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THE DEVELOPMENT OF SCIENCE IN CANADA

UNDER THE TITLE OF THIS PAPER a great array of information could readily be exhibited —all about millions of dollars, thousands of researchers, hundreds of laboratories, dozens of universities, and several government departments. However, it will perhaps be less fatiguing to go through to the other side of the statistics and attempt more modestly to enquire whether there is an identifiable direction that has been taken by Canadian science; whether, in other words, it represents an aspect of Canadian nationalism.

People who work at science are usually inclined to deplore any suggestion that their activities have a national flavour. The scientific worker, with an objective outlook in his own field and able to meet those in other countries on common ground, is inclined to pride himself that he has established an international framework which can serve as a model for all other fields of endeavour. Every effort is made, for example, to make Russian periodicals widely known in Canada, and if possible to have them translated into English. The spirit of science is in sharp contrast to proposals that would prevent American magazines from entering this country on the ground that they would compromise the ideals of our national culture.

It is a general aim of science to establish international laboratories working for the common good, beginning perhaps through such an organization as NATO. There are, however, practical reasons for doubting whether international support of science can be effective at the present time. In the first place, it is difficult to believe that nations that will not adequately support their own national laboratories will allocate to international organizations sufficient money for a major programme of research. Further, it is still very difficult in many countries to operate national laboratories in the spirit of academic freedom and in the creative atmosphere which great research institutes possess; to substitute international for national bureaucracy and centralized control would probably create an insuperable hazard. We require

another step forward in scientific administration before we can confidently entrust to international bodies the control of research laboratories.

Nevertheless, despite the spirit of idealism and the world aims of science, one could hardly believe that the political, historical, and social forces of a country could fail to shape the national scientific endeavour. As an introduction to the methodology by which the impact of society on science is studied, one might compare Russia with the West. The key to our Western political system is the opportunity that we are offered at frequent intervals to turn the government out. This creates the public sensitivity in our legislators that enables us the more easily to secure what we personally want in many activities of life, including science. Now what does each of us want? If one took a poll, the verdict would be virtually unanimous for the proposal "I want science above all to keep me alive longer". This was doubtless always the main democratic aim, but it becomes stronger as belief in an afterlife declines and Heaven comes to be identified with present-day North America. The recognition of our scientific preferences is evident from the scale of rewards, in which the medical profession leads all the rest, and in the first rank those who personally comfort the sick and dying. Second and considerably behind in favour, come the researchers who provide the information that the practitioners use. Third and some distance farther back comes biological research, which derives its methods and apparatus from the techniques of medicine, and on which is reflected from that subject some lustre through association. Few would quarrel with the affirmation that the countries of the West are better served with biological and medical science than is Russia.

Let us look now for a moment at Russia. Medical science cannot be neglected since it is impossible to keep people together in crowded cities without plague unless attention is paid to public health. The government, however, is not immediately sensitive to voters, and personal death is not in the first rank of problems confronting the state. In the realm of biology, food production through improved agriculture would probably have a preferred position. Among medical workers the researchers are best cared for, while the practitioners who attend to the dying are less esteemed. The dominant fear in Russia is for the death of the state, not of the individual, and the reactions to this today lie in the development of physics and its technological applications. Nobody can say whether or not physics is better in Russia than in the West; to make such a comparison would be an over-simplification. However, it is only in the applications of physics, such as in rocket technology, that a public challenge has been made to Western science.

The foregoing sketch illustrates how one might look for political and social forces to act on science, and gives some encouragement for us to seek a relationship

between political and scientific development in Canada. The conclusion to be drawn from the analysis that follows is that the three phases of Canadian public affairs—exploration, colonialism, and self-government—are paralleled by scientific exploration, technology, and pure science. Science, however, has marched along historically in the rear of political developments.

It is instructive to begin by comparing the advent of Canadian nationhood with that of the Congo, which is recent enough to be recalled. To Canada our fathers brought with them the heritage of European political traditions and political maturity. There was no period of disorder in which primitive tribesmen were struggling to learn the rudiments of the rule of law. The position of science is quite different. It is said that when the Congo received its freedom there were only about a dozen university graduates in the country. This was probably similar to the number of scientific workers in early Canada. Science in the old countries in those early days was mainly the pursuit of the amateur with private means. We would not have welcomed these gentry into early Canada, but would rather have preferred, as the Congo does today, so-called practical men who could teach us practical skills. The long-haired egg-head has no place in developing a new country. His plight today is sometimes even worse than it was in the old days, for in addition to being a worthless crackpot he is under suspicion as a potential Russian spy.

In some countries and in some fields, the course of development has been strongly influenced by the accident that a small number of great geniuses lived there. One suspects that if Mozart, Beethoven, and others had pursued their activity in, say, Edinburgh instead of in Vienna, the musical development of Scotland might have resulted today in that country being famed for some instrument other than the bagpipes. In Canada there have been great men of science, Sir William Dawson in geology for one. But I do not think that one can find a unique pattern of Canadian science in general that can be attributed to the influence of individual geniuses.

The problem of our new country then, was to recruit professionals and to decide in what direction their work should go. It seems inevitable that the first thing to do in a new country is to evaluate the natural resources, and in the nature of the Canadian terrain, this meant the development of geology. There was, in fact, an early flowering of geology, and Canadian geologists were world renowned. Thus when the Royal Society of Canada was founded nearly a century ago, of the five sections one was for French literature, one for English literature, one for Geology, one for the whole of Physics, Chemistry and Mathematics, and one for the whole of Biological and Medical Sciences. Probably it was very difficult to find competent

nominees for the last two sections. Probably, on the other hand, there were then more geologists in proportion to the population than there are now.

This phase of the description of the geological resources, and of the animals and plants as well, is the scientific equivalent of the voyages of the early explorers up the rivers in their canoes. Like exploration it will never be finished, and like exploration, it tapers off. One direction today of the geological drive, outside of special operations, is toward the North. We hear much of the vision of the Arctic, and activity will continue to evaluate the resources there. Another direction, now only in its beginning, is out under the oceans, and we may look forward to a long period during which the submarine resources will be studied.

The second phase of science is that of technology, or as it may be called, scientific colonialism. The white-coated laboratory worker comes out like the red-coated soldier, bringing us civilization. What we needed is what the Congo needs today: practical men in medicine, agriculture, fisheries, and engineering to show us how to do what more advanced countries were doing. Eventually, of course, any country expects to recruit its own white-coats. I would date the flowering of Canadian technology as the time of the first World War, at the beginning of which we were a scientific colony of England. By the end of it we were ready to embark on technology, and at that time there was a general development of agricultural and other stations—for example, the establishment of the Fisheries Technological Station at Halifax.

The general object of technology is to find out what principles have been discovered elsewhere and apply them to the local situation. It is presumed that principles are discovered by foreigners. Technology may yield great rewards, as for example in Japan, where it was possible to copy products from outside and place them on world markets at prices that ruined the original designers. It is very difficult to convince the public that there is any occasion for national science to progress beyond the level of technology. Surely, they say, the smart thing to do is to let the foreigners put in the tedious fundamental and often unrewarding work while we wait to skim off the profits. It is noteworthy in Canada today that when legislators appropriate or educators request money for scientific purposes, its use is nearly always justified on the basis of technological achievements rather than of the development of scientific ideas.

We come next to pure science, which in its ideal form is a search for laws and principles. It is the equivalent of political maturity in all its phases, including self-government and the management of foreign policy. "Pure science" is not a popular term; it has connotations of butterfly nets and worthless experiments. Euphemisms

with a better aroma and a more respectable claim on society are "fundamental science" or "prerequisite science" or "background science". Sometimes technologists, when they have failed to achieve the practical result that was sought in their experiments, refer to the outcome as pure science. This perhaps marks an ultimate degradation.

One reason for which there must be pure science is that it is impossible to maintain a good technological laboratory without the encouragement of curiosity by members of the staff. It is also impossible to maintain a good university unless the professors and students are free to pursue fundamental inquiries. Whether we like to admit it or not, the fact is that we can no more escape scientific maturity than we can escape political maturity. In contrast to the Congolese, we have in Canada, for strong reasons of sentiment, been at each stage reluctant to face the implications of maturity.

It is only within the last century or so that science has become firmly entrenched in the universities, even those of the older countries, and that the universities have become the main home of pure science. The universities were by no means eager to let science creep in through the door, and it is still not universally regarded as a full-fledged instrument of culture. Some professors of the humanities regret that it was ever let in at all, and for them it must be a sour joke that the atmosphere produced in universities by the humanities turned out to be the ideal one for scientific investigation.

One of the effects of the wartime expansion of scientific work was the increase, to varying degrees, of pure science in government laboratories. Another was the infiltration of technological activity into universities, where it is today often found easier to secure money for applied than for fundamental researches. This trend towards technology may destroy, first the dominant position of the universities in science, and eventually, the character of the universities themselves. It may be noted that technology is intruding just as much in the arts side of the university as in the scientific side. One thinks for example of Business Administration, Library Science, and Education.

A marked expansion of pure science in universities across Canada followed the Second World War and is in visible development today. One of its aspects is the general introduction of Ph.D.'s in science, proposals for which have aroused a measure of faculty opposition, on the ground that the departments concerned were not up to the standards of famous universities elsewhere. Would it not be better, and cheaper too, to send students abroad than to equip laboratories to receive them at home? The British universities retain, as well, an appeal to the sentiments of

professors of Old Country origin. Probably too, most teachers will always wish to see a favourite student go abroad, as students have always done.

The question of whether it is worth while to bring Canadian university science up to world standards is in essence the same as that confronting a proposal to assume political maturity. Where could we find diplomats to equal the smoothly efficient British type? Was it worth the cost of setting up embassies? How could we ever manage to think out a Canadian foreign policy?

Rightly or wrongly, one university after another has committed itself to the doctorate in science. How is it working out? In the matter of equipment, the National Research Council and other donors have brought many laboratories up to world standards. The library problem, through photo-copying devices, is amenable to solution. As to graduate scholarships, the National Research Council has thrown its support towards Canadian Ph.D.'s by postponing aid for overseas training until the post-doctorate level. The outstanding deficiency is in academic staffing, which is solely the responsibility of the university. On this score the effort does not bear close examination.

The opportunity for students to do their graduate work outside of Canada has recently been sharply restricted because universities elsewhere are becoming overfilled. In Canada there has been for many years a shortage of graduate students, but in 1960-61, while the undergraduate enrolment in Canada increased by about 12 percent, that of the graduates rose by 25 percent.

Canadian scientific workers, many of whom were skeptical a decade ago, are now approaching unanimity in their acceptance of scientific maturity at the graduate-school level. For this there are several reasons. In the first place, no visible habitat exists in Canada to support a really good college restricted to a limited enrolment of undergraduates, on the pattern of several famous institutions in the eastern United States. The system of "Massey" grants, of so much per head regardless of contents, together with either college Balkanization as in the Maritimes, or political pressures to admit the masses as in some provincial universities, prohibits that. The option to be small and wealthy and good and restricted to undergraduates belonged to the era of dependence on private donors. But science has now become expensive, taxes have eroded the private fortunes, and standards of admission and variety of vocational courses have been adjusted to meet democratic demands for mediocrity.

Among professors of the humanities the view is often expressed that undergraduate and graduate teaching are in competition, so that one thrives at the expense of the other. Similarly, graduate classes are held to be in competition with the writing of a thesis, which, in the extreme view, is thought to be a trivial bore and

an obstruction to the process of learning one's subject. Scientific workers differ sharply. They hold that graduate students, serving as laboratory demonstrators, improve their own education and that of the undergraduates; that the support of research brings in equipment and a point of view which strengthens the work at all levels; and that the thesis research is the core of graduate study.

The divergence of opinion may lie in a difference between the disciplines. Science has moved further in the last hundred years than in the previous ten thousand, so that lecture material has had to be continually scrapped. A science teacher aged fifty is unlikely, in senior classes, to be teaching anything that he was himself taught as a student. His student in turn is supposed to be acquiring mainly a point of view and serving as an apprentice in research work. It is supposed that the facts that the student learns will soon be obsolete. As for the undergraduate, the thing is to present to him the graduate point of view as early as possible in his course. In this way, there is some hope of maintaining, for the good students at any rate, a decent standard of education at the undergraduate level in spite of the mounting social pressures against it.

To arrive at the true cost of research to a university, an estimate would be necessary of the fraction of professors' time and laboratory space chargeable to scientific investigation. Such an analysis, which professors might regard as unwarranted prying, has not been generally attempted. The appropriations directly marked for research are, however, known, and they amount to about one tenth of the total budget of Canadian universities. Most of the money comes from outside; the universities themselves, from their own funds, pay about one tenth of the total (i.e. one percent of their total budget). The largest outside source is the National Research Council, which contributes about 40 percent. The Defence Research Board and other federal agencies bring the federal total up to over 60 percent. Provincial governments supply 10 to 15 percent, and the rest comes from industry and miscellaneous donors.

Canadian universities frequently have more or less affiliated laboratories or institutes on the campus. Some of these have complete autonomy, for example the NRC Laboratory at Dalhousie or the Laboratory of the Department of Agriculture at the University of New Brunswick. There may be varying degrees of joint management, extending eventually, as with the Oceanographic Institute at Dalhousie, to complete integration.

Federal and provincial agencies as well as private industry sometimes let out contract research to universities. This can be a major basis for financing a laboratory, as for example in the Scripps Institute of Oceanography in California. In Canadian

universities it has been of minor importance. In contracts the professor is told what to do, he is usually paid, and he is expected to report regularly. When a geologist, for example, is working for a private company, or a physicist on a defence project, or a medical researcher for a drug firm, the results of the investigation may be held secret. During the war some Ph.D. degrees were granted for work on which the candidate could not be examined, but this is an infrequent practice today and, if debated by a faculty, would probably be judged unacceptable as policy.

Grants-in-aid, as distinct from contracts, are initiated by application of a faculty member for support of work selected by him. He is not personally paid, and his work is his own to publish. Grants are made to individuals, not to the university. This is the main method by which research is supported. It is not unusual today for a department to have half or more of its budget provided from external sources, and designated for use at advanced academic levels. A recent large grant of particular interest to Dalhousie has made possible the initiation of graduate study and research in Oceanography, a brief description of which may illustrate the trend of events in Canada.

Oceanography has an engineering branch called the Hydrographic Service, which is responsible for chart making. The last British Admiralty chart is about forty years old, and subsequent charts of Canadian waters are made in Canada. The same Service produces our tide tables. About half a century old, too, is Oceanography as applied to fisheries. Some time before the first World War, a Canadian fisheries expedition, led by a Scandinavian, explored our Arctic waters. Of later origin are the special needs of the Navy, which became apparent during the second World War through the submarine menace. It turned out that the structure of the water, whether it had a warm layer on top or not, and the structure of the bottom, had an effect on the ability of sonic devices to pick up signals from submarines. The presence of microscopic organisms in the sea could also affect results, and all this has called for a specialized description of waters in which the Navy might be interested. Still another government department is concerned with ice and weather conditions insofar as they affect navigation.

All the foregoing activities are technological in aim, although all of them are accompanied more or less by fundamental investigations. The agencies concerned have been working together in harmony since the war, and together they saw the need for development of a programme that was uncommitted to any of the specialized directions and that might, among other things, provide recruits who could enter all fields of investigation. There had been for a decade an Oceanographic Institute at the University of British Columbia which had been proceeding with vigour

despite completely inadequate financial support. The NRC made grants to extend this institute and to establish a comparable effort on the east coast located at Dalhousie. These organizations it is hoped will support applied work at all stages by fundamental research.

Probably the largest civilian scientific activity in Canada is in agriculture, which is supported by both Federal and Provincial governments, and represented academically by colleges and university faculties. Provincial government activities are supposed to deal with provincial needs, leaving wider questions for Federal attention. At both levels experimental farms and regional laboratories are operated and in addition the Federal government maintains research institutes, which are the site of the Department's most fundamental studies. The institutes as named below are engaged on research of wide application to agriculture and forest biology.

The Animal Research Institute covers the fields of genetics and breeding, and investigates problems in the production of milk, beef, lamb, pork, poultry, eggs and fur. There are institutes for plant research and plant breeding where weeds, fruit and vegetables are studied. Genetic studies on cereal, forage, tobacco and horticultural plants are also carried out. The staff of the Soils Research Institute is engaged in studying the origin and classification, fertility, mineralogy and other aspects of soils. A major section of the Entomological Research Institute deals with the classification and physiology of insects, including apiculture. The Microbiological Research Institute is mainly concerned with the activities of bacteria of agricultural significance. The Dairy Technology Research Institute investigates problems in sanitary milk production and the processing of dairy products. The Pesticide Institute examines chemicals used for insect, disease, or weed control. The Biological Control Research Institute is concerned with efforts to control destructive insect pests and noxious weeds with parasitic and predaceous insects. The Insect Pathology Research Institute is a major importing centre for disease organisms. Insect diseases, including viruses, fungi, bacteria, and protozoa are studied. The Rust Research Laboratory at Winnipeg has a world-wide reputation for its contribution in the field of cereal rusts and is the national centre for investigations concerning insects in stored products.

The foregoing descriptions are summarized from the *Canada Year Book*. In its emphasis on practical matters it does a good deal less than justice to the large amount of fundamental research that is being carried out in the Department of Agriculture. It serves as illustration of a point of view referred to earlier, that in Canada it is considered prudent for people engaged in research work to allow the word to get about that they are quite fully occupied with technology.

Practical purposes provide the power that calls scientific programmes into being. It would, perhaps, not be unfair, in a fanciful way, to compare a list of purposes to the specialized portions of a brain, each of which is biased in a certain direction; one thinks for example of the eye-brain, the ear-brain, the smell-brain, the taste-brain, the balance-brain and so on. In such a figure the ideal position of university science might be that of the association areas of the brain, which are not biased towards any particular action. The possession of association areas, which appear only in the highest vertebrates, brings with it a power of alternative or long-term decision, or variable behaviour, which is supposed to lie at the base of the success of the mammals and particularly of man. The same may be true of mature scientific communities. The assumption of full responsibility in a national science programme is probably the outstanding problem confronting university science today.

In a university the primary product is men, and this to some extent determines the kind of activity in academic establishments. Research for a graduate degree has to have dimensions measured in months or years rather than decades. A student would not be very well trained, much less inspired, if he were kept at routine measurements on a project so large that no part of it could be extracted as his own. The optimal working unit in a university is small and informal, usually one professor and his students. On the other hand a key piece of equipment, such as an experimental farm or a sea-going ship, is so expensive to maintain that quite elaborate planning is needed to keep it in productive use. It seems likely that the academic ideal of lack of organization would be most easily maintained where large installations were in charge of government bodies with their own extensive programmes, and university interests would then be well served by occasional permission to use.