

Australians and Canadians at the Cavendish Laboratory in the Early Twentieth Century*

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캐브디쉬연구소는 호주와 캐나다 출신 연구원들에게 어떤 영향을 미쳤나?

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요 약

이 논문은 20세기 초 영국 케임브리지 대학 캐브디쉬연구소에 유학했던 호주, 뉴질랜드, 캐나다 출신 물리학자들의 활동을 분석한 것이다. 캐브디쉬연구소는 19세기말부터 우수한 연구자들을 이들 영연방 소속 식민지에 보내서 물리학자사회가 등장하는 데 커다란 영향을 미쳤다. 한편 이들 식민지들은 우수한 연구자들을 지속적으로 캐브디쉬연구소에 공급함으로써 연구소 발전에 커다란 공헌을 했다. 필자는 이 논문에서 식민지 본국에서 가장 중요한 연구기관이었던 캐브디쉬연구소와 식민지와의 관계가 단순히 “중앙부-주변부” 또는 “식민지 본국-식민지”간의 일방적인 관계가 아니라 훨씬 복잡하고 다양했음을 보이고자 한다.

주요어 : 캐브디쉬연구소, 물리학, 호주, 뉴질랜드, 캐나다

This paper analyzes the relationship between the Cavendish Laboratory and the Australian, New Zealand and Canadian researchers who worked there during the early twentieth century. From its inception, the Cavendish Laboratory at the University of Cambridge provided the former British dominions of Australia, New Zealand and Canada with prominent scientists including Richard Threlfall, William Henry Bragg, Hugh L. Callendar and Ernest Rutherford. The Cavendish also offered advanced physics students from these countries, first a fertile training ground, and then a springboard to prestigious positions in university teaching and research. As a result, many historians have concluded

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that this Cavendish connection was crucial to the development of the physics communities on two continents.

How did this connection begin? Which Australians and Canadians traveled to the Cavendish, and why? What effects did the Cavendish have on their learning and future career patterns? I will try to answer these simple but crucial questions from the point of view of the Cavendish Laboratory, rather than from that of either Australian or Canadian physics communities.

1. The Cavendish Laboratory at the Turn of the Twentieth Century

The Cavendish Laboratory opened its doors on June 16 1874, under the directorship of James Clerk Maxwell.¹⁾ During Maxwells tenure from 1871 to 1879, he established the three hallmarks of the Cavendish traditions—namely, research tradition, laissez -faire policy, and the tradition of precise measurement. Maxwell however only set up the organizational framework of the Laboratory. The completion of its infrastructure fell to his successor, John William Strutt, the third Lord Rayleigh. During his brief tenure from 1880 to 1884, Rayleigh created several Demonstratorships, improved the teaching system, raised the new fund for the purchase of laboratory equipment, expanded the store of available instrument, and added a workshop to the Laboratory. Rayleigh also made time for his own research, performing well-organized experiments on the determination of electrical standards.

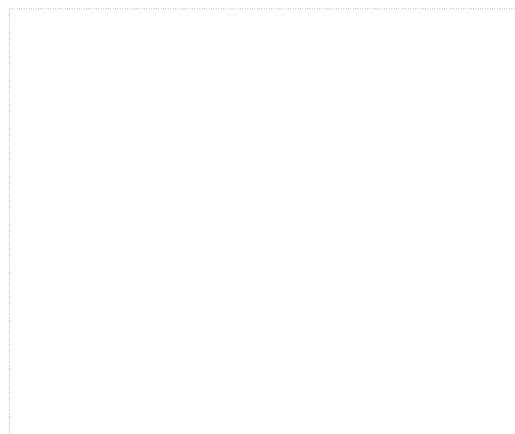
On December 22, 1884, Joseph John Thomson was elected as the Cavendishs third director and Professor of Experimental Physics. In the first decade of Thomson's directorship, the Cavendish developed certain essential characteristics that would make it famous: it attracted talented research students oriented toward experimen- tation, its teaching and research organization was growing in reputation, and it was headed by a mature, widely respected scientist, J. J. Thomson, who had opened new fertile research areas of physical chemistry and electrical discharge through gases.

Two events in 1895 furthered the Laboratory's development. The first was a regulation change at Oxford and Cambridge that permitted these institutions to accept

1) For the early history of the Cavendish Laboratory, see J.J. Thomson et. al., *A History of the Cavendish Laboratory, 1871-1910* (London: Longmans, Green, 1910); A. Wood, *The Cavendish Laboratory* (Cambridge: Cambridge University Press, 1946); E. Larson, *The Cavendish Laboratory: Nursery of Genius* (London: Ward, 1962); J. G. Crowther, *The Cavendish Laboratory, 1874-1974* (New York: Science History Publications, 1974); Dong-Won Kim, *Leadership and Creativity: A History of the Cavendish Laboratory, 1871-1919* (Dordrecht: Kluwer Academic Publishers, 2002).



Photo 1.
The Cavendish Laboratory
and its third director J. J. Thomson



graduates of other universities. According to the new regulations, so-called *advanced students* could receive bachelors degrees plus research certificates after completing two years of research.

As a result of this reform, 1851 Research Scholars flocked to these two venerable universities. The 1851 Research Scholarship had been founded by the Royal Commission for the Exhibition of 1851, and was intended to support two or three years of scientific training for students under the age of thirty from the British dominions.²⁾ The terms of this scholarship permitted recipients to attend the institutions they chose. Before the 1895 regulation change most recipients of the scholarship preferred German universities to Oxbridge primarily because of the German Ph. D. system. After the 1895 regulation change, however, 1851 Research Scholars were able to choose from a broader selection of institutions.

2) The Royal Commission for the Exhibition of 1851, *Record of the Science Research Scholars of the Royal Commission for the Exhibition of 1851* (London, 1930); *Record of the Science Research Scholars of the Royal Commission for the Exhibition of 1851* (London, 1961); Roy M. McLeod and E. K. Andrew, "Scientific Careers of 1851 Exhibition Scholars," *Nature*, 218 (1968), pp. 1011-1016.



Photo 2. 1897 Cavendish Annual Photograph. J.J. Thomson was sitting in the center and E. Rutherford sitting on the far right

At Cambridge University, the main beneficiary of the 1895 regulation change was the Cavendish Laboratory. The Cavendish now was an accredited graduate school and therefore attractive to a greater number of talented students. Before 1895, only a single 1851 Research Scholar went to the Cavendish. After 1895, however, the Cavendish became the school of choice for a majority of the 1851 Research Scholars studying physics. The increase in the number of advanced students at the Cavendish was largely responsible for a rapid increase in the total number of Cavendish students at the turn of the century. The first advanced student (but second 1851 Research Scholar) admitted to the Cavendish was none other than Ernest Rutherford of New Zealand.

The second great event of 1895 was Röntgen's discovery of X-rays.³⁾ J. J. Thomson was well prepared to exploit the potential of this discovery, and he became one of the first scientists to employ X-rays to investigate cathode rays, a pursuit that led him to his 1897 discovery of corpuscles or, as we know them today, electrons. This discovery was the result of an orchestrated collaboration in which Rutherford performed most of the routine experimental procedures. The success of this collaboration made it a point of departure for subsequent research: for example, J. S. Townsend of Ireland developed his ionization by collision theory, which was widely adopted by Cavendish researchers, including Thomson

3) For the effects of X-rays on Thomson's discovery of electrons and the development of the Cavendish Laboratory, see I. Falconer, "Corpuscles, Electrons and Cathode Rays: J.J. Thomson and the Discovery of the Electron," *British Journal for the History of Science*, 20 (1987), pp. 241-276; I. Falconer, "Transfer of Concept & Practice between J.J. Thomson and His Research Students," *Papers for the Meeting on the Transfer of Concepts and Practice in the Physical and Mathematical Sciences* (Maison Francaise, Oxford, 23 May 1996); Kim, *Leadership and Creativity*, chapter 4.

himself; C. T. R. Wilson's early model of the cloud chamber served as a very effective tool for ion counting to the Cavendish researchers. Between the close of 1895 and the start of 1900, these and several other important discoveries related to the electron made the Cavendish Laboratory one of the world's most respected physics research centers. In this process, the Cavendish advanced students, most of whom had spent their undergraduate years at institutions that were less prestigious than Cambridge, played a decisive role.

2. Australians, New Zealanders and Canadians at the Cavendish Laboratory

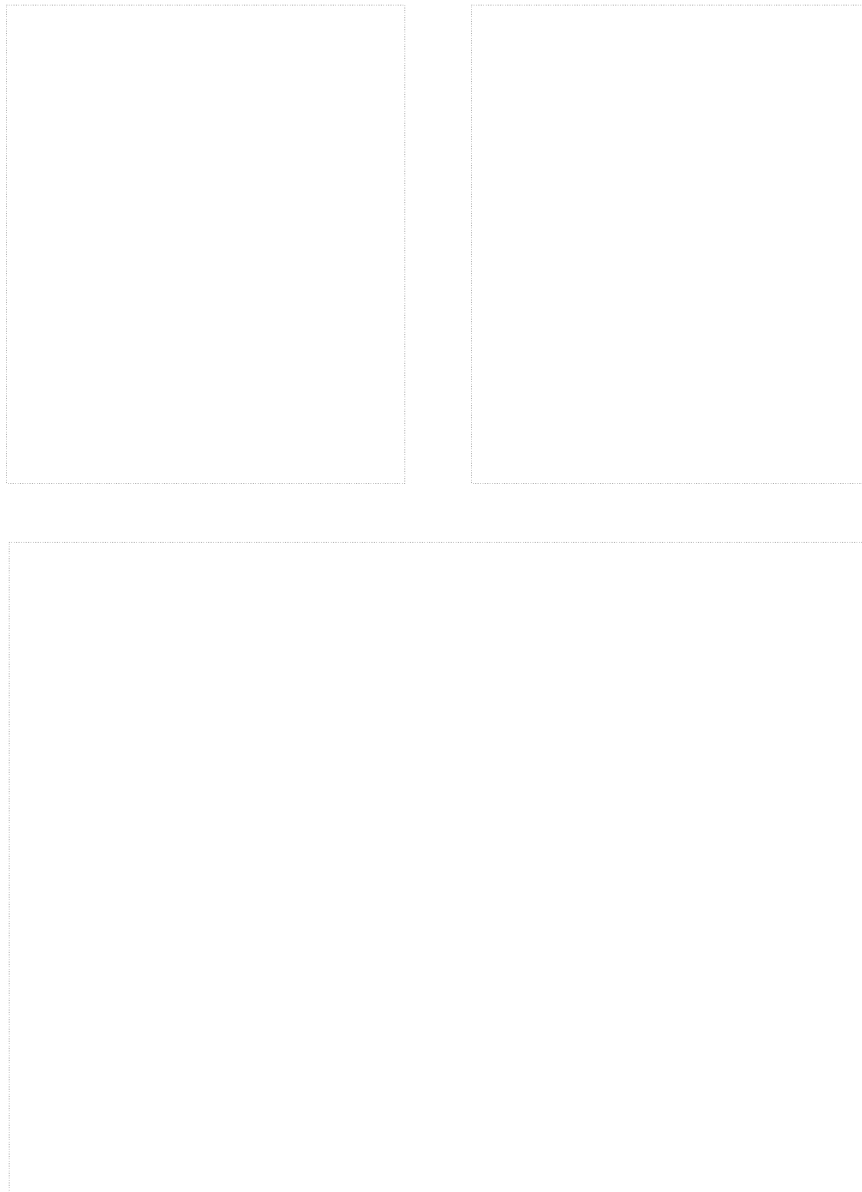


Photo 3. Richard Threlfall, William Henry Bragg, and Ernest Rutherford
From 1895 on, Australian (including New Zealand) and Canadian researchers became an

important component of the Cavendish manpower. In the total population of Cavendish advanced students, Canadians and Australians constituted the second and third largest groups respectively, only after advanced students from the British Isles. Moreover, Australia and Canada produced a constant supply of advanced students for the Cavendish over a long period of time, and, in this respect, Australia was more reliable than Canada. From the point of view of the Cavendish Laboratory, this steady supply of able researchers kept the institution afloat once the number of Cambridge graduates entering the Cavendish Laboratory began to decline.

The Australian connection started in 1885, when J. J. Thomson recommended that two truly outstanding physicists, Richard Threlfall and William Henry Bragg, to go to Australia.⁴⁾ Threlfall, appointed the first Professor of Physics at the University of Sydney in 1886, had been described as “one of the most outstanding appointment that that university has ever made.”⁵⁾ As an outstanding graduate of Cambridge’s Natural Sciences Tripos, he was widely praised as a first-rate experimentalist of his generation.⁶⁾ Before leaving for Australia, he served as Assistant Demonstrator at the Cavendish Laboratory, and was also a close collaborator of Thomson with whom he published two papers on the electric discharge through gases and the production of ozone.⁷⁾ At Sydney Threlfall established a well-equipped laboratory that would serve not only for teaching but also for the first true physics research in Australia: he and his students had worked on explosives, measurements of various electrical standards and the invention of several instruments. Threlfall had maintained a close contact with J. J. Thomson and the Cavendish Laboratory, even sending the first Australian, Miss F. Martin, there in 1894.⁸⁾ It is therefore no wonder that the University of Sydney became the preeminent center for physics teaching and research in the

4) For the British influence on the Australian physics community, see R. W. Home and Masao Watanabe, “Physics in Australia and Japan to 1914: A Comparison,” *Annals of Science*, 44 (1987), pp. 215–235; R. W. Home and M. Watanabe, “Forming New Physics Communities: Australia and Japan, 1914–1950,” *Annals of Science*, 47 (1990), pp. 317–345; R. W. Home (ed.), *Australian Science in the Making* (Cambridge: Cambridge University Press, 1988), Part II; John G. Jenkin, “British Influence on Australian Physics, 1788–1988,” *Berichte zur Wissenschaftsgeschichte*, 13 (1990), pp. 93–100.

5) R. W. Home, “First Physicist of Australia: Richard Threlfall at the University of Sydney, 1886–1898,” *Historical Records of Australian Science*, 6 (1986), pp. 333–357 on p. 333.

6) J.J. Thomson, *Recollections and Reflections* (New York: MacMillan & Co. 1937), p. 118. Thomson remembered Threlfall as one of the best experimenters he had ever met.

7) J.J. Thomson and R. Threlfall, “On an Effect produced by the Passage of an Electric Discharge through Pure Nitrogen,” *Proceedings of the Royal Society*, 40 (1886), pp. 329–340; J.J. Thomson and R. Threlfall, “Some Experiments on the Production of Ozone,” *Proceedings of the Royal Society*, 40 (1886), pp. 340–342.

8) Thomson and Threlfall exchanged many letters during the period between 1886 and 1898 that provide vivid descriptions of Threlfall’s activities in Sydney. See Cambridge University Library, MSS ADD 7654 T7–T36.

country.

William Henry Bragg was also an outstanding Cambridge graduate, the third wrangler of the Mathematical Tripos in 1884. Appointed Professor of Mathematics and Physics at the University of Adelaide in late 1885 at the age of only twenty-three, Bragg quickly and comfortably settled in colonial South Australia, “occupying his time with a heavy teaching round at the University, an active sporting and social life within the upper stratum of local society, and long summer holidays each year at the sea.”⁹⁾ He however suffered scientific isolation for two decades and began to exhibit his remarkable talent only after 1904 when he started researching radioactivity, the nature of X-rays and the conduction of electricity through gases.¹⁰⁾ Between 1904 and 1908, he not only published important research papers on these subjects but also trained several Australian researchers who later went to the Cavendish Laboratory.

Although both Threlfall and Bragg began teaching physics in Australia, Australian researchers did not appear at the Cavendish before 1900, with the single exception of F. Martin from Sydney. In the early decades of the twentieth century, however, the University of Sydney sent J. J. E. Durack (1900–04), T. H. Laby (1905–09), E. M. Wellisch (1907–14), S. G. Lusby (1909–11), and J. D. McGee (1928–30) to the Cavendish; the University of Adelaide sent Richard D. Kleeman (1905–13), J. L. Glasson (1909–11), and Marcus L. Oliphant (1927–36); the University of Melbourne sent R. Hosking (1902–04), J. K. Roberts (1920–22), L. H. Martin (1923–26), H. C. Webster (1928–30), and E. S. Hills (1929–31). New Zealand, home of Ernest Rutherford (1895–1898), also provided the Cavendish with Percy W. Burbidge (for three years between 1913 and 1921), Eric O. Hercus (1914–15, 1919), Robert R. Nimmo (1926–29), and Wallace A. Macky (1928–30).

The Canadian connection was also strong. Hugh L. Callendar was the first Cavendish man who in 1893 sailed to Canada to become Professor of Physics at McGill University in Montreal. Sixteenth wrangler in 1885, Callendar was also a fine experimenter who greatly improved the platinum resistance thermometer while working at the Cavendish.¹¹⁾ He also served as

9) R. W. Home, “The Problem of Intellectual Isolation in Scientific Life: W. H. Bragg and the Australian Scientific Community, 1886–1909,” *Historical Records of Australian Science*, 6 (1984), pp. 19–30 on p. 19. For his appointment at Adelaide, see John G. Jenkin, “The Appointment of W. H. Bragg, F. R. S., to the University of Adelaide,” *Notes and Records of the Royal Society of London*, 40 (1985), pp. 75–99. For Henry Bragg’s life, see G. M. Caroe, *William Henry Bragg, 1862–1942: Man and Scientist* (Cambridge: Cambridge University Press, 1978).

10) For Bragg’s intellectual isolation, see R. W. Home, *ibid.*, and R. W. Home, “Frederick Soddy’s 1904 Visit to Australia and the Subsequent Soddy–Bragg Correspondence: Isolation from Without and Within,” *Historical Records of Australian Science*, 6 (1985), pp. 153–169. For Bragg’s research on the nature of X-rays, see Bruce R. Wheaton, *Tiger and Shark: Empirical Roots of Wave–Particle Dualism* (Cambridge: Cambridge University Press, 1983).

11) H. L. Callendar, “On the Practical Measurement of Temperature: Experiments Made at the Cavendish

Assistant Demonstrator there in 1887–1888. At McGill he researched the calorimetric properties of water and also measured the temperature of dry steam expanding adiabatically.¹²⁾ Before returning to England in 1898 to become Professor of Physics at University College, London, Callendar contributed greatly to raising the quality of both teaching and research at McGill. He however did not send any of his students to the Cavendish during his five years of tenure at McGill.

Ernest Rutherford strengthened the Canadian connection with the Cavendish. As J. J. Thomson's most promising research student during the fruitful years of 1895–1898, Rutherford outshone many Cambridge graduates and Demonstrators at the Cavendish.¹³⁾ He supported Thomson's investigation into the nature of cathode rays in 1896–1897 and finished his first work on uranium rays before leaving for Canada.¹⁴⁾ When he applied for a vacant physics chair at McGill University in 1898, Thomson wrote the most praising, almost prophetic, letter of recommendation for him, claiming that "I have never had a student with more enthusiasm or ability for original research than Mr. Rutherford and I am sure that if elected he would establish a distinguished school of physics at Montreal."¹⁵⁾ Rutherford fulfilled this prediction at McGill, conducting impressive researches on the nature of radioactivity including the discoveries of emanation and decay.¹⁶⁾ One of his most important and enduring contributions was his training of many Canadian physicists during his tenure from 1898 to 1907, some of whom he recommended to go to the Cavendish Laboratory for advanced studies.

So, Canadian researchers began to arrive at the Cavendish Laboratory from the beginning of

Laboratory," *Philosophical Transactions*, 178 (1887), pp. 161–230. For short biography of Callendar, see "Callendar, Hugh Longbourne" (1863–1930), *The Dictionary of National Biography*, 4th Supplement (1922–1930), edited by J. R. H. Weaver (London: Oxford University Press, 1937), pp. 152–154.

12) Callendar's work on the calorimeter however was published much later. See H. L. Callendar, "Continuous Electric Calorimeter," *Philosophical Transactions*, 199 (1902), pp. 55–148.

13) Rutherford wrote to his fiancée in New Zealand, "I grimly rejoice for they [three Demonstrators] did not take any notice of us [Townsend, another research student from Ireland, and himself] the first two months although they knew we were strangers and had no friends in Cambridge. My paper before the Physical Society was a heavy blow to their assumed superiority, and now they all offer to help us in any way they can and tell me confidentially about their own little researches—so wags the world." [A. S. Eve, *Rutherford, being the Life and Letters of the Rt. Hon. Lord Rutherford*, O. M. (Cambridge: Cambridge University Press, 1939), p. 28.]

14) J.J. Thomson & E. Rutherford, "On the Passage of Electricity through Gases exposed to Röntgen Rays," *Philosophical Magazine*, 42 (1896), pp. 392–407; E. Rutherford, "Uranium Radiation and the Electrical Conduction produced by it," *Philosophical Magazine*, 47 (1899), pp. 109–163.

15) E. N. da C. Andrade, *Rutherford and the Nature of the Atom* (Garden City, N. Y.: Doubleday, 1964), p. 50.

16) For Rutherford's research and activities at McGill, see John L. Heilbron, "Physics at McGill in Rutherford's Time," in Mario Bunge and William R. Shea (ed.), *Rutherford and Physics at the Turn of the Century* (New York: Dawson and Science History Publications, 1979), pp. 42–73; A. S. Eve and J. Chadwick, "Lord Rutherford, 1871–1937," *Obituary Notices of Fellows of the Royal Society*, 2 (1936–1938), pp. 395–423 on pp. 398–403.

the new century. Rutherford sent the Cavendish his McGill students R. K. McClung (1901–04), H. Brooks (1902–03), F. C. Gates (1902, 1905), and H. L. Cooke (1903–06). After Rutherford returned to England to succeed Arthur Schuster at Victoria University of Manchester in 1907, his successors, including H. A. Wilson (another Cavendish researcher), continued referring their finest students to the Cavendish: A. N. Shaw (1911–13), E. S. Bieler (1920–23), F. R. Terroux (1927–29), and J. K. MacDonald (1929–31) were four McGill graduates who made their way to the Cavendish. J. C. McLennan of the University of Toronto, who had spent two years at the Cavendish (1898–99, 1901), sent J. Patterson (1900–02), E. F. Burton (1904–06), H. F. Dawes (1906–08), C. S. Wright (1908–10), A. R. McLeod (1914–15, 1915–20), and W. L. Webster (1923–26). Queen's University of Kingston, Ontario, sent W. C. Baker (1900–02), D. C. Rose (1924–27), H. M. Cave (1926–29), and B. W. Sargent (1928–30) to the Cavendish. Dalhousie University of Halifax, Nova Scotia, sent G. H. Henderson (1919–22), C. A. Mackay (1921–23) and G. C. Laurence (1927–29). The University of Alberta sent J. F. Lehmann (1923–26).

Some important trends arose from this connection between the Cavendish Laboratory and the British dominions. First of all, a cycle emerged: former Cavendish researchers went to Australia and Canada to teach and then sent their own students to the Cavendish for advancing training. At the beginning of the twentieth century, J. J. Thomson was busy replying to letters of inquiry from former students, and Rutherford's letters contained numerous references to students he planned to send, or had already sent, to the Cavendish. Some of Rutherford's references were: "I hope to get the 1851 Scholarship for him [McClung] next year to send him once to you in a little beyond the preparatory stage of research," and "I hope Miss Brooks and McClung are doing well."¹⁷ Typical of Thomson's replies were: "I shall be very glad to give Miss Brooks permission to work in the Laboratory & to attend lectures"; "McClung is doing very well"; and "Cooke is at present working at the question of the emanation from uranium."¹⁸

Cavendish alumni took responsibility for the quality of the students they recommended to the Cavendish, and most Australian and Canadian students were provided with research experience before they headed to the Cavendish. For example, before sending Kleeman to the Cavendish, Henry Bragg at Adelaide had Kleeman assist him in researching and writing three papers on the range of α particles using radium bromide that appeared in *Philosophical Magazine* in 1904 and 1905.¹⁹ Joseph L. Glasson and Henry

17) Cambridge University Library MSS ADD 7654 R66 (9 January 1900) and R67 (26 December 1902): Rutherford to Thomson.

18) Cambridge University Library MSS ADD 7653 T18 (2 May 1902), T19 (13 May 1902), T23 (18 February 1904): Thomson to Rutherford.

19) W. H. Bragg and R. Kleeman, "On the Ionization Curves of Radium," *Philosophical Magazine*, 8

Bragg published two papers with him on the nature of γ rays.²⁰⁾ Before sending P. W. Burbidge, J. K. Roberts and E. O. Hercus to the Cavendish, T. H. Laby published some papers with these junior researchers.²¹⁾ Rutherford at McGill University and J. C. McLennan at the University of Toronto acted similarly, entrusting to the Cavendish only students whose competence they trusted. One of Rutherford's students from McGill even declined Thomson's offer of working on thorium but instead continued his own research that Rutherford suggested to him before he had left for the Cavendish.²²⁾ Thomson greatly admired Canadian researchers, saying that "We have a great many men working here, among them two Canadians, Patterson and Baker, who are both doing well."²³⁾ It is therefore no wonder that most Australian and Canadian Cavendish researchers had been recipients of 1851 Research Scholarships.²⁴⁾

This superb quality of researchers from these two regions explains the sheer quantity of work that was produced at the Cavendish. Because the Australian and Canadian advanced students who came to the Cavendish were qualified for advanced research, their productivity at the Laboratory was higher than that of the average Cavendish researcher. Kleeman, for example, was a truly prolific writer of scientific papers. In eight years at the Cavendish (1905-1913), he published more than thirty substantial articles on the nature of various rays and on chemical attraction.²⁵⁾ During Marc Oliphant's stay at the Cavendish

(1904), pp. 726-738; W. H. Bragg and R. Kleeman, "On the α Particles of Radium, and Their Loss of Range in Passing through Various Atoms and Molecules," *Philosophical Magazine*, 10 (1905), pp. 318-340; W. H. Bragg and R. Kleeman, "On the Recombination of Ions in Air and Other Gases," *Philosophical Magazine*, 11 (1905), pp. 466-484.

20) W. H. Bragg and J. L. Glasson, "On a Want of Symmetry Shown by Secondary X-rays," *Philosophical Magazine*, 17 (1909), pp. 855-864.

21) T. H. Laby and P. W. Burbidge, "Nature of γ -Rays," *Nature*, 87 (1911), p. 144; T. H. Laby and P. W. Burbidge, "The Observation by Means of a String Electrometer of Fluctuations in the Ionization Produced by γ -Rays," *Proceedings of the Royal Society*, 86 (1912), pp. 333-348; T. H. Laby and J. K. Roberts, "New Method of Determining the Mechanical Equivalent of Heat," *Proceedings of the Royal Society of Victoria*, 32 (1920), pp. 34-45; T. H. Laby and E. O. Hercus, "Thermal Conductivity of Air," *Proceedings of the Royal Society*, 95 (1919), pp. 190-210.

22) Cambridge University Library MSS ADD 7653 M3 (10 October 1901): R. K. McClung to Rutherford.

23) Cambridge University Library MSS ADD 7653 T14 (15 February 1901): Thomson to Rutherford.

24) *Record of the Science Research Scholars of the Royal Commission for the Exhibition of 1851* (ref. 2). For Australian recipients of the 1851 Scholarship, see I. W. Wark, "1851 Science Research Scholarship Awards to Australians," *Records of the Australian Academy of Science*, 3 (1977), pp. 47-52.

25) Some samples of Kleeman's papers are: "On the Recombination of Ions made by α , β , γ , and X-rays," *Philosophical Magazine*, 12 (1906), pp. 273-297; "The Ionization in various Gases by Secondary γ -rays," *Proceedings of the Royal Society*, 82 (1909), pp. 358-377; "An Investigation of the Determination of the Law of Chemical Attraction between Atoms from Physical Data," *Philosophical Magazine*, 21 (1911), pp. 83-102; "Molecular Attraction and the Properties of Liquids," *Philosophical Magazine*, 22 (1911), pp. 566-586.

between 1927 and 1937, he published more than twenty papers on transmutation, isotopes, and other subjects.²⁶⁾ J. Patterson (1900–1902) from Toronto and E. M. Wellisch (1907–1914) from Sydney were also very busy at the Laboratory, each of them publishing at least six papers for prestigious journals like *Philosophical Transactions* or *Philosophical Magazine*.²⁷⁾ In an average stay of two or three years, Australian or Canadian Cavendish advanced students published an average of two papers. Most worked on the popular research topics of their day: radiation during the first and second decades of the twentieth century and nuclear physics during the third and fourth decades.

3. Not just a Turning Point but a Crossroad

How did the Cavendish Laboratory affect the future career patterns of its Australian and Canadian alumni? For these researchers the Cavendish was a true graduate school where they were exposed to cutting-edge theories and could learn state-of-the-art experimental techniques. Because their status as advanced students as well as the requirements of the 1851 Research Scholarship both demanded *visible* results of their time at the Cavendish, they published, often in the most respected journals, which was easier to do in Cambridge than in their home countries. By publishing in *Philosophical Transactions*, *Philosophical Magazine*, *Nature*, or *Proceedings of the Royal Society of London* instead of *Transactions and Proceedings of the Royal Society of South Australia* or *Journal of Royal Astronomical Society of Canada*, Australian and Canadian Cavendish advanced students achieved greater recognition among their peers. Thus, their true professional trajectories began while they were at the Cavendish.

The label, “worked at the Cavendish Laboratory from such year to such year, under J. J.

26) Some samples are: Marcus L. E. Oliphant, “The Action of Meta-stable Atoms of Helium on a Metal Surface,” *Proceedings of the Royal Society*, 124 (1929), pp. 228–242; M. Oliphant and E. Rutherford, “Experiments on the Transmutation of Elements by Protons,” *Proceedings of the Royal Society*, 141 (1933), pp. 259–281; M. Oliphant, E. S. Shire and B. M. Crowther, “Disintegration of the Separated Isotopes of Lithium by Protons and by Heavy Hydrogen,” *Nature*, 133 (1924), p. 377; M. Oliphant, “The New High-Voltage Laboratory at Cambridge,” *Nuovo Cimento*, 15 (1938), 160–166.

27) Some samples are as follows. J. Patterson, “On the Effect of Magnetic Field on the Resistance of Thin Metallic Films,” *Proceedings of the Cambridge Philosophical Society*, 11 (1901), pp. 118–119; J. Patterson, “On the Change of the Electric Resistance of Metals when Placed in a Magnetic Field,” *Philosophical Magazine*, 3 (1902), pp. 643–656; J. Patterson, “On the Ionization in Air at different Temperature and Pressures,” *Philosophical Magazine*, 6 (1903), pp. 231–238; E. M. Wellisch, “The Passage of Electricity through Gaseous Mixtures,” *Proceeding of the Royal Society*, 82 (1909), pp. 517; E. M. Wellisch, “The Mobility of Ions produced by Röntgen Rays in Gases and Vapours,” *Philosophical Transactions*, 209 (1909), pp. 249–279; E. M. Wellisch, “An Electric Detector for Electromagnetic Waves,” *Proceedings of the Cambridge Philosophical Society*, 15 (1909), pp. 500–517.

Thomson or Ernest Rutherford,” placed a premium on the services of these Australians and Canadians. They were now *Cavendish men*, trained at what remained the mecca of experimental physics for the first four decades of the century. In the 1900s and 1910s, the Cavendish was the center for research on the electron, ionization, radiation, positive rays, and *the* structure of atom.²⁸⁾ During the 1920s and 1930s, under the leadership of Rutherford, the Cavendish was *the* center for research on nuclear physics.²⁹⁾



Photo 4. 1932 Cavendish Annual Photograph

The Cavendish annual photograph of 1932 reveals the glory of the Cavendish Laboratory in the early twentieth century. In the picture, J. J. Thomson and Rutherford are surrounded by many of their distinguished “pupils” (as Thomson called them) or “boys” (in the words of Rutherford). Eight of these eleven men in the front line were current or future Nobel Prize winners! Another future Laureate, E. T. S. Walton is in the second row. It is certain that the fame of the Cavendish Laboratory and its directors not only attracted the most gifted researchers, but also helped to determine to their future careers. Indeed, from the beginning of the twentieth century, Cavendish alumni dominated academic positions in physics in Britain and its dominions. So, for the Australians and Canadians who were fortunate enough to work at the Cavendish in the early twentieth century, their career horizons were wider than they otherwise would have been without that opportunity.

Naturally, the majority of these researchers returned to their home countries to fill academic positions and train new generations of physicists, some of whom would then

28) Kim, *Leadership and Creativity*, chapter 5.

29) M. Oliphant, *Rutherford: Recollections of the Cambridge Days* (Amsterdam: Elsevier, 1972); J. Hendry (ed.), *Cambridge Physics in the Thirties* (Bristol: Adam Hilger, 1984).

sharpen their research skills at the Cavendish. T. H. Laby, who served as Professor of Physics at Victoria University College in the University of New Zealand for six years (1909–1915) and then as Professor of Natural Philosophy at the University of Melbourne for three decades, nurtured several dozen Australian and New Zealand physicists. Immediately after finishing their Cavendish studies, the Australians J. E. Glasson, R. Hosking, J. S. Rogers, and L. H. Martin returned home to contribute to the development of physical science, as did the New Zealanders P. W. Burbidge, E. O. Hercus, and R. R. Nimos. The Canadians R. K. McClung, A. N. Shaw, and E. S. Bieler, E. F. Burton, W. C. Baker, and G. H. Henderson also returned to their respective alma maters.

Nevertheless, a considerable number of Australian and Canadian researchers who were trained at the Cavendish between 1895 and 1930 did not return home after finishing their training. They instead found positions in Britain and other countries around the world. The number of these men reaches about 25% of the total number of Australian and Canadian researchers and almost 40% of the Australian and Canadian 1851 Research Scholars.

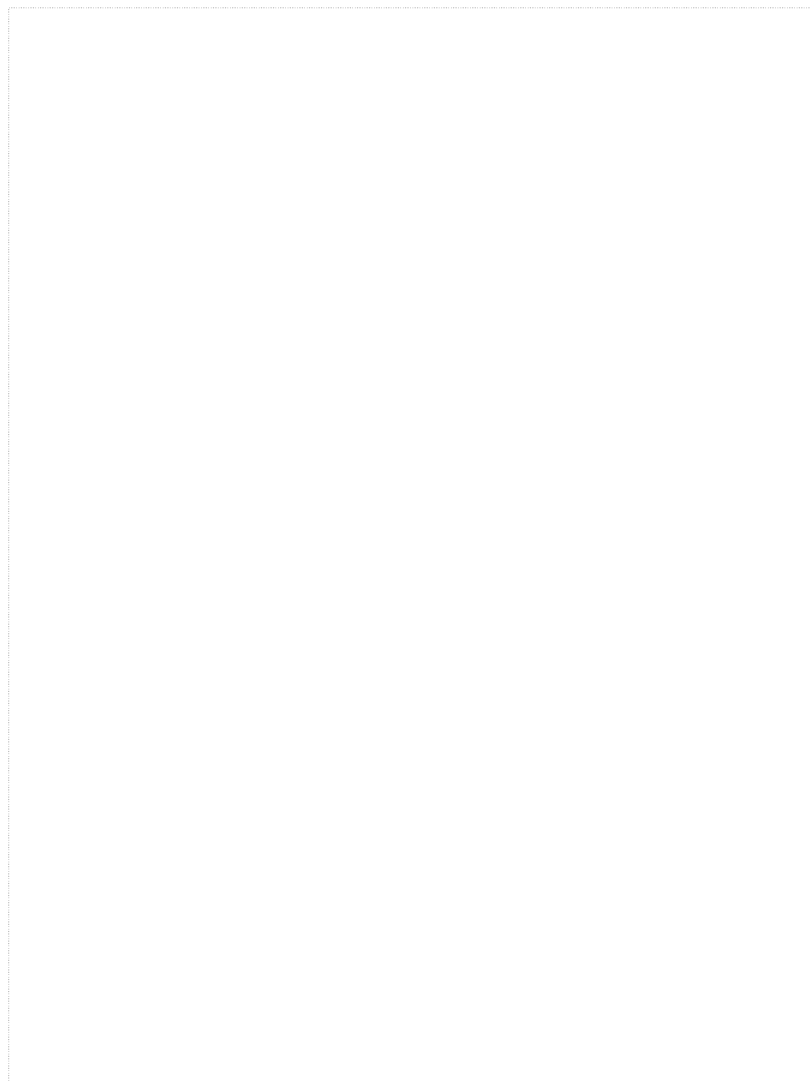
Among these, the most famous case was Rutherford. After serving as Macdonald Professor of Physics at McGill University from 1898 to 1907, he became Langworthy Professor of Physics at Victoria University of Manchester, England. In 1919, he succeeded J. J. Thomson to become the fourth Cavendish Professor of Experimental Physics. Under Rutherford's directorship, the Cavendish re-emerged as the mecca of experimental physics and made several important discoveries, including the discovery of the neutron in 1932.

Rutherford, however, was not the exception. There were many such cases.³⁰⁾ Among the Australians, J. J. E. Durack from Sydney became Demonstrator and Lecturer of Physics at King's College, London, and then served as Professor of Physics for a long period at Allahabad University in India. Richard Kleeman from Adelaide became Professor of Physics at Union College in Schenectady, New York, in 1914. John K. Roberts from Melbourne served as research assistant at the National Physical Laboratory in London from 1922 to 1924. He returned to the Cavendish as research physicist from 1928 to 1933, and then became assistant director of the Colloid Science Laboratory at Cambridge until 1939. Marc Oliphant, co-discoverer of tritium (hydrogen-3) and helium-3, spent ten years at the Cavendish as a close collaborator of Rutherford. In 1937, Oliphant became Professor of Physics at the University of Birmingham, where he stayed for thirteen years until returning to his homeland to head the newly founded Australian National University.

Many Canadians also settled into berths outside of their home country. When H. L. Cooke from McGill finished his training at the Cavendish in 1906, he accepted an assistant

30) *Record of the Science Research Scholars of the Royal Commission for the Exhibition of 1851* (ref. 2); *Dictionary of National Biography* (1901–1911), (1912–1921), (1922–1930), (1931–1940).

professorship of physics at Princeton University, where he remained to teach American students for more than three decades. John Patterson from Toronto spent eight years in India, first at Muir Central College in Allahabad (1902-04), then as Indias imperial meteorologist (1905-09), before returning to Canada in 1909. C. S. Wright from Toronto served as physicist to the British Antarctic Expedition in 1910 and then was appointed Lecturer in Cartography and Surveying at Cambridge University. After his 1851 Research Scholarship expired, W. L. Webster from Toronto continued to work at the Cavendish. J. F. Lehmann from Alberta, who had been researching ionization at the Cavendish, became a research physicist at an English chemical company.



- ▶ : Colonial Researchers from Their Home Countries to the Cavendish
 - - ▶ : Colonial Researchers Returning to Their Home Countries
 ···▶ : Colonial Researchers Moving to Other Destinations

Why and how did a large percentage of Australians and Canadians accept employment outside their homelands? I argue that, when they left the Cavendish, they no longer were viewed, and no longer viewed themselves, as *physicists from Australia, New Zealand, or Canada*. They had assumed the aura of *Cavendish men* with much wider vistas and opportunities. Like Rutherford, if they had the talent and the will, they could choose from any number of career paths. In other words, their final destinations no longer were determined by their origins or their pre-Cavendish experiences. The above diagram indicates that the Cavendish did not mean just a turning point (above) but a crossroad or a stepping stone for these Australians and Canadians (below).

4. Further Remarks

I would like to raise two questions for future research. The first is: How well can the traditional *center-periphery* relation or *metropolis-periphery* relation explain this case? In my opinion, *not very well*. These traditional tools imply, consciously or unconsciously, one-way power and control: the center or metropolis controls the periphery and the periphery depends exclusively on the center. In other words, the center is always the *giver* (or the *exploiter*) and the periphery always the *recipient* (or the *exploited*).³¹ In the relation between the Cavendish and the development of physics in Australia and Canada, however, there was a *reciprocal* relationship. The Australian and Canadian physics communities secured the best training camp for their most talented students, and the

31) For the recent studies about the metropolis-periphery relation, see R. W. Home (ed.), *Australian Science in the Making* (ref.4); Roy M. MacLeod (ed.), *The Commonwealth of Science: ANZAAS and the Scientific Enterprise in Australia, 1888-1988* (Melbourne: Oxford University Press, 1988); Lewis Pyenson, *Empire of Reason: Exact Science in Indonesia, 1840-1940* (Leiden: E. J. Brill, 1989); R. W. Home & S. G. Kohlstedt (eds.), *International Science and National Scientific Identity: Australia between Britain and America* (Dordrecht: Kluwer Academic Publishers, 1991); Svante Lindqvist (ed.), *Center on the Periphery: Historical Aspects of 20th-Century Swedish Physics* (Canton, MA: Science History Publications, 1993); Roy M. MacLeod (ed.), *Nature and Empire: Science and the Colonial Enterprise*, *Osiris*, 15 (2000); Edward Shils, "Metropolis and Province in the Intellectual Community," in E. Shils, *The Intellectuals and the Powers and Other Essays* (Chicago: University of Chicago Press, 1972), pp. 355-371; Roy M. MacLeod, "On Visiting the Moving Metropolis: Reflections on the Architecture of Imperial Science," *Historical Records of Australian Science*, 5 (1982), pp. 1-16; Barry W. Butcher, "Science and the Imperial Vision: The Imperial Geophysical Experimental Survey, 1928-1930," *Historical Records of Australian Science*, 6 (1984), pp. 31-42; Ian Inkster, "Scientific Enterprise and the Colonial Model: Observations on Australian Experience in Historical Context," *Social Studies of Science*, 15 (1985), pp. 677-704; Gabor Pallo, "Some Conceptual Problems of the Center-Periphery Relationship in the History of Science," *Philosophy and Social Action*, 13 (1987), pp. 27-32; Sharon Traweek, "Big Science and Colonialist Discourse: Building High-Energy Physics in Japan," in Peter Galison and Bruce Hevly (eds.), *Big Science: The Growth of Large-Scale Research* (Stanford: Stanford University Press, 1992), pp. 100-128.

Cavendish Laboratory enjoyed a steady flow of young scientists-in-training.

The other question that I want to pose is: How much and in what way the Cavendish *style* of physics influence the physics communities of Australia or Canada? It is quite certain that in the early twentieth century the Cavendish style of physics greatly influenced the *formation* of the physics communities in both Australia and Canada. However, even in the 1910s and especially after the end of the First World War, Canadian physicists became closer to the American physics community, and Australian physicists also began to be influenced by the American style of doing physics. One useful indication of this new trend, which I found while doing this research, is the rising number of publications in American physics journals by Australian and Canadian researchers. In short, we do not yet know how deep and how long the Cavendish style physics influenced the Australian and Canadian physicists' scientific works *at home*. Only by looking into more case studies can we answer these two questions.