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The Institutionalization of Scientific Research in Canadian Universities: The Case of Physics

OVER THE PAST FIVE YEARS a number of historians have discussed the problem of the development of scientific research in Canadian universities. All of them, however, limit their analysis to a single institution such as the University of Toronto, McGill University, or McMaster University.[1] While their work yields useful and important information about the way in which a particular university was affected by the growing demand for scientific research, these isolated studies have yet to give a general history of the emergence and institutionalization of scientific research in Canada. This broad perspective would relate such apparently unconnected events as the development of engineering education in the 1870s, the establishment of PH D programs at Toronto and McGill at the turn of the century, and the creation of the National Research Council in the middle of the First World War.

It might be argued that before writing this more general history, it is necessary to accumulate more case studies on the major universities and other institutions, such as the Canadian Institute of Toronto, that contributed to the development of scientific and industrial research in Canada.[2] These analyses will always be welcome, but it is also possible to explain the general development of scientific research in Canada by

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1 See, for example, Philip Enros, 'The University of Toronto and Industrial Research in the Early Twentieth Century,' in R.A. Jarrell and A. Roos, eds., *Critical Issues in the History of Canadian Science, Technology and Medicine* (Thornhill, Ont. 1983), 155–166; C.M. Johnston, 'Aspects of Science and Technology at McMaster University with Special Reference to Chemistry and Physics, 1939–1959,' ibid. 3–15.

2 Philip Enros, 'The Bureau of Scientific Research and School of Specific Industries: The Royal Canadian Institute Attempt at Organizing Research in Toronto, 1914–1918,' HSTC *Bulletin*, VII, 1, Jan. 1983, 14–26

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adopting a different approach – namely, the study of the formation of a scientific community.[3] Thus, instead of taking a particular institution and tracing the development of several scientific disciplines within it, the formation of a scientific community can be reconstructed by examining a single discipline, in this case physics. The significance of this approach lies in the fact that the pattern obtained is more general than that gained from the study of a single institution. The method may also be useful for the study of the development of research in other university-based sciences such as chemistry and biology.

The formation of a scientific community is a complex process but it can be approached analytically by distinguishing two important phases. The first is the emergence of the practice of research in Canadian universities. This emphasis on practice is important, for it must be distinguished from the discourse on the importance of scientific research which, in Canada, appeared as early as the 1860s but did not immediately lead to the development of research.[4] The second phase is that of the institutionalization of this research activity, a process which required important reforms in university structures. The failure to distinguish between these two different phases can easily lead to misleading conclusions about the history of scientific disciplines.[5]

As has been shown elsewhere, the emergence of research in physics in Canadian universities was the result of the importation of a practice from Europe during the last quarter of the nineteenth century. A new generation of university professors, trained in British and German physical laboratories, was more inclined towards research than

3 For a good example of a history of a scientific community see Karl Hufbauer, *The Formation of the German Chemical Community (1720–1795)* (California 1982). For a poor example see Daniel Kevles, *The Physicists: The History of a Scientific Community in Modern America* (New York 1978). For a sociological introduction see Warren O. Hagstrom, *The Scientific Community* (New York 1965).

4 Robin H. Harris, *A History of Higher Education in Canada, 1663–1960* (Toronto 1976), 80; Peter N. Ross, 'The Establishment of the Ph.D. at Toronto: A Case of American Influence,' in M. Katz and P.H. Mattingly, eds., *Education and Social Change* (New York 1975), 193–214; and A.B. McKillop, 'The Research Ideal and the University of Toronto, 1870–1906,' *Transactions of the Royal Society of Canada*, ser. 4, XX, 1982, 253–74

5 For an example of an inadequate treatment of the development of physics in Canada see Lewis Pyenson, 'The Incomplete Transmission of a European Image: Physics at Greater Buenos Aires and Montreal, 1890–1920,' *Proceedings of the American Philosophical Society*, CXXII, 2, April 1978, 92–144. By studying a single institution, McGill University, and by implicitly taking the activities of Ernest Rutherford as a model for the institutionalization of research, the author has taken the exception for the rule – for even in England and in the United States the 'Rutherfords' were the exception. Pyenson has thus misunderstood the process of development of a scientific discipline. His metaphor of an 'incomplete transmission' of physics is in fact the result of an incomplete study of the development of physics in Canada.

teaching. They identified their activities with those of an international community of scientists rather than with those incumbent upon traditional university teachers.[6] However, the institutionalization and consolidation of their research activity was attained only during the second decade of the twentieth century. This institutionalization was not the result of a single process, but the outcome of several independent but converging factors. At the centre were the researchers themselves, anxious to reproduce their group and their practice. Indeed, the institutionalization of research was a crucial step for the survival of these researchers as a group. The existence and development of a 'scientific community' are vitally associated with the existence of a means of production of knowledge and a means of training new members to continue the group's activities.

Though the endogenous process of training, which gave rise to a generation of research-oriented physicists, played a central role in the institutionalization of research, exogenous factors were more significant. The specific conjuncture of the First World War and the growing demands of Canadian industry to develop industrial research in Canada acted as catalysts to give national status to a claim that researchers dispersed across Canada had been pressing upon their university presidents for more than a decade. Though the National Research Council [NRC] was created in 1916 to foster industrial research, it was also to play an important role in promoting university research. The NRC established the first national system of grants and fellowships, and legitimized, in the name of national interests, the activities of those already engaged in research projects. By 1920 research was widely accepted as part of the task of a university professor and one of the missions of Canadian universities.

At the turn of the century, Canadian universities employed about six physics professors, only three of whom were conducting serious research projects. The 'fathers' of the discipline in Canada, James Gordon MacGregor at Dalhousie, Hugh L. Callendar and Ernest Rutherford at McGill, and John Cunningham McLennan at Toronto, not only introduced the practice of physical research in Canadian universities but also trained students in their new craft.[7] These research-minded professors, as well as their students who, after completing their doctoral degree, filled the new physics positions offered, for example, by

6 Yves Gingras, 'De l'enseignement à la recherche: l'émergence d'une nouvelle pratique de la physique dans les universités canadiennes,' *Histoire sociale/Social History*, forthcoming.

7 For more details on the career of these physicists see Yves Gingras, 'Les physiciens canadiens: généalogie d'un groupe social, 1850–1950' (Thèse de doctorat, Université de Montréal, 1984), 88–96.

the opening of universities in the Prairies, had to struggle to develop their research programs and to survive as a group.[8] The institutionalization of their practice, the only means of securing the future existence of physicists as a group, required the transformation of the present structures in order to favour the production of knowledge and the training of individuals with the expertise to continue original research. For example, the creation of PH D programs at Toronto in 1897 and at McGill in 1906, and the modification of master's degrees to make them an introduction to research, must be seen as instances of institutions adapting to serve the interests of the research-minded faction of university professors.

Prior to the First World War, the number of university professors in physics had grown to about twenty but most of those who could find time to work on research projects had few resources and were forced to use apparatus acquired for laboratory teaching. At Dalhousie, for example, J.G. MacGregor, who had trained at Edinburgh under Peter Guthrie Tait in the mid-1870s and specialized in the study of the physical properties of aqueous solutions, worked for twenty years without a real research budget. For some time he had to use his summer months to travel to Edinburgh where, 'through the kindness of professor Tait,' he could 'make use of the rich stores of the Natural Philosophy Laboratory of the University of Edinburgh.'[9] While MacGregor and his students were able to produce about sixty papers between 1879 and 1901, they worked with a minimum of resources.

In 1900 MacGregor finally received a grant of $100 from the Royal Society of Canada. Two years earlier the society had saved part of its annual federal grant of $5000 and applied the surplus, 'in view of stimulating scientific research,' to help research projects undertaken by members of the scientific sections. In 1899 the money was used by Section IV, biology and geology; next year it came to Section III, and MacGregor, a charter member of the society, received the grant under the condition that 'the results of such researches must be reported to the Section with the object of having them published exclusively in the Transactions.'[10] It was, however, a little late to help MacGregor, who left Dalhousie in 1901 to succeed Tait at Edinburgh. Unfortunately, there was no spare money in the following years and no more grants were made available to promote research.

8 For more details on the growth of university positions in physics see Yves Gingras, 'Le développement du marché de la physique au Canada, 1879–1928,' in Jarrell and Roos, eds., *Critical Issues*, 16–30.

9 Public Archives of Nova Scotia, MG 100, vol. 182, no 37, *Application of James MacGregor, Munro Professor of Physics to the Professorship of Natural Philosophy in the Edinburgh University* (Halifax 1901), 2–3

10 *Proceedings of the Royal Society of Canada* ser.2, IV, 1898, V

In contrast to the lack of funds at Dalhousie, the McGill Physics Department was lavishly supported from 1893 to 1907, thanks to the generosity of Sir William C. MacDonald, the well-known tobacco manufacturer. Opened in 1893, the MacDonald Physics Building was one of the best equipped in the world. In his report to the university for that year, director John Cox mentioned that 'the unusually complete set of electrical standards and instruments for comparison and the new instruments for thermometry and pyrometry, indicate that the laboratory may do useful work in these two branches of physics at no distant date.'[11] Cox, although not a researcher himelf, was anticipating that the contributions of his newly appointed colleague H.L. Callendar would add to the science of thermometry.[12] In 1892 MacDonald contributed $40 000 for the maintenance of the laboratory and the salary of a janitor and a technician. Four years later he added $110 000 to the fund to provide new instruments and an instrument maker.[13]

When new problems arose, MacDonald was nearly always there to solve them. In 1900 the growth of the student population required the hiring of new demonstrators for the physics laboratories but the resources of the university were not sufficient to meet this need. MacDonald accordingly gave $2000 to pay the salary of two new assistants.[14] This contribution also had positive effects on research, for most demonstrators were associated with the research projects of the professors. In addition to salaries, money was often needed for instruments. In 1902, for instance, Ernest Rutherford and Frederick Soddy were working on the nature of the Radium emanation (now known as Radon) but their work required the use of liquid air. 'On learning that several investigations were at a stand still for want of a supply of liquid air,' Cox reported, 'Sir W.C. MacDonald further caused a complete liquid air plant on Dr Hampson's plan to be purchased for the Physics Building at the cost of $1,250.' The very night the apparatus was installed, the gaseous nature of the emanation was finally proved beyond doubt.[15]

Notwithstanding the great success of Rutherford's research program at McGill, the Physics Department was created primarily to teach physics to engineering and medical students and the growing costs

11 *Annual Report of the Principal: McGill University*, 1892–3, 28

12 H.A.M. Snelders, 'Hugh Longbourne Callendar,' *Dictionary of Scientific Biography*, III (New York 1973), 19–21. See also John L. Heilbron, 'Physics at McGill in Rutherford's Time,' in M. Bunge and W. Shea, eds., *Rutherford and Physics at the Turn of the Century* (New York 1979), 42–73.

13 *Annual Report of the Principal: McGill University*, 1895–6, 28

14 Ibid., 1900–1, 32

15 Ibid., 1901–2, 27; and 1902–3, 35. See also Arthur S. Eve, *Rutherford* (London 1939), 86–9, 92, and Lawrence Badash, 'The Origins of Big Science: Rutherford at McGill,' in Bunge and Shea, eds., *Rutherford and Physics*, 23–41.

associated with the growth of the student population left little money for research. It seems clear that without MacDonald's patronage, Rutherford's research activities would have been much reduced.

In the years that followed, the situation become more and more difficult. In 1906 Cox noted that he had no money to hire demonstrators but mentioned with satisfaction that 'research has not, however, been hampered thereby, for the special research fund contributed by Sir William MacDonald some four years ago has been carefully husbanded, so that there is still a balance of $400.'[16] When Rutherford left McGill in May 1907, the epoch of patronage that helped him to stay on the crest of the wave of atomic physics was gone. Two years later when Cox retired as director, the thermodynamic laboratory was transformed in order to use 'the larger portion for medical students and reserving one for research.'[17] In 1910 H.T. Barnes, the new director of the department, complained that there was a real lack of space and that 'it is inevitable that the original work done in the Building must suffer in consequence.'[18]

This kind of conflict between teaching and research can also be seen at other Canadian universities. At the University of Toronto in 1908, Elie F. Burton, then assistant demonstrator in physics, wrote to the head of the department, J.C. McLennan, to complain that the rooms he was using for his research projects had been requisitioned as classrooms: 'my own research is now in progress in one of these rooms, and if this room is taken, and my apparatus dismantled, I must abandon my research.' He reminded McLennan that 'When I accepted my position here, instead of going to Princeton University, you will remember that it was on the distinct understanding that I should have reasonable time and advantage for my research work.'[19] McLennan agreed with Burton and wrote to President Falconer that 'after giving the whole question the fullest consideration, my opinion coincides with Mr. Burton's on the necessity for leaving undisturbed [the] rooms ... at present in use by Mr. Burton and his students.'[20]

At Queen's University A.L. Clark, a doctoral graduate from Clark University who specialized in the study of the thermodynamic properties of liquid and gases, was hired in 1906 as chairman of the Physics Department. Five years later he obtained a grant from the Rumford fund of the American Academy of Arts and Sciences to pay an assistant and buy some apparatus.[21] He used his annual report to the principal

16 *Annual Report of the Principal: McGill University*, 1905–6, 49

17 Ibid., 1909–10, 67

18 Ibid., 1910–11, 68

19 University of Toronto Archives, Falconer Papers, box 6, E.F. Burton to J.C. McLennan, 29 Sept. 1908

20 Ibid., J.C. McLennan to R.A. Falconer, 29 Sept. 1908

21 *Annual Report of the Principal: Queen's University*, 1911–12, 15

to complain about the difficulties in the way of doing research. In 1912, for example, he noted that 'Some of the very distressing features of our attempt to carry out research are the lack of private rooms and the scarcity of apparatus so much of which is needed for the regular class work.' Conscious of the fact that research could not yet be ranked ahead of teaching, he added that 'Our first duty is to our students and if apparatus is needed for the undergraduates' work it must be used even if the research be sacrificed.' In his conclusion, Clark pointed out that 'It is to be hoped that research may be more adequately provided for, so that Queen's University may take her place amongst Canadian Institutions in the way of original scientific investigations as she has in other lines of University activity.'[22]

In addition to their request for space, time, and money to pursue their research activities, the physicists had to ensure that the university recruited individuals interested in the development of research. In 1918, for example, Clark expressed the wish 'that in making appointments in the future a fair proportion of the men selected will be of the research type.'[23] Only in this way could the position of research be consolidated.

Until the beginning of the First World War, however, all these assertions of the importance of scientific research were made by a few individuals dispersed throughout the major Canadian universities. Moreover, these scholars spoke only on their own behalf. The war drastically changed this state of affairs by giving a new thrust to the demands of the researchers and making the theme of scientific research a national issue voiced through the offices of the Honorary Advisory Council for Scientific and Industrial Research, created in 1916, and soon known as the National Research Council.[24] This federal agency was the result of a movement promoting industrial research that had emerged in the period following the first decade of the century.

Promoted by the Canadian Manufacturers' Association and backed by the Royal Canadian Institute, an organization which acted as a bridge between academic and industrial circles, the industrial research movement was accelerated by the outbreak of war. The dependence of Canadian industry on European products and processes became strikingly evident.[25] Industrialists and academics alike attempted to press the Canadian government to action, resulting in a first meeting with the

22 Ibid., 16

23 *Annual Report of the Principal: Queen's University*, 1918–19, 41

24 For the history of the NRC see M. Thistle, *The Inner Ring: The Early History of the National Research Council* (Toronto 1966).

25 For more details on the promotion of industrial research in Canada see Enros, 'The University of Toronto and Industrial Research,' and 'The Bureau of Scientific Research.'

minister of trade and commerce in May 1915. Among the twelve people present at the meeting were, in addition to representatives of the major universities, the physicists H.T. Barnes from McGill, J.C. McLennan from Toronto, and the chemists R.F. Ruttan from McGill and W.L. Goodwin from Queen's. The discussion turned around the creation of a commission for industrial research, but action was delayed until November 1916 when the Honorary Advisory Council for Scientific and Industrial Research was created by Order-in-Council.[26]

Composed of eleven members and a secretary all chosen by the federal government, the Research Council was controlled by academics. The biochemist A.B. Macallum, who had played an important role in the development of scientific research at the University of Toronto, was named administrative chairman. Among the other members were F.D. Adams, dean of the Faculty of Applied Sciences of McGill, his colleague R.F. Ruttan, J.C. McLennan from Toronto, and A.S. Mackenzie from Dalhousie. A physicist, Mackenzie had been a student of J.G. MacGregor and had succeeded his mentor to the Munro Chair of Physics in 1901. A Johns Hopkins graduate, he became president of his university in 1910. Another university president, Walter C. Murray, a biologist from Saskatchewan, was a member of the council, as was S.F. Kirkpatrick, a professor of metallurgy at Queen's – in all, a total of seven academics. The other members were R.A. Ross and Arthur Surveyer, two Montreal consulting engineers, R. Hobson, president of the Steel Company of Montreal, and T. Bienvenu, vice-president of the Provincial Bank and the only French Canadian of the group. The superintendent of the Dominion Water and Power Branch, J.B. Challie, acted as secretary.[27]

In their consistent attendance at meetings of the council and their basic agreement on the needs facing Canadian scientific institutions, the academics effectively defined the policies of the NRC. They established a core group voicing the importance of scientific research which, before 1916, was only the opinion of scattered individuals. This change in the scale and status of the discourse on scientific research, which passed from an individual and personal level to a national and impersonal one, was a tremendous help to scientists, who were then able to legitimate their practice by appealing to national need.

At the first meeting of the council in December 1916 the members reserved 10 per cent of the $120 000 budget for the establishment of fellowships and studentships on the model of the 1851 Exhibition Scholarship. Created in 1891 by the British government with the profits generated by the London Exhibition of 1851, this scholarship

26 For more details on the these events see Thistle, *The Inner Ring*, 3–14.
27 Ibid., 9–11, 69

was directed to the training of researchers. Since the major universities of the empire were included in the scheme, each year two Canadians were eligible to go abroad for two or three years to obtain research experience that could hardly have been acquired in Canadian institutions. By 1914 forty-seven Canadians had benefited from this program, available only in science, and many of them went on to play an important role in Canadian scientific life. These scholarships, however, were used in foreign countries and did not stimulate research and graduate education at home. For this reason, the NRC fellowships were restricted to Canadian universities.[28]

At the third meeting, three months later, the members of the council established a system of grants for research projects submitted by university professors.[29] Though the NRC was created to co-ordinate the research activities of universities and industry, these steps were taken on the grounds that there was, in fact, little to co-ordinate. The NRC survey of the situation had shown, for example, that industry spent only $237 000 annually on research and that there were probably no more than fifty Canadians trained in research. Given this state of affairs, researchers, had industry needed them, could hardly have been found in Canada.[30] Consequently, the NRC saw as its first task the creation of the right conditions for industrial research which, according to the chairman of the council, A.B. Macallum, required students trained in pure and applied science.

Chairman of the Board of Graduate Studies at the University of Toronto for twenty years, Macallum had well-defined ideas about the needs of Canadian universities.[31] Indeed, a few months before becoming the first chairman of the NRC, he presided over a committee on graduate studies of the National Conference of Canadian Universities [NCCU] and reported that 'The two great needs of Canadian Graduate Schools were scholarships and increased library facilities, because it was through these that the American Universities were able to attract so many of our Canadian graduates.'[32] Now the head of a national institution and backed by the other members of the council, Macallum was in a position to promote his own view of the relationship between the universities and industrial research. This view gave ample room for the

28 National Research Council of Canada Archives, Minutes of the First Meeting of the Council, 4–6 Dec. 1916. For more details on the Canadian participation in the British scheme see Gingras, 'Les physiciens canadiens,' 118–27.

29 NRC Archives, Minutes of the Third Meeting, 13–15 Feb. 1917

30 Thistle, *The Inner Ring*, 29

31 A.B. Macallum, 'The Foundation of the Board of Graduate Studies,' *University of Toronto Monthly*, XVI, 1916, 217–24

32 Third Conference of the NCCU, McGill University, 22 and 23 May 1916, in *National Conference of Canadian Universities* (np, nd), 23–4

pursuit of academic ideals in the name of industrial development. Macallum maintained, for example, that 'on the general principle of utility as well as because of ideals, the student who is training for industrial research should during [the period of his fellowship] concern himself with problems in pure and applied science.'[33]

Macallum's view of the relations between universities and industry was also endorsed by a committee of the NCCU set up in 1919 to 'consider in what way the universities may best co-operate in the development of scientific and industrial research.'[34] In their report tabled four years later, the committee (containing, among others, the physicists A.S. Mackenzie, A.L. Clark, A.S. Eve, and J.G. MacGregor's former student, D. McIntosh) stated that 'The prime part which the scientific departments of our universities should take is ... the development of the spirit of research in [the students and the public] and finally the training of a body of young men capable of prosecuting research in pure science and, *ipso-facto*, in so-called industrial research.'[35] The subordination of the development of industrial research to the development of pure research through the training of graduate students greatly favoured the position of the university professors already engaged in research. In fact, given the scarcity of industrial research in Canada, the official position of the NRC could hardly have been different. The great majority of the scientists who could advise the government on what we now call 'science policy' were university presidents or professors who had themselves received doctorates two decades earlier and had since been trying to further the pursuit of research in their own universities.

During the interwar period this small group of people (essentially A.B. Macallum, J.C. McLennan, A.S. Mackenzie, W.C. Murray, H.M. Tory, and R.F. Ruttan) was responsible for most of the policies concerning scientific research in Canada. All these men met regularly. At the meetings of the NCCU they discussed the need for better graduate schools. At the annual meetings of the Royal Society of Canada they worked to improve the publication of the *Transactions* of the society. And, finally, they also met as members of different Associate Committees of the NRC to tackle more specific problems.[36]

By using the concept of national need, the NRC gave new fuel to the university professors' demand that more resources be allocated for research. As early as 1918, for example, the annual report of the

33 'Memorandum,' cited by Thistle, *The Inner Ring*, 57

34 Sixth Conference of the NCCU, Ottawa, 23 May 1919, in *National Conference of Canadian Universities*, 10

35 Ibid., Ninth Conference of the NCCU, Queen's University, 14–16 June 1923, ibid., 69

36 For more details on these events see Gingras, 'Les physiciens canadiens,' 222–91.

Physics Department of McGill University noted that 'In view of the establishment of studentships under the Honorary and Advisory Council for Scientific and Industrial Research, there will be an increasing demand for graduate instruction and research, especially after the conclusion of peace. To meet the needs of research in the field of modern physics, a special annual income for the purchase of new instruments and laboratory supplies is urgently needed.'[37]

The creation of graduate programs in Canadian universities thus facilitated the reformulation of the researchers' demands as 'training,' which was more congenial to the tradition of universities. In this way, what could have been seen as two separate and even conflicting activities (teaching and research) could be 'united' under the banner of training students in research. At the undergraduate level, the argument that 'good' teaching necessitates that the professor be engaged in research was also a strategy to unite research with the usual activity of a university which, as opposed to a research institute, is teaching. Though McGill and Toronto were the leading universities in scientific research, other Canadian universities were pushed in this direction by the NRC as well as by the competition existing between all the English-speaking universities, and rapidly adjusted their programs.

The importance of scientific research for the future of Canadian industry, a theme promoted by the NRC on a national scale, was rapidly diffused among the universities. It could now be found as a consistent concern in the annual reports of university presidents and was no longer confined to departmental reports. In his 1917 report, for example, President Murray of the University of Saskatchewan wrote: 'The war has awakened the nations to the importance of scientific research ... The nations of the world today have come to see what the scientists long have preached, that in science they have the most potent of instruments for extending human power.'[38] The same year the principal of Queen's noted that 'since the beginning of the war there has been a complete revolution in the British attitude toward [scientific research].' He was convinced that Queen's had to do her part in nurturing scientific research and that it was 'particularly necessary that those professors who show aptitude for research and zeal in its pursuit should not be handicapped by long hours of teaching.'[39] This was exactly what the head of his physics department, A.L. Clark, had told him nearly every year since 1910. By 1920 most institutions had internalized this function of a modern university and, in that year, the president of the University of Toronto gave a clear statement of the new wisdom before

37 *Annual Report of the Principal: McGill University*, 1917–18, 73
38 *Annual Report of the President: Saskatchewan University*, 1916–17, 4
39 *Annual Report of the Principal: Queen's University*, 1916–17, 15

a government committee: 'One chief function of a university is to extend knowledge and to train others who will extend knowledge ... The experiences of the great war and after have rendered unnecessary any extensive advocacy of the value of scientific research ... It was the application of the results of scientific research that contributed largely to the successful conduct of the war.'[40] In a more general sense, the first sentence only reiterated a position already taken by James Loudon at the end of the preceding century; the second sentence, however, was new and took advantage of and insisted upon the role that science played in the conduct of the war – a practical role for science that justified, in good part, the government funds spent through the NRC.[41]

Indeed, even though Toronto had offered a PH D degree since 1897 and McGill since 1906, these universities awarded few such degrees before the First World War. McGill produced only one PH D a year, all disciplines included. Toronto gave a similar number during the period 1897–1906 and only twice as many over the next ten years.[42] In fact, the development of these embryonic graduate structures came only after the creation of the NRC programs of research grants and fellowships. For example, in physics alone, there were about 2.5 doctorates awarded each year during the period 1920 to 1930 as compared to one every three years between 1900 and 1919. For masters' degrees the numbers were, respectively, 9 and 2.2. During the period 1930 to 1940, there were, on average, six PH D and twelve M SC degrees awarded each year. There are indications that a similar growth also occurred in chemistry and biology.[43] In all these sciences, PH D degrees were awarded only by the universities of Toronto and McGill. The other Canadian universities produced mainly M SC degrees and developed their own PH D programs only after the Second World War. Prior to that, their students went to McGill, Toronto, or the United States to obtain a doctorate. As a consequence of this growth in graduate studies, McGill and Toronto both created a Faculty of Graduate Studies in 1922.[44]

40 Cited by Peter N. Ross, 'The Development of the Ph.D. at the University of Toronto, 1871–1932' (ED D thesis, University of Toronto, 1972), 268

41 Concerning Loudon's point of view on scientific research see Ross, 'The Establishment of the Ph.D. at Toronto,' and McKillop, 'The Research Ideal and the University of Toronto.'

42 Ross, 'The Development of the Ph.D,' 195, and Stanley B. Frost, *McGill University: For the Advancement of Learning*, II: *1895–1971* (Montreal 1984), 177

43 The distribution of the NRC fellowships shows that these two disciplines greatly benefited from the NRC program. Indications about the evolution of the number of theses in these disciplines can also be found in F. Spitzer and E. Silvester, eds., *McGill University Thesis Directory, 1881–1959* (Montreal 1976), and J. Mills and I. Dombra, *University of Toronto Doctoral Theses: 1897–1967* (Toronto 1968).

44 Ross, 'The Development of the Ph.D,' 292; Frost *McGill University*, 177, and W.P. Thomson, *Graduate Education in the Sciences in Canada* (Toronto 1963)

The increase in the number of students enrolled in graduate programs and the research grants made available by the NRC also stimulated the growth in the number of scientific papers produced by Canadian universities. In the case of physics, the period 1910–17 saw, on average, the publication of seventeen papers a year, mostly from McGill and Toronto. For the period 1919–29 an average of forty-one papers were written, a figure that was maintained for the next ten years. The proportion of papers coming from Toronto and McGill then dropped, indicating an increase in research activities in physics in the other Canadian universities.[45]

In 1927 the NRC summarized the first decade of its activities and was proud to announce that 'an active and efficient research organization has been built in Canada, through which the investigation of any problem of national importance can be undertaken.' NRC funds had permitted 199 students sharing 344 fellowships, studentships, and bursaries to be trained at the graduate level in twelve universities across Canada. Though 'the main purpose of scholarships [was] to train men in research work,' and not necessarily to produce publications, the report noted that the 458 scientific papers produced by the holders of these scholarships were a good indication of the seriousness of their work. Sensitive to the problem of the brain drain, the report mentioned that out of the 155 students who had completed their training, 123 were still in Canada. In its survey of the research grants, the council noted that 120 projects involving universities had been financed and that though the majority of them involved specific industrial problems, it had also financed pure research on the grounds that 'industry can advance no faster than the principles upon which it is based.' As a further justification of this move, the report also stressed the fact that 'it is not often easy to differentiate between researches in pure and those in applied science, since it is frequently found that the pure science of yesterday has an industrial application to-day.'[46]

H. Blair Neatby has suggested that 'English-Canadian universities have experienced a revolution since the 1940's,' and that 'the impetus of this transformation has been the priority given to research.'[47] In fact, this 'revolution' had a long preparation and was a rather 'quiet' one. The emergence of research was the result of a long 'infiltration' in the universities by a new research-minded generation of professors, an infiltration begun at the end of the nineteenth century and which led to a truly consolidated position towards the end of the First World War.

45 Gingras, 'Les physiciens canadiens,' 398, Table A.4

46 *Annual Report of the NRC*, 1926–7, 17

47 H. Blair Neatby, 'The Gospel of Research: The Transformation of English-Canadian Universities,' *Transactions of the Royal Society of Canada*, ser. 4, XX, 1982, 275

By the mid-1920s the institutional structures that produced the university professor as a research-oriented professional were securely in place in Canadian universities. Though on a modest scale, university physicists as well as chemists and biologists could now develop their research programs in harmony with their institutional setting. Graduate programs provided them with students and the NRC provided grants and fellowships, as did the better endowed universities also.[48] In this way a system of production of scientific knowledge, the output of which was publication, was set in motion.

48 A good example of the importance of graduate students for the development of a professor's research program is provided by J.A. Gray, Chown Research Professor at Queen's University, who, in a letter to E. Rutherford in 1926, noted that: 'I have only one research student at present. I have three X rays outfits with a fourth one nearly complete and no one but myself to work them.' Fortunately for him, two other students joined him the following year, each with a NRC scholarship. Queen's University Archives, Gray Papers, box 4, J.A. Gray to E. Rutherford, 27 Oct. 1926