887), the Institution of Electrical Engineers (1891), the Society for Psychical Research (1897) and the British Association for the Advancement of Science (1898) proved tours de force and were widely reprinted or reported. Such was the worldwide furore over his British Association address, which was concerned with the desperate need to fix atmospheric nitrogen to solve the world's food shortages, that it was twice reprinted, as well as being reported in the world's newspapers. Communication through the scientific and popular press was clearly important for Crookes. Nowhere is this clearer than in the disputes surrounding his psychic research.

The most controversial aspect of his entire career was his investigation of mediums in the 1870s and 1880s. Following the death of a much-loved brother at sea (which also led him into a libel action), Crookes attended seances, becoming interested in the kinetic, audible and luminous phenomena that could be witnessed at the fashionable

seances of the period. To the disgust of certain members of the scientific community, Crookes was persuaded that the mediumship of some practitioners was perfectly genuine. In 1870 he subjected the famous medium Daniel Home to a number of tests, and convinced himself that Home possessed a psychic force that could be used to modify gravity, produce musical effects, and perform feats unknown to science or to conjuring. When the Royal Society rejected Crookes' papers on the subject on the grounds that the experimental conditions were not sufficiently exacting, he reported them extensively in his own *Quarterly Journal of Science*, from where they were reprinted by the burgeoning spiritualist press. Encouraged by the latter's support, he reported his sensational authentication of Florence Cook's materialization of a phantom called Katie King exclusively in *The Spiritualist*. Convinced that he had uncovered an unknown relationship between heat and gravity as a result of his work with mediums, Crookes was led to improve the air pump and to the creation of the lightmill or radiometer. In this popular instrument, a system of vanes, each blackened on one side and polished on the other, is set in rotation on a pivot in an evacuated space when exposed to radiant energy. The interpretation of the apparent attraction and repulsion resulting from radiation, which Crookes initially attributed to a psychic force, proved intensely controversial. Differing interpretations supported by Stokes, Maxwell and dozens of other leading physicists filled the pages of *Philosophical Magazine* and *Nature*, spilling over into *The Spiritualist* and *English Mechanic*, as well as European and American popular-science journals.

It is the reconciliation of Crookes' strange and unorthodox investigations and statements in the 1870s with his much praised and influential experimental work in chemical physics that makes him an intriguing subject for a biographer, and this was recognized by publishers when Crookes became President of the Royal Society in 1913. Like many a celebrity, Crookes had planned to write an autobiographical memoir that would preface a collected edition of his psychic investigations and scientific publications.[3] In this he was greatly encouraged by the publisher Fisher Unwin, but the outbreak of war and his wife Ellen Crookes' poor health and death in 1916 prevented the intention becoming reality. Unwin had already tentatively contracted the physicist and inventor Edmund Edward Fournier d'Albe to write the biography. Fournier d'Albe (1868–1933), a Franco-Irish physicist, inventor of the octophone and an assistant of Oliver Lodge's at the University of Birmingham, had a standing interest in the occult.[4] For several years he had acted as the secretary of the Dublin section of the Society for Psychical Research. In the early 1900s he had published a highly speculative work of metaphysics, *Two New Worlds*, which inventively used the new knowledge of radioactivity and atomic structure to argue for continuity between a physical and spiritual universe. This had been followed up by an even stranger speculation concerning immortality based both on his previous metaphysical speculations and the evidence of materialization established by Crookes in his work with Katie King. Fournier d'Albe, in 1908, thought Katie King was an

3 Crookes is still revered by the spiritualist community. The library of the Spiritualists' Association of Great Britain in Belgrave Square in London is named the Crookes Library. See Stemman (1972).

4 For Fournier d'Albe, see *Who Was Who*, vol. 3 (1929–40).

example of an 'objective and *bona-fide* character of supranormal occurrences'. The spirit might either have been a real entity 'living' in the atmosphere above the earth, or Florence Cook's double by the externalization of her soul! By 1921, however, when he compiled an adverse report on the mediumship of the Goligheer circle in Belfast, he had become sceptical of physical mediumship.[5] Given his interest in the occult and in the new physics of matter that had emerged largely as a result of Crookes' research on the radiometer, Unwin must have thought him the ideal biographer.

Soon after Crookes' death in April 1919 Unwin gained access to an estimated 40,000 letters and documents that Crookes had carefully amassed during his long and active career. This huge cache of documents had already been subjected to filleting by members of Crookes' family. Mindful of their father's scientific reputation, it appears that the family deliberately and hurriedly destroyed as much of Crookes' correspondence on spiritualist matters as it could identify. Crookes' laboratory assistant, James Gardiner, who had worked with Crookes for nearly 40 years, was given a year's salary upon Crookes' death and had no say in what he called the executors' regrettable decision to destroy 'an immense volume of correspondence and notes'. He recalled Crookes' methodical habits and his rule never to destroy a paper; 'every note connected with his activities from the commencement was indexed and stored in boxes with the greatest care'.[6] Unfortunately, he reflected, Fournier d'Albe, whose biography of Crookes appeared in 1923, had only seen what the executors selected after consigning the rest to a paper mill. Gardiner believed Fournier d'Albe would have made fewer mistakes if he had been able to make his own selection. What these 'mistakes' were Gardiner unfortunately did not specify. He also suggested that Fournier d'Albe had revealed matters that Crookes would not have wanted to see in print – no doubt the references to Crookes' disappointment with the careers his children had chosen. In fact, despite the prior destruction of materials relating to spiritualism, Fournier d'Albe had the last laugh and with Irish astuteness he identified the extent of the missing correspondence from names left in the letter index file to which he had access. On the other hand, it does not seem that evidence of any scandal was deliberately suppressed by the executors' decision. When he reviewed Fournier d'Albe's memoir in 1924, Gardiner observed that nothing new of significance over and above what was already known about Crookes' spiritualist activity was found in the biography. 'This will be disappointing,' he stated, 'but it is in no way connected with the destruction of the documents referred to. It is a fact that no such investigations were attempted after 1881, except a few attempts at so-called Spirit Photography, and these gave results that were capable of very simple [i.e. rational] explanation.'

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5 Fournier d'Albe (1907) and (1908). The latter includes two photographs of Katie taken by Harrison in 1874. Fournier d'Albe (1922). Fournier d'Albe also translated Albert von Schrenck-Notzing's sceptical findings on materialization into English. Schrenk-Notzing (1920).

6 Gardiner's review of Fournier d'Albe (1923) in Gardiner (1924), 355. Lord Rayleigh also referred to Crookes as scrupulously orderly and tidy, docketing everything. Strutt (1936).

While Gardiner undoubtedly revered Crookes and wished to guard his master's reputation as a rational scientist, because Gardiner was at Crookes' side daily from 1882 until the day of his death, we can take this as explicit evidence that there were and are no hidden spiritualist secrets waiting to be unveiled. Nevertheless, in 1962 Trevor Hall published a study of Crookes' spiritualist activities in which he made the sensational claim that for several months during 1874 Crookes had had an affair with the pretty young medium Florence Cook. Although supported by the doughty and highly sceptical anthropologist and psychic investigator Eric Dingwall, Hall's book was soon subjected to minute and damaging analysis and criticism by, among others, George Medhurst, Molly Goldney and Mostyn Gilbert. Despite severe criticisms, Hall's book had huge popular appeal and became the subject of radio and television programmes. While Hall brought Crookes back into public consciousness, the image conjured up was that of an investigator who had used 'science' to cover up an adulterous affair. A new biography was clearly called for, and readers may be puzzled why it has taken another 40 years.

Armed with 40,000 documents and a deadline, Fournier d'Albe found no need to undertake additional research. The recovery of a so-called 'unpublished chapter' of his book entitled 'Chapter XIV. Utilisation of Sewage' (now at the Royal Institution) reveals how Fournier d'Albe prepared copy for the printer by pasting original letters from Crookes' correspondents, or file copies of Crookes' letters to correspondents, into his typescript. Although this chapter was not published as it stood, much of its content was subsequently reworked into other published chapters. The rest of the biography was presumably prepared in the same way before going to a secretary for retyping, although it is also possible that the whole manuscript was sent to the printer in this scissors-and-paste form. The existence of the 'unpublished chapter' has had the unfortunate consequence of suggesting to potential biographers that the remainder of the printer's copy with hundreds of complete letters attached might still exist and deterred them from writing. It is now my own view that this was mistaken. What most probably happened was that, following the printing of Fournier d'Albe's biography, the pasted letters were removed from the printer's copy and returned to Crookes' married daughter, Mrs Alice Cowland, Fournier d'Albe's principal family contact. Although documentation is lacking, it must be assumed that Mrs Cowland returned the 40,000 documents (less those pasted into the draft chapter) to her two brothers, Bernard and Lewis, who had been appointed her father's executors. Over the next decade the brothers disposed of the materials to the Science Museum and Royal Institution, as well as to auction houses. A great deal was also probably destroyed as of no interest.[7] The draft chapter, with its letters dealing largely with commercial science, was somehow overlooked and remained in Mrs Cowland's possession until she gave it to Mrs Marjory Francis, the daughter of William Crookes' son Joseph. When she emigrated to the West Indies, Mrs Francis left the 'unpublished chapter' in the hands of a cousin, a descendant of one of Crookes' uncles. In this manner

7 The most important of the documents were undoubtedly the laboratory notebooks given to the Science Museum and Royal Institution. Much time and energy has been spent by me and others on a futile search for the other materials put at Fournier d'Albe's disposal. It now seems to me that this is a false trail and chimera.

the draft chapter, as well as other oddments connected with Crookes, came into the hands of Mrs Francis's nephew, Sir Charles Dixon Kimber (b. 1912), during the early 1970s.[8]

Kimber, a politician, market gardener and landlord, is proud of his Crookes connection and was keen to see a new biography published. In the early 1970s Kimber joined forces on a scientific biography with an Oxford chemist, David J.W. Robbins. At the same time, in America, Robert K. DeKosky, whose Wisconsin University doctorate had involved a detailed study of Crookes' work in chemical physics, also began work on a biography. Both projects were soon abandoned, mainly on the grounds that the treasure trove of Crookes' papers used by Fournier d'Albe could not be found. My own involvement in Crookes studies had begun in the mid-1960s while I was studying nineteenth-century ideas concerning the complexity of the chemical elements. In 1967 I was asked to compile the Crookes entry for the multi-volume *Dictionary of Scientific Biography*. Soon after this 10,000-word notice had appeared in 1970, I learned from the former journalist and psychic researcher Mostyn Gilbert that he was planning a study of Anna Eva Fay and Mary Rosina Showers and their dealings with Crookes. Although tempted by his offer of collaboration, any thoughts of producing a longer memoir were displaced by the demands of teaching and the attractions of other research projects. It was only 30 years later, following my retirement in 1998, that I was able to return to Crookes and embark on the present study. This has involved expanding my *DSB* article and examining Crookes' extensive business interests in mining, coal-tar chemicals, sanitary engineering, water analysis and electric lighting, as well as making a fresh study and assessment of his scientific work in chemistry and physics, and of his extraordinary involvement in paranormal phenomena.

Although, for the reasons previously given, I have not had the benefit of having 40,000 documents in front of me, Crookes' more than 800 publications, the laboratory notebooks and the large correspondence that is to be found in various libraries in Britain and America have proved more than sufficient to satisfy a biographer. The delay has also meant that I have been able to benefit greatly from several significant studies of particular aspects of Crookes' researches that have been written by professional historians of science since 1970. A satisfactory biography of a scientist has to combine an account of the subject's life and upbringing, family and personality with an account and analysis of the subject's scientific practices and beliefs, as well as those of his contemporaries. All this must be related against a background of the social, institutional and professional context in which the subject lived.[9] The aim of my biography is do all these things by placing Crookes' scientific activities in the context of the business of making a living from science – something many of his academic contemporaries frowned upon. Given Crookes' work habits, a strictly chronological approach to his life is not possible. His assistant James Gardiner recorded how there were two phrases Crookes would never allow himself or his

8 Kimber's father, Sir Henry Dixon Kimber, married Lucy Ellen Crookes, the youngest daughter of George William Crookes, in 1910. *The Times*, 9 December 1910. G.W. Crookes was descended from one of Crookes' uncles, George Crookes (1802–77).

9 Compare Rocke (2001), introduction.

assistants to use – 'cannot' and 'near enough'. Crookes drove himself hard, working day in, day out at his science and businesses. Another of his common sayings, apparently, was that 'a man could not be really happy unless he had just a little more to do each day than he could possibly finish'.[10] Given such working habits, any synchronous study of daily research, writing, editing and business activities would be difficult to effectuate and ultimately it would also be tedious. I have preferred instead to follow a rough chronological order, but to break this as necessity demands by treating Crookes' academic and commercial research programmes thematically. This means that there are some occasional repetitions of fact, though their reprise occurs in new contexts. The aim, above all, has been to produce a readable life story of a chemical physicist who was regarded from overseas as one of the 'plus pures gloires de la science anglaise'.[11]

The Crookes who emerges in my portrait is that of a scientific entrepreneur who, like the proverbial cat, had a dozen lives. Educated mainly at home until he entered the Royal College of Chemistry in 1848, Crookes began as a photographer before dabbling in various areas as journal editor, translator, businessman and director of public companies, inventor, expert witness, spectroscopist, analytical chemist and lecture demonstrator. As both an editor and as an independent researcher, he was intensely jealous and proud of his reputation. As a skilled experimentalist, he revelled in his powers of observation and, as J.J. Thomson once observed, he was often more interested in exploration for its own sake than the outcome of an investigation.[12] His lack of formal education meant that, unlike his contemporaries from Cambridge, he had no advanced mathematics and his knowledge of physics was elementary. Again, as J.J. Thomson observed admiringly, rather than critically, Crookes picked up his physics as he wanted it for the research he had in hand, relying on the advice of George Stokes and Clerk Maxwell 'when he got into difficulties on theoretical questions'.[13] For Thomson, Crookes' powers of observation were extraordinary, especially in the way that he isolated abnormalities and systematically tried one thing after another in order to make the unusual easier to observe, understand and explain. 'He was like an explorer in an unknown country, examining everything that seemed of interest, rather than a traveller wishing to reach some particular place, and regarding the intervening country as something to be rushed through as quickly as possible.'[14] There was nothing subtle about Crookes' experimental method – it was test it and see, change a variable, and test and see again. The brilliant demonstrations involving the radiometer effect and electric discharge phenomena were culled from hundreds of individual experiments and tests on different materials, different positions, different pressures and so forth. While the method was simple, the execution was terribly difficult, involving the intricate blowing of specially shaped glass vessels and the patient engineering of consistent vacuums.

10 Gardiner (1919), 169.
11 Berthelot (1919), 805.
12 J.J. Thomson (1936), 378.
13 Ibid.
14 J.J. Thomson (1936), 379.

His commercial sense led him into such diverse areas as gold mining, the development of disinfectants, sewage disposal, electric light illumination, glass making and nitrogen fixation, while his chemical training led him to the determination of the atomic weight of thallium, the element he discovered in 1861, the separation and identification of the rare earth elements, and the investigation of radioactivity. As editor of *Chemical News* for half a century, he ran campaigns on patent laws, food adulteration, river pollution, public health, the endowment of research, and electrical illumination – his own home being the first in London to be lit by electricity. His pride and conviction that he possessed unique powers of investigation also led him to spend a good deal of his time in the investigation of psychic and spiritual phenomena. Privately a deeply religious man, he believed that the science and technology of his day had reached a pitch where it could be used to investigate bizarre and irregular phenomena, whether occurring inside or around a medium, inside and around an evacuated glass tube, or in the myriad spectra of the elements. There was a strong thread of mysticism in Crookes' character and he eagerly embraced the occult.[15] It was in order to enhance his powers of understanding that he joined several of the 'mystical' organizations that attracted many middle-class men and women during the late-Victorian period. His involvement in a French occult organization and his membership of the Theosophical Society, the Hermetic Order of the Golden Dawn, the Psychical Research Society and the convivial Ghost Club were all additional means by which he sought to penetrate nature's secrets and to understand his own place in the great scheme of the universe. Although active participation in the occult seems to have been unusual behaviour in a Victorian scientist, an interest in mysticism and the occult was part and parcel of modernism and its search for an understanding of the 'self' that was, among other things, to lead to psychoanalysis.[16]

It was not until he reached his forties that Crookes ceased struggling to forge a career in science. Nevertheless, his life demonstrated how it was possible for someone to rise to a position of honour and power in science without the benefit of a university education or academic position. He was also singularly fortunate, unlike most Victorians, in enjoying robust health for most of his life. The widespread presence of poisonous thallium dust in his first home laboratory and of radioactive emanations in his Notting Hill laboratory that, under modern health and safety legislation, inhibits scholars from examining his laboratory notebooks left him totally unscathed. Despite a somewhat austere and secretive temperament no doubt engrained from priority disputes and business dealings, Crookes was never a recluse. He was much given to dinners and 'at homes', society functions and clubs. On the other hand, in contrast to many of his contemporaries, Crookes had few or no interests outside pure science and technology. He appears to have ignored what was happening in contemporary literature, music, painting, theatre and other aspects of culture that the Victorian middle classes aspired to. Nor, despite much self-education, did he (unlike many other aspiring scientists who lacked the benefits of an Oxbridge education, such as John Phillips, Thomas Huxley and John Tyndall) go in for cultural self-improvement. Although he quoted poetry, these were literary

15 J.E. Reynolds (1920), 147.

16 Owen (2004).

flourishes provided by his close friend Alice Bird; and although his Notting Hill house possessed landscape paintings and a fine library, the paintings were all mundane wall coverings and his large book collection was strictly a working reference library of volumes on chemistry, physics and spiritualism. In the whole of his surviving correspondence there is only one reference to his going to the theatre, albeit with reluctance in order to accompany some young visitors.[17] This narrowness of vision explains why Oliver Lodge, who shared Crookes' interest in spiritualism, was never impressed with him as a man.

If, despite his well-tailored clothes, striking beard and waxed moustache, and permanent cigarette, Crookes lacked charisma in company, it was obviously different when he was lecturing and demonstrating and writing up his results for publication. On the platform or at the demonstration bench he became the great experimental chemist blessed by flashes of inspiration and insight that seemed daringly speculative at the time. As an audacious thinker, he excelled in expressing ideas that engraved themselves upon the audience by clarifying them with experiments at once simple and beautiful. They seized the imagination so that once seen they were never forgotten. Given the pride he took in his own work and abilities, and his deep vein of mysticism, it is not surprising that Crookes used a Maltese cross to cast a shadow in his eponymous Crookes tube, or that he adopted a punning Latin tag as his business motto and later as his heraldic device. For, from wherever Crookes (*crux*) stood, light (*lux*) appeared to be shone on the darkest and most mysterious recesses of nature:

> Visions of beauty and splendour,
> Forms of a long lost race,
> Sounds and faces and voices,
> From the fourth dimension of space;
> And on through the Universe boundless
> Our thoughts go lightning shod,
> Some call it Imagination,
> And others call it God.[18]

17 Crookes to H.E. Armstrong, 14 March 1905, IC archives.

18 Quoted by Crookes in a dinner speech in 1913. Fournier d'Albe (1923), 398. From Crookes' reference the author was probably the parasitologist Ronald Ross, though the poem does not appear in Ross (1910).

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Preliminary: A Chemist at Work

The reporter from *Chemist & Druggist* enjoyed his periodic interviews with Presidents of the Chemical or Pharmaceutical Societies. Although he worked for a weekly trades journal, its founding editor had always understood the value and importance of keeping his pharmaceutical and druggist readership up to date with progress in the chemical sciences. Profiles of leading figures in the physical sciences demonstrated the important roles that the sciences now played in Victorian society. This year, 1888, the reporter's presidential profile promised to be of even greater interest than usual. Interviews with prominent scientists were usually conducted in large university and college laboratories, but on this occasion the interview with the celebrated chemist was to take place at his own home in fashionable Notting Hill from where his fascinating current research on rare earth elements was being pursued.

The Kensington Gardens estate had been developed in the 1840s on the former site of a failed waterlogged hippodrome and horse-racing circuit, the whole area having originally been part of the Kensington Palace estate. The *Chemist & Druggist* reporter was visiting its grandest road, the spacious Kensington Park Gardens that stretched between Kensington Park Road to the east and Ladbroke Grove to the west. The wiry-bearded and whiskered 57-year-old retiring President of the Chemical Society, whom he had come to interview, had bought the Italianate and three-storeyed, stuccoed house eight years before in 1880. Number 7 had been erected in 1846 and first occupied by a Spanish merchant who had added a fourth storey in 1863 for his growing family. The reporter gladly accepted the President's offer of a conducted tour of his home. The house had a large basement area for kitchens and domestic staff, a magnificent entrance porch, dining and living room as well as a capacious reception area on the ground floor for entertaining. A striking feature of the principal downstairs living room was a huge moulded fireplace and over-mirror that the President had personally designed. It contained bronze roundels carrying signs of the zodiac and alchemical symbols together with putti bearing scientific instruments, including the President's own invention, the radiometer, whose technology had made electric light possible. The mantelpiece was, he was assured, a talking point among the guests at the 'at homes' and grand receptions that the President and his wife, Ellen, held weekly during the season.

Upstairs, the whole of the first-floor area had been transformed into laboratories and a library. Three further floors provided family and servants' bedrooms as well as a lumber store. At the back of the house, opening from the basement and ground floor was a small garden that, in turn, gave direct access to the lawns and ornamental gardens that were maintained exclusively for the residents of the road.[1] The house,

1 F.H.W. Sheppard (1973), 234, 253. A blue plaque was erected by English Heritage in 1967.

the reporter noted, was also filled with pictures (mainly mundane landscapes, he privately thought), photographs and mementoes. A special feature was a 'gallery of leaders of modern thought' made up from framed photographs and cartes de visite of scientists the President had known or admired.[2]

The house's previous owner, the President privately reflected, had wanted £7,500 for the property – a huge price that he could only afford because of the large sums of money he had made from acting as a consultant for the Native Guano Company and the sale of various electrical patents.[3] How very different, he mused as the reporter admired the furnishings, from the Mornington Road house that he had rented from his father for over 20 years. As a young man in the 1850s he had been greatly dependent upon his parents for gaining a position in the world; establishing an independent career had been a struggle. Although fame had seemed to beckon in the early 1860s when he had the good luck to identify a new element, publicity had neither helped him into a university post that he would have liked nor to the wealth to which he aspired. But dogged persistence as an editor of his own weekly scientific journal, the cultivation of business opportunities, and patient laboratory research had slowly brought him world renown. And, indeed, some infamy and notoriety in the 1870s, as the reporter reminded him in quizzing him as to whether he still believed that the recently deceased Daniel Dunglas Home had been a genuine medium. Of course, he assured him, relieved not to be asked about his more embarrassing acceptance of the validity of materializations in the same decade. All that spiritualist activity had occurred in Mornington Road and that was in the past and the President preferred to talk about his current search for unknown elements in the minerals containing the so-called rare earth elements.

The President proudly displayed his carefully catalogued oak-shelved library and three interconnected laboratories – one 12-foot-square room for chemistry with its modern gas-exhausted fume cupboard and adjacent lean-to desk where observations were recorded and written up; another room for physics, mainly devoted to the study of spectra and of cathode rays and displaying an array of elaborated Sprengel vacuum pumps; and a workshop for mechanical manipulations and for building apparatus. Interconnecting corridors to the library housed apparatus and chemicals as well as samples from earlier investigations of thallium, the radiometer effect and the conduction of electricity through what had come to be called – in his honour – 'Crookes tubes'. By all accounts, the reporter enthused, it was one of the best-equipped laboratories in London and certainly the finest private laboratory in Britain.[4] When the young Scots-Australian physicist William Sutherland had been shown around, he had dramatically likened it to 'an arsenal where night and day the

2 Crookes to A.R. Wallace, 2 June 1911, thanking him for his photograph, BL Add. 46442, f. 143.

3 Fournier d'Albe (1923), 303. This represents about £400,000 at today's prices. Properties in Kensington Palace Gardens were valued at at least 4.5 million pounds in 2004.

4 For an excellent illustrated description of Crookes' facilities, Anon (1888). Other private laboratories and observatories were maintained in London and its environs by, for example, Lord Rayleigh, (at Terling, Essex), William Spottiswoode (in Grosvenor Place) and Lord Salisbury (at Hatfield House), but it was becoming unusual by the 1880s.

equipment of a great expedition into the unknown was being pushed on under the sleepless eye of a patriot leader'.[5] Indeed, the reporter was told, the research carried out in the house went on uninterrupted from 9.00 a.m. in the morning until midnight. A salaried assistant worked a full day before leaving in the early evening when the President usually took over. The 32-year-old unmarried daughter of the house also helped and had become adept at fractionating rare earth elements in the huge array of Winchester bottles that occupied much of the chemistry laboratory. She was also apparently no mean interpreter of spectra.

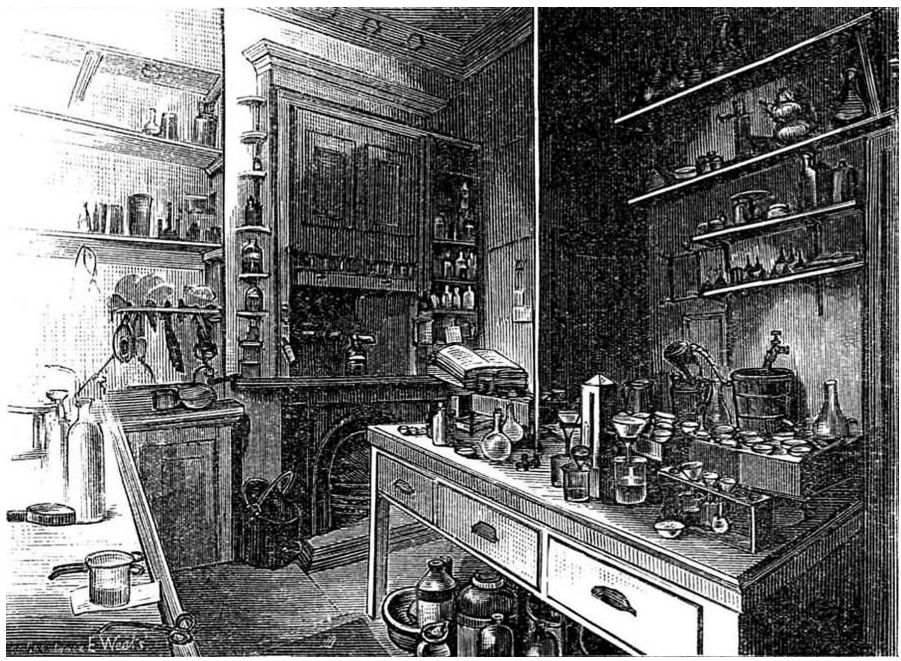

Fig. 0.1 Crookes' chemistry laboratory on the first floor of his house at Notting Hill in 1888. Note how the fireplace has been used as a fume cupboard and the laboratory notebooks to the right.

5 In fact in 1896, not 1889. Sutherland (1896), 373.

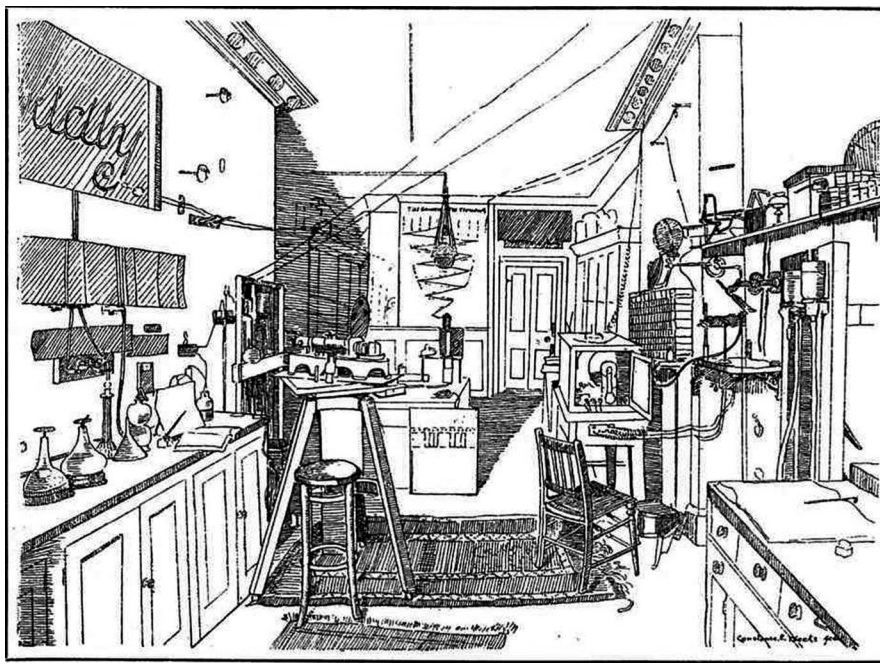

Fig. 0.2 Crookes' physical laboratory adjacent to the chemistry laboratory at Notting Hill in 1888.

No expense had been spared in furnishing the library, the reporter noted. It was lit by three huge windows fronting the street, and was fitted with oak shelving and a mantelpiece to match, a card catalogue and huge secretaire in which the President's correspondence and papers were carefully filed and docketed. The comfortable room was dotted with electric lamps, reminding the reporter that this was the first house to be wired for electricity in London and that everything had been made and laid by the President and his assistant. The President spoke excitedly about his future plan to provide electricity for all his neighbours by building a central power station from which electricity would be piped like water into Notting Hill homes.

The President's family was over a dozen strong. Besides William Crookes and his wife there was a 70-year-old mother-in-law, Mrs Humphrey, as well as their unmarried daughter, Alice. The Crookes' eldest son, Henry (aged 30), had been a student at the Royal School of Mines in Piccadilly and had recently become a mining manager and consultant. Their youngest son, Lewis (aged six), was still in the care of a nurse named Mary Birch (aged 50) and there were three other servants as well as a cook. Four other sons, all in their twenties, had been brought up in the house and returned there from time to time. Joseph and Bernard were developing careers in electrical and mechanical engineering, while John William and Walter Scott had embarked on careers in law and business. Another daughter, Florence, had been a victim of scarlet fever at the age of 14. This terrible loss in 1884 had coincided with the death of William's enterprising father at the age of 92.

What were the President's plans for the future, the reporter asked, and how would science change the world in the next decade or so? Crookes told him that his own current research on the spectra of rare earth elements was likely to confirm his belief that the known chemical elements had evolved from the radiant matter he had identified in his Crookes tubes. Physical scientists were poised to learn a great deal more about the nature of matter, and of the atom and about the energy it contained. Doubtless there were new forces and powers in nature awaiting discovery, and he was determined to be active in their investigation when they were identified. Nature still abounded in mysteries. Why were the atomic weights of elements so close to whole numbers? Why did a small part of nitrogen seem not to combine with oxygen when the two gases were sparked together? Why were his unused photographic films ruined when he stored them next to his Crookes tube? Why did certain minerals such as the uranium salts fluoresce? How were diamonds formed in the earth? Could they be made by chemists? Electricity, he believed, would transform mankind's existence as it moved from the laboratory into the home. Already used for transmitting messages through cables, it might be possible to transmit messages without wires. Perhaps something similar happened in human brains and it would one day be possible to transmit thoughts between people. However, such knowledge and applications would of little use if the supply of Chilean guano ran out. How was the world going to feed itself unless chemists came to the rescue?

Sir Willliam Crookes (as he became in 1897) was to be interviewed by many more newspaper and periodical reporters over the next 30 years of his life. He was always good copy because he was well endowed with a strong speculative streak that encouraged him to go beyond laboratory evidence. He epitomized the sage both in physical appearance and speech as he moulded heterodox views into evocative and plausible hypotheses. His opinions on the significance of new discoveries in the 1890s such as the inert gases, X-rays and radioactivity were eagerly sought. His warning about the consequences of failing food supplies at the end of the nineteenth century sent shockwaves around the world. By the time of Queen Victoria's death in 1901 he was a public celebrity and widely seen with Lord Kelvin as Britain's leading scientist. Showered with honorary degrees, he was awarded the Order of Merit in 1910 by King Edward VII – the highest honour royalty could and can bestow upon a commoner. A Fellow of the Royal Society since 1862, he was elected the society's President at the age of 81 in 1913 when he found himself thrown into a scientists' war. A brilliant experimentalist throughout his long life, he ended he spent the last years of his life investigating the chemistry of glass and perfecting that most mundane and useful of human accessories – sunglasses. This is his story.

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Chapter 1

A Tailor's Son

> I think that our friend the tailor is an honest man. I admit his airs and graces; I admit his fine-spun indignation; I acknowledge his passion for lucre which lies deep in his breast when he rebukes us for questioning his prices; I think there might fairly be some reduction in the cost of our coats and waistcoats, so that he need not retire so early in life to the delights of his little place in the country.
>
> Anthony Trollope, 'The Tailor', in *London Tradesmen* (1880)

During a competitive debate in *The Times* about the longevity of family memory in 1897, William Crookes wrote to the editor asserting that his family memory stretched back to the days of the Great Plague. As a boy, Crookes' father had listened to family stories told by his great-grandmother when she was over a hundred. She had heard them from her grandfather, who had lived through the plague year of 1665:

> The narrator, my great-great-great-great-grandfather, was born about the year 1639, and lived at Staveley in Derbyshire, where the Plague was brought in 1665 by refugees from London. He was one of the few who took the Plague and recovered, although it settled in his hip and made him lame. He was employed with a few others in going from house to house to bring out the dead and put them on horses and sledges, when they were taken to Marston [Mastin Moor] for burial. He died in 1729 aged ninety. His granddaughter, born in 1710, married a Mr Lound, and occupied a farm a few miles from Staveley. She died in 1814, aged 105, in full possession of all her faculties.[1]

Unfortunately, despite this remarkable example of the longevity of memory in the Crookes' family history, very little of it was recorded for posterity. At the suggestion of the publisher Fisher Unwin, Crookes had planned to write an autobiography, but like his intention to write an account of psychic research, this was stalled by his grief on his wife's death in 1916. Consequently, we know very little detail of Crookes' family background, or his childhood and education. From the quoted reminiscence, it is clear that his forebears on his father's side hailed from Derbyshire, where the surname Crookes is still common, and worked on the land. The surname is also common in south Yorkshire. Crookes' granddaughter, Mrs Marjory (Crookes) Francis, who emigrated to the West Indies, recalled a family tradition that the earliest known members of the Crookes family had been crusaders who became wealthy Yorkshire landowners around the village of Crux, now Crookes, a suburb of Sheffield. Although this tradition cannot be verified, it was undoubtedly the reason why Crookes later took 'Ubi Crux, Ibi Lux' [Where the cross is, there is light] as

1 Crookes (1897); Fournier d'Albe (1923), 10.

his motto and heraldic device. Crookes' father, Joseph Crookes, was born in 1792 at Masborough, an industrial village close to Rotherham famed for its huge eighteenth-century ironworks. Joseph's father, another William Crookes (1734–1814), made his living as a tailor, and this may well have been the profession of Joseph's grandfather, John Crookes (b. 1660), who was elected Mayor of Hartlepool, County Durham, on three occasions between 1691 and 1703.

From such sparse records we have a picture of a prosperous northern family engaged in various skilled trades, of which tailoring was but one of several. Joseph Crookes, the eldest son of four, served an apprenticeship as a tailor in Sheffield. Joseph did not serve his full apprenticeship since, at the age of 18 or 19, perhaps as a result of differences with his seemingly authoritarian father, he decided to move to London to seek his fortune. By family tradition, he walked all the way to London. Since the mid-eighteenth century, London had been moving westwards, leaving the City of London to become a business, rather than a residential, area. New shops and commercial possibilities were emerging in the West End at the time of Joseph's arrival in the first decade of the nineteenth century. Tailoring and clothes making had always been one of London's chief industries. The 1851 census highlighted the fact that something like 28,000 men and 84,000 women were employed in the clothing industry. Ready-made garments were chiefly the products of sweated labour (particularly female) in the East End, while the fashionable bespoke trade found its niche in the West End. It was the latter, fashionable branch of tailoring that Joseph Crookes entered, as an assistant to a master tailor named Atkinson. Regent Street had been planned by John Nash in 1812 as a triumphal way leading from the Prince Regent's palace on Pall Mall in the south to a new Regent's Park in the north and the bulk of it laid down between 1817 and 1823. To its east lay the working-class streets of central London and to the west the squares and streets of the aristocracy and gentry. Sometime in the early 1820s Atkinson moved his successful tailoring business to 143 Regent Street, taking Joseph Crookes into partnership. The firm of Atkinson & Crookes must have been one of the first shops to open on the western side of the street to the north of Piccadilly Circus and it rapidly became the leading tailors to the wealthy men of the West End. Number 143 is shown in Thomas Tallis's *London Street Views* (1838) as 'Atkinson & Crookes. Tailors and Habit Makers'.[2]

2 The shop retained its connection with clothing. It is currently 'Oxfords' (2007), a retail clothing outlet.

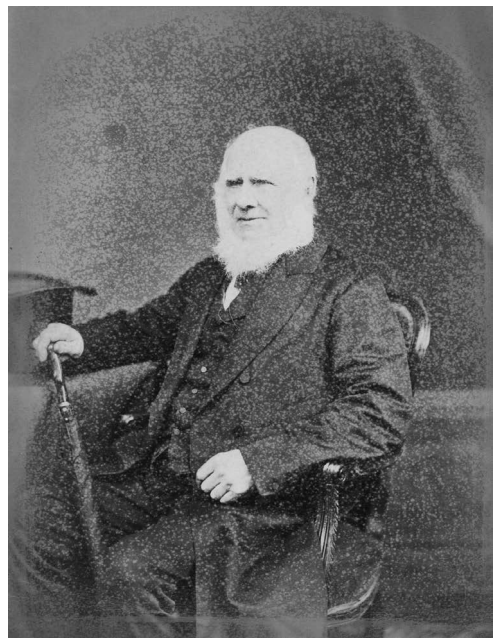

Fig. 1.1 Joseph Crookes (1792–1889), William Crookes' father. Photograph taken about 1880 after he had retired from tailoring.

Fig. 1.2 Mary Crookes, née Scott (1806–84), the second wife of Joseph Crookes and William Crookes' mother. Photograph from the 1880s.

While still in his early twenties Joseph married his partner's daughter, June Atkinson, and by the 1830s, with Atkinson's retirement, his son-in-law became the sole proprietor of the thriving business, living over the shop in Regent Street. Joseph and June had five children between 1818 and 1823. Two of the three sons, Joseph (1818–60) and Henry Crookes (1821–41), became booksellers in Regent Street, while the tailoring business was to be continued by his other son, Alfred (1823–1903),[3] and a grandson. Another brother, George Crookes (1802–77), also settled in London and became one of William Crookes' favourite uncles. George established a rival tailoring business at St James's Street, Piccadilly with his son, George William, who died before him in 1873. Like Trollope's model tailor, Joseph Crookes proved an astute businessman. Aware that London was expanding westwards, he invested in land and property as more and more of west London became paved with new streets and houses during the early Victorian period.[4]

June Crookes died during childbirth in the late 1820s. With five children on his hands, Joseph quickly remarried a Northamptonshire woman, Mary Scott, whose father worked on the estate of the great house at Aynhoe, on the Oxford canal. Mary was only 26 when she married the 40-year-old widower.[5] She bore her husband no fewer than 16 children, only 8 of whom survived into adulthood, the eldest being William Crookes who was born at 143 Regent Street, London, on Sunday, 17 June 1832 at half past five in the evening. Crookes was brought up amidst younger brothers and sisters and a smaller group of teenaged half-brothers and sisters who, by the time he was ten, were old enough to seem like aunts and uncles. His mother's sister, Martha Scott, lived next door at 141 Regent Street, having married a successful bookseller named Geeves. This bookshop was used by members of the literary and artistic world of the time, and besides books Geeves provided his customers with access to leading literary journals of the day such as the *Edinburgh* and *Quarterly* reviews, as well as *Blackwood's Magazine*. The fact that Crookes' maternal uncle, and his half-brother, Henry, were booksellers and connected with printing, illustrating and publishing may well have influenced the mind of Crookes as a boy and directed his thoughts away from tailoring as a career. There was certainly no pressure from his father to enter tailoring since Crookes' older stepbrothers Joseph and Alfred continued the family business.[6] Crookes kept every letter he ever received and, as Fournier d'Albe noted, the first letter in his enormous collection was one from his Aunt Martha in June 1832, enclosing a gift of money and a picture book, *The World with its Animals*. This must have been the first book Crookes ever held in his hands.

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3 The 1881 census records Alfred Crookes as a master tailor employing 20. He lived at 15 Holland Park Terrace with his wife and two servants.

4 Inwood (1998).

5 The marriage took place in Aynhoe on 24 February 1831. See Golden Wedding commemoration card, RI, Kimber papers.

6 The older brother, Joseph Crookes, died in 1860 to be replaced by Alfred. See Alfred Crookes, Tailor & Habit Maker, 143 Regent Street, *Kelly's London Directory* (1870 edn) The volume also lists 'Gurney, Crookes & Sons, Tailors & Outfitters' at 56 St James's Street. The relationship, if any, is not known. See also plan of street in Tallis (1838), view of Regent Street, Pa. 65, Part 12, No. 143.

Although we know little to nothing of Crookes' childhood, we can be sure that he was not deprived in any way. His parents were comfortably off, with servants to perform household duties, and he was wrapped around with a loving family of older and younger brothers and sisters as well as uncles and aunts from Yorkshire and London. Crookes sometimes told listeners that he could remember learning to walk and to seeing Halley's comet in 1835 when he was only three, but unfortunately did not record anything else about his childhood or parents. Fournier d'Albe had access to an autograph album that Joseph Crookes kept from about 1837, when Queen Victoria succeeded to the throne, and it shows that he clothed musicians such as Franz Liszt and Sir Jules Benedict; poets such as Samuel Lover, Thomas Campbell, Thomas Moore and the Sheffield 'Corn Law Rhymer', Ebenezer Elliott; the writers Theodore Hooke and Isaac D'Israeli; and William Upcott, the antiquarian and fellow autograph collector. By 1837 Joseph Crookes was sufficiently prosperous to buy one of the elegant and picturesque Italianate chalets in Park Village, a garden estate to the east of Regent's Park that John Nash and James Pennethorne had developed in the 1820s.[7] Until he was 14, William Crookes grew up in this Bute Cottage, as the new family home was named, in what must have been then almost a rural atmosphere of picture-book houses trimmed with fancy bargeboards, gables and balconies. It was during this time that his father also invested in new houses that were being built to the east of Park Village on the other side of the Great Northern Railway in the Mornington Estate of Ferdinand Fitzroy, the second Lord of Southampton.

Crookes received his basic schooling from tutors. In such a large family, this was a much cheaper way of educating sons and daughters than sending them all to school. When Francis Galton was preparing his hereditarian study of English men of science who had all received the accolade of the Fellowship of the Royal Society, he failed to include Crookes in his sample – probably because Crookes worked in commerce and not in academia.[8] However, although a planned revised edition did not materialize, Galton did question Crookes about his upbringing in 1904. He told Galton that, as far as he knew, none of his ancestors had shown a spark of interest in mathematics or science. Apart from his younger brother, Philip, who had died tragically at the age of 21, and who had shown talent for physics, he was the only member of the family to show any interest:

> I am what botanists would call a 'sport'. From my earliest recollections I was always trying experiments and reading any book of science I could find. A little older and I fitted up a cupboard as a sort of laboratory, and caused much annoyance and trouble in the house by generating smells and destroying furniture. I don't suppose any of my family even knew the meaning of the word 'science', and I was always regarded as a bit of a fool, who would never get on. It is a great satisfaction to me to think that my parents lived long enough to change their opinion, and to feel proud of the reputation I was making.[9]

7 Summerson (1978).

8 Hilts (1975), esp. 17–18; Galton (1874).

9 Fournier d'Albe (1923), 16. He also made guncotton at the age of 12. Fournier d'Albe (1923), 390.

Although such youthful chemical experimentation was not uncommon, given his parents' apparent lack of interest in natural philosophy, we can only speculate about what triggered this youthful interest. It is, of course, possible, that one of his tutors introduced him to some elementary science. A far more likely source were the lectures, exhibitions and scientific demonstrations that Crookes could have seen at the Royal Polytechnical Institution at the northern end of Regent Street, on the other side of Oxford Circus. This was but a short walk from his home and was one of the 'London sights'.[10]

This wonderful institution was something that would have attracted any child or any middle-class parent seeking somewhere to take their children with a moral and educational purpose. The Polytechnic had been established in 1837 to exhibit working scientific models (often on a spectacular scale) and to diffuse current science and technology through lecture demonstrations. Its charter spelled out its aims as the advancement of 'the arts and practical science, especially in connection with agriculture, mining, machinery and manufactures, the diffusion of the knowledge of useful mechanical inventions and the teaching of the applications of science to the common purposes of life.' There is ample evidence in some of his later *Chemical News* editorials that Crookes had a soft spot for the institution and was most concerned to ensure that its educational efforts were continued. The Polytechnic's most famous lecturer, John Henry Pepper (1821–1900), was not appointed until 1848, but his predecessors, such as Dr Ryan (who inspired the young Frederick Abel to become a chemist), would have given spectacular chemical demonstrations that Crookes would, inevitably, have tried out himself at home.[11] Although Pepper's writings aimed at the children's market were only published after Crookes was well launched on a scientific career, the Polytechnic would have encouraged him to devour earlier writings such as John J. Griffin's *Chemical Recreations*, the 1838 revised edition of which offered a chemical amusement set for sale.[12] The Dorking chemist Robert Best Ede, who made and supplied these chemistry sets, also published an instruction manual that Crookes may have used.[13] From 1851 onwards, the Chemical Society that had been founded in 1841 met in Pepper's house, part of the Polytechnic, at 5 Cavendish Square, where, as Hofmann's assistant, Crookes must have got to know him well.

When he was nine years of age, Crookes was sent to a proprietary boarding school within an omnibus ride of Bute Cottage run by a Mrs Keikhoffer and Mr Wilson. The school used the old warhorse of Mangnall's *Historical and Miscellaneous Questions* as its principal textbook of instruction.[14] This suggests that the school's teaching methods were those of rote learning, a method Crookes always deplored in later life when he campaigned for more practical kinds of teaching. What else the

10 Altick (1978). Crookes was always protective and concerned about the Polytechnic's future. Crookes (1861b).

11 Layton (1977); Secord (2002). Pepper's first publication for the young was *Popular Lectures for Young People* (1855).

12 Griffin (1838). The work had first appeared in 1825. Gee (1989).

13 Ede (1837).

14 Mangnall (1820). The book remained in print long after this.

school taught can only be guessed. Latin and Greek were probably in the curriculum, though in his twenties Crookes found it necessary to refresh his knowledge or to begin the ancient languages from scratch. It is also likely that the school taught French, a language that Crookes was to find useful in his later business activities. There was a French drawing master at the school and he encouraged Crookes' talent for executing pen-and-ink landscapes, and human and animal figures. A portfolio of youthful drawings was seen by his first biographer, who pronounced them delicate and accurate. Again, Crookes used his drawing skills throughout his life to illustrate his scientific papers.

Five years later, in 1846, Crookes was sent to Prospect House or College at Weybridge, some 17 miles from London, to which it was linked by the London & Southampton Railway, which had opened in 1838. Crookes was allowed home at the weekends, travelling back to Bute Cottage either by train or omnibus.[15] By then his wealthy 54-year-old father had retired from tailoring and decided to move away from central London. He bought an estate in the market-gardening area of Brook Green, near Hammersmith. The old farmhouse on the land was far too small, so Joseph proceeded to enlarge it, naming it Masborough House in memory of his birthplace. (Intriguingly, his brother George did exactly the same with his house in Balham Park Road.) Brooke Green was an idyllic spot with a huge garden for the Crookes children to play in, with the stream that gave the hamlet its name passing through the grounds. Here, Joseph Crookes established a new life as a local politician and counsellor, valued for his sterling work in the community while also making certain that he lived comfortably from ground rents from land that, being ripe for development, he had wisely purchased.[16] He served on the local Vestry from 1848 until 1877, acted as a trustee of the local almshouses (1852–81), served on the Board of Highways Surveyors, and was the treasurer of the Wormholt Wood Common on which Wormwood Scrubs prison was built in the 1870s. He always voted for a Tory candidate in parliamentary elections. After Joseph's death in 1884, Masborough House was demolished and the grounds redeveloped with rows of late Victorian and early Edwardian villas.[17] Today, only the street pattern and the names of Masborough and Aynhoe Roads reveal the large country home and gardens that had once stood there.

Crookes left his Weybridge school when he was 16. As we have seen, three of the sons by Joseph's first marriage to June Atkinson had entered the trades of bookselling and tailoring. There must have every expectation therefore that the five

15 See two letters from Crookes to his parents, 6 September 1841 and 8 November 1846, which were printed by Fournier d'Albe (1923), 17–18. I have accepted Fournier d'Albe's statement that the school was at Weybridge even though it cannot be verified in surviving local records or census material. According to William Tilden (1920), 444, Crookes was educated at a grammar school at Chippenham, Wiltshire, but this seems implausible in view of the distance.

16 The 1881 census records Joseph Crookes' income as derived 'from lands and houses'.

17 Death of Joseph Crookes, *West London Observer*, 16 January 1884, 5, copy Archives & Local History Centre, Hammersmith. The house was located to the east of present-day Masborough Road, fronting on Brook Green.

sons of the second marriage would do the same, perhaps with some initial financial assistance from their successful father. Unfortunately, one of William Crookes' brothers died at the age of four in 1839 and another, Richard, who had been born the year after Crookes, died on reaching his majority in 1854; Walter, who had been born in 1837, became a wine merchant in the city; it was left to Frank, born in 1839, to became a very successful tailor specializing in outfitting the military.[18] Crookes' youngest brother, Philip, whom all the brothers and sisters adored, seized the opportunity provided by the advent of electric telegraphy in 1837 to make his fortune in submarine telegraphy. His death from fever while laying cables at the age of only 21, his potential unrealized, was to influence Crookes profoundly. Crookes' two blood sisters, Emily and Alice, both died in infancy.

In 1839, when Crookes was seven, the world first learned of how Louis Daguerre in France and William Henry Fox Talbot in England had succeeded in fixing images from nature on glass and paper. Although protected by patents, photography quickly became accessible to anyone who could afford a lens to build a camera and the many chemicals needed to capture an image as a daguerreotype or photograph. Given his childhood interest in chemistry, it is likely that Crookes began to experiment with the new techniques at an early age and may well have persuaded his father that there was a commercial future in photography provided one knew sufficient chemistry. In 1851 Joseph built a laboratory in the garden for his son to continue photographic experimenting at weekends and vacations.[19] Although Joseph had wanted William to train as an architect (probably in view of his own financial interest in speculative building), it seems that his passion for photography was the reason his parents allowed him to enter the Royal College of Chemistry (RCC) in Oxford Street as a full-time student in the autumn of 1848 when he had turned 16. The college was less than half a mile from his father's former shop (now run by Crookes' half-brothers). The year's course of training cost Crookes' parents £25 (roughly £1200 at today's prices), which was not cheap. The two semesters ran in German university fashion from late October to February, and from March to July. Crookes, like his fellow students, was required to purchase his own set of apparatus and any expensive chemicals. He came up to the college from Brook Green each day on the horse omnibus, sometimes walking the three miles when the weather was fine.

The Royal College of Chemistry

The College of Chemistry was just three years old, having been founded in a blaze of publicity in 1845 by a diverse group of subscribers who were supported by Prince Albert's royal patronage. Through the propaganda of the German chemist Justus Liebig, who had toured Britain in 1837 and 1844, it was believed that knowledge of chemistry, especially of organic chemistry, would transform British agriculture by eradicating the need for crop rotation by the substitution of chemical feed or fertilizers. At the same time, Liebig held out the promise that chemical physiology

18 Censuses for 1871, 1881 and 1891.

19 Crookes to Spiller, Brook Green, 24 August 1851, Wellcome MS 5151 A/2/1.

and knowledge of the way food was metabolized in the body would transform medicine and lead to the eradication of disease. Finally, knowledge of chemistry promised to provide ways of dealing in an economically profitable way with the growing urban problem of the disposal of animal and human sewage. Given these possibilities of a civic chemistry that could transform and improve Victorian society, it is scarcely surprising that landowners, farmers, doctors, sanitary engineers and educationalists, as well as British chemists who had had the privilege of studying with Liebig at the University of Giessen, were willing to subscribe to a 'Giessen on Thames' laboratory.[20]

The Director of this important new educational institution was one of Liebig's favourite German pupils, August Wilhelm Hofmann (1818–92), who proved a superb choice. Cosmopolitan, charming, gifted with languages, a tireless worker and a brilliant exponent of the new organic chemistry that Liebig, Wöhler and Dumas had pioneered in the 1830s, Hofmann rapidly built up a research school that specialized in the chemistry of coal tar and its products. This knowledge proved to be the foundation for new artificial dyestuffs and a more science-based chemical industry. The college's curriculum was closely modelled on that at Giessen, with pupils' days being spent in the laboratory learning the ropes of inorganic and organic qualitative and quantitative analysis using English translations of Heinrich Will's *Outlines of the Course of Qualitative Analysis followed in the Giessen Laboratory* (1846). Each morning Hofmann also gave a lecture on chemistry, with a strong emphasis on what most interested him, the chemistry of carbon compounds. Hofmann would visit the laboratory and talk to each pupil at least twice a day, and everyone worked from 9.00 a.m. until 5.00 p.m. There were also evening meetings to discuss the publication of students' work. Hofmann's assistants, who received £40 a year, also earned extra amounts by offering private tuition to students at an agreed rate of between 3s and 5s an hour. At the end of a year's course of two semesters, or a semester if a student only attended for a period of months, Hofmann tested students' analytical competence and issued a certificate of proficiency stating that a student had attended a course of study. (Crookes commented later that the certificate was useless for obtaining a position, though this does not seem to have been the general experience.[21])

Crookes joined a cohort of 26 new students when he entered the college in October 1848 (there were 47 students all told in the college for the year 1848–49). He emerged as the best student in the group, and at the end of his first year Hofmann awarded Crookes the college's only prize, the Ashburton Scholarship, which the banker Lord Ashburton (one of the college's keenest supporters) had endowed in 1845.[22] This allowed him a further year's free tuition and the privilege of working directly with Hofmann. At the end of his second free year of training, Crookes was invited to become one of Hofmann's junior assistants, with responsibility for demonstrating to students in the laboratory and sometimes helping Hofmann with his own research and the commercial analyses he made for the RCC's subscribers. Hofmann, together with Thomas Graham and William Allen Miller, was at this

20 The *locus classicus* is Roberts (1976). See also Bentley (1970) and Brock (2000).

21 Crookes to Spiller, 23 July 1855, Durham University Library.

22 Alexander Baring, 1st Baron Ashburton (1774–1848). *ODNB*.

time a member of a Royal Commission investigating the quality of the water drawn from the River Thames for the drinking water supplied by private companies to consumers. It fell to Crookes to carry out many of the analyses, though, as was customary, his name did not appear in the report. This experience was to stand him in good stead in his later career as an analytical chemist and as an official analyst for London's private water companies.[23] It also impressed Hofmann sufficiently to promote Crookes to the position of senior assistant in October 1851. When the 15-year-old William Perkin entered the college in 1853, he later recalled how the first person he encountered was Crookes, who immediately set him to work studying the reactions of metals. Crookes remained one of Hofmann's two personal researchers until he left the college in the summer of 1854.

In a speech in 1898, Crookes reminisced about his time under Hofmann, whom he clearly revered even though, unlike the majority of RCC graduates, he was not greatly interested in organic chemistry. He recalled the dull November morning when he was first introduced to Hofmann by a fellow student, John Spiller, who had begun a few weeks before, and how he was immediately launched on gas eudiometry and Will's *Outlines*.[24] Later, when he assisted Hofmann in the investigation of the organic ammonium type, Crookes' glassblowing skills were urgently required to heat sealed tubes under pressure. The tubes frequently burst and he recalled Hofmann's Germanic comment when watching him: 'I think, Mr Crookes, the tube will now gradually commence to explode violently.' Crookes also remembered a water tap in the college basement that was fed from a cistern in the roof. The water came out at a great pressure. He and other students delighted in taking a bucket half filled with water and mercury and placing it under the tap. When the tap was turned on the rush of water forced air into the mercury, which consequently formed beautiful bubbles on the surface of the water.[25] He remembered, too, Hofmann taking him to a meeting of the Royal Society at Somerset House in 1850 where he first saw Faraday when he was demonstrating the paramagnetism of oxygen.[26] On a similar occasion he saw Faraday freeze mercury and hammer it on an anvil before it melted.

Like most Victorian men of science, Crookes revered Faraday. On the latter's death in 1867 he commented that 'A truly great man is, alas! gone from among us, and a man, moreover, whose place cannot be filled.' In giving an account of his life in *Chemical News* (after Frederick Ward declined to write an obituary), Crookes provided some personal impressions from his own friendship.[27] He was particularly interesting on Faraday's style and ability as a lecturer, stressing his enthusiasm. He cited Faraday's advice given to him as a young man: 'Work, Finish, Publish', noting sardonically that a lot of younger chemists now missed out the second step. Faraday should be commemorated by a statue at the very least, he thought, and better still, a

23 'Report on the chemical quality of the supply of water to the metropolis', *Report of the Government Commission*, Home Office, 17 June 1851. The report was summarized in *Journal Chemical Society*, 4 (1851), 375–413.

24 Anon (1898).

25 Crookes (1908a).

26 Anon (1913).

27 Crookes (1867a).

'public laboratory, as they have in France, where really deserving students may carry out their researches at the public cost.' Something similar was to be built at the Royal Institution at the end of the century by Ludwig Mond, though the Davy-Faraday laboratories were privately, not publicly, funded. Crookes wrote a further memorial to Faraday in the *Quarterly Journal of Science* in January 1868.[28] Part short biography, part lament that the deaths of scientific worthies attracted nothing like the attention of other kinds of hero, it ended with an amendment of an ode by the blind poet Anna Williams that Dr Johnson had rewritten on the death of the electrician Stephen Gray. The ode is so obscure (only mentioned in passing by Boswell, for example) that only a Johnson specialist could possibly have known of its existence.[29] It seems very likely, therefore, that Crookes was helped in writing this 'memorial'.

Crookes' fellow students and the students he subsequently supervised as Hofmann's assistant were of varied ages. With only a few exceptions, they all went into industrial or commercial careers, so that the trajectory of Crookes' subsequent career outside academia was not in any way unusual. One mature student under Crookes' supervision was the clergyman, the Reverend John Barlow, who was the Secretary of the Royal Institution. Barlow took his post so seriously that he decided to take a course in analytical chemistry. It was at one of Barlow's 'at homes' in Berkeley Street following a Royal Institution discourse in 1850 that Crookes first met the Cambridge wrangler George Gabriel Stokes (1819–1903), who had just been elected to the Lucasian chair of mathematics at Cambridge. Stokes had recently been working on the ultraviolet end of the solar spectrum by visual inspection at the same time that Crookes was trying to investigate it photographically. They immediately became correspondents and Stokes was to be one of Crookes' many 'invisible' helpers in his later investigations of the radiometer effect and spectroscopy generally.[30] He also met Faraday at Barlow's house in June 1853 when experiments were made on table-turning and Faraday showed that the phenomenon was due to 'a quasi involuntary muscular action' of the participants and not due to an unknown electrical or magnetic force. Crookes later saw the apparatus Faraday had devised to demonstrate this muscular effect being made by Robert Murray in John Newman's philosophical instruments shop in Regent's Street close to his birthplace.[31]

Family ties remained very strong during his college days. He still lived with his parents at Brook Green and during vacations he accompanied them and his younger brothers and sister on holidays rather than travelling abroad with friends of his own age. In a letter to a college friend in September 1853, he expressed his boredom about a holiday in Ramsgate in no uncertain terms. He had been on the pier and could find

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28 Crookes (1868a). For Ward's decline, see reproduction of his letter at the time of the Faraday jubilee, *CN*, 64 (10 July 1891), 16. Note also 'The Faraday memorial', *CN*, 19 (25 June 1869), 301–2.

29 Boswell (1857), ii, 16. 'Long hast thou borne the burthen of the day, / Thy task is ended, venerable Grey [rever'd Faraday]! / No more shall Art thy dextrous hand require / To break the sleep of elemental fire.' From Anna Williams, *Miscellanies* (1766).

30 Stokes (1907) contains 119 of the letters that Stokes had sent to Crookes.

31 James (1999), xxx–xxxii. 'Professor Faraday on table moving', *The Athenaeum*, 2 July 1853, 801–3.

no interest in salt water. He had read all his books and was reduced to reading one on higher mathematics. It was raining and next he would try getting drunk![32]

Throughout his six years at the Royal College of Chemistry, Crookes experimented with photographic techniques and the exploration of physical optics and the chemistry of photography. A fellow enthusiast was John Spiller (1833–1922), who like Crookes, became one of Hofmann's personal assistants in 1850. Spiller, who was a year younger than Crookes, was an architect's son and had been educated at the City of London School. The school had an excellent chemistry master, Thomas Hall, who had been one of Hofmann's earliest students at the RCC and who encouraged many of his brighter pupils such as Spiller to undertake further training at the college. Crookes and Spiller soon became bosom friends.[33] In their turn, Spiller and Crookes became great friends with Robert Murray (1798–1856), an Irish chemist who had assisted the instrument maker John Newman for over 40 years in his shop in Lisle Street and then Regent Street. London's scientific elite often used Murray's skills as an instrument maker and he was frequently asked to help arrange scientific demonstrations at the Royal Institution, King's College, and at the Royal Society, where he also kept meteorological records. With the advent of photography, Murray had begun to specialize in the sale of chemicals, and it was natural that the keen photographic duo of Spiller and Crookes should regularly visit his shop close to the RCC and to where Crookes had been born. Murray became something of a father figure to the two young men and they eagerly sought his advice on both technical and personal matters.[34] As we shall see in the next chapter, Crookes and Spiller made some important experiments in photography and took large numbers of pictures of friends and landscapes. These were still early days in photography and film emulsions were insensitive and slow. Crookes recalled in later life how 'Some of my friends whose portraits I wished to secure were victimized by five minute sittings in full sun.' Hofmann also introduced Crookes to the physicist and instrument maker Charles Wheatstone (1802–75), who worked at King's College London. Wheatstone interested Crookes in taking stereoscopic photographs using a stereoscopic camera he had developed. It seems that for the next 60 years Crookes never went on holiday without such a camera. He recalled forcing his wife to pose against a tree for up to 20 minutes at a time in order to give life to the landscape'.[35]

In 1850 Hofmann, who must have known about and approved the photographic and spectral work Crookes was doing in his spare time, asked Crookes to analyze a large sample of soot that he had been sent from a sulphuric acid works at Tilkerode in the Hartz Mountains. Apart from the presence of sublimed sulphur, Crookes found the soot to contain large amounts of selenium, an element first isolated and

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32 Crookes to Spiller, Ramsgate, 4 September 1853, Wellcome MS 5151 A/7.

33 Spiller (1922), 23–4; *ODNB*. According to Perkin (1901), 600, thirty of Tommy Hall's pupils later studied with Hofmann.

34 Murray (1856), 191. Crookes' dry collodion photographic portrait of Murray was taken in 1854 and is now in the Gernsheim Collection, The University of Texas at Austin, item 964:0389:0001.

35 Crookes (1913a), 71. An allegorical bronze panel by W.B. Fagan at the Royal Institution shows Crookes sitting next to Wheatstone while watching Faraday lecture. For its curious history, see Prescott (2002), 79–80.

identified by the Swede Jöns Berzelius in 1818. Berzelius had prepared potassium selenocyanide by fusing selenium with potassium ferrocyanide, but had not made a definitive examination of it or of any other substances that could be derived from it. Because sulphur and selenium formed analogous series of salts, rather than waste the recovered selenium, Hofmann urged Crookes to make a formal investigation of selenocyanides (-SeCN), the analogues of the well-known sulphocyanides (-SCN) and of the cyanates (-OCN). There was a possible photographic link because ammonium sulphocyanide (i.e. ammonium thiocyanate) was already being used by photographic chemists as a toner. The research was straightforward once Crookes had found a way of making potassium selenocyanide by fusing selenium with potassium ferrocyanide. From this starting point, he was able to characterize some further dozen selenocyanides as well as hydroselenocyanic acid. It proved an elegant exercise in purifying and crystallizing salts and determining their physical properties. Selenium compounds are notoriously noxious, but Crookes made no reference to noisome odours. The work was presented to the Chemical Society by Hofmann on 20 June 1851. Hofmann also arranged for its translation into German and this actually appeared in print before the English version.[36] This was Crookes' first appearance in print – always a proud moment at the start of a scientist's career. It was to be quickly followed by a spate of articles in the photographic press. Ironically, it was one of the very few purely chemical papers that Crookes published. Apart from studies of the salts of thallium and some of the rare earth elements, his huge corpus of published work was to be principally concerned with chemical physics and applied science.

A career in pure chemistry might not have seemed all that attractive in the 1850s. Crookes was uninterested in the kind of work that Hofmann and most of his other pupils were doing in organic chemistry (though Crookes was to write a couple of textbooks on synthetic dyestuffs as money-spinners in the 1870s). Without the organizing framework provided by the idea of valence and the periodic law that came a decade later, pure chemistry may have seemed an easy and dull routine of analysis and manipulation. Barlow had introduced him to Faraday and the Royal Institution. He had also met and become friends with Stokes, Wheatstone and Murray. These men appear to have attracted Crookes away from chemical problems towards physical problems in optics that were in any case essential to a true scientific understanding of photography, an art where light produces chemical effects that fix a portrait of nature in time. His final years at the Royal College of Chemistry were spent, with Hofmann's obvious approval, on using photography to investigate optical phenomena. In 1852, for example, Crookes tried to photograph the coloured rings or refraction patterns displayed by certain crystals, such as calcspar (calcite), when placed between tourmaline plates in polarized light. He was unsuccessful until Wheatstone loaned him two 'magnificent tourmalines and crystals'. It was then that Crookes made his first significant discovery: in addition to the coloured rings that other physicists had seen and recorded, Crookes noted other bizarre refraction

36 Crookes (1852a), read 20 January 1851. Crookes is cited as 'Assistant in the Royal College of Chemistry'. The German version appeared before the English in *Annalen der Chemie*, 78 (1851), 177–87 and in French in *Journal de Pharmacie et Chimie*, 19 (1851), 389–91.

phenomena caused by light beyond the visible spectrum and lying in the ultraviolet. It took him a year to perfect his results, which were reported, not to the Chemical Society, but to the new London Photographic Society in 1853.[37] The investigation made a considerable impact on George Stokes who, as a mathematical physicist, was able to develop the necessary theory to explain the phenomena.[38] Stokes quickly recognized Crookes' talent at instrumental investigations of physical phenomena and from this point on went out of his way to help Crookes with any theoretical problems met in his investigations.

While at the RCC, Crookes also conducted pioneering work on the spectra of chemicals that produced coloured flames when sprinkled into the wick of a candle or oil lamp. The technique was Newtonian: the spectrum was produced by passing the light through a prism and focused into the eye by means of a lens ruled with divisions 0.005 inches apart for purposes of accurate measurement. To all intents and purposes, he was engaged in what became known as spectroscopy, a technique not published by Bunsen and Kirchhoff until 1859. Crookes called his experimental set-up a 'spectrum camera' to emphasize his intention to record spectra photographically. Crookes published an account of the spectrum camera in 1856 and patented it five years later.[39] The presence of the ruled eyepiece clearly demonstrates that he was intending to plot the spectra of different substances for the purpose of accurate analysis, using the sodium spectrum as his standard of comparison. Crookes noted that sodium produced a brilliant double yellow line whose position corresponded exactly with the double black lines in the solar spectrum first noted by Fraunhofer. Unlike Bunsen and Kirchhoff later, however, he failed to invoke any explanation for the coincidence of the lines in terms of absorption and emission. This was undoubtedly because his primary interest was photographic, not analytical, namely the determination of the sensitivity of film to different wavelengths of light. For whatever reason, the work remained unpublished and has not survived. Only a tantalizing fragment of a paper drafted in April 1854 was published by Fournier d'Albe in 1923.[40] As a consequence of Crookes mentioning this research to him, the chemist John Hall Gladstone (1827–1902) referred to the phenomena in a Royal Institution lecture in 1857, and the two men became firm friends.[41]

The Radcliffe Observatory at Oxford

By the time Crookes became a senior assistant at the RCC in 1852, the college was no longer paying its way. Although student numbers remained buoyant, subscriptions had fallen off and the institution faced a financial crisis. To ensure its future, and using some of the profits from the Great Exhibition, it was taken over by the government

37 Crookes (1853b).

38 Stokes (1880–1905), vol. 4, 30–37.

39 Crookes (1856a), with plate. Patent (1861), no. 1181.

40 'Examination of the spectrum produced by coloured flames', in Fournier d'Albe (1923), 26–7. For a discussion, see James (1984).

41 Gladstone to Crookes, 4 February 1857, Fournier d'Albe, 37–8. See Gladstone (1857) and (1858).

in 1853 as part of the Department of Science and Art's Royal School of Mines in Jermyn Street. There is no reason to suppose that Crookes was unhappy with this transformation, though it may have caused him to consider his future. He was now 21 and anxious to pursue an independent career. The opportunity to move came in the summer of 1854 when Wheatstone informed him that the Professor of Astronomy at the Radcliffe Observatory in Oxford planned to set up a Meteorological Department with a view to seeing whether astronomical events influenced weather conditions. Given Crookes' expertise in photography and instrumentation, Wheatstone believed that the keeping of weather records could be automated and that Crookes was the ideal person to bring this about. Such methods had already been demonstrated at the Great Exhibition in 1851 by the Cambridge-educated surgeon and inventor Charles Brooke (1804–79). His prize-winning exhibit of a 'photographic self-registering magnetic and meteorological apparatus' had led to the installation of a self-recording magnetometer at the Royal Observatory in Greenwich.[42] Observatories had a great interest in such developments since automation reduced the number of assistants required and also permitted the easier detection of disturbances to regular patterns. Brooke's method was to wrap sensitized paper around a drum rotated by clockwork. A light beam attached to the magnetometer was then focused on the rotating paper over a 24-hour period. On development, the film provided a permanent trace of any diurnal variations in the earth's magnetic field. The principle, as Crookes saw, could be easily applied to other kinds of apparatus. The Oxford post was therefore attractive, particularly since he now began to entertain an ambition to take an Oxford degree. The observatory post, he believed, would allow him sufficient time for study to take the matriculation examination. If successful, he presumably believed or had reason to be certain, that his proud father would pay for his Oxford education.

Accordingly, in May 1854, after consulting his friend James Murray about meteorological instruments, Crookes resigned from the RCC and began work at the Radcliffe Observatory under the astronomer Manuel J. Johnson (1805–59). He also registered his name at Magdalen Hall as a Commoner, acting therefore as a part-time undergraduate.[43] Johnson had attended the East India Company's military school at Croydon and served in the company's artillery division on the island of St Helena. There he had catalogued the positions of the stars of the southern hemisphere and made his reputation as an observer. When the military station on St Helena was abandoned in 1834, he had returned to England and taken his degree at Magdalen College, Oxford in 1839. The Radcliffe Observer died the same year, and Johnson was his obvious successor. He quickly re-equipped the observatory and returned to his passion for cataloguing the positions of stars. Inspired by Brooke's suggestions, Johnson's predecessor, Stephen Peter Rigaud, had already begun a programme of meteorological observations and this Johnson continued.[44]

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42 Brooke (1847). For Brooke, see Lightman (2004), vol. 1, 295–7. On the Radcliffe Observatory, see Burley & Plenderleith (2005).

43 *Oxford University Calendar*, 44 (1855) lists Crookes as a Commoner, but he does not appear in subsequent volumes. Hertford College, the present-day successor to Magdalen Hall, has no records of Crookes.

44 On Johnson, see entry in *DSB*, vol. 7, 145–6.

At first Crookes felt elated at his new responsible position. His afternoons and evenings were largely free and he discovered a well-lit empty room that was ideal for the optical and photographic experiments he planned to undertake.[45] Crookes' observatory duty was to measure and record temperature, pressure, rainfall, and duration of sunlight and wind direction and speed at hourly intervals throughout the day. Together with an assistant, George Green, Crookes automated these determinations using photography to provide a continuous record of variations. The advantage of photography (rather than an inked stylus and paper) was the sharpness and sensitivity of definition produced, as well as the degree of permanence of the record for later consultation. The difficulty was the avoidance of paper contraction when chemicals were applied to paper to form a photographic emulsion.[46]

Crookes' ingenious solution, and improvement over Brooke's technique, was to employ a wax-paper surface for photographic film that had been introduced by the French painter and photographer Gustave Le Gray in 1851 and which was slowly replacing the Talbotcalotype. By waxing paper, Le Gray had prevented paper shrinkage and distortion of the image during its development in baths and washings of chemicals. Crookes applied the process successfully to the barograph and thermograph already installed in the observatory. In addition he designed and made an automatic 'pluviograph', or rain gauge, and a photometrograph for recording the amount of daylight. Several of his meteorological photographs, including one of an atmospheric storm wave that passed over Europe in November 1854 and waves in a storm in the North Sea taken in 1857, were exhibited by the London Photographic Society in 1858.[47] A letter from George Green to Crookes written after the death of Johnson in 1859 shows that the observatory continued to use waxed-paper recording after Crookes left Oxford.[48] Waxed-paper recording was also introduced at the Royal Society's observatory at Kew as a result of Crookes' innovations following their full publication in Crookes' first book, mostly written while he was at Oxford but not published by Chapman & Hall until 1857.[49]

Initially Crookes boarded with the Johnsons in Corn Market Street, but the following year he took lodgings in Park Place. What of Crookes' educational aspirations at Oxford? To matriculate at the university he had to demonstrate a sufficient knowledge of Latin and Greek, languages that his limited schooling had left below standard. In a letter to his friend Spiller, who since 1853 had been doing metallurgical work with John Percy at the Royal School of Mines in Piccadilly, Crookes lamented the hours he had to spend at Latin, and that it was costing him £60

45 Undated and misidentified fragment of letter Crookes to Spiller [1855] in Hartwell letters, RAS.

46 Adapted from Crookes (1856b). The meteorological observations made prior to Crookes' appointment, from 1828 to 1853, are found in the same source, vol. 14 (1853).

47 Roger Taylor's website 'Photographic Exhibitions in Britain 1835–1865' at http://peib.dmu.ac.uk (accessed 22 August 2005). Several of these photographs are in the Gernsheim Collection, items 964:0803:0010–12.

48 Fournier d'Albe (1923), 30–31. A few of Crookes' Oxford photographs survive in the Gernsheim Collection: the Meridian Circle (964:0381:0002), an instrument in observatory (964:0381:0011–12), a wet collodion spectrum (964:0387:0004).

49 Crookes (1857a). Crookes to Spiller, 23 April 1855, Wellcome MS 5151 A/14.

for a private tutor. In another letter he complained of having to read Homer in the original. Perhaps, not surprisingly, Crookes never took a degree, though like many famous men he was to be honoured with doctoral degrees late in life when he was a celebrity. Meanwhile, in February 1855, Spiller was wavering over taking a position with Pepper at the Royal Polytechnic Institution, a post Crookes encouraged him to take. It was obviously an opportunity he regretted he could not himself seize:

> I assure you I speak the truth when I say I would gladly be there instead of where I am myself. But when I had the choice I had no idea of what Oxford was or I might have decided differently. I look at our affairs in this light. On starting in life we have the choice of two roads: one leads to a European reputation, and possibly the admiration of the scientific world, and your name handed down to posterity as a benefactor to mankind but leaves you terribly minus as to the £.s.d. The other road leads you safely to in a dozen or so years time to a snug sum in the three per cents with the consolation of being called a humbug, accused of charlatanism and lowering the dignity of science into a trade, and consequently are looked down upon by the aristocratic followers of the 'Bubble reputation'.[50]

Like the majority of Hofmann's pupils, both men chose the route of £.s.d. Being a popular lecturer at the Polytechnic was not for Spiller who instead made his career from 1856 onwards working for the government as a photographic chemist at the Woolwich Arsenal with Hofmann's pupil Frederick Abel. In 1868 he joined his brother William Spiller as a coal-tar chemist in the firm Brooke, Simpson & Spiller. He never achieved the fame of Crookes, but probably made as much money as an industrial chemist during the heyday of the British dye industry. He remained an enthusiastic photographer all his life and was an influential member of the Royal Photographic Society.

As the quoted letter reveals, after only a few months in Oxford, Crookes was feeling thoroughly sorry for himself. Although he had made the acquaintance of another keen photographer, Nevil Story-Maskelyne, the Deputy Keeper of Mineralogy in the Old Ashmolean Building, he decided there was no future for him at Oxford. Gloomily, he saw the workhouse staring him in the face! 'I am sick of it, and the worst of it is nobody will understand my situation. They all say how fortunate I ought to feel myself and say I am lazy and do not like the work.' In this state of depression, Crookes wondered about an earlier idea he had had to open some sort of chemical business in London, and asked Spiller whether an empty property opposite the RCC in Oxford Street was still available.[51] Crookes' decision to quit the observatory position after only twelve months owed much to a decision that he was not cut out for an academic course in his twenties. He believed that he had done all he could regarding meteorological recording and that there were no fresh challenges

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50 Crookes to Spiller, from 24 Cornmarket Street, Oxford, 23 July 1855, Durham University Library MS 417. This is a fugitive from the set of Spiller–Crookes letters at the Wellcome Library for the History and Understanding of Medicine.

51 Ibid. The phrasing is unclear and may be open to other interpretations: 'Is that crossing disengaged opposite the old college, you know I fixed on that some time ago. I wish you would see about it and engage it for me.' Here 'crossing' might refer to an empty building site rather than an empty office.

at the observatory. In the event, he decided not to return to London but to become a science teacher and accordingly resigned from the observatory in May 1855.

Although his father continued to give him generous financial support, Crookes was desperate for money. In an extraordinary letter to Spiller he confided his interest in the will of an elderly aunt:

> A friend of mine has asked me something about a doctor or physician who is up to all kinds of insanity. He wants an introduction to one in order to have his opinion on the capability of an old lady (whom everyone knows to be mad) for making her will and leaving nearly £30,000 away from her heir, to charities. Do you know of any such? I mentioned Dr Diamond [Superintendedent of the Surrey County Asylum and leading photographer] – do you think he is good as could be had? If so, how can an introduction be got to him for my friend … I may as well state in explanation of my troubling myself about this matter, that '*a certain party*' has an interest in this Will, do you understand.[52]

Two months later it seems the aunt had altered her will to Crookes' satisfaction, which made Crookes' conscience prick.

Science Teaching at Chester

Following Oxford, Crookes spent a year teaching chemistry and natural philosophy at Chester where, in 1839, John Bird Sumner, the Bishop of Chester, and others, had established a diocesan training college for teachers who would be posted to the National Schools that the Church of England had been opening all over England since the 1820s.[53] Its dynamic first Principal was the Revd Arthur Rigg, a Cambridge wrangler and a former mathematics and natural philosophy teacher at the Royal Institution Academy in Liverpool.[54] Rigg was keen on science teaching and soon after he moved to Chester he created a boarding school for boys that he called a Science School where 'actual articles and contrivances were made for use'.[55] To this, Rigg added a Commercial and Agricultural School in 1843. To all intents and purposes, therefore, Chester College was a Normal School. The formula of students being taught to teach by practising their skills on the boarding pupils prospered from the start and, if anything, the Science School, which attracted boys from a wealthier cohort of middle-class parents, prospered at the expense of teacher training. Rigg was appealing successfully to middle-class parents who could either not afford a public-school education, or who wished to avoid the emphasis upon classical education in such schools. The curriculum was designed to appeal particularly to parents who aspired for their sons to enter the civil or colonial services or careers in which more practical skills were required. The school worked because of Rigg's

52 Crookes to Spiller, Oxford, 23 April 1855 and 3 July 1855, Wellcome MS 5151 A/14, A/16 …

53 Foden (1959).

54 Foden (1959) and 'The late Rev. Arthur Rigg, MA', *Chester Courant*, 15 September 1880 (copy Chester Record Office).

55 Bradbury (1975). Minute Book, 1854–67, Chester Record Office, CR 86.

enthusiasm and authority. When he suddenly resigned in 1869, his Science School collapsed, because he had not made any provisions for its future.[56]

There are very few archives that survive from this period in the college's history and none tells us anything of Crookes' appointment and little of his teaching there. The salary was £60 p.a. together with board and lodgings, and the Science division had some 55 pupils on its roll.[57] The earliest laboratory had proved too small by 1854, so Rigg arranged for a new laboratory to be erected on a yard to the north of the college buildings. Crookes must have arrived at the college in time to supervise the layout and fixtures of this workshop.[58] In line with Rigg's heuristic pedagogy, the students themselves built the laboratory with their own labour, learning as they did so about bricklaying and plumbing. In this small laboratory Crookes introduced the hands-on methods of Liebig and Hofmann, emphasizing the learning of qualitative and quantitative analysis. In some correspondence from former pupils in *Chemical News* in 1914 it was suggested that under Crookes there was no better chemistry laboratory in England than the one at Chester and that his practical method of instruction (copied from the RCC) worked extremely well.[59] At least one of Crookes' former Chester pupils, John Collins, enjoyed a successful career as an analytical chemist in Bolton and previously as a metallurgist. He was the same age as Crookes and, like him, he patented a sewage treatment process.[60]

Nevertheless, it does not sound as if conditions were ideal – at least in the winter months. In November 1855 Crookes complained that the laboratory was unheated because of a mechanical breakdown. Far from sympathizing, Rigg simply arranged that Crookes should teach in ordinary classrooms where, no doubt, it was difficult or impossible to demonstrate with experiments.[61] Anecdotal evidence handed down by subsequent generations of science teachers in the college records that like many chemists in the 1850s, Crookes made his own reagents, but was annoyed when Rigg used them in his own lessons. Accordingly, Crookes resorted to labelling his bottled chemicals in code.[62] Crookes did not have a free hand in what he taught since this had already been firmly established and advertised by Rigg. The chemistry syllabus was to be practical and applied to:

56 Rigg sometimes advertised the school in *CN*, e.g. 4 (7 December 1861).

57 Chester Record Office, CR 86/12/14 for a salary quoted in June 1852.

58 Minute Books, 7 December 1854 and 29 March 1855, Chester Record Office, CR 86 and SC 1/42/1–7. The laboratory cost £240. According to Bradbury (1975), 99, the laboratory was demolished in the 1920s following its use as a changing room.

59 F.J.R. Carulla in *CN*, 110 (21 August 1914), 95–6.

60 Obituary of John Collins, *CN*, 58 (30 November 1888), 267–8.

61 Rigg to Crookes, 21 November 1855, Fournier d'Albe (1923), 31.

62 Information from John Cartwright, Department of Biology, Chester College, 5 June 2000.

AGRICULTURE, manures, soils, etc.
COMMERCE, including means for estimating the value of raw prices, etc.
MANUFACTURES, including the processes of dyeing, bleaching, tanning, etc.
DOMESTIC ECONOMY, including the adulteration of articles of food and the nourishment of various kinds of meat, grain, vegetables, etc.
GEOLOGY, MINING, HEAT, LIGHT, VENTILLATION etc.

It is interesting that these were all subjects that Crookes was to specialize in as a consultant chemist and as editor of *Chemical News*. What he had not already learned under Hofmann at the RCC, he certainly must have learned as a teacher during his brief interlude in Chester, especially blowpipe analysis, for which he asked Spiller to draw up a printable schedule for his pupils. It was unfortunate, he told Spiller, that his one or two star pupils had to devote so much of their time to other subjects.[63]

Just as in Oxford, Crookes' initial euphoria for his new position quickly dwindled. By October he was already 'in great doubt about that great bugbear, the future again', he told Spiller.

> I cannot keep on at this work. I am afraid it is too much for any one to do and I feel my health will not bear it. I fancy that by Christmas I can manage to get a connection about Liverpool and the neighbourhood for analyses and if so perhaps it would not be a bad thing for me to start a lab on my own account down there and take in pupils &c. What do you think of my scheme? I do not want if I can help to go back to London, should much prefer Liverpool.[64]

Crookes must have soon discovered that such a scheme had already been thwarted by Liebig's pupil James Sheridan Muspratt, the son of the eminent Liverpudlian alkali manufacturer James Muspratt, who had opened a chemistry school modelled on the RCC in 1848. But why was Crookes interested in Liverpool?

Crookes was expected to teach and supervise in the afternoons only, when the Science School classes were held.[65] Rigg's idea was that students from other schools, artisans and labourers could then attend more easily, and the arrangement worked. Whether Crookes' mornings were free, or he was required for other duties, is not recorded, though he was obviously free to leave Chester at the weekends and during the vacations. He continued his photography with another amateur, Thomas Brushfield, the superintendent of the Cheshire County Lunatic Asylum who, Crookes boasted, looked up to him 'as one of the shining lights.'[66] No more is heard of Brushfield for Crookes soon began to spend his free days in Liverpool, some 30 miles away by road and ferry from Birkenhead. As we shall see in the following chapter, Crookes established contact with the Liverpool astronomer John Hartnup and, using his telescope, took some of the earliest photographs of the moon. A photographic community was also emerging in Liverpool and Crookes joined in the formation of what was the very first Photographic Society in Britain in 1855.

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63 Crookes to Spiller, 2 October 1855, in RAS, Hartwell papers 8 (1), A-H.

64 Crookes to Spiller, 23 July 1855, Durham University Library.

65 See elaborate handbill, *Prospectus of an Industrial, Trade or Scientific School at Chester* (July 1854), Chester Record Office, CR 86/12/16.

66 Crookes to Spiller, 2 October 1855.

Chester was also within striking distance of the Yorkshire relatives of his father, and it must have been on one of these visits to a female cousin that he met her school friend, the 19-year-old Ellen Humphrey. She was the only daughter of her widowed mother, Elizabeth, from Darlington, County Durham, and strikingly beautiful, as a surviving early photograph taken by Crookes confirms. Writing after her death in 1916, Crookes recalled that 'her eyes were of a blue-grey colour, and her complexion was a very good pink and white. Her hair was of a rather dark brown colour, and it kept its colour almost to the end'. A photograph of Crookes at this time shows a smartly dressed young man with a prominent forehead and eyes sunk below well-defined black eyebrows, a large mouth, a chin surrounded by the fashionable 'Crimean fringe' beard of the fifties, and his sidelocked hair sides swept forward in a fashionable curl. Neither Crookes nor his children left any record of Ellen's upbringing and degree of cultivation. Fournier d'Albe, who met her when she was already in her seventies, implied that he thought her a little common and her husband's inferior intellectually. Whatever their social differences may have been, they became a devoted couple and Crookes could not bear to be separated from her.

The Return to London

William and Ellen decided to marry immediately, which meant that whether or not Crookes enjoyed his teaching position in Chester, he had to resign since it was a strict rule that staff had to be bachelors. (The rule did not apply to Rigg himself.) And so Crookes was obliged to resign at the end of the Easter term in April 1856 when he returned to his parents' house in Brook Green.[67] Whether Ellen brought a dowry to her marriage is not known, though one of the conditions was clearly that the couple would support Ellen's mother, Elizabeth, and house her for the rest of her life. Mrs Humphrey lived with the Crookes for the next 40 years. For many couples this would have been a recipe for disaster. But Crookes was used to living in a home bustling with people of different ages, and the arrangement obviously worked successfully. Crookes was to be away on business frequently during his long marriage or otherwise occupied in his laboratory or library, and Mrs Humphrey undoubtedly gave her daughter companionship as well as a helping hand with their large family and would have been accommodated in her own quarters in the Crookes' Notting Hill house by the time she reached her seventies.

Crookes' savings cannot have been large from his two years' employment at Oxford and Chester. The immediacy of the marriage was only made possible because Joseph Crookes offered the couple a house in Brompton that he was building on the site of former nurseries and market gardens.[68] Crookes and Ellen

67 A plaque commemorating Crookes as the Chester College's first science teacher was erected in the 1930s on a wall near the site of Crookes' laboratory. *The Collegian*, Christmas 1935, 127 and Easter 1936, 24. The wall was demolished in the 1960s to make way for the Aubrey Price Tower, a new science block, to which the plaque was relocated. During alterations to the tower, *c.*1990, the plaque disappeared (information courtesy of John Cartwright).

68 Needless to say, it is idle to speculate that the marriage was hastened by a pregnancy that subsequently miscarried, though that would certainly explain the curious fact that the

chose not to be married in Yorkshire, but in London at St Pancras Church, Euston Road on the 10 April 1856, with John Spiller as best man.[69] After a honeymoon in Brighton, where they went on ten-mile hikes and rowed along the seashore for two hours each day, husband, wife and mother-in-law lived in Bute Cottage for a few months before moving into the small house at 15 Stanley Street, Brompton, their wedding gift from Crookes' parents.[70] On their marriage, the Crookes adopted a monogram of an elephant impressed on the letters WEC (William & Ellen Crookes). On one level the heraldic elephant was a symbol of chastity and of the redemption of mankind; however, the choice of emblem was more mundane. Ellen's pet name was evidently Ellie, which resonated with elephant.[71] The monogram varied over the years but always contained this private joke.[72] In typically Victorian fashion, the Crookes' family grew rapidly. Their first child, a daughter, Alice Mary, was born in the year following their marriage (1857). Their first-born son, Henry, arrived in 1859 and was educated at University College School (1871–76) before training in mining engineering at the Royal School of Mines. Five more sons followed: in 1861 (Joseph, named after his father and a stepbrother who had died the year before), 1863 (John William), 1865 (Bernard Humphrey), 1867 (Walter Scott) and 1874 (Lewis Philip). A second daughter, Florence Ellen Jane, was born in 1870. Sadly, Florence was to become a victim of typhoid fever in 1884 and never reached adulthood. Another daughter christened Nellie survived only a few weeks after her birth in 1870. It is a measure of the medical improvements and growing prosperity of the Victorian age that seven of the Crookes' nine children reached adulthood. This is also reflected in the boys' education and choice of careers. Like Henry, both Joseph and John were also educated at University College School (1872–78 and 1874–79 respectively), with the former becoming a Post Office (electrical) engineer. Following some preparatory education in Uxbridge, Bernard, Walter and Lewis all went to the City of London Boys School, completing their education at Felsted, the famous public school in Essex.[73] Like brother Joseph, Bernard chose a career in

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wedding took place in London rather than in Darlington.

69 They were not married in Hammersmith, where Joseph and Mary Crookes resided, because, until their new house was ready, William and Ellen Crookes first lived temporally in the family's former home, Bute Cottage, then registered by the Post Office as 18 Stanhope Street. This fell within the parish of St Pancras.

70 With the development of the Lennox Gardens estate in the 1870s, Stanley Street became Lennox Garden Mews, off Walton Street. Crookes' house is probably still extant.

71 It is possible that there was also a contemporary rhyme or song about Ellie or Nellie the elephant, though the most famous elephant in the Regent's Park zoo during the 1850s was named Butcher. The children's song 'Nellie the Elephant' is twentieth century.

72 The earliest example of the monogram occurs in Crookes to Spiller, Brighton, 24 April 1856, Wellcome MS 5151 A/20.

73 Orme (1892). Henry Crookes was at Royal School of Mines 1879–81, where he specialized in metallurgy. He joined the Institution of Electrical Engineers and was Manager of the Incandescent Department of the Geilcher Co.; Battery Manager both of Moss Rose Gold Mine and Orkney Gold Mine; Assayer for the Morgan Gold Mine; Manager of Waterhouse Co. and Engineer to the Tyddyn Gwladys Silver Mine. He was also a consulting chemist, assayer and analyst. In 1896 he was living in Harrow. Chambers (1896).

electrical engineering while, to the Crookes' disappointment, both Walter and Lewis chose professional careers in accountancy and the law. In any large family there is always a black sheep and this was the fate of John William Crookes. No documents record his misdemeanours or felonies, but at some stage he emigrated to Canada, remaining on poor terms with his parents who virtually disinherited him. Only Alice was educated at home, remaining there and looking after her elderly parents until her eventual marriage to a solicitor in 1897.

What was Crookes proposing to do following his marriage in the spring of 1856? He had abandoned a research post at Oxford that might have led him to academic distinction and a university career; he had abandoned a teaching post in science that could easily have led to a similar appointment in a prestigious public school at a time such schools were becoming interested in science teaching. He had about 20 publications to his name and had become well known in photographic circles. Could he make a career as a photographic chemist? In the knowledge that his parents would save him from complete penury, this was the course that Crookes now took back in London.

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Chapter 2

Photographic Chemist. The Making of an Editor

> The new art of photography early caught my attention. I remember the excitement caused by the announcement of Daguerre's and Fox Talbot's discoveries.[1]

William Crookes is an example of a mainstream nineteenth-century scientist who also devoted all of his life to editing several journals, while at the same time pursuing an active research and writing career – and, indeed, many other activities. Crookes may well be exceptional in combining editing with a huge range of other activities; only Norman Lockyer, the founder-editor of *Nature*, approaches comparability. Crookes more or less fell into editing because he expected to follow a career as a photographic chemist after becoming interested in photography as a teenager. Daguerre's invention of a method for making accurate and permanent illustrations in 1839 (the daguerreotype) and William Henry Fox Talbot's invention of a method of 'photogenic drawing' using chemically sensitized paper in the same year attracted an enormous amount of contemporary attention. By the end of 1841 Talbot had developed and patented a process whereby latent images captured on sensitive paper (the negative) could be developed into permanent positive prints using silver salts, gallic acid and other chemicals.[2] Both methods of reproduction could be easily learned and experimented with by amateurs – provided they had sufficient wealth to pay for the necessary chemicals.[3] Young Crookes was certainly in this position since, as we have seen, his father was a successful Regent Street tailor and property

1 Crookes (1910a); Fournier d'Albe (1923), 389.

2 With the disappearance of private darkroom photography in the twentieth century and the replacement of chemical photography by digital photography in the twenty-first century, readers may require further information on the calotype process. Good-quality paper was impregnated with silver nitrate solution and partially dried before being soaked in potassium iodide. Immediately prior to exposing this paper in a camera, it was placed in a solution of silver nitrate and gallic acid and dried with blotting paper. These procedures were performed in dim candlelight. The film was then exposed for between ten seconds and ten minutes, depending upon the subject matter. The latent silver image was then developed by washing the paper film in silver gallo-nitrate solution in the dark, and the image 'fixed' by further washing in a solution of potassium bromide or 'hypo' (sodium thiosulphate). The resulting negative was a calotype, which could be transformed into a positive by placing the negative on Talbot's 'sensitive paper' – a salted paper washed in silver nitrate. On exposure to light for up to a quarter of an hour, a positive image was developed that was then fixed in hypo solution. Leggat (1995).

3 Seiberling & Bloore (1986), 4. Buckland (1980).

investor. Moreover, by a happy accident, Joseph Crookes' gentlemen's outfitters was only a few doors away from number 122, the shop of the instrument maker John Newman, whose manager, Robert Murray, had a scientific and commercial interest in the new photography. Murray ensured that Newman's shop became a centre for the supply of chemicals and photographic equipment before, in 1855, he set up his own philosophical and photographic instrument firm (Murray & Heath) in Jermyn Street. Murray became a good friend to young Crookes and encouraged his interest in the chemical processes that made photography possible.[4] Crookes was a capable amateur photographer by 1848.

It was this interest that decided the 16-year-old Crookes to study chemistry with Hofmann at the Royal College of Chemistry in 1848, and it was here that he made close friends with John Spiller who shared his interest in photography and with whom he was on Christian-name terms.[5] The two friends were soon experimenting together in their spare time with photographic chemicals and roaming the countryside around London taking pictures of landscapes, or photographing their contemporaries. When Crookes completed his first chemical paper on the selenocyanides in 1851, he commented that their silver salts blackened in light and might find uses in photography. Following this, he spent at least 18 months investigating with Spiller how photographic images could be stabilized and improved. As the friends' correspondence shows, while Spiller worked at home during college vacations trying to develop a system of photographic electrotyping, Crookes was greatly concerned how to improve the quality of the paper used in Talbottypes, as Talbot' s calotypes were often called.[6] Such experimentation was all the rage amongst contemporary amateur photographers.[7] It was to this end that Joseph Crookes installed a laboratory for his son at Brook Green in 1851.

4 For a helpful chronology of Crookes' photographic work and his collaboration with John Spiller, I am indebted to John Sawkill, 'William Crookes and John Spiller: their contribution to photography particularly in the 1850s' (unpublished essay, January 1996); copy in library of the Royal Photographic Society [RPS], National Photographic Museum, Bradford. For an obituary of Robert Murray, see Murray (1856), 191. Crookes and Spiller's albumen print photograph of Murray is in the Gernsheim Collection, item 964:0383:0030.

5 See dry and wet collodion portraits of Spiller taken by Crookes in 1852, Gernsheim Collection, item 064:0387:0002–3.

6 See Crookes to Spiller, August 1851, Wellcome MS 5151 A/1 and Spiller to Crookes, 26 August 1851, MS 5151 A/3.

7 Seiberling & Bloore (1986), 3 and elsewhere.

Fig. 2.1 Masborough House at Brook Green, Hammersmith and home of William Crookes' parents. The house occupied extensive grounds at the corner of present-day Brook Green and Aynhoe Road. A photograph from the 1880s.

Photographic Improvements

In the same year, the French artist and photographer Gustave Le Gray (1820–82) published an account of the waxed-paper process as an alternative and improvement upon Talbot's calotypes.[8] Since the latter had involved printing through a paper negative, any imperfections in the grain of the paper, however thin and transparent, appeared as blemishes in the positive. It was for this reason that Niépce had replaced paper by glass in 1848, using egg whites to 'stick' the photosensitive chemicals. The disadvantage of this glass-plate 'albumen' process was that longer exposures were required. By waxing the paper before it was exposed, Le Gray overcame some, but not all, of the defects of salt-paper photography as well as restoring shorter exposure times. (Prior to this calotypes were sometimes waxed after fixing.) Crookes quickly investigated this new method, which offered the additional great advantage to photographers that film could be prepared for the camera several days or even weeks before use in the camera without deterioration. The original calotype process, on the other hand, involved preparing a film *in situ* for immediate use and therefore carrying apparatus and chemicals to wherever a photograph was to be taken. The disadvantage of Le Gray's method, which involved saturating the pores of paper

8 Le Gray (1851).

with wax before adding a surface glaze of silver nitrate, was that the developed picture could still appear spotted from particles of iron or brass produced from the machinery of the paper mill or the buttons on recycled rags used to make paper. In the summer of 1852 Crookes used his knowledge of inorganic chemistry to invent a method of eradicating these blemishes. In the autumn he made a 'photographic tour' to test the method, which he published in *Notes & Queries* in November.[9] Later, while living at Oxford, Crookes sought the advice of Story-Maskelyne on the chemical composition of different waxes, but decided eventually that it was a wax's physical properties that were more important.[10]

In developing his pictures, Crookes adopted the familiar process of placing the exposed film in a solution of gallic acid mixed with the previously used exciting mixture of silver nitrate and acetic acid. It was then washed in a strong solution of sodium hypersulphite to remove the yellowing silver iodide. Crookes laid great stress on the absolute cleanliness of the dishes used in order to prevent contamination and spoiling of the developed image. Provided photographers followed his instructions precisely, he asserted, anyone could be certain 'of getting excellent results'. He emphasized the superiority of using pre-excited papers because there was no apparatus to be carried into the field, as with the rival collodion process. Surviving waxed-paper negatives in the Gernsheim Collection show that Spiller was also involved in Crookes' investigations since there are portraits of Spiller and his relatives, as well as samples of different kinds and thicknesses of paper. Some of the photographs, according to Spiller's obituary of Crookes, were taken by Crookes in the photographic studio of Nicolaas Henneman (a former assistant of Talbot's) and Thomas Malone, which occupied rooms above Newman and Murray's premises in Regent Street.[11] The advice was warmly welcomed by readers of *Notes & Queries* and Crookes answered a few questions over the following months, revealing in January 1853 that he was conducting further experiments on further improvements he had made to the process.[12]

9 Crookes (1852b). Also, correction of a misprint, 13 November, 470; advice on using a different paper, 4 December, 541; further discussion of process, 25 December, 613–14; advice on strength of solutions, 8 January 1853, 48. The RPS owns a small handmade book, $4^{1}/_{2}$ x 6 inches, of papers iodized and waxed by Crookes, with pencilled notes on their methods of preparation. The envelope is annotated 'W.C.'s I.Br.Cl paper. 26/8/[18]53'. This and many other experimental photographs made by Crookes and Spiller were presented to the RPS by John Spiller.

10 Story-Maskelyne (1853), 24–6.

11 Spiller (1919), 189. This obituary reproduced the portraits of Crookes and Spiller now in the Gernsheim Collection.

12 Crookes (1853a). A similar welcome was given in the first and second issues of the *Liverpool Photographic Journal*, 1 (January and February 1854), 5, 18.