EMERGENCE OF PHYSICS GRADUATE WORK IN CANADIAN UNIVERSITIES 1945-1960

by Mel A. Preston and Helen E. Howard-Lock

In the decade following World War II, the Canadian university community experienced a most dramatic phase change. In 1945, as the war ended, there were 28 universities in Canada; of these, only two, Toronto and McGill, were research institutions with established graduate programs leading to the Ph.D. degree. Even in these two universities the enrolments were hardly what now would be considered academically viable. In the 20 years, 1920-1939, the University of Toronto granted 231 Ph.D. degrees, of which only one or two per year were in physics. In 1941 the total doctoral student enrolment in all departments at McGill was 100, and at Toronto, 140. Most of the other universities offered masters' degrees and some granted an occasional doctorate -- in 1925, Queen's gave its only physics Ph.D. in the twenty-year period.

> In the decade following World War II the Canadian university community experienced a most dramatic phase change. In 1945, as the war ended, there were 28 universities in Canada. By the mid 1960s the number of Canadian universities had increased to 50, and of these at least a dozen had doctoral programs.

It seems quite fair to say that in the 1930's and 40's there was a general sense amongst the academic leaders of our universities that there was no justification for a substantial graduate enterprise. They felt it was enough to give Canadians a good education and then, if some wanted to study further, they could go to the leading American and European universities, for which they would be well prepared. In fact, the typical promising graduate did not even consider staying in Canada for a Ph.D., although this attitude was beginning to change somewhat after NRC established a small scholarship program in the 30's.

The universities did recognize that, in order to achieve excellent education, a good faculty was required, and that therefore some research opportunities were necessary. Consequently many universities encouraged masters' level work in selected disciplines. They felt no need, however, to give much priority to graduate students, even though without them research and scholarship are inhibited.

Of course there were Canadian academics who did pursue research, often of outstanding quality, and indeed with support from their institutions. For example, Rutherford at McGill, McLennan at Toronto, and Herzberg at Saskatchewan. But, in general, research funds were not readily available and support for graduate students was quite limited, both in finances and in the time faculty could make available for advanced instruction and research guidance.

Now, the change: By the mid 1960's the number of Canadian universities had increased from 28 to 50, and of these at least a dozen had doctoral programs operating in many disciplines. Indeed, in 1962, there was felt to be a need to establish the Canadian Association of Graduate Schools. The number of doctorates awarded in Canada in the year 1960 was 306, three times as many as in 1945. By 1965, the number was 696. And these were not "dubious"

M.A. Preston (prestonm@mcmail.mcmaster.ca) and H.E. Howard-Lock, Department of Physics and Astronomy, McMaster University, 1280 Main Street West, Hamilton, Ontario L8S 4M1

degrees; many of the departments were now doing internationally recognized research. It is fascinating to examine the cause and mechanism of this dramatic and rapid expansion, and the sudden emergence of a national system of research universities. In this short paper, the story is confined mostly to the science disciplines and to physics in particular. Even within this scope an effort to deal in any detail with the postwar development at each university would either be voluminous or consist of dry statistics. Instead I will try to illustrate the overall experience with references to a few typical situations. Not surprisingly, some will be ones I (M.A. Preston) know personally.

The immediate enrolment growth in 1946 was a result of the government rehabilitation program for war veterans. As the veterans returned to Canada and to civilian life, 53,000 of them entered universities in the six postwar years. This required large university expansion and gave the universities much larger funding. But that in itself would not inevitably have led to scholarly development. Indeed, a mind set emphasizing undergraduate instruction might well have continued, especially since it was thought (wrongly) that the enrolments would drop again. The change in research activity was not attributable mainly to demographics but rather to the leadership of some remarkable people with a clear vision of a strong Canadian role in basic research.

It was widely appreciated that a major transition in Canada's cultural affairs was underway. The pressure for opportunities would grow as the veterans finished their undergraduate education and sought scholarly activity, and there was an inescapable role for the federal government if Canada were to become a culturally, economically and technologically advanced country. As early as 1949 the government responded by creating A Royal Commission on National Development in Arts, Letters and Sciences. The report of this Commission emphasized the need for nurturing basic and applied research. Toward this end, the government accepted its recommendations that the National Research Council (NRC) play a much wider role outside its own laboratories and that the Canada Council be established as an independent body to support not only the arts but also humanities and social sciences in the universities.

It is no coincidence that one of the five members of the commission was Chalmers Jack Mackenzie, the president of NRC. He was arguably the single most important influence in the immediate post-war growth of Canadian science. Just as war began in 1939, he came to NRC from the University of Saskatchewan where he had been dean of the College of Engineering since its founding in 1921. He brought with him a clear understanding of the need to improve the research environment in the universities, and a definite intention to do so. By 1943 there had developed a policy that, although NRC would have some groups working on "pure" science, its own research would emphasize applied areas and it would support basic research in universities. Throughout the 1930's the deep economic depression had starved all efforts at academic development. The National Research Council would now support the universities both with grants for research expenses and with the relatively new idea of national scholarships for graduate students. It was foreseen that at war's end there would be a very sudden increase in demand for research personnel. During the war, Canadian industry grew in support of the military effort, and much associated research took place, both within NRC and in several universities. The level of government funding grew rapidly when the war ended. In 1947-48 NRC grants to universities reached nearly $1,000,000 - five times the prewar level. By 1960 NRC was granting nearly $10,000,000 per year. During the 1950's some additional government agencies began to give research grants, notably Atomic Energy of Canada, which in 1960 gave $700,000 in university grants.

Another major initiative introduced in 1945 was the awarding of postdoctoral fellowships. Although the rapid university expansion meant that there was no shortage of faculty jobs, this funding for full-time research workers was of great importance, both for the fellows and for the burgeoning research groups which they joined.

In 1952 Edgar W.R. Steacie became president of the National Research Council. He was a physical chemist who had been on the McGill faculty and director of NRC's chemistry division. He vigorously continued Mackenzie's policy, taking initiatives to promote university development and to increase federal funding.

There was a positive legacy from the war years in several physics departments: Some had become involved in research in radio physics and in the training of military personnel in radar. A natural outgrowth developed in electronic physics and related areas such as solid state physics. The nuclear physics activity in Montreal (described in this issue in the article by Philip Wallace) was a background to the immediate postwar developments at McGill under the leadership of J.S. Foster -- acquisition of Canada's first cyclotron in 1949 and the initiation of a theoretical physics group.

Another very important element fostered in this era by NRC and other government institutions was scientific collaboration. Many university physicists had research projects or worked with groups in laboratories at NRC and at AECL, Chalk River; government scientists had leaves and adjunct appointments in universities. Also inter-university groups developed, often involving professors at developing universities. Although they are somewhat later developments, TRIUMF (Tri-University Meson Factory) and the joint Guelph-Waterloo Ph.D. program are examples of the continuity of the cooperative spirit of the postwar era.

International collaboration is basic to scientific progress. The new faculty members of 1945-1960, whether or not they were Canadians, overwhelmingly had taken their graduate studies abroad. So the connections were there, and fortunately they were fostered by NRC's postdoctoral scholarship programs. And the reverse flow began at this time. Foreign students wanted to study in Canadian departments. This development was an indication of the growing reputation of our research quality.

To many of us, the internationalism of science is very important. In the mid-1970's, provincial governments "began to suggest" higher tuition fees for foreign students, and the federal government introduced constraints on the appointment of non-Canadian faculty. However valid or invalid such policies are, they did not exist in the 1945-1960 era we are describing, and Canadian physics became a significant part of the world physics community.

I have already said that the post-war research growth was dependent on the vision of a number of remarkable leaders. Dr. Mackenzie and Dr. Steacie were very influential in the development of the new government policies. These policies would be effective only if there were also people in the universities eager to use them, and able to generate other opportunities and mechanisms for local development. There will be a number of examples in the rest of this story.

THE SASKATOON STORY: THE AURA OF THE AURORA AND A BETTER BETATRON

The University of Saskatchewan was founded in 1909 and it was guided into the 1930's by its first president, Walter Murray. A good university developed, which was well suited to the perceived needs of the province. In keeping with the general position we have noted, however, President Murray said, in 1922, "the University has no intention of preparing candidates for the Doctor's degree... It would be folly...to add another feeble graduate school to those that encumber the land." At the same time he boasted about the wide acceptance of Saskatchewan graduates in leading American schools. On the other hand it was considered important to have well qualified faculty with Ph.D.s and research was encouraged, particularly if it had practical applications. As a result there were some masters' students who participated in research.

Yet, in the depths of the Depression, this same Walter Murray stretched the resources of the university to appoint Gerhard Herzberg. In 1932, a young chemist, Dr. John Spinks, had been asked to save the university money by taking a leave on minimal pay, and he was able to arrange to work with Herzberg in Germany. Later, in 1935, Herzberg felt compelled to flee Nazi Germany and he wrote to ask Spinks if he could help him go to Toronto where there was extensive work in spectroscopy. Spinks took the problem to Murray. After Toronto and McGill, the only places with doctoral programs going, decided they could not help, Murray invited Herzberg "with joy" to join the University of Saskatchewan's physics department, even though there was neither suitable equipment nor money. The appointment was made possible only because Murray convinced the Carnegie Corporation that he had a good use for a grant. Herzberg had ten very successful years in Saskatoon, completing two of his authoritative books on spectroscopy, and investigating new spectra as some apparatus was obtained. He supervised ten masters' students, most of whom went on to demonstrate the saying that "one of Saskatchewan's major exports is good people". Although Herzberg left just as the war ended, his presence had helped lead to the recognition of the physics department as a place where research was encouraged, and so placed it in a position to be able to take advantage of the opportunities provided by the new government policy.

Professor E.L. Harrington, head of the department from 1925-1952, had a special genius for design and construction of apparatus. In the 1930's he had been asked by the Saskatchewan Cancer Commission to build a radon plant. This he did, not only introducing novel design features, but also doing much glass-blowing himself. Thus, the physics department had some continuing involvement with medical uses of nuclear radiation. Also through Newman Haslam, there was a connection with more basic nuclear physics. Haslam was a native of Saskatoon who was able to spend the two years, 1933-35, in Leipzig as a postdoctoral assistant to Werner Heisenberg, one of the founders of quantum mechanics. Incidentally, Newman had done his doctoral work at McGill, a departure from the usual pattern of going abroad. After his time with Heisenberg, Newman was able to obtain an appointment at his home-town university--this was an achievement for the Depression years, even though the rank was instructor. Haslam did research on photonuclear reactions. Thus the ground was laid for post-war expansion into nuclear physics and its medical applications.

Harold Johns had finished a Ph.D. at Toronto in low-temperature physics just as the war began in 1939. He had won a scholarship for research abroad but the scholarships were cancelled for the duration of the war. Harold was fortunate to secure employment at the University of Alberta, although there was little opportunity for research there. In addition to his teaching, which included radar instruction for the military, Harold became familiar with energetic X-ray technology, inspecting aircraft castings made in western Canada. This interest in radiology made it reasonable for Professor Harrington to bring Harold Johns to Saskatoon in 1945 by arranging a joint appointment with the Saskatchewan Cancer Commission with which, as we have noted, he had close contacts.

Also Leon Katz, a Queen's graduate who obtained his Ph.D. at the California Institute of Technology in 1942, came to Saskatchewan in 1946 with the hope of doing research in nuclear physics. At that time, betatrons were commercially available. These electron accelerators give high energy X-rays and electron beams. The younger members of the department, Haslam, Johns and Katz, each thought that a betatron would be a splendid tool for his research, but they saw no way they could get one. On the other hand, Professor Harrington told them that they were a department that was to be a place of top quality research, and they must not be daunted. He took the lead in obtaining federal funds for the machine and in inducing the provincial government to provide the laboratory for it. Harold Johns had the principal role in negotiating the purchase. They wanted a 25 MeV betatron model, manufactured by Allison-Chalmers. However, Allison-Chalmers had agreed to sell only agricultural equipment in Canada and scientific equipment in the USA, while General Electric would sell only scientific equipment in Canada and agricultural in the USA. Johns knew that Allison-Chalmers had the better betatron. He called General Electric and said if they wouldn't let Allison-Chalmers sell it to him he was going to call a press conference at 4 o'clock and publicize their policies. Within two hours they called back and agreed. Nowadays we would say that Johns broke a monopoly.

The betatron acquisition in 1948 was an early portent of the future. The physics community saw that Saskatchewan had ambition and determination to develop a strong research department, and undoubtedly other departments were encouraged by their success.

There was another significant pre-war activity that prepared Saskatchewan for rapid research growth. It was the auroral and meteorological research of Balfour Currie, who began his scientific career as a young physicist in the Canadian program for the International Polar Year, 1932-33. Later, on commission by the Meteorological Service of Canada, he made a comprehensive study of the climate of the prairies and the northern territories, leading to papers and a book. But his real love was the "Northern Lights". By the war's end Currie's excellent work was well known and this field was set to develop rapidly.

The urge to develop research on the Saskatoon campus was not confined to physics, and the College of Graduate Studies was established in 1946, largely as a result of the desire in the sciences to attract research students. In 1948, President Murray's fear of encumbering the land with another feeble graduate school was fully abandoned and the enrolment of Ph.D. students was authorized. The first Ph.D.'s were granted in 1952 and, perhaps not surprisingly, they were in physics. Both were students of Leon Katz. Alastair Cameron became a professor of astrophysics at Harvard, and Ray Montalbetti remained at Saskatchewan and was for a long time department head. In 1948 then, the foundation was laid in Saskatchewan in two major areas.

Throughout the 1950's, funding for radar and instruments for auroral studies was generous. In 1957 the Institute for Upper Atmospheric Physics was set up with Dr. Currie as Director and with sustained funding, much of it from military sources in Canada and the USA because of the importance of Northern Canada's skies to missile defence. Despite this, the research was not pushed into an overemphasis on applications. Soon there was a group of professors working on auroral studies. And the quality of their work attracted others. By the time of the international Geophysical Year, 1957-58, the Saskatchewan physics department had become recognized as one of the world's most important centers for auroral studies. As the field of research has broadened over time, this status has continued, and the current members of what is now called the Institute for Space and Atmospheric Studies engage in a great deal of international research activity.

The post-1948 development of the radiological and nuclear side of the department had its first widely publicized success in 1952, when Harold Johns designed and built the first ^{60}Co unit for the treatment of cancer. Throughout the late1940's and early 50's, much research was done by Johns and his students and colleagues on the medically significant interaction of X-rays with matter, including living tissues. In 1954 he was awarded the medal of the Roentgen Society. In 1956, Harold left Saskatchewan to accept a position in Toronto, again in both the Cancer Foundation and in the University. He did so with considerable reluctance, but he saw an opportunity for greater impact as a leader of the biophysics and cancer research in the Toronto medical community.

The nuclear physics area burgeoned with the activities of Leon Katz and Newman Haslam. Katz's research was with students, colleagues and apparatus at both Saskatoon and Chalk River. The work focussed initially on the identification of new isotopes, and of nuclear energy levels and spectra, together with theoretical interpretation. Towards the end of the 1950's, the nuclear group saw that their future research depended on the higher energy accelerators that were becoming possible. This time Leon took the lead and in 1961 the first shovelful of ground for an accelerator was turned by Sir John Cockcroft of Cambridge in company with Dr. Steacie. This was made possible by NRC's first significantly large grant under a new policy to support a few "big science" projects. The linear electron accelerator (LINAC) was to stimulate research not only in nuclear physics, but also in radiation chemistry and biology. Thus the interdisciplinary activity that used the betatron continued. Inter-university collaboration was also a major aspect of the LINAC, with users from several countries. Scientists from many institutes used the accelerator just as Saskatchewan physicists also used accelerators of different types at other sites. This brings us to the end of the post-war period, but it is significant to note that, just as with auroral studies, nuclear physics continued to flourish at Saskatoon.

As our knowledge grows, learning interesting new nuclear physics requires higher energies than the LINAC can provide. But the LINAC is being put to excellent use as the basis of the Canadian Light Source that is now under construction. Again this major development, which required a great deal of both scientific and political expertise, was headed by a physicist, Dennis Skopik, who had used the LINAC but then devoted his efforts to ensuring the growth of science in Saskatoon, even though he could no longer do his own nuclear research there.

This account of the emergence of Saskatchewan's department as a physics research center illustrates many of the factors outlined in my general introduction. One other thing worthy of note is that the successful leaders were not only very productive scholars, but also were good at working with people and were willing to assume organizational and administrative responsibilities. Balfour Currie had succeeded Harrington as department head in 1952 and was in turn followed by Newman Haslam, who a few years later became Dean of Arts and Science. In 1961, the year of the LINAC, Leon Katz became vice-president of the Canadian Association of Physicists, and a year later, president. Also in 1961, Currie received the CAP gold medal for achievement in physics, and became Dean of Graduate Studies; he later became Vice-President (Research). Even after his retirement he continued to be active in university affairs. Indeed, in 1977, he was to some extent responsible for recruiting me to Saskatchewan where

I followed immediately in the footsteps of Haslam as Vice-President (Academic). There can be productive scientists who simultaneously commit themselves to the progress of academia.

THE HAMILTON STORY: CRITICAL MASS, RADIOISOTOPES, AND A NUCLEAR REACTOR

Another outstanding scientist and administrator was Henry George (Harry) Thode, one of the pioneers of isotopic geochemistry and the leader of the development of the modern McMaster University. When Harry came to McMaster in 1939, it was a small liberal arts college that had moved to Hamilton from Toronto ten years before, just as the Depression began. When Harry retired as its president in 1972, McMaster was a research intensive university that had increased enrolment by a factor of 10 over the past 20 years, and that had more students in the graduate school than the whole university had in 1952. Throughout this time and indeed until his death in 1997, Harry was a major leader in the field of isotopic chemistry and geochemistry, and was recognized as one of Canada's most influential science administrators.

Sharing the common ethos of the 1930's, McMaster saw undergraduate work as its predominant function and, indeed, discouraged "specialization". During the design of the Hamilton campus, Chancellor Whidden contemplated quite happily a single science building, designed for "general science" and unable to accommodate "advanced work". However, in 1930, its first year in Hamilton, McMaster was joined by the chemist Charles Burke, who was an experienced professional in both academic and industrial areas. He was a McMaster graduate of some 20 years standing who had maintained close interest in his alma mater. After only two years he was appointed associate dean with responsibility for science. He introduced a wider perspective. The desire to attract good students led him to encourage innovation in the courses offered, an approach initially opposed by the senior physicist H.F. Dawes. Burke also wished to strengthen the faculty, particularly by recruiting both a physical chemist and a physicist able to supervise the work of M.Sc. students. By 1939 funds were in place and two persons of "great promise" were found. They were Harry Thode and Gerald Wrenshall. While at McMaster, Wrenshall continued to work on nuclear physics in both Hamilton and Rochester, but unfortunately for McMaster he left after two years.

Thode, another important Saskatchewan export, had taken his Ph.D. at Chicago and had just finished two years as a research associate with Harold Urey who had won the Nobel Prize for discovering deuterium. Harry Thode worked on the separation of the rare isotopes ^{13}C, ^{15}N and ^{18}O. His intention to continue isotopic studies required a mass spectrometer. Immediately on arrival he began construction of the first one in Canada, aided by a $3000 grant from NRC that Urey helped to arrange. Thode also offered an evening course on topics of interest to industrial chemists. This shows his interest in being closely tied to the Hamilton community, a "town-and-gown" relationship that proved very important in the post-war development, just as had Harrington's work with the Saskatchewan Cancer Commission.

The impact of the war-time research was very significant for McMaster. Harry's first project was analysis of sulphur isotopes related to chemical warfare and the production of ^{18}O. In 1942 he was persuaded to join the Anglo-Canadian-US project located in Montreal, working on nuclear research and reactor design. Although Harry spent some time in Montreal, his contention was accepted that use of his equipment already in Hamilton would save a great deal of time. Part of the top floor of McMaster's only science building, Hamilton Hall, became a site of secret work, but the students of course knew that something mysterious was going on. The results included the discovery of the radioactive isotope ^{85}Kr and a great deal of data significant for understanding the fission process, and for the later development of the shell structure model of nuclei. The importance of this work would lead to a sudden awareness of McMaster by other scientists and, on the campus itself, it began to prepare the way for an improved status for science. By 1945, Harry had seven research assistants, two of whom played key roles later in the development of the physics department.

The physics department involved itself in war-time projects. In response to urgent requests in 1940, its two members, Henry Dawes and Boyd McLay, organized and taught courses in radar and electronics for the air force, navy and army. They built for this purpose special equipment that was also used in the regular laboratory classes. In addition, Boyd, who had an interest in marine matters, acted as the commanding officer of the University Naval Training Detachment. There was clearly little time for research. Professor Dawes, who was appointed in 1910, retired in 1947, and Boyd became acting head and then was chair of physics from 1950-56.

Between 1945 and 1947 there had been significant developments. It was the policy of the Ontario government to give no financial support to a "denominational institution". McMaster was under the aegis of the Baptist Church. Indeed only Baptists could be members of the Senate. Moreover, it was the position of Baptist institutions that they ought not to seek state aid that would "endanger the absolute freedom of the church from the state". It was suggested that this dilemma, at least for the government, would vanish if there were an affiliated college devoted to science education and research, totally separate from the university in finances and governance. This proposal clearly would need public and political support. It ran the risk of causing a schism in the church since the college would be teaching McMaster students. George Gilmour, the Chancellor and himself a Baptist clergyman, guided the university through this controversy. Additional money from private sources would be needed, and it was important to have the deep involvement of the major Hamilton industries and business community. In this connection, the contacts that the scientists, especially Burke, already had forged in Hamilton proved significant.

Hamilton College was established by legislation late in 1947 with a Board of Governors reflecting Hamilton's industrial leadership. It was then accepted by the McMaster University Senate and Board. The organization was now in place for aggressive development in the sciences. After Dean Burke died suddenly in May 1949, Harry Thode became the first principal of Hamilton College. He had already taken the lead in persuading the university to offer Ph.D. studies. Conservative faculty opposition was overcome, in part by establishing the condition that the university's reputation be guarded by offering degrees only in fields in which there was undoubted competence, judged by distinguished external consultants. (This appraisal system was later extended throughout Ontario, a development in which I played a leading role when I joined the decanal ranks.) Authorization for Ph.D. studies came for chemistry in 1949 and for physics in 1951.

Very soon after the war's end, a senior position was authorized in physics and in 1947 Fricis Gulbis was appointed. He had been the Professor of Physics at the University of Riga. Latvia had been occupied successively by both Germany and Russia and, like many Baltic academics, Gulbis was a refugee. Also in 1947 Professor Dawes retired and Martin Johns was appointed. Johns' research interests in nuclear spectroscopy and Gulbis' in cosmic rays fit McMaster's growing emphasis on sub-atomic physics.

Martin Johns had completed his Ph.D. at Toronto in 1938, one year before his brother Harold, and he had immediately joined the staff of Brandon College, where there were no research facilities. He arranged to come to McMaster for several summers and to work with Harry Thode's group. He tells me that, in 1946, he was being recruited by Queen's but Harry told him that that move would be unwise. He should instead go to Chalk River and really get into nuclear research. He did so and one year later came to McMaster. Again NRC played a crucial role: Martin got an equipment grant of $10,000, albeit in two instalments, the second of which required Thode's personal intervention.

More research space was becoming essential. Hamilton College found the money and in 1951 opened the Nuclear Research Building with laboratories, a small seminar room and a few offices, including Thode's. This was the first new building after the war, and it was important for the future because it established that science, and nuclear science in particular, was to be emphasized at McMaster.

There were now the facilities to make a fourth appointment in physics possible. Like Martin Johns, Harry Duckworth had worked in Thode's wartime group. He had completed doctoral work at Chicago in 1942 and joined the Canadian Army, but was assigned to war research at NRC and then in 1944 to Hamilton. After one year on the faculty at his alma mater University of Manitoba, Duckworth taught for five years at Wesleyan University, in Connecticut, where he built a mass spectrometer. In 1951, Thode and Johns decided he should return to McMaster. (We're still well before the days of appointment committees). Duckworth agreed, took over one of the new laboratories, and soon had a functioning spectrometer and a very active group of students. Duckworth later served as McMaster's Dean of Graduate Studies (1961-65), and Vice-President of the

University of Manitoba and President of the University of Winnipeg (1971-78).

The next faculty appointment was a theorist, Mel Preston. I had been in the army but was back in Canada before the war's end, and so was able to return quickly to Toronto for an M.A. I then went to Birmingham for the Ph.D. studying nuclear theory with Sir Rudolf Peierls. In 1949, I became an assistant professor at Toronto, but spent the summers at Chalk River with the theory group, because there were no nuclear physicists to talk with in Toronto. In 1952 Harry Duckworth asked me to come to Hamilton once a week to teach a course for McMaster's few graduate students. I agreed but with no thought that any sane person would leave Toronto for one of the "little places". My attitude changed as I became aware of McMaster's plans. When I received a challenge from Thode to join in building "Canada's best physics department", I decided to do just that. Of course, before accepting, I had ensured there would be support for the graduate students and postdocs needed to begin a theory group.

In 1954 what might be seen as the core of the department in the 50's was completed by the appointment of Howard Petch. He was one of the veterans who started university in 1945 at McMaster. He obtained his Ph.D. in 1952 at one of the other rapidly developing universities, the University of British Columbia. After a post-doctoral year at McMaster and then a Rutherford Fellowship at Cambridge, he came to McMaster to begin the development of solid state physics. He later served as vice-president of the University of Waterloo and president of University of Victoria (1975-1990).

McMaster's first three Ph.D.s were awarded in 1953, to Benjamin Hogg who had worked with Duckworth, Carmen McMullen with Johns, and Robert Wanless with Thode. Hogg went to teach at the Royal Military College and later at the University of Winnipeg. He maintained research on the measurement of atomic masses; in Winnipeg he worked with the group established at the University of Manitoba when Duckworth went there in 1965. McMullen stayed at McMaster, initially working for the Defense Research Board on classified work and later joining the faculty. Wanless's career was with the Department of Mines and Technical Surveys in Ottawa, working initially on mass spectrometry.

Department growth accelerated through the second half of the 1950's. The policy was to strengthen the established research fields to a "critical mass" rather than to start new ones. The first faculty appointment in this period was Bob Summersgill in nuclear physics. Later Rudy Haering and then Sy Vosko came to develop the theoretical side of condensed matter physics, an area that has continued to flourish steadily.

The number of graduate students also grew rapidly. The five Ph.D. graduates in 1956 included the first non-Canadian, Kailash Kumar, who, after postdoctoral positions at McGill and Purdue, returned to India for some time and for many years now has been a professor at the National University of Australia in Canberra. In 1961 Agda Artna became one of the first women to earn a physics Ph.D. in Canada. By 1957 university-wide development of graduate studies had led to the establishment of a Faculty of Graduate Studies with its own dean, Arthur N. Bourns.

The decade culminated for McMaster with the opening, in 1959, of the nuclear reactor, the first one at a university in the British Commonwealth. It was clear by 1955 that reactors would be research instruments in many areas of basic science, and not simply power generators. They could be used to study nuclear structure and nuclear phenomena and to make isotopes having medical applications. Also the neutron beams were beginning to be used to study the structure of materials. These were all principal research areas at McMaster. Harry Thode's gifts of leadership became evident again. As Chancellor Fox said at the reactor opening: "He had the vision of what was wanted and he enjoyed the confidence of those people who made it possible". Amongst those people were Mackenzie and Steacie, by now the principal figures at AECL and NRC, and also those who brought financial assistance from Ontario Hydro and from some other industrial sources. The extent to which the universities had public support in the 1950's is illustrated by the fact that Prime Minister Diefenbaker would come to open the reactor and call it "a symbol of mankind's quest for peace and an assertion of faith in the constructive benefits of science."

To examine the degree to which the reactor enabled such goals to be achieved would take us beyond our

1960 cut-off, but it must at least be said that its presence was a significant factor in persuading Bert Brockhouse to come to McMaster in 1962. Even then we thought his work was due for a Nobel prize; more than twenty years before the award was given, I helped Harry Welsh prepare the first nomination.

The presence of the reactor naturally made McMaster an important centre for the training of nuclear engineers and health physicists. Although its importance for physics research has lessened, the reactor continues to fill a useful role, and it is used now extensively for biological and medical research. As at Saskatchewan, the principal foci of McMaster's research continued successfully after the immediate post-war era. A tandem Van de Graaf accelerator was obtained and, although it is no longer useful for nuclear physics, the nuclear group is active with off-campus accelerators. The condensed matter group developed steadily, produced many significant findings and now has an endowed chair named for Brockhouse. Medical physics, now an important part of the department's teaching and research, developed mostly after 1960. And it is only a few years ago that the department became the Department of Physics and Astronomy.

Research emphases change with time but the Saskatchewan and McMaster stories illustrate that once a research ethos was established it persisted.

THE ROLE OF THE CAP

One more significant factor in the research growth of the 1945-60 years was the Canadian Association of Physicists (CAP). It began in 1945, partly because some physicists in industry felt the need for a professional association, but it also had academic goals. Its annual conferences gradually became an important factor in promoting the informal communications that can be so significant in establishing a community of scientists and in generating ideas and catalysing research. This led to the establishment of subject divisions and the organization of summer institutes. (See the articles by D.D. Betts and F.M. Ford in this issue for more information on the CAP's history and evolution of activities.)

Recently, lobbying the government for research funding and advising on granting policy have been very significant roles of the CAP, but this also had occurred earlier. In 1955, some physicists began to suggest that Canada should maintain its enviable reputation for scientific and technological progress by building a high energy accelerator. The CAP established working committees to examine the possibilities and, in 1958, it presented a brief to the Minister of Trade and Commerce with specific recommendations. They were the result of much careful work, including visits to places in the USA and Europe having operating or planned accelerators, consideration of the most promising energy and type of accelerator, detailed analysis of proposed sites and of organization. The result was a proposed 15 GeV proton accelerator, to be located in Kingston near Queen's University, costing $25 million, organized as a corporate subsidiary to NRC with university shareholders. It was even established that at least five suitable Canadian physicists would consider the position of director.

This CAP proposal shows how far research in universities had come in the ten years since 1945. The committee preparing the proposal was headed by Dr. R.J. Hay of Aluminum Co. of Canada and its members came from NRC, Laval, McMaster, Saskatchewan, UBC and Montreal. Queen's administration strongly supported their potential involvement, as did that of UBC which was the alternative site recommended. UBC made very rapid progress in physics research, again with important leadership, in this case from Gordon Shrum. A vignette of Shrum appears elsewhere in this issue but one tale illustrative of his positive attitudes may be in order. When the committee was visiting Vancouver, two serious problems were raised. If the accelerator were at Point Grey, obtaining a supply of sufficient cooling water and adequate electrical power would be difficult. Looking over the broad expanse of English Bay, Shrum asserted "I'm sure we can find a way to use that salt water -- and we can put electrical cables under it if we have to".

The accelerator initiative ended with a government decision in March 1959 not to fund it. Although the nuclear reactor at McMaster opened the same year and cost $2 million, Ottawa was not ready for sums like $25 million. A few years later, money was found for TRIUMF -- Shrum had not given up.

CONCLUSION

It is the author's hope that this article may convey something of the ebullient atmosphere of Canadian university physics between 1945 and 1960. Some universities were able to develop much more rapidly than others, and I have described two of these in some detail. They are examples of the remarkable progress and expansion that is really the story of the nation-wide physics community. The University of British Columbia was probably the institution that grew most rapidly. It was granting Ph.D.s by 1952 and the first were in physics; by 1960, UBC was Canada's third largest university and the physics department had produced almost 100 Ph.D. degrees.

Another initiative of the 1950's was at the University of Manitoba where Robert Pringle began very productive research in nuclear physics that led to the birth of Nuclear Enterprises Ltd., Winnipeg and Edinburgh, a short time later. B.G. Whitmore, who succeeded Pringle as department head in 1957, together with K.G. Standing, initiated the acquisition of a negative ion cyclotron for Manitoba. Under the leadership first of J A. Gray and then of B.W. Sargent, who had been at Chalk River, Queen's University, by 1958, had come to the point where it was the recommended site for the proposed proton accelerator. Although the accelerator did not materialize, important nuclear research has continued to the present. As another article in this series describes, F. Rasetti gave Université Laval a strong beginning in graduate work in physics in the 1940's and it developed extensively in the 1950's.

This article is intended to portray the emergence of new programs, but a complete 1945-1960 picture of physics graduate research would have to include the developments at McGill and Toronto. McGill's initiatives in nuclear physics and theoretical physics have already been mentioned. The major emphases of Toronto's physics research in the 1950's were on the optical and spectroscopic studies of M.F. Crawford, H.L. Welsh and Elizabeth Allin, and on the pioneering work on plate tectonics of an expanding geophysics group led by Tuzo Wilson. In 1951, when the University of Toronto acquired Canada's first major computer, it was Calvin Gotlieb of the physics department who took the leadership in developing Canadian computer science.

In contrast with the situation in 1945, the Canadian universities had, by 1960, entered upon a new age. By ending this narrative at 1960 we fail to describe the unfolding of this new age in which physics research groups developed, not only in the older universities but also in the many newly established ones. Some of the universities first chartered between 1959 and 1969 were Waterloo, York, Windsor, Victoria, Simon Fraser, Guelph, Calgary, Winnipeg, and Québec.

Not all the stories of growth in the '60's have the same factors that we have portrayed in the '50's, but in all, the successful leaders had multi-disciplinary research interests and they were skilful at building their own apparatus, including glass-blowing. They were not only very productive scholars, but also were good at working with people and were willing to assume organizational and administrative responsibilities. They were willing to move around the country and spread their influence. They were stubborn in the face of opposition. All these characteristics of the leading science administrators have been seen over and over. In all the stories, the essential elements have been vision, leadership, enthusiasm and support from the external scientific community.

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