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December 1979

The Honourable W. Heward Grafftey, PC, MP
Minister of State for Science and Technology,
House of Commons,
Ottawa, Canada.

Dear Minister Grafftey,
In accordance with Section 13 of the Science Council of Canada Act, I take pleasure in forwarding to you the Council's Report No. 31, *University Research in Jeopardy: The Threat of Declining Enrolment.*

While this Report was in press, you made your most welcome announcement concerning major additional funding for university research through the Natural Sciences and Engineering Research Council. We cannot at this point say what the impact of this additional funding will be on the issues addressed in this Report, although it will clearly be beneficial. Readers of the Report will have to bear in mind that you have already taken a major step in the directions Council has indicated.

Yours sincerely,

Claude Fortier,
Chairman,
Science Council of Canada

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Preface

In its brief to the Prime Minister in March 1976, the Royal Society of Canada pointed out that,

> "At no time in our history have we been confronted with so many problems needing science-based solutions. It is hardly possible to exaggerate the importance of the decisions that confront Canada in such areas as resource management, energy options, health care, food supply, pollution, transportation, and so on. Furthermore, the choices that we, as a nation, make in these areas will be dependent on the maturity, knowledge, versatility and stature of contemporary Canadian science and engineering. Canada cannot afford to depend on the scientific and engineering skills of other countries to solve its problems. Even choices as to the best kinds of technology to be imported and adapted to Canadian conditions (and some of it certainly should be) must be made on the basis of sound scientific and engineering knowledge, which can only be obtained from a community of highly competent and active Canadian scientists and engineers."

Events of the last three years have reinforced these views and have provided further evidence of the need for scientific and engineering solutions to a wide range of national problems. Whether such solutions will be forthcoming, will depend in large measure on the wisdom of our decision makers in choosing and supporting the right projects. Since its inception, the Science Council of Canada has been concerned with such matters. Most recently, this concern has been expressed in Report No. 29, *Forging the Links: A Technology Policy for Canada*, and Report No. 30, *Roads to Energy Self-Reliance: The Necessary National Demonstrations*. But making the correct policy decisions is only one requirement. We must also have scientists and engineers of the highest quality to carry out these decisions.

In recent times, a great deal of attention has been drawn to the financial plight of the universities and the need for greater support for university research. Council's Standing Committee on Research has made its views known in the Statement by Council, *Supporting Canadian Science: Time for Action* (May/June 1978). However, following its mandate "to assess the state and potential of research in Canada", the Committee has become increasingly concerned with an even more serious problem; one that cannot be resolved simply by the provision

of more money for research. This is the danger to the quality of university research and to the training of scientists and engineers that will arise as the result of the imminent decline in the number of young people of university age. In this Report, it is shown that this demographic change could easily bring about a sequence of events, the end result of which would be a university system severely impaired in its ability to serve the needs of the country. Strong countermeasures must be undertaken immediately, and to this end a number of recommendations are directed to the universities themselves and to the two senior levels of government.

I would be remiss if I did not mention the many contributions made by members of Council, by Council staff, and by the many people who participated in the Workshop on the Optimization of Age Distribution in University Research held in June 1977. Special thanks are due to Dr. D.J. Le Roy, whose imprint the Report bears.

Louis Siminovitch,
Chairman,
Standing Committee on Research.

I. Overview

Following a period of continued economic growth and social and cultural development, disconcerting features began to appear in the economy as Canada entered its second century. The rate of inflation began to take on serious dimensions and the number of unemployed Canadians increased from an almost defensible 3.4 per cent in 1966 to an intolerable 8.6 per cent in 1978. Concern for the impact of these factors on our national well-being has been foremost in the minds of our government, business and labour leaders for the past decade. The task of resolving economic problems has pre-empted most other political issues. Solutions are urgently being sought through federal-provincial consultations and international negotiations.

The intensity of these problems and the urgent need for remedial action have tended to overshadow consideration of substantial structural changes in our social fabric. As a result of rapid economic growth and the increased productivity of our labour force in the post-war period, Canadians have come to expect a continuing improvement in their standard of living; for not only the privileged few, but for the population as a whole, including the underprivileged and the elderly. Universal social security, welfare and health programs have become the order of the day and educational and cultural opportunities have been enlarged. However, our economy is slowing down, and we are faced with high inflation and high unemployment. The ability of the public and private sectors to support continued social and cultural progress is in jeopardy. Unless we increase our wealth, little surplus will be available to improve the lot of our citizens.

Canada's economic problems are complex. The wider application of science and technology to productive activities is one of the many factors that must be taken into consideration when steps are taken to revitalize our economy. This fact was emphasized in the recent Science Council Report, *Forging the Links: A Technology Policy for Canada.*[1]* The important role of research and development has been acknowledged in recent meetings of First Ministers, by actions of the former Minister of Finance in the April and November 1978 budgets, and by the policy statements in June 1978 of a former Minister of State for Science and Technology. The report of the Second Tier Committee on Policies to Improve Canadian Competitiveness, a committee representing labour and management, also emphasized the role of research and development (R & D).[2] More recently, the newly elected government has made it clear that a program of specific measures in support of R & D is to be a component of its "National Economic Development Strategy."[3]

Thus, there would appear to be wide acceptance for the view that Canada's R & D efforts must be greatly expanded. Our universities have a crucial role to play. As the site of most of our basic, and an appreciable amount of our applied research, and as the chief supplier of the highly qualified manpower required for R & D, it is essential that they be able to maintain and improve the quality of their teaching

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* See Notes on p. 51.

and research. For the past ten years their ability to perform this function has been severely tested, as a result of the financial restraints imposed by federal and provincial levels of government. During the next decade our universities will face a greater challenge; one that cannot be resolved simply by the provision of more generous provincial operating grants and larger federal research grants. The challenge of the eighties will arise as the result of demographic factors – namely the dramatic drop in the birth rate that followed the post-war baby boom.

The baby boom actually began as early as 1938, when the pattern was set for an almost continuous increase in the annual birth rate for the next two decades. The increase reached a peak in 1959, when more than twice as many children were born as in 1937. The result was unprecedented growth in the numbers of elementary, then secondary, and finally post-secondary students, and also unprecedented growth in the size of the labour force. Reflecting a burgeoning young population, our society became more growth-oriented, more youth-oriented and, incidentally, more highly educated.

These aspects of Canadian society are now in the process of undergoing a dramatic change. After 1959, the birth rate declined rapidly; since 1974 it has been below the long-term replacement level. The number of students in elementary schools, which had reached a maximum of 3.8 million in 1968, is expected to fall to a minimum of 2.9 million within the next few years – a decrease equivalent to the entire elementary school enrolment in the province of Quebec in 1975. This decline will necessitate the termination of literally tens of thousands of elementary school teaching contracts. A similarly dismal picture is beginning to reveal itself in secondary schools. Some high school teachers have already been given numbers signifying their priority rank, on the basis of which they will be removed from the system when the time comes. The social and economic costs of career disruption and the impact that the decreased size of the elementary and secondary school systems will have on the quality of teaching are matters of public concern. These issues are now receiving careful study by provincial governments, school boards and teachers' associations.

Of immediate concern to this Report, however, is the examination of the consequences of the decline in the number of young people of university age, which will arise after 1982. The stage will then be set for a series of events which, taken together, could very well cause irreparable damage to the quality and effectiveness of university research in science and engineering. But the crisis will not be confined to these areas; it will be felt throughout the universities, in all disciplines and in both teaching and research.

A decline in the number of young people in the relevant age group could have a much greater impact on the universities than on the primary or secondary schools, because the universities are extremely vulnerable to the possibility of major changes in the *proportion* of their age group (18-24) who choose to enrol. This "participation rate" has more than doubled in the past twenty-five years, although it is still

appreciably less than the rate in the United States.[4] However, there are recent signs that it is falling off. Any decline in the quality or relevance of teaching and research could lead to a major decrease in the participation rate, with our young people either turning away from higher education or seeking it outside Canada. The universities would then be faced with problems many times more severe than those created by demographic change alone. Furthermore, the impact would not be confined to the universities. Grave consequences for Canadian society as a whole would follow if the educational clock were to be turned back. The complex scientific, technological, and economic problems of the future cannot be met using second-rate institutions to generate new concepts and to train the manpower required.

As enrolment shrinks the demand for new staff will fall off. Even now in many departments, no new full-time appointments have been made for several years, in spite of retirements. During the period when the universities were growing rapidly, most faculty appointments went to young people. The age structure that developed was in the form of a broadly based pyramid, with very few older professors at the top and increasingly large numbers of younger faculty members at the bottom. Natural attrition of existing faculty will, therefore, be quite small for the next ten to twelve years, and there is talk in some circles about the possible release of tenured staff.

Although it is impossible to predict precisely what will happen in a particular department or university, the overall national picture is quite clear. Universities will be unable to utilize the services of many highly qualified young faculty, and the calibre of teaching *and* research will suffer as a result. To make the problem more complex, in about fifteen years there will be a substantial increase in demand for academic staff. By that time, many of those now in the middle of the age pyramid will have reached retirement age and, at the same time, enrolment will begin to increase as the children of the baby-boom generation reach university age. To avoid recruiting large numbers of faculty members from other countries at that time, the continuity of graduate training must be maintained. Counting only the post-secondary period, including post-doctoral work, about nine or ten years are required normally to train a university faculty member. Thus, maintaining continuity will require not only dedication from the student, but also a commitment and a capability on the part of the university to provide the best possible training. The quality of teaching and research must be maintained and improved in the years ahead. Furthermore, strenuous efforts and imaginative decisions will be demanded not only of the universities, but of the governments and agencies that provide their resources.

Before considering responses to the threat of declining enrolment, it is necessary to examine the demographic situation in greater detail and to review the pattern of participation rates. (See Chapter II.) Consideration is given in Chapter III to a number of measures at the disposal of the universities for maintaining and improving the quality of teaching and research and maximizing the intake of new faculty, even under conditions in which the operating grants provided by the

provinces would continue to be based on the number of students enrolled. However, these measures alone will not be enough, and so in Chapter IV emphasis is placed on the new approaches required of provincial governments and federal granting agencies.

If academic science and engineering is to make a worthwhile contribution to national productivity and economic health, it must be through the quality and nature of university research and by the entry of adequately trained scientists and engineers into effective careers. For economic reasons, employment opportunities in both government and the private sector have become restricted, although the demand in the latter sector is high in a number of the engineering and applied science disciplines.

In the case of government, demands for a reduction in the expenditure of public funds have begun to take effect and are likely to have the same impact on government research that reduced enrolment will have on university research. The situation in the private sector is somewhat different. It is becoming apparent to increasing numbers of Canadians that impediments to industrial R & D must be removed. Greater numbers of highly qualified people will be required in the future, if we are to close the productivity gap between Canadian industry and its foreign competitors and meet the scientific and technological challenges that lie ahead. Recognition of this fact is not enough. In Chapter V consideration is given to a number of mechanisms for "bridging" the university-industry interface.

To complete this overview, attention should be drawn to two aspects. First, throughout the Report attention is directed to "average effects" as assessed at the national level. Both the percentage of young people of university age and the participation rate vary considerably from province to province. Also, the nature and severity of the problems will differ not only among individual provinces, but among different universities and disciplines. If, in some cases, the situation should turn out to be less critical than indicated, in other cases it will be even more so.

Secondly, emphasis on the need for more generous funding of university research to overcome the ravages of inflation is deliberately avoided. Council has recognized and stated its concern for this need.[5] The gravity of the financial plight of our universities must not be underestimated.[6] However, the problems of the eighties cannot be solved simply by the provision of more money. It would be a disservice to the universities to convey that impression.

II. The Shrinking Cohort

Customarily, two sets of data are used to forecast university enrolment: the size of the 18-24 age group, to which over 80 per cent of university students belong, and the participation rate (the percentage of young people in this age group attending university). Insofar as the country as a whole is concerned, by far the most important factor in determining the size of the 18-24 group is the number of live births in the past. The effects of mortality, immigration and emigration necessitate only minor corrections. The pattern of births, based on historical data up to June 1976 and projected to the year 2001, is shown in Figure II.1,[1] The projections are calculated from assumed total fertility rates (the average number of children expected to be born to a woman throughout her lifetime) and assumed rates of migration. In 1959 the fertility rate was 3.94; by 1976 it had fallen to 1.82. In projections 1 and 2, it is assumed that the fertility rate will rise to 2.1 by 1991; in projections 3 and 4, it is assumed that it will decrease to 1.7 by 1991. The average net annual immigration is assumed to be 100 000 in projection 1, 75 000 in projections 2 and 3, and 50 000 in projection 4. The projected maximum number of births, between 1985 and 1989, is referred to as the "echo" of the post-war baby boom. The echo is predicted because of the entry of the first baby boom generation into the child-bearing age group (usually taken to be the ages of 15 to 44). The size of this age group is expected to more than compensate for its low fertility rate.

The estimated number of persons in the 18-24 age group up to the year 2001, allowing for the effects of mortality and net migration, is shown in Figure II.2. It is evident that this number is levelling off at present. It should reach a maximum of approximately 3.4 million in 1982, and then decrease to less than 2.7 million by 1994 – a drop of over 20 per cent. The projections in Figure II.2 are likely to be quite accurate up to 1994 because they are based largely on historical live birth data. Beyond this period the degree of uncertainty increases, since the projections will depend more and more on estimated fertility rates.

The number of students attending Canadian universities will not necessarily follow the pattern seen in Figure II.2. This would happen only if the participation rate remained constant, at its present value. In this connection it should be noted that over the past twenty-five years, the increasing participation rate has actually had a greater effect on university enrolment than the baby boom itself. In 1951-52, the participation rate was 4.2 per cent; by 1975-76 it had reached 12.4 per cent. If account were taken of the fact that the first year of undergraduate teaching in all Quebec universities was transferred to the CEGEPs,* when they were established about ten years ago, the comparable participation rate for university-level education in 1975-76 would have been close to 15 per cent. The reasons for this dramatic increase are complex, but the explanations of such a trend, offered in the Bladen Report of 1965, are significant:[2]

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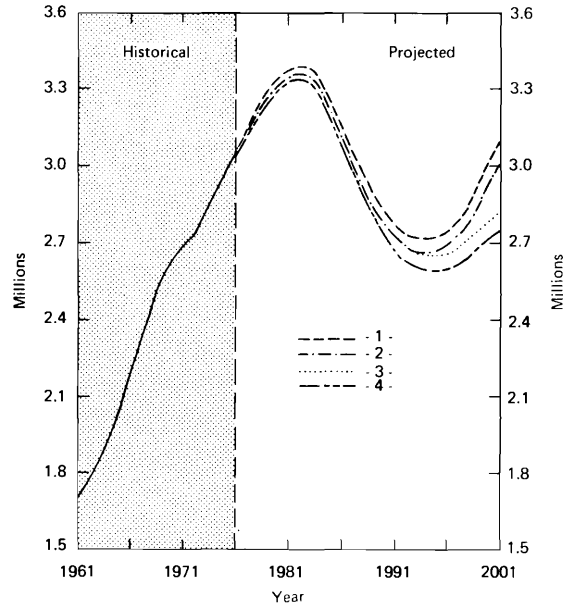
* *Collèges d'enseignement général et professionel.*

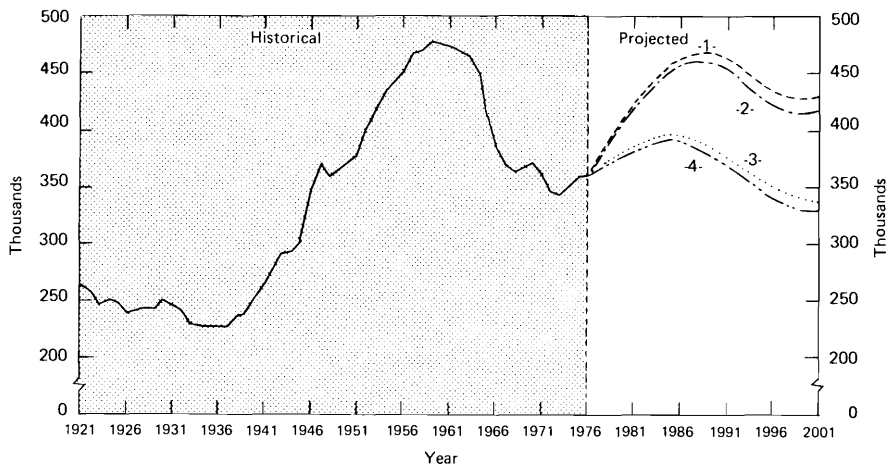
Figure II.2 – Number in Age Group, 18-24



Note: See text for explanation of the projections.

Source: W. Clark, M.S. Devereux, Z. Zsigmond, Statistics Canada in collaboration with the Canadian Teachers Federation, *The Class of 2001*, February 1979, p. 22.

Figure II.1 – Live Births, 1921 to 1976, and Projected to 2001



Note: See text for explanation of the projections.

Source: W. Clark, M.S. Devereux, Z. Zsigmond, *The Class of 2001*, Statistics Canada in collaboration with the Canadian Teachers Federation, Ottawa, February 1979, p. 21.

"... the steady increase in personal incomes has made it easier for more and more Canadians to finance higher education. At the same time, there have been strong influences reinforcing their desire for further education: the excitement of the explosion of knowledge; the growing recognition of the high financial return which could be expected, on the average, from investment in such education; the fears of unemployment in an age of automation, and the belief that the incidence of unemployment varies, and will continue to vary, in inverse proportion to the number of years of schooling; the recognition that social mobility is most effectively promoted by wider participation in higher education ... ."

What effect current economic conditions and changing social patterns will have on the participation rate in future is difficult to predict. In contrast to its rapid growth in the previous decade, the participation rate increased by only 0.6 per cent between 1970-71 and 1976-77. In a recent publication, *Out of School – Into the labour force*, the authors looked into a number of factors which might affect the participation rate over the next few years and gave greatest weight to those leading to a decrease.[3] Among the factors considered were the difficulty many graduates are having in the labour market, a continued decline in the proportion of government expenditures devoted to education, and a reconsideration of the objectives of university education. In relation to the last point, it is relevant to note that several speakers at the May 1978 conference of the Canadian Society for the Study of Higher Education observed that university students, albeit in small numbers, were transferring to community colleges either during or after their degree programs. Actually, 5 per cent of the new entrants into community colleges in the fall of 1977 had previously attended Canadian universities.[4] In December 1978, Statistics Canada reported preliminary enrolment data for the 1978-79 session,[5] which showed a decrease of 1.4 per cent in the number of full-time students in Canadian universities, as compared to the previous year. Decreases were evident both in full-time undergraduate and full-time graduate enrolment. Part-time enrolment, which had been increasing in recent years, also showed a decline.

It is evident that there is a great deal of uncertainty in predicting participation rates. However, there is no doubt that the size of the 18-24 age group will decrease by about 20 per cent between 1982 and 1994. Therefore, it would seem reasonable to assume that full-time university enrolment will decrease by at least this amount over that period. (The situation will, of course, vary appreciably from one discipline to another.) The decrease in students would be approximately equivalent to the present full-time enrolment of all of the universities in Saskatchewan, Alberta, and British Columbia.

The impact on the demand for academic staff will be traumatic. At present, the operating funds that are provided by the provinces, are based on the number of students to be taught. If present faculty/student ratios are maintained, the resulting reduction in faculty would cause almost irreparable damage to the universities. The percentage of academic staff over 50 years of age was 17.9 in 1977-78, and so a re-

duction of 20 per cent could probably be obtained through normal attrition. However, this would mean that no new faculty could be appointed for a period of fifteen years or so, except to replace those who withdraw from academic careers for various reasons. And then, an abrupt demand for thousands of new faculty members would arise as those who are now fifty years old and less, reach retirement age and as the number of young people in the 18-24 age bracket begins to increase (see Figure II.2). It would be wishful thinking to expect this demand to be met by a university system which, for over fifteen years, would have offered little incentive for young people to embark on a career of university teaching and research.[6] Quite apart from the numerical aspects of this scenario, there is the question of the quality of teaching and research that would result if our universities were deprived of the enthusiasm, imagination and competence of young faculty members. There is no doubt that the quality of research in science and engineering would deteriorate in the absence of an adequate number of new recruits to replace those whose research productivity has fallen off.

The people of Canada must not allow their universities to be forced into this kind of drastic retrenchment. Although taxpayers are reluctant to pay for what they consider to be unreasonable university expenditures, they do expect their children to receive an education of the highest quality in institutions with international standards. They also have a right to expect that the research carried on in the universities, and the researchers turned out, will be able to contribute in a significant way to the future well-being of the country. If the quality and effectiveness of the university system is to be maintained during the most critical period of its existence, special efforts must be made to ensure a steady intake of young faculty in spite of decreasing enrolment. The universities themselves, provincial governments, and federal agencies must assume an appropriate degree of responsibility.

III. The Responsibility of the Universities

If a 20 per cent reduction in university faculty by 1994 should be required to accommodate a corresponding decrease in enrolment, the consequences would be so serious that the provinces would probably modify their funding procedures to soften the blow. In certain instances this is already being done. However, substantial reductions in faculty will undoubtedly have to take place. Whatever the overall national figure turns out to be, there will be wide variations among different departments, universities and provinces. In most cases attrition through retirement and death will probably be sufficient to achieve the required reduction; in others tenured staff may have to be released. Under these conditions many difficult decisions on the part of the universities will be required if they are to maintain and improve the quality of teaching and research. But unless they show leadership and imagination in facing the demographic challenge, the universities are unlikely to receive very much consideration from government.

A 20 per cent reduction in the number of 18-24 year olds within a period of 14 or 15 years need not, in itself, constitute a threat to the universities or to the quality of teaching or research. The threat would arise only if the universities were unable or unwilling to respond to the problems created. To maintain and, if possible, to increase the participation rate becomes of crucial importance. If, for any reason, the participation rate should fall substantially during the next 10 or 15 years, the effect on the universities could be disastrous. The drop in enrolment would then be much larger than 20 per cent. Such a decrease in the participation rate could, and undoubtedly would, be brought about if the quality of teaching and/or research were to decline to such an extent that challenging opportunities for students or the possibility of rewarding careers for graduates were no longer provided. Our most talented young people would either turn away or seek their university education abroad. Thus, it becomes doubly important to maintain and improve the quality of teaching and research and to overcome the obstacles that might stand in the way.

The Turnover of Academic Staff

The turnover of academic staff, other than by normal retirement and death, has received very little attention, probably because turnover was looked upon simply as a minor perturbation when the system was growing. However, as the universities undergo no growth and then an actual reduction in the number of faculty, turnover will become a crucial means of maintaining the quality of teaching and research. Its importance can be visualized by considering the case of a university with *no* turnover for 15 years, during which the faculty would be reduced by 20 per cent through retirement and death. Such a university, unable to take on any "new blood" for half a generation and with an ageing staff would not long be able to hold a place at the forefront of teaching or research. The quality of both would inevitably decline. In spite of this, faculty members would undoubtedly

continue to "progress through the ranks", requiring ever larger proportions of the budget for salaries, and leaving ever smaller amounts to cover the non-salary items needed for good teaching and good research. On the other hand, if there were, say, a 5 per cent turnover rate in all ranks every year in addition to natural attribution through retirement and death, it would be possible, in principle, to maintain and even improve the calibre of the staff, to keep the average age from increasing, and to maintain a dynamic balance among the academic ranks. In short, it would be possible to improve the quality of teaching and research and reduce the size of the staff at the same time.

In spite of the important role that turnover could play during the next ten or fifteen years in maintaining and improving the quality of teaching and research, and hence in maintaining the participation rate, very little information on the subject is available. It is, therefore, strongly recommended that the universities, through the Association of Universities and Colleges of Canada in collaboration with the Canadian Association of University Teachers, undertake, as a matter of urgency, a major study on the magnitude and nature of the turnover of academic staff, and on the factors which encourage or inhibit it. Due to the importance of this study to all Canadians, it should be financed by the federal government.

Turnover could, of course, be of two types. A faculty member might remain within the university sector and simply move from one Canadian university to another, or he or she might leave the university sector altogether, either through early retirement or by making a mid-career transition.[1] Both types are important. A move from one university to another could help to bring about the concentration of expertise necessary to create a centre of excellence or simply to preserve an area of scholarship. Thus, it is necessary to examine impediments to mobility within the university sector as well as those between employment sectors.

Lack of Pension Portability as an Obstacle to Turnover

The results of the recommended study are not necessary in order to conclude that the lack of portable pensions is an important obstacle to the turnover of academic staff, particularly senior staff. One of the anomalies of our time is that a society that has emphasized both personal freedom and social welfare, has also created a multiplicity of pension schemes which often restrict personal freedom by penalizing people who change employers. Not only does the lack of portable pensions impede mobility, but it is an obstacle to the optimum use of manpower. This impediment did not exist when there were no pensions! The portability of pensions, within and among all employment sectors, is, of course, desirable. However, it will be of particular importance to the universities during the next ten or fifteen years as a means of encouraging staff mobility and turnover. This being the

case, it is incumbent upon the universities to play an active role in investigating and promoting mechanisms for achieving such portability. One mechanism has been proposed recently by the Canadian Life Insurance Association.[2]

Retirement Policies

Early retirement has frequently been suggested as a means of increasing the turnover of academic staff. In-depth discussion of this possibility would require consideration of retirement policies in general, including the widely discussed concept of raising the mandatory retirement age from 65 to 70.* The Special Senate Committee on Retirement Age Policies has been holding hearings and will eventually report its findings, and therefore independent recommendations from the Science Council at this time would seem inappropriate. However, attention should be drawn to the following observations made by the Canadian Association of University Teachers in its brief to the Special Senate Committee.

> "It would be disastrous if the policy of the federal government, the provinces and the universities were to make the age of 70 the normal age of retirement, in the sense that everyone would be obliged to retire at 70 and not before. As we have seen, such a policy would have the following results:
> (1) some academics would then be forced to continue teaching for financial reasons, even though they were physically and mentally ready to retire;
> (2) this would cause a reduction in the hiring of young academics for many years;
> (3) this would accelerate the 'ageing' of the profession;
> (4) the cost to universities in salaries would be substantially increased."[3]

One further observation should be made. While early retirement enhances turnover and late retirement hinders it, turnover is not an end in itself, but only a means to an end. The objective of the universities should be to improve the quality of teaching and/or research. In many cases this could be achieved by retaining the services of an outstanding person long after normal retirement age. Federal granting agencies have no age limit on grantees, but expect them to have faculty status. The term "professor emeritus" has come to mean simply a retired professor. Universities should indicate their concern for scholarship of the highest quality by granting special status to outstanding staff members when they reach normal retirement age, and encourage them to continue their work. Ideally, the pensions of such people should be supplemented by funds from sources other than the regular university budget.

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* A number of universities have been considering policies that would permit the early retirement or part-time employment of senior faculty. An interesting plan was announced by the University of Waterloo in October 1979.

Pruning the Tree

Trees are pruned to remove deadwood, to improve symmetry and balance, to stimulate desired growth, and to encourage the bearing of fruit. The analogy with universities is apt. A pruning operation has, of course, been going on throughout the present decade, in response to the cut-back of provincial support for universities. But universities, like governments, rarely abolish an activity once it has started. Almost invariably cut-backs have been applied across the board, and to the complete spectrum of activities rather than to particular ones. The result has been a general weakening of the whole structure.

The range of courses and programs offered by the average Canadian university has expanded tremendously since the early sixties; first, to meet the needs of the flood of students seeking admission; more recently, in an attempt to attract students from a diminishing supply. The result has been a duplication of courses, programs, expensive equipment and library holdings, frequently in areas with relatively small numbers of students. This kind of proliferation is already draining the financial resources of many universities. How much worse will the situation become when the demographic "ebb tide" begins?

The problem is not just financial. The concept of a critical mass, essential for the liberation of energy in a nuclear reaction, is equally important for productive scholarship. If a discipline's resources for teaching and/or research are spread thinly over a number of universities in a particular geographical area, then inevitably the stature and impact of that discipline will be greatly weakened. In the interests of good scholarship, as well as economy, inter-university transfers of faculty members and facilities in specialized areas should be undertaken whenever they are likely to fall below the critical mass in a particular university, and when the transfer could bolster a more flourishing activity in another university. Today, such action may seem drastic, but in the long run a rational redistribution of specialization among universities may be the only way to avoid mediocrity in many areas. Public regard for the universities and the preservation of their autonomy would be greatly enhanced if the universities would initiate such action themselves.

Inter-University Collaboration

An alternative to deleting a course of study and possibly transferring it to another university is the consolidation of teaching and/or research among universities in adjacent centres. Although the concept is not new, a relatively recent and striking example of inter-university cooperation is the Guelph-Waterloo Centre for Graduate Work in Chemistry. The separate departments in the two universities are by no means small, but by consolidating their graduate work in a single Centre they have achieved a quality and range of facilities and competence that neither department could have acquired alone. Hopefully, other universities will examine the feasibility of following in their footsteps. This type of collaboration could occur in many places in

Canada, particularly in cities such as Halifax, Montreal,* Ottawa, Toronto, Winnipeg, and Vancouver. A unique multi-campus structure has allowed the Université du Québec to ensure collaboration and to avoid unnecessary duplication of programs in its four main branches (Chicoutimi, Trois-Rivieres, Rimouski, and Montreal).

Inter-university collaboration is sometimes easier to achieve if centred around the common use of a major facility. For example, after overcoming parochial interests, Canadian astronomers now have access to one of the best facilities in the world: the Canada-France-Hawaii Telescope. Similarly, by joining together to form the Institute of Particle Physics, Canadian physicists can now engage in frontier research in high energy physics, using foreign accelerators as well as the Tri-University Meson Facility (TRIUMF) at the University of British Columbia. Other examples of successful collaboration could be cited. However, many cases exist in which, by going it alone, universities have acquired costly facilities which have become outmoded, are a burden on the university, and contribute little to the advancement of science. In one such case a review committee actually recommended hiring people to use the facility in order to justify the investment!

Clearly, a great deal of scope exists for university collaboration. By providing a special incentive, the demographic challenge could precipitate development of a more mature and effective Canadian university system and, in particular, have a positive effect on the quality of university research.

* Université de Montréal and McGill University have established collaborative arrangements in geology research.

IV. The Changing Role of Government

Implementation of the proposals outlined in the previous chapter would go a long way toward maintaining the quality of both teaching and research in the difficult years ahead. Furthermore, the financial burden on the universities would be eased, since certain economies would be introduced. However, these measures alone would not prevent the gradual erosion of research capability as long as the hiring of new recruits for directing research is based on teaching requirements.

During the past twenty years, the dominant factor in determining the level of provincial support has been the need to provide for the tremendous influx of students resulting from the baby boom and an increasing participation rate. This support was based essentially on the criterion used by the provinces for elementary and secondary education: the number of students. Direct support of research was left almost entirely to the federal government, while decisions as to the level of general university support, including that for faculty salaries, teaching, and overhead for research, have devolved largely on the provinces.* This *de facto* sharing of responsibility for teaching and research, the two essential features of university life, was fairly successful during the period of rapid growth. Provincial grants to universities provided the salaries for the professors and the buildings in which they worked. As long as the number of students was increasing, the provinces continued to provide this support, whether it was used for teaching or research. In most cases they were very generous in providing facilities and overhead for research, but teaching alone provided justification for the expenditures. Thus, the fact that federal granting agencies were able to make significant contributions toward the development of academic research capability was, to some extent, fortuitous. They were able to do this because the flood of students justified the use of provincial funds for hiring and housing the staff capable of doing research.

Now that enrolment is levelling off, and universities are facing a possible decline in teaching requirements of 20 per cent or more within the next 10 to 15 years, the tenuous nature of the federal-provincial sharing arrangement is becoming apparent. During the period of rapid growth, the methods used by the federal granting agencies made development of a reasonable level of research capability possible, in spite of provincial preoccupation with teaching. New recruits were continually taking the place of those who did not survive the process of constant judgement and rejection, characteristic of the peer system. In future, these agencies will have to devise methods for maintaining and enhancing excellence in research when the demand for teachers is dropping.

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* The federal government has, nevertheless, made a substantial contribution toward general university support. From 1951 to 1966, direct grants were made to the universities, by a formula based on provincial populations. Since 1967, federal support of post-secondary education has been given to the provinces in the form of tax points and contributions. During the period when direct grants were made, the federal funds provided did not exceed 16 per cent of the income of the universities receiving them.

This responsibility need not rest with federal agencies alone. Provincial governments are likely to assume a greater degree of responsibility for the direct support of university research than they have in the past, particularly in areas closely related to provincial goals. Quebec has played a very active role in this regard. A well developed program of university grants and scholarships has been in place in Quebec for a number of years. Also when the Université du Québec was established almost ten years ago, the Institut national de la recherche scientifique (INRS) was set up as a branch of that university. INRS now has a number of laboratories in the province. The recent green paper, *Towards a Scientific Research Policy for Quebec*, indicates quite clearly the province's intention to play an even more active role in university research, although its precise nature is a matter of some controversy.[1] British Columbia, through its recently established BC Science Council; Ontario, through the Provincial Research Grants Program of its Ministry of Health; and Alberta, through its $300 million endowment for medical research, as well as grants to Alberta universities awarded by the Alberta Oil Sand Technology and Research Authority (AOSTRA), provide further examples of the provincial trend to become involved in the direct support of university research.

Discussion has taken place in some circles as to whether this trend should be looked upon as a long overdue development and a natural consequence of provincial responsibility for the growth and maintenance of the universities; whether it should be lamented as an example of the balkanization of our country; or whether it is a consequence of the reduction in federal support for university research, which began in 1969. The Science Council views the trend as evidence of increasing maturity in the Canadian attitude toward research. The provinces are beginning to appreciate that direct support of academic research can contribute to provincial objectives, and this fact should in no way interfere with the achievement of national objectives. There should be no question of conflict. Indeed, one of the benefits of greater provincial involvement could be a change in the federal attitude. Throughout most of the present decade, the federal government has tended to disregard the essential role of academic research in the attainment a of national goals, and has put the onus on its practitioners to lobby for handouts.

Provincial Research Chairs

The provinces could benefit from direct involvement in university research in areas of provincial concern such as natural resources (both renewable and non-renewable), energy, transportation and the environment. In most cases, a need for increased R & D exists because of the regulatory responsibility of the provinces and their concern for proper development, but this need is in conflict with public pressure for restraint in the growth of the public service.

An effective way of getting around this problem would be for the provinces to establish research chairs in the appropriate disciplines or sub-disciplines. This step would be certain to meet with public acclaim, both locally and provincially. The chair concept in universities

has fallen into disuse in recent years because chairs were normally endowed. Not only have donors become an "endangered species", but the current rate of inflation has diminished the effectiveness of endowments in providing an adequate income over a period of years. On the other hand, a provincial government could easily make a commitment for a period of, say, ten years with a renewal option. This action would be in line with the "sunset law" approach to financing government activities, whereby programs would be automatically terminated at the end of a fixed period unless given a new mandate. Advocates have pointed out that this approach is likely to lead to enhanced performance and effectiveness. In this respect a research chair, financed under such an arrangement, could be a better investment than an institute or possibly even a branch of a government department – organizations more likely to exhibit the semblance of immortality.

Basic annual support for a research chair would consist of the salary of the professor together with an unrestricted grant of, perhaps, $100 000(1979) to maintain the nucleus of the research group. The incumbent would be expected to compete for and receive grants and contracts from other sources as well. In fact, if these were not forthcoming perhaps someone else should be considered for the chair. If provincial governments, in collaboration with the appropriate universities, utilized the best national and international advice in establishing the chairs and choosing the incumbents, provincial objectives would be furthered, and centres of excellence, of which all Canadians could be proud, would be established.*

Provision for Future Retirements and Enrolment Growth

As mentioned previously, the consequences of maintaining faculty/student ratios at present values in the face of a more than 20 per cent decrease in enrolment, are so serious that the provinces are likely to use funding schemes that will buffer the universities against the worst effects. This is already being done to some extent. However, advance planning must be undertaken to meet the abrupt demand for new staff which will occur in the mid-nineties. Not only will the retirement rate have accelerated, but there will undoubtedly be a substantial and simultaneous increase in enrolment as the children of the baby boom generation reach university age (see Figure II.2). A rough estimate of the number of retirements can be obtained by examining the age structure of university faculty. Data provided by Statistics Canada show that in 1978 there were 3975 full-time staff in the age group 46-50; these people would retire in the period 1993 to 1997; a further 5348 are in the age group 41-45 and would retire in the years 1997 and 2002. Thus, the number of retirements in the 10-year period beginning in 1993 would be in the order of 30 per cent of the

* It should be noted that Alberta, through AOSTA, recently established chairs in petroleum science at the Universities of Calgary, Lethbridge, and Alberta.

present staff. To wait until the last minute to replace these people and, at the same time, provide the additional staff required to handle the anticipated increase in enrolment, would place unreasonable demands on the ability of this country to supply qualified people. If our universities are to use Canadian sources of manpower and to maintain high standards, they must be able to spread the intake of new faculty members over a longer period, beginning well before 1993.

During the period of rapid expansion, the continually increasing participation rate made it difficult for the provinces to anticipate future requirements for operating and capital funds. As the result, a certain amount of chaos was inevitable, and little attention was paid to realistic long-term planning. Today the situation is quite different. The participation rate has levelled off, and it is possible to estimate enrolment with some degree of certainty for at least the next 20 years. Major expansion of facilities has already taken place and capital expenditures will be much less than in the past. Thus, the provinces will be able to devote more attention to the quality, rather than to the quantity of university education. In this respect the quality of the faculty members is paramount. To ensure that it is maintained and improved, the provinces will have to take a flexible attitude toward faculty/student ratios so that the universities can continue to hire young people and establish a sound age structure. The simple headcount system of university financing will not be adequate.

Although it is to be hoped and expected that in future the provinces will take a greater interest in university research, as distinct from teaching, the major responsibility for the direct support of research will continue to lie with federal granting agencies. The Natural Sciences and Engineering Research Council (NSERC) has come into existence at a crucial time. While expected to maintain the standards of excellence that characterized the support by the National Research Council, it will be faced with new challenges and opportunities. In particular, its reputation will stand or fall on how it adjusts its methods to take account of the changing circumstances under which university research in science and engineering will be carried out in future. Particular attention will have to be given to methods for preserving and enhancing the quality of research that do not rely on the teaching requirements of the universities to supply competent young recruits.

A New Approach to Research Manpower

In centres of excellence, people use excellent facilities to do excellent research in fields of generally agreed significance. The most important ingredient is the people. With minor exceptions, to have such a centre in a university at the present time requires that the people directing research projects be hired, not because there is research to be done, but because there are students to be taught. In view of the decreasing teaching requirements in the future, are we to forego the prospect of centres of excellence? It has been emphasized several times in

this Report that a continuous inflow of competent young researchers is essential for high quality research. The challenge faced by the NSERC will be to provide these independently of the demand for teaching.

The concept of separating research and teaching manpower is not new. It was used when the National Research Council undertook a special program for increasing the level of research activity in the francophone universities of Quebec several years ago; it is still used by NSERC for the same purpose. With the cooperation of the universities, a number of *attachés de recherche* have been appointed. NSERC pays their entire salary, plus fringe benefits, for a period up to five years. During this time their status corresponds to regular faculty members and they compete for grants under the same conditions. Up until March 1979, a total of 28 appointments had been made, of which 21 were still being held; four of the appointees had been taken on as regular staff members in francophone universities of Quebec and three had taken up appointments elsewhere. Although of modest dimensions, the program has been successful in every respect.

The Medical Research Council (MRC) has gone much further than NRC/NSERC in separating research and teaching manpower. In 1956, MRC established a program of Associateships "as a means of providing funds for the salaries of a limited number of individuals of outstanding ability and training who wished to make research a full-time career."* After an initial award of three years, appointments are renewable for five-year periods until normal retirement age is reached. They are tenable in schools of medicine, dentistry, pharmacy, and veterinary medicine. As the result of a MRC policy decision, no new Associateships have been awarded since 1975, but in 1977-78, seventy were still being held; 18 of these had been held for 15 years or more. In 1979, the name of the program was changed to Career Investigators' Program.

When MRC established this program, there was an obvious need to stimulate an interest and capability in research in the medical schools where, up to that time, it had been almost non-existent or was being carried on only with great difficulty by staff who were overburdened with teaching. By bringing in outstanding people and giving them the opportunity of engaging in essentially full-time research over the whole of their professional careers, the Career Investigators' Program played a major role, both directly and indirectly, in establishing the spirit of research in the health sciences and raising it to the high standards that exist today.

While MRC Career Investigatorships are not directed specifically toward the young scientist, its Scholarships program is. Scholarships are intended to provide the opportunity for a young person to develop and demonstrate his or her ability to engage in independent research, without carrying the normal teaching responsibilities of an

* In 1956, MRC did not exist as such; it was the Division of Medical Research of the National Research Council. MRC was established as a semi-autonomous branch of NRC in 1960 and became a fully independent Crown corporation in 1969.

assistant professor. MRC provides the funds to cover the salary, which is paid by the university in the same way as usual staff salaries. The awards are tenable for up to five years. Scholars, like Career Investigators, compete for MRC grants in the regular way. In 1977-78, there were 125 Scholarship awards being held.

In 1977-78, 195 Career Investigators and Scholars comprised approximately 13 per cent of the 1512 independent investigators whose research was supported by MRC. The cost of their salaries amounted to approximately $4.9 million, or about 8.5 per cent of MRC's budget.

Although MRC, through Career Investigatorships and Scholarships, and NSERC, through *attachés de recherche*, have gained valuable experience in supporting research manpower independently of teaching, as yet neither council has taken steps to utilize this approach to overcome the research manpower problem likely to arise as the result of falling enrolment. In the case of MRC this is not surprising. The passing of the baby boom is unlikely to bring about any significant decrease in the teaching requirements of most departments in faculties of medicine, dentistry, and pharmacy. The number of undergraduates enrolled in these faculties is determined by political and professional considerations rather than by demographic factors. The number of students seeking admission is always considerably greater than the number admitted, and this trend is likely to continue in the future. Faculty in these disciplines teach relatively few students outside the health sciences, where the decline in enrolment will take place. Problems could arise if, for financial reasons, these faculties were unable to replace regular staff lost through death, retirements, or resignations. However, MRC Scholarships, if maintained at the present level of 25 new awards a year, would help to ensure that, even under these circumstances, research in the health sciences would not suffer from the absence of a continuous intake of competent young scientists.

In comparison to the relative immunity of research in the health sciences to the passing of the baby boom,* research in the natural sciences and engineering will be severely affected by the declining enrolment and the consequent decrease in need for teaching staff unless NSERC takes steps to alleviate the problem.

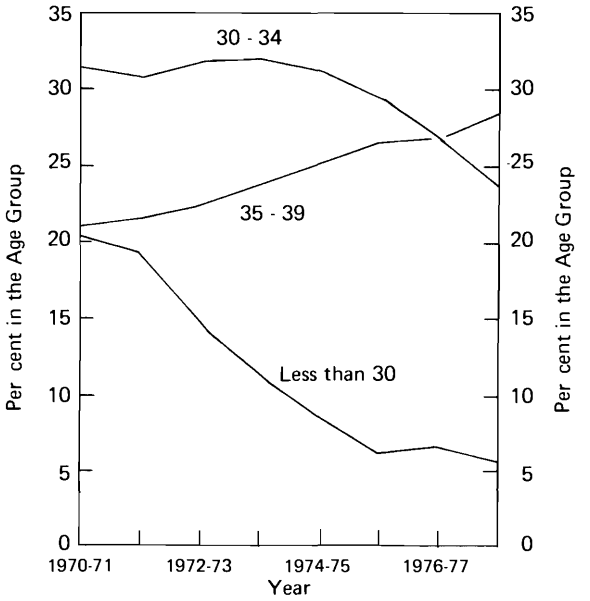
NSERC should give immediate attention to launching a program similar to MRC's Scholarship scheme. The program should be designed not simply to alleviate the shortage of young research talent among university faculty, but also to strengthen specific areas of research within a department or a university. Frequently the addition of a colleague with special qualifications or experience can improve the productivity of a research group significantly. By initiating such a program, NSERC could play a more positive role than it or NRC has played in the past.

The need for the program becomes evident on examining Figure IV.1, which shows the changing age profiles over the period 1970-71 to 1977-78 of NRC/NSERC grantees under the age of 40. Although univer-

* Although immune from direct effects, it will not be immune from indirect effects; the various faculties of a university are expected to share their burdens.

sity enrolment was still increasing, the rate was falling off and, combined with restricted university budgets, the result was fewer appointments of young faculty members eligible for research grants. The percentage of grantees under the age of 30 fell from 20.4 per cent to 5.2 percent and that of grantees from 30 to 34 years of age fell from 31.4 per cent to 23.3 per cent. The percentage in the age bracket 35 to 39 increased during this period, as did that in the higher age brackets,

Figure IV.1 – The Changing Age Profile of Research-Active Academic Scientists and Engineers



Source: Based on information in, "Background Study on Age-Relevant Characteristics of University Researchers Supported by the National Research Council of Canada," A.L. Derikx, *Background Papers For a Workshop on Optimization of Age Distribution in University Research*, Science Council of Canada, Ottawa, June 1977, p. 37.

which are not shown. With this graph as a starting point, it is not difficult to imagine the form such a graph could take between now and 1992-93, when university enrolment is likely to have decreased by over 20 per cent. Even before the effect of the decrease has set in, we find that some science departments have not appointed any new faculty for several years, and universities have begun to announce plans for reductions in faculty, through natural attrition if possible. Unless NSERC comes to the rescue, the gradual elimination of talented young research workers will cause irreparable damage to academic research in science and engineering. NSERC has a crucial, although not exclusive role to play in alleviating the problem. The universities and the provincial governments must also play their part, as was emphasized earlier.

The development of the present level of competence in scientific and engineering research arose largely through *laisser faire* methods, in the sense that NRC/NSERC supported or rejected the grant applications of faculty members who were appointed because of the teaching needs. To be sure, many of the scientists and engineers in our universities have received international recognition for their research, but we owe this to the wisdom of the universities; they chose their teachers wisely. In the future the universities will have less scope. If high quality academic research is to be recognized as an economic necessity, and not simply a part-time activity to keep teachers happy, then NSERC must take a more positive approach to research manpower. In retrospect such action would have been justified in the past – providing a scientist here or an engineer there to strengthen a research group and improve its productivity. But today more than "fine tuning" is required; a program of some magnitude will have to be initiated.

In recommending that NSERC launch a program of Research Associateships, analogous to MRC's Scholarships,* it must be emphasized that this should *not* be looked upon as a "make-work" program for unemployed PhDs, but as one of a number of devices for maintaining and improving the quality of research in science and engineering. Effective implementation will require considerable investigation by NSERC. The initial target should be an immediate start, with 110 awards annually. This would mean awarding one Research Associateship for about every 50 regular grantees, which is about the same as the proportion of MRC Scholarship awards to regular MRC grantees. The initial cost would be about $2 million in salaries per annum. Continuous monitoring of the situation will be necessary to determine the number to award in the future. If the number remained at 110 per year, the salary cost in the fifth year would be approximately $12 million (1979). The number of Research Associates in the fifth year would undoubtedly be fewer than 550 because some would have become regular faculty members or have withdrawn to take up positions outside the university sector. The total annual cost would, of course, include research grants received, but the number of NSERC grantees would not necessarily have increased by the number of Research Associates supported. Many of the regular grantees would have been turned down in the annual competitions during the intervening period, and over 100 would have either died or retired. By placing greater emphasis on quality of research, the total number of grantees might even be decreased.

Providing the universities with young NSERC Research Associates would help to restore and maintain a more stable age distribution among those engaged in research. However, to treat this as the pro-

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* It is regrettable that the two councils use the same terminology to describe different programs. NSERC, following the practice of NRC, uses the term "Scholarships" to designate awards to graduate students. While it would be up to NSERC to name the proposed awards, "research associate" would seem to be appropriate; it is already in use for the same kind of award in the form *attaché de recherche* and is widely used to designate people of professional or professorial status.

gram objective would put the cart before the horse. The objective should be to maintain and improve the quality of research. Only young people with the highest qualifications should receive appointments, and these should be held in departments or research groups where the researchers can best achieve their potential. Thus, the committee that reviews applications will have to assess not only the candidates, but the departments or research groups in which they would be working. Many of the several hundred departments in the approximately 50 universities that receive operating grants would be unlikely to receive NSERC Research Associates. This will have to be the case if the program is to achieve its purpose.

The program was compared with MRC's Scholarships program to emphasize that it should be aimed largely, but not necessarily exclusively, at *young* scientists and engineers. A reasonable minimum qualification would be that candidates should have completed a PhD and at least two years of post-doctoral work. In the case of engineers, and possibly some others, this could involve having held an NSERC Industrial Postdoctoral Fellowship.

The effectiveness of MRC's programs of Career Investigatorships and Scholarships has been due, in no small part, to its policy that holders of these appointments should be integrated as completely as possible into the academic life and structure of the departments in which they work. NSERC should adopt a similar policy with regard to its Research Associates.

MRC's present policy limits tenure of a Scholarship to a maximum of five years, and it is recommended that a similar policy be adopted by NSERC for its Research Associateships. However, both councils should monitor the situation closely and be prepared to change their policies to permit renewal of these awards for an additional period beyond the initial five years, if this should appear to be desirable. Such a change in policy would provide an opportunity for those who are appointed within the next few years to have their salaries taken over by their universities at a time when the retirement rate of existing faculty will have become significant.

V. Bridging the University-Industry Interface

As noted earlier in this Report, there is a growing awareness on the part of government, business, and labour of the importance of R & D as an effective tool in creating employment, raising productivity, and strengthening the competitiveness of Canadian industry. In line with this awareness, measures to encourage industrial R & D through modifications in the Income Tax Act were provided for in the federal budgets of April and November, 1978. It would seem likely that further measures in support of R & D will be forthcoming in the future.

The stimulation of industrial growth and employment through research and development is a major challenge to government, and many facets of the problem go far beyond the scope of this Report. However, two aspects are relevant: a significant proportion of all research in the country is centred in the universities and supported by the public purse; the universities are the predominant source of the highly qualified manpower required for industrial R & D. As a result, questions have arisen about the nature and objectives of university research and about whether the training being given, particularly for PhDs, is adequate.

The universities have often been criticized for giving too much attention to "unoriented" or "curiosity-oriented" research, and not enough to the solution of practical problems. Such criticism is largely unwarranted. The implication is that basic research is uncoordinated and is carried on by dilettantes, generously supported by public funds. Far from being uncoordinated, *good* basic research is extremely well coordinated; not by some overall authority, but more effectively by the discipline of the scientific method. Research findings must be accepted for publication by international scientific journals and must be exposed to criticism by scientists and engineers working in the same field throughout the world. In this way, experimental results can be checked, theories confirmed or rejected, and new knowledge and principles established. Although this kind of research is not undertaken primarily for possible practical application, applied laboratories around the world are dependent on the literature of basic research, both for reliable data and for the latest information on the state of knowledge.

In many university departments, the nature of research is said to be applied because of its close connection with problems of direct concern to industry or the wealth-producing sector in general. This is particularly true in faculties such as engineering, forestry and agriculture. But even here much of the research is basic in the sense that it is concerned with knowledge and methods that might be applied in a number of different situations. This factor provides the strength and versatility that differentiates applied academic research from applied research in industry, where the objectives are usually highly specific. To maintain the health and capabilities of university research in the applied sciences, the people involved must continue to have the freedom to undertake research of a general and longer term nature and not be restricted to the specific, shorter term problems of the private sector or government.

It is interesting to compare public attitudes toward basic research in the United States and Canada. During the past year or so, policy makers in the United States have shown an increasing appreciation of the importance of basic research as a source of new concepts and approaches. In the "lean and austere" budget proposals of President Carter for the fiscal year ending in 1980, total spending on R & D would increase by only 4.2 per cent, but support for basic R & D in the US would increase by 9 per cent. This swing toward greater emphasis on basic research has resulted from observations such as those made in the recent (1977) survey sponsored by the National Science Foundation (NSF), *The State of Academic Science.*[1] The survey found that the quality of research in American universities, both basic and applied, had been deteriorating because of the tendency to concentrate on shorter-term, less imaginative problems with a more certain outcome. This trend arose because of the shortage of research funds and public pressure for rapid pay-off from the investment in university research. The short-sightedness of placing undue emphasis on short-term or directly applicable research is now being realized. It discourages university scientists and engineers from undertaking imaginative and venturesome research where the outcome may be uncertain, but the rewards upon success are great. It is also likely to discourage the brightest young people from choosing research careers. This concern has also been expressed in a recent British statement on the need to support basic research.[2]

In Canada, the attitude of the federal government toward basic research has not always been clear. Many research workers in universities across the country have gained the impression that support for basic research was to be soft-pedaled in future and that most academic scientists and engineers would have to re-direct their efforts toward the solution of more "practical" problems. If this were indeed government policy, it would be disastrous for university research and for the future welfare of Canada. The almost total federal control of funds for the direct support of academic research, places the universities in a very vulnerable position. Fortunately, the Natural Sciences and Engineering Research Council is aware that the unique role of university research is to investigate fundamental scientific and engineering problems objectively, and in depth. It is also aware that the most effective way to achieve practical benefits is through *transfer* to the sectors with the capability and the responsibility for utilizing the knowledge. The integrity of basic research in science and engineering must be preserved, but emphasis must be placed on mechanisms for achieving spin-off: to act otherwise would kill the goose that lays the golden egg. A number of NSERC programs have been designed to encourage spin-off from university research. Some of these programs will be discussed briefly.

Senior Industrial Fellowships

One of the anomalies of applied science and engineering in Canadian universities is that the proportion of faculty who have actually worked in industry for any length of time is relatively small. Although many take pride in consulting work, it is not a substitute for immersion in the industrial milieu. As a result, the correlation and linkage of applied research in the universities with the needs and opportunities in industry is not as close as it could be, and the industrial spin-off from university research is not very impressive. As one method of alleviating these problems, the National Research Council initiated a program of Senior Industrial Fellowships in 1971,

> "... to stimulate productive interchange between universities and industry, by allowing staff members of Canadian universities who have had little or no industrial experience, to spend a minimum period of one year with industrial organizations in Canada and with certain quasi-industrial federal corporations and provincial utilities. No restriction is placed on the kind of work to be carried out during tenure of the Fellowship. NRC [now NSERC] provides a component of the Fellow's salary as a supplement to the university contribution, to ensure that the Fellow remains on the staff of the university and receives *in toto*, an amount equal to his (or her) normal salary."

A travel allowance for the Fellow and family is also provided.

Both former Fellows and the companies with which they were associated have praised the program very highly. It has given faculty members a better understanding of the realities of the industrial world, and in many cases has resulted in continued interaction between the sectors.

In spite of the qualitative success of the program, only 62 awards were made during the eight-year period 1971-72 to 1978-79; only ten were made in 1978-79. The reasons for the lack of popularity appear to lie within the universities. At the time the program was launched, the industrial Members of NRC shared the view that a minimum tenure of one year was essential: the length of time normally given for sabbatical leave. But one university, which provided 60 per cent of a faculty member's salary if sabbatical leave were spent at another university, would provide only 20 per cent if the leave was spent in industry. In a recent case at another university, the Fellow's colleagues tried to dissuade him from accepting the award for fear the time spent in industry would delay a promotion. Much of the difficulty seems to arise because the old bugbear, "publish or perish", has not been laid to rest. These attitudes have constituted serious obstacles to the success of the program. They also question the sincerity of the avowed desire of the universities to bridge the university-industry interface.

Senior Industrial Fellowships are, of course, by no means the only method for university staff members to gain practical industrial experience. A number of applied science and engineering faculties have developed other methods of achieving close collaboration with industrial

firms, many of which have not yet built up their own capacity for R & D. The Fellowship can play an important role in areas where effective collaboration does not yet exist.

As a means of stimulating a better correlation between university research and the needs and opportunities of all sectors of Canadian industry, and of encouraging more effective spin-off, the Science Council strongly recommends that NSERC make strenuous efforts to expand its Senior Industrial Fellowship program. Ten times the current number of annual awards could be made at a cost to NSERC of less than $2 million. However, before attempting to expand the program, NSERC should re-examine the conditions of award to make it more attractive and effective; for example, by removing the present emphasis on *young* faculty members, by making it possible to hold it in relevant industrial companies outside Canada, and by providing a more appropriate stipend.

Project Research Applicable in Industry: PRAI Grants

From time to time a scientist or engineer, in the course of carrying out regular university research, will reach the conclusion that certain research findings could have industrial application. However, before this can be firmly established, and before the transfer to industry can take place, it is usually necessary to do a considerable amount of additional work in close association with a firm in a position to utilize the results on an industrial scale. PRAI grants, established in 1972, are designed to capitalize on such advances in university research by providing financial support for their development to the point at which they can be transferred to industry. The collaborating company is expected to contribute know-how, facilities and services.

The number of applications for PRAI grants reached a peak of 80 in 1973, but then gradually declined to a low of only eight in 1977. There appears to have been a resurgence of interest in 1978, when 27 applications were received. The rejection rate has been high; over the seven-year period, 1972 to 1978, it averaged over 60 per cent. Also insofar as patents are concerned, the results have not been impressive. As of September 1978, out of 86 awards, only two patents had been issued, two were pending, and five potential patents were still under investigation by Canadian Patents and Developments Limited. More are likely to arise out of some of the grants currently being held. Patents are not, of course, the only measure of successful interaction. Many concepts can be applicable without being patentable. In a number of cases, collaboration through a PRAI grant has led to industrial employment for graduate students. It has also helped, in a practical way, to give university staff members a better understanding of the difficulties associated with transposing a research result into an industrial product or process. Not every research finding with potential applicability will turn out to be industrially viable. This fact is more familiar to people in industry than to their university counterparts, and has an important bearing on the role of universities in relation to

industrial research. If industry is not hampered in other ways, it is quite prepared to undertake research that may not turn out to be fruitful, because *some* research will be successful and thus justify the overall effort. This *modus operandi* is not as acceptable in a university as in industry. In the eyes of those who have engaged in it, and possibly of those who have funded it, lack of success in applying a particular piece of research to industry is not compensated for by the successes that might have resulted from other projects. Hopefully, this perception will change, and industrially-oriented projects will be evaluated in proper context.

Without doubt industrial spin-off from academic research can occur, and mechanisms such as PRAI grants are essential tools for the success of NSERC's mission. The initial, large number of applications is not surprising; new sources of money always attract large numbers of applicants. Many applicants were relatively junior in terms of their performance in the regular Operating Grant competitions. Some were under the mistaken impression that the program was designed simply to provide services to industry. After a shake-down period of several years, the quality of the applications is improving. Now the major concern is the relatively small number of applications, which does not correctly reflect the potential of the program for achieving industrial spin-off. An in-depth investigation is required to find a solution, and it is encouraging that NSERC is now taking steps in this direction.

Industrial Postdoctoral Fellowships

For many years young scientists or engineers have frequently undertaken a year or two of postdoctoral work immediately after receiving the PhD degree. The purpose is analogous to that of the internship of the young physician – to gain the required additional experience to fit him or her for a career of professional practice. Departments that place strong emphasis on high quality research consider postdoctoral work a prerequisite for appointment to an assistant professorship.

Postdoctoral training has normally been obtained at another university, either in Canada or abroad, and has been financed either by the Postdoctoral Fellowship program of NRC (now NSERC) or through research grants of faculty members. For a period of 27 years (1948-1975), NRC also had a separate program of Postdoctoral Fellowships tenable in its own laboratories (as well as in the laboratories of a number of government departments). Such training is invaluable, not only for the person, but for the institution that provides it. There is little doubt that the high quality of the research in Canadian universities, and in those divisions of NRC which took Fellows, has been due in no small measure to the new ideas and fresh approaches brought to the various laboratories by young Postdoctoral Fellows coming from other institutions. However, postdoctoral training had been largely confined to basic research, and tended to neglect the applied types of research more appropriate for careers in industry or as faculty members in applied science and engineering departments. To overcome

this gap, NRC initiated a separate program of Industrial Postdoctoral Fellowships in 1970; the program is still being carried on by NSERC.

This program has proven to be quite successful. Up to March 1979, 443 awards had been taken up, of which 121 were still being held. Of the 322 Fellows who had completed tenure of the award, employment information was not available for 42, but of the remaining 280, 79 per cent had immediately taken up regular positions in industry, 7 per cent in educational institutions and 6 per cent in government. Although the largest percentage of awards went to PhDs in engineering (32.5 per cent) and chemistry (31.9 per cent), every area of the natural sciences was represented, including mathematics and psychology. In contrast to the Senior Industrial Fellowship program, the number of awards has been increasing in recent years. However, the number awarded annually is still less than 10 per cent of the number of young people receiving the PhD degree in science or engineering in Canadian universities. Some of these people, of course, find their way into industry by other routes, but if the private sector is to be the main source of employment for PhDs in the future, then a doubling of the present program would seem to be called for.

The current level of about 70 to 80 new awards per year is not limited by NSERC policy. The program is considered one of high priority, and money for it is "scraped up" in one way or another. Lack of publicity and the lack of assistance provided to potential candidates by NSERC seem to be problems. At present, 205 companies have indicated their willingness to participate in the program and to interview potential Fellows. The number has grown in recent years, but largely as the result of the students seeking out new companies and explaining the program. This approach, while undoubtedly a good exercise for the student, is not the most effective way to expand the program.

There are many success stories associated with the Industrial Postdoctoral Fellowship program that bear testimony to the versatility and competence of the PhDs turned out by our universities and to the contributions they have made to the private sector. If this message could be carried more effectively, not just to the manufacturing industry, but to the resource industries and the service sector, through newspaper advertisements, trade publications and otherwise, there is little doubt that the list of participating companies could be greatly enlarged. In doing this, NSERC would not only stimulate employment opportunities for PhDs, but contribute to the improved performance of the private sector and to the strength and vigour of science and engineering in our universities.

VI. Principal Recommendations and Conclusions

As the result of the coincidence of the threat of declining enrolment with a period fraught with economic problems, the universities are about to undergo difficulties of a magnitude never experienced in the past. To maintain and enhance teaching and research of the highest quality will require imaginative and difficult decisions on the part of the universities, the provinces, and federal agencies.

Although this Report has been concerned primarily with university research in science and engineering, many of the comments and recommendations apply equally to teaching and research in all disciplines.

A crucial requirement for the maintenance of the quality of teaching and research is a steady influx of competent young faculty members. To achieve this goal under conditions in which the total number of academic staff will probably have to be reduced and when the number of retirements will be very small, will pose a major challenge for the universities. They will have to concentrate on mechanisms for the turnover of faculty. It is therefore recommended, as a matter of urgency, that

1. **The federal government should finance a major study, sponsored by the Association of Universities and Colleges of Canada, in collaboration with the Canadian Association of University Teachers, on the magnitude and nature of the turnover of academic staff in Canadian universities and on the factors which encourage or inhibit turnover.**

(pp. 22,23)

The absence of portability clauses in pensions is certainly one obstacle to turnover. Therefore,

2. **It is incumbent on the universities to play an active role in investigating and promoting mechanisms for achieving pension portability.**

(pp. 23,24)

To indicate concern for the maintenance of scholarship of the highest quality,

3. **Universities should grant special status to outstandingly productive staff members upon retirement and encourage them to continue their work.**

(p. 24)

Many universities are coming to the realization that their resources are being drained through offering courses and programs that require specialized staff and expensive equipment or library holdings, but attract relatively small numbers of students. In the interests of good scholarship, as well as economy,

4. **Inter-university transfers of staff and facilities should be undertaken whenever research and/or teaching in a specialized area falls below the critical mass for productive scholarship in a particular university.** (p. 25)

Although universities have cooperated in the past, they will have to

do so to a much greater extent in the future if the quality of teaching and research is to be preserved and improved. For example, there are seven major cities in Canada with two or more universities. It is strongly recommended that

5. **Universities in adjacent centres should make efforts to develop joint graduate programs in appropriate disciplines, along the lines established by the Guelph-Waterloo Centre for Graduate Work in Chemistry.**

(pp. 25,26)

Although in the past, provincial governments have depended largely on federal agencies to provide direct support for research, many areas of provincial concern and jurisdiction would benefit from a more active provincial role. It is therefore recommended that

6. **The provinces should consider establishing research chairs in their universities in disciplines or sub-disciplines with particular relevance to provincial responsibilities and priorities.**

(pp. 29,30)

As enrolment declines, the ability of the universities to hire new staff will be reduced. However, the present age structure is such that about 30 per cent of the existing faculty will retire within a ten-year period, beginning in 1993.

7. **To avoid lowering standards or having to hire large numbers of faculty from outside Canada, the provinces should make it possible for the universities to spread the acquisition of new faculty over several years, beginning well before 1993.**

(pp. 30,31)

A major challenge for the new Natural Sciences and Engineering Research Council (NSERC) will be to develop methods for preserving and enhancing the quality of research that do not rely on the teaching requirements of the universities to provide competent young recruits.

8. **NSERC should take immediate steps to establish a program of Research Associateships, analogous to the Scholarships of the Medical Research Council, awarded on a highly selective basis, and tenable in Canadian universities for up to five years.**

(pp. 32-36)

Re-institution of the awarding of Career Investigatorships by MRC, or the adoption of such a policy by NSERC, is not recommended. However,

9. **Both should monitor the situation as time goes on and be prepared to extend the period of tenure of MRC Scholarships and the proposed NSERC Research Associateships beyond five years, if this should appear to be necessary.**

(p. 36)

There has been, in Canada, a tendency to downgrade basic research and to encourage universities to re-direct their efforts toward tackling the practical problems of government and the private sector. Such a policy could be self-defeating in the long run.

10. **The integrity of basic research in science and engineering in our universities must be preserved, but, in doing so, emphasis must be placed on mechanisms for achieving spin-off.**

(pp. 38,39)

Present circumstances are accentuating the importance of establishing closer links between universities and the private sector. In the applied sciences in particular, greater complementarity in research and improved mechanisms for achieving spin-off from university research are needed. A prerequisite is that applied scientists in universities gain first hand knowledge of the industrial sector. As a proven but little used method of accomplishing this objective,

11. **The Natural Sciences and Engineering Research Council should take the steps necessary to expand its Senior Industrial Fellowships program by a factor of ten.**

(pp. 40,41)

One of the main obstacles to the expansion of NSERC's Senior Industrial Fellowship program is the generally negative attitude of the universities toward allowing their staff to gain practical industrial experience.

12. **The universities should recognize that by encouraging their staff to spend a year in the private sector they will increase the potential of making significant contributions to industrial performance and, at the same time, stimulate the most important market for their graduates.**

(p. 40)

Although the private sector will undoubtedly become the most important outlet for highly qualified manpower in science and engineering, this development must be stimulated. The Industrial Postdoctoral Fellowships program of NSERC has been effective, but it lacks the necessary scope for reaching its optimum potential.

13. **The Natural Sciences and Engineering Research Council should attempt to at least double the present size of its Industrial Postdoctoral Fellowships program through a campaign to expand the number and types of participating companies.**

(pp. 42,43)

If implemented, these recommendations would go a long way toward preserving scientific and engineering research as a vital element in our universities, and adapting it to make more effective contributions to society in the future. The total cost would be modest, and would be far outweighed by the benefits.

The six recommendations, directed to the universities (1, 2, 3, 4, 5,

12), would entail no additional cost on their part, but the extent to which they are implemented will have a strong influence on the willingness and ability of provincial governments and federal granting agencies to act on the other recommendations.

Of the two directed to the provinces (6,7), the political and scientific benefits of the first could very well be matched by the financial benefits. While the second would entail increased expenditure, the provinces would find the consequences of not implementing it difficult to live with.

The Natural Sciences and Engineering Research Council clearly has an important role to play. The eventual magnitude of the proposed Research Associateships program (8) will obviously depend on the degree of implementation of recommendations 1-7, as well as on the financial resources and priorities of the Council. The initial cost of salaries and grants would only be in the order of 3 per cent of its current budget. While salaries alone might grow to 8 or 9 per cent in five years, the corresponding increase in the cost of grants to the Research Associates would be melded into that of the regular grants competition, in which excellence takes precedence over the number of applications. The full implementation of recommendations 11 and 13 would probably require two or three years, but when this is achieved their combined cost would probably amount to less than 5 per cent of the total budget.

Recommendation 10, while directed primarily to federal policy makers, is crucial for the future health and effectiveness of university research in science and engineering; its message must be carried to the public at large.

The quantitative effect of many of the recommendations is difficult to predict with any degree of certainty, because it will depend on the extent of implementation. However, the effect of the proposed NSERC program of Research Associates (8) and the suggested modifications in its Senior Industrial Fellowships program (11) and in its Industrial Postdoctoral Fellowships program (13) can be estimated more easily.

The initial target of 110 Research Associateships a year would be equivalent to 1.2 per cent of the present full-time staff in the natural sciences and engineering, or about 2 per cent of the number currently receiving research grants from NSERC. If the number of awards granted annually were to remain the same, in five years these new recruits would comprise about 10 per cent of the current number of NSERC grantees. Since they would be carefully selected and strategically placed, their influence would be considerably greater than their numbers would suggest. A program of this magnitude, combined with the implementation of the other recommendations, would ensure that the quality of university research would be maintained and improved during a period which will undoubtedly be the most challenging in the history of our universities.

Senior Industrial Fellowships are particularly relevant to staff members in the applied sciences and engineering, about 1400 of whom receive research grants from NSERC. Assuming sabbatical leave would be allowed every seven years, about 200 would be on leave each

year. The proposed expansion of the program (11) would permit 60 of these, or 30 per cent to spend a year in industry. On their return to academic life, these people would undoubtedly transfer their knowledge of the industrial sector to their colleagues. When the benefits to be derived from a Fellowship are realized, a demand for additional awards is not unlikely.

At present, about 70 to 80 Industrial Postdoctoral Fellowships are awarded by NSERC each year. This is between 9 and 10 per cent of the number of PhDs in the natural sciences and engineering turned out by the universities each year. If, as recommended (13), the magnitude of the program is doubled, up to 20 per cent would have access to careers in industry through this particular route. After gaining their initial experience with PhDs in this way, many companies decided to take on more. Thus, a relatively modest program can serve as a catalyst to produce both benefits to industry and rewarding careers for many highly qualified young people.

Assuming that all of the recommendations are acted upon, what would be the likely result? Qualitatively, a major improvement in morale would occur, and a feeling of optimism on the part of faculty and students alike would be engendered. Our brightest young people, with leanings toward careers in science and engineering, would be encouraged to continue their studies with some confidence in being able to play a useful role in society. If the universities grasp the opportunity for leadership and implement the recommendations addressed to them with vigour and imagination, a major step will have been taken in the establishment of a more mature and effective university system; it could also prove to be a turning point in the development of the quality and significance of university research.

Notes

I. Overview

1. Science Council of Canada, *Forging the Links: A Technology Policy for Canada*, Report No. 29, Supply and Services Canada, February 1979.

2. *Policies to Improve Canadian Competitiveness*, a report by the Second Tier Committee, Office of Information and Public Relations, Department of Industry, Trade and Commerce, Ottawa, October 1978.

3. Remarks by the Honourable Robert de Cotret, Minister of Economic Development and Trade to the Canadian Chamber of Commerce 50th Annual Meeting, Vancouver, BC, 23 September 1979.

4. Science Council of Canada, "Universities and Academic Research at the Crossroads: Statement of the Chairman," *Thirteenth Annual Report*, 1978-79, Supply and Services Canada, Ottawa, 1979.

5. *Supporting Canadian Science: Time for Action*, A statement by the Science Council of Canada, Science Council of Canada, Ottawa, May-June 1978.

6. See, for example, Ontario Council on University Affairs, *System on the Brink: A Financial Analysis of the Ontario University System*, September 1979.

II. The Shrinking Cohort

1. Figures II.1 and II.2 are taken from *The Class of 2001*, published by Statistics Canada in February 1979, in association with the Canadian Teachers Federation. Please refer to this publication for more extensive demographic information, including material relating to individual provinces.

2. Association of Universities and Colleges of Canada, *Financing Higher Education in Canada*, Report of the Commission on the Financing of Higher Education in Canada, University of Toronto Press, Toronto, 1965, p. 12.

3. Z. Zsigmond, G. Picot, W. Clark and M.S. Devereaux, *Out of School – Into the Labour Force*, Statistics Canada, June 1978.

4. Statistics Canada, *Enrolment in Community Colleges, 1977-78*, Catalogue No. 81-222, 1979.

5. Statistics Canada, *Advance Statistics of Education*, 1978-79, Catalogue No. 81-220, 1978.

6. Problems could also arise in trying to meet the demand from foreign sources. The demographic challenge is not confined to Canada. See Philip Handler, "Basic Research in the United States," *Science*, Vol. 204, 4 May 1979, p. 474.

III. The Responsibility of the Universities

1. Carl V. Patton, *Academia in Transition: Mid-Career Change or Early Retirement*, Abt Books Inc., Cambridge, Massachusetts, 1979.

2. Frank W. Speed, *A Portable Pension System for Canadians*, The Canadian Life Insurance Association, 55 University Avenue, Toronto, 1979.

3. *Proceedings of the Special Senate Committee on Retirement Age Policies*, Issue No. 16, Thursday, 8 February 1979, p. 16A:48.

IV. The Changing Role of Government

1. Québec, *Le ministre d'État au développement culturel, Towards a Scientific Research Policy for Quebec*, Éditeur officiel, Québec, 1979, 384 pp.

V. Bridging the University-Industry Interface

1. Bruce L.R. Smith and Joseph J. Karlesky, *The State of Academic Science*, Change Magazine Press, New Rochelle, NY, 1977.

2. United Kingdom, *Third Report of the Advisory Board for the Research Councils, 1976-78*, HMSO, London, February 1979.

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Publications of the Science Council of Canada

Annual Reports

First Annual Report, *1966-67* (SS1-1967)
Second Annual Report, *1967-68* (SS1-1968)
Third Annual Report, *1968-69* (SS1-1969)
Fourth Annual Report, *1969-70* (SS1-1970)
Fifth Annual Report, *1970-71* (SS1-1971)
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Eleventh Annual Report, *1976-1977* (SS1-1977)
Twelfth Annual Report, *1977-78* (SS1-1978)
Thirteenth Annual Report, *1978-79* (SS1-1979)

Reports

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Report No. 6, **A Policy for Scientific and Technical Information Dissemination,** September 1969 (SS22-1969, $0.75)
Report No. 7, **Earth Sciences Serving the Nation — Recommendations,** April 1970 (SS22-1970/7, $0.75)
Report No. 8, **Seeing the Forest and the Trees,** 1977 (SS22-1970/8, $0.75)
Report No. 9, **This Land is Their Land...,** 1970 (SS22-1970/9, $0.75)
Report No. 10, **Canada, Science and the Oceans,** 1970 (SS22-1970/10, $0.75)
Report No. 11, **A Canadian STOL Air Transport System — A Major Program,** December 1970 (SS22-1970/11, $0.75)
Report No. 12, **Two Blades of Grass: The Challenge Facing Agriculture,** March 1971 (SS22-1970/12, $0.75)
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Report No. 17, **Lifelines: Some Policies for a Basic Biology in Canada,** August 1972 (SS22-1972/17, $1.00)
Report No. 18, **Policy Objectives for Basic Research in Canada,** September 1972 (SS22-1972/18, $1.00)
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Report No. 20, **Canada, Science and International Affairs,** April 1973 (SS22-1973/20, $1.25)
Report No. 21, **Strategies of Development for the Canadian Computer Industry,** September 1973 (SS22-1973/21, $1.50)

Report No. 22, **Science for Health Services,** October 1974 (SS22-1974/22, $2.00)

Report No. 23, **Canada's Energy Opportunities,** March 1975 (SS22-1975/23, Canada: $2.75, other countries: $3.30)

Report No. 24, **Technology Transfer: Government Laboratories to Manufacturing Industry,** December 1975 (SS22-1975/24, Canada: $1.00, other countries: $1.20)

Report No. 25, **Population, Technology and Resources,** July 1976 (SS22-1976/25, Canada: $2.00, other countries: $2.40)

Report No. 26, **Northward Looking: A Strategy and a Science Policy for Northern Development,** August 1977 (SS22-1977/26, Canada: $2.50, other countries: $3.00)

Report No. 27, **Canada as a Conserver Society: Resource Uncertainties and the Need for New Technologies,** September 1977 (SS22-1977/27, Canada: $2.25, other countries: $2.70)

Report No. 28, **Policies and Poisons: The Containment of Long-term Hazards to Human Health in the Environment and in the Workplace,** October 1977 (SS22-1977/28, Canada: $2.00, other countries: $2.40)

Report No. 29, **Forging the Links: A Technology Policy for Canada,** February 1979 (SS22-1979/29, Canada: $2.25, other countries $2.70)

Report No. 30, **Roads to Energy Self-reliance: The Necessary National Demonstrations,** June 1979 (SS22-1979/30, Canada: $4.50, other countries: $5.40)

Report No. 31, **University Research in Jeopardy: The Threat of Declining Enrolment,** December 1979 (SS 22-1979/31, Canada: $2.95, other countries $3.55).

Background Studies

Background Study No. 1, **Upper Atmosphere and Space Programs in Canada,** by J.H. Chapman, P.A. Forsyth, P.A. Lapp, G.N. Patterson, February 1967 (SS21-1/1, $2.50)

Background Study No. 2, **Physics in Canada: Survey and Outlook,** by a Study Group of the Canadian Association of Physicists, headed by D.C. Rose, May 1967 (SS21-1/2, $2.50)

Background Study No. 3, **Psychology in Canada,** by M.H. Appley and Jean Rickwood, September 1967 (SS21-1/3, $2.50)

Background Study No. 4, **The Proposal for an Intense Neutron Generator: Scientific and Economic Evaluation,** by a Committee of the Science Council of Canada, December 1967 (SS21-1/4, $2.00)

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Background Study No. 7, **The Role of the Federal Government in Support of Research in Canadian Universities,** by John B. Macdonald, L.P. Dugal, J.S. Dupré, J.B. Marshall, J.G. Parr, E. Sirluck, and E. Vogt, 1969 (SS21-1/7, $3.00)

Background Study No. 8, **Scientific and Technical Information in Canada,** *Part I,* by J.P.I. Tyas, 1969 (SS21-1/8, $1.00)
Part II, Chapter 1, Government Departments and Agencies (SS21-1/8, $1.75)
Part II, Chapter 2, Industry (SS21-1/8, $1.25)
Part II, Chapter 3, Universities (SS21-1/8-2-3, $1.75)
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Part II, Chapter 7, Economics (SS21-1/8-2-7, $1.00)

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Background Study No. 10, **Agricultural Science in Canada,** by B.N. Smallman, D.A. Chant, D.M. Connor, J.C. Gilson, A.E. Hannah, D.N. Huntley, E. Mercer, M. Shaw, 1970 (SS21-1/10, $2.00)

Background Study No. 11, **Background to Invention,** by Andrew H. Wilson, 1970 (SS21-1/11, $1.50)

Background Study No. 12, **Aeronautics — Highway to the Future,** by J.J. Green, 1970 (SS21-1/12, $2.50)

Background Study No. 13, **Earth Sciences Serving the Nation,** by Roger A. Blais, Charles H. Smith, J.E. Blanchard, J.T. Cawley, D.R. Derry, Y.O. Fortier, G.G.L. Henderson, J.R. Mackay, J.S. Scott, H.O. Seigel, R.B. Toombs, H.D.B. Wilson, 1971 (SS21-1/13, $4.50)

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