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Bringing Together Academic and Industrial Chemistry: Edmund Ronalds' Contribution

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Abstract. Born 200 years ago, Edmund Ronalds (1819–1889) obtained his doctorate in Germany under Liebig, became a professor at Queen's College Galway and ran the little-studied but significant Bonnington Chemical Works in Edinburgh. His few mentions in the modern literature relate generally to the legacies of his actual and assumed academic supervisors of renown, yet his hitherto unknown mentors included family members and the important chemists Graham, Magnus, Tennant and Tennent. The novelty of his shift from university to manufacture has also been noted. With the aid of little-known primary sources, this biography details the evolution of Ronalds' career, exploring the context and influences for his diverse accomplishments and in particular the new and successful ways he bridged academia and industry through technological education and industrial research.

Keywords. Chemical technology, coal-tar processing.

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UPBRINGING AND EDUCATION (1819-1842)

Edmund Ronalds, the eldest of at least twelve children, was born on 18 June 1819 at "No 1 Canonbury Square Islington", which then denoted the house on the west end of the partially-completed square (Figure 1).[1] His father Edmund Sr had lived his early years just down the road in Canonbury Place and now ran the family's large wholesale cheesemonger business in Upper Thames Street, London.[2] Edmund's mother Eliza Jemima was the only daughter of James Anderson,[3] a Scot who graduated from the University of Edinburgh and was awarded a Doctor of Laws there in 1794.[4] He ran a respected academy at Mansion House in Hammersmith offering a broad-based and vocationally-oriented curriculum.[5]

[1] The address of the house is given in Ronalds' birth registration at Dr Williams's Library (now in the National Archives) and its location can be discerned from the extended series of rate books held at the Islington Local History Centre.
[2] B. F. Ronalds, *Sir Francis Ronalds: Father of the Electric Telegraph*, Imperial College Press, London, **2016**.
[3] *Gentleman's Mag.* **1818**, *88:2*, 178.
[4] *Register of Laureations in the University of Edinburgh M.DLXXXVII–M.DCCC.*
[5] N. Hans, *New Trends in Education in the Eighteenth Century*, Routledge, London, **2001**, p. 111.

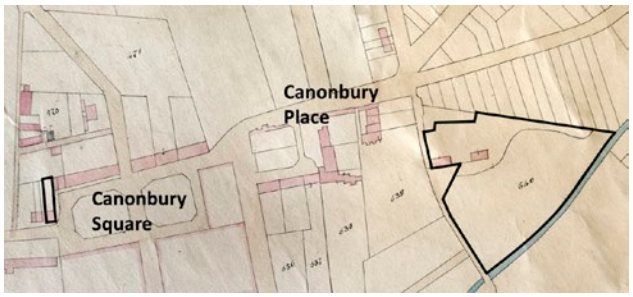

Figure 1. Locations of Ronalds' two homes in Canonbury, Islington. Source: Titheable Lands in the Parish of Saint Mary Islington, 1849, London Metropolitan Archives DL/TI/A/029/A. By permission of the Bishop of London and the London Diocesan Fund.

The family soon after moved to Brixton Hill, "nearly opposite the Telegraph",[6] where Edmund fell seriously ill[7] and a number of his siblings died. As a result, his surviving brothers were more than thirteen years his junior. Despite the spread of ages, it was a close and happy family, with later letters reminiscing of their "merry and boisterous" evenings.[8] They sang and played music together and conversation was informed by well-rounded education and their parents' friendships. Christmas Day was often spent with the Martineau family:[9] Edmund's aunt had married Peter Martineau, through whom they met his cousin, the sociologist Harriet Martineau. Edmund Sr and Eliza's associates included the early socialists and educational reformers Robert Owen and Fanny Wright. Edmund's brothers attended from about age five an "admirably-kept" preparatory boarding school[10] and his own education would have commenced in a similar manner, while his sisters were described by associates as "well educated" and read several languages.[11]

The Ronalds family being Dissenters – of the Unitarian faith – could not graduate from the English universities Cambridge and Oxford. Students of the first secular institution, University College London, were not awarded degrees until 1839. Any continuation of Edmund's studies of this kind would necessarily be undertaken elsewhere. His obituaries noted that he spent time in "Giessen, Jena, Berlin, Heidelberg, Zurich, and Paris",[12] a list that would have been provided by someone who knew him well. His entry in the *Dictionary of National Biography* and all but one of these obituaries (that written by his friend John Young Buchanan who lived near his widow and children) prefixed the descriptor "successively" to the names and, as a result, inaccurate assumptions have been made as to the identity and timing of his professors. The list is actually in a decreasing order of importance, based on such factors as stage in his education and length of attendance, and thus largely in reverse chronological order.

Edmund probably commenced his university studies in Paris as, like others in the family, he was most comfortable in French. Years later he edited a booklet for his uncle Sir Francis Ronalds in that language; Sir Francis – who was knighted for developing the first working electric telegraph – was a key influence for him and the two were always close and mutually supportive.[13] Once Edmund was sufficiently confident living abroad, and had shown his potential, he headed to the German regions and their renowned academics.

His teacher at Heidelberg could not have been Robert Bunsen as has on occasion been presumed,[14] as Bunsen was then elsewhere and Ronalds would still have been taking general courses. In late 1838 a family associate, the Unitarian diarist Henry Crabb Robinson, organised a letter of introduction to his botanist friend Professor Friedrich Siegmund Voigt at the University of Jena. Ronalds matriculated at this university on 29 April 1839 and remained three semesters, his major subject being philosophy with Jakob Friedrich Fries.[15] He had a break at home in April 1840, during which he was invited to breakfast with Robinson. His host, although admitting he did not understand science, noted in his diary that he "was pleased with him".[16]

Ronalds moved to the University of Berlin later in 1840 for the next three semesters.[17] He told his uncle Sir Francis that there it was Gustav "Magnus the professor of physicks & technology in whose laboratory I worked or rather idled a good deal of time", although he did

[6] E. Ronalds to R. Owen, 7 September 1829(?), Robert Owen Collection, National Co-operative Archive, Manchester, ROC/17/31/1.
[7] J. Lawe to E. Ronalds, 24 October 1834, Ronalds Family Papers, Harris Family Fonds, Western Archives, Western University, London, Ontario, Canada (hereafter WU), B1450.
[8] H. Ronalds to E. Ronalds, 28 March 1854, Alexander Turnbull Library, Wellington, New Zealand, qMS-1719 (hereafter ATL).
[9] S. Flower, *Great Aunt Sarah's Diary 1846–1892*, Printed privately, **1964**, p. 45.
[10] England Census, 1841; *Edmund Yates: his Recollections and Experiences*, Vol. 1, Richard Bentley, London, **1884**, p. 35.
[11] G. H. Scholefield, Ed., *Richmond-Atkinson Papers,* Vol. 1, NZ Government Printers, Wellington, **1961**, p. 473.
[12] *Proc. R. Soc. Edinburgh* **1889–1890**, *17*, xxviii; *J. Chem. Soc. Trans.* **1890**, *57*, 456; *Proc. Inst. Chem.* **1890**, *14*, 53.
[13] Ronalds, *Sir Francis Ronalds*.
[14] George Ronalds (unrelated to Edmund) studied with Bunsen at Heidelberg in the 1850s. See J. T. Krumpelmann, *Jahrbuch für Amerikastudien* **1969**, *14*, 167.
[15] University Archives Jena, Bestand BA, No. 815/9; Bestand G, Abt. 1, No. 67–72.
[16] H. C. Robinson, Diaries, 29 April 1840, Dr Williams's Library, London, with permission from the Trustees.
[17] *Amtliches Verzeichnis des Personals und der Studierenden der Königlichen Friedrich-Wilhelms-Universität zu Berlin*, Berlin, **1840–1841**, **1841**, **1841–1842**.

not neglect Magnus' colleague Heinrich Rose, whom he called "the great analytical chemist of the age".[18] It is of note that he was now orienting towards "technology"; this was already an academic field in Germany, associated with cameralism – administrative sciences promoting efficient stewardship of economic activity for the benefit of the state.[19] A short stay with Magnus' friend Justus Liebig at the University of Giessen formed the capstone of his formal education: he enrolled on 7 May 1842 and was awarded the degree of Doctor of Philosophy less than three months later on 2 August 1842.[20] He mentioned just these last two professors – Liebig and Magnus – and their laboratories in a brief statement of experience on his later professorial appointment.[21]

Ronalds' thesis, which contributed to Liebig's agricultural and physiological chemistry studies, addressed the analysis of wax by oxidation. He found that a crystalline material was produced after an extended reaction time with nitric acid; this proved to be succinic acid, which has biological functions. The work was published immediately in Liebig's journal under Ronalds' name, abstracted in *Pharmaceutisches Central-Blatt*, and quickly referenced by Charles Gerhardt, Bernhardt Lewy and Liebig himself in subsequent papers.[22]

The extent of his education and its subject matter indicate the family's affluence. When he embarked on his university training, there were few academic positions in chemistry in Britain (and even fewer for Dissenters) and these were not always salaried. It was largely his share of the family's accumulated wealth that would enable him to pursue his scientific interests while supporting a sizable future family and maintaining his accustomed lifestyle. Sir Francis had chosen this life of "gentleman scientist", determining his own research priorities and only taking on roles in an honorary capacity. Sir Francis' "chief amusement" in his youth had been chemistry.[23]

The family's religious and moral values in addition emphasised the application of knowledge acquired to bring benefit for society;[24] this ethos is apparent throughout Ronalds' career and is a central theme of this paper. The last two supervisors he chose were known for their laboratory-based teaching and gave him a strong grounding in practical science. Aided by his doctorate, a path in analytical consulting was thus also open to him. By way of example, Edmund Sr's cousin Silvanus Ronalds was Chemical Operator and a consultant with the Society of Apothecaries.[25] Another possible avenue was the growing manufacturing sector. Various members of his extended family were largescale industrialists – his uncle Peter Martineau owned and ran a sugar refinery.[26] Ronalds was to pursue all these options in the course of his career.

ACADEMIA (1842-1856)

In London

Immediately after completing his thesis, Ronalds returned home to his family, who were now living at a property of three acres called the Grove at the east end of Canonbury Place; its location is shown in Figure 1. Liebig visited him there right away – in mid-August 1842 – at the commencement of a trip around England, and kept his luggage there.[27] Liebig then met up with Thomas Graham, chemistry professor at University College, before heading to the regions.

A cousin reported the next step very soon afterwards. Ronalds had "most fortunately met with a situation exactly suited to him as assistant to a M^{r} Graham the first Chemist in London which will occupy him from 11 Oclock to 5 every day and be the means of introducing him to become a popular man himself if he makes good use of the advantages he now enjoys".[28] Liebig must have been complimentary about Ronalds' abilities. Sir Francis could also have provided a recommendation to Graham: they knew each other quite well,[29] in part through their shared interest in the Kew Observatory that Sir Francis was beginning to set up for the British Association for the Advancement of Science (BAAS).

Just as his cousin recommended, Ronalds used every opportunity to meet other chemists and be helpful. Graham having begun his career in Glasgow, there

[18] E. Ronalds to F. Ronalds, 19 June 1858, Institution of Engineering and Technology Archives (hereafter IET), 1.9.1. See: A. W. Hofmann, *Allgemeine Deutsche Biographie* **1884**, *20*, 77.
[19] E. Schatzberg, *Technology: Critical History of a Concept*, UCP, Chicago, **2018**, p. 77–81.
[20] F. Kössler, *Register zu den Matrikeln und Inscriptionsbüchern der Universität Giessen 1807/08–1850*, Universitätsbibliothek, Giessen, **1976**, p. 155; Kössler, *Verzeichnis der Doktorpromotionen an der Universität Giessen von 1801–1884*, Universitätsbibliothek, Giessen, **1970**, p. 84.
[21] *Galway Vindicator*, 11 August 1849, 2.
[22] E. Ronalds, *Ann. Chem.* **1842**, *43*, 356. Summarised in *Pharmaceutisches Central-Blatt* **1842**, *2*, 926.
[23] F. Ronalds to S. Carter, 21 February 1860, University College London (UCL) Special Collections, GB 0103 MS ADD 206.
[24] Ronalds, *Sir Francis Ronalds*, pp. 53–54, 93–94.
[25] A. E. Simmons, *The Chemical and Pharmaceutical Trading Activities of the Society of Apothecaries, 1822 to 1922*, Ph.D. Thesis, The Open University, UK, **2004**.
[26] B. F. Ronalds, *Martineau Society Newsletter* **2018**, No. 41, 10.
[27] J. Volhard, *Justus von Liebig,* Vol. 1, Verlag, Leipzig, **1909**, p. 160.
[28] M. Ronalds to H. Ronalds, 12 October 1842, WU, B2284.
[29] Ronalds, *Sir Francis Ronalds*, p. 546.

was a steady stream of Scots to his laboratory. He was the founding president of the Chemical Society of London and the Cavendish Society,[30] and Ronalds joined both immediately, becoming a council member of the latter. Another original member of these organisations was John Tennent, denoted erroneously at times as "Tennant".[31] Both Johns – Tennent and Tennant – had grown up in the Glasgow area, studied chemistry under Thomas Thomson (as had Graham)[32] and became chemical manufacturers, and both would be prominent in Ronalds' future. The two men have been confounded over the years. For example, the Chemical Society's Jubilee Album featuring its founding members contains Tennant's rather than Tennent's portrait.[33]

Tennant (1796-1878) was the managing director of the "gigantic" Charles Tennant & Company established by his father, with its St Rollox chemical works that made bleaching powder.[34] Tennent (1813–1862) was the son of Barbara née Graham and Hugh Tennent, who helped run the famous Tennent Brewery. It was apparently the Tennent family who sold the land for St Rollox to the Tennants.[35] John Tennent and John Tennant partnered in the Bonnington Chemical Company in 1847, with the former being the manager of the facility.[36]

There was in addition a strong network of alumni from the universities Ronalds had attended. Former Giessen students Edward Frankland and Robert Angus Smith both asked him to be a referee when they applied for the professorship at Owens College, Manchester.[37] Ronalds also hosted numerous visitors that he had met abroad. Within weeks of arriving home, he had as guests "2 young Hungarians who could not speak one word of English but they were very animated & agreeable, both professors".[38] Fortunately several family members could contribute to the conversation in German.

Liebig visited again in 1844. It was Graham who took him to visit Sir Francis at the Kew Observatory on 4 September[39] and both also went to the BAAS annual meeting at York. This was the first BAAS conference that Ronalds and his uncle attended,[40] and he would have been proud to be associated with these mentors while meeting more of their associates. In 1851 Liebig visited him in Galway.[41]

Ronalds became a member of the BAAS in 1846[42] and, slowly gaining confidence, contributed increasingly to the technical discussions there.[43] He served as secretary of the chemical science section at the 1852 meeting held in Belfast and later as section vice-president at Edinburgh in 1871 and Sheffield in 1879. This was perhaps one of the ways he kept in touch with Magnus, who also visited him, his uncle and the Kew Observatory on a trip to England.[44] Ronalds in addition translated and summarised papers by his colleagues (as well as Liebig's) for publication in English journals.[45]

Already he had mix of experiences relevant for his later career path across academia and industry. He had started with a sojourn in Germany, where he received the best practical chemistry training in a culture of science utilisation, along with numerous contacts and associated kudos. He was now active in the overall chemical profession at its hub in his London hometown, with its links to commerce and government. He had friends and family from Glasgow and Edinburgh, important industrial centres that had close connection with their universities, and he was interacting with other chemists and industrialists at the BAAS. These built on the foundation of his Unitarian circle with its accent on societal benefit through education. Although the groupings overlapped significantly, as Bud and Roberts have illustrated through Lyon Playfair and others, Ronalds was unusual in having the influence of all of these education-practice networks early in his academic career.[46]

He now determined to develop his teaching skills and was soon giving lectures in London and further afield. On 19 February 1845, for example, he lectured on "Chemical principles of Gas Manufacture" at the Derby Mechanics' Institution and he taught at a school in Worksop, near Sheffield, that had a chemical laboratory.[47] Beginning in October 1845 he gave lectures at the

[30] W. H. Brock, *Ann. Sci.* **1978**, 35, 599.
[31] See for example: *Proc. Chem. Soc.* **1842**, *1*, 1.
[32] R. D. Thomson, *Edinburgh New Philosophical J.* **1853**, *54*, 86.
[33] *Jubilee of the Chemical Society of London*, Chem. Soc., London, **1896**, p. 24.
[34] *Glasgow Herald*, 18 April 1878, 4.
[35] Tennent Family Trees, University of Glasgow Archive Services, GB 248 T 13/1; G. Stewart, *Curiosities of Glasgow Citizenship*, James Maclehose, Glasgow, **1881**, p. 239.
[36] J. A. Anderson, Bonnington Chemical Works, 1851, National Records of Scotland (hereafter NRS), CS313/946; *Proc. Chem. Soc.* **1868**, *21*, xxix.
[37] E. Ronalds to E. Frankland, 10 May 1850, Papers of Sir Edward Frankland, Special Collections, University of Manchester, RFA OU mf 01.03.0900.
[38] E. Ronalds to H. Ronalds, 2 October 1842, WU, B558.
[39] Kew Observatory Diary and Accounts, 1844, National Meteorological Library and Archive, Exeter.
[40] Ronalds, *Sir Francis Ronalds*, p. 336.
[41] E. K. Muspratt, *My Life and Work*, John Lane, London, **1917**, p. 36.
[42] *Report of the 59th Meeting of the British Association for the Advancement of Science*, John Murray, London, **1890**.
[43] For example: *Annual of Scientific Discovery: or, Year-book of Facts in Science and Art*, Gould and Lincoln, Boston, **1850**, pp. 207–08; *Daily News*, 9 September 1852, 3.
[44] E. Ronalds to F. Ronalds, 19 June 1858.
[45] For example: *Philos. Mag.* **1846**, *28*, 161, and *29*, 25, 31.
[46] R. Bud, G. K. Roberts, *Science versus Practice: Chemistry in Victorian Britain*, MUP, Manchester, **1984**.
[47] *Derby Mercury*, 15 January 1845, 2; Muspratt, *My Life and Work*, p.

Aldersgate School of Medicine through the winter session and offered practical classes three days per week – this increased to four days the following year.[48] He was additionally lecturing regularly at the Middlesex Hospital School of Medicine and offering "Private Instruction in CHEMICAL MANIPULATION and ANALYSIS… at the Laboratory of the Hospital School" there.[49] The latter was affiliated with the nearby University College.

His role as "Lecturer on Chemistry at the Middlesex Hospital" was a continuing appointment and he began to use it as his affiliation for publications and in societies. The chemical laboratory was available to him to conduct consulting activities and research. He quantified the copper content of ores provided by the Australian Mining Company from their proposed Tungkillo mine near Adelaide, and published the results in the literature.[50] Mining continued there for some years.

He also devised and performed tests to assist medical questions. He discovered taurine in human bile, which was announced in the *Chemical Gazette* by his Giessen friend William Francis (who was later a partner in Taylor and Francis publishers).[51] Links between the impurities in water and its utility were beginning to be considered in this period and he undertook water quality analyses in several locations. These included the water supply for the new railway town of Wolverton, to help determine the best treatment for ailments experienced by residents, and spring water from the Colne Valley near Watford that was proposed to be pumped to Hampstead.[52] He also studied how the amount of organic matter taken up by water from peat increased with its temperature.[53]

On 18 June 1846 Golding Bird, a physician at Guy's Hospital, read a paper by Ronalds to the Royal Society. He had shown in what was viewed as "a series of well-devised experiments"[54] that urine contained sulphur and phosphorus in both unoxidised and oxidised states and quantified the amounts in 24-hour urine tests. The higher unoxidised sulphur in a diabetic patient illustrated the potential use of the results in diagnosis. The article was included in the *Philosophical Transactions* and republished in the *Philosophical Magazine* and German journals.[55] The results were quickly picked up in summaries of medical advances and in pathology lectures and continued to be referenced into the twentieth century.[56]

Figure 2. Edmund Ronalds, photographed in May 1878 by George Shaw in Edinburgh. Source: Sir George Grey Special Collections, Auckland Library, New Zealand, NZMS 1235.

With his reputation growing, Ronalds (Figure 2) was given the opportunity to undertake two significant projects. Becoming secretary of the Chemical Society, he was the inaugural editor of its first journal. He was responsible for the first two volumes of the *Quarterly*

36. The school was founded on Johann Pestalozzi's educational philosophy, with which Ronalds' aunts had strong links, and the principal Dr Benjamin Heldenmaier was active in the Derby Mechanics' Institution.

[48] *Morning Chronicle*, 22 September 1845, 5; *Lancet* **1845**, *46*, 339; *Lancet* **1846**, *48*, 345.

[49] *Exeter Gazette*, 19 September 1846, 2; *Athenæum* **1846**, 1009; *Lancet* **1847**, *50*, 361.

[50] E. Ronalds, *Chemical Gazette* **1846**, *4*, 463.

[51] *Chemical Gazette*, **1846**, *4*, 281, 295; *Lancet*, **1848**, *52*, 335.

[52] G. Corfe, *Pharmaceutical Journal and Transactions* **1849**, *8*, 30, 71; *Morning Post*, 11 January 1850, 5.

[53] *Q. Rev.* **1850**, *87*, 479.

[54] G. Day, *Half-yearly Abstract of the Medical Sciences* **1847**, *5*, 285.

[55] E. Ronalds, *Philos. Trans. R. Soc. London* **1846**, *136*, 461. Also in: *Philos. Mag.* S3 **1847**, *30*, 253; *Journal Prakt. Chem.* **1847**, *41*, 185; *Notizen aus dem Gebiete der Natur- und Heilkunde* **1847**, *3*, 214.

[56] For example: A. B. Garrod, *Lancet* **1848**, *52*, 441, 469, 599; *Sci. Am.* **1869**, *21*, 249; J. J. Rae, *Biochem. J.* **1937**, *31*, 1622.

Journal published in 1849 and 1850, and received an honorarium of £50 each year. He incorporated a list of all papers published in chemistry locally and overseas and prepared abstracts of interesting papers appearing in foreign language journals.[57] When he retired to move to Galway, Henry Watts was employed as a paid editor but, unlike Ronalds, his name did not appear on the title page.

Chemical Technology

The other project was a large book. Friedrich Ludwig Knapp, professor of technology at the University of Giessen, was preparing a text called *Lehrbuch der chemischen Technologie* and it would have been his brother-in-law Liebig who invited two of his past students, Ronalds and Thomas Richardson, to translate it into English. The preface to the first volume of their edition bore the same date of 1847 as Knapp's work and so they must all have been working in concert. In the English publication, entitled *Chemical Technology; or, Chemistry Applied to the Arts and to Manufactures*, Knapp was denoted as the author and it was "edited with numerous notes and additions" by Ronalds and Richardson; it was of credit to Ronalds to be the first-named of these two authors so early in his career. Their additions to the book included "excellent" figures[58] to give a total of over 550 illustrations. Knapp's first volume covering fuel, alkalies and earths was split into two, both appearing in 1848, and their third volume on food was completed in 1851.[59] They formed part of a new Library of Illustrated Standard Scientific Works published by Hippolyte Bailliere in London.

Although Ronalds downplayed the academic rigour of the book, calling it before it appeared "a merely popular treatise",[60] its research would have deepened his technical knowhow across the breadth of British chemical manufacture. Colleagues and family members like Tennent, Tennant and Martineau who owned processing plants offered assistance and in return benefited from the resulting amalgamation of current scientific thinking with industry best practice and trends.

Reviews in the press were very positive. The opinion of the *Athenæum* was that "To the manufacturer this publication must prove eminently useful" and it is also "most valuable as one of general reference".[61] The *Economist* highlighted "the good judgment of the translators, who have… done a great service to the public". "Scientific knowledge… is explained in a simple manner" while "Scientific men will hail with delight the quantity of practical information". "It is a book for everybody".[62] Even the *Lancet* gave a page-long review. Overseas, *Scientific American* called it a "great work" while the *Journal of the Franklin Institute* wrote that "The English editors have also performed their task with talent and faithfulness, as is evidenced by the large and judicious additions which they have made, describing British inventions and improvements, and giving us the latest results of British science and ingenuity".[63] An American edition of the first two volumes was quickly published in which Walter Rogers Johnson made further additions emphasising US industry.[64]

There was initially little mention of the potential value of the book in formal education. The authors had lamented in their preface the lack of higher education establishments with a technical emphasis. Chemist George Wilson was the first professor of technology in Britain and he explained in his inaugural lecture in Edinburgh in 1855 that "the word Technology has been introduced into our language" through the book.[65] Subsequent assessments suggest comparable conclusions on the text's novelty and significance.[66] "Technology" has a Greek etymology and, because it was then in few dictionaries, was described by the authors as "the systematic definition (λογος) of the rational principles upon which all processes employed in the arts (τεχνης) are based"; (after coming into use its meaning altered in the twentieth century as described by Schatzberg).[67] Their focus was thus a framework to aid understanding, use and development of plant processes, equipment etc. *Chemical Technology* can be considered to be a key early emphasis outside Western Europe on a distinct educational discipline of chemistry application for industry.[68]

Ronalds and Richardson soon began work on an updated edition of *Chemical Technology*. This became

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[57] R. S. Cahn, *Proc. Chem. Soc.* **1958**, 157.
[58] *Sci. Am.* **1855**, *11*, 112.
[59] F. Knapp, E. Ronalds, T. Richardson, *Chemical Technology; or, Chemistry Applied to the Arts and to Manufactures*, Bailliere, London, **1848–1851**.
[60] E. Ronalds to L. L. Dillwyn, 20 September 1848, Swansea University Archives, GB 217 LAC/26/D/55.
[61] *Athenæum* **1849**, 321.
[62] *Economist*, 2 December 1848, 1364.
[63] *Sci. Am.* **1852**, *7*, 221; *J. Franklin Inst.* S3 **1848**, *15*, 449.
[64] Johnson's career is described in: G. E. Pettengil, *J. Franklin Inst.* **1950**, *250*, 93.
[65] G. Wilson, *What is Technology?* Sutherland and Knox, Edinburgh, **1855**. See also: R. G. W. Anderson, *Br. J. Hist. Sci.* **1992**, *25*, 169.
[66] Schatzberg, *Technology*, pp. 81–82, 91–94; J. M. van der Laan, *Narratives of Technology*, Springer, New York, **2016**, pp. 25–27; R. P. Multhauf, *The History of Chemical Technology: An Annotated Bibliography*, Garland, New York, **1984**; Bud, Roberts, *Science versus Practice*, p. 108.
[67] E. Schatzberg, *Technology and Culture* **2006**, *47*, 486.
[68] W. Schneider, *Neue Deutsche Biographie* **1979**, *12*, 151. Schatzberg, *Technology*, p. 81.

essentially a new work, much rewritten and enlarged. They were now the named authors, but noted that it "incorporated a revision of Dr Knapp's "Technology"". The text needed to be further divided, and the first two volumes covering Fuel and its Applications were published in 1855. They also received strong reviews, the *American Journal of Science* calling it "by far the most full, scientific and satisfactory exposition of the subjects of Fuel and Illumination to be found".[69]

Ronalds' priorities changed abruptly in this period, as explained below, and he stepped aside after these two volumes. Richardson and his new co-author Henry Watts completed the material on Acids, Alkalies, and Salts in 1867, which is the year Richardson died.[70] That it took twelve years to issue these later books hints at the scale of Ronalds' contribution to the earlier ones. The volume on food was not updated.

The overall book "became a standard work" internationally;[71] it was still advertised for sale in the *Chemical News* in the 1870s. Material was commonly quoted in other texts[72] and is referenced today in histories of the chemical industry to explain nineteenth-century processes.[73] It stood the test of time for over thirty years.

Watts had begun preparing an update before his death in 1884 and Charles Edward Groves, who replaced him as editor of the Chemical Society's journal, then took on the role of general editor for a new edition with oversight of numerous authors.[74] The first volume emerged in 1889 – the year Ronalds died – followed by three more in the period to 1903. The preface erroneously described them as being founded on Richardson and Watts' work but in fact they covered only fuel and lighting and thus used Ronalds and Richardson's volumes as their basis. This edition also received good reviews and maintained the strong reputation of the title. It is of interest that editors of the Chemical Society journals played a leading role in all the versions.

Chemical Technology featured increasingly in university education over time. It was included in the recommended library list published by the Canadian *Journal of Education* as early as March 1854.[75] Ronalds presented the 1848–1851 edition to the Queen's College Galway library and subsequent versions were acquired by the college as well. The 1855–1867 and 1899–1903 editions are held by innumerable universities around the world and Kikuchi has outlined how they would have been used in teaching.[76] Putting this progression into context, university chairs in chemical engineering were only established in the early twentieth century.[77]

In Galway

Non-denominational higher education had commenced in Ireland in 1849 with the creation of the Queen's University of Ireland, which awarded degrees for the new Queen's Colleges of Belfast, Cork and Galway. These offered academic positions for which a Dissenter like Ronalds was eligible and he was appointed as the inaugural chemistry professor at Galway at age thirty. His salary would be £200 plus additional student fees.[78]

He asked Sir Francis to dine with him in Canonbury on 14 October 1849 to say farewell, along with Graham, and also Thomas Andrews, who was the first vice-president of Queen's College Belfast. He suggested his uncle's "advice about the purchases of physical apparatus would be of service to the irish colleges".[79] Ronalds and his sister left London immediately afterwards and were in Galway in a week.[80]

He gave his introductory chemistry lecture on 11 December.[81] Impatient to begin in earnest, he complained to Sir Francis the next February that "the intolerably dawdling habits of all workmen in this place has prevented me from yet getting to work in the laboratory. I do not think I shall be able to begin my course for some weeks".[82] Once up and running, he delivered up to 140 lectures each year at the college, around 40 being in practical chemistry in the laboratory,[83] and "he was

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[69] *Am. J. Sci. Arts* S2 **1856**, *22*, 149.
[70] E. Ronalds, T. Richardson, H. Watts, *Chemical Technology; or, Chemistry in its Applications to the Arts and Manufactures*, Bailliere, London, **1855–1867**.
[71] "Richardson, Thomas (1816–1867)", *Oxford Dictionary of National Biography*.
[72] Muspratt, for example, referred to "the valuable treatise" numerous times in his *Chemistry, Theoretical, Practical & Analytical*, William Mackenzie, Glasgow, **1860**.
[73] For example: C. A. Russell, *Chemistry, Society and Environment: A New History of the British Chemical Industry*, Royal Society of Chemistry, Cambridge, **2000**.
[74] W. H. Brock, *The Case of the Poisonous Socks: Tales from Chemistry*, Royal Society of Chemistry, London, **2011**, p. 247.
[75] *Journal of Education for Upper Canada*, **1854**, *7*, 33.
[76] Y. Kikuchi, *History of Science* **2012**, *50*, 289. See also: *Anglo-American Connections in Japanese Chemistry: The Lab as Contact Zone*, Palgrave Macmillan, New York, **2013**, p. 44.
[77] C. Divall, S. F. Johnston, *Scaling Up: The Institution of Chemical Engineers and the Rise of a New Profession*, Kluwer, Dordrecht, **2000**.
[78] A. J. Ryder, *An Irishman of Note: George Johnstone Stoney*, Printed privately, **2012**, pp. 89–92.
[79] E. Ronalds to F. Ronalds, 12 October 1849, IET, 1.3.332.
[80] *Freeman's Journal*, 23 October 1849, 2.
[81] *Galway Vindicator*, 28 November 1849, 3.
[82] E. Ronalds to F. Ronalds, 9 February 1850, IET, 1.3.362.
[83] See for example: *Report of the President of Queen's College, Galway,* for the academic year 1852–53, HMSO, Dublin, **1854**, p. 7; and, for the year 1856, **1857**, p. 4.

remembered as a successful and inspiring teacher".[84] His first course outline and examination questions survive in the college calendar.[85] In 1854 he was able to take on Edward Divers as an assistant to help with the demonstrations.

Giving his new affiliation on the title page of *Chemical Technology* would have been a welcome boost to the reputation of the embryonic university. It was formally listed as a course textbook by Ronalds' successor.[86] Teaching of "chemistry applied to the arts and to manufactures" began to receive attention at various colleges from around mid-century, and Galway is an early example that has gone unnoticed in previous analyses of this curricular development. With his authorship and German education, Ronalds' approach was presumably more rational and balanced than efforts elsewhere in Britain, which matured only very slowly as alluded to above. Donnelly and others have discussed how this was in part because academics argued that their preferred "pure" chemistry was what industry needed, hinting at an academic elitism that appears again below. The technology chair at Edinburgh lapsed with Wilson's death in 1859 for similar reasons.[87] Ronalds suffered the disadvantage however of Galway having limited manufacturing industry and thus needing to rely on the book to illustrate how different chemical processes could be deployed at scale.[88]

He pursued other teaching opportunities as well. He gave a course of nine public lectures illustrated by "a series of beautiful and highly-successful experiments" under the auspices of the Board of Trade and the Royal Galway Institution. The press was most complementary about "the able and talented lecturer" – "we have never attended any Lectures with more pleasure". One commentator did regret however that he "does not avail himself of the opportunities… of directing the attention of the hearers to that Great and Almighty Being".[89] This was a reflection of widespread antipathy towards the new "godless colleges".[90]

He quickly adopted a priority of investigating local natural resources with a view to possible new and enhanced industries for the area, which had suffered terribly during the recent potato famine; the results would also have informed his lectures. He analysed peat found in different situations in Galway, including the quantity and composition of its ash and how the water content varied with drying method, both of which affected its value. The results were summarised in *Chemical Technology* (1855), repeated almost verbatim in the 1889 edition and continued to be quoted into the next century.[91] He had earlier studied the ash of several coals and these data were included in both editions of the book as well. He also analysed a peat fertiliser and fungicide for a new company.[92] He later donated "Specimens illustrative of the products of the destructive distillation of wood, bones, and coal, &c" to the Museum of Irish History in Dublin.[93]

The Irish press was delighted to announce in September 1852 that "The eminent authoress" Harriet Martineau was "on a visit with Dr. Ronalds".[94] She described in the national *Daily News* and in her subsequent book that the "professor of chemistry" attempted to demonstrate how the local red seaweed could be burnt to produce iodine and potash salts to supplement its traditional use as a fertiliser.[95] The locals, after accepting his advance payment to conduct a trial, apparently declined to participate. The new industry did develop however and continued into the twentieth century.[96]

She also highlighted work he presented to the 1852 BAAS meeting on the oil of the basking shark, which was found off the Bay of Galway. The fish contained large quantities of a very light oil and Ronalds emphasised its unusual and valuable properties, including its bright flame and possible medicinal uses, in the hope that the fishermen might obtain a higher price for it in new applications. The results were summarised in the *Athenæum*, published in the *Chemical Gazette* and included in *Chemical Technology* and other texts.[97] He also advised Sir Francis in this period on oil lighting for the continuously-recording cameras he had developed. In return he later teased his uncle that he "may possi-

[84] *Dictionary of Irish Biography,* Vol. 8, CUP, Cambridge, **2009**, pp. 597–98.
[85] *Calendar of Queen's College, Galway*, Hodges and Smith, Dublin, **1851**.
[86] See for example: *Report of the President of Queen's College, Galway,* for the academic year 1863–64, HMSO, Dublin, **1865**, p. 22; and, for the year ending 31st March, 1867, **1867**, p. 24.
[87] J. F. Donnelly, *Social Studies of Science* **1986**, *16:2*, 195; J. F. Donnelly, *History of Education* **1997**, *26:2*, 125; Bud, Roberts, *Science versus Practice*; Schatzberg, *Technology*, pp. 64–65; J. F. Donnelly, *Chemical Education and the Chemical Industry in England from the Mid-Nineteenth to the Early Twentieth Century*, Ph.D. Thesis, University of Leeds, UK, **1987**; Anderson, *Br. J. Hist. Sci.*
[88] Kikuchi, *History of Science*.
[89] *Galway Vindicator*, 10 February 1855, 2; 5 May 1855, 2.
[90] J. O. Ranelagh, *A Short History of Ireland*, 3rd Ed. CUP, Cambridge, **2012**, p. 141.
[91] W. A. Kerr, *Peat and its Products*, Begg, Kennedy & Elder, Glasgow, **1905**, p. 27.
[92] *Galway Vindicator*, 28 August 1852, 3.
[93] *Fourth Report of the Department of Science and Art*, HMSO, London, **1857**, p. 94.
[94] *Freeman's Journal*, 3 September 1852, 2.
[95] *Daily News*, 3 September 1852, 4; H. Martineau, *Letters from Ireland*, John Chapman, London, **1852**, pp. 82–91.
[96] G. H. Kinahan, *Q. J. Sci.* **1869**, *6*, 331.
[97] E. Ronalds, *Chemical Gazette* **1852**, *10*, 420. Also in: *Athenæum* **1852**, 1042. Summarised in: H. Watts, *Dictionary of Chemistry and the Allied Branches of other Sciences*, Vol. 5, Longmans, London, **1868**, p. 404.

bly… find time to make me that glass float w^{h} has been five & twenty years in process".[98] Ronalds was presumably wanting a better hydrometer.

FROM UNIVERSITY TOWARDS INDUSTRY

The 1850 BAAS meeting had been held in Edinburgh. On 23 December that year Ronalds married his friend Tennent's sister Barbara Christian at her mother's home: 128 Wellington Street, Glasgow.[99] The couple went on to have three daughters followed by three sons.

Not long afterwards, the Ronalds family suffered a major change of fortune. With Edmund Sr's younger sons now completing their schooling, he wished to fund their establishment in life. He had borrowed £12,000 from his elderly mother during the economic recession of the late 1840s and, on her death in 1852, the family cheesemonger business was sold and he invested his inheritance in a large silk mill in Derby that was in debt. The idea was that his son Hugh would learn the business and then start running it. Instead the current managers apparently absconded with the money.[100] A cousin summed up the outcome for Edmund Sr: "he must be much reduced in circumstances as two of his daughters have been obliged to go out as Governesses".[101] One went on to establish a respected school and another became a nursing sister. Their brother Hugh later reminisced about "the careless way I thought of money and time… no care or anxiety for the future" in the years before "the smash".[102]

Another of the sons had attended Queen's College Galway for a year, but did not continue his studies.[103] The three young men, aged eighteen, nineteen and twenty, set sail for New Zealand in February 1853 with their fares and early subsistence funded by Uncle Martineau. It was intended that the rest of the family would follow once they were settled as it was "mother's wish… to fly from all society" and escape her embarrassment. After arriving, however, Hugh quickly warned her not "to induce Edmund to come out, the settlement is too young and poor to attempt any experiments… I suppose there is no chance of his thinking of giving up his chymistry".[104] In the meantime Edmund Sr and Eliza joined Ronalds in Galway. Eliza's death there altered plans – two of Ronalds' sisters joined their brothers but the rest of the family remained in Britain.

The brothers took labouring work to support themselves while clearing a farm in the bush outside New Plymouth. Ronalds tried to help as he could, sending money and practical agriculture books. He was elected Examiner across the three Queen's Colleges, which supplemented his income by £100, and became Dean of Science and a member of the Galway College Council.[105]

This same year, 1853, his brother-in-law Tennent became a partner in Charles Tennant & Company and manager of the St Rollox works.[106] Ronalds had the opportunity to move into a much more remunerative role running the Bonnington chemical works. With him having other commitments however, Tennent's brother Hugh Brown Tennent, the assistant manager, cared for the facility until his death two years later.

CHEMICAL MANUFACTURE (1856-1878)

In March 1856 Ronalds and Barbara were able to leave their home at Nun's Island in Galway and relocate to Bonnington:[107] he had extricated himself from his academic duties, the two *Chemical Technology* volumes were printed, and their new baby was three months old. Tennant, Tennent and Ronalds had all been on the chemical science committee for the BAAS meeting in Glasgow the previous September (with Liebig also being an attendee),[108] which is perhaps where the handover was organised. Ronalds became a partner in the Bonnington Chemical Company, with his contribution being the management of the facility. Tennant and Tennent remained non-active partners, the company being under the Tennant corporate umbrella.[109]

That Ronalds' career change was atypical has been noted by Fox and Guagnini in their discussion of applied science, but without comment on the context.[110] There were many interactions between universities and industry in his education-practice networks outlined earlier, and elsewhere, but it was very rare to swap sec-

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[98] E. Ronalds to F. Ronalds, 30 March 1858, IET, 1.9.1.
[99] *Glasgow Herald*, 27 December 1850, 2.
[100] *Derby Mercury*, 27 April 1853, 4.
[101] H. Ronalds, Diary, 1851–1854, WU, B1462.
[102] H. Ronalds to M. Ronalds, 14 November 1854, ANL; E. Ronalds to J. Greg, 7 October 1928, Ronalds Family Papers, Sydney, Australia.
[103] *Queen's Colleges (Ireland), Return to an Order of The House of Commons dated 25 May 1857*, p. 22.
[104] H. Ronalds to M. Ronalds, 14 November 1854, H. Ronalds to E. Ronalds, 19 September 1853, ATL.
[105] *Cork Examiner*, 26 June 1854, 2; *Nenagh Guardian*, 29 October 1853, 1.
[106] *One Hundred and Forty Years of the Tennant Companies 1797-1937*, Tennant Companies, London, **1937**, p. 2.
[107] *Galway Mercury*, 15 March 1856, 3.
[108] *Athenaeum* **1855**, 1092.
[109] Bonnington Chemical Company v. Gibson and Walker, 1868, and 1874, NRS, CS242/203, CS242/208.
[110] R. Fox, A. Guagnini, *Hist. Stud. Phys. Biol. Sci.* **1998**, *29*, 55, esp. 75–76.

tors and integrate an academic experience base into the running of an established manufacturing business. Generally in such interactions the academic passed across scientific knowledge while ensuring their distinctive position: "they presented themselves above all as the theorists of industry… without becoming wholly assimilated in the industrial world"; they were the "elite".[111] Indeed, it has been presumed on occasion that Ronalds must have been "a chemist" or "consultant" at Bonnington rather than the managing partner.[112]

His closest university associates adopted comparable approaches, even in Germany with its cameralist links between state, commerce and science. Magnus supported "technology" through university teaching and research in experimental science, by visiting factories and advising government. In enthusiastically promoting industrial application of his research ideas, Liebig provided scientific guidance (often through his assistants), while also seeking commercial returns to supplement his academic income. Knapp aided Liebig in several of these endeavours and held the position of technical director at a government porcelain manufactory for a time – together with his professorship. Richardson's career was the other way round: he specialised in industrial chemistry at several different plants, and after a few years also took an appointment as a lecturer. Another Giessen associate, August Wilhelm Hofmann, Director of the Royal College of Chemistry, proudly associated himself with a further and oft-quoted model of technology transfer – his student William Perkin discovered the coal-tar dye mauveine in 1856; Perkin became what Homburg has called an "inventor-entrepreneur" when he established a factory and entered into production.[113] As a final example, Kranakis has identified academics who melded theory and practice in noteworthy "hybrid careers", but they did so while remaining attached to the university.[114]

Ronalds contrasts with these and other cases in that he moved at top level and permanently from academia to an operating manufacturing firm where he had little first-hand experience, and took responsibility overall rather than for technical aspects. Sharing scientific knowledge was part of his role but the imperative was to quickly acquire quite different skills while building credibility as the manager. Universities and manufacturing facilities were highly disparate entities in this era, which made the transfer demanding and risky. It was only later when industrial companies had research laboratories, universities became businesses, and the class structure changed that advantages could be seen in senior staff cross-fertilisation.[115]

An early ramification of Ronalds' move was an altered standing in the community in comparison with being a professor: he quipped to Sir Francis that he was now "completely ignored, as a tradesman, by the entire society".[116] Fortunately, as outlined below, status was of little concern to him. In the same light-hearted vein, he explained: "I have entirely changed my mode of life & have (with a view to the future of the bairns) taken seriously to money grubbing, an occupation sufficiently disgusting & only tolerable in consideration of the results which I hope may be successful". Like his uncle, he was unaccustomed to the marketing, sales and negotiation side of business and also ill-suited to it with his retiring nature. More importantly, there was a lot to learn about the plant and he admitted (with some self-deprecation) that he had "been kept & am still very hard at work, having hardly had time to master the details of manufacture & trade".

Despite these challenges, he welcomed his new opportunity. Not only could he now better support the Ronalds family, but he was responsible himself for the type of largescale manufacture he had before only written about and could trial ideas suggested by his studies. Barbara would also have enjoyed returning to family and friends in Scotland. It can be surmised however that without the trigger of financial distress he would not have taken on the job and also that its risks would have been too great if he not researched *Chemical Technology* and had the support of his relationship with Tennent. His partners, having studied at university, would also have appreciated that his alternative skillset could bring plant innovations. A career change from the academic to the manufacturing world at that time almost certainly required special circumstances, notwithstanding the potential benefits it brought.

The Bonnington chemical works was located close

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[111] Fox, Guagnini, *Hist. Stud. Phys. Biol. Sci.* 79; See also: Bud, Roberts, *Science versus Practice*; E. Homburg, *Isis* **2018**, *109*, 565; E. Schatzberg, *Isis* **2012**, *103*, 555; *Technological Development and Science in the Industrial Age: New Perspectives on the Science-Technology Relationship*, (Eds.: P. Kroes, M. Bakker), Kluwer, Dordrecht, **1992**, pp. 1–15.

[112] W. H. Brock, *Ambix* **2013**, *60*, 203; W. H. Brock, *Justus Von Liebig: The Chemical Gatekeeper*, CUP, Cambridge, **1997**, p. 349.

[113] Hofmann, *Allgemeine Deutsche Biographie* ; Brock, *Justus Von Liebig*; Schneider, *Neue Deutsche Biographie* ; "Richardson, Thomas", *Oxford Dictionary of National Biography*; L. F. Haber, *The Chemical Industry during the Nineteenth Century*, OUP, Oxford, **1958**, pp. 80–87; Donnelly, *Social Studies of Science*; E. Homburg, *Br. J. Hist. Sci.* **1992**, *25*, 91.

[114] E. Kranakis in *Technological Development and Science in the Industrial Age*, pp. 177–204.

[115] On when and how manufacturing firms developed research arms, and their links with academia, see for example: Homburg, *Br. J. Hist. Sci.*, and D. A. Hounshell and J. K. Smith, Jr., *Science and Corporate Strategy: Du Pont R&D, 1902–1980*, CUP, Cambridge, **1995**.

[116] E. Ronalds to F. Ronalds, 30 March 1858.

to the Water of Leith on Newhaven Road, Edinburgh. It was a pioneer coal-tar processing facility established around 1822 to distil naphtha from the residues of the Edinburgh gasworks for Charles Macintosh's eponymous waterproof fabrics; Macintosh's firm was a special customer for two decades and probably longer.[117] The plenteous residues were transported from the gasworks to Bonnington by a dedicated pipeline over Calton Hill. In the words of Ronalds' Giessen friend Professor Frederick Penny, the processing works were "so extensive and so important" and were now run by "a distinguished scientific and practical chemist".[118]

Within months of arriving, Ronalds donated a large series of specimens to the Industrial Museum of Scotland showing the numerous intermediate, final and by-products created from gasworks waste.[119] The collection formed a valuable companion to the descriptions and illustrations of coal-tar processing in *Chemical Technology* and was used by the museum director (technology professor Wilson) as a teaching aid. From Ronalds' perspective, by looking outward to support technological education he was seemingly already in command of his role, which indicates both his prior understanding of industry practices and his adaptability.

His detailed summary of plant operations was published in the *Cyclopædia of Useful Arts*.[120] Bonnington's most important products were rectified naphtha, creosote, sal ammoniac (ammonium chloride), ammonium sulphate, and anticlor (sodium thiosulphate). He noted that "we have a good deal of business with the owners of the steamers"[121] exporting these commodities around the world and indeed George Seater, the director of the Leith, Hull & Hamburg Steam Packet Company, christened his son "Edmund Ronalds". He also made all his sulphuric, hydrochloric and sulphurous acid requirements and a new acid plant was the first facility he commissioned. Figure 3 shows the plan of the facility from the 1876 ordnance survey map. Comparing this with the first survey in 1852 indicates the extent of his alterations, with the facility's footprint increasing from two to approaching three acres. One of the motivations for the enhancements he made (including waste-gas capture equipment and a large new chimney) was to reduce emissions, which was an emphasis in *Chemical Technology*. The gamble of his appointment had paid off.

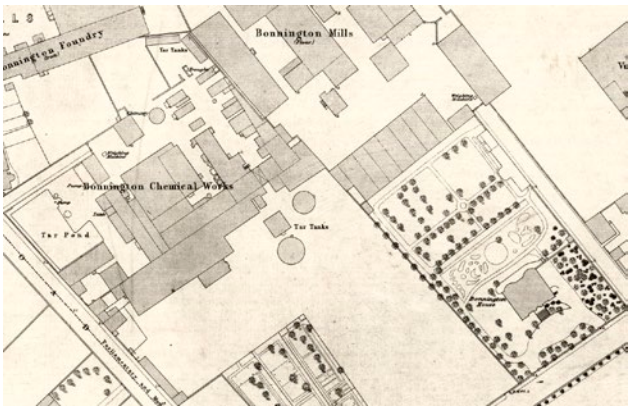

Figure 3. Bonnington chemical works near Edinburgh. Bonnington House is at the southeast corner of the overall site. Source: Ordnance Survey, Edinburgh, Sheet 16, 1876, National Library of Scotland.

Ronalds and Richardson had noted in the preface to the second edition of their book that "the valuable constituents of coal-tar [have not] yet been fully worked up into a merchantable form" and the chance to be part of a rapidly developing sector was another inducement to come to Bonnington. His longer-term aim would have been to build on the current efforts of Hofmann and others in fossil fuel chemistry and its applications by conducting in-house research. In the early years he had little time "for prosecuting my chemical enquiries connected with the manufacture which, however, exist in sufficient abundance & would well repay the time expended upon them, could it only be afforded by the more pressing demands of everyday business".[122] Unfortunately details are relatively scant on the science he was able to oversee when circumstances allowed, and how it was utilised in plant operations.

He was however elected a Fellow of the Royal Society of Edinburgh in 1862, proposed by Professor Peter Guthrie Tait,[123] and quickly served on the council. Interested to explore both the composition and handling risks of the light petroleum recently discovered in Pennsylvania in comparison with coal tar, he read a non-proprietary research paper to the society on its volatile components in February 1864. He discovered several lower members of the methane series dissolved in the crude: ethane, propane and butane. He described the proper-

[117] B. F. Ronalds, "Bonnington Chemical Works (1822–1878): Pioneer Coal Tar Company", Submitted. The Bonnington works is not listed in P. J. T. Morris, C A. Russell, *Archives of the British Chemical Industry 1750–1914*, BSHS, Faringdon, **1988**, but considerable archival material has now been identified.

[118] F. Penny, Report to the Provost, Magistrates, & Council of Leith on the Bonnington Chemical Works, 1865, Edinburgh City Archives, E32, MYBN U140G Box 00 01 20.

[119] *Fourth Report of the Department of Science and Art*, pp. 162–63.

[120] C. Tomlinson, *Cyclopædia of Useful Arts*, Vol. 1, James Virtue, London, **1862**, pp. 751–52.

[121] E. Ronalds to F. Ronalds, 19 June 1858.

[122] E. Ronalds to F. Ronalds, 30 March 1858.

[123] Royal Society of Edinburgh, *Biographical Index of Former Fellows of the Royal Society of Edinburgh 1783–2002*, **2006**.

ties of the last, also for the first time[124] – with a specific gravity of 0.600 at zero degrees Celsius, it was the lightest liquid known and it began boiling at that temperature. The paper was included in the society's transactions, reprinted in the Chemical Society's journal and the German literature, and was referenced numerous times as petroleum research progressed.[125] He presented product samples to the industrial museum in Edinburgh.[126]

Another aim was to investigate the properties of the pyridine series, which were very minor constituents of coal tar. He prepared a significant quantity of these bases by repeated fractionation but, perhaps due to time constraints, he then gave the various fractions to James Dewar. Dewar's analyses of this "liberal supply" enabled him publish the proposal that pyridine had a ring formula.[127]

Ronalds was able to determine that the tar he received from the gasworks contained almost no anthracene, and its relatively little benzene was often uneconomic to separate from the methane series of compounds also in the naphtha. This precluded him from contributing to the new synthetic dyestuff industry that was commencing to manufacture the dyes alizarin and mauveine from these components following Perkin's discovery. He also ascertained how the detailed properties of his coal tar varied with the coal mix and retort temperature being used at the gasworks. When Bonnington was closed he provided the results for Lunge's respected treatise on coal-tar processing.[128] These examples suggest that Ronalds had succeeded in building up advanced research capability, with experimental apparatus that was unusually sophisticated for a manufacturing environment.

In the meantime, his brothers and sisters in New Zealand had become embroiled in the Maori Wars in 1860 and their timber cottage and farm were destroyed. He encouraged Hugh, the most despondent and unsettled of the siblings, to return to Britain[129] and he became a partner in the firm in 1867 after Ronalds had trained him in the business.[130] Ronalds' eldest son Edmund Hugh later became an assistant chemist.[131] His other sons, christened Tennent and Frank, became respectively a fellow of the Edinburgh Obstetrical Society[132] and a merchant. His daughters attended the respected Rowdon House school for ladies in London until their late teens, continuing the family's emphasis on education.[133]

LAST YEARS (1878-1889)

The Bonnington chemical works closed in 1878. Tennent and Tennant were dead, Ronalds had been "afflicted with very bad health" for some years that a spell on the North Berwick coast did not alleviate,[134] and his family members did not wish to take on the management responsibility. Since 1868 he had lived in the "beautiful" Bonnington House (Figure 4) with large ornamental gardens close to the works.[135] It and several smaller houses had been purchased by the chemical company before he joined and now became his personal property.[136] Hugh lived nearby at another "good house" called Hillhousefield.

This part of the family had become very wealthy – Ronalds had assets to the value of £136,000, exclusive of his recent real estate acquisition.[137] In addition to his portion of Bonnington's worth over two decades, Barbara and the children had been the major beneficiary of her brother Tennent's estate, which included his £54,000 share of St Rollox, an £8,300 contribution from Bonnington, plus real estate.[138] Hugh had married into Samuel Greg's family, renowned for their large cotton spinning mills. Ronalds repaid his good fortune by continuing to support other siblings through trust funds.

He occupied his last years in an "admirably appointed laboratory" he established,[139] denoting himself as a "scientific chemist".[140] It was a lifelong goal to pursue science of interest in a private facility in the mould of Magnus' teaching and research laboratory in Ber-

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[124] Ronalds' discoveries are noted, for example, in: Watts, *Dictionary of Chemistry*, Vol. 4, p. 385; H. E. Roscoe, C. Schorlemmer, *Treatise on Chemistry*, Vol. 3, Macmillan, London, **1881**, pp. 144–45; W. T. Brannt, *Petroleum*, Henry Carey Baird, Philadelphia, **1895**, pp. 56–80; C. F. Maybery, *Proc. Am. Acad. Arts Sci.* **1896**, *31*, 1.

[125] E. Ronalds, *Trans. R. Soc. Edinburgh* **1864**, *23*, 491. Also in: *J. Chem. Soc.* **1865**, *18*, 54; *J. Prakt. Chem* **1865**, *94*, 420.

[126] Edinburgh Museum of Science and Art, *Catalogue of Industrial Department*, Neill, Edinburgh, **1869**, p. 94.

[127] J. Dewar, *Trans. R. Soc. Edinburgh* **1872**, *26*, 189.

[128] G. Lunge, *Treatise on the Distillation of Coal-tar and Ammoniacal Liquor*, John van Voorst, London, **1882**, pp. 12–13.

[129] H. Ronalds to E. Ronalds, 25 September 1860, ATL.

[130] *Inquirer* **1911**, 821.

[131] Scotland Census, 1881.

[132] *Trans. Edinburgh Obstetrical Society* **1888–1889**, *14*, xiii.

[133] Barbara, Eliza and Emily Ronalds, England Census, 1871.

[134] *Proc. Inst. Chem*. **1890**, *14*, 53.

[135] Property descriptions are in the Midlothian Ordnance Survey Name Books 1852–1853, ScotlandsPlaces, OS1/11/87.

[136] Ground Belonging to the Trustees of the Late Dr. Ronalds, Bonnington, Historic Environment Scotland, EDD 804/1–3; Valuation Rolls, 1885–1886, ScotlandsPeople, VR005500031-/386–387.

[137] Edmund Ronalds, Inventory, 1889, ScotlandsPeople, SC70/1/278.

[138] John Tennent, Will and Testament, 1867, ScotlandsPeople, SC36/48/58, SC36/51/52.

[139] *Proc. R. Soc. Edinburgh* **1889–1890**, *17*, xxviii.

[140] Scotland Census, 1881. In the 1861 and 1871 Censuses Ronalds called himself a "manufacturing chemist" and a "chemist and manufacturer", respectively.

Figure 4. Bonnington House, Ronalds' home in the period 1868-1889. Source: J. Grant, *Cassell's Old and new Edinburgh: Its History, its People, and its Places*, Vol. 3, Cassell, Petter, Galpin, London, **1887**, p. 93.

lin and the well-equipped workshop that Sir Francis set up at each of his homes.[141] He had come full circle and was now enjoying the life he had imagined he would lead when he was studying. "[H]e made any chemist welcome"[142] in the laboratory and, according to his obituary, was well known and remembered "with affection" by all chemists who had resided in Edinburgh. Little is known of the work conducted there, although his son's analyses aided George Beilby in the production of ammonia from shale and coal.[143]

In 1875 he was appointed a foundation trustee of the Ronalds Library at the Institution of Electrical Engineers bequeathed by Sir Francis – he had always cherished his copy of Sir Francis' 1823 booklet describing his telegraph.[144] He joined the new Society of Chemical Industry, became a Fellow of the Institute of Chemistry of Great Britain and Ireland when it was formed,[145] and along with other former professors was awarded the honorary D.Sc. degree by the Queen's University of Ireland in 1882.[146]

"He was a constant attendant at the meetings" of the Royal Society of Edinburgh and "always took a lively interest in everything", "although he rarely took an active part in its proceedings".[147] Similarly, when Tait invited him to help found a new learned club, he replied that he would be "be delighted to join if Smoking & good listening without much talk will qualify".[148] Like Sir Francis and other members of his Unitarian family, he was an introvert, with no interest in status or recognition and avoiding public roles. He was motivated in his work simply by the personal knowledge of achieving scientific and technical goals. There are therefore few institutional records of his contributions and this, together with his small portfolio of academic papers, helps to explain his comparative absence in the history of science literature.

Never recovering his health, he died on 9 September 1889 and was buried in Rosebank Cemetery diagonally opposite Bonnington House.[149]

CONCLUSION

Ronalds had a highly advantageous entry to his lifelong field of chemistry through his international education and initial work experience and he brought significant talent and energy to his subsequent career. From his relative obscurity today it could be construed that he did not fulfil this early promise. He has been categorised in studies of the students of Liebig (and Bunsen) as an academic and his traditional metrics of science output are not strong.[150] He himself found that his focus on industrial interests equated in Britain to a lowered status, and even today dual academic and industrial achievement is not commonly embraced and quantified, despite the culture of science utilisation these students were exposed to in Germany.

Ronalds in fact had an unconventional two-stage career, spending fourteen years in academia and then twenty-two years in the quite different setting of large-scale manufacture. His change was abrupt but cogent because he always linked scientific insight and industry practice. As an academic, his research and teaching addressed local problems and facilitated the study of chemical technology through a seminal book that synthesised theory and application. He then put his advanced knowledge of technology into practice while also bringing research into a manufacturing firm, and

[141] C. Jungnickel, R. McCormmach, *Mastery of Nature: The Torch of Mathematics 1800–1870*, UCP, Chicago, **1986**, pp. 107–10; Ronalds, *Sir Francis Ronalds*, p. 95.
[142] *J. Chem. Soc. Trans.* **1890**, *57*, 456.
[143] G. Beilby, *J. Soc. Arts 33* (**1885**): 313; also *J. Soc. Chem. Ind.* **1884**, *3*, 216.
[144] Trust Deed of the Ronalds Library, 1875, IET; E. Ronalds to J. Fahie, 26 April 1882, IET, 1.9.2.119.
[145] *Proc. Inst. Chem.* **1878**, *2*, 13.
[146] *Belfast Newsletter*, 2 February 1882, 8.
[147] *Proc. R. Soc. Edinburgh* **1889–1890**, *17*, xxviii.
[148] E. Ronalds to P. Tait, 25 October 1869, National Library of Scotland, Archives & Manuscript Collections, MS.1704 f.74 v1.
[149] C. Napier, *Scottish Genealogist* **2012**, *59*, 176.
[150] For example: J. S. Fruton, *Proc. Am. Philos. Soc.* **1988**, *132*, 1; Brock, *Ambix*.

this resulted in new discoveries, plant improvements, business expansion and significant profits. These two cross-sector unions – technological education and industrial research – were then very novel but presaged what became key trends into the twentieth century, yet his accomplishments have been largely overlooked by historians.