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The Role of Fundamental Physics in Canada

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THE ROLE OF THE PHYSICIST is evidently a serious subject. There is no one more solemn than a physicist explaining the role of the physicist. It is important to him also that the public know his purpose. Society presumably knows why it supports the doctor and the engineer; but does society know why it should support the fundamental physicist?

The role of the engineer is more obvious. Engineering skill is the first impression in visiting for example Canada's first nuclear electric power station, NPD, which has now been operating for a year and a half. The performance of NPD had been a test of Canada's nuclear energy technology that has been closely watched throughout the world. The success of NPD is an emphatic confirmation of the belief of Canadian scientists and engineers in the heavy-water-moderated power reactor.

A 200 MW nuclear power station is now being constructed at Douglas Point. A 1,000 MW station is now being designed which may be built on a site not yet chosen in Ontario. Another large plant of Canadian design will be built in India. Several other nations are enquiring about the possibilities of obtaining nuclear power stations from Canada. A great expansion of our nuclear industry is expected during the next few years.

Canada's achievements in nuclear science and technology have helped to make the world aware of Canada as an industrial nation. They have added to its prestige. They have given greater weight to Canadian opinion in international affairs—in the General Assembly and other organs of the United Nations, in the World Health Organization and in the International Atomic Energy Agency. This country, of scarcely
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20 million people, is recognized as one of the five nations most advanced in nuclear energy development.

What has all this to do with fundamental physics? This would not have happened if there had not been a background and a tradition of fundamental physics in Canada—if in 1942 C. J. Mackenzie had not been able to assure C. D. Howe that Canada had scientists—in particular, that Canada had physicists—who could make a creditable contribution to the work of a joint American, British and Canadian Laboratory for atomic energy research in this country. There would have been no Montreal atomic laboratory, no Chalk River Nuclear Laboratory as we know it today, no Canadian nuclear manufacturing industry, nor the impressive record of Canadian research in nuclear science, if we did not have in 1942, and could not continue to recruit since then, young fundamental scientists to keep alive—to keep productive—the application of physical science in the development of nuclear electric power.

I am not forgetting that chemists, metallurgists, biologists, engineers and others are playing important, indispensable roles in Canadian nuclear research and development. Their achievements, however, are beyond the breadth of my topic "The Role of Fundamental Physics in Canada".

Let us recall what this role has been, why it was a necessary preparation for Canada's emergence as one of the leaders of nuclear energy development.

In 1898 Ernest Rutherford came to Canada. Nine years in the career that brought him recognition as the greatest experimental physicist of his time were spent in this country. Rutherford's enthusiasm and genius were a continuing inspiration to his contemporaries and to his students. Through Rutherford, McLennan and others of that period, and through their students in turn, the spirit of enquiry in physics has been kept alive in Canada through two-thirds of a century. Thus when the opportunity came, commencing 1942, to work towards and to attain one of the leading positions in atomic energy development, we were able to do so.

The role of fundamental physics is more than its own preservation. It is only important if it serves society—the society which supports it. The material benefit that society may derive from fundamental science is to be seen in comparing the industrial and economic advancement in nations where it is generously supported and in nations where it is not, for example in comparing some of the countries of Western Europe with some in South America.

There is in this, of course, a feed-back of effect and cause. A wealthy nation can better afford to support science—but fundamental science...
makes possible technological progress which, in the modern world, creates wealth. The primary reason for this dependence of technological progress on basic science is the influence of scholarly minds on the standards of education and training in the community, through all levels of the university, the high schools, primary schools and even the kindergarten. In science, the scholars are those who do research.

It is the fundamental scientists chiefly—because they have more opportunity than the applied scientists—that resist the pressure to lower the standards of teaching of science in the universities, the standards for graduation and for matriculation, and the standards for qualification of teachers in the schools. In nations where fundamental research is not encouraged these standards become lax. Examples will occur to you.

Research in science is very different from the application of science. There is a technique to research—a method which has to be learned. A post-graduate degree in science means that the holder has been trained in the method of research, trained by men of longer research experience, and has proven his ability to do research. The method of research is learned by doing research under supervision. Governments, in supporting research in the universities are thereby supporting the training for research.

Most of the research in the universities is fundamental research. Are they therefore neglecting training for applied research? Many people are asking this question. They feel we should be giving greater support to applied research. The expenditure on research in Canadian industry was only about 100 million dollars in 1961. In proportion to gross national product that is only about one-seventh of the corresponding investment in the United States. For a nation that looks for foreign markets for its manufactured goods, it is not enough. What can be more absurd than to attempt to compete in commerce with countries on whom we depend for technological advancement. To build up our competence in applied research, to train more physicists to do applied research, should the emphasis in the university be shifted from fundamental to applied research?

No. It would be a grave mistake. It would have the opposite effect to what we want. The best training for applied research is experience of fundamental research. Most of the men who are leaders in applied physics research in this country were trained in fundamental research. What better example than the distinguished scientist that follows me on this programme this morning? Of course, there are exceptions—some excellent applied physicists who were not trained by fundamental research. Nevertheless, experience in fundamental research is a great advantage in providing background in fundamental science that is not so easily acquired later.
Of course, when the graduate in physics goes out into industry there is a gap in his productiveness while he learns his new job. That is true whether the research he was doing in the university was fundamental or applied. In any case, it would not be feasible to provide every graduate student in the university with research experience that is closely related to the industry in which he may later be employed. He must expect to learn the specialized technology of that industry on the job. In preparation for it, it is much better that he acquire the deeper acquaintance with fundamental physics that comes through fundamental research.

Mention of industrial research in physics brings to mind such companies as Bell Telephone, General Electric and Westinghouse. They are interested in the application of science—and therefore in applied research. Yet they also support fundamental research strongly in their laboratories. It not only provides new knowledge as background for the applied research, but also—and more important—it provides an atmosphere of scientific vitality that attracts and holds good scientists in their employ, and it stimulates scientific thinking that leads to invention.

Applied research will not thrive on nourishment that comes only from the past. Applied research depends on more than the fundamental research of yesterday. It flourishes best in the presence of the fundamental research of today.

For similar reasons fundamental research is essential for the scientific vigour of government research organizations such as the National Research Council, Atomic Energy of Canada Limited, and the Defence Research Board.

The universities, as centres of learning, should be places where the different disciplines not only come together but also work together. There is a good example in the close and fruitful collaboration of the engineering and medical faculties of the University of Saskatchewan. A lack of collaboration between physics departments and other departments of the universities is a loss of opportunity, because collaboration can bring so much benefit to both sides in broadening of interest and mutual assistance.

The engineers, for example, can help the fundamental physicists in the development of instrumentation and research equipment. A great change is taking place in many of the engineering departments in our universities with the growing influence of younger engineering professors with interest and experience in research. The younger men are endeavouring to awaken in Canadian industry a wider realization of the importance for it of research and development done in Canada. They are making progress in this purpose in spite of the discouraging lack of interest of most of their fellow engineers in research. Physicists with their well-established traditions in research can give encouragement to
their colleagues in the engineering departments by sharing their problems with them. In return they will learn much from them.

Physics offers a wide choice of subjects for research. In this country we hold that it is better to do a few things well than to attempt to do too many things. More than half of the financial support of physics research in the universities is supporting nuclear physics—and Canada is doing nuclear physics well. There are nine large research facilities for nuclear physics in Canadian universities either under construction or in operation at present. I began by pointing out how this concentration of most of the available support for physics on one specialty is beginning to pay off.

We must continue to support nuclear physics because it is easier to hold a bridgehead than to win another. Our position in nuclear energy is far too valuable to lose. During the last two years governments and power utilities throughout the world have come to the realization that economic nuclear power is overtaking us. We shall see a great expansion in nuclear industry during the next decade. The expansion has already begun. If Canada is to share in this profitable development we will need to train nuclear physicists and other nuclear specialists in increasing numbers. With that purpose in mind I am hopeful that it will be possible to increase the support of nuclear physics in the universities substantially during the next few years.

Continuing to support nuclear physics strongly does not imply that all other branches of physics must be neglected. Indeed, while firmly holding our bridgehead we should look for the possibilities of others. It is not necessary that all of our universities be equipped to do nuclear physics. Physics departments in the newer universities, before starting nuclear research, should consider other fields where research might be equally rewarding at less cost.

Mention of other possible fields of research reminds us of the recommendation from the Canadian Association of Physicists that Canada should enter the field of fundamental particle physics and that a high energy accelerator should be built for this purpose. As the Honourable Mr. Drury pointed out in reply to a question in the House of Commons “With the rapid expansion of universities and a plan for a corresponding expansion of our scholarships and grants in aid of research in the next few years, it is not considered possible at the present time to embark on a project of such magnitude as a high energy laboratory that would involve an initial expenditure of 25 million dollars and an estimated operating cost thereafter of 3½ to 4 million per year.”

I have no doubt that when financial prospects are more favourable the Canadian Association of Physicists will be considering the question of
renewing its efforts to get a high energy accelerator in Canada. If it
does decide to do so I would suggest that it use arguments that appeal
to the majority of citizens who are not physicists. It is not enough to
say that high energy particle physics is “exciting”. Who cares if it is
exciting but a physicist? The government will want to know how it will
benefit Canada. What opportunities would it provide for the training of
new physicists? What contribution would it make to scholarships in
physics in this country, and to the maintenance of high standards of
education and of technical training?

Would the apparatus be manufactured in Canada? The construction
of the big accelerators in other countries has faced their industry with
new development problems. The solution of those problems is adding to
the industrial capability of those countries. It would not be right if
grants of money for this equipment is spent in the development of that
equipment abroad if it can possibly be developed and built in Canada.
I am sure that it can.

The construction and the operation of a high energy accelerator
laboratory and its equipment should be administered by a large govern­
ment organization such as the National Research Council or Atomic
Energy of Canada Limited. They have experience and the organization
for such an undertaking. No university or group of universities should
be burdened with it. A good precedent for the administration of research
facilities for universities by a government body is the Rutherford
Laboratory in England.

Indeed I do not believe that a proposal to establish a high energy
accelerator laboratory in Canada would get very far unless it was
sponsored by either the National Research Council or Atomic Energy
of Canada Limited. Even before approval of this proposal could be
expected, a feasibility study of the apparatus and definite proposals
regarding financing, organization, administration, location and building
design, would be needed, and would require more effort than the
Canadian Association of Physicists seems able to provide.

In the United States the universities have a much greater say in the
planning of fundamental research in government organizations than they
have in Canada and they participate in that research to a much greater
extent. There is much to be said for such collaboration. I would expect
that if the National Research Council or Atomic Energy of Canada
Limited were to undertake responsibility for a large accelerator there
would be close collaboration with the universities in planning and
carrying out its research programme. This close association would be
of great benefit to both the administering organization and the univer­
sities.
One sometimes hears the view that university research would receive more support if government organizations did not engage in fundamental research. It seems to me that this opinion is very short sighted. University research has received much more support in Canada than it would have if National Research Council, Atomic Energy of Canada Limited and Defence Research Board did not have fundamental research scientists. It is they who have been most effective in convincing federal government of the importance of university research. If there were not in the National Research Council's laboratories opportunities for fundamental research, I am sure that E. W. R. Steacie would not have become its President. Our universities owe more than is generally realized to Dr. Steacie for his efforts which have increased the research grants to universities very greatly during the last few years of his life.

It is usual to justify the support of science by pointing to the material benefits from it. Too little is said about its cultural significance.

For many centuries learning found shelter only in the church, where the greatest interest was naturally in the humanities. Scientists were few. Through the dark ages the humanists guarded their heritage from Greece and Rome. Their interest, of course, was in man's behaviour, man's will, and man's emotions. Until recently they rejected any suggestion that there might be causal connection between such experience of the mind and physiological process. In short, they tried to understand humanity as if it was disembodied—as if it was removed from its external, and even its internal, environment like the voice of Hamlet's father. They denounced as blasphemers those who said that the physical world was governed by physical laws. Some, like Bishop Berkeley, affirmed that the objects of their sensory perceptions were illusions of a non-existing physical world. We do not know if this doctrine brought them comfort when they had the toothache.

Berkeley's philosophizing is, of course, not too strange an exercise for an active imagination. It is not necessarily wrong—or silly—to expound such a philosophy, or some other philosophy such as determinism, if it is developed logically. It is insistence on one philosophy with the rejection of all others that exposes a cultural immaturity—as revealed, for example, by those humanists who look upon the other of the two great divisions of learning—natural science—as no more than the recipes and working knowledge of tradesmen.

As the universities developed from the church schools and the monasteries the humanists dominated the intellectual life of these institutions. Even today there are some that have the notion that a liberal education needs include no understanding of the physical world. Although a Bachelor of Arts degree, recently won, may not imply
matured learning, even in the arts, at least it should imply an awareness of important trends in contemporary thought. The new graduate's education can scarcely be called liberal if he does not know, for example, that there has been great advance in recent years in the understanding of the biochemical mechanism of heredity, or if he is ignorant of the discovery of the van Allen belt.

Education in only the natural sciences is, of course, no less restricted than education in only the humanities. Formal education in each of the complementary divisions of learning develops certain good habits and qualities of the mind that one expects to find in a true scholar.

It is worthwhile, therefore, to remind ourselves of the habits and qualities that we value in the natural scientist. He distrusts rigid dogmatism in his science. He expects error in observation and he looks for exception to the rule. He is accustomed to change and evolution in his philosophy, and he is quite happy to describe the same process in the language of two or more theories and find truth in each of them. He recognizes in this ability to view nature from more than one viewpoint the means of deeper knowledge. He may prefer a particular theory but he does not flee from others for fear of betraying it. He does not reject the others out of hand, but examines them critically looking for still another perspective. Like the humanist he may fight for an ethical or an esthetic principle, but he less often becomes militant and bitter in support of his theories and doctrines because they are built on premises that are not so rooted in human emotions. The natural scientist therefore is generally less conscious of cultural solitude.

These are qualities that become an educated man, whether his special interest be in social or in natural science. Their encouragement is needed for the balanced education of the university student. Training in natural science provides for their development.

A leader in the intellectual life of the twentieth century is necessarily a specialist. He must have depth, and it can only be in a small area—but if that leadership is to have any breadth of influence there must be some breadth, even though it may be shallow, in awareness of other disciplines. The humanists and the scientists share a responsibility to promote intellectual breadth of vision—vision that can recognize in man's moral strengths and his follies the influence of physical and physiological process; that equally can recognize in natural science metaphysical premises, psychological influences, and something of man's own creating, like in a painting or an opera. In this purpose the fundamental physicist particularly has a part to play, for his is the most basic of the natural sciences.

Since the first atomic bomb there has been, as you know, great
searching of conscience by physicists. Increasing public awareness of the physicist has also added to the physicist's anxiety to see clearly his purpose and to recognize his proper role in society. He knows that he is intelligent, although his wife may tell him that if he was really intelligent he would not be a physicist. Indeed, he tends sometimes to underestimate the intelligence of others, and in that frame of mind he is an innocent that is easily imposed upon to give a semblance of respectability to some crackpot society or an outlet for ideological propaganda. He feels sometimes that physicists should play a more active role in public life—an occupation for which he is rarely suited.

There are few that can be expert in more than one profession at a time. That is why the fundamental physicist need not feel that he is especially chosen to engage in occupations where he is not experienced, or to solve great social problems. His role is in physics, in intellectual leadership through scholarship in physics. In that role he will strengthen the cultural and the intellectual vitality of his country, and help to insure its technological competence to compete as an advanced industrial nation for world commerce.