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Science Council of Canada

August 1972
Report No. 17

Lifelines: Some Policies for Basic Biology in Canada

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Information Canada
Ottawa, 1972

February 1972*

The Hon. A.W. Gillespie, P.C., M.P.,
Minister of State for Science and Technology,
House of Commons,
Ottawa, Ontario.

Dear Mr. Minister:
In accordance with sections eleven and thirteen of the Science Council Act, I take pleasure in forwarding to you the views and recommendations of the Council as they concern policies for the development of basic research in the life sciences, in the form of a report entitled "Science Council Report No. 17, Lifelines: Some Policies for Basic Biology in Canada".

Yours sincerely,

O.M. Solandt,
Chairman,
Science Council of Canada.

*This is the date on which the manuscript was completed.

Recommendations

The Science Council recommends that:

1. the National Research Council (NRC) continue to be the major federal source of support for research and research training in university faculties of science (p. 34).

2. the NRC Advisory Committee on Biology be especially concerned with the direction, scale and management of the intramural and extramural research programs of NRC in the life sciences, on a continuing basis; and that there should also be a quinquennial review, at a higher level, of all federal activities in the life sciences (p. 37).

3. NRC, with the assistance of its Advisory Committee on Biology, give serious consideration to the best means of developing its granting policies along present lines, including such possibilities as:

a) a more rigorous attempt, including the regular use of referees, to assess the research ability of each applicant, in order to secure more adequate funding of the best applicants at the expense of those now funded at a sub-critical level;

b) greater availability of long-term support (3 to 5 years) for applicants of established productivity; and

c) increased use of negotiated grants for research teams, either building on existing strength or starting new ventures (p. 38).

4. NRC, in suitable circumstances, be alert to the opportunity of involving biologists in university science departments in applied research related to its own in-house biological research missions (p. 39).

5. NRC, through its Advisory Committee, be asked to advise federal departments, universities and industry regarding the most effective ways of facilitating liaison and mobility of personnel among these sectors (p. 39).

6. NRC, in consultation with its Advisory Committee on Biology, advise the universities about developing training programs, pre- and post-doctoral, that might increase the flexibility and cross-disciplinary expertise of Canadian biologists. In this context, particular attention should be given to the desirability of ensuring that a proportion of trainees has adequate experience in mathematics and the physical sciences or engineering (p. 40).

7. the National Research Council, with the aid of its Advisory Committee on Biology, determine the areas of biological research that deserve its special attention because of their relevance to Canadian needs, and, when necessary, encourage the growth of research in these fields through preferential granting and training policies (p. 40).

8. the intramural biological research of NRC continue to develop along present lines, emphasizing interdisciplinary applied research in aid of fresh missions, and that NRC encourage increased collaboration among its biologists and those in other government agencies, the universities and industry (p. 42).

9. NRC, in collaboration with university libraries, make further efforts to maximize the usefulness to university biologists of the National Science Library's resources (p. 42).

10. NRC continue, and if possible strengthen, its support of Canadian biological journals (p. 43).

11. mission-oriented federal departments limit their own basic biological research to what is needed for effective prosecution of their applied research (p. 46).

12. direct external support of basic research by mission-oriented federal departments be limited to research that is clearly relevant to immediate Canadian needs (p. 46).

13. mission-oriented departments, in selecting university biologists for grant support, be guided mainly by the relevance of the research to their mission, rather than by its relevance to activities of the faculty where the research is done (p. 46).

14. NRC and the National Museum jointly examine the status of Canadian biological inventory studies, with a view to proposing the administrative arrangements, and the direction and scale of activities, which are appropriate for present and foreseen Canadian needs (p. 48).

15. any scientific activities assigned to the National Museums be budgeted separately from the Museums' other activities (p. 48).

16. there be close cooperation between federal and provincial authorities in the promotion of wildlife and ecological research, as well as in the planning of university research and training programs in the biosciences (p. 51).

17. university biologists and biology departments be ready to consider remoulding their research and training programs in ways that would permit increased flexibility and ability to cross disciplinary boundaries; for example, by having post-doctoral training in a field quite different from that of the thesis, by increased concentration of research personnel into teams and groups capable of forming centres of excellence, and by increased attention to applied research, especially on problems of relevance to Canada, while retaining broad opportunities for effective basic research (p. 55).

18. university biologists be as fully acquainted as possible with the problems of biological research and technology in government and industry, through collaboration and visits between sectors, through service on advisory boards for government departments, and through other joint enterprises. Students who are thinking of entering careers in biological research and graduate students in biology should consider, in planning their training and post-Ph.D. experience, that applied research in biology is likely to grow more quickly than basic research, and, at least as a possibility, that team research may give them more rewarding opportunities than strictly individual research (p. 55).

19. the NRC Advisory Committee on Biology, which is to include members from industry, investigate the possibility of increased collaboration between NRC and academic biologists and Canadian industry (p. 58).

20. the BCC* and CFBS† provide a common forum for the discussion of biological research needs and policies, and that they should be

* The Biological Council of Canada.

† The Canadian Federation of Biological Societies.

prepared to assist NRC and other federal agencies in arriving at policy decisions on matters related to NRC programs in biology, including the assignment of priorities in research and training (p. 60).

21. the funds devoted by NRC to the support of biological research increase for three years at an annual rate of from 5 to 10 per cent, to match the effects of inflation and of a possible further increase in university enrolment in the life sciences (p. 61).

22. the Canadian biological community, through its societies and in collaboration with NRC and other agencies, begin immediately to participate in identifying Canadian needs and priorities in the area of bioscience research, and in deploying its forces for an early acceleration of the pace of research in that area (p. 61).

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Introduction

This report is concerned mainly with some 1 200 Canadian professional biologists: the thousand or more who combine research with teaching in university faculties of Science (or Arts and Science), and the hundred or more who work in the laboratories of the National Research Council. Most of them are Ph.D.s; most of them expect to continue in part-time or full-time research; and most of the research they do–though by no means all of it–would be classified as basic rather than applied if it were judged by the usual (and rather unsatisfactory) criteria.[1] The Science Council recognizes that these are not the only Canadians who are doing basic research in the life sciences. Much of the biological research that is done by scientists who work in other settings–for example, in medical and agricultural faculties and in several departments of the federal government–is also basic rather than applied. But, in the Science Council view, any research that is done in those settings should find its *principal* justification as an activity that supports some clearly identified practical mission, such as health or food production or environmental management. It is therefore best examined in the context of reports that deal with these missions. The Science Council has issued several such reports.[2]

This was a primary reason for devoting special attention to those biologists, in university faculties, government departments or industry, who work outside the agencies to which the traditional missions have been assigned. The Science Council had two further reasons in mind. The first was that these "administratively uncommitted" biologists represent the principal pool of scientists whose expertise can be drawn on to develop new areas outside the fields of the traditional missions. The second was that such an approach permitted a clearer focus on a number of administrative aspects, since these are the biologists whose research is especially dependent on support by the National Research Council.

This report's focus is similar to that of the recently published background study[3] written for the Science Council by Dr. P.A. Larkin and Dr. W.J.D. Stephen. The Science Council has found this an interesting and valuable study, and it has been used extensively in the preparation of the present report. Drs. Larkin and Stephen, in turn, had made effec-

[1] The "usual" criteria are those stated by the Organisation for Economic Cooperation and Development (Directorate for Scientific Affairs, DAS/SPR/68.24, 2nd revision, Paris, 24 March 1970) as the "Frascati definitions". They can be found in Science Council of Canada Report No. 18, *Policy Objectives for Basic Research in Canada*. Information Canada, Ottawa (In Press).

[2] Science Council of Canada, Report No. 8. *Seeing the Forest and the Trees*. Queen's Printer, Ottawa, October 1970.

Science Council of Canada, Report No. 9. *This Land is their Land*. Queen's Printer, Ottawa, October 1970.

Science Council of Canada, Report No. 10. *Canada, Science and the Oceans*. Queen's Printer, Ottawa, November 1970.

Science Council of Canada, Report No. 12. *Two Blades of Grass: The Challenge Facing Agriculture*. Information Canada, Ottawa, March 1971.

A report on the Health Sciences in Canada is scheduled for completion in 1972.

[3] P.A. Larkin and W.J.D. Stephen, *From Formalin to Fortran: Some Facts and Futures about Basic Biology in Canada*. Science Council of Canada Special Study No. 18. Information Canada, Ottawa, August 1971.

tive use of an earlier series of surveys. This series was prepared by the twenty-six panels of specialists selected by the late Dr. Kenneth C. Fisher, who directed the study of Canadian Biology undertaken by the Biological Council of Canada and the Canadian Federation of Biological Societies; these surveys have since been published by the Biological Council of Canada as "Panel Reports of the Study of Basic Biology in Canada", and they, together with the verbal and written comments on them that Dr. Fisher was able to make before his unexpected death, have also been of direct value to the Science Council through its Committee on Basic Biology. The papers by Dr. Fisher and his colleagues examined the work of Canadian basic biologists in a very broad context, and did not separate those who work in mission-oriented settings from those who work elsewhere, as did Drs. Larkin and Stephen.

Many Canadian biologists would no doubt have preferred a survey that gave the same attention to the "mission-sponsored" as to the "administratively uncommitted" life scientists; such an approach has indeed been urged on the Science Council by representatives of the Biological Council of Canada and the Canadian Federation of Biological Societies. Though it has adopted a different treatment, the Science Council nevertheless wishes to emphasize that the spectrum of research in the life sciences is a continous one. There are no clear or well-defined boundaries between the traditional biological disciplines, or between basic biology and applied biology. In distinguishing between the "mission-sponsored" and the "adminstratively uncommitted" scientists, the Science Council does not wish to minimize the contributions of either group, or their unity or purpose, or the value of increased collaboration between them.

Why Basic biology in Canada?

The arguments for supporting basic biological research in Canada are largely those for supporting basic research in general. These arguments will be examined in a forthcoming report[1] by the Science Council and thus need not be set out here at length. In brief, the Science Council recognizes that the progress of technology has depended, and will depend, on the progress of basic science (even though technology may advance for a time on an empirical basis while some of the basic principles remain undefined). As Canadians, we should contribute our share to the world's pool of basic knowledge. "Our share" is what our resources of wealth and manpower justify; if our military and space ambitions are to remain modest, or if we fancy ourselves as especially far-sighted or generous, we might for those reasons make a bigger commitment to basic science. Philanthropy aside, we should create, in all the fields that matter to us, enough of the knowledge we ourselves need to make us competent at importing the rest. If we do no basic research, and thus exclude ourselves from the global society engaged in extending the frontiers of knowledge, we shall inevitably be slow and inefficient in applying new concepts and techniques. Perusal of the research literature, however conscientious, is an imperfect substitute for actual participation in research. Personal contact with one's peers abroad is just as necessary; in this arena, research achievement is the price of the ticket for a ringside seat. And in addition to all this, it is obvious that wherever new basic knowledge is needed to solve problems that are special to Canada, it is up to Canadians to provide that knowledge; no one else will feel obliged to do it for us.

It is the Science Council's opinion that in the foreseeable future the life sciences ought to account for a larger fraction of the world's basic research effort than they do at present, because applied biological research–on problems of health, population, resource conservation and environment–ought to develop faster than applied research in the physical sciences. But the shift of emphasis will have to be gradual rather than dramatic, because it will take time to plan strategies and deploy forces for the new advances. It should also be understood that in the future, as in the past, progress in the life sciences will go hand-in-hand with progress in the physical sciences and in the technologies that are based on them. Computers, electron microscopes, ultracentrifuges, automated apparatus for chemical and radiochemical microanalyses–all these and many more of the standard tools of the modern biologist have been gifts from the physical scientist and the engineer.

If it is true that global needs demand a more vigorous pursuit of the life sciences, the same can surely be said of Canadian needs. We can indeed be comfortably conscious that problems of many sorts press more lightly on us than on less fortunate nations. We have been blessed, but we shall have to use our scientific wits if we are to hold on to our blessings. Already, our inland waters and our urban air carry a growing burden of poisons; our shores have been smeared with unwanted oil; some of our most charming wildlife species are threatened with extinction; the conti-

[1] Science Council of Canada, Report No. 16. *Policy Objectives for Basic Research in Canada.* Information Canada, Ottawa. (In Press).

nuing capacity of our fields and forests to earn us wealth cannot be taken for granted. Part of what we need to do to preserve our heritage is obvious, but much is not. We Canadians find ourselves in charge of a large part of the world's land and water area. Its renewable resources will be of value to us and to others so long as we maintain and develop them properly. Our ecosystems are numerous and specialized, and they are exposed to hazards that are also somewhat special. As yet we understand them poorly. Even in gross terms, we can give no proper account of the flux of energy and materials through the soil and air that support an acre of wheatland or an acre of conifer forest. We have hardly begun to catalogue, let alone study, many of our smaller biota such as soil invertebrates and freshwater bacteria. Our biochemical sophistication relates mainly to our own bodies and those of our farm animals, and to a few crop and microbial species. With increasing frequency, as our industrial efforts add to the complexity of our chemical environment, we are brought up short by our inability to explain and predict, for example: when metallic mercury dumped into our water becomes transformed by bacteria into the more dangerous methylmercury; or when insect pests become resistant to pesticides; or when algae begin to foul our beaches; or when we have to compare the economics of competing sewage treatments or pipeline routes, or to decide whether bulldozers or bacteria are best for mopping up bunker oil on rocky coastlines.

We shall be safe in guessing that such problems as these will multiply, even if our industrial housekeeping becomes far more careful, as it ought to. Trial-and-error solutions will not be good enough; we must learn to understand the complex systems we shall inevitably disturb, and to understand what we are doing to them. And "understand", in this context, will often mean something much more than mere empirical testing of input-output relations, with all the organisms in between regarded as so many "black boxes"; we have to know what is inside each black box and how it works.

This will be no light task, as the example of human biology readily shows us. The human black box still holds many mysteries. Some of its problems have yielded to frontal attack, others are yielding to piecemeal erosion, and a few remain quite baffling. Both basic and applied medical science have met with many frustrations; many enthusiastic investigators have pursued their quarry until it became lost in the thickets. But it can scarcely be doubted that the billions spent have been well repaid already, and that firm foundations have been laid for greater successes. The time is now ripe for matching the continuing efforts in medical and agricultural research with an equal effort directed toward the animals, plants and microbes which have hitherto been neglected, for lack of resources, by biological science.

The effort called for is enormous, and priorities within it will be hard to set; more than 100 000 species are already catalogued for Canada, and the number of their significant interactions, as predator and prey or as competitors, is also very large. The task is indeed one for generations of biologists. But it can be confronted hopefully, for much important basic knowledge has already been acquired and applied, and

future successes should accumulate in proportion to the effort. There will no doubt be some unforeseen benefits, as in the past, when bacterial enzymes have been found useful for *débridement* of wounds or (of more dubious value!) for supplementing laundry detergents, or when a chemical from fir trees turned out to mimic an insect hormone so closely that it has been proposed as a pest-control agent. Even more encouraging than such serendipitous discoveries is our growing awareness of living organisms, from microbe to man. These similarities entitle us to expect that progress in health science, and in agricultural science, will increasingly assist progress in other fields of basic and applied biology. Nor will the flow of useful knowledge be only in that direction. As every schoolboy now knows, the experimental breeding of fruit flies led directly to fundamental advances of incalculable value in human, animal and plant genetics. As fewer people know, the next great advance in genetics, which is in process of revolutionizing the whole of biology, can be traced back to the analysis of the "transformation" of one type of bacterium into another type when the first type was treated with a chemical extracted from the second type. And as perhaps only biologists know, our present knowledge of how excitation is triggered and conducted in nerves, muscles and hearts can be readily dated back to experiments some 20 years ago, which became feasible when the squid was discovered to possess some relatively huge nerve fibres. These were some of the giant steps forward; but of equal or greater importance has been the total of smaller contributions by many biologist working on many species with many techniques. Canadian biologists, in both basic and applied work, have played respectable roles in all this, though they have seldom held the centre of the stage in the more exciting dramas.

There remains plenty of room for argument, in relation to Canadian and world goals, about whether the common interest is best served by emphasizing basic research in the life sciences, or by emphasizing the application of the basic knowledge we have now. There is no easy answer; either basic research or applied research can be rate-limiting for progress. Many biologists would agree with Sir Macfarlane Burnet's recent remark that "what is needed is not new principles but the application of what is known to the urgent tasks of the world as a whole". On purely practical grounds, though, it sometimes turns out that the spending of money on basic research has provided a more economical, and even a quicker, solution of a problem than could have been achieved by a direct attack on an empirical basis. It is also true that basic researchers nowadays are likely to be alert to the practical significance of their findings; this is one of the reasons why the lag between a basic discovery and its application is getting shorter. Many Canadian biologists, indeed, are engaged in research problems that have both basic and applied aspects, or direct their attention to basic and applied problems alternately. For all these reasons, the scientist who is engaged in basic biological research is not necessarily retreating to an ivory tower; he might be making a real contribution to the solution of urgent practical problems.

Moreover, a plausible case might be made for the statement that Canadian university biologists have achieved more in their applied re-

search than in their basic research. Nevertheless, the balance between basic and applied research in university biology appears to the Science Council to be too heavily weighted toward the basic side. It seems fair to say that in the past the incentives–in terms of academic career opportunities–for doing basic research that would win approval abroad have been stronger than the incentives for doing good research, whether basic or applied, that might be of special significance in the Canadian context. The reasons for such a preference are obvious, especially as so many of our ablest biologists have had part or all of their training abroad; and they cannot be simply written off as bad reasons. It is natural and proper for an ambitious scientist to want to make discoveries of global significance. Such discoveries will help to keep his country in the mainstream of science. But if *all* our ablest academic biologists were to be uninterested in the particular organisms and ecosystems that seem to be important in the Canadian context, we could not expect them to produce many good young researchers with the will and skill to tackle our own problems. Here, as elsewhere, good basic science and good applied science should both be conspicuous on the academic scene.

Basic Biology in Canada: the Present

Quantity

As already noted, this report deals mainly with the 1 200 biological researchers who may be classed as "administratively uncommitted". Most of them are part-time researchers who spend much of their effort on teaching and, in some cases, on committee work and administration. Not counted in the 1 200 are their technical assistants, graduate students and post-doctoral fellows, though all of these form an important part of the biological research community.

The largest *identifiable* source of money for their research is, by far, the National Research Council (NRC), which allocates about 20 per cent of its external grant funds, and perhaps half that percentage of its internal expenditures, to biology. The total sum granted by NRC, on the recommendations of its four biological committees[1], was about $9.8 million in 1971-72–of which, however, a substantial portion went to biologists in faculties of agriculture (with smaller portions to faculties of forestry, medicine, pharmacy, etc.). "Negotiated grants" (to certain groups of scientists on a longer-term basis), grants in support of the International Biological Program (IBP), scholarships, and fellowships added about $3.5 million to the $9.8 million, and the parallel costs for NRC intramural research added perhaps another million, for a total of about $14 million. Tables 1 and 2, and Figure 1, show the yearly totals of the extramural grant support allotted since 1962 by NRC to the biological sciences. As in most of the other research fields supported by NRC, the totals rose sharply until 1968-69, but have now nearly levelled off, in spite of inflation and the still growing number of investigators eligible for support.

Grants from government agencies other than NRC, and grants from private agencies, made a further contribution; but science faculty biologists are not often awarded grants in these categories. In the absence of complete data for such awards, it seems safe to conclude that the maximum figure for the direct funding of research by the "administratively uncommitted" group has never exceeded $18 million a year.

If one uses the broader definition of basic biological research and includes also the basic research done in the mission-oriented agencies and faculties, while excluding the applied research done by the "administratively uncommitted" faculties and schools, the total federal support (including MRC[2]) for basic biological research might well be about double the amount just mentioned, say $35 million a year. This is at best a very rough calculation, because there are at present no really useful figures for the ratio of basic to applied research, either in relation to either of

[1] The four committees are those for plant biology, animal biology, population biology and cell biology. Much of the research supported through the committee for experimental psychology has a strongly biological flavour, but this research is not considered in the present report.

[2] Science-faculty biologists have sometimes suggested that where the Medical Research Council (MRC) and NRC support (as they often do) research in the same general area, an applicant to MRC usually gets more money than an equally well-qualified applicant to NRC; but data that would support or refute this suggestion are not available, and to obtain them would require a quite elaborate investigation.

Table 1–NRC Operating and Major Equipment Grants in Biology, 1962-1972*

Year	No. of Applications	No. of Grants	Total Applications	Total Grants	Average Grant
			$ '000	$ '000	$
1971-1972	1 503	1 221	21 802	9 808	8 032
1970-1971	1 504	1 199	20 972	9 833	8 201
1969-1970	1 434	1 146	21 002	9 468	8 261
1968-1969	n.a.†	1 089	n.a.†	8 568	7 868
1967-1968	1 072	945	11 261	6 831	7 228
1966-1967	952	815	8 971	5 377	6 597
1965-1966	720	571	6 163	3 392	5 941
1964-1965	527	431	4 148	2 761	6 412
1963-1964	387	326	2 672	1 885	5 784
1962-1963	n.a.†	272	n.a.†	1 717	6 312

* The tabulation includes all grants made on recommendation of the grants committees in the biology sector, including those (160 in 1970-71) made to scientists in agricultural faculties and in university physics and chemistry departments. Excluded are the "Negotiated Development Grants" inaugurated in 1967-68; these are shown in Table 2. It was not feasible to quantitate the cost of in-house NRC life science research.

† n.a.: not applicable.

Sources: NRC's Annual Report on Support of University Research provided the data for the number and dollar value of grants from 1962-63 to 1969-70. All other data were supplied by NRC's Office of Grants and Scholarships.

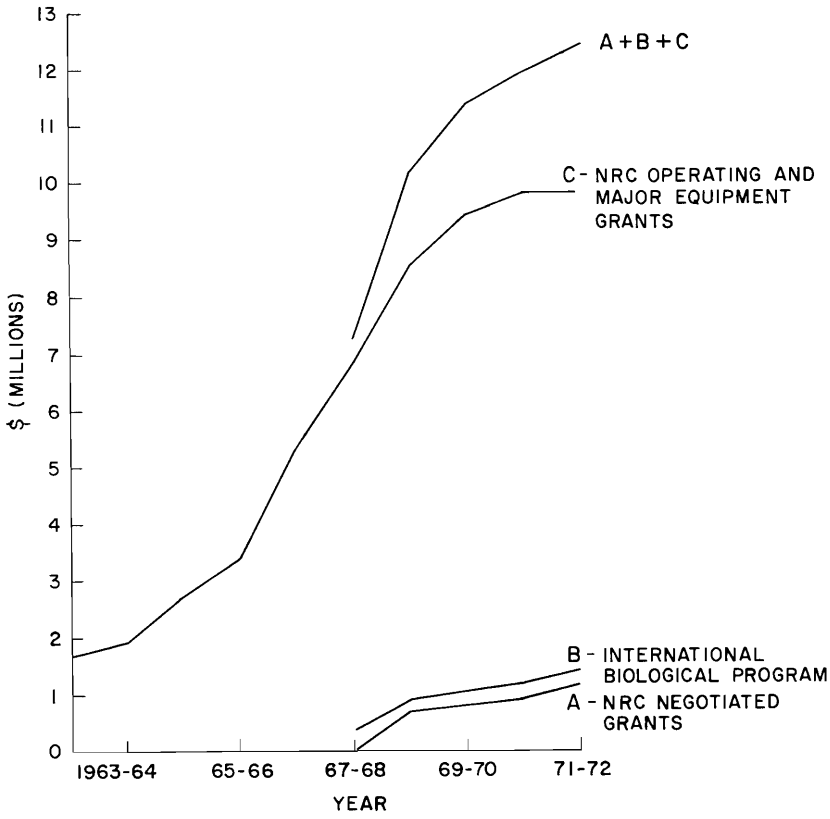
Table 2–NRC Negotiated and Special Grants in Biology

Year	International Biological Program	Negotiated Grants
	$ '000	$ '000
1971-1972	1 407	1 500
1970-1971	1 181	909
1969-1970	1 075	808
1968-1969	896	754
1967-1968	342	61

Sources: NRC, *Annual Report on Support of University Research* and Office of Grants and Scholarships. The above sums were all spent in the stated year. The 1971-72 IBP total is an NRC estimate. It was not feasible to quantitate the biological content of certain Negotiated Grants awarded in multi-disciplinary areas, e.g. oceanography.

the two groups of life scientists we have distinguished here, or in relation to the research budgets of the major federal agencies. It has not seemed useful to attempt a closer estimate. The basic/applied distinction is in practice even more arbitrary in the life sciences than it is in the physical sciences, and the standard definitions, such as those used by Statistics Canada, are of quite limited value in this context. Moreover the taxpayer, besides supporting the NRC, also supports the universities, which absorb much of the indirect cost (professional salaries, laboratory space and services, administration) of life science research. As a "ball-park" figure, it seems that the average Canadian spends between a dollar and two dollars a year to pay for the acquisition of basic knowledge about

Figure 1–Extramural Grant Support Allocated since 1962 by NRC to the Biological Sciences



living organisms and life processes, including those in his own body; about a third of this sum, say 50 cents, goes to support research by the "administratively uncommitted" biologists.

Quality

The Science Council believes that, by world standards, Canadian biological science has attained a respectable level of achievement. Qualitatively, this level is one of modest competence. There is some excellence, much worthy but less distinguished work, not much that is downright bad: in general, a "high-quality, small tributary to the total flow of science".[3] Quantitatively, the Canadian investment in biological research, in relation to our population or economic productivity, is probably not far from the average for countries at our level of development. But in the Science Council's opinion, the level is lower than is appropriate for a country that has our area and biological diversity, as well as our resources.

Canada's share of the world effort in basic biological science is quite impressive in some areas of research, less so in other areas. At present, many would agree, the most glamorous fields in the life sciences are at opposite ends of the spectrum: *molecular biology,* which deals with the most basic levels of organization, and *ecology,* which deals with the most complex levels. Canada played only a minor role in the dramatic surge of molecular biology during the last two decades, and is only now beginning to catch up. In ecology, which accelerated somewhat later in response to the double spur of the computer and the environmental challenge, Canadians had already done more than their share of the pioneering and have thus been able to stay in the forefront. In the broad middle bands of the spectrum, the contrasts are less striking, though there are brighter and darker regions. Much of *plant and animal biochemistry, physiology, genetics and pathology* is reasonably well represented, mainly because of what has been done during the last 10 or 15 years. At the *cellular* level, Canadian biology presents a brighter picture than at the molecular level; and on one of the frontiers between cellular and molecular biology there have been some noteworthy developments in immunological research. *Microbiology* has also made important strides, though in some important areas, as has already been suggested, the basic studies do not yet provide an adequate basis for serious applied work. Communication among these groups of biologists, though improving, is still imperfect. They usually work in different buildings, belong to different societies, publish in different journals, and are often supported by different granting agencies, even though their research interests have much in common. In molecular biology we are emerging from the lag period; perhaps we are also beginning to do so in *theoretical* and *mathematical* biology, and in *ethology,* which is one of the fields in which biology and psychology interdigitate. It is also to be hoped that we shall do our full

[3] P.A. Larkin and W.J.D. Stephen, *From Formalin to Fortran: Some Facts and Futures about Basic Biology in Canada.* Science Council of Canada Special Study No. 18. Information Canada, Ottawa, August 1971.

share toward the needed expansion of *toxicology* to cover biota other than man and his plant and animal crop species. These are studies that need to be vigorously pursued at various levels, from the molecular to the ecological, in view of the threatened chemical degradation of important parts of our environment.

Perhaps surprisingly, one of our greatest shortcomings is in *inventory studies* of the traditional kind: the identification, description, classification and life cycles of our less conspicuous species of animals, plants, and micro-organisms. At one time, such studies represented a favorite field for Canadian biologists. Some important and even distinguished work of this sort is still being conducted in government laboratories, but most academic departments of biology appear to have lost interest in it; nor have they been active in developing the newer approaches to systematics, which use mathematical and chemical tools and are certainly not without intellectual challenge. We are concerned about this deficiency. As Larkin and Stephen have written:

"Much of the background of systematics, morphology, plant and animal natural history, descriptive ecology, biogeography and palaeontology, has not yet been done in Canada to the level achieved in Europe.... It is a feature of Canadian field biology that we are commonly trying to do sophisticated research without having a sufficient knowledge of the living or fossil materials that we are handling. No other technologically progressive country, except possibly Australia, has such a high proportion of unstudied floral and faunal elements".[4]

Finally, as has often been pointed out, Arctic and sub-Arctic biology in many of its aspects must be counted as an under-developed area. Here, however, the necessary logistic support is becoming easier to find, and a growing number of younger Canadian biologists are looking forward to combining this kind of science with adventure. The study of some of the northern eco-systems offers a special challenge because they are dominated by relatively few species, which respond sharply to changes of season and local variations in micro-climate; thus, it may be relatively easy to pinpoint interactions that may provide useful models for the analysis of more complex systems. It should not be assumed, though, that every proposal for research in the North deserves support; there can be poor work in this area too.

[4] P.A. Larkin and W.J.D. Stephen, *loc. cit.* p. 21.

Basic Biology in Canada: the Future

Under this heading the Science Council offers some comments on the directions, the management and the scale that seem to be appropriate for basic biological research in Canada during the next few years. The scale of the research effort must depend on the availability of manpower and money, and some attention is given to each of these factors.

Directions

Biology, like other sciences, continually re-orients itself, thrusting forward new salients while consolidating the fronts between earlier ones. The last big thrust, whose impetus is still being well maintained, has been on the molecular front. The next one will be on the broad ecological front; in addition, strong forces have been massed in other sectors – for example those of neurobiology, developmental biology and immunology – where major advances can be expected. Global as well as national needs call for Canadian participation in all these developments.

There are, in addition, important needs for basic biological knowledge that relate especially to Canada. These have been noted in the Larkin-Stephen report. Besides the neglected inventory studies of our plants, animals and microbes, we need sophisticated analyses of our most important ecosystems, natural or man-altered, and of the flow of energy and materials through them. Our success in these analyses will determine our ability to control and protect these ecosystems, to maximize their useful harvest, and to help them recover from damage. To do this effectively, we shall eventually have to study our major biota at several levels, from the ecological to the molecular, and to use sophisticated techniques of systems analysis for evaluation and prediction. From experience–our own experience and that of others–we can be confident that as our knowledge of the basic biology of our milieu expands, it will create new openings for applied biology, and as the applied biology develops, it in turn will present further challenges for basic research. These are tasks, as has been stated earlier, to keep future generations of biologists busy. Meanwhile, the knowledge accumulated by biologists up to now must be put to use. It should already be understood that much of what we have now learned is ready for application, and that we ought not to delay in applying it.

Management

Basic science, by its nature, is less susceptible to management than applied science. It has been argued that the less management the better, and that the insights of individual scientists lead to an efficient selection of the problems that are ripe for attack and provide a better strategy for research than any committee or any institute director can achieve. The Science Council agrees, as its forthcoming report on Basic

Research[1] will make clear, that the ablest researchers should be allowed to do what most engages them, and that research funds should normally be allotted to projects on the basis of peer judgment. The Science Council believes, nevertheless, that there is a place for leadership in basic research, and, within limits, a place for central management; the role of the granting agencies should not be an entirely passive one. The degree of central management, and the nature of the management, should not, however, be the same for all the agencies. For example, the federal mission-oriented departments can properly undertake a closer supervision of the research they support than would be appropriate for NRC or MRC. On the other hand, because of the breadth of their interests, NRC and MRC should have some special responsibilities for long-term planning. These points of difference will be discussed more fully later on. Setting them aside for the moment, the Science Council suggests that the agencies can exert their influence in a number of ways:

1. They can and should increase research productivity, quantitatively and qualitatively, by encouraging the concentration of research in centres of excellence.

2. They can and should ensure a fairly even geographical distribution of the country's overall research effort, without interfering with the development of centres for specialized research, which should themselves be widely dispersed. The arguments for dispersing the research effort to some degree, and the counter-arguments for concentrating it as much as possible, are too familiar to need spelling out here. It is not necessary for every university and college to mount a major research effort, but there should be opportunities in every region for able young people to enter on careers in science.

3. They can and should engage the interest of basic research scientists in research oriented toward Canadian requirements: by preferential granting and training policies; by facilitating communication and exchange of personnel between basic and applied sectors; and by greater use of contracts for specific pieces of applied research. The Science Council does not suggest that basic biologists be asked to switch *en masse* to applied research. The Council does suggest that many–perhaps most–of the biologists who do only basic research would find it stimulating and rewarding to allocate at least part of their efforts to studies that, during their own lifetimes, would be clearly useful to their fellow countrymen (and not just to their fellow scientists).

4. Progress in modern biology requires such essentials as information services, museums, identification facilities, highly specialized equipment and technicians trained to use it, special regional facilities, and national biological journals of high quality. Such services are expensive, and cannot be duplicated extensively. The granting agencies have a major responsibility for ensuring that they are available to the investigators who need them, and that they are efficiently used.

[1] Science Council of Canada, Report No. 18. *Policy Objectives for Basic Research in Canada.* Information Canada, Ottawa (In Press).

5. It can be stated as a general principle that, because basic research and graduate training belong together, the government agencies should not do in-house basic research that can be done as effectively at the universities. This statement should apply to NRC as well as to the other government agencies that employ career scientists. It should be recognized that NRC, like any other organization that does research, should do as much basic research in its own laboratories as is needed to support its applied research; and it is agreed that in certain fields, e.g. radiobiology, the national interest may indicate that NRC should be the principal centre for basic research. Nor should it be obligatory for an NRC scientist who can do research of outstanding quality to seek academic employment if he wishes to pursue basic rather than applied projects. As to biological research, it can be expected that NRC's efforts will be increasingly, but at no time exclusively, on the applied side–a point which will be discussed in more detail later (pp. 40-42).

6. The granting agencies should encourage the national biological societies to play a more effective part in formulating both the main lines and the details of policy for the support of both basic and applied biology. In proposing this, the Science Council is reiterating a view it has already expressed, especially when it approved its Chairman's advice to the Canadian Association of Physicists.[2] For the societies to play their proposed role well, their own resources will need to be supplemented by government funds, supplied by the Research Councils or perhaps directly by the Minister of State for Science and Technology.[3]

7. Federal and Provincial government departments whose missions relate to the life sciences should make full use of the research capabilities of Canadian university biology departments, through grants and contracts for applied research and through grants for such basic research as may be oriented to their short-term needs. Except in unusual circumstances, they should leave the direct support of other kinds of basic research to NRC and MRC.

8. NRC, and other government departments whose scientific missions touch on global problems, should continue to be sympathetic to Canadian participation in world-wide biological research programs, and to Canadian initiatives in aid of biological research and research training in underdeveloped countries. There is need, though, for a much sharper focus on the goals to be achieved by Canadian participation in international scientific programs. The Science Council is currently devoting some attention to this point.

The Science Council believes that NRC in particular will find that many of the views expressed here accord well with the policies

[2] O.M. Solandt, "Open Letter to Physicists from the Chairman of the Science Council of Canada". *Physics in Canada,* Volume 26, No. 7, November 1970. pp. 130-135.

[3] The Science Council is cooperating with the Association of the Scientific Engineering and Technological Community of Canada (SCITEC) in a study of the role of the societies in relation to the development of policies for science.

it is now developing. The recent appointment of a Minister of State for Science and Technology now makes it possible to have such policies discussed at the Cabinet level.

Some critics may feel that the rather modest role here assigned to the central management of basic research goes too far. They would prefer a "Republic of Science", in which all research priorities are determined by the judgements offered by the scientific community itself, on the merits of each proposal. Others, taking the contrary view, may argue that much more direction of science is needed to achieve its maximum productivity. The Science Council has no doubt that research in government missions and in industry should be subject to close review and supervision, in which, however, expert scientists from outside should also be involved. When the research is basic, with no immediate pay-offs expected, the appropriate basic research scientists should help to review it. But the Science Council does not think that basic research in the universities should be managed to the same degree; in that sector, the initiative of individual investigators should determine research strategy and tactics, subject to local resources and to peer judgement expressed through the granting agencies. It is true that the initiative of scientists has its limitations. The "Ph.D. cycle" does exist; it happens frequently enough that intelligent and devoted researchers continue to cultivate and transmit to their students the concepts and skills developed at the outset of their careers, when they would do better to switch to a new line. But the indictment has often been exaggerated. Most basic researchers have a rather sound instinct for what is important and what is trivial, and prefer to work on what is important.

What has just been said is intended to refer to basic research in the narrow sense, where the research is motivated by the investigator's curiosity. University research of the applied sort, in support of a specific mission, can properly be subjected to tighter control, especially when it is done on a contract basis.

It follows from all these statements, if they are accepted, that the federal research councils and the other federal agencies ought to have different standards for guiding university research. The councils should use a light rein, the departments a tighter one. Moreover, while the councils should have money available to support research that is not specifically related to Canadian needs, the departments may well restrict their funding, with few exceptions, to studies that pass the test of relevance to Canada and to their own missions.

Scale

The scale of a research effort depends on the number and the quality of the people involved in it and on the resources available to them. These factors also determine its cost. A concern of science policy should be to match manpower supply and demand to need and cost. In the case of policy for university research, the match is unlikely ever to be a perfect one because educational policy is also involved,

and it is in the hands of a different set of people. Involved too are the private policies of a great many individuals in the universities, especially those who are embarking on their own careers. In discussing the scale of the research effort that will be appropriate for Canadian university biology over the next few years, it may be useful to consider the situation in regard to manpower first, and then the desirable level of funding.

Manpower

In the Science Council's view the *need* for more biologists exists now. The *demand* for more does not yet exist; the current *supply* of graduates is numerically more than adequate to fill the vacant jobs. It seems likely, however, that demand will soon rise, and that most of the demand will be for applied biologists, especially in the environmental field; by no means all of the demand will be for ecologists since, as has been pointed out earlier, environmental problems have to be solved at various levels, of which the ecological level is only one. The increased demand will originate especially with government and industry; both these sectors urgently need the results of applied research. But whether the new jobs are within those sectors, or within the academic sector in response to these requirements, will depend partly on whether the universities wish to accept the challenge to do more applied work, and partly on whether government and industry will be ready to entrust urgent problems to scientists whose primary job is teaching, and who therefore cannot always give priority to research. There is a need for discussion of these matters among the sectors, perhaps under the auspices of the Minister of State for Science and Technology.

Except for the possibility just mentioned, of a switch to *ad hoc* research by many of the people concerned, no more than a modest increase in the number of "administratively uncommitted" biologists is to be expected over the next few years. It is dangerous, as a recent report[4] for the Science Council shows, to extrapolate academic employment graphs from their current slopes. But at present it seems likely that student registration in science faculties will grow no faster than about 5 per cent per year, and that the number of faculty members (and research laboratory space) will not be allowed to grow much faster than that. It is quite possible that there may be a further shift of popularity in favour of the life sciences[5], which will justify a somewhat more rapid increase of faculty than in the physical sciences. Such a shift of popularity may well extend into the graduate schools and, if so, it would permit a tightening of admission standards, besides increasing the number of graduates.

It would be pleasant, but unrealistic, to hope that Canadians

[4] Frank Kelly, *Prospects for Scientists and Engineers in Canada.* Science Council of Canada Special Study No. 20. Information Canada, Ottawa. March 1971. (especially pp. 38-39).

[5] As the data in Appendix A of this report illustrate, such a trend has been apparent during the last decade in both Canada and the U.S.A.

and their governments would, in the next few years, become so conscious of the global needs for progress in the life sciences that they would devote a steeply rising (though still modest) share of their resources to fostering a rapid growth of basic biological research. This is quite unlikely to happen soon. The prospects are, rather, for a slowly rising demand for research and graduate training in biology, accelerating later, as organizational set-ups are developed and problems more clearly identified, especially in the environmental field. Most of the accelerated demand will be for applied biologists. Biology teachers and their students should take note of that. In the more basic fields of research, supply may outrun demand, at least temporarily. If there is a temporary surplus of biologists it can be at least partly accommodated by a shift of young researchers into other fields, including teaching below the university level, or by an increase in the number of postdoctoral research fellowships. Another possible "holding pattern" for periods when there is an apparent surplus of life scientists would be the employment of young biologists trained in other fields to help accelerate the inventory studies in which Canada is so far behind. This device, besides contributing useful information, could add to the breadth and flexibility of the people involved, and might even enable some of them to open up exciting new fields for research.

There are other devices that should be employed for increasing the flexibility and interdisciplinary expertise of Canadian biologists. The Larkin-Stephen report[6] has some good advice to offer on these points. The Science Council agrees that special attention should be given to the recruitment of a proportion of biological trainees with graduate experience in the physical sciences, engineering or mathematics. It is probably harder for a biologist to learn to think like a physicist than vice versa, but both kinds of thinking are necessary for the solution of problems at many levels of biological organization. At later stages of a research biologist's career, his training should be periodically reinforced by visits to laboratories that do research different from his own. The length of such visits may vary. For most scientists, the sabbatical one-year-in-seven is too infrequent and too long to be compatible with continuity of research.

The Federal Government has always been a major employer of biologists, but its employment practices have been far from ideal. The Science Council welcomes the action by the federal authorities, through the Ministry of State for Science and Technology, in establishing machinery for surveying the nation's highly qualified manpower so as to obtain the information required for proper regulation of supply and demand.

Funding

The Larkin-Stephen report, in an "Epilogue on Expenditures", offers the following comment and advice on this inescapable subject:

[6] P.A. Larkin et W.J.D. Stephen, *From Formalin to Fortran: Some Facts and Futures about Basic Biology in Canada.* Science Council of Canada Special Study No. 18. Information Canada, Ottawa, August 1971.

"The expenditure on basic biology in Canada will be larger in the future than it has been in the past if we respond to what seem to be the potentials and problems ahead. The present expenditure of about $9 million per year by the National Research Council, augmented by about $3.5 million by grants to NRC applicants from other sources, is not a large sum by comparison with other national expenditures on research and development.[7] Viewed in relation to problems of the day, it is far from adequate to enable us to both catch up and keep abreast of the times. A five-fold increase in research fund allocations to basic biology by 1980 [the report was written in 1970] does not seem an unduly ambitious or imprudent forecast.... For the future, there will be hard competitive business reasons, convincing philanthropic reasons, and compelling national social reasons for raising our sights to new levels of investment in all the life sciences. It is important that this long-term prospect be clearly envisioned now. Of all branches of natural science, biology is one of the least responsive to the massive very short-term blitz.

In the total pattern of investment in life science research, it is urgently necessary to reinforce the basic component, which serves the applied fields, and which provides a national investment in scholarship."[8]

A five-fold increase of funding in 10 years means a yearly increase of 20 per cent over each preceding year. Of this 20 per cent, 4-5 per cent would represent inflation; the "sophistication factor" (increasing reliance on complex instrumentation and highly trained personnel) would account for another 4-5 per cent; and the remaining 10-12 per cent could represent either expansion of the research work force or more ambitious research projects.

The advice of Larkin and Stephen may be compared with that offered recently to the U.S. government by the Committee on Research in the Life Sciences, of the National Academy of Sciences (NAS)[9]. The Committee, having expressed its regret that budgets for life science research in the U.S. had actually declined (though they still offered the average biological investigator at least half as much again as his Canadian counterpart), went on to say:

"From the best estimate we can make, in the current year (fiscal year 1970) appropriations for research, *per se,* are approximately 20 per cent less than required to ensure that the nation's truly qualified academic life scientists are fully and usefully engaged. We urge that this deficit be eradicated as soon as possible and that, thereafter, the

[7] The Larkin-Stephen figures include grants to many investigators in faculties of agriculture, forestry, etc., as well as in faculties of science.

[8] P.A. Larkin and W.J.D. Stephen, *loc. cit.* p. 63.

[9] *The Life Sciences.* NAS, Washington, 1970. (pp. 25-26). The average size of research grants in 1967 in various field of basic life science ranged from $11 000 to $23 000 (p. 270). For comparison, NRC grantees in biology (irrespective of faculty) averaged $7 545 in 1968-69, plus about $3 400 from other sources (Larkin-Stephen, pp. 43, 45).

research-support system grow at a rate commensurate with the ability of the system to utilize such funds efficiently and wisely. The frequently proposed formula of an annual increment in research support of about 12-15 per cent appears to us to be a rational approximation of desirable growth as long as the system continues to expand to meet the perceived needs of society. This would accommodate the increasing numbers of graduate and medical students, meet the increased costs of research due to increasing sophistication particularly noticeable in the life sciences as they lean over more heavily on instrumentation, and compensate for the losses due to general inflation.... it is abundantly evident that the academic endeavour in the life sciences must continue to expand by about 5 per cent of the trained scientists per year and the employment opportunities for trained life scientists will exceed the supply for at least a decade."

The advice of the NAS Committee has not, so far, been accepted by the U.S. Government. If it were, and if the advice of Larkin and Stephen were taken by the Canadian government, an average Canadian biologist would begin to catch up to his American counterpart in respect of his extramural grant support. After six or seven years, the two would have equal resources, and then the Canadian would move ahead.

Such prospects are hardly realistic. The Science Council is not yet satisfied that this is the time to seek to restore the rates of budgetary increases of a few years back for any group of basic scientists, including the biologists. At the present time, it feels compelled to place a high priority on the needs of science as applied to Canadian requirements. There are such requirements in the field of applied biology, but as yet the "administratively uncommitted" biologists, as a group, are not deployed to meet them. The biologists should not be blamed for that; they have been doing what they were expected to do, their primary task being to build up the teaching and research programs of our expanding universities. Now they can expect to be confronted with new tasks and, as a group, to become more "committed"; in other words, to devote a greater fraction of their effort to applied research. But this cannot happen overnight. It will take time for plans to be made, by NRC jointly with other agencies of government and the biological research community, for the identification of research priorities and the establishment of machinery. And it will take time for the biologists to find problems to match their skills. It is suggested therefore that during this reorientation period, which might last three years, the funding of the research done by the academic biologists outside the professional faculties might increase at only a modest rate. The overall budget might then be one that would maintain the average competent investigator at his present level of funding in real terms, and would thus not slacken the pace of activity in his laboratory; the budget would allow for inflation and for any increase in the number of biology teachers that might be justified if student enrolment in the life sciences continues to increase. It seems likely, though the statistical basis for

forecasting is inadequate, that this would mean an annual increase of between 5 and 10 per cent over the three-year period. Thereafter, it would be expected that a much more rapid expansion of research support would be justified by the quality of the proposals and the "relevance" of an increasing number of them. (It would also be expected that part of the budgetary increase for biological research might be channelled through the new federal department, Environment Canada, as it identifies the priorities within its mission; but it would not be proper for the Science Council to attempt to allocate the respective responsibilities of NRC and Environment Canada where their interests overlap.)

What is proposed here is a significant, though only partial, shift in the aims of the biological community to which this report refers. A statement made earlier should be repeated: it is not proposed that all basic biologists should become applied biologists, or that any biologist capable of good independent research should be forced to accept direction from a central agency. The Canadian, as well as the global, need for first-class basic research is no less than it has ever been–indeed it is greater than before–and it must be met. Indeed, those who do such research should have their efforts supported better in future than they have in the past. But it may be hoped that many Canadian biologists will respond to the challenge to put their expertise to work to protect and improve the quality of Canadian life, and that they will find no smaller intellectual challenge, and at least equal satisfaction, in their attack on new problems.

The Role of NRC

The National Research Council, through four of its grants committees, provides most of the funds that go from the Federal Government to support biological research in university faculties of science. The Science Council believes that it should continue to do so.

There have been occasional suggestions, before and after the formal separation of MRC from NRC in 1969, that NRC's activities in support of biology should be joined with those of MRC through the establishment of a single Life Sciences Research Council. The arguments put forward were not convincing. It is true that much of the research supported by MRC, especially in cellular and subcellular biology, is quite as basic, or "pure", as the research suported by NRC in those fields. This MRC-sponsored research is, however, done within faculties that have health care as their mission, and it ought to be appraised, as was stated earlier, primarily on the basis of its value–in the long run or the short run–to that mission. Conversely, there are good reasons for having a single federal agency that is concerned with the support of both physical and biological research in faculties of science. Physicists and chemists (and even engineers) deal increasingly with the materials and processes of life, and biologists increasingly use the concepts and techniques of mathematics, physics and chemistry. A single granting agency concerned with all these fields can promote their mutual interpenetration and give effective supervision to interdisciplinary research programs. As for research training programs, since they cannot be separated from research itself, they should be approved by the agency that supports the research. The Science Council therefore recommends that **the National Research Council (NRC) continue to be the major federal source of support for research and research training in university faculties of science.** It should not be the sole source; as will be suggested later, other agencies can properly contribute, but on a smaller scale. Nor should NRC be limited, at the present time, to supporting research within faculties of science. (The current practice, in which NRC supports much research in agricultural schools but little in health professional schools, is not particularly logical; but it deserves to be continued pending the establishment of an Agricultural Research Coordinating Council, which the Science Council has suggested in an earlier report.[1])

NRC also does biological research in its own laboratories. Its Applied Biology Division, in which basic research tended to predominate, was superseded by separate Divisions of Biosciences and Radiation Biology; they in turn, with the incorporation of some physical and chemical research programs, were replaced in 1968 by a Biology Division and a Biochemistry Laboratory. In spite of the name changes, the shift of emphasis in these Ottawa laboratories has been clearly in the applied direction. The Atlantic Regional Laboratory in Halifax and the Prairie Regional Laboratory in Saskatoon have always been concerned largely with biological research, most of it oriented toward application. Research training in the NRC laboratories has been mainly at the post-doctoral level.

[1] Science Council of Canada, Report No. 12. *Two Blades of Grass: The Challenge Facing Agriculture.* Information Canada, Ottawa, March 1971.

It is fair to say that most of NRC's intramural life-science programs have been in fields of science that have not been cultivated by other federal agencies. It is also fair to say that in recent years NRC's in-house biology has been in fields that have not been much cultivated at Canadian universities. That may have come about partly because much of the NRC research had an applied flavour; but no doubt another reason was that the NRC teams were strong, and maintained research at a level that discouraged rivalry on the part of academic investigators with less ample resources.

In addition to its extramural and intramural research programs, NRC engages in several other activities of importance to biology in Canada. These include its informal services centred on the National Science Library, its sponsorship of research journals, a Computation Centre and an office for International Relations. It will be convenient to discuss these programs and activities in that order, after some preliminary comments on NRC's administrative structure as it relates to biology. This structure can be expected to change in the near future as a result of initiatives within the Federal Government and within NRC itself.

Biology and NRC Administrative Structures

Biology appears to be under-represented at the governing levels of NRC. Only two of the Council's 18 members–one academic biologist, and the President of MRC as an Associate Member–and none of its six top executive officers have backgrounds in life science. In contrast, about 23 per cent of the total NRC awards go to biologists. The Science Council realizes that many considerations enter into the choice of NRC Council members and executives, and makes no formal recommendation on this point, but does suggest that an increased representation of the life sciences would be of value to NRC in the near future, in view of the great and growing social importance of these sciences.

The extramural support program in biology is supervised by four Grants Selection Committees–Animal Biology, Cellular Biology and Genetics, Plant Biology, Population Biology–each of which has six or seven academic biologists, including its Chairman. The subdivision of biological research into these four sectors is a natural one. Each sector seems, however, to be rather too broad to permit a committee of only six or seven members to exercise a scrutiny sharp enough to clearly distinguish the best proposals from those that are merely good. Perhaps there should be more, or larger, committees. The operating procedures that the committees are expected to adopt could also be improved, in the Science Council's opinion; this point will be discussed later.

When they drafted their report in 1970, Larkin and Stephen proposed the establishment of a "parent committee" for biology, perhaps comprising the chairmen of the above grants committees and the biologists on Council, whose role would be to coordinate the work of the four committees. The Science Council agrees that such a supervisory committee is needed, but with broader membership and terms of reference;

it therefore welcomes the recent (February 1971) decision of NRC to establish an *Advisory Committee on Biology*, whose composition and duties are outlined in the document printed here as Appendix B. It is useful that some of the members will be from other federal agencies concerned with biological problems and some from industry, and it is especially timely that the biological societies will be strongly represented. If the Advisory Committee is to comply fully with its directives, its members will have to work hard, and they will need substantial staff support. Some of the more important questions the Advisory Committee has been asked to consider are: the evaluation of NRC's existing extramural and intramural research programs in the life sciences; the choice of priorities and the level of support for new and continuing programs in biology; mechanisms for liaison in this field between NRC, other branches of government, universities and industry; and the regulation of scientific manpower through training program in relation to forecast needs.

The Advisory Committee is to be appointed by NRC, and clearly it is to NRC that its advice must be directed. Its advice should be all the better because people from other federal agencies, with first-hand knowledge of those agencies' problems and plans, will help to formulate it. Conversely, the representatives of the other agencies will get important information to take home; and equally, these agencies should have their own advisory groups with cross-representation from NRC. Such advisory committees should be able to review current programs and needs, identify Canadian priorities, and suggest new lines of attack; there should be no excessive duplication of interests among the groups advising the different agencies.

Bioscience research is of direct concern to the Department of Agriculture, the Department of National Health and Welfare and Environment Canada, and, on a more limited basis, to the Department of National Defence and Atomic Energy of Canada Limited, as well as to NRC and MRC. These agencies have established fairly satisfactory mutual guidelines for dealing with research proposals from the universities, but their long-term planning is carried out independently. One consequence of this, perhaps a minor one, is that they have developed different philosophies and practices for supporting research in the universities. What is more important is the need for some integration of the whole national effort in life science research, to identify gaps and unnecessary overlaps in their research programs, with due attention also to the roles of the provincial governments, of industries and of other non-governmental organizations.

It is therefore most desirable that there should be an overview, on a continuing basis, of federal activities in the life sciences, undertaken by a part of government that has no operational responsibility for any of those activities. But an overview should be as comprehensive as possible, with professional staff work to support it, and, without becoming involved in the details of particular programs, it should examine all the major aspects of the country's effort in the life sciences. Included in the overview would be the overall scale of the effort; the priorities, including the balance between basic and applied research; the distribution of the

effort among government, academic and industrial sectors, and between government agencies; and the general policies for management at the federal level. Out of such an examination, it can be hoped, the role for basic biological research would clearly emerge and be defined in relation to national and global needs. Such overviews might be completed at intervals of, say, five years, and would provide NRC and other agencies with a basis for long-term planning. During the intervals there might be similar overviews in other areas of science and technology, in addition to studies more specifically concerned with the performance of R & D in the various sectors and regions, and with broad problem areas. While it is not the Science Council's responsibility to prescribe structures or procedures in this context, it is reasonable to suppose that the Minister of State for Science and Technology will be concerned with the coordination of the federal scientific effort on a long-term basis, and that he will not exclude the life sciences from his attention.

The Science Council therefore recommends that **the NRC Advisory Committee on Biology be especially concerned with the direction, scale and management of the intramural and extramural research programs of NRC in the life sciences, on a continuing basis; and that there should also be a quinquennial review, at a higher level, of all federal activities in the life sciences.**

Extramural Programs

The Science Council wishes to commend NRC for its support of the life sciences during a period when there were strong competing claims; for minimizing bureaucracy in the handling of grant and scholarship applications; and for selecting the right sort of people to sit on its grants selection committees. The granting system has on the whole improved in recent years, and further improvements may be expected, especially when the new Advisory Committee on Biology begins to make its influence felt. It is hardly the Science Council's prerogative to tell the Committee what advice it should give. Nevertheless the Science Council's own studies on the present NRC granting machinery suggest some points that the Committee might be urged to consider. In the Science Council's view, a noteworthy fraction of the Canadian research effort in biology is aggressive, imaginative and successful. But much of the effort is too fragmented, too pedestrian or too inadequately supported for it to make a satisfactory contribution toward meeting global and Canadian needs for biological knowledge. The shortcomings of Canadian biological research are not entirely the fault of the researchers; the research community could do a better job if it were given better guidelines.

In this context, there are some interesting differences between NRC and MRC granting practices. MRC grants committees always obtain confidential advice from external referees (usually two for each application), to which committee members add their own assessments before the committee arrives at a recommendation. NRC grants committees for biology seldom obtain such outside help in dealing with the 200 or more requests each committee receives. It does seem that the expertise of

committee members in such a situation is too thinly spread, and that, as a result, committees may dispense some random justice. It may be partly for this reason that NRC's proportion of rejection has been much lower than MRC's. It seems probable also that, within the category of worthy requests, MRC procedures facilitate the identification of individuals of superior merit. In recent years, both agencies have found it desirable to move toward three-year grants for investigators of proven merit, and to provide block support for promising research teams. The Science Council welcomes this trend, which indeed is almost a prerequisite for an effective attack on many applied and on some basic research problems.

The Science Council therefore recommends that **NRC, with the assistance of its Advisory Committee on Biology, give serious consideration to the best means of developing its granting policies along present lines, including such possibilities as:**

a) a more rigorous attempt, including the regular use of referees, to assess the research ability of each applicant, in order to secure more adequate funding of the best applicants at the expense of those now funded at a sub-critical level;

b) greater availability of long-term support (3 to 5 years) for applicants of established productivity; and

c) increased use of negotiated grants for research teams, either building on existing strength or starting new ventures.

A more searching evaluation of requests would no doubt eliminate some of the weaker investigators from the list of grantees. It has been urged, with some reason, that this would discourage them and make them poorer teachers. However, for those investigators who deserve support mainly to make them better teachers, modest assistance might come from their universities or provinces, if local assessors so recommend; the cost should be charged to education rather than research. There are also investigators whose potential worth is hard to assess at the level of a national committee, because they have not troubled to practice the arts of grantsmanship, or because they are just beginning to do independent research.

It is fashionable to say that as much research as possible should be conducted in "centres of excellence", where a number of able researchers can stimulate one another to high achievement while providing useful opportunities for employing less able people and training promising young scientists. The theory is good, and in practice it sometimes works. In judging whether this will be so in a particular case, NRC must consider personalities and the local setting, as well as the proposed program. Other things being equal, such a consolidation of research efforts in a single centre is more likely to be productive when applied, rather than basic, research is in question.

The broad responsibility of NRC for the health of Canadian basic science requires it to operate under special rules. Adjudicators acting for mission-oriented granting agencies have a different set of rules, which include giving special attention to the relevance of the proposal.[2]

[2] Further discussion of the criteria for evaluating basic research can be found in Science Council of Canada Report No. 18, *Policy Objectives for Basic Research in Canada*. Information Canada, Ottawa (In Press).

When they assess applications, the regular grants committees of NRC ought to consider the scientific importance of the proposed research problem and the researcher's probable success in attacking it. As to how far the research may be basic or applied, or curiosity-motivated or mission-oriented, that is not the affair of the regular NRC grants committees, who should judge on scientific merit alone. But NRC, besides its responsibility for supporting basic research, should also have the responsibility for identifying new missions that are important to Canada but are clearly outside the scope of existing missions. When this happens, NRC funds to support mission-oriented research should be placed in a separate category and handled in the same way as the research funds of other mission-oriented agencies, whether intramural or extramural research is concerned. It is entirely proper that the "administratively uncommitted" biologists in university science faculties should then be invited to commit themselves, on a short- or long-term basis, to the interests of the new mission.

In recent years, as has already been mentioned, NRC's in-house research has become oriented to a number of applied research themes, such as radiobiology, culturing of plant cells from crop species, and environmental pollution by insecticides. Unless these activities are transferred to a different agency, NRC, after consulting its Advisory Committee on Biology, might wish to share them with academic investigators on either a grant or a contract basis. In summary, the Science Council recommends that **NRC, in suitable circumstances, be alert to the opportunity of involving biologists in university science departments in applied research related to its own in-house biological research missions.** ("Applied research" in this case may well include the basic research needed for tackling specific applied problems. A recent example has been NRC's support of the Canadian contribution to the International Biological Program (see page 44), which was concerned with obtaining baseline information about biological productivity in a great variety of ecosystems by the use of internationally compatible methods, in order to permit the assessment of the effects of subsequent natural changes or human intervention.)

In its role of helping to mobilize Canadian scientific and technological manpower in support of Canadian needs, whether economic or social, NRC might help to break down the barriers, still nearly impermeable, that separate the researchers in the different sectors of life science research–academic, governmental and industrial. No other agency seems so well suited to this assignment. The Science Council therefore recommends that **NRC, through its Advisory Committee, be asked to advise federal departments, universities and industry regarding the most effective ways of facilitating liaison and mobility of personnel among these sectors.**

Flexibility is important in other contexts too. One is that academic scientists should often be allowed, or sometimes urged, to re-charge their scientific batteries through visits, of shorter or longer duration, to other centres to acquire new techniques that will enable them to redirect their research toward more productive themes. It has been

suggested earlier that the traditional sabbatical leave of one-year-in-seven is too infrequent and too long for most investigators, and that more frequent, shorter visits are preferable. NRC, through its grants committees, should be generous in supporting well-thought-out proposals for such visits (and should sometimes take the initiative in proposing them); it should also show reasonable patience when, as a result of his absence, the investigator takes up a new line of research.

In relation to training programs, the risk that these may be too narrowly based–at both Ph.D. and postdoctoral levels–is a real one. There is a further risk that too many candidates for graduate degrees may have little experience outside the biosciences. The Science Council therefore recommends that **NRC, in consultation with its Advisory Committee on Biology, advise the universities about developing training programs, pre- and post-doctoral, that might increase the flexibility and cross-disciplinary expertise of Canadian biologists. In this context, particular attention should be given to the desirability of ensuring that a proportion of trainees has adequate experience in mathematics and the physical sciences or engineering.**

The Science Council does not believe that all sub-disciplines of biology in Canada need be cultivated with equal vigour; nor should all decisions about emphasis be left entirely to the collective judgement of the investigators. The Science Council recommends that **the National Research Council, with the aid of its Advisory Committee on Biology, determine the areas of biological research that deserve its special attention because of their relevance to Canadian needs, and, when necessary, encourage the growth of research in these fields through preferential granting and training policies.** The Science Council does not feel that it should try to specify these fields itself, though it has little doubt that ecological and other studies related to the present-seen problems of our environment will be among them. Fortunately, we have strength in some of these areas; we should become strong in others. It may not be necessary for Canadians to catch up completely in every field of biology in which our productivity is below average, even if the fields are scientifically exciting and currently popular; our national needs should determine the emphasis.

Intramural Programs

Along with the other NRC laboratories, the four NRC divisions whose work is largely biological report to the President and Council of NRC through a Board of Directors chaired by the Vice-President (Laboratories); and in common with all NRC activities, their progress and plans are reviewed by a Program Planning and Analysis Group under the Délégué-Général. These administrative arrangements, which date only from 1968, seem to be rational and effective and, as has already been noted, they have led to a reorganization of the biological research efforts in the Ottawa laboratories. But as yet, though there has been a good deal of in-house reassessment of priorities, it does not appear that NRC has produced any comprehensive statement regarding the

scale, directions and priorities appropriate for its own biological research. Indeed, it would hardly be feasible to produce such a statement at the present time, when many federal activities in applied biology have just been transferred to a new department, Environment Canada. Meanwhile, it can be expected that the equally new NRC Advisory Committee on Biology will soon have some useful advice to offer about intramural as well as extramural research activities.

In spite of these uncertainties, some general comments can be made about the current status and directions of NRC's in-house biology: it is very diverse, ranging from the chemistry of natural products to ecology; it is of high quality, with some tendency to conscious elitism on the part of its people; its instrumentation and supporting technical services are very good; its scientists tend to work in small groups rather than as individuals; there is a great deal of basic research, with many projects that could equally well be pursued in academic laboratories, but under present administration there is a clear tendency to choose projects that stress the interdisciplinary approach, especially those that have social significance or technological promise. There are few obvious areas of overlap with existing programs in the federal resource departments, although some joint projects with those departments can be identified, especially in the case of the Prairie Regional Laboratory (PRL). Direct collaboration with industry and (except again for PRL) with the universities is less conspicuous, and there has been relatively little exchange of career biologists between NRC and the universities or industry. NRC scientists on study leave are likely to go abroad. The Science Council recognizes the full participation of NRC life scientists in the affairs of the national scientific societies and journals, but would be pleased to learn of plans for increasing research collaboration and movement of personnel between academic and NRC biology.

NRC foresees a major role for its biologists in the national attack on problems of the environment, and is receiving their cooperation. The Science Council thinks this a proper enterprise for NRC, and welcomes the participation of its biological group in the work of the Associate Committee on Environmental Quality, recently formed by NRC. The Science Council has already, in several reports, expressed its views on various aspects of the environmental situation, and intends a further publication on this topic. It can be expected that useful interfaces can be established in this area between NRC and other government departments, at least on a short-term basis.

One interface that has already been established typifies the kind of role that NRC biology may increasingly be expected to play. This is the collaboration between the Prairie Regional Laboratory, the Canada Department of Agriculture and the University of Saskatchewan in the development of plant-cell fusion techniques for the production of new strains (and even species) of crop plants. Other examples could be cited.

In the opinion of the Science Council, the biological laboratories of NRC can best contribute to the national effort in science and techno-

logy by continuing to develop their interests along the lines that now seem to be apparent. They should be project- rather than discipline-oriented, and they should increasingly apply the interdisciplinary team approach to the solution of problems that appear to be ripe for vigorous attack, but are not yet within the missions of other federal departments. Certain limited missions, such as applied radiation biology and the supervision of biological inventory studies in collaboration with the National Museums, might be permanently centred in NRC. But in general, the NRC biologists should have no permanent administrative commitment. Their mission should be, rather, to identify and attack–often on a relatively short-term basis–important problems which are unlikely to be effectively tackled elsewhere. As such problems are likely to grow in number and importance, further growth of NRC biology will no doubt be justified. Though most of the research should be applied, a higher proportion of basic research will be appropriate than would be normal for a government department with an identified long-term mission; otherwise the organization will lose in flexibility. It would be expected, therefore, that the ratio of basic to applied research at NRC would be higher than in other federal agencies, but lower than in the universities, which would do most of the country's basic research. Such basic research as is done within NRC will properly be oriented to a great degree toward existing or future programs of applied research, subject to the proviso already stated that a researcher of the highest calibre should be given great latitute in the choice of his research problems. The Science Council thus recommends that **the intramural biological research of NRC continue to develop along present lines, emphasizing interdisciplinary applied research in aid of fresh missions, and that NRC encourage increased collaboration among its biologists and those in other government agencies, the universities and industry.**

Information Services

These are centred on the National Science Library (NSL), whose key role in the dissemination of information to Canadian scientists and technologists was underlined more than two years ago in Science Council Report No. 6.[3] The recommendations of that report have been partly implemented and need not be repeated here. In the meantime, NSL has extended existing services and implemented new ones; in particular, it has set up information-retrieval facilities available to individual researchers, and has made progress toward nation-wide integration of scientific and technical library resources. Progress to date makes it reasonable to expect that, after the NSL moves into new quarters in 1973, it will provide Canada with information storage and retrieval systems equal to the best in any country. Meanwhile, in spite of NRC's substantial effort at publicizing these services, their life-science components are not fully used by scientists outside Ottawa. The Science Council recommends that **NRC, in collaboration with university libraries,**

[3] Science Council of Canada Report No. 6, *A Policy for Scientific and Technical Information Dissemination.* Queen's Printer, Ottawa, 1969.

make further efforts to maximize the usefulness to university biologists of the National Science Library's resources.

NRC Journals of Research

Ten Canadian Journals of Research are published under the guidance of a Standing Committee of NRC. Six of these–the Canadian Journals of Biochemistry, Botany, Microbiology, Physiology and Pharmacology, Zoology (all monthly), and the Canadian Journal of Forest Research (quarterly)–are of interest to biologists. The Journals are well produced, and their standards, set by editorial boards composed mainly of academic biologists, are generally high; their world circulation, heavily subsidized by NRC, is adequate. Their relations with the corresponding biological societies, though somewhat informal, are reasonably close; they could with advantage be closer still. However, in spite of their merits, they have not been fully supported by the Canadian biological community, many of whose members prefer to submit their papers to more specialized journals, or to "prestige" journals abroad. It would be good for the Canadian biological community if most of its best wares could be displayed in the shop-windows of its national journals and thus be clearly identified with Canada. Progress in this direction, though steady, is somewhat slow; the initiative rests with individual biologists, and it is hard to see what further assistance NRC could give, or how any other organization could do as well. Some active fields, for example, entomology, have journals that might also be included in the NRC enterprise. The Science Council can only recommend that **NRC continue, and if possible strengthen, its support of Canadian biological journals.**

Other Activities

The Computation Centre in Ottawa is now concerned mainly with intramural support, but it may in future have wider responsibilities. In general, it is appropriate for the computation needs of university biologists to be supplied from local resources and paid for from grants to institutions or individuals. However, though little demand is now identifiable, it might in future be useful to biologists, especially those in the smaller centres, to be able to get specialized programs and computational aid from a national centre.

The Office of International Relations discharges a number of functions that are useful to Canadian biologists. It makes arrangements for exchanges of visits and information, subsidizes Canadian adherence to international scientific unions, and is concerned with Canadian participation in joint scientific programs such as those sponsored by the International Council of Scientific Unions. Among the latter, the International Biological Program (IBP) has been of special concern to biologists. Conceived about ten years ago, at a time when the importance of such studies was not widely recognized, IBP aimed to provide baseline studies of biological productivity over a wide range of the world's ecosystems, using uniform methodology, to provide a basis for maxi-

mizing their useful harvest. Its progress in some areas has been rather erratic, but it will certainly repay the money and effort put into it. The Canadian contribution to IBP consisted mainly of a number of projects involving typical Canadian ecosystems, supported over a five-year period by NRC after critical scientific evaluation as being likely to provide information of value to Canada. The IBP is due to end in 1972, but successor programs are under discussion. While these successor programs should be examined sympathetically and critically, it should be stressed that follow-up efforts do not always match the quality of the original programs. Programs tend to have a finite life and should not be automatically extended.

The Role of Other Federal Agencies

University biologists supported by the National Research Council in 1968-69 received from other granting agencies about 45 per cent as much money as they did from NRC. To some extent, this percentage represents the presence in the NRC grant tabulations of biologists in faculties of agriculture, veterinary science and forestry, who are eligible for support from the federal departments responsible for applying those sciences; investigators in science faculties have received little support from the Canada Department of Agriculture or from the Forestry Branch of the Department of the Environment. The Fisheries Research Board, the Defence Research Board, the Canadian Wildlife Service and some others, as well as a number of provincial agencies and a few private foundations, do make grants to science faculty biologists, as does the Medical Research Council (though only when the relevance of the proposal to medicine is clearly demonstrated). Between 2 and 3 per cent of NRC grants in biology go to workers in medical or dental faculties.

The picture is fairly satisfactory, but has some imperfections. It is proper that biologists in science faculties should be encouraged by federal mission-oriented departments[1] to do applied research, and even basic research, that is related to their missions. The Science Council indeed believes, and again recommends, that **mission-oriented federal departments limit their own basic biological research to what is needed for effective prosecution of their applied research.** When such a department recognizes an immediate need for more basic research in a field important to it, and when the research is likely to be done well in a Canadian university, the department should be ready to support the research by grants or even by contracts. But basic research that is of only long-term relevance to a department's mission is best left for NRC (or MRC) to underwrite. The recommendation, in short, is that **direct external support of basic research by mission-oriented federal departments be limited to research that is clearly relevant to immediate Canadian needs.**

It is natural that mission-oriented departments, in making grants to university biologists, should show some preference for those working in the mission-oriented faculties. In doing so they are dealing with the scientists they know best; they are also giving general support to the disciplines essential to them, and helping to train young investigators who may soon be useful to them. But it can easily happen that the best people to do the research are in science faculties, and when that is the case departmental polcies should not be so rigid as to prevent these biologists from making their contributions. It is recommended therefore that **mission-oriented departments, in selecting university biologists for grant support, be guided mainly by the relevance of the research to their mission, rather than by its relevance to activities of the faculty where the research is done.**

[1] This somewhat clumsy phrase, as used here and elsewhere in this report. is meant to include all the federal agencies that support extramural or intramural research, except NRC, MRC, and Canada Council.

The Science Council has already made clear its view that government departments with in-house research programs should have those programs critically reviewed from time to time by outside experts, who should consider whether it would be wise for some of the work to be contracted out to universities or industry. These reviewers could often call attention to sources of relevant advice in these sectors. In making these comments, as in earlier reports that dealt with similar problems, the Science Council does not wish to imply that the administrators of research in government missions have been misguided or inefficient in their relations with university scientists. These relations have generally been cordial and good for both sectors and for Canada, but there is room for improvement.

There is also room for improvement in relations among the several federal agencies that support life-science research. Better channels of communication would help in defining areas of responsibility, in assigning priorities, and in promoting collaboration. This report has already noted the need for more clearly marked boundaries (though with collaboration across them) between NRC and other federal agencies. This is a requirement that will have to be spelled out in detail when Environment Canada adds new responsibilities to its inherited ones in fisheries, forestry, wildlife, water and meteorology.

This report has made frequent reference to Canada's "neglected inventory studies". The neglect is real but by no means universal; in some areas–for example, vertebrates–studies in systematics and natural history are quite adequate. The deficiencies relate especially to organisms of small size or difficult taxonomy. Studies of these small or difficult biota have been supervised by a variety of agencies, and not always well managed; the same may be said of the identification services, which are vital for many population and productivity studies, as well as for the practical agronomist or forester. Especially now that some of the traditional activities are being given reduced priority by their sponsoring departments, the time seems ripe for developing a concerted policy at the federal level with respect to systematics and natural history research, including such related fields as descriptive ecology, biogeography and palaeontology. Included in this effort should be all the organizational devices needed for classifying and storing information: collections, catalogues, identification manuals, identification services (where well trained technicians could sometimes replace scientists), and computer retrieval systems. To start by consulting all the agencies that might be involved would be to invite failure. In the Science Council's view, the lead toward a national plan for Canadian inventory studies should be taken by NRC and the National Museum in collaboration. Between them, they possess or can obtain most of the necessary expertise for the study; they might also find that between them, and with appropriate use of grants and contracts, they could supervise most of the work. They should be asked to make recommendations, not only about the appropriate organizational machinery, but also about the appropriate pace for inventory studies in relation to probable needs.

In this context, as has already been suggested (page 29), they might propose accelerating the pace during any periods of temporary overproduction of biologists. It will be obvious that the suggested study could not be successful without the cooperation of other federal agencies, the provincial governments and to some extent the universities.

It is therefore recommended that **NRC and the National Museum jointly examine the status of Canadian biological inventory studies, with a view to proposing the administrative arrangements, and the direction and scale of activities, which are appropriate for present and foreseen Canadian needs.** In this connection, the Science Council has noted that the Secretary of State and his Board of Trustees for the National Museums control a remarkable variety of activities, some of which have a strong flavour of science, not to mention of biology. While these diverse cultures seem at present to be at peace with one another, this might not always be the case; in particular, it does not seem desirable that the scientific and the display activities of the museums should compete for the same budget. It is recommended that **any scientific activities assigned to the National Museums be budgeted separately from the Museums' other activities.**

It is already clear that the Minister of State for Science and Technology will be directly concerned with planning at the federal level for the scientific activities of departments and agencies concerned with biological research. In a sense, therefore, the foregoing recommendations are directed to the Federal Government and its agencies through him.

The Role of the Provincial Governments

The Provincial Governments support biological research mainly through their support of the universities where so much of it is done, but also, to some extent, through provincial research councils and through work under the auspices of their resource departments and museums. The provincial research councils, besides helping to create a climate favourable to research, occasionally ask university biologists to help them with their problems in applied biology, a field in which they do more work than is commonly realized.[1] Similar requests are occasionally made by resource or other departments, usually for advice on a contract basis. Such involvement of university biologists in practical local affairs is to be welcomed, should become more common, and is unlikely to be excessive. In the provincial, as in the federal, sphere governments should, as far as possible, use university and industrial facilities in preference to building up their own research facilities.

Some provinces are beginning to support university research on a more continuous basis, and this also is desirable within limits, especially (in the case of biology) where this permits an attack on local problems of an applied nature that would otherwise be neglected. It is, however, to be hoped that provincial support of research would be complementary to, rather than competitive with, federal support. Few provinces have the resources to assemble good teams for assessing grant proposals, but a province can properly support its post-secondary education programs in biology through institutional grants, scholarships, student summer employment and "start-up" grants for young professors.

(It is a familiar–some would say notorious–fact that university research involves indirect costs as well as direct costs, and that the indirect costs are in general charged to the provinces through their education budgets. The main items under this heading are, of course, the salaries of teacher-researchers, the construction and maintenance of laboratories, and the provision of the necessary libraries and administrative services. On this basis it has been reckoned that when a university attracts federal funds for research, the province pays about a third of the total cost. The Science Council, in an earlier report[2], noted the complexity of the problems arising from this situation, and concluded that no simple solution is feasible; it did, however, indicate some general principles for guiding decisions about the distribution of costs. One of these principles was that, except for certain special cases, the university should remain responsible for the salaries of academics. The Science Council has not changed its view that the major responsibility for governmental funding of basic research at the universities ought to remain with the federal research councils.)

Lastly, the provinces, in serving their own interests by good environmental housekeeping, can incidentally contribute to the health of their biological research. The Science Council recommends, as it

[1] Andrew H. Wilson, *Research Councils in the Provinces: A Canadian Resource*. Science Council of Canada, Special Study No. 19. Information Canada, June 1971.

[2] Science Council of Canada, Report No. 5. *University of Research and the Federal Government*. Queen's Printer, Ottawa, 1969.

has done earlier[3], that **there be close cooperation between federal and provincial authorities in the promotion of wildlife and ecological research, as well as in the planning of university research and training programs in the biosciences.**

[3] Science Council of Canada, Report No. 9, *This Land is Their Land*. Queen's Printer, Ottawa, 1970.

The Role of the Universities

Most of what the Science Council might feel entitled to say, by way of advice to university biology departments and their staff and students, has been said or implied already. The brief but exciting period–when basic research and training activities in the life sciences were accelerating, in response to bulging student enrolment, a booming economy and unprecedented hopes about what science can do for the world–is over for the time being. Most of the academic jobs have been filled, and new ones are being created more slowly; the young biologists who have just emerged from the training pipeline will have fewer chances to reproduce their kind; the Ph.D. cycle will slow down. From the same quarters where, a decade ago, the call was for more science, and the more basic the better, there now comes the cry for more relevance in science. The change of tune has been somewhat disconcerting, but both tunes have been in harmony with their times, and biologists will learn to sing to one as they did to the other. What has not changed is the need for biological knowledge, and demand is bound to follow need unless catastrophe occurs.

Translated into research and training policies, the new demand will mean–indeed has already meant–some shift of emphasis in university bioscience departments. More of the new crop of biologists will have to find jobs in applied biology, and jobs outside the university. Though ecology will be a basic science rather than an advanced specialty, much more than ecological expertise will be in demand. Environmental problems will have to be attacked at every level of biological organization, right down to the molecular one. There will be new challenges in such fields as food production, population control, genetic engineering, transplantation, artificial cells and organs, experimental gerontology and tissue regeneration, enzyme and antibody syntheses, and solar energy capture, in addition to many straight-line developments in the sciences of health and renewable resources. The distinction between basic and applied science will become more blurred, and the lag between discovery and application shorter. These developments will not all wait for the 21st century. They have already begun, and the universities should plan accordingly.

No one set of plans could be appropriate for every situation, but it seems likely that opportunities will generally be greater where several researchers share a common theme than where each is an isolated specialist. With the growth of applied and interdisciplinary research, the advantages of teamwork will become more apparent; this should mean the interplay of equals more often than domination by one powerful figure. In every field, however, the ablest–say the ablest tenth, for great ability is not as rare as some seem to think–should have full support, within reason, for whatever they wish to do. Study leaves, normally shorter and more frequent than sabbatical years, should be urged upon all who remain in research, but research itself should not be forced on anyone who prefers teaching, writing or administration, and can do such work well. University and government scientists should collaborate, and the free flow of scientists between university, government and industry should be encouraged. As has

been suggested earlier, university scientists should be ready to serve on the advisory boards of government agencies, as well as on grants and other committees and on the editorial boards of scientific journals. Some scientists at least should feel a responsibility for informing the wider public about the achievements and needs of the bioscience enterprise.

On the teaching and training side, consideration should be given to the fusing of small biological departments, or at least of their undergraduate programs; to recruiting research trainees with unconventional backgrounds, including those with special qualifications in physical science and mathematics; to designing programs that will produce good biology teachers for all levels, from primary to post-secondary; and to encouraging all programs that appear likely to increase the trainees' flexibility and interdisciplinary expertise. There is unlikely to be a shortage of able trainees; as the data in Appendix A show, recent tendencies of undergraduates to favour the social over the experimental sciences have not affected recruitment for biology, which has gone up in both Canada and the U.S.A.

Summarizing these somewhat nebulous observations, it may be recommended that **university biologists and biology departments be ready to consider remoulding their research and training programs in ways that would permit increased flexibility and ability to cross disciplinary boundaries; for example, by having post-doctoral training in a field quite different from that of the thesis, by increased concentration of research personnel into teams and groups capable of forming centres of excellence, and by increased attention to applied research, especially on problems of relevance to Canada, while retaining broad opportunities for effective basic research.** It is further recommended that **university biologists be as fully acquainted as possible with the problems of biological research and technology in government and industry, through collaboration and visits between sectors, through service on advisory boards for government departments, and through other joint enterprises. Students who are thinking of entering careers in biological research and graduate students in biology should consider, in planning their training and post-Ph.D. experience, that applied research in biology is likely to grow more quickly than basic research, and, at least as a possibility, that team research may give them more rewarding opportunities than strictly individual research.**

The Role of Industry

There is not much to be said under this heading because, hitherto, Canadian industry has recruited few biologists and has had little interest in academic biological research. The food processing industry, the pharmaceutical industry and a few others have been exceptions, but only on a modest scale. There can be little doubt that this situation is changing, and that the change will accelerate. Besides the urgent need for industry to know what it is doing or might do to the environment, there is the prospect of new industrial efforts to be spun off from applied biological research in a variety of fields, ranging from enzyme technology to biological pest control. Much of this applied research will be done in academic and government laboratories, and some of it will be done in Canada; however, at present, prospects for successful Canadian innovation in these areas are rather poor because of limited industrial interest in this sort of bio-technology, and because of all the other problems that currently limit the innovation capacity of our secondary industries.[1] It may be recommended that **the NRC Advisory Committee on Biology, which is to include members from industry, investigate the possibility of increased collaboration between NRC and academic biologist and Canadian industry.**

[1] Science Council of Canada, Report No. 15. *Innovation in a Cold Climate: The Dilemma of Canadian Manufacturing.* Information Canada, Ottawa, October 1971.

The Role of the Scientific Societies

This report, like other Science Council documents, has reiterated the theme that Canadian scientists should not merely respond to government initiatives in determining the scale, direction and management of the country's scientific effort, but should actively participate in creating those initiatives. The matter was first raised formally in an "Open Letter to Physicists from the Chairman of the Science Council of Canada".[1] In that letter, Dr. Solandt made the suggestion, among other points, that while an organization at the Science Council level should be able to give useful advice as to the relative importance of different areas of science, it can do so best after hearing the case for each discipline put forward by its ablest representatives. Within each discipline, on the other hand, the guidelines and priorities should be set by the scientists themselves, working through the appropriate scientific society. Dr. Solandt made a number of further suggestions about decisions to which the scientists ought to contribute–on such subjects as how to match manpower supply and demand, and the desirable institutional relationships among academic, government and industrial sectors. He noted that such contributions by scientists were most appropriate in the field of basic science, "where the system involving the scientists and their funding agencies should be, as nearly as possible, self-governing", and added: "The organizations that normally support research in physics should also, where necessary, finance the general studies that are needed to back up these proposals".[2]

This still seems to the Science Council to be good advice, and as applicable to biologists as to physicists. In the case of biology, the appropriate society groups would be the Biological Council of Canada (BCC) and the Canadian Federation of Biological Societies (CFBS), which have overlapping memberships but which, between them, include most of the biologists in university science departments and at NRC, as well as many others elsewhere. The principal granting agency for the science-faculty biologists is NRC, and its Advisory Committee on Biology is already intended to include representatives of other granting agencies and of the biological societies. It is therefore within the Science Council's established guidelines to recommend that **BCC and CFBS provide a common forum for the discussion of biological research needs and policies, and that they should be prepared to assist NRC and other federal agencies in arriving at policy decisions on matters related to NRC programs in biology, including the assignment of priorities in research and training.**

The funding of research by NRC, as by other agencies in Canada and abroad, has reached a rather steady level, at present not even growing apace with inflation or with the number of well-trained applicants. The proportion of funds allotted to the basic biology group of grantees is also nearly stable. This pause in research funding, though unwelcome to biologists, should not be regarded as wholly bad. It is

[1] O.M. Solandt, "Open Letter to Physicists from the Chairman of the Science Council of Canada". *Physics in Canada,* Volume 26, No. 7, November 1970. pp. 130-135.

[2] *Ibid.*

time for some aspirations to be modified and for some directions to be changed. Giving advice to American biologists, whose current situation is similar, the remarkable volume *The Life Sciences* says:

"The present pause in research funding should be utilized as an opportunity for planning a complete system of support for the future, which should not be a haphazard patchwork but an orderly continuum".[3]

This seems to be good advice for Canadian biologists also. It might be guessed that the time they will need for this sort of study and planning, both within their own societies and in concert with NRC and others, would be about three years. During the first part of that period, the main results of the federal government's re-examination of priorities for science and technology should have become evident, in its identification of the missions that require increased research support and in its allocation of the management of that research to the appropriate agencies. The role of NRC in this context may well be somewhat different from its present role. During the latter part of the period, it may be hoped, the present climate of austerity for research funding will have been ameliorated as the result of a brighter economic outlook. On this basis, it seems acceptable to recommend that **the funds devoted by NRC to the support of biological research increase for three years at an annual rate of from 5 to 10 per cent, to match the effects of inflation and of a possible further increase in university enrolment in the life sciences.**

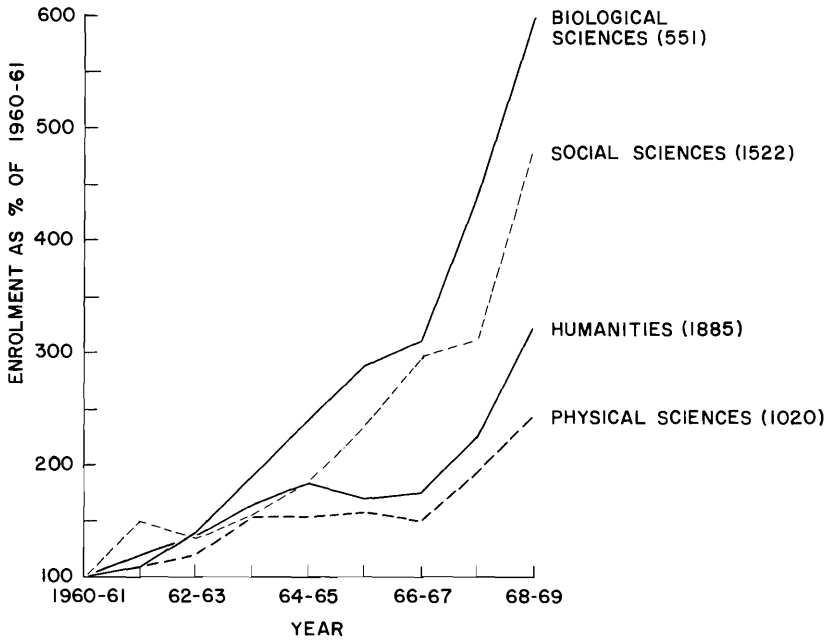
By the end of the three-year period, both the agencies and the biologists, if they have done their work well, should be able to look forward to a longer period during which research funds should again increase at a higher yearly rate than the one just suggested. The increase would then be justified by a clearer identification of Canada's needs for biological knowledge–needs that will certainly be identical, at least in part, with the world's needs, but which will certainly also include the need for solving problems that are especially important for Canada. Without such an identification of Canadian problems and the means of attacking them, the case for increased support of bioscience research will not be convincing. It will thus be necessary, and the Science Council recommends, that **the Canadian biological community, through its societies and in collaboration with NRC and other agencies, begin immediately to participate in identifying Canadian needs and priorities in the area of bioscience research, and in deploying its forces for an early acceleration of the pace of research in that area.**

[3] *The Life Sciences*, National Academy of Sciences, Washington, D.C., 1970. p. 9.

Appendices

Appendix A

Figure A.1–Growth in Enrolment for Honours Bachelor's Degrees, by Field of Study



Notes: In each case, the 1960-61 figures are taken as 100.

Figures in parentheses at the right give the number of 1968-69 graduates in each area of specialization.

Source: "Survey of Higher Education, Part II, 1968-69", Dominion Bureau of Statistics. Queen's Printer, Ottawa, 1969.

Table A.1–Science Graduates in the United States in 1960 and 1969, Bachelor's and First Professionnal Degrees

Field of Study	Number of Graduates		As % of Science Graduates		As % of Total Graduates	
	1960	1969	1960	1969	1960	1969
Total Science	**45 090**	**89 740**			**11.53**	**11.80**
Biological Sciences	15 578	36 940	34.55	41.16	3.98	4.86
Anatomy	122	30	0.27	0.03	0.03	0.00
Bacteriology	533	1 380	1.18	1.54	0.14	0.18
Biochemistry	108	340	0.24	0.38	0.03	0.04
Biology, General	8 345	24 540	18.51	27.35	2.13	3.23
Botany	385	740	0.85	0.82	0.10	0.10
Entomology	108	190	0.24	0.21	0.03	0.02
Physiology	63	140	0.14	0.16	0.02	0.02
Zoology	2 241	5 580	4.97	6.22	0.57	0.73
Biological Sci., Other	3 673	4 000	8.15	4.46	0.94	0.53
Mathematics and Statistics	11 399	28 570	25.28	31.84	2.91	3.76
Physical Sciences	16 007	21 070	35.50	23.48	4.09	2.77
Astronomy	41	130	0.09	0.14	0.01	0.02
Chemistry	7 569	12 000	16.79	13.37	1.93	1.58
Earth Sciences	2 570	1 990	5.70	2.22	0.66	0.26
Meteorology	201	250	0.45	0.28	0.05	0.03
Physics	4 322	5 560	9.59	6.20	1.10	0.73
Physical Sci., Other	1 304	1 130	2.89	1.26	0.33	0.15
Science, General	2 106	3 160	4.67	3.52	0.54	0.31

Source: Educational Division, Dominion Bureau of Statistics *and* Office of Education, U.S. Department of Health, Education and Welfare.

Appendix B

National Research Council of Canada
Advisory Committee on Biology

Terms of Reference

To provide a forum for the synthesis and integration of advice to Council on matters relating to Biology in Canada, and more specifically:

1. To assist Council with the evaluation, promotion and coordination of Biological research in Canada, with particular attention to the research efforts in government laboratories, universities and industry.

2. For Biological programs of national significance–

a) to evaluate these programs in relation to the Canadian Scientific, economic and social scene, and to make recommendations regarding their selection, with particular reference to their order of priority;

b) to assess and recommend where these can be best undertaken and what level of financial and staff support they should receive;

c) to assist Council in the identification and development of proposals for concerted action;

d) to review them periodically with a view to assessing their results, effectiveness, and possible modifications to their priority brought about by changing conditions.

3. To examine mechanisms for encouraging liaison and to promote improved relations between universities, industry and government.

4. To study specific problems at the request of Council.

5. To be empowered to appoint and disband subcommittees for specific purposes.

6. Members from Council to serve for a term coincident with their term on Council; other members to serve for a term of not more than three years, except that initial terms would be 2, 3, 4 years to provide for rotation and continuity.

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Chairman
Members of Council (up to 3)
Member of Medical Research Council
Up to 4 members nominated by the Biological Societies
3 members from the Federal Government Departments and Agencies (one of these from NRC Laboratories)
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Plus 4 other members to balance subject areas and neighbouring disciplines
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