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Agricultural Science in Canada

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"Upon this gifted age, in
its dark hour,
Falls from the sky a
meteoric shower
Of facts . . . they lie un-
questioned, uncombined.
Wisdom enough to leech
us of our ill
Is daily spun; but there
exists no loom
To weave it into fabric."

Edna St. Vincent Millay,
Huntsman, What Quarry?

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Foreword

In mid 1966, at about the time that the Science Council was created, the Science Secretariat contracted with a group of scientists led by Dr. B. N. Smallman of Queen's University to write a report on the state of agricultural science in Canada. The present document is that report, and it is now being published by the Science Council which assumed administrative responsibility for the contract in early 1969. The text was completed September 1, 1969.

The problems facing Canadian agriculture are to be seen in many of today's headlines...overproduction of wheat, dairy subsidies, insufficient earnings in the farm labour force. To put the present report in perspective, the reader should be reminded that the terms of reference given to Dr. Smallman and his colleagues were quite restrictive, and limited them to a study of research. Within this framework the authors have produced a report whose conclusions might seem controversial to some. In publishing this report, the Science Council is in no way seeking to pass judgement at this time, but the Council does believe that the report will serve as a useful starting point for informed debate on some of the options facing agricultural research. The Science Council will be continuing its own discussions on the topic and will make public its own views at a later date.

P. D. McTaggart-Cowan
Executive Director
Science Council of Canada

Preface

In its hundred years of development, agricultural science in Canada has not previously been the subject of a comprehensive study. The Study Group is deeply aware of its responsibility and the associated hazards of presenting a public report recommending major changes in this well-established science with its impressive record of accomplishment in the scientific development of Canada.

Agriculture has been, and continues to be, the most important primary industry in Canada, contributing major economic and social benefits to Canadian society as a whole. Research and development constitutes the key to its continued progress. However, the organization for research, the philosophy of research, and research itself, must reflect the needs of the agricultural community, and utilize all the relevant disciplines in new forms of integration, if agriculture is to meet fully the problems and opportunities of the immediate future.

Within the compass of this report, it is inevitable that the emphasis falls on the deficiencies rather than the virtues of Canadian agricultural research and development. The implicit charge in the assignment of a review such as this is to be critical of the present and constructive for the future. The primary responsibility is to point to deficiencies where they are seen to exist, to make positive suggestions for change, and to add force to evolutionary movements already contemplated or in motion–and to do all this with the emphasis required to challenge the universal resistance to change.

Our report will be widely interpreted as advocating a swing back to an earlier emphasis on applied research. This is true; but the analogy of the pendulum seems to us less appropriate than that of the auger, which as it reverses itself on one plane, advances steadily in the other! We believe we have caught the tenor of the times in anticipating that mission-oriented research will be judged and supported increasingly on the evidence of its usefulness. This emphasis will involve, as it always has, a good deal of plebian fact-finding–but no one should scorn to do what needs doing. The difference–the advance of the auger–will be that these facts will not be left "unquestioned, uncombined" but will be integrated into the sophisticated prognostications now required by the users of agricultural science.

Believing that the impact of a public report is proportional to the inverse of its volume, we have tried to confine ourselves to the broad issues, as we see them. If these can be clearly defined, the details can be fitted into context and seen in clearer perspective. For instance, we have written much about future needs and priorities at the levels of organizational and disciplinary integration, and little at the level of priorities between detailed areas of research, believing that the latter can be rationally resolved only in the context of the former by a management system capable of assessing the whole and making continuous adjustments within it.

Our projections of future needs and priorities for agricultural science deviate from the school of thought which holds that scientists charged with reviewing their own fields should confine themselves to *needs* and leave matters of feasibility to others. We believe this attitude simply invites and perpetuates parochialism. It deprives the policy-makers of the fully responsible advice they need, and makes it easy for them, when expedient, to ignore their scientist advisors. Our projections are therefore based, insofar as we can make them, on our judgement of the realistic claims for agricultural science.

Our central theme is the search for a framework–of working arrangements, organizational structures, and philosophy–to promote dynamic interaction between the constituent disciplines and research agencies in an integrated system for the application of science to agriculture–in short, for the "loom" of Edna St. Vincent Millay.

Acknowledgements

The Study Group wishes to acknowledge first the magnificent response to our survey questionnaires by the national community of agricultural scientists. In the face of the universal abhorrence of yet another questionnaire, Canadian agricultural scientists nevertheless demonstrated their responsible interest by the extraordinarily high return achieved from the survey.

Among the many persons who have assisted us in many ways, we wish to acknowledge particularly Mr. J. J. Comeau, our Secretary, for his skill and devotion in the management of our affairs throughout the study; Dr. A. Macpherson, who effected liaison between the Science Council of Canada and the Study Group at the highest level of responsible judgement, and who contributed also the understanding and knowledge of a renewable resource scientist; Dr. C. E. Chaplin, for his invaluable and extensive contribution to the design of the survey questionnaires and to the tactical planning for the whole complex operation of the survey; Mr. R. Needham, for his effective liaison with the Central Data Processing Service Bureau on programming for data retrieval from the questionnaires; Dr. J. A. Anderson, then Director General of the Canada Department of Agriculture Research Branch, for his generosity in making Dr. Chaplin and Mr. Needham available; Dr. C. G. E. Downing and Dr. K. W. Domier for knowledgeable assistance respectively, with the development of the agricultural engineering questionnaire, and interpretation and advice regarding the engineering component; Dr. K. C. Fisher for his co-operation and good-will in combining our survey for the natural sciences with that of his survey undertaken for the Biological Council of Canada, and the Canadian Federation of Biological Societies, and for his close collaboration with us in the development of this common survey.

Table of Contents

Continued on next page

Summary of Conclusions

The Study Group concludes that:

1. Canada should establish an Agricultural Research Board, with representation from all sectors performing or funding agricultural R & D, to advise and recommend to the federal Minister of Agriculture on the conduct and development of an integrated Canadian program.

The Board would:

a) maintain a small permanent secretariat supplemented as necessary by experts employed or seconded to undertake special studies;

b) function to design and co-ordinate a Canadian policy and program by advice to the Minister on priorities and funding, and through its influence with the performing agencies;

c) exercise substantial powers for managing, through grants and contracts, the orderly development of a balanced program within and between the performing agencies.

Chapter IV, page 52

2. Canada should establish a Renewable Resources Research Council composed of the Chairmen of Research Boards (or bodies equivalent to the Agricultural Research Board) for agriculture, fisheries, forestry, water resources, and wildlife, to effect co-ordination and to exploit opportunities for collaboration in the scientific management of the nation's renewable resources.

Chapter IV, page 53

3. A major readjustment between the disciplinary components of agricultural R & D is urgently required to achieve a substantially greater capability in the management sciences of economics, engineering, and sociology, relative to the current emphasis on the natural sciences; and furthermore, the costs of this readjustment should be met in large part, and over a limited period, by transfers of a proportion of the normal turn-over in the natural sciences, with due regard for the continued viability of this component.

Chapter V, page 61

4. The Federal Government should contract with the provincial governments for the total management of a number of federal research stations and soil survey units, thus to promote increased emphasis on local development work and increased provincial responsibility for managing agricultural R & D in their own interests.

Chapter V, page 61

5. The Federal Government should reduce its responsibilities for the performance of agricultural R & D in favour of increased performance by the provincial and private sectors, and the costs of this readjustment should be met in large part by transfers of normal turn-over, or dollar equivalents, in the natural science component of the federal sector.

Chapter V, page 61

6. The Federal Government should increase its responsibility for the funding and co-ordination of this nationally important activity coincident with reducing its relative role as a performer of agricultural R & D.

Chapter V, page 63

7. The agricultural industries, both primary and secondary, should be supported and should themselves participate as a major force in agricultural R & D at all levels from national policy and decision-making to research, development, and innovation in their own interests, in collaboration and without competition from publicly supported agencies, and the proferred financial interest of commodity groups of producers should be exploited and directed mainly toward management studies in their area of interest; all this, we believe, in the interests of maintaining the relevance of agricultural R & D to modern agriculture and for the benefit of the Canadian economy.

Chapter VI, page 91

8. Interdisciplinary research, particularly the interaction between the natural and management sciences, should be encouraged and supported by educational preparation, by establishment of the interdisciplinary research centres we have proposed elsewhere, and by the use of scientific task forces for specific problem-solving, thus to improve the developmental end of agricultural R & D and to promote the integration of knowledge for the holistic management of agricultural problems.

Chapter VI, page 87

9. The universities should actively seek and promote collaboration with government and industry research establishments in the education of graduate students, thus to maximize the use of manpower and facilities for the production of agricultural scientists and to provide a continuing mechanism for the improvement of communication between agencies.
Chapter VI, page 85

10. Agricultural technical assistance should be recognized as a major means for meeting Canada's responsibilities for international development; should be exempt from current financial constraints in Canadian development assistance policy; and should be implemented through the specified educational and development programs in selected disadvantaged countries, with due regard for the special capabilities and responsibilities of the provincial governments, and the central co-ordination function of the proposed Agricultural Research Board.
Chapter VII, page 97

11. An annual increment, currently estimated at 6 per cent, should be applied to all budgets for agricultural R & D as a matter of necessity to maintain the viability of agricultural scientists and the quality of research programs in the face of the increasing inflation and sophistication costs of research.
Chapter V, page 59

12. Within existing programs high priorities should be given to marketing research throughout the entire food industry from producer to consumer, studies on rural adjustment, systems engineering in livestock production, biomathematics, food research, and plant cell research.
Chapter V, page 63

13. Within new programs, an Agricultural Centre for Bio-economics Research and Development should be established to develop model systems for integrating research in economics and the natural sciences to yield principles of management and advice for optimizing the production and marketing of agricultural products.
Chapter V, page 66

14. A Population Ecology Research Centre should be established to develop principles for applying scientific knowledge to the purposeful management of populations of cultivated plants, domestic animals, and agricultural pests and diseases, by using a broad mix of disciplines and the methods of systems analysis and operations research.
Chapter V, page 69

15. A Research Centre for Rural Adjustment should be established to promote research on the pervasive social factors involved in the technological transformation of agriculture, its repercussions on rural life, and the social adjustments necessary to optimize the benefits for rural people.
Chapter V, page 70

16. An Atlantic Resource Management Centre should be established to develop a capability for the multidisciplinary application of scientific knowledge required to direct the large-scale adjustment and development of Atlantic industries based on renewable resources, including agriculture.
Chapter V, page 71

17. A Research Centre for Cold and Drought Resistance should be established to intensify basic research on the physiology, biochemistry, and genetics of resistance to cold and drought, thus to seek means for extending current efficiencies of crop production in Canada.
Chapter V, page 72

18. A new program of graduate student support in the management sciences should be inaugurated and funded at the levels and with the checks suggested, thus to produce the additional engineers, economists and sociologists required for readjustment within existing programs, and to staff the proposed new programs.
Chapter V, page 74

19. Research on the characteristics of the education, employment, and motivations of agricultural scientists should be undertaken to guide and maximize the diverse talents of individual scientists and to foster fruitful collaboration between them.
Chapter VI, page 79

20. Employers of agricultural scientists should institute appropriate forms of periodic educational leave as a norm of the employment of scientists, thus to protect from obsolescence their most valuable asset.
Chapter VI, page 79

21. Longer probationary periods should be used to evaluate and orient young scientists before tenure is granted; and evidence of research versatility should be included in the criteria for the promotion of agricultural scientists.
Chapter VI, page 80

22. A significant proportion of the budget for governmental agricultural scientist positions should be converted, as vacancies allow, to a new class of position reserved for the employment of scientists on short-term contracts for specific research objectives, thus to counter the tendency towards perennial projects and to provide a means for quickly responding to changing priorities and opportunities.
Chapter VI, page 81

23. Directors of government agricultural research establishments should be assigned full authority for the tactical management of their resources to achieve the broadly defined objectives assigned to their establishments.
Chapter VI, page 82

24. A formal program of temporary transfers of scientists between agencies conducting agricultural research should be initiated to improve active collaboration, to promote interaction and communication, and to counter parochialism.
Chapter VI, page 83

25. The National Advisory Committees for agricultural R & D should be placed under the sponsorship of the proposed Agricultural Research Board.
Chapter IV, page 53

Chapter I

History and Achievements

Agriculture has been a fundamental force in the development of Canada. As in other advanced countries, improvements in the efficiency of agriculture was a key mechanism for the transformation of Canada from a predominantly rural to a prosperous urban society. In this process, agriculture itself became a large and complex industry embracing the production, processing, transportation, and marketing of agricultural products. Moreover, an important reciprocal relation or feedback system developed between the agricultural and industrial sectors of the Canadian economy. With improvements in efficiency, for instance through mechanization, there has been a corresponding increase in the demand for an ever-growing volume and variety of industrial products and services from the producers, processors, and merchants of agricultural products. These industrial and service inputs to agriculture constitute a major benefit to the Canadian economy, now generally recognized as an integral part of the total agricultural enterprise. As a result of this continuous development, agriculture has been historically and remains today the most important primary industry in Canada.

Agricultural research has provided, in turn, the key mechanism for this development of agriculture. The rich potential of Canada's resources of land and water could not have been realized without the imaginative application of scientific knowledge and the development of agricultural technologies appropriate to Canadian conditions. Many intractable problems of unfavourable climate, difficult soil conditions, introduced pests and diseases, and a small population distributed over immense distances required solutions. The variety of agricultural conditions from the Atlantic, through the Prairies, to the Pacific introduced another dimension of challenge for agricultural science; the technologies developed for one region were often quite unsuited to another. For the same reason, solutions to many agricultural problems developed in other countries required scientific effort to adapt them to Canadian conditions. The unsurpassed success of Canadian agriculture in the face of these problems is a direct reflection of the importance and excellence of Canadian agricultural research and development.

The early contributions of research to agriculture in Canada were outstanding because leaders in the field recognized the fundamental needs of the agricultural industry and planned a program of research to meet these needs. Research in the biological and physical sciences was closely associated with the immediate and practical problems of the farmer. When the agricultural colleges were first established, the curriculum was designed to produce "general practitioners" who either returned to the farm or who, in their research and extension activities, were expected to work very closely with the farmer. Therefore, research workers were at all times conscious of the problems associated with the management of the farm business. Some of the first work in farm management in both Canada and the United States was started in agronomy departments of colleges of agriculture.

Gradually, however, agricultural research was characterized by an increasing degree of specialization and complexity. The development of genetics, chemistry, physics, physiology, etc. led to the development of more sophisticated scientific investigation. This, in turn, led to the separation of each discipline, and subdivisions of them into administrative units and corresponding "specialist" departments. This organizational structure permitted tremendous advances to be made in these particular and separate areas of basic research. Concomitantly, this increasing specialization led to less communication between disciplines and between research and the problems of agriculture. Extension departments attempted to bridge the latter gap but the ever-increasing complexity of the total industry has made the task very difficult. An adequate communication system between agricultural science and its ultimate users is still in the formative stages.

In the context of the history of Canadian agricultural research, we believe this report is timely. The agricultural industry is evolving and changing rapidly and the research needed to support the industry must form the basis for wise and relevant change. Organization, administration for research, and research itself must respond to the changing needs of the industry. New concepts, new techniques and new organizational units, involving all disciplines in co-operative research, will be required to meet the needs of a dynamic evolving industry. History indicates that Canadians have met the challenge in the past, and we have no doubt that, given the resources, we will do so in the future.

The British North America Act gave concurrent jurisdiction for agriculture to the provinces and federal government. An examination of the historical role of the federal and provincial governments, universities and of the National Research Council in agricultural research places much of our report in perspective and will provide the historical basis which has influenced some of our conclusions.

Canada Department of Agriculture (CDA)

Development of Legislation

Before Confederation agricultural matters were managed by a Bureau of Agriculture in the Province of Canada under the direct supervision of a Minister. Although conditions were reported as unsatisfactory, this experience provided background for the subsequent development of the present Department of Agriculture under Confederation.

The British North America Act clearly defines the powers of the provincial and federal authorities in the field of agriculture. Section 95 of the Act provides that

"In each Province the Legislature may make Laws in relation to Agriculture in the Province, and to Immigration into the Province; and it is hereby declared that the Parliament of Canada may from Time to Time make Laws in relation to Agriculture in all or any of the Provinces, and to Immigration into all or any of the Provinces; and any Law of the Legislature of a Province relative to Agriculture or to Immigration shall have effect in and for the Province as long and as far only as it is not repugnant to any Act of the Parliament of Canada."

The Act for the organization of the federal Department of Agriculture was passed by Parliament and assented to May 22, 1868. The Act did not specifically mention research, but it was assumed that when Agriculture was designated specifically (Section 5, subsection 1) as a departmental function, it encompassed all activities necessary for its well-being in Canada.

Research programs in the Department of Agriculture were developed in response to the needs of agricultural practice. In 1869, an "Act Respecting Contagious Diseases of Animals" was passed by Parliament. The intent of the Act was to exclude animal diseases from abroad as well as to control and eradicate diseases already existent in Canada. This document continues to be the basis for the research and regulatory actions required for the maintenance of the health of livestock in Canada.

In 1868, Canada acquired a vast area of country, then known as the Northwest Territories and which now comprises Saskatchewan and Alberta and the present Northwest Territories. These territories, along with the other provinces of Canada, opened up large tracts of land for agricultural settlement. The variety of conditions and problems found in this far-flung empire induced Parliament to establish a research organization to serve agriculture. In 1884, a Select Committee of the House of Commons was appointed to recommend on the needs for agricultural improvement.

The initial recommendation was that an experimental farm be established. In 1885, Professor William Saunders was appointed to investigate further. He recommended that experimental farms should be established throughout Canada. In 1886 the House of Commons voted into law "An Act Respecting Experimental Farm Stations" which provided for the establishment of five experimental farms. These were subsequently located at Ottawa (central farm); Nappan, Nova Scotia; Brandon, Manitoba; Indian Head, Saskatchewan; and Agassiz, British Columbia. William Saunders was appointed the first director with James Fletcher, an entomologist, and Dr. Frank T. Shutt, a chemist, as chief assistants. The objectives were

"to carry on experimental and investigational work in connection with livestock breeding, dairying, field husbandry, horticulture, and entomology, in order to discover methods, breeds, and varieties best suited to the different parts of Canada. Information obtained from these experiments was to be published in bulletin form for popular distribution." [1]

These objectives remain the guidelines for research in the federal Department of Agriculture.

The first major expansion in the research facilities of the Department came in the early 1900s as a direct response to the problems created by the large-scale immigration of settlers to the agricultural areas. Fifteen new experimental stations were established between 1905 and 1915. The Tobacco Branch became part of the experimental farms sys-

[1]Canada agriculture: The first hundred years. Queen's Printer, Ottawa, 1967.

tem in 1912. Between 1912 and 1916 plant pathology laboratories were established at St. Catharines, Ontario; Charlottetown, Prince Edward Island; Fredericton, New Brunswick; Brandon, Manitoba; and Indian Head, Saskatchewan. In 1914, the Entomology Branch was created and by 1916 had established nine regional laboratories throughout the country. The Entomology Branch derived its authority from "The Destructive Insect and Pest Act" and had responsibility for the control and eradication of injurious insects and plant diseases, and for preventing their introduction from abroad.

The years between 1919 and 1937 saw only modest expansion in the research activities of the Department. Rather, the program was intensified and developed on a broader scientific base. Investigations in agricultural bacteriology were added in 1923. Forage crop breeding was undertaken in 1931 at a newly created laboratory on the campus of the University of Saskatchewan.

Wheat production on the prairies suffered from repeated losses from stem rust in the period 1911-1924. In 1924, a conference attended by representatives from federal and provincial government agencies, universities and United States institutions recommended that a Rust Research Laboratory be established and that a multidiscipline research program be initiated to solve the problems of rust on wheat. The laboratory was located on the campus of the University of Manitoba, Winnipeg, and opened in 1925. The formation of this unit established two main principles:

1. the philosophy that multidiscipline research groups be utilized to solve agricultural problems; and
2. that federal research units be located on or near universities to permit the maximum co-operation in research and education.

These principles are still applicable in the current operation of the Department.

Mechanization of agriculture brought new problems and different research needs. Machinery tests were begun at Swift Current in 1922 and in the ensuing years many aspects of agricultural engineering were studied. Instrumentation and development of specialized equipment for research was a featured phase of the engineering sections at Swift Current and Ottawa. In 1955 the Canadian Farm Building Service was established. This was a co-operative venture between federal, provincial and university authorities to place an emphasis on the research, design and development of farm buildings for Canadian conditions. In spite of the success of the projects undertaken, engineering research has not received the same emphasis in the Department as other areas of endeavour.

In 1929, the need for economics research in agriculture was recognized by formation of the Agricultural Economics Branch within the Department to study farm management, land problems, credit, finance and taxation, transportation, marketing, agricultural co-operatives, statistics, agricultural history, and rural sociology. However, the Branch has not been able to develop all aspects of these responsibilities.

As a result of severe drought on the prairies in the early 1930s the "Prairie Farm Rehabilitation Act" was passed "to provide for improvement of agricultural conditions in those parts of the Prairie Provinces which in recent years have suffered from drought and soil drifting". The research undertaken had three main objectives:

1. to develop improved cultural practices;
2. the conservation of water supplies; and
3. greater efficiency in land utilization.

A Soils Research Laboratory was established at Swift Current to conduct the basic research on soil moisture, soil drifting, and soil fertility. Federal funds were made available to provincial governments to make a thorough soil survey throughout the dry areas–the beginning of the National Soil Survey which is still in operation today and which represents a truly co-operative venture between federal, provincial, and university agencies.

In 1937 the Department underwent a major reorganization "to bring under one administrative head services similar in character and purpose in the broad fields of activity, with respect to the marketing of different agricultural products, their production from a national standpoint, and the experimental and scientific work in connection therewith". The research components were:

1. The Experimental Farms Service, oriented around products, included research responsibility for animals, bees, cereals, fibre crops, forage plants, field husbandry, horticulture, extension (Illustration Stations), poultry, and tobacco.

2. The Science Service, with research organized on a discipline basis, with responsibility for animal pathology, botany and plant pathology, bacteriology, chemistry and entomology.

In 1942, the Plant Protection Division was added. Later a Forest Biology Division was established to conduct research on forest insects and diseases in conjunction with that of agriculture. The work of the latter division had to be closely integrated with the effort expended by the provinces since forest resources, unlike those of agriculture, were completely within the jurisdiction of the provinces. However, some excellent co-operative arrangements were developed based on guidelines appropriate to the times.

Experimental work beyond the traditional agricultural zones was initiated in 1940 in the permafrost areas of the Yukon and the Northwest Territories. The objectives were to determine the agricultural potential of these areas and to provide supplementary food supplies for the native population.

The most recent major change in the Department's organization for research occurred in 1959 and reversed previous trends with a decisive move towards reconsolidation. All research activities, except those directed by the Health of Animals Branch and the Economics Division, were grouped together into one unit, the Research Branch. The Administrative Branch, the Health of Animals Branch, and the Production and Marketing Branch made up the remaining units of the Department.

The basic philosophy enunciated for the Research Branch was "a team approach" to research. Scientists representing many disciplines were brought together under one director to work on specific problem areas. However, the main objective remained the same–solving agricultural problems by using the full range of research activities from basic through developmental.

In 1962, a Food Research Institute was formed to study the characteristics of plant and animal products that affect food quality, consumer acceptance, storage, processing and new types of agricultural foods. This innovation recognized that food research is a major responsibility and integral component of agricultural research. In 1960, the Board of Grain Commissioners and its associated research activities were brought under the jurisdiction of the Department of Agriculture.

The Agricultural Rehabilitation and Development Act, passed by Parliament in 1961, has had a significant influence on Canadian agriculture and its research needs. It empowers the federal government to make agreements with the provinces or other agencies for the development of research and action projects affecting many sectors of the agricultural economy. A significant feature is the philosophy behind the Act–the provinces are the "doers" while the federal government co-ordinates the work and assists in the financing.

The organization for research in the past 100 years has been influenced by the problems of agriculture, political activity, and the guiding hand of strong men. At present the Research Branch has 26 Research Stations, 14 Experimental Farms, 8 Research Institutes, and 3 Research Services, manned by more than 700 research scientists.

Co-ordination

Co-ordination of effort in a field as broad and complex as modern agriculture can be a difficult task considering the number of agencies involved, the numerous legislative acts governing agricultural activities, the wide variety of disciplines encompassed, and Canadian geography. The Department of Agriculture has assumed major responsibility for co-ordination through various mechanisms, the most recent being the Canadian Agricultural Services Co-ordinating Committee.

The first attempt to effect co-ordination of research and education between federal and provincial governments occurred in 1914 as a direct result of the need to co-ordinate activities stimulated by funds provided by the Agricultural Instruction Act. A conference was called by the Minister of Agriculture to discuss plans and exchange ideas about the work carried on by the provinces under the agricultural instruction grants. However, no further meetings were held until 1920 when the deputy ministers of provincial departments of agriculture and their senior officials met in Ottawa to discuss means of developing greater co-ordination of federal and provincial activities. The relationship of the work of the experimental farms to that of the provincial departments was discussed. The meeting recommended the formation of an Advisory Board in each province to make recommendations on the location of work and the research to be undertaken. However, because of circumstances, the Advisory Boards were never formed. The Agricultural Instruction Grants were discontinued in 1923 and thereafter the work became a charge on the provincial treasuries.

In the ensuing years there was a tendency for the "have-not" provinces to surrender programs to federal agencies in areas of concurrent jurisdiction. These circumstances led to the present federal dominance in agricultural research.

The next significant step in the development of co-ordination came in 1932 when the National Advisory Committee on Agricultural Services was formed to advise the National Committee on Agricultural Services, the latter being comprised of the Ministers of Agriculture. Within a very short time the main Committee ceased to meet and, simultaneously, the Advisory Committee ceased to provide advice *as a committee*. It did continue, however, to function as an autonomous body and became a more or less voluntary coming together of senior representatives of government and agencies which provided services at the official level.

In 1960 the name of this body was changed to National Co-ordinating Committee on Agricultural Services (NCCAS). The major failure of NCCAS was not defining for itself a role that was clearly different from that of other national co-ordinating agencies functioning in the interests of Canadian agriculture. Secondary difficulties stemmed from inadequate terms of reference and operational instructions for the national committees established under NCCAS authority.
A special Committee was appointed in 1963 to examine the history and terms of reference of NCCAS. The Committee's recommendations were accepted and the Canadian Agricultural Services Co-ordinating Committee (CASCC) was formed in 1964. Its purpose was to review governmental and institutional services affecting the general welfare of Canadian agriculture, including co-ordination and adequacy of those services. It was agreed that henceforth CASCC would place major emphasis on the national needs of agriculture.
Two sections were formed:

1. the Deputy Minister's Section with responsibility for co-ordination of regulatory matters and of general policy, and
2. the Research Section which concentrates on the co-ordination of research and educational activities.

Each section meets separately for at least part of their deliberations. Some accomplishments of CASCC to date include agreement in principle as to the type of research to be conducted by each agency, a study of the methods of establishing priorities for research, and the establishment of an inventory of agricultural research projects.

Co-ordination of research has developed in response to specific circumstances influenced by individuals. The present organization is a significant first step in that it recognizes the need for a national integrating agency for agricultural research.

Federal Grants for Research
The question of how to finance research has been a problem in Canada since Confederation. It stems primarily from the fact that research and education (both extension of results and the education of professionals) are intimately linked in practice but responsibility for support is generally interpreted to be separated by our Canadian constitution. The Rowell-Sirois Commission report states:

"On balance there is a *prima facie* case for the Dominion withdrawing from many of its activities in connection with experimental farms, and either for disposing outright of most if not all experimental farms and illustration stations, or for handing them over to the provinces".

The fact that this has not happened is evidence that many factors other than research needs influence the decisions of governments.

The first federal grants given directly for agricultural research came as a result of the Agricultural Aid Act of 1912. These grants enabled the provinces to extend agricultural activities, including education. The initial act was superseded by the Agricultural Instruction Act of 1913 which restricted the monies to agricultural education "because so doing we get at the true basis of successful production". The grants under this Act were appropriated for a 10-year period and were used for the introduction and extension of the agricultural representative services. Owing to a series of circumstances, the grants were discontinued in 1924. No further direct grants were made until the early 1950s when the Extra-Mural Research Grants, developed by Science Service and the Experimental Farms Service, Canada Department of Agriculture, were provided to university scientists to stimulate research on problems related to the Departments' own research programs. This type of grant is still being used.

Operating grants for research support were initiated by the Canada Department of Agriculture in 1966. The program is operated under a committee of university and departmental representatives and is administered by the Research Branch. The purpose of the grants is to provide a stimulus for the development of areas of research and education to meet the national needs of agriculture. Both types of grants amounted to a total of $624 750 in 1968.

A Postdoctorate Fellowship program enables a limited number of scientists from Canada and abroad to spend a period of up to two years in the Department's research establishments. The number of fellowships is being increased each year and significant results have been obtained from this program.

Provincial Departments of Agriculture

At the time that legislation was being enacted to establish departments of agriculture in each province, there was little awareness of of the need for research in support of agriculture, or that the provinces should play a role in such activities. Ontario and Quebec were the first to initiate agricultural research when they developed experimental stations in connection with agricultural colleges. This was done partly with federal grants received under the Agricultural Instruction Act during the period 1913-1923.[1] However, policies varied in each of the provinces and resulted in wide variations in research support and research activity throughout the past century. Authorities in some provinces held the view that research at all levels was a federal responsibility and consequently they were prepared to leave all such activities under the control of the senior government. This philosophy arose as a result of the Federal-Provincial Conference of 1935 where tacit agreement was reached that the federal government would be responsible for research, the provinces for extension, and the universities for education. Events since that date have altered the general acceptance of this view. For example, research is being developed as a normal responsibility by some provincial governments.

The recommendations of the Rowell-Sirois Commission, 1940, that "local aspects of research such as soil surveys" and "that research should be kept decentralized among colleges and individual workers as much as possible" expressed the philosophy which is presently being accepted by an increasing number of provincial authorities.

Alberta, Manitoba, Ontario, and Quebec have each developed significant research programs and support a wide range of projects in various ways.

Alberta established an Agricultural Research Trust in 1964 to support individual projects initiated by university personnel. Funds received from industry are matched by the provincial treasury up to a maximum of $200 000 annually. In addition, projects are supported through the Alberta Research Council, and direct support is given by the Department of Agriculture to units such as the Horticultural Station at Brooks.

Ontario, through the Agricultural Research Institute established in 1964, supports a wide range of research activities by grants to the University of Guelph, by direct funding of provincial research stations such as Vineland, and regional units at Kemptville and Ridgetown. Before 1964 projects were supported on an individual basis by the Department of Agriculture and Food.

In Manitoba, the Department of Agriculture and Conservation allots funds directly to the Faculty of Agriculture, University of Manitoba, to conduct research of particular significance to Manitoba. The Department does not operate research units as such, but uses the Faculty of Agriculture as its operational research arm.

In Quebec the Agricultural Research Council finances projects in the Faculties of Agriculture at Laval, McGill (Macdonald College), and in the Faculty of Veterinary Medicine of the University of Montreal. In addition, the Department of Agriculture and Colonization operates five developmental stations throughout the province as well as operating testing stations on leased land.

In the remaining provinces support for individual projects is granted for particular purposes. However, no continuous programs are maintained in these latter provinces.

The distribution of federal support for agricultural research varies widely between provinces. The lack of a definite division of jurisdiction for agricultural education and research in the British North America Act has left the way clear for many anomalies to develop. The reasons for such anomalies are closely tied to government philosophies,

[1] Developments in Ontario were initiated much earlier. See following section, "The Universities".

financial capabilities, and urgency of the problems at a particular time.

From current trends, it appears that the provinces will play a more dominant role in agricultural research in the future. How they will develop their roles to accommodate such factors as constitutional rights, fiscal priorities, and competition for research funds is a matter of crucial importance to the future of agricultural research in Canada.

The Universities

Universities have had two types of responsibilities in agricultural research over the years–the education of agricultural scientists and the conduct of research itself. These two types of responsibilities may be combined in graduate programs offered by universities, but education remains the primary responsibility.

Faculties of agriculture are, in general, less than 100 years old in Canada. The Ontario School of Agriculture, the first to offer formal agricultural education in Canada, was founded in 1874 at Guelph under the Commissioner of Agriculture for Ontario. This action resulted from recommendations made by W. F. Clarke after a study of the American Land Grant Colleges. Initially there was no specialization in the educational program. The objective was to train Ontario farmers. Only simple experimental work was undertaken in the early years. In 1880 the Ontario Agricultural College and Experimental Farm were incorporated by an Act of the Ontario Legislature. In 1887 the College affiliated with the University of Toronto, which remained the degree-granting body until 1964 when the University of Guelph was established. During the period 1924-1945, a gradual expansion in facilities and staff occurred. Postgraduate programs were established but the number of graduate students remained low. Development since 1945, in staff, students and facilities, has been more rapid. A dynamic research program is presently carried at the University in conjunction with its educational responsibilities.

In 1905 Sir William C. Macdonald founded and endowed Macdonald College at Ste. Anne de Bellevue, Quebec. It has been affiliated with McGill University from its inception. Research, education and extension have been recognized and accepted as major responsibilities of the College since its founding. Research results from Macdonald College programs have been instrumental in supporting agriculture in Canada. Montcalm, the famous malting barley, was developed by researchers at Macdonald College.

In other historical developments in Quebec, the Oka School of Agriculture, founded in 1893, became affiliated with the University of Montreal in 1909. In the eastern part of the province, the School of Agriculture at Sainte-Anne-de-la-Pocatière was founded in 1859 and became affiliated with Laval University in 1912. The two French-speaking schools conducted little research until Laval recognized Sainte-Anne-de-la-Pocatière as its Faculty of Agriculture in 1940; both schools received support for research projects from the Quebec Agricultural Research Council, beginning in 1947. The Oka School was closed in 1962, and a single French-speaking Faculty of Agriculture was established on the campus of Laval University with superb facilities, excellent staff, and promising cross-relationships with other faculties.

In 1906, the Manitoba Agricultural College opened its doors and Manitoba became the first province west of Ontario to offer formal education in agriculture. In 1924, the Manitoba Agricultural College became the Faculty of Agriculture and Home Economics of the University of Manitoba. The faculty has carried a vigorous program of research, education and extension ever since.

Faculties of Agriculture were established at the University of British Columbia (1908), the University of Saskatchewan (1912) and the University of Alberta (1915). All have made telling contributions to agricultural science within their constituencies and Canada as a whole.

Both agricultural education and agricultural research have evolved extensively in the past 75 years. Research in the universities grew slowly in the shadow of the federal programs which dominated those of all other sectors in the earlier years. Originally, research at the universities was a rather restricted adjunct to undergraduate instruction. More recently the emphasis has been on disciplinary research in depth, through which the universities contribute significantly to the development of knowledge in the context of agriculture and to the education of those who do the research.

The National Research Council of Canada (NRC)

Historical Base

The function of the Council, as originally conceived by its founders was "to aid secondary industry, encourage scientific research wherever it was done and to advise the government on scientific matters" and thus "to put science and industry together for the benefit of the people of Canada".[1] A clause of the original version of the Research Council Act, passed by Parliament in 1917, empowered NRC to undertake, assist or provide scientific and industrial research, including (*i*) the utilization of the natural resources of Canada, ... (*viii*) researches, the object of which is to improve conditions in agriculture. The Council, therefore, has always had a legal responsibility for agricultural research.

Role of the Division of Biology and Agriculture

The Council's research in these fields began in 1928 at the University of Alberta and was carried on there until the opening of the NRC laboratories in Ottawa in 1932. The guiding philosophy in the development of the Division was to support and amplify the work of other government departments and research institutions. Initially some work was conducted on plant breeding and related research. However, this was gradually relinquished by the National Research Council as the research facilities of the Department of Agriculture increased and developed in these areas.

In March 1942, the Council officially changed the name of the Division to the "Division of Applied Biology" which undertook applied investigations on food preservation, industrial fermentations and utilization of agricultural wastes. Few of the discoveries resulting from this research were ever developed by Canadian industry, although several NRC patents were exploited in other countries. Once again in 1964 the Division shifted emphasis and its name was changed to "Division of Biosciences" to reflect the broader base of biological research to be undertaken. Throughout this period the Division exercised its directive with respect to agriculture by undertaking research in areas where it felt that gaps existed between the work of Canadian industry and of the Canada Department of Agriculture.

The role of the National Research Council has been one of co-ordination and "gap closing" in research. The Council has gradually withdrawn from particular kinds of research as these areas were developed by the Department of Agriculture, substituting areas of work not satisfactorily covered by either industry or government.

The Associate Committee Mechanism

The Associate Committees were introduced by the Council at a very early stage to coordinate research being carried on in various fields at the regional and national levels. This has proved to be a simple and effective mechanism for research co-ordination. When a major problem arises, the Council forms a committee of leading authorities in the field who are particularly qualified to give guidance and advice. Without salary from Council, these people meet and by exchanging views, work out a co-ordinated approach to the problem. When the purpose for which the committee was formed has been met, the committee is disbanded or transferred to an operating department.

Committees with relevance to agriculture have been:

1. the Associate Committee on Grain Research,
2. the Associate Committee on Plant Diseases,
3. the Associate Committee on Plant Breeding,
4. the Associate Committee on Animal Nutrition,
5. the Canadian Committee on Fats and Oils, and
6. the Associate Committee on Agricultural and Forestry Aviation.

Operational responsibility for the first four committees has recently (1969) been transferred to the Canada Department of Agriculture.

During the Second World War the National Research Council established the Prairie Regional Committee (PRC) to deal with grants requested by the Associate Committees on Grain Research, Plant Diseases, Plant Breeding and Animal Nutrition. Grants in fields outside the areas covered by the above committees were made by the Standing Committee on Grants and Scholarships. Eventually most grants were given in fields outside the area of responsibility of the Associate

[1]Thistle, Mel. The inner ring: the early history of the National Research Council of Canada. University of Toronto Press, 1966.

Committee, and the Prairie Regional Committee was left without a role. Therefore, in March 1963, the National Research Council established the Special Western Agricultural Committee on a reconstituted basis to provide for an exchange of information and work planning among the universities, the Canada Department of Agriculture, and the National Research Council in the field of agricultural research in western Canada; in other words to deal with policy and co-ordination. The activities of four long-established and highly successful Associate Committees on Grain Research, Plant Diseases, Plant Breeding, and Animal Nutrition were thus brought under the general jurisdiction of the Special Western Agricultural Committee. On transfer of the Associate Committees to the Canada Department of Agriculture in 1969, and in keeping with the philosophy of the National Research Council, the Special Western Agricultural Committee was disbanded.

Institute of Parasitology, Macdonald College
The Institute was established in 1931 with joint support of the National Research Council, the Empire Marketing Board, the Quebec Department of Agriculture, and McGill University. Its purpose was to train senior and postgraduate students in parasitology, especially in relation to agriculture and veterinary medicine, and to conduct research in parasitology and on the application of existing knowledge for the control of parasites. The Institute has, through the years, made notable contributions to parasitology. Although some of the contributing agencies have changed in the intervening years, it provides a Canadian model for a broadly supported institute for advanced studies in a specialized field–a model which could be copied to advantage in other areas.

Support for University Research in Agriculture
The university support program of the National Research Council provides research grants for professors, scholarships and fellowships for outstanding graduate students, and assistance for a variety of general scientific activities. For example, major equipment and operating grants in 1967-68 totalled $29.5 million of which $1.8 million was used to support research in identifiable agricultural units.

The granting program of the National Research Council has been most successful in stimulating and developing research in areas of need. Agriculture has benefited, and continues to benefit, from this program. For example, in 1967-68, the National Research Council provided funds for 72 per cent of the $2.19 million in operating and extramural grants provided by both the National Research Council and the Canada Department of Agriculture to the faculties of agriculture. The operating philosophy of the National Research Council to co-operate and co-ordinate research through its granting function has provided a most advantageous program for Canada.

Summary

Canada has achieved great success in many areas of agricultural research. Contributions have derived from many and varied administrative agencies. The total accomplishments outlined in this brief history have established the pre-eminence of Canadian agricultural science and scientists. In general, the goals set for research have been achieved and the results, put to use by the producers, have maintained a healthy production agriculture. It remains for this report to discuss the means which will now exploit this success and provide the flexibility required to meet the rapid changes and increasing complexity of the total agricultural enterprise in Canada.

Chapter II

The Components of Agricultural Research and Development

Modern agriculture is an industry based on a complex technology. The function of this technology is to optimize a multicomponent system of resource inputs (capital, labour, land, water, seed, machinery, chemicals, etc.), thus to maximize the efficient production, conversion, and marketing of agricultural products as food and fibre for economic and social benefits.

The research needed to support this technology must also be structured as a multicomponent, yet integrated system, consciously directed towards the same useful ends. Thus, agricultural research and development (R & D) may be viewed as a system of disciplinary inputs (biology, chemistry, physics, engineering, economics, sociology) selectively integrated to provide comprehensive guidance for improved efficiency and innovation by the producers, processors, and merchants, serving the consumers, of agricultural products.

This definition contains important extensions of the traditional concept and the current profile of agricultural R & D in Canada. It extends the disciplinary dimension to include, unequivocally, the socio-economic sciences. It requires the integration of the component sciences and scientists in working relations that span the traditional disciplinary boundaries. It recognizes that agricultural research and development cannot be limited to production research, terminating at the farm gate, but must extend to the conversion and marketing of agricultural products as desirable consumer goods. Throughout, there is the implicit commitment to social usefulness, to delivering economic and social benefits, and to the "mission" orientation.

The multicomponent structure of agricultural research and development has important implications for national planning and policy decisions. It can be thought of in terms of a multidimensional matrix with at least four main axes:

1. The Disciplinary Axis–the spectrum of disciplines required;
2. The Sectors of Performance–the range of agencies, from government to private, conducting agricultural R & D;
3. The Level of Attack–the research, development, innovation spectrum;
4. The Time Dimension–the time-scale for reaching various objectives.

This matrix can be used, we believe, to characterize any mature field of applied science. All fields require a multidisciplinary approach; in all of them research and development is performed by several agencies; all are dependent on the generation of basic new knowledge, and seek to extend it to development and innovation; and all have the need for short-term specific solutions and long-term general solutions.

The problem for the planners and policy-makers is the enormously complex one of plotting the interrelations between these axes, and of integrating them into the desired profiles for effective attack on particular areas of social consequence. Certainly, within these four dimensions there is the latitude for the variability we will need, if only we have the wisdom and the flexibility to change the shapes of our profiles to meet the swiftly changing priorities and opportunities for agricultural research and development.

The Disciplinary Components

Agriculture is based on the purposeful management of living things–of plants, animals, and microorganisms. Agricultural science is therefore traditionally and currently based on the biological sciences. Many early successes in the solution or prophylaxis of agricultural problems derived from the unidisciplinary application of biological knowledge. Increasingly, however, improved understanding demonstrated the essential chemical and physical nature of living things; and this understanding has now been elegantly verified by the demonstration that the physico-chemical structure of the double helix of DNA provides the basic mechanism for heredity–a discovery of immense significance for agriculture. But long before this improved understanding, the soil scientists had already embraced chemistry and physics as necessary disciplines to understanding the basic substrate of agriculture. Thus, agricultural science adopted the multidisciplinary approach early. This approach was characterized by the application in concert of those sciences, conveniently grouped as the natural sciences, to the problems of agricultural production. The natural sciences have always constituted and remain today, the dominant disciplinary component of agricultural research and development.

Agricultural science, itself a pioneer in the multidisciplinary approach to practical problems, seems nevertheless to have developed a curious hiatus in the logical extension of its disciplinary components. The impressive effort in manpower and scientific expertise

assembled in the natural sciences has been accompanied by minimal growth of the economics and engineering sciences in the context of agriculture, while the effort devoted to rural sociology is both miniscule and fortuitous. Yet these disciplines, concerned with the scientific management of capital, material, and human resources, are essential components of agricultural R & D, and are increasingly relevant to the complexities of modern agriculture.

Agricultural engineering is responsible for the advanced mechanization of agriculture and the associated neo-agricultural revolution which have steadily released from the land the labour required for the industrialization of advanced countries. Engineering science links agriculture with the vast development of machines, materials, structures, and control systems characteristic of our society. Many advances in agricultural production, derived from application of the natural sciences, could not be realized without the parallel application of engineering science to the systematic management of agricultural materials.

Economics is also an essential component of agricultural science, aimed as it is at maximizing economic benefits. Like engineering, economics is also a management science concerned with optimizing the total system of capital, labour, machines, biological materials, to yield profit.

Finally, after having lavished so much care on bringing these various scientific disciplines to bear on the problems of agriculture, the pervasive human factor cannot be left to chance. Sociology is needed to understand the motivations and values of rural people, to promote the adoption of new technologies and new products, and to reduce human resistance to change, if all the effort towards innovation in agriculture is to be put to use. Sociology is needed also to understand and exploit the highest potential of agricultural scientists themselves–their personal goals, value systems, and adaptability to change.

It is not sufficient simply to ensure that these disciplinary components of agricultural R & D are available. They must be integrated in close working relationships to promote new interactions and higher levels of synthesis of scientific knowledge. Within the natural sciences these interactions between disciplines and subdisciplines are increasingly commonplace and have yielded rich rewards. But between the natural sciences and the management sciences these interactions, and the opportunities for them, require strong development.[1] There are real difficulties, of course; the more disparate the disciplines, the greater the difficulty of communicating across barriers of vocabulary, basic concepts, and professional chauvinism.

These normal difficulties are further increased by the current numbers of natural scientists versus management scientists engaged in agricultural research and development in Canada. We believe that a degree of proportionality is necessary to provide the opportunities and excite the desired interactions among the scientists of all disciplinary components. In particular, we believe that dominance by the natural sciences reduces the opportunity for the engineering and socioeconomic sciences to contribute to the required broad mix of disciplines, and to exert their influence as sciences particularly concerned with principles of management.

The Sectors of Performance

Organizational integration is as important as disciplinary integration for the formulation of national policy and the conduct of a national program of agricultural research and development in Canada. The organizations concerned may be broadly grouped as the federal government, the provincial governments, the universities, and the private sector which comprises mainly the agriculture-based secondary and service industries and the producers' organizations. No single body exists in Canada at present, representative of all these various agencies and constituted with the clear aim and necessary authority to formulate, promote, and monitor a national system of agricultural research and development.

Overlapping roles between these sectors of performance are unavoidable and to some extent desirable. Each sector may, at times and to varying degrees, perform the functions of research, development, technical service, and teaching. However, each sector must have a central role which distinguishes it from all other sectors. This dominant function should exploit the elements of uniqueness in a particular sector, and should involve its self-interest. Clear recognition of these cen-

[1]The reorganization of the Economics Branch of the Canada Department of Agriculture, which was recently announced, appears to recognize this need by providing for an interdisciplinary research group.

tral roles provides the necessary frame of reference for national co-ordination between sectors, and for the regulation of peripheral roles within sectors. As long as these central roles are kept vigilantly in view, it is often advantageous for agencies to pursue their interests by extending to functions which overlap with those of other agencies. The resultant areas of overlap provide opportunities for interchange and interaction. The identity and uniqueness of a sector, or an agency within it, is determined by the characteristics of its central function; but peripheral activities shared with other sectors will promote cohesion and interaction between the sectors of performance to forge a national system for agricultural research and development.

A viable principle is that scientific work involving the application of existing knowledge to the direct solution of practical problems (development) should be performed in the closest possible proximity, physical and organizational, to the problems. In keeping with this principle, the central role for the provincial and private sectors should be technological development and innovation. The political and economic self-interest of provincial governments, and the profit motive of the private sector, dictate their strong orientation towards regional and product development. In fact, our data presented in Chapter III confirm that these sectors currently conduct more of this kind of scientific work than any other sector. Nevertheless, both these sectors will find it necessary and profitable at times to generate new knowledge needed for a particular application, that is, to undertake research. Moreover, in the case of provincial governments, there is both self-interest and constitutional responsibility to extend the results of development and innovation to the ultimate users, in the form of adult education. Beyond this, we see no intrinsic impediment, and much advantage, for involving individual scientists from both private and governmental sectors in university teaching and graduate thesis supervision in their areas of special expertise.

The federal government has overall responsibility for the co-ordination and funding of the scientific development of Canada's resources. Within this global responsibility, the federal government supports a number of departments, such as the Department of Agriculture, assigned to particular missions which require the performance of research and development. A basic difficulty for the federal sector of agricultural R & D has been to withdraw from the legacy of its beginnings when it was virtually the sole performer and endeavoured to fill all roles–research, development, service, and extension.

However, currently and for the future, we believe that the central role of the federal sector should be as a performer of research, generating new knowledge clearly relevant to agricultural problems and opportunities of national and broadly regional significance. Nevertheless, the extension of research to development will in some cases be necessary, and technological services such as identifications and diagnoses will continue to be needed as peripheral functions. Finally, the research facilities and scientific excellence in the federal sector can also be utilized as a peripheral but integral resource for the education of agricultural scientists.

The role of the universities in research and development has been the object of recent and intensive examination, notably in Special Study No. 7 of the Science Council of Canada and the Canada Council, *The Role of the Federal Government in Support of Research in Canadian Universities*. We agree with the consensus that teaching and research are complementary and indivisible in the context of the university, and that they constitute, together, the central role of this sector. Moreover, we agree that the kind of research associated with university teaching should exploit the freedom, unique to the universities, to generate new knowledge without regard to particular social objectives. This freedom is not to be equated with licence. Quite the reverse, it should be clearly recognized as the *responsibility* of the universities to conduct research without particular social commitments, thus to foster the unpredictable and improbable discoveries which open new ways of thought and new approaches for mission-oriented research.

This definition of the central role of the universities presents a dilemma for the professional faculties of agriculture, veterinary medicine, forestry, engineering, and medicine. These faculties are, *ipso facto*, devoted to education and research in fields of direct and practical importance to society. Historically, the specifically applied component of agricultural science provided the *raison d'être* for faculties or schools of agriculture; logically, it still does, for what distinguishes agricultural science from the disciplines basic to it is the applied orientation. Yet, didactic instruction in the technology of husbandries, and empirical search for the solutions to specific agricultural problems can no longer be accepted as primary functions in the universities. Rather, university education and research must be centred on the self-discovery and generation of unifying principles.

We believe that the answer lies in a clear recognition that agricultural education and research are concerned with the scientific management of a multicomponent system. The resource components are land, water, biological materials, machines, capital, labour, etc.; the disciplinary components are the natural sciences, economics, engineering, and sociology. The need is to apply the systems analysis approach derived from the concepts of cybernetics and applied so successfully as "operations research" to military, engineering, and business problems; the variant known as "linear programming" has been appropriately developed by agricultural economists.

This systems approach affords an integrating central theme for agricultural education and research, appropriate to the university function and to the applied orientation of agricultural science. Consistent with the role of the universities, systems research is concerned with the development of new knowledge at the level of principles; with methods of analysis of the interactions, and predictions of the probable outcomes of complex systems; with the formulation of rigorous, quantitative statements of concepts. Consistent with the practical aims of agricultural science, systems research can yield principles and models for the solution of particular agricultural problems. In fact, it consists of identifying relevant segments from the broad spectrum of research findings and forging them into a body of principles for problem solving.

This central theme will not, of course, exclude many of the kinds of research projects now current. In fact, it will undoubtedly generate more of them, for systems analysis typically reveals gaps in our knowledge of discrete events which must be filled before we can move closer to understanding the whole. But individual research projects are more likely to be selected for their pertinence to broad problem areas, and more likely to be designed to yield data compatible with that from other disciplines, if the systems approach pervades.

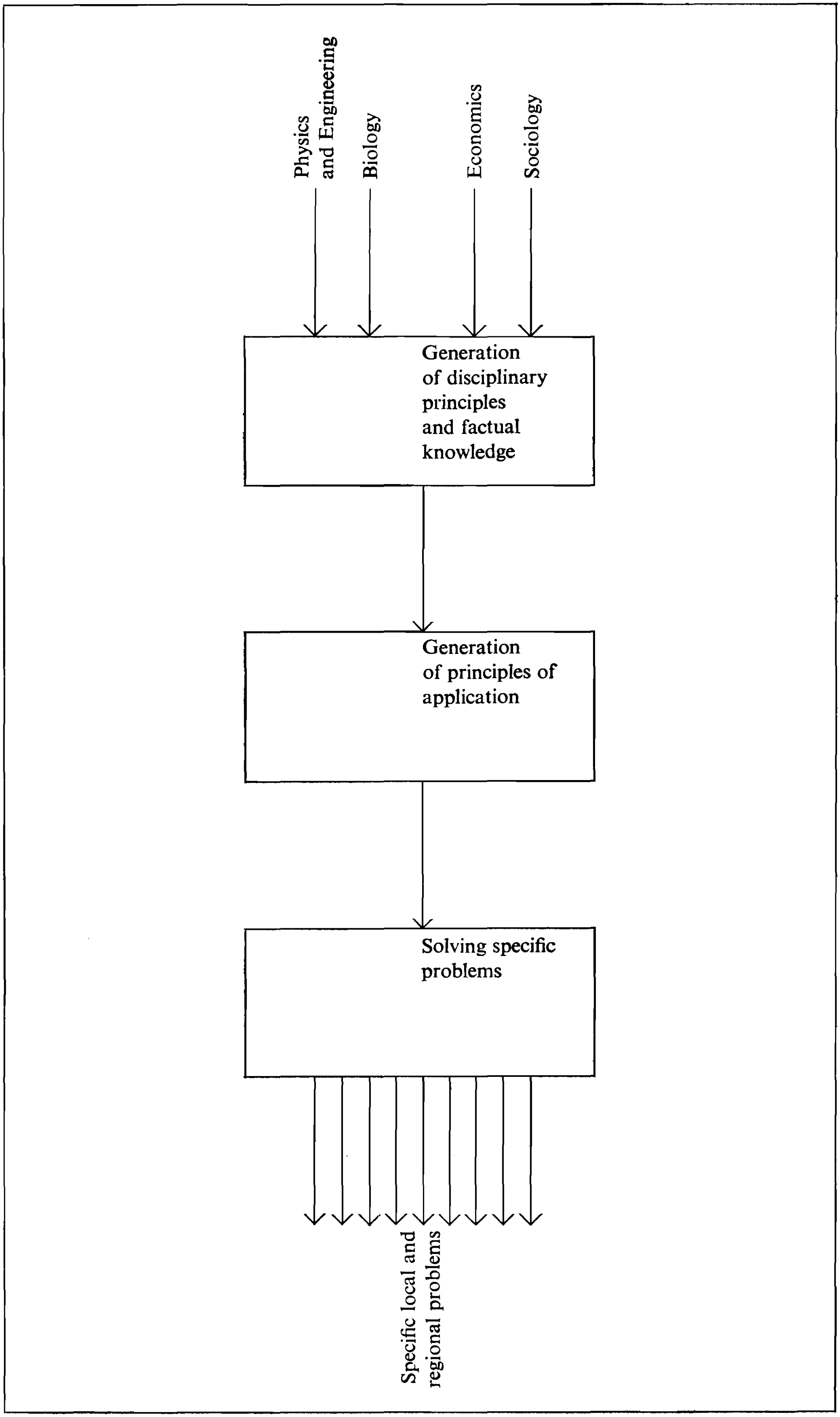
The Mission Orientation

Agricultural science is by definition a science committed to the support of the social enterprise, agriculture. This mission imposes constraints on those axes of agricultural research and development which we defined earlier as the levels of attack and the time dimension. The levels of attack should conform with the multidisciplinary requirement for a holistic approach to the multicomponent problems of modern agriculture. The levels of attack must also be consciously directed to generating the background knowledge for the solution of agricultural problems *and* to applying existing knowledge for the direct and immediate solution of these problems.

A recurring theme in this report reflects our concern that a relatively low proportion of the total scientific effort is directed towards the development of immediately useful products, processes, and methods. This lack of emphasis on development seems to us inconsistent with the concept of agricultural R & D as a mission-oriented scientific activity.

The time dimension is also relevant to the mission-orientation. We fully recognize the need to support many research themes over long periods of time to accumulate the background knowledge needed before a technological breakthrough is possible. But there is always the risk of overextending this need, thus endowing some traditional lines of research with self-perpetuating permanence. In this context we recognize the need for scientific task forces, temporarily assembled with specific objectives to be achieved against a short time-scale and then disbanded.

Finally, we believe the systems approach, outlined in the preceding section in the context of the role of the universities, is highly relevant to the mission orientation. In our total perspective, we see the need to adapt and apply modern management approaches to agricultural technology, exploiting the systems methods of business and engineering, and generating a body of principles for integrating the various disciplinary inputs and applying them to the comprehensive management of agricultural problems. The following diagram illustrates this concept.


Physics
and Engineering
Biology
Economics
Sociology
Generation
of disciplinary
principles
and factual
knowledge
Generation
of principles of
application
Solving specific
problems
Specific local and
regional problems

Chapter III

The Present Status of Agricultural Research and Development

The full dimensions of agricultural research and development in Canada have not previously been measured. In fact, before our survey, only one other census of the national effort in agricultural R & D had been conducted. This was the survey conducted by the Canadian Agricultural Services Coordinating Committee in 1966. Its purpose and accomplishment was to identify the professional man-years of effort devoted to particular broad categories of agricultural research. However, the survey was restricted mainly to scientists in readily identified agricultural organizations–the Canada Department of Agriculture and other federal agencies with agricultural interests, the provincial departments of agriculture, and the faculties of agriculture and of veterinary medicine.

Our survey included these organizations, and also the agricultural industry and the non-agricultural faculties of the universities. Moreover, besides obtaining data on the total manpower devoted to agricultural R & D, we sought and obtained data on the distribution of effort between research, development, and service; on the expenditures for agricultural R & D, and their distribution between disciplines and sectors of performance; and on the characteristics and current production of agricultural scientists. These data formed the basis for our appraisal of the current status of agricultural research and development in Canada.

Conduct of the Study

Data were accumulated and opinions sampled by means of a program which included a questionnaire survey, a series of interviews across Canada and the United States, two seminars, and requests for submissions from professional and commercial organizations.

The Questionnaire Survey

The Study Group conducted the most comprehensive survey of agricultural research and development ever attempted in Canada. A series of questionnaires elicited returns from 1 869 research project leaders reporting details on the allocation of their time and on the subject matter of 3 358 current research projects oriented towards agriculture. A separate questionnaire, directed to heads of institutions or departments conducting agricultural R & D, elicited data on costs, sources of funds, and personnel. The returns from the project questionnaires and from the institutional questionnaire are estimated conservatively at 85 per cent and 95 per cent, respectively, of those persons actually conducting or directing projects in agricultural research and development. These unusually high returns, coupled with accuracy checks we have made, give us considerable confidence in the validity of our data.

In an extensive effort to survey for all possible R & D activity in the agriculture-based secondary and service industries, many small firms surveyed did not reply and were assumed to have no research and development. Of those surveyed, about one-quarter responded, and these included most of the known larger industries.

The life sciences, and associated natural sciences, constitute the major disciplinary component of agricultural science. They are central also to a contemporaneous study by the Science Council on basic biological research and to several anticipated Science Council studies. To spare the life science community from repetitive questionnaires, the Study Group took pains to develop a questionnaire that would serve its own needs in this disciplinary area, and meet the needs of the other studies as well. The life sciences project questionnaire was developed therefore in close collaboration with Dr. K. C. Fisher, Director of the Study on Basic Biology. Consultation with representatives of industries involved in biological research revealed that their terminology, organization, and security requirements differed from those in university and government research establishments. Two different forms of the questionnaire were therefore developed–one for research projects in industry, the other for projects in universities and governments.

To meet its own particular needs, the Study Group developed additional questionnaires for agricultural engineering, agricultural economics, and rural sociology. The engineering and economics questionnaires were also developed in two forms appropriate to industry, and to universities and governments; the sociology questionnaire was directed to project leaders regardless of sector. Finally, an "institutional support" questionnaire was developed and directed to the administrative heads of all reporting units, regardless of discipline, to obtain financial and personnel data.

Altogether then, eight different questionnaires were developed, designed in appropriate formats, translated and printed in English and French versions (see Appendix A).

Basically, there were three kinds of questionnaires–one for university and government scientists (App. A1), one for scientists in industry (App. A2), and one for the administrative heads of identifiable agricultural research institutions (App. A3).

To avoid duplication only one complete sample of each questionnaire is included. Where details of the research conducted were unique to a particular discipline, the relevant parts of the other questionnaires are also included. Sample pages of a scan sheet (App. A4) and of an answer sheet (App. A5) are added to illustrate the techniques employed.

The above distinction between "developed" and "designed" is a real one. It is one thing to develop a questionnaire in the sense of deciding what information is needed, and of defining the terms, criteria, and classification schemes for framing the questions to obtain this information. It is quite another and highly expert task to *design* a questionnaire by phrasing and arranging these questions in simple, direct, and logical sequence and groupings so that reluctant respondents are clearly led through the distasteful exercise; and beyond that to ensure, through unequivocal questions, correct responses in a form suitable for computer retrieval and compilation. For this crucially important task the Study Group had the expert advice and invaluable and unstinting assistance of Dr. C. E. Chaplin and Mr. R. Needham of the Canada Department of Agriculture. Dr. Chaplin brought to this task his experience in the conduct of the CASCC survey and an unparalleled knowledge of, and empathy with, the agricultural research community; Mr. Needham brought the expertise of a statistician and computer specialist to bear on the design of the questionnaires.

An outline of the survey methods follows. Lists of units in which agricultural and related research was performed were painstakingly compiled by Mr. J. J. Comeau, Secretary of the Study Group. The procedure he employed was to search university calendars (departments and institutes) for relevant units; to write deputy ministers, directors and chairmen asking them to list units engaged in agricultural and related research in federal, provincial and municipal government departments; to compile lists of industrial companies from Canadian manufacturing and trade journals, and to write to their managers asking if their activities included research. The compilations were extended and checked by reference to professional society membership lists; some units were identified through the mailing address of members; and those members of two societies, the Canadian Agricultural Economics Society and the Canadian Society of Agricultural Engineering, whose home addresses only were listed, were sent letters asking if they were active in research and by whom they were employed.

A card index of all the units identified was prepared as a basis for future mailings. It consisted of:

	Universities and Governments	Industry
Natural Sciences	729 units	244 units
Agric. Engineering	68 units	181 units
Agric. Economics	73 units	34 units

A letter announcing the survey was mailed on December 20, 1967, to the heads of all the units identified. Each letter was accompanied by a letter of endorsement from the president of the appropriate professional organization–the Biological Council of Canada, the Federation of Canadian Biological Societies, the Canadian Agricultural Economics Society, or the Canadian Society of Agricultural Engineering.

Each unit head was asked to submit a list of the members of his staff who were actively engaged in research as project leaders, first to determine how many questionnaires were required by the unit, and second to provide an index of project leaders, by name, province, and institution. Rural sociologists were identified through an earlier survey conducted by Dr. D. M. Connor for the Canadian Sociology and Anthropology Association. The index record finally totalled some 5 300 cards and was used to produce machine listings of non-respondents when required.

Questionnaires directed to project leaders in all disciplines were mailed between February 20 and 22, 1968, to the heads of all units previously identified as engaged in research, with a copy of the staff list they had submitted earlier and a letter soliciting their support in seeing that the questionnaires were promptly completed and returned. On March 25, 1968, the "institutional support" questionnaire was mailed to all unit heads.

The daily rate of return of completed questionnaires was plotted on a chart. By April 5, 1968, 45 days after the initial mailing, questionnaire returns stood at 2 700 and the first follow-up letter, including a machine listing of non-respondents from each unit, was mailed to the unit heads. By April 25, 1968, some 3 410 completed questionnaires had been returned. Sixty-five days from the initial mailing, a second reminder was sent out to unit heads, again with a machine listing of non-respondents. A final telephone follow-up was made during the latter part of May.

By June 5, 1968, all returns received had been recorded on tape. The count of questionnaires completed then stood at:

Natural Sciences	3 700
Agricultural Engineering	77
Agricultural Economics	126
Rural Sociology	35
	3 928

A letter of appreciation was sent to all project leaders who had responded, as well as to their unit head, on August 1, 1968. This completed the extramural operation of the survey, an operation which had required the collaboration of some 5 000 individual scientists. Each return included "scan sheets" capable of being "read" by an electronic recorder, or optical scanner, for quantitative information, and written answer sheets for answers to more general questions.

As each completed questionnaire was received, the respondent's index card was removed from the record and his reply sheets were coded to show the province, the institution and the individual's assigned number. The scan sheets were then carefully checked for errors. This was important since the optical scanner would automatically reject sheets with missing information or with improper code marks. The most common errors were those which resulted from using the column for units rather than that for fractions of units, when asked for a reply in tenths of man-years.

The written answer sheets were retyped and duplicates made. These were coded in the same way as the scan sheets and then filed by province and by institution within the province.

Thirteen hours of optical scanning time at the Canada Government Central Data Processing Service Bureau were required between June 3 and 5, 1968, for scanning over 17 000 sides contained in the 3 928 questionnaires received, and for transferring the responses to tape. The rejection rate for missing data and other errors was about 3 per cent. All were corrected on the spot and the scan sheets reintroduced into the electronic recorder. Drs. Fisher and Chant edited the tape between June 7 and 21, 1968.

The program for the output from the computer produced over 300 pages of tables of statistics. In addition some 100 pages of raw output, the "computer dump", were produced as a reference record of the entire input.

Interviews

Sixty-two interviews were held between January 9 and April 28, 1967. These were as follows:

22 with representatives of federal agencies;
8 with representatives of provincial agencies;
22 with representatives of universities;
5 with representatives of industrial companies;
5 with representatives of U.S.A. institutions.

A complete list of these interviews, showing institutions visited and persons interviewed, is attached as Appendix B.

Seminars

A first seminar was held in Ottawa on March 6, 1967, on "The Role of Economists in Agricultural Research". Papers were presented by Dr. W. J. Anderson (Agricultural Economics Research Council of Canada), Dr. D. W. Slater (Queen's University), Dr. G. N. Irvine (Board of Grain Commissioners for Canada), Dr. S. H. Lane (University of Guelph), Dr. T. H. Anstey (Canada Department of Agriculture, Lethbridge), Dr. W. M. Schultz (University of Alberta), Dr. Earl O. Heady (Iowa State University), and Dr. S. C. Hudson (Canada Department of Agriculture, Ottawa).

The second seminar, also held in Ottawa, March 10, 1967, was convened to discuss the various aspects of "The Relative Responsibilities of Universities and Government Laboratories for Training and Research in Biology". Prepared statements were made by Dr. W. H. Cook (National Research Council), Dr. K. C. Fisher (University of Toronto), Dr. Robert Glen (Canada Department of Agriculture), Dr. F. R. Hayes (Fisheries Research Board of Canada), Dr. A. G. McCalla (University of Alberta), Dr. B. B. Migicovsky (Canada Department of Agriculture), Dr. A. C. Neish (NRC Atlantic Research Laboratory), Dr. M. L. Prebble (Canada Department of Forestry and Rural Development), Dr. W. E. van Steenburgh (Canada Department of Energy, Mines and Resources).

Submissions

Eighteen national organizations concerned with agriculture were invited to submit briefs for consideration by the Study Group. They included professional societies, producers' organizations, and commercial organizations. Only five submissions were, in fact, received. All of these were from producers' or commercial organizations, and provided useful insights on the problems and interests of these sectors in agricultural research and development.

Distribution of Expenditures

Summaries of the more important sections of our data on the distribution of expenditures are presented. All data pertain to fiscal year 1967-68.

Federal in-house research accounts for more than half (53%), and industry for less than one-tenth (7.3%), of the total national expenditure on agricultural R & D (Table 1); the corresponding ratios in the United States in 1965 were 19.5 per cent for federal and 53.9 per cent for industry.[1] Provincial governments' expenditures on agricultural R & D amount to one-fifth of the expenditures by the federal government; the constitutional joint jurisdiction for agriculture is not reflected in this disparity between the federal and provincial expenditures. More than one-quarter of all university expenditures are made by departments outside the faculties of agriculture and veterinary medicine, and constitute in fact about two-fifths of the expenditures by these faculties; the extent of contribution by this subsector was previously unknown, and its clear importance relative to both the university and the national effort suggests that it should be challenged to accept a more conscious and responsible role.

Table 1 provides the most comprehensive data yet available on the total expenditures for agricultural research and development in Canada. For the fiscal year, 1967-68, the total operational expenditures are shown as $74 668 000. For this same period, the national operational expenditure for R & D of all kinds is estimated at $582 700 000 (Science Secretariat statistics). Agricultural R & D therefore represents 12.8 per cent of the total national R & D expenditure.

[1]A national program of research for agriculture. Report of a study sponsored jointly by the Association of State Universities and Land Grant Colleges and the U.S. Department of Agriculture, Washington, D.C. October, 1966.

The data for Table 1 and the following tables are derived mainly from the institutional support questionnaire and the industry questionnaire. A more detailed presentation of the data and their derivation is contained in Appendix C, Tables 1-4.

The natural sciences receive more than 80 per cent of the total support (Table 2), reflecting the traditional and continuing emphasis on production research. Engineering, economics, and sociology, concerned with the management of material and human resources, receive together less than 20 per cent of the total support. Rural sociology, concerned with the vital human factor in the adaptation of rural people to technological changes, is supported at a level which suggests it is regarded as peripheral to agricultural research and development.

The federal and university sectors devote over 85 per cent of their support to the natural sciences (Tables 3, 3*a*, 3*b*). The provinces devote more than one-third, and industry more than one-half, of their support to engineering and economics; but their total expenditures are relatively small. This relative emphasis on engineering and economics is associated with a similar emphasis on development work by the provinces and industry (see Table 5). Industry contributes more than 40 per cent of the total national expenditure on agricultural engineering R & D, and devotes more than 40 per cent of its own expenditures to engineering R & D. Rural sociology is performed almost entirely in the universities; none is performed by the faculties of agriculture and veterinary medicine.

From Table 4 it can be calculated that the federal sector performs 53 per cent and funds 59 per cent of the total operational expenditures for agricultural R & D. The difference between the two percentages is due mainly to research grants to universities funded by the National Research Council, Medical Research Council, Agricultural and Rural Development Agency, and the Canada Department of Agriculture. Provinces support agricultural R & D in the universities by direct research grants and also indirectly by general grants to universities from which professors' salaries and departmental operating expenses are paid. The industry sector performing agricultural R & D reported no financial support other than its own.

Table 1–Total Expenditures on Agricultural R & D by Sectors of Performance[1]

Sectors of Performance	Expenditures ($'000)	% of Total
Federal Government	39 616	53.0
Provincial Governments	7 901	10.6
Industry	5 464	7.3
University[2] (agricultural units)	(15 498)	(20.8)
University[2] (non-agricultural units)[3]	(6 189)	(8.2)
Total University	21 687	29.0
Grand Total	**74 668**	**99.9**

[1]Reported operational expenditures, including grants, for all institutions or units identified as engaged in agricultural R & D, plus the estimated expenditures on agricultural R & D in university non-agricultural units (e.g. departments of biology).

[2]All university expenditures adjusted by deducting, from the total for each discipline, a percentage equal to the reported percentage of time spent on teaching.

[3]Estimate based on the number of researchers reporting one or more projects oriented to agriculture, and the per capita costs of research in the appropriate discipline in faculties of agriculture and veterinary medicine.

Table 2–Total Expenditures on Agricultural R & D by Discipline Areas[1]

Disciplines	Expenditures ($'000)	% of Total
Natural Sciences	61 597	82.5
Agricultural Engineering	5 248	7.0
Agricultural Economics	7 086	9.5
Rural Sociology	737	1.0
Total	**74 668**	**100.0**

[1]Reported operational expenditures, including grants, within the main disciplinary components of agricultural R & D performed by all sectors. University expenditures adjusted to delete teaching as noted in Table 1.

Table 3–Total Expenditures on Agricultural R & D by Disciplines within Sectors of Performance

	Natural Sciences	Engineering	Economics	Sociology	Total
	$'000	$'000	$'000	$'000	$'000
Federal	35 074	962	3 466	114	39 616
Provincial	5 021	943	1 937	0	7 901
Industry	2 509	2 282	673	0	5 464
University	18 993	1 061	1 010	623	21 687
Total	**61 597**	**5 248**	**7 086**	**737**	**74 668**

Table 3a–Expenditures by Disciplines within Sectors

	Natural Sciences	Engineering	Economics	Sociology	Total
	%	%	%	%	%
Federal	88.5	2.4	8.7	0.3	99.9
Provincial	63.5	11.9	24.5	0.0	99.9
Industry	45.9	41.8	12.3	0.0	100.0
University	87.6	4.9	4.7	2.9	100.1
Total	**82.5**	**7.0**	**9.5**	**1.0**	

Table 3b–Expenditures by Sectors within Disciplines

	Natural Sciences	Engineering	Economics	Sociology	Total
	%	%	%	%	%
Federal	56.9	18.3	48.9	15.5	53.1
Provincial	8.1	18.0	27.3	0.0	10.6
Industry	4.1	43.5	9.5	0.0	7.3
University	30.8	20.2	14.3	84.5	29.0
Total	**99.9**	**100.0**	**100.0**	**100.0**	

Table 4–Total Expenditures for Agricultural R & D by Source of Funds and Sector of Performance

Source of Funds	Performing Sectors				
	Federal	Provincial	University[1]	Industry and Private	Total
	$'000	$'000	$'000	$'000	$'000
Federal	39 616	91	4 544		44 251
Provincial		7 810	15 026		22 836
University			248		248
Industry and Private			479	5 464	5 943
Foreign			220		220
Other			1 170		1 170
Total	**39 616**	**7 901**	**21 687**	**5 464**	**74 668**

[1]*Provincial* support includes 1 211 in project grants *plus* the residue of all university expenditures (13 815) after grants.

Table 5–Per Capita Costs of Support for Agricultural Scientists by Disciplines within Sectors of Performance

Sectors	Disciplines			
	Natural Sciences	Engineering	Economics	Sociology
	$	$	$	$
Federal	34 285	27 485	27 728	22 800
Provincial	24 856	18 490	20 389	
Industry	23 018	91 280	30 590	
University:[1]				
agricultural units	33 583	25 535	24 905	
non-agricultural units	34 808	26 222	22 600	21 818
Means	**32 648**	**33 255**	**25 030**	**21 918**

[1]Whole time support, including teaching.

With two exceptions, natural scientists are supported at a higher mean level than scientists in any other disciplinary group (Table 5). One exception is the high per capita support for engineers in industry, which reflects the high costs of industrial engineering development work. The higher per capita costs for both engineers and natural scientists, relative to economists and sociologists, probably result from the need of the former for expensive laboratory and field equipment and supplies, and for specialist support staff. The other exception is the relatively high per capita support for economists in industry. In view of the current scarcity of agricultural economists, it seems to us likely that industry has accepted a more realistic standard of the level of support necessary to attract economics talent, than the other sectors have yet accepted. The relatively low mean levels of support for both economists and sociologists suggest that scientists in these disciplines are in general restricting their research to projects which avoid the use of extensive computer time, the employment of computer programmers and other specialist support staff, the use of sophisticated survey techniques, and interview surveys involving travel.

Distribution of Professional Manpower

In this section we present data on the professional man-years of effort devoted to agricultural research and development, and the distribution of this effort between types of professional staff; sectors of performance; research, development, and service work; disciplines, and research objectives within disciplines. The data are derived from the project questionnaires; more detailed data are provided in Appendix D, Tables 1 and 2.

The questionnaires requested project leaders to report on the allocation of their own time and of the time of their professional staffs, in units of one-tenth of a man-year. Professional staff were categorized as including the project leaders themselves; postdoctorate students and fellows, visiting scientists with Ph.D. on sabbatical leaves or transfers of work; professional staff with doctorate or equivalent research experience employed to work under supervision of project leaders. "Man-year" was defined as "the total work effort of one person in a full-time job for one year, regardless of the actual hours worked". (See Appendix A.)

The Study Group made a particular effort to elicit information on how professional agricultural scientists allocated their time between research, development, and service, by carefully defining these categories of work. We were acutely aware of the danger of distorted answers to this question, resulting from conditioned biases for or against "pure" as opposed to "practical" scientific work. Much effort was spent on designing this question and testing it on sample groups of scientists. In the end, we adapted to our purpose definitions for research and development of the Organisation for Economic Co-operation and Development. No distinction was made between "basic" and "applied" research; rather, we recognized only "research" which was defined simply as "the generation of new knowledge". The crucial definition was that for "development" which was defined as "work undertaken with the primary objective of improving existing or of generating new and immediately useful techniques, practices, materials, varieties, devices, products, etc., including final evaluation and testing". The third category, "service" was defined as "work including activities such as diagnosis, quality control and evaluation, animal and plant identification, chemical, soil, and water testing and analysis, extension, etc.".

Project leaders clearly play the dominant role in the total effort, suggesting that many projects are conducted by project leaders alone, without associated professionals, and that few projects are conducted by teams of associated professionals, either within or between disciplines. Equally clear is the dominance of the effort devoted to research, as compared to development and service work.

The 2 350 man-years devoted to research, development, and service actually represents the proportion of time allocated to these activities by 2 756 scientists whose remaining time (as a population) is devoted to teaching, committee work, administration, etc. The total professional manpower involved in research and development in Canada in 1967-68 is estimated from statistics of the Science Council at about 20 000 scientists. The professional manpower devoted to agricultural research and development and related activities is therefore 13.7 per cent of the estimated national investment of scientific manpower.

Tables 7 and 7*a* show that more than two-thirds of the total effort is devoted to research as distinct from development and service. Development alone accounted for only 16

Table 6–Allocation of Time of Professional Staff, All Disciplines, by Type of Professional and Category of Activity (Man-Years)

Type of Professional	Activity			
	Research	Development	Service	Total
Project Leaders	971	168	202	1 341
Postdoctorates, etc.	174	15	9	198
Professionals	391	109	156	656
Industry Professionals	51	87	17	155
Total	**1 587**	**379**	**384**	**2 350**

Table 7–Allocation of Time of Professional Staff, All Disciplines, by Sector of Performance and Category of Activity (Man-Years)

Sector	Activity			
	Research	Development	Service	Total
Federal	935	175	154	1 264
Provincial	132	62	108	302
University	469	55	105	629
Industry	51	87	17	155
Total	**1 587**	**379**	**384**	**2 350**

Table 7a–Allocation of Time

Sector	Research	Development	Service	Total
	%	%	%	%
Federal	39.8	7.4	6.5	53.8
Provincial	5.6	2.7	4.6	12.9
University	20.0	2.3	4.4	26.7
Industry	2.2	3.7	0.7	6.6
Total	**67.5**	**16.1**	**16.3**	**100.0**

Table 8–Allocation of Time of Professional Staff to Research by Disciplines, Objectives, and Sectors of Performance (Man-Years)

Discipline and Objective	Federal Government	Provincial Government	University	Industry	Total	% of Grand Total
Natural Sciences:						
Plant Production	192.8	22.5	55.1	2.2	272.6	18.4
Animal Production	60.9	5.4	55.2	2.6	124.1	8.4
Plant Protection	222.1	18.9	28.6	3.7	273.3	18.4
Animal Protection	45.7	2.1	46.6	0.6	95.0	6.4
Soil, Water	96.6	9.4	18.2		124.2	8.4
Food Products	24.8	3.4	10.1	17.3	55.6	3.7
General	197.9	3.8	173.9		375.6	25.3
Subtotal	**840.8**	**65.5**	**387.7**	**26.4**	**1 320.4**	**89.0**
Agricultural Engineering:						
Machinery	1.4	1.0	3.1	10.9	16.4	1.1
Power		0.1	1.0		1.1	0.1
Structures	0.3		2.3	1.2	3.8	0.3
Environmental Control	0.2	0.3	0.8	0.1	1.4	0.1
Crop, Food Processing		0.2	1.0	0.3	1.5	0.1
Materials		0.2	0.5	0.1	0.8	
Water Resources	4.0	5.1	5.1		14.2	1.0
Soils			0.2		0.2	
Research Equipment	2.9				2.9	0.2
Subtotal	**8.8**	**6.9**	**14.0**	**12.6**	**42.3**	**2.9**
Agricultural Economics:						
Economic Development		2.7	1.1	0.1	3.9	0.3
Econ. of Production	22.3	20.8	7.4	3.6	54.1	3.6
Marketing, Dist. and Trade	5.1	8.4	3.0	1.8	18.3	1.2
Resource Use and Develop.	3.2	3.6	3.5		10.3	0.7
Agricultural Policy	0.6	0.5	0.9	2.8	4.8	0.3
Co-operatives	0.2	2.2	0.5		2.9	0.2
Methodology and Theory	1.1		0.7		1.8	0.1
Econometrics	0.6		0.8		1.4	0.1
Interregional Compet.		0.5	0.3		0.8	
Subtotal	**33.5**	**38.7**	**18.3**	**8.3**	**98.8**	**6.5**
Rural Sociology:						
Anthropology	0.2		3.5		3.7	0.2
Social Psychology	0.6				0.6	
General Sociology	1.9	4.1	4.1		10.1	0.7
Rural Sociology	1.4	2.7	2.6		6.5	0.4
Extension			1.0		1.0	0.1
Subtotal	**4.1**	**6.8**[1]	**11.2**		**22.1**	**1.4**
Grand Total	**887.2**	**117.9**	**431.2**	**47.3**	**1 483.6**	**99.8**

[1]In provincial departments other than agriculture.

per cent of the total effort, which reinforces our concern that the proportion of effort on this kind of work is inconsistent with the concept of a mission-oriented scientific activity. Within sectors of performance, the federal government and the universities devoted nearly three-quarters of their respective efforts to research. Significantly, the provincial governments and industry, operating in close proximity to the problems and needs of the users of agricultural research and development, devoted one-half to two-thirds of their overall effort to development and service. Industry, with its high motivation towards innovation, devoted 56 per cent of its total man-years of effort to development.

The reported low proportion of development work will confirm for many a widely held impression; for others, it will seem unrealistically low and contrary to their impression of the overall practical orientation of agricultural research. This latter view contains some danger of confusion. All projects, and associated man-years, reported to us were *oriented* towards agricultural problems; this was the principal criterion for identifying "agricultural" scientists and projects. Within this general orientation to agricultural problems, agricultural scientists spend a portion of their time on work aimed directly at "immediately useful" practices, products, etc. This portion of allocated time is what we sought to measure under the term "development". The term was explicitly defined, and we received explicit replies from those doing the work, on the portion of time allocated to it. We believe the data represent the most reliable estimate available on this category of activity.

Table 8 summarizes the allocation of professional man-years devoted to *research* projects oriented to agriculture, and categorized by the broad objectives of these projects. Nearly 90 per cent of the national effort to generate new knowledge in the interests of agriculture is concentrated in the natural sciences. We do not believe that this overwhelming emphasis on research in the natural sciences has resulted from a conscious decision. Rather, we believe it results from the impetus of early successes when production agriculture was not only necessary but appeared to be total agriculture. Only recently has it become necessary to look "beyond the farm gate" to perceive total agriculture and its research needs.

The distribution of effort within the natural sciences places more emphasis on plant production and protection than on the corresponding categories in animal research. However, cultivated plant species are more susceptible to environmental influence than domestic animals so that plant research must be conducted at a greater number of locations in the wide range of Canada's climatic conditions and so results in a larger manpower requirement. In addition, most of the research on forage plants, feed grains, and pastures is conducted in direct support of the livestock industries. Another factor affecting the current balance of effort between plant and animal research is the greater costs of the latter. The estimates of the Canada Department of Agriculture suggest that the per capita costs for animal research are approximately twice the average per capita costs for agricultural research in general. To support these higher costs and maintain the required quality of research, it seems particularly appropriate to seek collaborative arrangements in animal research. An excellent example is afforded by the new Western College of Veterinary Medicine–a truly collaborative accomplishment of the provincial departments of agriculture, the faculties of agriculture, and the veterinary profession in the western provinces, in concert with the federal Department of Agriculture. Particularly in the field of large-animal genetics and breeding there is need for integrating research at a limited number of centres, broadly sponsored and supported by the relevant agencies, including the livestock industry. Beyond such national major programs, we believe there is scope for seeking international collaboration on major programs in animal production and protection.

The effort devoted to research on food products is low relative to the effort on production and protection of food plants and animals. This distribution of effort scarcely reflects the fact that food is the primary end-product of agriculture, and gives force to our view that food research is scarcely yet recognized as an integral part of agricultural research and development.

The large component of the total research effort categorized as "general" includes the man-years invested in many research projects with objectives so general or basic that their ultimate application could be of value in several of the more specific objectives. It includes studies on broad problems and general principles in taxonomy, ecology, biochemistry, genetics, cell biology, etc. which constitute the "risk capital" investment for the future development of agricultural R & D. We are quite convinced that this type of research is essential and that its concentration in federal and university laboratories is appropriate. However, we believe that the current investment of 25 per cent of the total research manpower places too high a priority on this category of research.

Between sectors of performance, the universities expend a greater proportion of their research effort on animal research than do the federal and provincial sectors. Industry devotes a larger proportion of its effort to food product research than any other sector.

The disciplines other than natural science all receive relatively weak support and the distribution of effort raises many questions. In engineering, for instance, the important problems of structures, environmental control, and food processing appear to need more attention. In economics, marketing research over the entire spectrum from primary producer to food consumer needs much more support; resource use and development, methodology and theory, and econometrics also require more research. In sociology, increased research on social psychology and extension seem particularly important for improving adoption of technological changes. Even those sociologists reporting rural research indicate that half their investigations are focussed on general themes in the discipline, reflecting their typical institutional setting in non-agricultural faculties.

Generation of Manpower

Data on Canada's current population of agriculturally oriented graduate students are presented.

Table 9–Number of Graduate Students Assigned to Agricultural Research Projects

Disciplines	Agricultural and Veterinary Medicine Faculties	Other Faculties	Total
Natural Sciences	751	343	1 094
Agricultural Engineering	62	6	68
Agricultural Economics	86	4	90
Rural Sociology	0	38	38
Total	**899**	**391**	**1 290**

Table 9 shows the self-perpetuating potential of the natural sciences and the relatively low potential for increasing the scientific manpower devoted to the other components of agricultural research and development. Both the high and low potentials are consequences of the numbers of professors doing research in the various disciplinary areas. Students trained for the natural sciences in non-agricultural faculties have traditionally seen agricultural research as a career opportunity; but this tradition is not nearly as prevalent among engineering, economics, and sociology students. Thus, there is cause for concern about the number and quality of sociologists oriented towards agricultural problems when none are currently trained in faculties of agriculture.

The Profile of Agricultural Scientists

Research is essentially a *human* enterprise. Despite the importance of funds and facilities, areas of specialization, and administrative jurisdictions, the whole endeavour depends upon human individuals–at the bench, in the field, in the seminar room. The creativity and efficiency of the total research operation are substantially affected by the kinds of people who staff it.

What kinds of people make up the agricultural research system in Canada? Where do they come from? How were they educated and formed professionally? These are some of the questions which are addressed briefly, with the aid of survey data, in the pages which follow, principally with reference to project leaders.

Geographic Distribution

Almost half of the project leaders (42.9%) are located in Ontario, which reflects the predominance of federal involvement, the largest provincial government establishment, and the greatest number of university and industry researchers. By contrast, the four Atlantic Provinces combined have less than 7 per cent, while the remaining provinces each possess 8-12 per cent of the project leaders. (Appendix E, Table 1.)

Location of Undergraduate Training

More than three-quarters (77.5%) of the project leaders took their undergraduate work in Canada and, in almost all cases, are native-born Canadians. For the three principal types of employer, the proportion varies from 70.9 per cent for universities, to 79.4 per cent for the federal government, and 89.6 per cent for provincial governments. More than half of those with foreign undergraduate degrees come from the United States or the United Kingdom. (Appendix E, Table 2.)

This distribution suggests that immigrant agricultural researchers are most likely to be devoting a considerable portion of their time to university teaching, are less likely to be applying their varying viewpoints in federal laboratories and are least likely to be found on the provincial scene. However, from the perspective of innovative agricultural research, especially in the developmental end of the research spectrum, it may be argued that a larger proportion should be encouraged through systematic management to work at the provincial level.

Graduate Degrees

Of the total of 1 869 project leaders, 1 141 (61%) have Ph.D. degrees, 99 (5%) have D.V.M. degrees, 15 (1%) did not report a degree, and the remaining 614 (33%) hold bachelor's, master's or some other type of degree. Most of the Ph.D.'s are employed in federal laboratories (50%) and in universities (45%). The universities employ about 60 per cent of the D.V.M.'s, and the federal government most of the remainder (33%). There are 935 project leaders in federal agencies, and 570 (61%) of them hold Ph.D. degrees. The corresponding statistics for the other sectors of performance are: provincial, 204 project leaders, 25 Ph.D.'s (12%); universities, 658 project leaders, 519 Ph.D.'s (79%); industry, 60 project leaders, 27 Ph.D.'s (45%). (Appendix E, Tables 3 and 4.)

Location of Graduate Training

More project leaders received their graduate training in the United States (44.8%) than in Canada (40.2%). American-trained researchers are found most frequently in universities (48.3%), somewhat less often in the federal service (45.3%), and considerably less frequently in provincial service (22.9%). Canadian-trained project leaders are located especially in provincial settings (71.6%), with 41.3 per cent in federal positions and only 32.6 per cent in universities. Of the 10.1 per cent of the total receiving their graduate training in the United Kingdom, most are at universities (13.4%) and the least at the provincial level (2.8%), while 8.8 per cent are in the federal employ. Some 4.9 per cent of all project leaders were trained in countries other than the "big three"; they are more highly represented in university (5.7%) and federal (4.6%) establishments than in provincial research positions (2.7%). (Appendix E, Table 5.)

Postdoctoral Experiences

More than two-thirds (68.2%) of those with Ph.D. degrees have not had a postdoctoral experience or an equivalent. Only 8.2 per cent report two or more such learning opportunities, while 23.6 per cent report a single occasion. The proportion reporting no postdoctoral experiences is 92.0 per cent for provincially based researchers, 72.1 per cent for federal government workers, and 62.4 per cent for university project leaders. (Appendix E, Table 6.)

This situation does not augur well for the dynamism of agricultural research, given the velocity of the knowledge explosion, the rapidity of adaptations elsewhere in the development end of the spectrum and the need for cross-training in relevant disciplines.

Employment History

More than half of the project leaders (56.7%) have not known any employment setting other than their current one. Federal researchers indicated the greatest stability (60.4%), provincial workers were very similar (59.8%), and university-based investigators, the least (50.4%).

Amongst those presently at universities, 21.7 per cent were previously employed by the federal government, while 10.3 per cent worked with provincial institutions. In an almost identical reciprocity, 11.8 per cent of provincial researchers were last employed by a university, as were 22.8 per cent of current federal project leaders.

However, in the case of federal-to-provincial mobility, the relationship differs: 13.2 per cent of the provincial project leaders were previously employed by the federal government, compared with 5.0 per cent of federal researchers formerly working for provincial agencies. (Appendix E, Table 7.)

National Origin of Graduate Students

Some 57.5 per cent of the 1 444 graduate students described by project leaders obtained their first degree in Canada and are most likely to be native-born Canadians. Of the remainder, 12.2 per cent did their undergraduate work in Asia, 8.0 per cent in India or Pakistan, 5.3 per cent in the United Kingdom, 5.2 per cent in the United States, and 3.0 per cent in Africa. Two-thirds (67.8%) received stipends from their professor's research grants. (Appendix E, Tables 8 and 9.)

These figures represent both a portion of Canada's effort in international agricultural aid and also the source from which many non-Canadians are recruited to agricultural research in Canada.

From the foregoing, we can synthesize a composite project leader in agricultural research in Canada as a resident of Ontario who took his first degree at a Canadian university before completing a Ph.D. in the life sciences at an American institution. He has not taken a postdoctoral year. He works in a federal research agency and has not had employment experience in provincial or university settings. Indications from the present population of graduate students are that his successor will be similar to him in many respects.

Other Data

Appendix F, Tables 1-15, presents other data not used directly in this report but which we believe may be of interest or use to those concerned with agricultural science in Canada.

Chapter IV

National Organization for Agricultural Research and Development

Most important to this report are the conclusions on organizational means for the integration of the national effort on agricultural research and development, and for articulation between it and the national R & D programs in the other renewable resource areas. While many of our other conclusions can promote action to good effect by themselves, none of them will, we believe, have the same force and assurance of relevance without the implementation of action on organization. The reason, of course, is that relevance is temporal; in the face of change, what is relevant today may be redundant, irrelevant, or ridiculous tomorrow. A central organizational mechanism is required, sensitive to changing needs and priorities, and capable of dynamic response to them. We believe our proposals for the establishment of an Agricultural Research Board and a Renewable Resources Research Council will provide this mechanism through representation from all sectors performing or funding pertinent research and development, and through formal access to federal policy decisions and funding at the ministerial level.

Current Organization

The need for an organizational mechanism to integrate the national effort on agricultural research and development has been recognized by the establishment of the Research Committee of the Canadian Agricultural Services Co-ordinating Committee (CASCC). This Committee now provides the most comprehensive forum yet developed in Canada for the national co-ordination of agricultural R & D and related services. The Committee comprises representation from all faculties of agriculture and veterinary medicine, provincial departments of agriculture, the Canada Department of Agriculture, the National Research Council and other federal agencies concerned with agricultural research. It reports to the federal and provincial Deputy Ministers of Agriculture as members of the parent Committee (CASCC). In addition to this national Committee, a system of regional research and co-ordinating committees has been established to promote regional co-ordination; these regional committees report to the national Research Committee of CASCC directly, or indirectly through the Canada Department of Agriculture.

This organizational structure marks the first serious attempt to develop a capability for the national integration of agricultural research and development in Canada. Importantly, it has provided a forum for the exchange of information and opinion between the current major participants in agricultural research. It has, of course, more concrete accomplishments to its credit: notably, the 1966 inventory of agricultural research projects; establishing policy and selection committees for Canada Department of Agriculture Operating Grants; proposals for establishing new fields of agricultural research at universities; and fostering the development of the Regional Committees. This experience in collaboration has been important in establishing a basis of understanding for the much more extensive and intensive collaboration we believe to be necessary in the immediate future.

National Research Committees

CASCC, CDA, and until recently the National Research Council, sponsored technical committees to co-ordinate research relevant to agriculture. These technical committees provide an important means for co-ordinating research between federal, provincial, and university scientists. The co-ordination is between scientists at the working level, and is effected by exchange of information on recent findings and by joint planning and partitioning of research projects between individuals and groups of individuals. Normally, these committees meet annually; reports are prepared and recommendations made to the sponsoring agency. The subject matter of the committees involves particular commodities (grain research) or particular scientific approaches (plant breeding) to regional or national problems. Other examples are the NRC Associate Committee on Animal Nutrition, and the CDA National Weed Committee.

As already noted in Chapter I, operational responsibility for the pertinent NRC Associate Committees has now (1969) been transferred to the Canada Department of Agriculture.

Agricultural Economics Research Council (AERC)

This Council was founded in 1963 as a result of a national conference at Winnipeg involving the federal and provincial governments, the universities, farm organizations, and agricultural business. The Winnipeg Conference recommended the founding of an Agricultural Economics Research Council to conduct independent studies on conflicts within existing agricultural policies, and to meet the need for evaluation and projections on new agricultural policy proposals. It was felt that the establishment of a disinterested and competent professional research group for this purpose would have the support of governments, farm organizations, and agri-business, i.e. those needing sound information for short- and long-term decisions. As originally conceived, the AERC would act also as a granting agency in support of agricultural economics research in the universities.

On the basis of the mandate provided by the national conference, the Agricultural Economics Research Council was established as a nonprofit, nonpartisan, and nonpolitical agricultural research organization with a Board of 15 Governors drawn from agribusiness, farm organizations, universities, and federal and provincial governments. The Board of Governors appointed a Research Directorate composed of agricultural economists, general economists, natural and social scientists. The Directorate appointed a Director of Research who, in turn, recruited a small research staff, located at Carleton University in Ottawa.

From its inception, the Council has encountered financial difficulties. A meeting of the federal and provincial Ministers of Agriculture gave tentative approval to the proposals of the national conference, with the exception of the method of financing. However, a five-year program was arranged on the basis of an annual budget of $150 000 to be provided by equal contributions from the federal government, the provincial governments, and the farm organizations and agribusiness. The private sector failed to meet their quotas and there was some difficulty initially in obtaining funds from some of the provinces. Current funding is at a level of about $100 000 per year.

The Council made some grants to universities but most of its limited funds were used to support studies conducted by its own staff. To date, 18 studies have been published by individual staff members rather than as reports approved by the Council.

In 1968, the Board of Governors reviewed the five-year operation of the Council and concluded there was little evidence that it had established its *raison d'être*. The funding agencies showed little enthusiasm for increasing their financial support. The Council was therefore reorganized by replacing the Research Directorate by a Research Committee of the Board of Governors, and the Director of Research by a full-time President. The objective of the reorganization was to ensure that studies would have immediate relevance to farm organizations and the agricultural industries, and that these studies would be published by the Council, rather than the individual researchers.

It seems clear that, in the eyes of its own Board of Governors, the future of the Council depends crucially on the confidence and support it can win from the private sector.

A Mechanism for National Integration

It seems self-evident that agricultural research and development, distributed between a variety of public and private agencies and serving a basic national industry, requires an organizational mechanism to effect action in concert to define and meet national policies, priorities and objectives. Notwithstanding the organizational devices outlined above, there remains today no *comprehensive* mechanism for assembling the views and exciting the participation of all actual and potential partners in this enterprise.

We claim no special insight in recognizing this need; few subjects discussed during our interviews across the country met with such a consensus of interest and approval. Why then has Canada so far failed to develop a comprehensive mechanism for the national integration of agricultural R & D?

A primary reason, we believe, has been the dominance of the field by the various research arms of the Canada Department of Agriculture since the very beginnings of agricultural research in Canada. This traditional dominance was virtually complete in the early days and has continued to be a characteristic of this area of research and development. With a high proportion of the nation's agricultural research being performed by the federal Department, increasingly well-integrated within itself, there has been little incentive, and many would have said, little need to seek broader integration.

It would be wrong to conclude that this situation arose as a simple consequence of bureaucratic aggression. Rather, it resulted from lack of interest, or reluctance to commit resources, on the part of the other potential partners; and from the reciprocal acceptance by the federal Department of the philosophy that its role was to fill the gaps in the national program by expanding its own establishment.

Despite the constitutionally shared jurisdiction for agriculture, the provinces in general were slow to claim their share of this responsibility. Between the provinces, a wide spectrum of degrees of involvement has developed; at one end, Ontario and Quebec currently provide substantial support for their own research organizations and programs, while at the other end, British Columbia, Saskatchewan, and the Atlantic Provinces remain virtually dependent on research done by the federal research stations located in the provinces. Likewise, the faculties of agriculture have interpreted their roles in research variously across a spectrum that extends from the conventional academic role to that of a provincial experiment station. The private sector, with few exceptions, has failed to develop an aggressive role with respect to policy, performance, or funding of agricultural R & D.

The institution of the Research Committee of CASCC has recognized the need, and its operation has developed some of the working methods for the national integration of agricultural R & D. However, in our view, it falls short of the full requirement in several important respects.

1. The function is too important to be contained as a section of a broad policy committee. The importance of agricultural R & D to agriculture, and of the resources devoted to it, requires the attention of a distinctive national body empowered to act under the authority of, and to provide advice directly to, a Minister of the Crown.

2. It seems self-evident that national integration must involve participation by all actual or potential sectors of performance or of funding for agricultural R & D. In particular, representation must be provided, as it is not now, for the producers' organizations, the agricultural industries, and the non-agricultural faculties of the universities, consistent with their obvious interests in, or contribution to, agricultural R & D.

3. An autonomous secretariat is essential to serve a national integrating agency by maintaining continuity of action and conducting special studies.

4. Centralization of the allocation of financial resources will be required for the strategic management of agricultural R & D through grants and contracts to foster priority research areas and projects.

An Agricultural Research Board

To meet these needs the Study Group proposes the establishment of an Agricultural Research Board, as a matter of first priority and pressing urgency.

Our concept of the Board is that of a prestigious body, appointed by the Governor in Council, and composed of representatives of all sectors conducting or funding agricultural R & D, plus a number of merit appointments without regard to affiliation. The Chairman and Vice-Chairman of the Board will devote their full time to the affairs of the Board. The full Board should, we suggest, be convened at least four times each year to maintain the continuity of their franchise.

We consider that the Board should comprise a body of not more than 25 persons, including the full-time Chairman and Vice-Chairman. The membership should provide comprehensive representation of performers and users of agricultural R & D, as follows:

the Canada Department of Agriculture;
the National Research Council;
the provincial departments of agriculture;
the universities, both agricultural and other faculties;
the producers' organizations;
the agricultural industries;
merit appointments, without regard to affiliation.

Membership terms should normally be of limited duration, with provisions for rotations and reappointments.

The limitation of membership to 25 persons is necessary, of course, for the efficient conduct of business. This limitation will also impose on members a high degree of responsibility to be informed and truly represent their constituencies. For instance, we would anticipate that the faculties of agriculture would be represented by no more than one or two of their deans who would be challenged to speak for the whole community. The Board would probably make extensive use of working parties, drawn from outside its membership but chaired by its own members.

The Board must be provided with a Secretariat composed of professional staff competent to conduct special studies, assemble and analyse relevant information to provide the basis for the Board's decisions. We suggest that the Secretariat be limited to a maximum of 12 persons, 4 of which would be permanent, and the rest recruited on a term basis for special studies or general research reviews, from units conducting research in Canada.

The primary responsibilities of the Agricultural Research Board may be stated as follows:

1. to develop the base for dynamic national policies for agricultural R & D in Canada;
2. to provide the mechanism for setting, and for changing, national priorities and objectives within a national program for agricultural R & D;
3. to monitor the national program with the aim of providing continuously updated information on the strategic deployment of manpower and expenditures with respect to national priorities and objectives;
4. to foster, through its influence and funding powers, the co-ordination, balanced development, and efficient management of the national strategy of priorities and objectives.

Management of the national system for agricultural R & D cannot be achieved by fiat. No single jurisdiction can exact or ensure co-ordination of action between governmental, university, and private sectors of performance. The Agricultural Research Board must therefore use its influence and funding powers to foster the orderly development and achievement of national priorities and objectives.

"Influence" in this context should not be underrated. Through its representative membership, the Board will have direct, two-way communication with all sectors involved in agricultural research and development. It will have up-to-date, factual information and a unique overview of the nation's needs. Its composition will favour respect for its collective judgement and ensure its freedom from parochialism. Most importantly, its influence will extend to a Minister of Canada in the form of objective and knowledgeable advice and recommendations for serving the nation's agricultural industry through research and development.

The funding powers of the Board will be derived in two ways: (1) indirectly, through its influence on the distribution of expenditures by the performing sectors; and (2) directly, through use of funds provided by the federal treasury, and from the provinces and the private sector on a contract or matching fund basis.

The recommendations of the Board are expected to exert a strong influence on the distribution and objectives of expenditures by the federal, provincial, university, and private sectors of performance. Individual sectors will be susceptible to guidance, based on a national consensus, on how to deploy their manpower and dollar resources to serve best their national, regional, or profit-making responsibilities.

In its direct funding role, the Board will act as the principal agent for the allocation of federal funds for effecting the balanced development of the national effort, for encouraging participation by the private sector, and for initiating new programs. For instance, the Board would seek, through its Minister, approval and budget support for new research centres such as those recommended in Chapter V, or to provide incentive for a particular developmental project by industry. Within federal funding, we believe the Board should administer funds currently allocated to the Canada Department of Agriculture and the National Research Council for operating grants to university scientists for identifiable agricultural research; however, scientists in faculties of agriculture should remain eligible for NRC grants because most of their research is directed towards work of general significance (see Chapter IV).

In addition to federal funds, the Board should exploit the clear potential which currently exists in Canada for funds exacted by producers' organizations as commodity levies, or volunteered by industry, to support research in their particular interests. As detailed in Chapter VI, the producers' organizations are increasingly aware of their need for research, and are prepared to provide substantial financial support by use of commodity levies. We believe the Board will be able to develop other sources of support than those now visible. For instance, marketing research is now widely recognized by agricultural producers as their most pressing need; most national business firms would regard an investment of $\frac{1}{10}$ of 1 per cent of their sales in marketing research as ridiculously low, yet a general levy on sales of agricultural products at this rate would have yielded more than $4 million for marketing research in 1967-68. The agricultural industries also provide unexploited opportunities for increasing their contributions to both the performance and funding of agricultural R & D, for instance, in food processing. Excellent models for these developments exist in Australia and New Zealand where important segments of agricultural R & D are supported jointly by government and the private sector. In New Zealand, for instance, the Industrial Research Associations contributed in 1966 about 15 per cent of the total national investment in research on agricultural production and processing in shared-cost programs to which the industries concerned contributed more than half from their own funds. The Board should have the powers to negotiate contracts for the use of federal funds where appropriate and necessary to foster a specific development by the private sector.

Provincial governments and municipalities will increasingly encounter agricultural problems susceptible to short-term studies but beyond the capacity or competence of their regular staffs; rural adjustment problems provide an example. In these circumstances, the Board would be empowered to receive and administer funds provided by these agencies, to provide supplementary funds if necessary, and to use these monies to negotiate contracts for the required research.

The Board will be responsible for awarding contracts to industries, private consulting firms, universities, and in one particular circumstance, to provinces.[1] Contracts would be awarded for specific objectives to be achieved within specific time limits. Broad criteria suggested for the award of contracts are: need for the work in relation to the total national program and the competence of the contracting agency to undertake the work.

Accordingly, we conclude that Canada should establish an Agricultural Research Board, with representation from all sectors performing or funding agricultural R & D, to advise and recommend to the federal Minister of Agriculture on the conduct and development of an integrated Canadian program. The Board would:

a) maintain a small permanent secretariat supplemented as necessary by experts employed or seconded to undertake special studies;

b) function to design and co-ordinate a Canadian policy and program by advice to the Minister on priorities and funding, and through its influence with the performing agencies;

c) exercise substantial powers for managing, through grants and contracts, the orderly development of a balanced program within and between the performing agencies.

A Renewable Resources Research Council

The Study Group believes that provision must also be made for a higher level of co-ordination between agricultural R & D, and the R & D conducted in the interests of other renewable resources. Fisheries, forestry, wildlife, and water resources all impinge on agriculture in reciprocal interactions of great importance for Canada.

Some of these interactions involve formidable conflicts of interest. Agriculture is now known to be a major contributor to water pollution (fertilizers, pesticides, agricultural wastes, soil erosion), which brings its interests into direct conflict with national interests in uncontaminated water and in fisheries. Some interests of wildlife management and of forestry are in conflict with those of agriculture. These zones of conflicting interests urgently require collaboration and integration between the research and development programs in the various renewable resource areas.

Other interactions clearly point to promising new opportunities for exploiting the parallel goals and common research approaches which characterize the application of science to the problems of managing the renewable resources. In each case, the goal is to optimize the economic or social benefits from the particular resource. The disciplinary components are highly similar, involving the biological sciences, chemistry, physics, engineering, economics, and rural sociology. Moreover, all are concerned ultimately with the scientific management of a renewable resource, and the concomittant need for the multidisciplinary systems approach to the development of management principles and practical solutions. Principles of management developed in the context of fisheries or forestry may therefore prove highly significant for agriculture. These interactions point again to the desirability of developing a mechanism for the integration of research and development between the renewable resource areas.

We therefore propose the establishment of a Renewable Resources Research Council. A similar proposal was made by Dean A. G. McCalla to the Resources for Tomorrow Conference in 1961. Our concept of the organization of the Council is that it should be composed of the Chairmen of Research Boards, or of bodies equivalent to the proposed Agricultural Research Board, for the renewable resource areas of fisheries, forestry, water resources, and wildlife. The Chairmen of these Boards would have a unique overview of the total national effort on the scientific development of Canada's renewable resources. On this basis, they would report and recommend to a body of federal Ministers responsible for the appropriate renewable resources.

[1]For the operation of certain federal research stations, see Chapter VI.

Accordingly, we conclude that Canada should establish a Renewable Resources Research Council composed of the Chairmen of Research Boards (or bodies equivalent to the Agricultural Research Board) for agriculture, fisheries, forestry, water resources, and wildlife, to effect co-ordination and exploit opportunities for collaboration in the scientific management of the nation's renewable resources.

Integration of the National Advisory Committees

In the new context of the proposed Agricultural Research Board, we believe there will be advantages in transferring the sponsorship of the National Advisory Committees from the Canada Department of Agriculture to the Board. These Committees constitute important means for co-ordinating sections of the national program, and the Board will now become the primary national agency for this function. Moreover, there are important advantages for free and vigorous exchanges between representatives of different operational groups, if their affairs are presided over by a disinterested body, itself not involved at the operational level.

We conclude therefore that the National Advisory Committees for agricultural R & D should be placed under the sponsorship of the proposed Agricultural Research Board.

The Role of the Agricultural Economics Research Council

The role of this organization must now be reconsidered in the context of the proposed Agricultural Research Board. In many ways, the founders of the Council anticipated our emphasis on the importance of economics research for agriculture, and the concept of involving the governmental, university, and private sectors in policy decisions and funding for agricultural research and development. Nevertheless, as outlined in the first section of this chapter, the Council has so far failed to win the full support of its intended users, and remains a relatively small organization now in the process of reorganization with the aim of reviving the objectives and support on which it was founded.

We have considered two alternative possibilities for embodying the Council's function within some other organizational structure. The first was the possibility of transferring the function to the Economic Council of Canada. However, the Economic Council is concerned with agriculture mainly in the context of the total Canadian economy, whereas the Agricultural Economics Council is specifically concerned with economics research on agricultural problems, and is constituted to respond directly to the self-declared needs of producers and agri-business. Within the general philosophy of this report, it would be anomalous to reject the aim and constitutional working methods of the Agricultural Economics Research Council.

The second alternative considered was to integrate the Council with the proposed Agricultural Research Board. However, the Council is specifically constituted to conduct research; its integration with the Board would therefore be anomalous with our view that national bodies empowered to fund research through grants and contracts should in no sense compete for funds to support their own research.

We have concluded, therefore, that the Agricultural Economics Research Council should remain an autonomous organization subject to the decision of its Board of Governors on whether or not it has proved its viability. The rationale for its foundation is more valid today than when it was constituted. There are encouraging indications that the recent reorganization is beginning to win renewed confidence and support. We propose, therefore, that the Council should come under the general aegis of the proposed Agricultural Research Board in the same way as any other agricultural research organization.

Chapter V

Projections of Future Needs and Priorities

We are acutely aware that projections on the distribution of manpower and expenditures, and for the development of new programs over a five-year period, must be carefully balanced between what is practically possible and what is ideally desirable. To be acceptable, they must be realistic, yet not so patently attainable that they fail to challenge imagination and excite the effort to effect change. There are other hazards. If sufficiently realistic and challenging to promote action, such projections may initiate a pendulum effect, building up a momentum that cannot be checked short of overshooting the original objectives. And finally, objectives judged valid and appropriate under present conditions may outlive their validity and appropriateness in the face of changing conditions.

Projections are increasingly likely to become unrealistic, to overshoot their objectives, and to foster resistance to change, the longer the period over which they are extrapolated. For these reasons we have limited our projections to a five-year period. We believe that realistic projections, capable of achievement, can be made within this relatively short period. At the same time, the five-year limitation will ensure re-evaluation and the opportunity to change direction and emphasis towards the end of this period. The generation of scientific manpower in desired disciplines is particularly susceptible to overshoot because of the time-lag between enrolment and graduation of scientists; for this reason, our projections for increasing the current manpower in the management sciences include a built-in "hold" towards the end of the five-year period. As for challenge, we believe our projections will be seen to have the capability for initiating, and in some respects for achieving, a transformation of the scope and profile of agricultural R & D in Canada.

Our projections are grouped to permit separate consideration of: (*a*) readjustments of the distribution of manpower and expenditures within existing programs, and (*b*) proposals for the staffing and funding of new programs. Throughout, we have developed our projections on the basis of program budgeting rather than incremental budgeting; that is, we have rejected the usual device of proposing general percentage increases each year in favour of projections based on specific programs or proposals. Finally, we have tried to make our projections realistic and responsible by suggesting means for meeting costs by reductions within existing programs.

The Need for Readjustment

The main force of Canadian agricultural research and development is currently directed towards production research supported by an overwhelming emphasis on the natural sciences. Yet many of the more pressing problems facing Canadian agriculture are concerned, not as much with increasing the aggregate production of conventional commodities, as with managing the complex of resources required for their efficient production, with marketing them, and with developing alternative products, new processing, preserving, and transportation methods to extend the industrial and consumer market for agricultural products. These problems require interdisciplinary research with major components of the management sciences at levels not now deployed or available in the context of agricultural research.

We believe, therefore, that a major readjustment is necessary, involving substantial increases in the effort devoted to the management principles of engineering, economics, and sociology, and in their application, in concert with the natural sciences, to agricultural problems at both the operational and policy-making levels.

A second dimension of agricultural research which we believe requires adjustment is the research-development spectrum. As we have reported previously, our data show that about two-thirds of the total effort is devoted to research and the remaining one-third to development and service work; the proportion of effort consciously directed towards development alone is 16 per cent. While we are thoroughly convinced that research in support of agriculture is essential, we believe that the effort devoted to applying the results of research to the direct solution of agricultural problems is disproportionately small. We are unaware of any formula for determining the ideal balance between research and development; as in so many other areas of human endeavour, it remains a matter for informed judgement. Within an applied science there should be growing points where, in fact, the effort is largely or entirely devoted to the search for new knowledge. But across the whole spectrum of a well-established field of applied science we would expect a higher proportion of the total effort to be consciously directed towards immediately useful ends than that reported by the constituent scientists for agricultural R & D.

To meet this need, we do not attempt to establish standards for setting an ideal balance between research and development. Rather, we propose means for generating an increased and self-regulated thrust towards technological development and innovation by increasing the research and development capabilities of the provinces, producers' organizations, and agricultural industry, thus to exploit the self-interest and demonstrated ability of these sectors to perform this kind of work.

These considerations lead directly to the third dimension of agricultural R & D, concerned with the distribution of effort between the performing agencies. Here also, we believe there is need for readjustment. In particular, it seems inappropriate and inhibitory for the full development of Canada's potential for agricultural R & D that the federal government is the dominant partner and the agricultural industry the weakest. We believe there is need and opportunity for a substantially greater involvement of producers' organizations and the agricultural industries as performers and funders of agricultural R & D. The need relates to our conviction that the initiative of the private sector is best stimulated by research and development done in the context and within the security of private enterprise; and that the private sector, as the ultimate users of agricultural R & D, must participate in the total national program from planning to performing and funding. The opportunity relates to the relatively unexploited source of scientific manpower, funds, and innovative drive based on self-interest, that exists actually or potentially in the private sector.

The corollary of this position is that the federal agencies, as performers, should contribute a relatively smaller proportion of the total effort but should assume greater responsibility for the co-ordination and funding of the national program. In particular, the federal government should challenge the provinces and the agricultural industry to accept a greater share of the responsibility for local and industrial developmental research. This redistribution is necessary, we believe, to wean the provinces and industry from overdependence on performance by federal research agencies, and to stimulate their rightful initiative to manage their own research and development programs.

Fourthly, we identify the need for discrete new programs to fill gaps in the current national effort or to strengthen current weaknesses. A common theme in our rationale for these new programs is the need to adapt and apply modern management approaches to agricultural technology, exploiting the systems methods of business and engineering, and generating a body of principles for integrating the various disciplinary inputs and applying them to the comprehensive management of agricultural problems. These new programs, in the form of research centres and support for graduate education, are described later in this chapter in relation to our projections on manpower and expenditures.

Finally, there is need to ensure the continued viability of agricultural scientists and research programs in the face of the rising costs of doing research. These increasing costs result from general inflation and from the increasing sophistication of research equipment and facilities. Failure to provide for these costs will result in progressive deterioration of the quality of research. Our projections therefore include the proposal that budgets for agricultural research and development must be adjusted annually to provide for the increased inflation and sophistication costs of research.

A Mechanism for Readjustment

A major aim of our projections is to effect a substantial increase in the proportionate effort devoted to the management sciences of economics, engineering, and sociology, as compared to the natural sciences. Logically, there are three possible alternatives for achieving this aim.

1. Allow the natural sciences to continue to increase, and add the manpower and expenditures to effect the desired increase in the management sciences.
2. Hold the natural sciences at their present levels of manpower, and add the manpower and expenditures to effect the desired increase in the management sciences.
3. Reduce the levels of manpower now committed to the natural sciences, and use these positions or dollar equivalents to effect the desired increase in the management sciences.

The first of these alternatives was rejected on the grounds that it is unrealistic in the present climate of scientific and political opinion. It would be highly expensive in terms of manpower and dollars and would be unconvincing as a responsible and effective method for readjustment. Depending on the rate at which the natural sciences are permitted to grow, it would have little or no effect on the relative balance between the natural and the management sciences, because of the current massive dominance of the former. Similarly, it would have little effect on the relative balance between agencies, because the dominant agencies–the federal government and the universities–are the most heavily committed to the natural sciences.

The second and third alternatives constitute, in our view, the opposite ends of a spectrum of possibilities for effecting a phased redistribution of effort over the five-year period. At one end, the natural sciences are held at their present level with respect to manpower (though not with respect to expenditures because the costs of inflation and sophistication must be provided to maintain viability), while the management sciences are supported preferentially to grow to the desired levels during this period of readjustment. At the other end, the natural sciences are progressively reduced with respect to manpower, and the resulting savings are transferred to strengthen the management sciences. Obviously, the latitude within this spectrum will depend on the rate of the reduction of manpower in the natural sciences. Obviously too, the process of readjustment will be more rapid and less expensive to the extent that attrition of the natural sciences can be reasonably applied. But the first requirement is for a practical mechanism for transferring manpower from the natural sciences to the management sciences. Clearly, agricultural biologists and chemists cannot be transformed into agricultural economists, engineers, or sociologists. The mechanism must provide for the transduction as well as the transfer of manpower.

The very magnitude of the natural science component offers a means for achieving the aim of strengthening the other disciplines within a more rigorous budget than that resulting from simply adding the required new support to current basic costs. In any research organization, personnel are continually lost to the system through death, retirement, and resignation. This is *turn-over*. By using statistics from the Canada Department of Agriculture, it was calculated that the annual rate of turn-over for agricultural scientists with a bachelor's degree is 12 per cent, and for those with a master's or Ph.D. degree it is 6 per cent. However, not all those lost through resignation are necessarily lost to the system as a whole; they may be merely moving around within it, by transferring for instance, from the federal to a provincial department of agriculture. The Study Group calculated that the net turn-over loss per year is 6.2 per cent of the total population of professional scientists in the agricultural research system. This represents 128 positions vacant each year in a total population of 2 076 natural scientists in all agencies.

This substantial turn-over clearly affords a mechanism for transferring manpower to effect readjustment. These vacant positions, or some portion of them, could be used to create new positions in the management sciences rather than to refill existing positions in the natural sciences. The mechanism would operate as a push-pull device, increasing the growth of the management sciences and retarding the growth of the natural sciences, thus accelerating the process of readjustment between the disciplines. It is in keeping with the science management principle advocated by the Science Council of Canada[1]–that new priorities should be met as far as possible by sacrifices within existing programs.

The management of manpower by transfer of vacancies is a well-recognized and well-used method within government. In principle, there is no impediment and ample precedent for transferring positions or dollar equivalents to other functions, other branches of government, or even to other agencies in the form of grants. However, this management method cannot readily be applied in the university faculties of agriculture and of veterinary medicine where the research function is necessarily confounded with the teaching function. The professor-scientist is employed not only on the basis of his research but also because he is needed to teach students in particular subjects; his research is funded mainly by federal or provincial agricultural agencies, but his teaching function is supported by provincial departments of education or university affairs. Nevertheless, we believe that deans of agriculture have latitude and considerable incentive for transferring vacancies in the natural sciences to strengthen the management sciences in the interests of producing the professional manpower that will be required to effect the desired readjustment in the national system.

[1]Science Council of Canada. Report No. 4, Towards a national science policy for Canada. Ottawa, Queen's Printer, 1968.

There remains the question of the extent to which the 128 vacancies per annum should be transferred from the natural sciences to the management sciences. This, in turn, depends on the extent and rate at which vacancies in the natural sciences can be realistically used to create new positions in the management sciences; the rationale and projections on this matter are developed in the next section of this chapter. Equally important, however, was our concern that the loss of positions should not be at such a rate as to seriously impair the quality of research in the natural sciences. We recognize fully the major and essential role of the natural sciences in agricultural research and development, and the contingent need to maintain its vitality and provide the latitude for program development and change during the period of readjustment. For purposes of this model we propose, therefore, that one-half of the annual vacancies in the natural sciences should be retained for recruitment in these disciplines, and the remainder transferred to strengthen the management sciences. As we will show in the next section, this 50 per cent transfer of the turn-over in the natural sciences is designed to meet the manpower requirement and the entire costs of the proposed readjustment towards a more effective balance between the natural and management sciences.

Obviously, a spectrum of possibilities exists between no transfers from the natural sciences and transfers to the extent of 50 per cent of turn-over within this component. To provide perspective and a basis for our recommendations, we present five-year projections of the consequences in manpower and dollars for models based on each extreme.

Projected Distribution of Manpower and Expenditures

The "R & D Inflation-Sophistication Factor" is defined as the mean percentage increase in the annual costs of research and development per qualified scientist/engineer engaged full-time equivalent in R & D. It is intended to provide a measure of the increased costs of R & D resulting from the rising costs of goods and services used in research (inflation), and the rise in the cost of research per se owing to the increasing complexity of science and its associated instrumentation (sophistication). Quantification of this factor has been developed by studies in the United States and Britain, and has been the subject of a special study conducted by the Science Council of Canada (Special Study No. 6, *Background Studies in Science Policy: Projections of R&D Manpower and Expenditure*). Obviously, an estimate of this factor is necessary for projections of expenditures on agricultural research and development over the immediate future.

In its Fourth Report, *Towards a National Science Policy for Canada*, the Science Council of Canada stated that the best estimate for Canada of the combined effects of inflation and sophistication is an annual escalation of 6 per cent in the costs of research and development. Special Study No. 6, on which this estimate is based, comments on the rather remarkable constancy of this factor between countries and between the sectors of R & D, including the social and "hard" sciences.

The best available data for deriving the inflation-sophistication factor for agricultural R & D are the operating expenditures and associated scientific manpower in the Canada Department of Agriculture for 1963-64 and 1967-68. From these data, the average annual increase in costs per scientist was about 5 per cent over this five-year period, but increased above this rate in the latter part. It seems reasonable, therefore, to adopt the Science Council of Canada's estimate of 6 per cent for this factor as applied to agricultural R & D in Canada.

Accordingly, we conclude that an annual increment, currently estimated at 6 per cent, should be applied to all budgets for agricultural R & D as a matter of necessity to maintain the viability of agricultural scientists and the quality of research programs in the face of the increasing inflation and sophistication costs of research.

With no increase in agricultural research manpower, the costs of agricultural R & D will therefore rise over a five-year period as follows (in thousands of dollars):

Table 10

Present	74 668
Year 1	79 148
Year 2	83 897
Year 3	88 931
Year 4	94 267
Year 5	99 923

The increase over the five-year period is 33.8 per cent above current expenditures, and this increase is mandatory to maintain the viability of the existing research scientists conducting agricultural research and development.

To provide the second and more rigorous model for our projections, we calculated the consequences in manpower and expenditures of effecting the desired readjustment by transfers from the natural to the management sciences, within these annual increases for existing programs. In other words, this model was designed to accommodate the costs of readjustment within the current budgetary commitment for existing programs, *plus* the 6 per cent annual increments to meet the rising costs of research (Table 10).

A major aim of our projections is to effect a substantial increase in the absolute and proportionate effort devoted to the management sciences of economics, engineering, and sociology. The initial problem was to determine what levels of increased manpower can be realistically afforded, achieved, and usefully absorbed, in the management sciences within a five-year period of readjustment. We therefore calculated a series of projections based on various rates of transfer of turn-over from the natural sciences to the management sciences. When these projections were compared with estimates of the realistic needs for strengthening economics, engineering and sociology, it was found that transfers at the rate of about one-half the turn-over in the natural sciences came closest to meeting these estimates. Higher rates of transfer appeared, in our judgement, to be detrimentally severe on the natural sciences, and to release more positions than could be realistically produced or filled in the management sciences during the five-year period; lower rates of transfer would not provide enough positions to meet the need for significant strengthening of the management sciences. Because of the current low proportion of expenditures devoted to the management sciences, the 50 per cent rate of transfer of vacancies from the natural sciences enables the expenditures on the management sciences to be more than doubled during the five-year period, within the above budget projections for existing programs.

Current per capita costs for the support of scientists in the various disciplines (see Appendix C) enable interconversions between expenditures and manpower. In the following items, we have chosen to present, first, the projections for manpower. It is important to note that (*a*) all projections include the 6 per cent per annum increase in per capita costs for both increases and decreases of professional manpower in the various disciplines; and (*b*) all per capita costs *exclude* teaching time for university staff, to provide values for manpower and expenditures devoted to agricultural R & D only.

Projections based on the model of *no transfers* of turn-over in the natural sciences can be derived directly from Table 11. In this model, *all* vacancies in the natural sciences would be refilled with natural scientists, and the objective of strengthening the management sciences to the same extent would require the addition of 362 new positions over the five-year period.

The potential of the model based on transfers to effect maximum readjustment at minimum costs in manpower is obvious. In this case, the economy of manpower is augmented by the fact that current differences in the per capita costs for the support of the natural versus the management scientists make it possible to support 362 additional management scientists by the transfer of 302 natural scientist vacancies over the five-year period (Table 11).

The projected manpower increases in the management sciences must be regarded as conservative. For instance, C. G. E. Downing, commenting in the context of the restricted population surveyed in the CASCC inventory, stated that a fourfold increase in the manpower devoted to agricultural engineering would be minimal.[1] Again, J. C. Gilson, in a survey and analysis conducted subsequent to ours, proposed that the manpower devoted to agricultural economics should be doubled by 1975.[2] We do not disagree with these estimates as statements of need. However, we do question the feasibility of generating and funding these manpower requirements within the next five years. Our more conservative, but still substantial projections are, in our judgement, more realistic.

Manpower can be converted to expenditures on the basis of current per capita costs for the various disciplines and the 6 per cent per annum inflation-sophistication increment. Tables 12 and 13 show the consequences in expenditures over the five-year period on the basis of the manpower projections for the

[1]Downing, C.G.E. Agriculture's Cinderella: Engineering research and development. Agricultural Institute Review, March-April, 1969.

[2]The demand for agricultural economists by Canadian universities and governments. Presented to the Annual Meeting of the Canadian Agricultural Economists Society, August, 1969.

"50 per cent transfer" model and the "no transfer" model, respectively.

Both models provide an approximate doubling of expenditures in the management sciences over the five-year period. The rate of increase for agricultural engineering is somewhat higher because of the higher costs of engineering research and development. The model based on 50 per cent transfer of natural science vacancies provides for this substantial readjustment with no additional costs other than the 6 per cent per annum sophistication-inflation increment. Without transfers, the costs of this same readjustment would be $12 million more in the fifth year; the cumulative costs over the five-year period would, of course, be much higher.

Accordingly, from all the above, we conclude that a major readjustment between the disciplinary components of agricultural R & D is urgently required to achieve a substantially greater capability in the management sciences of economics, engineering, and sociology, relative to the current emphasis on the natural sciences; and furthermore, that the costs of this readjustment should be met in large part, and over a limited period, by transfers of a proportion of the normal turn-over in the natural sciences, with due regard for the continued viability of this component.

A second major aim of our projections is to promote a readjustment of the balance between research and development, in favour of a substantially greater effort on agricultural development and innovation. A major means for promoting this shift is to increase the R & D capabilities of the provinces and the private sector, thus to exploit the self-interest and demonstrated ability of these sectors to emphasize development work. The corollary is that the federal sector should challenge the provincial and private sectors to accept a greater share of the responsibility for local and industrial development by reducing its own responsibilities in these areas. The aim is, therefore, twofold: to promote readjustments towards proportionately more emphasis on development and innovation, and proportionately more performance of agricultural R & D by the provincial and private sectors.

To accomplish this aim we propose, in part, that the federal government should contract with the provincial governments for the total management of a number of the smaller Canada Department of Agriculture research stations concerned primarily with local problems; the management of federal soil survey units should be similarly transferred, since the provinces already accept major responsibility for this work. These contracts should include provincial responsibility for all extension activities. For purposes of the financial projections that follow (Table 14), we have provided in our calculations for the transfer from the federal to the provincial governments of the full support for 25 existing professional positions in these stations in each year over a five-year period. We estimate that at this rate of transfer, the provinces will be responsible for the management of 12 to 15 existing Canada Department of Agriculture research stations at the end of this period.

Accordingly, we conclude that the Federal Government should contract with the provincial governments for the total management of a number of federal research stations and soil survey units, thus to promote increased emphasis on local development work and increased provincial responsibility for managing agricultural R & D in their own interests.

Further to the need for readjustment between sectors of performance, we believe the federal government should reduce its responsibilities as a performer of agricultural R & D in favour of increasing its support of the other performing sectors, particularly the private sector. The mechanism we propose to accomplish this aim is the transfer of a proportion of the turn-over in the natural science component of the federal sector, as positions or dollar equivalents, to the other sectors of performance. The projections that follow (Table 14) include, and show the consequences of, transferring one-third of the turn-over in federal natural scientist positions to the other sectors (21 vacancies in the first year).

The projections provide for readjustments which will approximately double the capability of the provincial and private sectors over the five-year period. The relative expenditure for agricultural R & D performed by these sectors is correspondingly increased, the federal sector is reduced by 9 per cent, and the university sector remains about the same. The total readjustment is accomplished with no additional costs other than the 6 per cent per annum sophistication-inflation increment (Table 10).

Accordingly, we conclude that the Federal Government should reduce its responsibilities for the performance of agricultural R & D in

Table 11–Projected Distribution of Manpower by Disciplines
(Based on the Model of 50% Transfer of Turn-over in the Natural Sciences)

Discipline	Present Numbers	Numbers, Year 5	Change
Natural Sciences	2 076	1 774	−302
Engineering	176	313	+137
Economics	300	474	+174
Sociology	49	100	+51
Total	**2 601**	**2 661**	**+60**

Table 12–Projected Distribution of Expenditures by Disciplines
(Based on the Model of 50% Transfer of Turn-over in the Natural Sciences)

Discipline	Present		Year 5	
	$'000	% of Total	$'000	% of Total
Natural Sciences	61 597	82.5	70 440	70.5
Engineering	5 248	7.0	12 497	12.5
Economics	7 086	9.5	14 988	15.0
Sociology	737	1.0	1 998	2.0
Total	**74 668**	**100.0**	**99 923**	**100.0**

Table 13–Projected Distribution of Expenditures by Disciplines
(Based on the Model of No Transfer of Turn-over in the Natural Sciences)

Discipline	Present		Year 5	
	$'000	% of Total	$'000	% of Total
Natural Sciences	61 597	82.5	82 432	73.6
Engineering	5 248	7.0	12 497	11.2
Economics	7 086	9.5	14 988	13.4
Sociology	737	1.0	1 998	1.8
Total	**74 668**	**100.0**	**111 915**	**100.0**

Table 14–Projected Distribution of Expenditures by Sectors of Performance

Sectors	Present		Year 5	
	$'000	% of Total	$'000	% of Total
Federal	39 616	53.0	43 881	43.9
Provincial	7 901	10.6	15 915	15.9
Universities	21 687	29.1	28 813	28.8
Industry and Private	5 464	7.3	11 314	11.4
Total	**74 668**	**100.0**	**99 923**	**100.0**

Table 15–Projected Distribution of Expenditures by Source of Funds

Funding Agencies	Present		Year 5	
	$'000	% of Total	$'000	% of Total
Federal	44 251	59.3	59 217	59.3
Provincial[1]	22 836	30.6	30 560	30.6
Universities	248	0.3	334	0.3
Industry and Private	7 333	9.8	9 812	9.8
Total	**74 668**	**100.0**	**99 923**	**100.0**

[1]Includes university budgets.

favour of increased performance by the provincial and private sectors, and that the costs of this readjustment should be met in large part by transfers of normal turn-over, or dollar equivalents, in the natural science component of the federal sector.

Finally, the consequences of these projections for the funding of existing programs in agricultural R & D are shown in Table 15.

The projections involve no change in the relative responsibilities of the various sectors for the funding of existing programs for agricultural research and development. The federal government remains the principal source of funds for this nationally important activity; its responsibility will increase to 61 per cent with the additional support required for the new programs outlined in the next section. With respect to funding by the private sector, it must be remembered that these projections are for a five-year period only, during which it will be necessary to provide incentive funding to stimulate the initiative and increase the research and development capability of this sector. Subsequently, we believe that the returns from this investment will stimulate the private sector to increase their funding of agricultural R & D steadily. Proposals for fostering this increased involvement of the private sector are advanced in Chapter VI.

We conclude therefore that the Federal Government should increase its responsibility for the funding and co-ordination of this nationally important activity coincident with reducing its relative role as a performer of agricultural R & D.

Within existing programs there are many specific priority needs within our preceding broad treatment of priorities for readjustment. A number of these are well recognized, as for instance, pesticides research, agrometeorology, and the development of diagnostic methods for animal diseases. Others, we believe, require particular emphasis. Preeminent among them is the need for marketing research, currently supported at a ludicrously low level and desperately needed by all segments of Canadian agriculture. Similarly neglected and in need of priority support are studies on the adjustment of rural people to technological change. In agricultural engineering there is particular need for systems engineering of environmental control and automated handling of materials in livestock production. Throughout agricultural research and development, we believe there will be increasing need for the application of biomathematics and for scientists with high capability in this discipline. Finally, we believe higher priorities are required in food research, concerned with the ultimate use of agriculture, and in plant cell research, concerned with the basic processes on which all agriculture depends.

Accordingly, we conclude that within existing programs high priorities should be given to marketing research, throughout the entire food industry from producer to consumer, studies on rural adjustment, systems engineering in livestock production, biomathematics, food research, and plant cell research.

Projected New Research Programs

In addition to the above readjustments in the structure of the existing national effort in agricultural research and development, the Study Group has identified the need for five new research programs. To give these programs substance, they are proposed in the form of discrete research centres. However, in our view these research centres constitute models with high potential for proliferation in the same context or in other contexts than those we have chosen. They provide models for the integrated, interdisciplinary, systems approach to agricultural R & D, and a means for training the new kinds of scientists needed to propagate this approach. The term "centre" does not necessarily imply the development of physical administrative structures; at least in some cases, the objective can be approached by a realignment of existing resources to focus on the defined program.

The high generalizing capabilities of these research centres, and the importance of their specific missions as outlined below, constitute the rationale for identifying them as first-priority objectives requiring additional new support.

An Agricultural Centre for Bio-Economics Research and Development

Recently, important advances have been made in developing interdisciplinary research involving agricultural economists and natural scientists. Heady and his colleagues at Iowa State University have pointed out areas with exciting opportunities for interdisciplinary research, and have demonstrated how effective this approach can be made. More and more, leading commercial farmers and the industrial users of agricultural research are demanding this kind of approach to the solution of their problems.

The framework outlined opposite provides the means for the systematic integration of economics and the natural sciences in agricultural research and development. The proposed framework is comprised of three major components: an interdisciplinary research group; a management-systems group; and a panel of commercial farmers. All three groups are closely integrated within the framework of an "Agricultural Centre for Bio-Economics Research and Development."

Interdisciplinary Research Group

The interdisciplinary research group is comprised of natural scientists (preferably a balance among animal, plant, and soil science) and production economists mutually interested in the planning, conduct, and execution of various types of interdisciplinary research projects relating to agriculture. The production economists would actively participate with the biologists in the development of experimental designs, the execution of research, and analysis and interpretation of the research results. The results from the various research projects would flow from the interdisciplinary research group to the management-systems group.

The interdisciplinary research group is not intended to supplant, but rather to complement, the research work of the unidiscipline-oriented departments or agencies. Indeed, the interdisciplinary research group will require the basic research findings of the separate and highly specialized scientific disciplines which characterize agricultural research at the present time. It is not likely that the interdisciplinary research group will be interested in probing the mysteries of the cell or in analysing trace elements in the soil; but they will be interested in the extended application of these results to their various interdisciplinary research projects.

Management-Systems Group

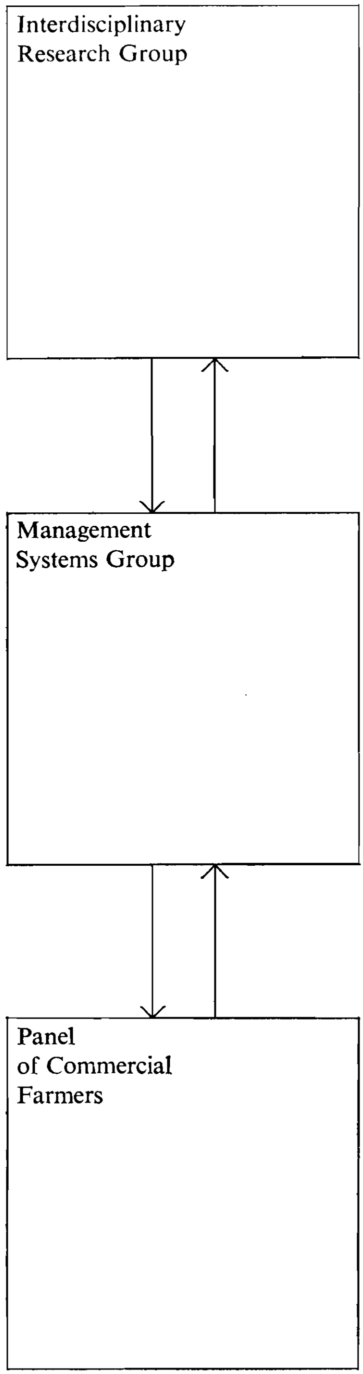
The management-systems group is comprised of another small group of natural scientists and production economists highly trained in mathematics, systems analysis, operations research techniques and computer programming. The management-systems group will require ready access to computer facilities. The group will be responsible for data processing, data storage and the development of simulation models and programs. The simulation models and programs would be designed to provide the commercial farmer or the industrial user of agricultural research with a decision-making framework for the commercial application of agricultural research and technological innovations. All data received from the interdisciplinary research group together with the various simulation models and economic data would be stored in a computer bank. As new data are received from the interdisciplinary research group, or when modifications are necessary in the economic data, corresponding changes would be made in the computer data-bank.

Panel of Commercial Farmers

The panel of commercial farmers will be selected by the management-systems group. The farmers selected would be expected to keep detailed records on their operations and they would have complete access to the management-systems group from whom they would obtain an integrated package of "prescribed" recommendations. The prescribed recommendations would be based on the simulation programs developed by the management-systems group. The problems and needs of the panel of commercial farmers would be fed back, in turn, through the system to the interdisciplinary research group where appropriate changes or refinements may be made in the selection and design of particular research projects. The panel could be extended to large numbers of farmers whose self-interest would involve them in large-scale field-plot testing with rapid feedback of results and elimination of obsolete data.

Administrative Considerations

The proposed Centre for Bio-economics Research and Development does not necessarily require the establishment of new or


Interdisciplinary
Research Group
Management
Systems Group
Panel
of Commercial
Farmers

separate administrative institutions. It would seem more appropriate to initiate such a program at existing institutions where the administrative and intellectual "climate" is conducive to the concept, and where the nucleus of a team of scientists already exists who would be willing and competent to participate in such an undertaking. Ready access to university graduate training and computer facilities is indispensable to the ultimate success of such a program.

The initial stages of the program will, necessarily, be devoted to the development of an appropriate conceptual and methodological basis for the bio-economics research work and for the operations of the management-systems team. Above all, considerable flexibility must be provided in the administrative structure and in terms of the scientific relationships between the production economists and the natural scientists. Provision will have to be made very early for the development of a suitable graduate training program for the production of scientists whose professional training will be well adapted to the type of research work conducted by the Agricultural Centre for Bio-economics Research.

In general, the Centre for Bio-economics Research and Development will provide the framework for greater integration among economists and natural scientists at the research level, and also bring about a systematic integration of research and the application of research at the level of the commercial farmer and the industrial user. The proposed Centre will not replace the need for unidiscipline-oriented research but rather, it will complement and strengthen such research.

The Centre is intended to provide a model which would be expected to proliferate variants designed to serve other regional or commodity problems, and particularly appropriate to the needs of the provinces and industry.

We conclude therefore that within new programs, an Agricultural Centre for Bio-economics Research and Development should be established to develop model systems for integrating research in economics and the natural sciences to yield principles of management and advice for optimizing the production and marketing of agricultural products.

A Population Ecology Research Centre

Agriculture is basically the process of manipulating or managing populations of living organisms to meet man's needs and preferences. This process involves the maximization or optimization of certain populations such as cultivated plants and domestic animals, or the suppression of other populations such as harmful insects, plant diseases, and weeds. Costs and social preferences must also be included in this generalization to allow consideration of optimizing financial and social resources.

Successful agriculture therefore depends ultimately on a thorough understanding of the dynamics of populations of organisms interacting in an ecosystem, and of the principles that govern these interactions. The dynamics of populations within ecosystems involves the influence of a multitude of factors–competition, parasitism, exploitation rates, motility, weather, soil, etc.–on the number of organisms comprising each of the constituent populations. Holistic management of desired populations requires knowledge for predicting and controlling the effects of the complex of interacting factors impinging on them.

One of the greatest gaps in our knowledge of biological phenomena is the principles of population dynamics. There are two basic reasons for this: 1) their significance has only recently been realized; and 2) a new and different method of conducting research is required for their elucidation. Population phenomena are so complex and difficult to study that the traditional approach of the one-man project is completely inadequate. Moreover, their complexity demands a methodical, step-wise research operation that breaks the phenomena into their component parts while at the same time preserving the holistic viewpoint. Such an operation is systems analysis or operations research. The philosophy behind it and the mathematical and analytical techniques it requires were only recently developed, and are only slowly being adopted by agricultural scientists.

Our present deficiency stems not only from inadequacies in our knowledge on the principles of population dynamics. It stems also from our lack of information and methods on a different set of principles: those underlying the application of this knowledge to the manipulation of actual populations and the solutions of real problems relevant to agriculture. Even if adequate basic knowledge on the principles determining the role of nutrition in plant culture or of predation in insect pest control was available (and it is not), we still would not know how to translate this knowledge into action programs–we would not know how to optimize nutritional factors for maximum plant production and yield, nor how to harness predation effectively for the suppression of insect pests.

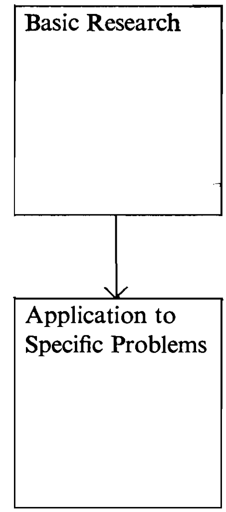
Two things, then, are obviously required: research on basic principles of population phenomena; and research on the principles of applying the resultant knowledge to the solution of practical problems.

Present Research and Facilities

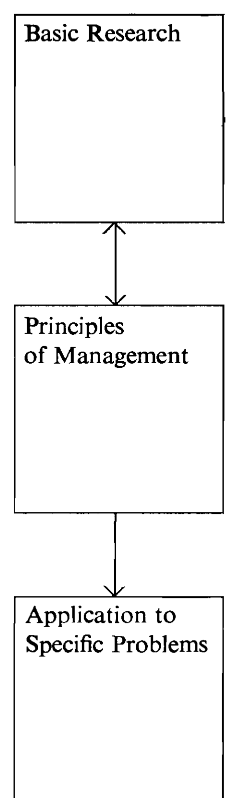
Research aimed squarely at population phenomena and motivated clearly by a desire for understanding them is rare in Canada and throughout the world. Canada occupies a position of leadership in this field by virtue of the efforts of a few men whose work has served to demonstrate the tremendous potentials of the team approach which should now be exploited on a much wider scale. An example is the Green River Project on the spruce budworm in New Brunswick; a closely integrated team working for two decades was able to document the major factors involved in the population dynamics of this forest pest and to suggest practical ways in which mortality factors can be maximized. Another example is the wheat rust team research effort that so justly earned an enviable and enduring reputation for the Canada Department of Agriculture Research Station at Winnipeg.

Such examples, however, are rare and our present research efforts on understanding basic population ecology remain diffuse and unco-ordinated, unexploited, and inadequate.

Research to develop principles for applying such an understanding to the solution of specific population problems is even more inadequate–it is virtually nonexistent. One reason is that this research need also has been recognized only recently. A short time ago applied biologists thought in terms of taking basic research information and applying it directly and immediately to the solution of specific problems of importance, like this:



Now, we recognize that an intermediate step is essential:



For example, it is not sufficient to take all the basic information available on animals broadly, and insects particularly, and to attempt directly to use this information to control pest A on crop B in province C. Rather, this basic information must be integrated to provide, first a basic understanding of animal population ecology and dynamics, and then to develop principles whereby insect populations can be managed or regulated. These strategic principles can then, but only then, be applied to the development of tactics for the control of specific insect pests on specific crops in specific areas.

Another important inadequacy stems from the general failure to recognize that research on the principles of population management must not only be organized and conducted in teams, but that these teams must be truly multidisciplinary. The basic understanding of population ecology on which our future ability to manage populations must rest will be produced by biologists because the phenomena of interest are biological in nature. However, *management* requires much more than the biologist alone can contribute; it requires as well the attention and contributions of economists, sociologists, and engineers, at the very least. Unfortunately, existing administrative compartmentalization in all agencies concerned with population management in agriculture makes the establishment of such multidisciplinary teams difficult.

The Proposed Research Centre

Clearly, what is required as an initial step to overcome these deficiencies is to expand our national research efforts on biological population phenomena, to bring together multidisciplinary teams to develop principles of population management, and to integrate the two components so that there is two-way exchange between the population ecologists and the developers of management principles. This requirement suggests the establishment of an institution charged with studying population ecology and with developing principles of population management. This Centre for Population Ecology will not only contribute to agricultural research and development in the ways already outlined but, hopefully, would provide the leadership and would serve as a model to catalyze population research and its application in other sectors of Canadian agricultural science.

Eventually this Centre could serve Canada beyond the need for managing populations of agricultural importance. Understanding populations and the principles of their management are vital to many other renewable resource fields as well such as forestry, fisheries, wildlife, the total environment, and indeed to the understanding and management of the human population explosion. It should be established, therefore, in such a way that these additional components can be added, and so that it can be co-ordinated with a wide variety of administrative units to which its work is relevant. For this reason, it should not be established in the isolation of any one government department or agency. Eventually, its support could most appropriately be channelled through the proposed Renewable Resources Research Council; initially its formation and guidance can best be accomplished by the proposed Agricultural Research Board.

The Centre itself should contain a large complement of biologists conducting research on basic population ecology designed to elucidate the mechanisms of population dynamics. This research should be both laboratory and field oriented and should be concentrated on all of the phenomena or processes relevant to dynamics such as aging, genetic interactions, natality, mortality, maturation, etc.; and to the major factors involved in these phenomena such as parasitism, predation, competition, nutritions, climate, physical substrate, etc. This research should be organized into complementary teams; it should be experimental and highly quantitative; it should include strong components of biomathematics and biostatistics; and it should rest firmly on the philosophical approach of systems analysis and operational research.

The Centre should contain an equally large component of research on the principles of population management and regulation. As outlined above, this requires the establishment of multidisciplinary teams that will include initially, at the very least, biologists, chemists, economists, mathematicians, sociologists, and engineers; and in the future possibly urban and rural planners, legal experts, and political scientists as well. The strategies of population management cannot be determined alone on a unilateral biological (or any other) basis; questions of interest conflicts and cost versus benefit are absolutely central to such determinations, and specialists on these matters must be integral components of the research teams from the very first moment of the establishment of this Centre.

The Centre should be established in close association with a major university community, if not actually within its administrative framework. This association would enable the Centre to play a role in the education of future scientists in the population field, to benefit from the academic environment and resources of a university, and would protect it to a degree from undesirable involvement in and demands for the direct application of its knowledge output to the solution of specific and pressing population problems. Adequate provision should be made for the movement of individual scientists from both the universities and government through the Centre on term appointments against the background of a large component of resident specialists.

We conclude therefore that a Population Ecology Research Centre should be established to develop principles for applying scientific knowledge to the purposeful management of populations of cultivated plants, domestic animals, and agricultural pests and diseases, by using a broad mix of disciplines and the methods of systems analysis and operations research.

A Research Centre for Rural Adjustment

Sociology focusses the scientific method on the social behaviour of human groups. Agricultural research is the output of human groups of researchers, and it then forms an input to a series of other humans–researchers, teachers, liaison personnel, farmers and consumers. It seems unreasonable to pursue technical improvements scientifically, and then leave the pervasive human element to chance.

Social variables definitely affect the productivity of persons engaged in research and development work. Social factors are equally important in conveying the findings and recommendations of science-based technology to final producers and consumers. Rural sociology has established a substantial body of knowledge concerning the behaviour of rural people and the variables which affect the adoption of new ideas.

Such related disciplines as anthropology and social psychology, together with a number of specialities from general sociology, can make significant contributions to understanding and overcoming many of the current problems of agriculture. In many instances, the poverty of the non-farm population is inextricably woven into the structural problems of agriculture, so that the betterment of the one cannot be achieved without some success in the other. Thus, the anthropologist, who studies the way of life of a disadvantaged minority group living in a rural area, can also make a contribution to its land use problems.

In brief, sociology and related fields provide systematic understanding of human behaviour which is as relevant to agricultural research and development as it is to education, medicine, or administration. The application of relatively small quantities of pertinent sociological findings to agricultural research and development can have the same effects as trace element applications to deficient soil, crops, and livestock.

A Research Centre for Rural Adjustment is proposed to meet this need and to win recognition of sociological research as an integral component of agricultural R & D. The Centre would provide a major means for generating the professional staff to rectify the current virtual absence of sociological research oriented towards agriculture. It would also carry out some of the more basic and innovative research required for the advancement of the field and the stimulation of the staff of the more applied units. Such a Centre, would consist of an interdisciplinary research team located at a university which has already a substantial department of sociology and anthropology, and a well-established faculty of agriculture with strong departments of agricultural economics and extension education. With this supportive institutional setting, the team would be in a position to work at a high level of efficiency both in its research and in its work with graduate students enrolled in related departments of the university.

Typical research problems for the Centre would include:

a) Basic culture-and-personality research on rural subpopulations to obtain an inside view of the people for whom agricultural and regional development programs are framed.

b) Reviews of agricultural policies (federal and provincial) and the extent to which they have assisted or prevented the full impact of the adoption of improved technology.

c) Studies of the assumptions underlying programs and procedures of various agricultural extension services, e.g. focus on commodity groups rather than rural people.

d) The life cycle of selected agricultural policies–a chronicle of a given policy from its initiation with an individual or group, through legislation, program formulation, funding, specification of operating procedures, implementation, farmer and public reaction, subsequent repercussions and (or) modifications, etc. The discrepancies between intention and outcome would become evident, together with lessons to reduce such gaps, in this and other instances.

e) A series of interdisciplinary studies of the interrelations between agriculture and finance, agriculture and education, agriculture and health, agriculture and family life, etc.

f) A total systems approach to disseminating the concepts of regional development to disadvantaged rural residents through a concerted use of every relevant means to communicate concepts and motivate people by creating a pervading climate of opinion favouring action by all concerned.

In addition to its primary research and graduate training functions, the staff of the Centre would also provide consultation with operational agencies as a means of obtaining first-hand data with which to identify research problems, as an opportunity to demonstrate the value of sociological research, and to promote acceptance of forthcoming graduates of the training program. A clearinghouse function, particularly with regard to published material, would also be provided by the Centre.

The number and nature of the professional staff of the Centre would vary over time depending on the current research foci and the particular strengths and weaknesses of the relevant university departments. However, an initial configuration should include a group of sociologists associated with at least one specialist in each of anthropology, economics, and social psychology. Particularly appropriate for the initial Centre, and for its proliferations at other universities, are the opportunities for cross-appointments of staff between the Centre and relevant university departments, and for the joint education of graduate students in this important interdisciplinary field.

We conclude therefore that a Research Centre for Rural Adjustment should be established to promote research on the pervasive social factors involved in the technological transformation of agriculture, its repercussions on rural life, and the social adjustments necessary to optimize the benefits for rural people.

An Atlantic Resource Management Centre

Resource adjustment will evidently be a major activity in the Atlantic Provinces for at least the next 10 years. Current and projected agreements between federal and provincial governments call for the expediture of hundreds of millions of dollars in the rationalization of the traditional rural industries of the region–agriculture, forestry, and fishing. For these plans and funds to be effective, hundreds of persons must be trained in interdisciplinary fields relating to the management and harvesting of renewable resources, and in methods for extending these ideas to obtain the acceptance and participation of local people. The situation presents an unusual opportunity for experimentation in holistic approaches to resource management and in the education of professionals to work in this field.

An Atlantic Resource Management Centre is proposed to meet this opportunity with an institution focussed primarily on *development* rather than research, and on generating professional resource managers rather than disciplinary scientists. The Centre's main aim will be to influence the development of the region's renewable resources so as to increase labour productivity and total income from the continued and improved use of these resources. In this context, the creation of new knowledge is secondary to attention to the transfer and application of knowledge and techniques to problems of regional development. This will require the kind of careful judgement and imaginative adaptation which could be engendered when regional youth are provided with both technical and social science training in a developmental climate. A generation of university graduates must be produced who will feel that such a career is both satisfying and meaningful. Through their participation in a learning community many may commit themselves to shared goals and then permeate the agencies of government and industry across the region for a concerted effort to achieve what to some now seems impossible.

The curriculum in this program, by way of illustration, could consist of an initial core of two years of arts and sciences followed by an emphasis on (*a*) the applied social sciences as related to economic, social and cultural change, extension, etc. and (*b*) the application of the natural sciences to agriculture, forestry or fisheries with relation to the development of these industries. Initially, it is not envisaged that this Centre would have a graduate research and training program. It would be characterized by a service orientation to the region, initiating studies on particular regional resource problems and providing consulting services. Regional problems would be used as a basis for teaching management principles, and students as well as staff would participate in developmental studies and consulting services, thus to produce graduates possessing the knowledge, skills, and attitudes relevant to regional development.

The Centre must of course be established as an integral part of an Atlantic university, and with opportunity for close association with one or more universities or federal institutions conducting research in agriculture, fisheries, and forestry, to exploit the possibilities for cross-appointments. Our projections provide for the initial employment of a director, the construction and equipping of a building, and the phased recruitment of a staff consisting of ecologists, sociologists, and economists over a five-year period.

Although this Centre is designed to meet the particular needs of the Atlantic region, and to exploit the current opportunities in that region, we believe it will constitute a model with high potential for adoption in other regions. Moreover, like our proposed Population Ecology Research Centre, the Atlantic Resource Management Centre extends beyond the traditional boundaries of agriculture to provide an arena for practical interaction with the other renewable resources; this is one of the kinds of interaction we anticipate will be fostered by a Renewable Resources Research Council.

We conclude therefore that an Atlantic Resource Management Centre should be established to develop a capability for the multidisciplinary application of scientific knowledge required to direct the large-scale adjustment and development of Atlantic industries based on renewable resources, including agriculture.

Centre for Research on Cold and Drought Resistance in Plants

Successful crop production depends upon the successful management and manipulation of plant growth and development. Growth and development, and the responses of plants to environmental stress, are the results of the co-ordinated interplay of genetic and environmental factors on physiological and metabolic processes. Water supply and temperature are paramount among the environmental factors that affect growth under field conditions. Variation in temperature limits the growing season throughout Canada, and limits the rate of growth in many environments. Damage from low or freezing temperatures is an ever-present annual threat, particularly in the spring and fall. Water supply is the major limiting factor in crop production in almost all areas of Western Canada. However, most of the 100 million acres of arable and potentially arable land in the West lies in latitudes subject to the hazards of both cold and drought stress. In addition, on the prairies, low soil moisture levels combined with high surface temperatures can result in heat injury to emerging seedlings.

Despite modern developments in large-scale irrigation, in cloud seeding, and in frost avoidance through the use of burners or foams, man's ability to control water supply and temperature in the macroenvironment is still very limited in relation to the vast areas of land under cultivation. Modern research has indicated that resistance to heat, cold, and water stress all have a common cell-biological basis. Genetic work has shown that many genes are involved, but our knowledge in this area lags a long way behind our knowledge of the genetics of resistance to plant diseases, such as the rusts.

Clearly, what is required is basic and applied research on the genetics, ecology, and cell biology of cold and drought resistance. This area of research holds great potential for increasing food production and is one in which Canada should be pre-eminent.

Virtually all the research on cold and drought resistance in plants at present underway in Canada is being conducted in laboratories of the Canada Department of Agriculture. The Cell Biology Research Institute in Ottawa has developed an excellent program on the cellular basis of cold resistance. Other work on winter hardiness is being conducted at Lethbridge and Beaverlodge, Alberta, and at Prince George and Summerland, B.C. Work on drought resistance is being conducted at Saskatoon and Summerland.

However, the effort currently directed to this research (about 10 man-years) is quite inappropriate to the importance and scope of the problem. Moreover, the current effort is scattered and lacks the cohesion of disciplines and of purpose that could be derived from a research centre with frost and drought resistance as its central theme and objective. Such a centre should be developed in close association with a faculty of agriculture and a federal research station with climatic opportunity for investigating this problem.

We conclude therefore that a Research Centre for Cold and Drought Resistance should be established to intensify basic research on the physiology, biochemistry, and genetics of resistance to cold and drought, thus to seek means for extending current efficiencies of crop production in Canada.

Projected Manpower and Costs for New Research Programs

To provide projections on the costs of these new programs, we have estimated the manpower we believe will be required to staff the proposed Centres over a five-year initial period of development. We estimate that a total of 70 scientists at the Ph.D. level will be required. By disciplines, our estimate comprises 33 natural scientists, 14 economists, and 23 sociologists. Within these traditional disciplines, special skills in biomathematics, computer science, systems analysis, and operations research will be required in some of the staff. Quite senior and distinguished people will be required to act as directors and team leaders. It will be important to launch these programs under the direction of the best leaders available anywhere in the world. Until our graduate program can catch up, it seems certain that some of the required staff will have to be recruited from outside Canada. The concepts embodied in the proposed Centres are, we believe, sufficiently challenging and novel to attract superior scientists; equally important, however, is the assurance of whole-hearted support over a limited period to test fully the validity of the programs.

Expenditures for the new programs were calculated from the estimated manpower requirements, by using current per capita costs for support in each discipline, as derived from the survey data. Increased costs resulting from inflation and sophistication are applied at the rate of 6 per cent to all existing staff in each year. In addition, capital costs for buildings and equipment are considered necessary for the Population Ecology Centre and the Atlantic Resource Management Centre, and are included in the projected expenditures for these Centres. Apart from these capital expenditures, costs will increase from year to year as additional staff are added. A summary of these projected expenditures for new programs is presented in Table 16.

Projected Needs for Manpower Production

The projections for readjustment within existing programs, and for the proposed new programs, will require the production of additional engineers, economists, and sociologists. No additional production of natural scientists is proposed because the current rate of production is expected to continue and to be adequate to meet the need for replacements over the five-year period. However, the current production of engineers, economists, and sociologists educated to the M.Sc. or Ph.D. levels is grossly inadequate to meet the projected needs. Because of the time required to educate graduate students, the early stages of the expansion of the management sciences will have to be staffed in part by recruiting from sectors other than agriculture or from foreign sources. This timelag in the production of graduate scientists makes it essential that additional new support for graduate students in agricultural faculties should be provided immediately to begin to train the scientists our projections show will be needed.

To determine the needs for additional manpower in engineering, economics, and sociology, we have calculated for each year of the five-year period the additional manpower required for the projected readjustment within existing programs, for the proposed new programs, and for the manpower required to replace annual turn-over. The sum of these three *less* the current production of graduate programs in these disciplines yields the net need for additional graduate scientists over the five-year period. These needs can be stated in terms of the

Table 16–Projected Expenditures, New Research Programs

Programs (Research Centres)	Years[1]				
	1	2	3	4	5
	$'000	$'000	$'000	$'000	$'000
Bio-Economics	190	261	337	417	502
Population Ecology	100	2 281[2]	1 473[2]	826	1 051
Rural Adjustment	180	241	305	373	445
Atlantic Resource Management	200	1 312[2]	531	863	1 065
Cold and Drought	100	226	348	487	640

[1]All expenditures include the 6 per cent per annum inflation and sophistication factor applied to all existing staff in each year. Costs for staff and their support are calculated from the survey data on current per capita costs.

[2]Includes capital costs for building and equipment.

Table 17–Requirement for Additional Staff in the Management Sciences

Disciplines	Year 1		Year 2		Year 3		Year 4		Year 5	
	M.Sc.	Ph.D.	M.Sc.	Ph.D.	M.Sc.	Ph.D.	M.Sc.	Ph.D.	M.Sc.	Ph.D.
Engineers	11	21	11	22	12	23	12	24	13	24
Economists	16	31	16	32	17	33	18	34	18	36
Sociologists	5	8	5	9	6	9	6	9	5	9

Table 18–Number of Additional Students Required to Produce New Staff in the Management Sciences

Disciplines	Year 1		Year 2		Year 3		Year 4		Year 5	
	M.Sc.	Ph.D.	M.Sc.	Ph.D.	M.Sc.	Ph.D.	M.Sc.	Ph.D.	M.Sc.	Ph.D.
Engineers	36	36	72	36	75	36	39	36	0	36
Economists	51	54	105	54	108	54	54	54	0	54
Sociologists	18	14	36	14	33	14	15	14	0	14

Table 19–Projected Expenditures for New Program of Student Support in the Management Sciences

Disciplines	Year 1	Year 2	Year 3	Year 4	Year 5
	$'000	$'000	$'000	$'000	$'000
Engineering	360	540	555	375	180
Economics	525	795	810	540	270
Sociology	160	250	235	145	70
Total	**1 045**	**1 585**	**1 600**	**1 060**	**520**

Table 20–Summary of Projected Expenditures

Disciplines	Present		Year 5	
	Expenditures	% of Grand Total	Expenditures	% of Grand Total
	$'000		$'000	
Natural Sciences:				
Existing Programs	61 597		70 440	
Population Ecology Centre			1 051	
Frost and Drought Centre			640	
Subtotal	**61 597**	**82.5**		**69.3**
Agricultural Engineering:				
Existing Programs	5 248		12 497	
New Program, Student Support			180	
Subtotal	**5 248**	**7.0**	**12 677**	**12.2**
Agricultural Economics:				
Existing Programs	7 086		14 988	
New Programs, Student Support			270	
Bio-Economics Centre			502	
Subtotal	**7 086**	**9.5**	**15 760**	**15.1**
Rural Sociology:				
Existing Programs	737		1 998	
New Programs, Student Support			70	
Rural Adjustment Centre			445	
Resource Management Centre			1 065	
Subtotal	**737**	**1.0**	**3 578**	**3.4**
Grand Total	**74 668**	**100.0**	**104 146**	**100.0**

numbers of M.Sc. and Ph.D. graduates required, by assuming that the current proportion of Ph.D.'s in the community of agricultural scientists (64%) will pertain in these disciplines. The results of these calculations are shown in Table 17.

To produce these numbers of scientists will require substantially higher numbers of graduate students to be enrolled in the graduate schools. Various factors operate to reduce the yield of graduates entering careers in research and development below the numbers of students enrolled in any one year. M.Sc. students require on the average 2.5 years from their bachelor's degree to obtain the higher degree; the corresponding average for Ph.D. students is 5 years. Therefore, the numbers of students and the associated support funds must be provided in year 1 to produce the required number of M.Sc.'s in year 3 and of Ph.D.'s in year 6. In year 2 and subsequent years, students and funds *additional* to those already provided will be necessary to meet the needs in years 4 and 7, and so on. Allowance must also be made for the losses resulting from students who fail to complete their degrees, and those who enter fields other than agricultural research and development. To provide a basis for estimating the numbers of students and associated funds required, we have assumed that these losses amount to two-thirds of the enrolment of M.Sc. students, and one-third of the enrolment of Ph.D. students; we have assumed also that one-half of all students enrolled for the master's degree will proceed directly from obtaining this degree to studies for their Ph.D. (Our data suggest that one-half the current Ph.D.'s in agricultural R & D also hold master's degrees.) Finally, a return to the current level of production is assumed after year 5 as a *holding device* to allow for reassessment and to prevent the possibility of over-production in the management sciences.

Using these assumptions, we provide, in Table 18, estimates of the number of graduate student enrolments required in each year of the five-year period to meet the projected staff needs.

The funds required to support a graduate student for stipend, equipment and supplies, computer time, survey expenses, etc. is usually estimated at $5 000 per year. Translating the above student numbers into annual expenditures at this rate yields the projected costs of the new program for graduate student support in the management sciences, as shown in Table 19.

We conclude therefore that a new program of graduate student support in the management sciences should be inaugurated and funded at the levels and with the checks suggested, thus to produce the additional engineers, economists and sociologists required for readjustment within existing programs, and to staff the proposed new programs.

Summary of Projected Expenditures

The overall expenditures and the associated shifts in emphasis resulting from our projections for readjustment within existing programs, new research programs, and a new program for graduate student support are shown in Table 20.

Table 20 shows that these projections will achieve a significant shift in the proportionate emphasis on the management sciences over the five-year period. In absolute terms, the support for agricultural engineering and economics has been approximately doubled, and support for the currently neglected social sciences has been increased approximately fivefold. A new program of graduate student support is provided to meet the needs for new staff and replacements in the management sciences. New research programs are also provided to fill specific gaps in the current national effort and to serve as models for the multidisciplinary operations research approach to the management of agricultural problems. Finally, the projections provide throughout for the application of a 6 per cent per annum increase to maintain the viability of agricultural scientists in the face of inflation and the increasing sophistication of agricultural research and development.

A most important feature of these projections is the demonstration that normal turn-over in the natural sciences provides a mechanism for effecting readjustment at minimal cost. Transfers of a portion of vacant positions or dollar equivalents from the natural sciences to the management sciences can in fact cover the cost of readjustment *and* pay for the new programs. With respect to current expenditures for agricultural R & D, our budget projections accomplish a substantial increase in support for the management sciences by redistribution of funds within existing programs, leaving only the 6 per cent annual increment for inflation-sophistication and the new programs to be supported by additional revenue over the five-year period. We believe these projections provide realistic and responsible means for effecting challenging changes and vigorous development of Canadian agricultural research and development.

Chapter VI

Mechanisms for Achieving Dynamic Balance

Our principal proposal for achieving dynamic balance in agricultural research and development in Canada is the establishment of an Agricultural Research Board. This organizational mechanism provides the basic capability for monitoring the national effort, and for detecting and promoting change in response to changing priorities and opportunities. Moreover, the composition of the Board provides representation from all performing and funding sectors, thus ensuring sensitivity to the whole system.

However, the effectiveness of this organizational means for reacting to the changing needs and opportunities for agriculture depends crucially on the ability of the performing sectors to respond by appropriate adjustments at the operational level–hence our concern about means to improve flexibility to meet changing priorities, to effect economies through collaboration between agencies, to foster the interdisciplinary mix, and to encourage greater participation by industry.

Flexibility to Meet Changing Priorities

Increasingly, science and technology are the agents of social change and the swiftness of change. Inevitably, these changes create new problems which usually require quite different scientific approaches for their solution. It follows that science itself must be capable of swiftly changing its approaches to meet the new set of problems. The process amounts to a kind of feedback system in which science generates change and must then respond in new ways to the new situation. In short, science must increasingly develop the flexibility to meet the changing priorities of science and society.

This flexibility is not easily achieved in agricultural science or in any other applied science operating on a national scale in Canada. Serious impediments exist as a result of the training of scientists and the organizational structures within which they work.

Typically, the candidate scientist spends 8 to 10 of his most formative years in the academic environment, and achieves his first professional satisfactions in an apprentice relationship with his professors. Inevitably, his personal attitudes, goals, and ideas of prestige are influenced by those of the university and his professors. A common result is that his first choice for employment is in a university. Because some form of teaching experience is normally included, the long academic preparation constitutes an on-the-job apprenticeship for a career as scientist-professor. But if he lacks the predilection or opportunity for an academic career, he nevertheless tends to transfer the academic pattern to other forms of employment. This pattern, with its emphasis on the scientific excellence of the individual and on the freedom to choose problems for their scientific interest alone, is often inimical to the team approach and the search for solutions to particular problems of social significance which should characterize the mission-oriented agencies.

In short, it seems to us detrimentally restrictive to allow the necessity for the academic education of scientists to impose, however fortuitously, an academic pattern on the scientific community as a whole. We believe that scientists would be better prepared for adaptation to changes in occupational demands if there was general recognition of other value systems, more immediately relevant to the needs of society, and that many would then find greater satisfactions and productivity within them.

Another factor tending to restrict the flexibility of the individual scientist is the disciplinary compartmentalization of his education. Typically, the 8 to 10 years of university studies leading to the Ph.D. degree are spent mainly within one disciplinary department, albeit at several universities. This disciplinary restriction is narrowed further by the requirement for specialized knowledge in a subdiscipline and intensive research on a particular problem within it. Commonly, the scientist graduates with an implicit disciplinary label attached to his Ph.D. and with little actual or psychological preparation for collaboration in interdisciplinary research.

Finally, the Ph.D. thesis often tends to fix the scientist's interest on its subject matter and techniques to the extent that he seeks to extend them into a lifelong career. The requirement for conducting and communicating a significant piece of research is an essential part of the education of a scientist. Clearly too, it must be focussed on a narrowly defined problem. But its proper role is as a specific, intensive *exercise* in the development of a *general capability* for the scientific solution of problems. To fail to utilize this general capability in favour of a continuation of the specific exercise is to thwart the fundamental objective of higher education and to risk irrelevance in the face of social change.

Obviously, there are brilliant exceptions to these generalizations, both in Canadian agricultural research and in the general case of academic scientists adapting to highly applied research projects during war-time. This fact raises important questions about how best to maximize the generalizing potential in the education of scientists, and minimize the restrictive tendencies we have noted. But before we can approach these questions we need to know much more than we do about the initial aspirations, fears, prestige associations, and value systems which motivate students towards a career in science, and how these motivations are modified during their subsequent employment.

We believe that these matters are amenable to sociological research, as outlined in Chapter III, and that this kind of research is urgently needed. While there are undoubtedly general characteristics of science and scientists as a whole, we believe further that research on the sociology of science will be most meaningful when directed towards a particular field such as agricultural research.

We conclude therefore that research on the characteristics of the education, employment, and motivations of agricultural scientists should be undertaken to guide and maximize the diverse talents of individual scientists and to foster fruitful collaboration between them.

Continued self-education is implicit in a scientific or any other scholarly career. However, the rate and diversity of scientific and technological change suggest the need to foster this process in directed ways and in the context of particular employment situations. It seems to us therefore that it would be enlightened self-interest for scientific institutions to encourage and support their constituent scientists to update and re-orient their efforts to meet changing opportunities and priorities.

Less than one-third of the agricultural scientists in Canada have ever had any exposure to professional refreshment in the form of postdoctoral fellowships, sabbatical leaves, or transfers of work in settings outside their normal employment. Moreover, nearly 57 per cent of agricultural project leaders reported that they had spent their entire careers within the same employment setting. This "stay-at-home" pattern augurs poorly for the dynamism of agricultural research. Since more than 60 per cent of these agricultural scientists have been educated to the Ph.D. level, it seems wasteful in the extreme to allow this large investment to deteriorate with time and the advance of knowledge. As the Economic Council of Canada has emphasized, the educational equipment acquired during initial schooling can no longer be expected to last a lifetime but will require periodic repairs and alterations to remain relevant.

This need, as applied to agricultural scientists, has been recognized in the universities through the device of sabbatical leave, and in the Canada Department of Agriculture through educational leave and "transfer of work" leave. However, both types of institution appear to operate these schemes within restrictions on the number of individuals granted leaves in any one year and, therefore, on the basis that such leaves are granted as a privilege rather than as a right or obligation. We believe this attitude is short-sighted. We suggest that employers of agricultural scientists should encourage, support, and even *require* their scientists to take periodic leave to update and redirect their work, and that this should be done simply as a means for protecting the employers' large capital investment in scientific manpower from potential obsolescence.

The low proportion of agricultural scientists who have had any form of postdoctoral leave cannot be attributed solely to the resistance of employers. From our experience, it results also from the reluctance of many scientists to expose themselves to a period of re-education. Many university scientists consider it a virtue that they have never taken a sabbatical, and many scientists from the Canada Department of Agriculture have never requested a transfer of work. For this reason, we suggested in the previous paragraph that employers should *require* their scientists periodically to take a form of educational leave, as in fact some American universities do with respect to sabbatical leaves.

We conclude therefore that employers of agricultural scientists should institute appropriate forms of periodic educational leave as a norm of the employment of scientists, thus to protect from obsolescence their most valuable asset.

The orientation of university scientists to their employment setting is virtually assured by their long apprenticeship in this same environment. However, since only 35 per cent of agricultural project leaders are currently employed in the universities, it seems desirable to provide orientation towards other careers, particularly in the mission-oriented agencies. Otherwise, the academic attitudes acquired during the formative years of university education will remain dominant, often to the detriment of effective and personally rewarding work in applied agricultural research. Too often, we believe, the mission-oriented agencies themselves fail to discriminate between their research goals and those of the universities so that the new Ph.D. graduate is recruited with the implicit understanding that the same goals and standards pertain. We believe important gains in morale and motivation would result if mission-oriented agencies were to take deliberate formal measures to screen scientist candidates for their aptitude to oriented research, and then to inform them fully through an orientation program on the broad goals, immediate objectives, the components of past successes and failures, and their role as individuals in the future of the organization. Against this background of understanding, subsequent redirections of effort will be more acceptable and more challenging to all concerned.

Flexibility in the individual scientist's approach to his research should be encouraged and reinforced by the reward system of promotion and salary increase. Currently, scientists have good reason to believe that the quickest way to promotion is to concentrate on a particular problem by using a few standard techniques, and to ring the changes on it through a long series of publications. Persistence is undoubtedly an attribute of the scientist but it should be coupled with the competence and initiative to change the method of attack within established problems, and to shift objectives from old to new problems according to scientific opportunities and social needs. This suppleness can be extended further by cultivating an acquaintance with the concepts and methods of a disparate discipline so that collaboration at the interface between disciplines opens new approaches to the solution of problems. At the other end of the spectrum we recognize the danger of dilettantism, but see it as the lesser danger because it runs counter to the traditional reinforcement for establishing oneself as an authority on a particular subject. We suggest that versatility in the individual scientist should be encouraged and rewarded by including, in the criteria for his advancement, evidence of his ability and efforts to bring new techniques to bear on his research, and to diversify his research to more than one particular problem.

In the search for individual excellence, we believe more use should be made of the probationary period of employment, and more rigorous standards applied to the granting of permanency. Probationary periods of two years or less, as commonly used to establish tenure in the universities and permanency in governmental civil services, are too short a period to judge the abilities and aptitudes of a newly graduated scientist. The granting of permanency is a most crucial step in the construction of a research establishment; yet, short of dereliction of duty or gross misconduct, permanency is virtually assured after completion of the probationary period. Much longer probationary periods coupled with a rigorous procedure for granting permanency would, we believe, have a salutary effect on the future excellence of agricultural research. Each permanent appointment should be approached from the point of view that confirmation involves a potential commitment of employment to retirement–currently, for as much as 35 years. We believe that this important decision should be based on a careful evaluation of performance over a probationary period of four to five years for newly graduated scientists; shorter probations or none at all might be required of more experienced scientists depending on the pertinence and extent of their experience. Challenged in this way, the young scientist would be expected to exert his full capacity for development during this formative period and establish effective work habits for a productive career.

We conclude therefore that longer probationary periods should be used to evaluate and orient young scientists before tenure is granted; and that evidence of research versatility should be included in the criteria for the promotion of agricultural scientists.

Besides providing the climate and opportunity for the continued development of their permanent staff, research establishments can improve their flexibility through the use of short-term appointments for specific, limited objectives. Such appointments afford an efficient means for exploring high-risk research approaches or testing promising leads or mounting a major short-term program without an indefinite commitment of scientific manpower to the objective. Short-term appointments also provide a means for bringing disparate disciplines to bear for discrete inputs to long-term projects. And, most importantly, they can provide a succession of newly trained challenging minds moving through a research establishment to introduce new techniques, new knowledge, and to open new pathways for the solution of old problems.

The universities have many of these advantages by virtue of their teaching function. Graduate students, in particular, bring young minds to bear on discrete research problems for limited periods of two to five years, advancing their professors' programs and keeping them alert through a relationship in which the professor is both teacher and pupil. Postdoctoral fellows or research associates, visiting professors and nontenured appointees serve the same purpose at a more sophisticated level. But, except for the relatively few NRC Postdoctorate Fellows and the equally few seconded graduate students, Canada Department of Agriculture and provincial agricultural scientists do not share these advantages.

We believe it is highly important to seek means for extending this element of flexibility to the governmental sector. We suggest that some established positions should be filled, as vacancies occur, with scientists on short-term contracts for specific assignments. Precedence for this device exists in use of permanent positions by the National Research Council to employ a succession of Postdoctorate Fellows. We have in mind that at least 10 to 20 per cent of governmental agricultural scientist positions might eventually be held for "permanent vacancies" to employ scientists on term contracts of up to five years. This mixture of normal permanent employees with a succession of short-term employees would provide an important means for self-refreshment and would greatly improve the capability of the scientific work force for responding to changing priorities and opportunities. We realize that this proposal involves an innovation for governmental civil services, with respect to scientists, but the objective is so clearly consistent with their responsibility for improving the efficiency of government services that we are confident means can be found to accommodate it.

We conclude therefore that a significant proportion of the budget for governmental agricultural scientist positions should be converted, as vacancies allow, to a new class of position reserved for the employment of scientists on short-term contracts for specific research objectives, thus to counter the tendency towards perennial projects and to provide a means for responding to changing priorities and opportunities.

Agricultural research in the government service is subject to other strictures. Government departments of agriculture, like any other government departments, must be politically responsive. Political considerations may therefore conflict with scientific considerations. For instance, the Canada Department of Agriculture Research Branch has more than once initiated action to close one of its smaller research stations, on grounds of research priorities and the more efficient use of research personnel and resources, yet have been prevented from doing so by local political pressure to retain the station. We believe that our proposal for a politically disinterested and prestigious Agricultural Research Board will influence such decisions to be made on the basis of program budgeting and research priorities.

Government departments of agriculture have many responsibilities other than research. Problems associated with the marketing of agricultural surpluses, with subsidies for the support of particular segments of the agricultural industry, and with the administration of regulatory acts must regularly loom larger than research on the agenda of a Minister of Agriculture and his immediate colleagues. Despite clear recognition of the importance of research to departmental goals, as marked for instance by the position of Assistant Deputy Minister (Research) in the Canada Department of Agriculture, the urgent day-to-day affairs tend to take precedence over the more easily deferred matters relating to research. Moreover, because of their lack of immediacy, research programs offer tempting targets when budget cuts are imposed. We believe that our proposal for an Agricultural Research Board will serve significantly to buffer the long-term planning and development of agricultural research against the exigencies of government by bringing the advice of a prestigious national body to bear on relevant government decisions.

Finally, the traditional safeguards on the spending of public money and on the employment of public servants impose restrictions on flexibility at the operational level of research establishments. Currently, these safeguards provide the rationale for a paternalistic pattern of management of research establishments by departmental headquarters. Ideally, we believe the directors of government research establishments should be assigned broad objectives, consistent with national or regional goals, and should then be given complete responsibility, authority, and accountability for managing the budget and personnel allocated to the establishment to achieve these objectives. To a degree, this ideal has been recognized, and greater discretionary powers have been granted to directors of establishments in recent years. But directors must still seek approval for expenditures above certain amounts and within certain categories of their assigned budgets, for changes in programs, and the deployment of personnel. These are matters of tactical management which should, we believe, fall clearly within the authority of directors. In general, these men are carefully selected for their scientific competence, initiative, and responsibility. Their talents will not be fully challenged or exercised, nor can they be held accountable, as long as full authority for the management of allocated resources to achieve assigned objectives is withheld. Our view on this matter is consistent with that of the Royal Commission on Government Organization which made proposals for "... placing responsibility and the necessary degree of authority to discharge it in the hands of the government's operating management, the only place where the necessary links can be forged between people and programmes, between performance and objectives."[1]

We conclude therefore that directors of government agricultural research establishments should be assigned full authority for the tactical management of their resources to achieve the broadly defined objectives assigned to their establishments.

[1]Report of the Royal Commission on Government Organization. Vol. 1, Queen's Printer, Ottawa, 1962. p. 300.

Collaboration Between Agencies

The diversification of Canada's capability for agricultural research between the federal and provincial governments, the universities, and industry is, in our view, highly desirable. These different agencies with their different central roles and degrees of proximity to agricultural problems have, together, a high potential for serving the wide spectrum of research required for the effective application of science to agriculture. However, each agency can profit by collaboration and exchange with other agencies, without losing its essential identity. We are not concerned here with administrative co-ordination, but rather with means for promoting collaboration at the operational level. We believe there are largely unexploited opportunities for collaboration between agencies in the conduct of agricultural research and development and in the production of graduate students.

Currently, the various National Committees sponsored by the Canada Department of Agriculture annually bring together research workers in specific areas of agricultural research, regardless of affiliation, to exchange information and plan informally the next year's program. This is a healthy arrangement, provided only that no one agency is allowed to impose its particular objectives and planning on the other agencies. Interagency collaboration can develop also around a particular project, as for instance the rapeseed project in Saskatchewan which ultimately involved the Canada Department of Agriculture, the National Research Council, and two industrial firms. Other examples involve collaboration between federal and provincial scientists in the Canada Land Inventory, and between university and scientists of the Canada Department of Agriculture in the supervision of graduate student theses research.

Our proposal for transferring the operation of a number of the smaller regional research stations from the Canada Department of Agriculture to provincial departments of agriculture will, we believe, open a significant new channel for collaboration between these agencies. The personnel of these stations will bring established contacts with their former colleagues to their new institutional role, thus providing a ready-made basis for collaboration and reciprocal understanding. With the clear focus of the provincial agencies on the developmental end of the research spectrum, we would expect more effective feedback to ensure that their needs are met by the more basically oriented research stations of the Canada Department of Agriculture.

Temporary exchanges of scientists between agencies should be widely encouraged and supported. Important reciprocal benefits would accrue to individual scientists, their institutions, and agricultural research as a whole by opening these individual channels of communication to counter parochialism. We have in mind the transfer of interested and mutually acceptable individuals, within their current employment status, to a new and stimulating research setting for a period of one to two years. Such transfers from industry and government establishments to universities should involve some teaching duties as well as research, and would be highly desirable both for the refreshment of the visitor and as a means for orienting students and professors to the challenge and opportunities in applied research. Transfers in this direction could be regarded as a form of "transfer-of-work" as currently used by the Canada Department of Agriculture Research Branch.

Transfers in the opposite direction would be designed to accommodate university professors seeking a period of relief from teaching duties to concentrate entirely on their research in appropriately staffed and equipped government or industrial laboratories. University sabbatical leaves could be exploited for this purpose; however, to attract professors under this arrangement, industry and government establishments would normally have to provide some financial incentive because sabbatical leaves are usually granted with only partial salary payments.

We believe these exchanges would prove especially important for encouraging the greater involvement of industry in agricultural research, and that preference should be given to opportunities for temporary transfers of scientists from industry to the laboratories of other agencies.

We conclude therefore that a formal program of temporary transfers of scientists between agencies conducting agricultural research should be initiated to improve active collaboration, to promote interaction and communication, and to counter parochialism.

The education and training of graduate students offers an important objective and opportunity for interagency collaboration. Our projection of the future needs for agricultural scientists indicates that our current production must be increased, particularly in certain fields, if Canada is to meet its own needs and its international obligations. The responsibility for this increased effort will fall, of course, on the universities because of their central role in education. But participation by other agencies would provide important assistance and open viable channels of communication between agencies.

The most obvious participant in this kind of collaboration is the Canada Department of Agriculture Research Branch. This agency, as previously noted, has excellent research facilities at many of its institutes and stations, and many staff members whose research qualifications and standards easily meet those of their counterparts holding university appointments. Yet, in general, these scientists and their facilities remain reproductively sterile, lacking the stimulus and the function of generating their kind. Canada cannot afford this prodigality of scientific talent. These scientists could contribute much to the production of agricultural scientists, to the benefit of their own research and at no extra cost to the system as a whole. Furthermore, the orientation towards non-academic careers in applied research would be automatically promoted in those students given the opportunity for taking a part of their graduate education in a mission-oriented research establishment. And finally this whole argument is capable of extension to selected industrial and provincial laboratories as well as the Canada Department of Agriculture establishments, as a means for increasing the production of agricultural scientists and for proliferating understanding and laying the basis for future extensions of collaboration within the entire interagency dimension of agricultural research.

The onus for the failure to exploit first-class competence outside the traditional forms of graduate education lies mainly with the universities. This position was stated by the Dean of Engineering at Carleton University during a recent symposium:[1]

"I submit the university has to take a much broader view. I think you have to involve all people in the educational process. I think you must realize that competence lies outside the university. Our right, within the

[1]Collaboration in research. Canadian Research and Development. Nov.-Dec. 1968. pp. 22–23.

university, is that conferred by the state to grant and govern degrees, but I think we can devise methods to broaden our approach. I know this is not the traditional university point of view, but I think it is one that has to be accepted more and more."

In Britain, the Sutherland Report[1] carefully considered the extension of graduate education to include government research establishments, and concluded that there are important advantages and encouraging precedents for this form of collaboration. In Canada, at least three universities have formal agreements with government research establishments on their campuses to provide for participation by selected government scientists in graduate education.

Within our context, the location of a number of Canada Department of Agriculture research establishments on or near university campuses has encouraged informal and individual arrangements for shared responsibility in the education of graduate students, particularly by joint supervision of their thesis research. About 20 Canada Department of Agriculture establishments are involved in these arrangements, some of them remote from university campuses although most of the graduate students are accommodated by those on or near campuses. Dr. R. Glen, then Assistant Deputy Minister (Research) for the Canada Department of Agriculture, informed us of the following instances of collaboration between universities and establishments of the Canada Department of Agriculture in 1967. Besides this participation in the research supervision of graduate students, staff of the Canada Department of Agriculture contributed to university teaching, committee work, and research projects.

Research Supervision of Graduate Students using CDA Facilities

Supervision	M.Sc. Students	Ph.D. Students	Total
By CDA Personnel	18	27	45
By University Personnel	12	7	19
Total	**30**	**34**	**64**

[1]Report of the working party on liaison between universities and government research establishments. Council for Scientific Policy. Her Majesty's Stationery Office, London, 1967.

Despite these precedents, we know from our many interviews and from a symposium we convened on this subject that, in general, the universities remain tentative or resistant towards this kind of collaboration. Certainly there are valid concerns and the need for safeguards to protect the university's role and to ensure the student of a full educational experience. But the advantages to agricultural research as a whole offer compelling reasons for actively seeking such safeguards and working arrangements acceptable to the universities and to those agencies with the competence to enter this form of collaboration. The exchange program, which was announced in July, between Carleton University, the Canada Department of Agriculture and the National Museum of Natural Sciences, in Ottawa, appears to meet this aim precisely. Government scientists will be appointed as adjunct professors in the university, and government research facilities will be available for use by university staff and students. We applaud this development.

The universities must, of course, be the leading partners in all collaborative arrangements for the education of graduate students–their standards for awarding their degrees must be maintained. It follows that the university must have competence in the research areas chosen for joint supervision of graduate studies. The procedure and objective should be precisely the same as that when a university department or research group seeks to strengthen an established area of research by adding a new staff member. That is, individual scientists in the regular employ of non-academic research establishments would be considered by the staff of the department or research group as potential graduate supervisors and selected by the same procedure as full-time colleagues. Scientists invited to serve in this capacity would be granted an appropriate rank with associated rights and privileges. Their responsibilities should also be without restriction as to type, including when appropriate to the university and commensurate with their normal employment, teaching at either the graduate or undergraduate levels within their special authority. However, their central role and responsibility would be focussed on the supervision of the thesis research of particular graduate students. They would be involved from the beginning in planning and evaluating the student's program of courses and research along with their university colleagues on his Supervisory Committee and would take primary responsibility for the supervision of the student's thesis research. This research must be closely related to the interests of the research establishment and the authority of his supervisor in that establishment.

To provide for flexibility and turn-over, we suggest that the "tenure" of such appointments in the university should be limited to the period from initiation to completion of the particular graduate student's program. To take advantage of both milieus for learning, the student would spend most of his time during the first part of his graduate education in the university for course work and for establishing relations with professors and fellow students; the latter part would be spent mainly at the research establishment of his supervisor for concentrated research and interaction with his supervisor and other scientists, and for the establishment's research facilities. However, during this latter period, contacts with the university should be maintained by meetings with the Supervisory Committee, by presentation of and attendance at seminars, by journal club meetings, graduate student associations, and so on.

If these proposals are to be given force, the universities must assume the leadership. With suitable safeguards, such as those suggested above, we believe the universities can serve their own interests by broadening the educational experience and diversifying the employment opportunities of some of their students. Moreover, by grasping their rightful initiative in this matter, the universities can counter the criticisms of insularity and the cyclical production of professors, and open through their students new and continuing channels for communication and collaboration between research agencies. It could prove to be a decisive and self-perpetuating move towards maximizing the use of our total resources of manpower and facilities for agricultural research.

To achieve these benefits, the graduate schools and faculties will have to take a less reactionary view and liberalize their regulations to recognize non-academic institutions as regular partners in graduate education. Moreover, it will be necessary, initially at least, to encourage and support staff members to seek opportunities for this kind of collaboration. The non-academic institutions on their part must undertake that all research completed under these arrangements is freely available for publication under joint authorship of the student and either or both of his university and institutional supervisors, as appropriate to their contributions. Under current conditions, it will also be necessary in many cases for the non-academic institution to assume part of the cost of the graduate student's stipend.

We conclude therefore that the universities should actively seek and promote collaboration with government and industry research establishments in the education of graduate students, thus to maximize the use of manpower and facilities for the production of agricultural scientists and to provide a continuing mechanism for the improvement of communication between agencies.

Fostering the Interdisciplinary Mix

Throughout this report we have emphasized the multidisciplinary nature of agricultural research. In the broadest terms, the disciplinary components are the natural sciences, engineering, economics, and sociology. *Within* these components, interaction between the constituent disciplines and subdisciplines is practised and promoted in the conduct of agricultural research. Within the natural sciences, for instance, biologists, chemists, physicists, and statisticians commonly collaborate in various mixes to solve agricultural problems. Moreover, an increasing number of natural scientists have acquired a degree of competence in one or more of the cognate disciplines or subdisciplines so that they are able to conduct research at the interfaces in their own right or through informed collaboration. These generalizations apply equally, if not more so, within economics, or engineering, or sociology applied to agriculture.

In fact, it is interaction at this level–between the constituent specialties and specialists *within* these broad disciplinary groups–that is generally meant and understood when we speak of interdisciplinary research. However, the need for interaction *between* the disciplinary groups has not been generally recognized and is virtually nonexistent in the current conduct of agricultural research. Yet, we believe that the promotion of interaction at this level is now essential for agricultural research to respond adequately to the increasingly complex management problems of agriculture. Recognition of the management sciences of engineering, economics, and sociology as integral components of agricultural research, and their application in appropriate mixes with the natural sciences, constitute the most important unexploited opportunity for improving the relevance of research to modern agriculture.

An applied science is necessarily a multidiscipline science. The more applied the objective of a piece of research, the more likely the requirement for the viewpoints and techniques of several disciplines. In fact, as research progresses along the spectrum from the generation of knowledge for its own sake, to the application of knowledge to a particular human enterprise, to the development of a particular useful device or process, the need for inputs from other disciplines increases. An applied science is also committed to generating new knowledge on the principles, and developing methods for applying these principles to the practice, of managing a total process, situation, or resource. In this process, engineering, economics, and sociology, concerned with the management of materials, capital, and human resources, have particularly pertinent viewpoints and techniques to contribute. Many instances can be cited, of course, where natural scientists attacking agricultural problems have reached successful solutions yielding improved management practices with no apparent input or collaboration with the other disciplines. In our view, these gifted individuals have in fact been thinking and acting as engineers, or economists, or sociologists in applying their knowledge of natural science to the improvement of agricultural practice. However, we believe that this fortuitous and generally unsophisticated approach will no longer serve to meet the increasingly complex problems of agriculture requiring holistic solutions. Hence our concern about means for fostering the interdisciplinary mix.

Our proposals for increasing the numbers of agricultural engineers, economists, and sociologists will in itself increase the opportunities for interdisciplinary research. At present, the populations of these scientists are so low that they are needed and used mainly for research within the clear boundaries of their disciplines. For instance, all economists employed by the Canada Department of Agriculture are assigned to the Economics Branch and none are currently assigned or seconded to the Research Branch for collaboration with its natural scientists and engineers. Similarly, all university sociologists doing research of significance to agriculture are currently clustered in departments of sociology and none are employed in faculties of agriculture with opportunities for interacting with other types of agricultural scientists. The phased increase we have proposed for these relatively scarce scientists will, we believe, provide the basis and increase the probability for interdisciplinary contacts, communication and collaboration.

However, the opportunities created by increasing the numbers of agricultural economists, engineers, and sociologists will not be fully realized without deliberate, planned efforts to encourage and support their involvement in interdisciplinary research. These efforts must be directed at least as much to the re-orientation of the natural scientists as to the management scientists. All are ill-prepared for interdisciplinary research of this kind by the disciplinary departmentalization of their education and the consequent difficulties of communication across gaps in vocabulary and concepts. Organizational means for bringing the disparate disciplines within the same institutional setting will not necessarily yield the desired result. Witness, for instance, the faculties of agriculture which embrace under one administration and in close physical proximity all the component disciplines of agricultural research (except sociology) yet produce little research planned and executed jointly by natural scientists, economists, and engineers. A climate must be developed in which the scientists themselves are convinced that new, exciting, and important avenues for research are open to those willing and able to span the disciplinary barriers, and that participation in this kind of research need not involve sacrificing their disciplinary bases.

Educational preparation for interdisciplinary research obviously should not attempt to bring even the most gifted students to research competence in two disciplines. The result would be superficiality in both. Every scientist must acquire during his initial education a firm basis in the concepts, techniques, and practice of his chosen discipline. But during this period he should be exposed early and often to the multidisciplinary nature of agricultural research, its disciplinary components, and an introduction to their principles and working methods. The essential point is to create an awareness of the pertinence of the interdisciplinary approach to agricultural problems and to establish an attitude which recognizes this approach as a valid and rewarding method of research.

The graduate research thesis offers another opportunity for reinforcing this viewpoint by providing an actual experience in interdisciplinary research. At present, the graduate thesis is supposed to provide an exercise in strictly independent research under the general guidance of a supervising professor. Yet, during their employment careers, scientists will be required increasingly to work collaboratively in teams, especially in the applied fields such as agricultural research. We suggest therefore that the faculties of agriculture and veterinary medicine should begin to experiment with forms of the graduate research thesis which will provide the apprentice scientist with experience in collaborative research with other graduate students.

Finally, beyond the university we believe there are opportunities for the mature scientist to prepare for participation in interdisciplinary research. Postdoctoral leaves or transfers for this specific purpose should be supported preferentially, subject only to the normal criteria for the appropriateness of proposed training.

But the commonest and eventually essential step will be taken when an engineer seeks advice of a biologist, or an economist, or a sociologist. By finding common interests in the problem and the potential for solving it by a joint attack, each sets himself to learn what he needs to know of the other's discipline.

Interdisciplinary research is increasingly necessary, we believe, for generating principles and developing models for the holistic management of agricultural problems. Several of our proposals for new research centres involve the institutionalization of interdisciplinary research groups for this long-term purpose. Interdisciplinary research is also highly appropriate and increasingly required for the direct application of principles and research findings to the solution of particular problems. This is the "pay-off" end of agricultural research, where it is particularly important that scientific advice to the user should be couched in terms of his total operation which will almost always include economic factors and often engineering and human factors. The use of interdisciplinary teams for the integration and application of existing knowledge to the direct solution of problems can transform the developmental end of agricultural research in Canada.

For the purpose of direct problem-solving, we suggest that temporary assemblies of appropriate specialists in scientific task forces is the method of choice. The objectives for such task forces should be highly discrete and terminable. In general, they should not be concerned with generating new knowledge but with integrating existing knowledge to yield advice, often in terms of probabilities and alternatives, on the management of a specific production, processing, marketing, or social adjustment problem. The input of the economist and the engineer with their operations research and systems analysis techniques will often be central. The scientists selected for such task forces should be amenable to the philosophy that characterized much war-time research–of putting themselves in a service relationship to meet the challenge of an immediate and pressing problem. The task forces could be assembled by cross-appointments or temporary secondment of member scientists from their administrative bases to which they would return on completion or termination of the mission.

It will be essential, in our view, to resist the temptation to give such groups administrative reality by organizing them into departments or institutes. Our taxonomic tradition will ensure for a long time an adequate base of labelled, categorized, research units in administrative hierarchies; the temporary, mobile, interdisciplinary task force provides a healthy diversity. We believe therefore that such task forces should never be institutionalized by buildings or by budget arrangements other than those provided by the contributing agencies for strictly limited periods. These scientific task forces for problem-solving in agriculture offer a new dimension, not only for extending the developmental end of agricultural research, but also for purposeful collaboration between universities, government, and industry in the service of agriculture.

We conclude therefore that interdisciplinary research, particularly the interaction between the natural and management sciences, should be encouraged and supported by educational preparation, by establishment of the interdisciplinary research centres we have proposed elsewhere, and by the use of scientific task forces for specific problem-solving, thus to *improve the developmental end of agricultural R & D and to promote the integration of knowledge for the holistic management of agricultural problems.*

Fostering the Involvement of Industry

We are convinced that agricultural research in Canada is in danger of becoming increasingly irrelevant to the problems of modern agriculture unless there is substantially greater involvement of the industry it serves. Consistent with this conviction, a number of our previous proposals are designed to foster this greater involvement. In particular, we see it as essential that producers' organizations, the processing industries, and the agricultural chemicals industry should have representation on our proposed Agricultural Research Board; in addition, we believe that a share of the merit appointments to this Board can validly be drawn from industry. By this means, industry will be provided, for the first time, with a voice in national policy and decision-making for agricultural research. Participation by industry at this, the highest level of national planning and integration, will provide a most effective means for ensuring that agricultural research and development remains relevant, simply because decisions will be reached in full partnership with the principal users. Furthermore, our proposals for increased financial incentives for the conduct of research by agricultural industries, and for a higher proportion of the national effort on developmental research are, we believe, complementary. The self-interest of industry dictates, and our data show, that work performed or funded by the private sector is strongly oriented towards development and innovation; and successful innovation provides the source and incentive for further investment in research by industry. Finally, we believe that the agricultural industries should play an important role in effecting our various proposals for improving flexibility to meet changing priorities, collaboration between agencies, and in fostering the interdisciplinary mix, by involving their scientists and contributing their management expertise.

In this section, we are concerned with mechanisms for the greater involvement of the agricultural industries as performers and as funders of agricultural research and development.

We are well aware of the Canadian lament that industrial R & D in this country is stultified because most of it is done by parent companies in the United States or abroad, or the results are available as manufacturing licences or patents. Certainly, this is an important reason for the fact that 53 per cent of the United States budget for agricultural R & D is performed or funded by industry, while the corresponding statistic for Canada is about 7 per cent. Certainly, too, we agree that Canada should exploit research findings and technologies developed elsewhere in product areas where we lack the base industries and pilot-plant facilities needed for instance in the primary development of pesticides. However, these arguments apply to only a portion of the agricultural industries, and only partially within that portion; they apply mostly to the agricultural chemicals industry, much less to the agricultural processing industry, and scarcely at all to the agricultural producers. In addition, there is the largely unexploited field of scientific consulting services which is open to development for the solution of specifically Canadian problems.

We believe, therefore, that there is ample latitude now visible for substantially greater involvement of industry in agricultural research, development and innovation. We suggest further that this greater involvement will generate a new climate of entrepreneurship in the industrial sector which will discover new opportunities, now unforeseen, for profitable product development and services based on Canada's great resources of land and water for agriculture.

Opportunities now visible include, for example, research and development leading to innovations in food products, processing and packaging; the development of improved varieties of useful plants and animals; innovations in farm machinery and farm structures; the development of improved storage and transportation systems for agricultural products; the development of bioengineering systems for the disposal or utilization of agricultural wastes; provision of analytical services for leaf and soil analyses, pesticide residues, etc.; provision of custom services such as the prescription and application of crop protectants; and the provision of consulting services based on sophisticated analyses and projections of the operations of individual producers, commodity groups, or regional development projects.

To foster the involvement of industry in agricultural research and development, it is necessary for government to play a support role by funding and by adapting its own research programs to mesh with those of industry as opportunities occur. A principal method for funding industrial R & D should be provided in the form of contracts for discrete R & D projects designed to meet particular needs or exploit new opportunities, and to fit the existing scientific talents, facilities, and profit interests of particular industries. Such contracts should enable selected firms to assemble around their own staffs, scientific and technical task forces of the type discussed in the previous section, and to tool up their research facilities as required. The terms of such contracts should also provide the contractor with preferential rights to negotiate for licensing or patent rights if the research should yield a commercial product or process. Latitude should be allowed also for subcontracting particular facets of the research, for instance to university specialists.

An example of the need and use of such contracts is afforded by the current lack of pilot-plant facilities and engineering studies in food research and development, except for those in a few major food-processing companies; promising leads obtained from basic studies in the Food Research Institute of the Canada Department of Agriculture, for instance, could form the basis for a contract with one of these companies to test and develop a commercial product or process.

Again using the food-processing industry as an example, we believe there is need and potential profit for allied groups of smaller companies, now virtually without research and development capabilities, to form research consortia to support a research facility preferably located in an environment such as that provided by the Sheridan Research Park Community in Toronto.

Besides the support derived from government contract research, industrial research and development related to agriculture should be financially assisted by the federal government on the basis of a percentage of actual expenditures for research by individual companies or groups of companies, as recommended for industrial research in general by the Economic Council of Canada. We would expect the proposed Agricultural Research Board to be alert to any opportunities to provide financial assistance for imaginative industrial research and development programs through either or both its own authority and by advice and support for assistance available under the Industrial Research and Development Incentive Act.

The federal government's role in support of industrial research and development extends not only to financial assistance but also to its own research programs. Government research programs have the potential for being competitive and inhibitory rather than supportive of private research; this is true also for provincial and university research programs. For instance, the lack of private firms in Canada based on the development of improved and hybrid crop plants, such as exist notably in the United States and Sweden, can be attributed mainly, we believe, to the inhibitory effect of government and university programs aimed at this same objective. Moreover, judging from some of our interviews with industry and at least one brief submitted to us, there is a tendency not only to surrender to government paternalism but to demand that government perform research and development functions which we believe rightfully belong to a healthy and aggressive agricultural industry. Too often, government-developed innovations are not taken up by private industry because they are protected by public service patents which thwart the proprietary interests of potential developers, or more importantly, because they have not been developed in the context of a particular company's operations. It seems to us most important, therefore, that government and university research programs with a potential for industrial development should be designed to develop only the basic findings or materials and the model projections required to excite the initiative of industrial developers. This process will be most successful when there is early and intimate communication between government or university scientists and the scientists in the appropriate industry sector. Merit credits should accrue to those government and university scientists whose research, and imaginative communication of it, lays the foundation for a successful commercial development.

If the role of industry in agricultural research and development is to be enlarged to become the major influence we believe it should be, then its involvement must be total. That is, given a place in national policy and decision-making, financial assistance, and a favourable climate for research collaboration, industry must be prepared also to invest risk-capital in agricultural R & D, both intramurally for work in its own clear interest, and extramurally for work of general importance in areas peripheral to its interests. Moreover, we are convinced that the long-term interests of the agricultural industries will be well served by actively seeking extensive involvement in collaborative research with other agencies and in the education and training of agricultural scientists.

Realistic and responsible interest in this total involvement on the part of producers' organizations was made clear to us in a brief submitted by the Canadian Federation of Agriculture, from which we quote as follows:

"In our statement of policy it will become clear to you that the feeling of farm organizations is increasingly that they must become more deeply involved both in the doing of research of certain kinds, and in assisting in the better identification and promotion of research needs. For this, it will itself need to become better equipped in staff and program.

"In this connection, while it would be difficult to give a detailed picture of farm organization plans and activities in the research field across the country, there are, at national and regional levels, three developments related to your interests of which you might like to take note:

"1. At its recent Annual Meeting in January our organization passed a resolution in support of the request of prairie farm organizations for the creation of a farmer-financed and farmer-run grain research fund, using the mechanism of deductions from Wheat Board payments for collecting the money. An initial one-year deduction of 1/10 of 1 per cent of total Wheat Board payments is suggested, creating a fund of perhaps $1 million which would be placed at the disposition of a Board composed of representatives of prairie organizations. The thought here is that there is a place for farmer initiatives in a number of research fields related to the production, marketing, promotion and transportation of grain. The support of the Study Group for this proposal would be appreciated.

"2. As a result of a series of national conferences on swine improvement, originated on the initiative of the CFA, a Canadian Swine Council has been formed. It is at present in the early stages of organization only. It hopes and expects soon to develop a system of financing from producer deductions which will enable it, among other things, to carry out and constructively promote improved and expanded research in the fields of swine breeding, production and marketing.

"3. A Canadian Beef Improvement Conference was held in 1966 under the joint sponsorship of the Canadian Cattlemen's Association and the Canadian Federation of Agriculture. This Conference showed, we think, clearly that research in beef breeding, and pasture and farm management, particularly, is definitely inadequate. Here again, producers showed a sharp awareness that they themselves must acquire increased funds to participate adequately and constructively.

"These examples are we think of interest in themselves, and also are clear indicators of the increasing concern of farmer organizations that they play a more positive and active role in stimulating, guiding and carrying out necessary research, not only in the field of marketing, but in basic areas of productivity improvement."

This statement heralds a new development in Canadian agricultural research and development. Models for this development exist in the well-established commodity research centres, initiated by producers and supported by levies on their production, in the United Kingdom, New Zealand, and Australia. Such centres provide the ultimate mechanism for direct response to the producers' needs for research and development. As such, we would expect programs initiated and supported by producers to be strongly oriented towards development, innovation, and management studies, thus to improve what we regard as an imbalance in the current national effort. We suggest that producers' interests would be served best at present by directing most support towards multidisciplinary management studies in the commodity area providing the support. We suggest further that our proposal for a Bio-Economics Research Centre, providing as it does direct participation by producers with feedback of prescription management advice and alternatives, constitutes a model with potential for adaptation to many commodity and regional problems. Financial assistance from producers' organizations to ensure the full development of this model would, we believe, constitute a sound investment. Producers' interest in economics research, especially marketing research, clearly points to the open opportunity for funding university chairs, scholarships, and research projects in these areas, either directly or through the proposed Agricultural Research Board, with the objective of improving the available numbers of agricultural economists, now in such short supply. Finally, we believe that producers' initiative in sponsoring agricultural research and development should be encouraged and supported by proportional grants funded through the Agricultural Research Board.

We conclude therefore that the agricultural industries, both primary and secondary, should be supported and should themselves participate as a major force in agricultural R & D at all levels from national policy and decision-making to research, development, and innovation in their own interests, in collaboration and without competition from publicly supported agencies, and that the proferred financial interest of commodity groups of producers should be exploited and directed mainly toward management studies in their area of interest; all this, we believe, in the interests of maintaining the relevance of agricultural R & D to modern agriculture and for the benefit of the Canadian economy.

Chapter VII

Agricultural Research and International Development

At the United Nations Conference on Trade and Development in 1968, Canada agreed to achieve, as soon as possible, a level of foreign aid equal to at least 1 per cent of its Gross National Product. The Agricultural Institute of Canada believes that this is a minimum objective and a minimum responsibility, considering that "foreign aid" is defined to include loans and private capital movements, as well as grants for technical assistance, food aid, capital projects, etc. The Institute states that this acknowledged objective is one "...that Canada is yet a long way from achieving. It should be met, and as it is now defined it should, indeed, be exceeded and in the near future."[1] Thus, Canada and the technical agriculture community within it have recognized the responsibility to contribute substantially to international development through the use of Canadian agricultural productivity and of Canadian expertise in agricultural technology.

The disadvantaged countries have in general neglected agricultural development in favour of non-agricultural industrial programs. However, there is now a growing conviction among all participants that the need is for balanced programs embracing both agricultural and industrial development, and providing for their essential interdependence. Thus, the simple transfer of agricultural production technology to the less developed countries will not be enough. Additional technologies are required, overlapping with industrial development, and concerned with the storage, preservation, processing, and transportation of agricultural products. Of overriding importance is the need to transfer the techniques for systematic management of agricultural resources with particular concern for sociological differences. In short, agricultural development in the less industrialized countries must be as broadly based as it is in the industrialized countries. We believe therefore that much of the basic philosophy and the particular emphasis on the scientific management of agricultural development advanced in this report are highly pertinent to the problems of agricultural development in the less developed countries.

We do not attempt a comprehensive treatment of Canada's role in agricultural international development in this short chapter. The subject has been well-reviewed recently by the Agricultural Institute of Canada[2] and by Hudson and Shefrin[3]. Rather, we wish to add our support to the consensus that Canada has the obligation and resources to make a telling contribution in this area; and beyond that to suggest mechanisms for ensuring that this contribution is made with greatest effect abroad and least disruption at home.

Current Organization and Support for International Agricultural Development

Canada's central agency for international aid and development is the newly organized Canadian International Development Agency (CIDA). This Agency is responsible for the co-ordination of Canada's participation in many multilateral programs conducted by United Nations organizations, and of bilateral programs between Canada and selected countries. However, agricultural technical assistance represents a very small part of the programs under the aegis of CIDA. The Agency has only a few agricultural scientists abroad, and has so far developed no specific policy in the area of agricultural research, development and technical education.

Both the Canada Department of Agriculture and the Agricultural Institute of Canada have recently made organizational moves towards greater participation in technical assistance programs. The Canada Department of Agriculture has established an External Aid Unit to collaborate with CIDA on matters of policy, personnel, and direct participation, with respect to agricultural technical assistance. The Agricultural Institute of Canada in its declaration of policy[4] has advanced its qualifications and proposed the role for its participation, as the most broadly based professional agricultural organization in Canada, "...to establish a systematic and consultative relationship..." with CIDA, and "...to establish the necessary committees and consultative and working arrangements for this purpose."

Total Canadian aid to the less developed countries is far from achieving the agreed goal of 1 per cent of the Gross National Product. In 1967-68 it amounted to $319 million, or less than 0.5 per cent of the Gross

[1]Food and peace: a declaration of policy. The 48th Annual Meeting and Convention of the Agricultural Institute of Canada, 1968.

[2]Food and peace: a declaration of policy. *Ibid.*

[3]Hudson, C. and Shefrin, F. Canada's contribution to agricultural foreign aid. Can. J. Agric. Econ. **16**: 61–73. 1968.

[4]Food and peace: a declaration of policy. *Ibid.*

National Product. The largest item in the Canadian cumulative bilateral program was for direct food aid to meet emergency shortages (40%), and the smallest for "other, including specific agriculture and rural development projects" (7%). An overriding restriction on the acceptance of Canadian technical assistance is the current requirement that developing countries must pay all local costs, including housing, local help, equipment, and facilities. Within the declared goal there is, therefore, latitude for a much greater thrust towards the transfer of technical knowledge and skills in the vital agricultural sector.

Canadian agricultural technical assistance programs include Wheat Breeding Program in Kenya; Agricultural Mission to India; Dairy Mission to Trinidad; Dairy Project Development in Korea; Rural Development Mission in Morocco.

Commenting specifically on Canada's contribution to agricultural technical assistance, the Development Assistance Committee of the Organisation for Economic Co-operation and Development stated in its report for 1966:

"Canada's technical assistance potential would seem to be considerable in terms of the existing domestic stock of highly qualified manpower in certain agricultural subjects and in view of the existing agricultural training institutions. It should be noted, however, that the Canadian authorities themselves see serious limitations to expanding their supply of skills; in their view, 'technical assistance for agriculture has not been stressed because Canadian experience is not particularly adaptable to the problems of developing countries.' "

Needs and Mechanisms for International Agricultural Development

The Study Group takes strong exception to the alleged statement by Canadian authorities that the expertise of Canadian agricultural scientists is inapplicable to the problems of developing countries. We reject this position on the basis of principle and of fact. In principle, we believe that the generalizing nature of scientific knowledge permits its extension to a wide range of particular circumstances, often with renewed vigour and new insights. In fact, Canadian agricultural scientists have demonstrated their capability for transferring and applying their knowledge to problems in Kenya, Ghana, Ethiopia, Thailand, Korea, India, Morocco, and the Caribbean Commonwealth.

The Study Group believes that Canada has an opportunity, unequalled in the world, to use its competence in agricultural technology for the benefit of the less developed countries. No other country combines Canada's political acceptability abroad with the capacity and excellence of our capability in agricultural technology and education. We believe, therefore, that agricultural technical assistance should be used as a major means for meeting Canada's responsibilities for international development.

Technical assistance in the form of agricultural research and education is, in our view, most likely to yield maximum benefits when concentrated in a few selected countries. There is a growing consensus in Canada and elsewhere favouring such bilateral arrangements.

A second maxim is that agricultural education and the transfer of technical skills are best accomplished in the context of the agricultural and food production problems of the less developed countries. It is increasingly evident that Canada and other donor countries will have to find more suitable environments than their own universities to educate agricultural scientists and train technicians from the disadvantaged countries; too often this training disorients foreign students from the kinds of problems needing solutions at home, unfits them for cultural readaptation in their own countries, and seduces the best of them to seek job opportunities abroad.

On the basis of these considerations, the Study Group believes that the following three types of programs provide appropriate mechanisms for Canada's role in international agricultural development.

1) Education and Research Centres in Third Countries

Since it is unrealistic to organize centres for agricultural education and research in each country receiving Canadian assistance, Canada should support a few institutions in a limited number of "third" developing countries for this purpose. These institutions and countries would be chosen to provide a broadly comparable environment suitable for the training of research workers and technicians from the less developed countries who would be oriented towards the solution of problems similar to those in their own countries. Such a program would be of benefit to, and should be undertaken with the active collaboration of, the "third" or host country. On both sides of the equator there are suitable countries for training students from English-speaking and French-speaking countries which receive technical assistance from Canada.

We believe these centres should educate and train the great majority of graduate students from the less developed countries currently receiving advanced education in our own universities. The programs at these centres would be oriented towards maximum pertinence for the agricultural problems of the disadvantaged countries. Only a few quite outstanding students would be accepted in Canadian graduate schools, preferably after having taken an advanced degree at one of these centres; these scientists would then be more inclined to return home, as research leaders, knowing they were assured of competent support staff produced by the centres.

2) Training and Development Centres in Assisted Countries

These centres are proposed for support in all countries receiving Canadian agricultural aid. Their purpose is to provide a training and development centre for local agricultural officers and leading farmers, and to test, extend and demonstrate the application of known technologies to local agricultural products and problems. Officers of local agricultural advisory services would be recycled through these centres to update their training or to introduce them, by participation in field trials and development projects, to some new possibilities for increase or diversification of agricultural production. It seems most important also to bring to these centres leading farmers to participate in demonstration projects and to take short courses on specific agricultural subjects.

3) Scientific Missions

In this third type of program, Canada should support teams of first-class scientists, chosen from appropriate Canadian institutions, to attack defined agricultural problems in assisted countries. This is a type of activity in which Canadian scientists have already accumulated considerable experience, and have proved their capability.

Staffing Canada's International Agricultural Development Programs

We believe that Canada has the capacity, in numbers, diversity, and quality of professional manpower, to staff the above programs at levels adequate to make a substantial contribution abroad–with some sacrifice, but no serious disruption at home. However, care must be exercised to ensure that the sacrifice is regulated with respect to Canadian national and regional obligations and aspirations.

Provincial governments, through their departments of agriculture and their support of the universities' faculties of agriculture and veterinary medicine offer an attractive reservoir of professional manpower for the training and development programs. Through these agencies, the provinces are involved in agricultural education, research and development programs, and the extension of agricultural technologies to farmers. Moreover, provinces can quickly form interdisciplinary teams of specialists from their own services who would be able to retain their employment status while abroad, reintegrate with their departments on return, or be called back if unable to adapt to conditions abroad.

We believe this high potential within the provincial governments should be utilized. However, we believe much of this potential would be lost, with dangerous and disruptive consequences, if for instance the Canadian International Development Agency attempted to meet its need by direct employment of provincial personnel. Rather, we believe, the federal government should recognize provincial interests in, and capability for, international agricultural development by sharing the responsibility for this activity within the constitutional joint jurisdiction for agriculture. We suggest therefore that the Canadian International Development Agency should base its procedure in this area on close consultation and direct contracts with provincial governments, or indeed, with any other agencies having the appropriate expertise.

Finally, we believe the proposed Agricultural Research Board must be pre-eminently involved in Canada's strategy for international agricultural development. The Board will be in a central position to advise on the proportion of Canada's agricultural research effort that can be deployed to this important obligation without serious disruption of the national program.

We conclude therefore that agricultural technical assistance should be recognized as a major means for meeting Canada's responsibilities for international development; should be exempt from current financial constraints in Canadian development assistance policy; and should be implemented through the specified educational and development programs in selected disadvantaged countries, with due regard for the special capabilities and responsibilities of the provincial governments, and the central co-ordination function of the proposed Agricultural Research Board.

Appendices

Appendix A1

A Survey of Research in Biology for Science Council of Canada and the Science Secretariat, Privy Council Office, by the Biological Council of Canada and the Canadian Federation of Biological Societies

Please Read the following before Proceeding

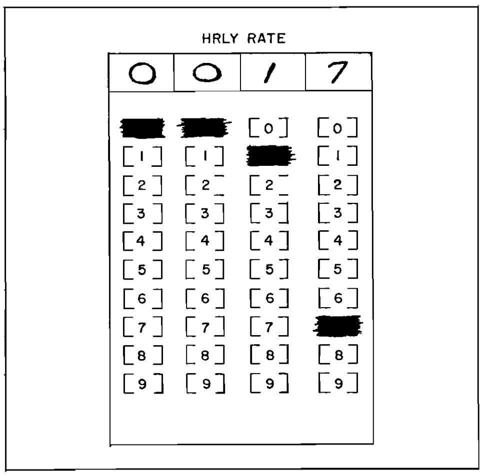
The answers you are asked to give will be in two forms; those written on the answer sheet and those coded on the scan sheets. The scan sheet is the most efficient means of transmitting information from the originator to the computer. Your coded answers will be "read" by an optical scanner and transferred directly to magnetic tape. In this way no errors can be introduced between you and the computer.

The spaces provided for answers on the scan sheets are identified by the question numbers. Indicate your response by a single, dark horizontal stroke through the appropriate letter or digit, keeping the mark within the block, as shown in the example.

For many of the questions spaces are provided at the top of the code columns on the scan sheets. These are for you to write in the answer prior to coding it. Where these spaces are provided, please write in your response as shown in the example.

It is important to use the utmost care in your responses. Therefore, please:

1. Print your name on each scan sheet.
2. Mark the scan sheet only where directed. Do not make any unnecessary marks.
3. Use an ordinary lead pencil only (preferably an H or HB). Make sure marks are dark, and extend across the response blocks but not beyond them. Do not use a pen or ballpoint.
4. If you make a mistake, erase thoroughly and correct.
5. Do not separate the scan sheets.
6. Always include leading zeros if they exist, e.g. 17 in a four-digit code is recorded as 0017 as in the example.
7. If your answer is zero, mark it as such.
8. Return your *answer* sheet and all scan sheets in the envelope provided.



Note: The questions asked in this booklet are taken from a longer list which is being used for several closely-related surveys. The list was intended to include the activities of all government, industry, and university, etc., research workers. Some questions do not apply to all three groups. The obviously inappropriate questions have been omitted from the version of the questionnaire here presented to you. For this reason there are breaks in the numerical sequence of the questions.

Your name appears on the scan and answer sheets only so that the total response may be determined. Thereafter, your coded answers will become part of a computer memory from which your name will have been excluded.

At all stages the information you supply will be treated confidentially. The report of the committee will contain no references to individuals but will deal only with totals.

Questionnaire

You and your profession

Coded answers to questions 3 to 22 are to be entered in the appropriate numbered boxes on the *blue* scan sheet. Written answers go on the *answer* sheet.

1. Print your name in the space provided on the *blue* scan sheet: *surname first.*

2. Write your name and the name and address of your principal employer (i.e. Department, Faculty, University; or Establishment, Location and Government Department, etc.) in the space provided on the *answer* sheet.

3. Is your position with this employer full time or part time?
   a) full time
   b) part time

4. Do you hold a formal joint or cross appointment between the above department or establishment and any other?
   a) yes
   b) no

5. If the answer to 4 is "yes", what is your commitment to the principal employer referred to above as a percentage of your time?
   a) 10 or less
   b) 20
   c) 30
   d) 40
   e) 50
   f) 60
   g) 70
   h) 80
   i) 90

6. If your answer to 4 is "yes", write the name and address of the second department or establishment in the space provided on the *answer* sheet.

7. What is the type of organization of your principal employer?

Mark this in the first column. If you were ever employed by a different type of organization, indicate your next previous employment in the second column, and so on.

Example: If your present employer is a university and you were previously employed in industry, mark space "d" in the first column and space "e" in the second column.
   a) federal government
   b) provincial government
   c) municipal government
   d) university
   e) industry
   f) private institution
   g) other

If "other", specify type of organization on the *answer* sheet.

8. What degrees do you hold and when were they awarded?

Give the last two digits of the year in which each of your degrees was awarded under the appropriate heading ("B"—bachelor, "M"—master, "V"—DVM, "MD", "D"—doctor; if your actual degrees are not among these, use an equivalent heading), *and* in the adjacent column headed "C" indicate the geographic area (see list below) in which the degree was awarded. *Example:* If you received a bachelor's degree in France in 1954 and a Ph.D. in Canada in 1960, mark 54 in the "B" column, and mark "e" in the adjacent "C" column. Then mark 60 in the "D" column and "a" in the adjacent "C" column.
   a) Canada
   b) Africa
   c) Asia
   d) Australia or New Zealand
   e) France
   f) Germany
   g) United Kingdom
   h) United States
   i) India or Pakistan
   j) Other

If "other", specify country on the *answer* sheet.

9. From what Faculty did you receive your first degree?
   a) Agriculture or Veterinary Medicine
   b) Arts and/or Science
   c) Engineering
   d) Forestry
   e) Medicine or Dentistry
   f) Other

If "other", specify Faculty on the *answer* sheet.

10. To what Faculty did the Department belong in which you specialized for your final degree?

Use the Faculty code provided for 9. If "other", specify Faculty on the *answer* sheet.

11. What was the major discipline of your final degree?

a) Biological sciences
b) Chemical sciences
c) Earth sciences
d) Economics
e) Engineering
f) Food sciences
g) Mathematical sciences
h) Medical sciences
i) Physical sciences
j) Sociology
k) Other social sciences
l) Other

If "other", specify discipline on the *answer* sheet.

12. What is the major discipline in which you are now working?

Use the discipline code provided for 11.

If "other", specify discipline on the *answer* sheet.

13. If you have ever spent a period of six months or more in formal postdoctoral work, including sabbatical leave or transfer of work, in what country were you working immediately before you started this period?

(Boxes 13, 14 and 15 are repeated on the scan sheet so that up to 3 such periods may be reported.)

Use the geographic area code provided for 8.

14. In what country did you spend the period(s) in 13?

Use the geographic area code provided for 8.

15. If you have answered "Canada" to either 13 or 14 when was it and how was it financed?

Enter the last two digits of the year the period started in the double column and identify the agency in the adjacent "c" column.

a) financed by a Canadian agency
b) financed by a U.S. agency
c) financed by foreign agency other than U.S.

Allocation of your time

You are asked in question 16 to indicate how you allocate your total professional time (as a project leader) between *Research* on the one hand and all other activities that are not included in your research responsibilities on the other: *Development*, *Service*, *Teaching*, and *Other* including administration.

Development

Work undertaken with the primary objective of improving existing or of generating new and immediately useful techniques, practices, materials, varieties, devices, products, etc., including final evaluation and testing.

Research

Research is the generation of new knowledge. For the purpose of this survey it is defined in terms of research projects. A project is an identifiable unit of research for which you have responsibility as a leader. It normally has a single objective and is conducted for a limited time, characteristically a few months or years. If possible, the project title should distinguish your work from that of others. (You may report a group of closely related activities as one project.)

Service

Work including activities such as diagnosis, quality control and evaluation, animal and plant identification, chemical, soil and water testing and analysis, extension, etc.

Estimate your time for each activity to the nearest one-tenth of a man-year. A man-year is the total work effort of one person in a full-time job for one year, regardless of the actual hours worked. Therefore, the answers given here will total one man-year. Include in total time any extramural consultative activities that fall in any of the above activities.

16. How many tenths of a man-year do you allocate to:

a) development
b) research*
c) service
d) teaching, including formal course instruction, committee work on curricula, and advising students
e) other, including administration

*The activity of university staff with respect to graduate students includes both training and teaching, as well as research. However, university staff are asked to include under "research" the total time allocated to all activities associated with their personal graduate students, as well as that allocated to their own research.

17. Give a brief descriptive title of your developmental work, if any, on the *answer* sheet.

18. Give a brief description of your service work, if any, on the *answer* sheet.

Allocation of your staff's time

19. How many people in the following categories report directly to you as project leader and are actively involved in your research project(s), development, service, or teaching activities? (Note: Questions about your graduate students appear later in this questionnaire.)

a) postdoctorate students, visiting scientists with Ph.D., Postdoctorate Fellows, those on sabbatical leave and on transfer of work

b) professionals (staff with doctorate degree or equivalent research experience who work under your supervision)

c) technicians (*not* general service personnel)

d) clerical and stenographic staff

e) other

20. How much time do each of these categories contribute to Development, Research, Service, and Teaching?

Report time in tenths of a man-year.

Enter the postdoctoral, etc., time in box "20a", the professional time in box "20b", and so on, apportioning this time to Development, Research, Service, and Teaching in the double columns headed D, R, S, and T/E respectively.

21. How many professionals on your staff (those in 19b) received their final degree in each of the following major disciplines?

Select the letter representing the number of professionals:

n) 0
o) 1
p) 2
q) 3
r) 4–10
s) 11–20
t) 21–30
u) 31–40
v) 41–50
w) over 50

and mark in the column indicating the discipline, as follows:

a) Biological sciences
b) Chemical sciences
c) Earth sciences
d) Economics
e) Engineering
f) Food sciences
g) Mathematical sciences
h) Medical sciences
i) Physical sciences
j) Sociology
k) Other social sciences
l) Other

If "other", specify discipline on the *answer* sheet.

22. How many of these professionals received their final degree in each of the geographical areas listed in 8?

Select the letter representing the number of professionals from the list in Question 21, and mark in the column indicating the geographical area.

If "other", specify country on the *answer* sheet.

Your research

Coded answers to questions about your project(s), i.e. work identified in 16 b, are to be entered in the appropriate numbered boxes on the *green* scan sheet. These answers, together with the project title are required for each project for which you are responsible.

Code this information for two projects on one *green* scan sheet: one project on each side. If you are responsible for more than two projects, use the extra sheets supplied.

Print your name in the space provided on the *green* scan sheet.

23. Write your project title(s) on the *answer* sheet and number the *green* scan sheets in the same order.

24. What is the entity on which this project is centered. Select the code number from the following list and enter it in the first triple column in box 24. There are four triple columns. Therefore, up to four entities may be entered. If more than three entities in any one major category are involved, use the appropriate general classification.

Entity List

Note: Animal and plant products, exclusive of foods which are listed separately, should be listed under the taxonomic entities from which they are derived.

100	*Animals General*
110	Mammals general
111	Rodents (includes rabbits)
112	Carnivores
113	Ungulates (includes swine, horses, cattle)
114	Humans
115	Primates (other than humans)
116	Cetaceans
117	Other (specify)
120	Birds general
121	Anseriformes (includes ducks, geese)
122	Galliformes (includes chickens, turkeys, grouse)
123	Passeriformes
124	Raptores
125	Other (specify)
130	Amphibians
140	Reptiles
150	Fishes general
151	Salmonids
152	Pleuronectids
153	Gadoids
154	Cyprinids
155	Other (specify)
160	Invertebrates general
161	Helminths
162	Insecta
163	Arachnida
164	Crustacea
165	Mollusca
166	Other (specify)
200	*Plants General*
210	Gymnosperms
220	Angiosperms general
221	Gramineae
222	Leguminosae
223	Solanaceae
224	Cruciferae
225	Compositae
226	Rosaceae
227	Other (specify)
230	Other Vascular plants
240	Mosses, Liverworts, and Lichens
250	Algae general
251	Marine
252	Fresh water
260	Fungi general
261	Basidiomycetes
262	Ascomycetes
263	Phycomycetes
264	Fungi imperfecti
265	Myxomycetes
300	*Protozoa*
301	Parasitic
302	Free-living
400	*Bacteria*
450	*Viruses*
500	*Soil*
600	*Fossils*
700	*Water*
710	Fresh
720	Marine
800	*Air*
900	*Food Products*

25. On the *answer* sheet write the common name of the organism on which your project is centered. If the organism has no common name, give its scientific name and taxonomic class to which it belongs.

List more than one if appropriate.

26. At what level of organization is this study carried out?

Mark one only.

a) geographical area
b) community of species
c) single species
d) population—individuals
e) cell—tissue
f) subcell—molecule

27. What approach is used in this research? Every project may appropriately have elements of several of the approaches listed below. If you must record more than one, record them in descending order of importance to this project. Confine your answer to this moment in time and stage of evolution of your project and to the approaches that genuinely are *central* to the present main themes of your research.

If more than 4 subcategories in any major category apply, use the "general" category.

You should examine the entire list before making your selection.

Approach list

Biochemical

0100 General biochemistry
0101 Amino-acids, peptides, proteins
0102 Antimetabolites
0103 Biochemical mechanisms
0104 Carbohydrates
0105 Endocrines
0106 Enzymes-coenzymes
0107 Technology
0108 Lipids
0109 Organic acids
0110 Pigments
0111 Nucleic acids
0112 Vitamins
0113 Photosynthesis
0114 Physical biochemistry
0115 Steroids
0116 Pheromones
0117 Methodology
0118 Other (specify)

Biomathematical

0200 General biomathematics
0201 Systems analysis and design
0202 Models
0203 Biometrics-statistics
0204 Cybernetics-management systems
0205 Demography-life tables
0206 Sampling theory
0207 Methodology
0208 Other (specify)

Biophysical

0300 General biophysics
0301 Structure and design
0302 Bioacoustics (incl. communications)
0303 Bioelectricity
0304 Bio-optics
0305 Biosystems and control
0306 Biothermics
0307 Biotransport, membranes
0308 Radiation biology
0309 Isotopes
0310 Geochronology
0311 Meteorology
0312 Climatology
0313 Methodology
0314 Other (specify)

Ecological

0400 General Ecology
0401 Ecosystems
0402 Productivity
0403 Community or population dynamics
0404 Control—chemical
0405 Control—other
0406 Behaviour
0407 Phenology
0408 Life history
0409 Physical factors
0410 Epidemiology
0411 Human ecology
0412 Biogeography—distribution
0413 Bioclimatology
0414 Host-parasite relations
0415 Methodology
0416 Other (specify)

Genetical/Breeding

0500 General genetics and breeding
0501 Population genetics
0502 Molecular genetics
0503 Breeding, hybridization, testing
0504 Cytogenetics
0505 Mutations
0506 Linkage, segregation, transmission
0507 Development
0508 Genetics and control
0509 Radiation
0510 Immunogenetics
0511 Biochemical genetics
0512 Physiological genetics
0513 Behavioural genetics
0514 Psycho-genetics
0515 Methodology
0516 Other (specify)

Immunological

0600 General immunology
0601 Allergies
0602 Antibody formation
0603 Antibody structure
0604 Antigens; antibodies
0605 Antigen-antibody reaction
0606 Blood groups
0607 Cell culture
0608 Complement
0609 Hypersensitivity
0610 Enumeration and identification of macromolecules
0611 Immunogenetics
0612 Infection, resistance

0613 Tissue antibodies, auto-antibodies
0614 Transplantation antigens
0615 Vaccines
0616 Methodology
0617 Other (specify)

Morphological

0700 General anatomy-morphology
0701 Comparative
0702 Embryology-developmental
0703 Gross
0704 Microscopic anatomy
0705 Ultrastructure
0706 Cell-tissue culture
0707 Cyto-histochemistry (incl. autoradiography)
0708 Methodology
0709 Other (specify)

Nutritional

0800 General nutrition
0801 Cell; tissue culture
0802 Clinical
0803 Digestion
0804 Energy metabolism—intermediary
0805 Nutritional diseases
0806 Nutrients; nutrient values
0807 Requirements; deficiencies
0808 Methodology
0809 Other (specify)

Pathological

0900 General pathology
0901 Epidemiology
0902 Diagnostic services
0903 Disease control, chemical
0904 Disease control, other
0905 Host resistance
0906 Non-infectious diseases
0907 Host-parasite relations
0908 DNA-RNA virus relations
0909 Interferon, interference
0910 Synergism
0911 Latency
0912 Vaccines
0913 Toxins
0914 Cardiovascular
0915 Cell; tissue culture
0916 Clinical pathology
0917 Hematology
0918 Immunopathology
0919 Oncology; carcinogenesis
0920 Radiation
0921 Anatomical—structural pathology
0922 Infective processes
0923 Parasitology
0924 Methodology
0925 Other (specify)

Pharmacological-Toxicological

1000 General pharmacology-toxicology
1001 Phytotoxicity
1002 Mutagenic compounds
1003 Autonomic
1004 Biochemical
1005 Cardiovascular
1006 Cellular
1007 Chemotherapy
1008 Clinical
1009 Drug metabolism
1010 Antimetabolites
1011 Endocrines
1012 Neuropharmacology
1013 Pharmacodynamics
1014 Renal
1015 Psychopharmacology
1016 Narcosis—anesthesiology
1017 Methodology
1018 Other (specify)

Physiological

1100 General physiology
1101 Altitude, environment, stress, space, exercise
1102 Narcosis—anesthesiology
1103 Cardiovascular
1104 Cell-tissue culture
1105 Central nervous system
1106 Water balance—electrolyte
1107 Endocrines
1108 Gastrointestinal (incl. digestion)
1109 Hematology
1110 Energy metabolism
1111 Muscle and physiology of locomotion
1112 Lactation
1113 Host-parasite relations
1114 Neurophysiology
1115 Radiation
1116 Renal
1117 Reproductive system
1118 Development, growth
1119 Senescence, gerontology
1120 Post-harvest physiology
1121 Growth substances
1122 Respiratory system
1123 Behaviour
1124 Transport

1125 Sensory processes
1126 Photosynthesis
1127 Photoperiodism
1128 Bioengineering
1129 Methodology
1130 Other (specify)

Taxonomical / Classification
1200 General taxonomy—classification
1201 Description, discrimination—fine categories (e.g. species)
1202 Description, discrimination—broad categories (e.g. families)
1203 Phylogeny, evolution, adaptation
1204 Numerical taxonomy
1205 Experimental taxonomy
1206 Chemical taxonomy—palaeobiochemistry
1207 Survey
1208 Identification services
1209 Methodology
1210 Other (specify)

Technological / Biological Products
1300 General

Food Products
1401 Food preservation
1402 Food processing
1403 Evaluation of quality
1404 Other (specify)

Forest Products
1500 General
1501 Pathology
1502 Entomology
1503 Wood anatomy
1504 Other (specify)

Support

28. How many graduate students are assigned to research on this project?

29. How much time was contributed *to this project* in the last 12 months by each of the following?

Report time in tenths of a man-year. Only your time (i.e. part of your time given in 16 b) and the time of those who report directly to you (as defined in 19) should be included.

a) project leader
b) postdoctorate students, etc.
c) professionals
d) technicians
e) other

31. What financial support from sources outside your department do you receive for this project?

Give the amount(s) in *thousands* of dollars in the two left-hand columns and identify the source in the columns headed "c". If you are not able to separate grant support for your individual projects divide your grant support by the number of your projects and enter the quotient.

Remember to code leading zeros.

a) Canada Council
b) Canada Department of Agriculture
c) Canada Department of Forestry
d) Canadian Arthritis and Rheumatism Society
e) Canadian Heart Foundation
f) Defence Research Board
g) Fisheries Research Board
h) Industry and private organizations
i) Medical Research Council
j) National Cancer Institute of Canada
k) National Research Council
l) Provincial Government
m) Sources outside Canada
n) University grants (i.e. not from your Department)
o) Other

If "other", specify source on the *answer* sheet.

32. To which problem areas, if any, do you as project leader feel that this project is oriented?

If there is more than one orientation, indicate primary orientation in the first column, secondary in the second column and so on.

a) Agriculture
b) Dentistry
c) Fisheries
d) Forestry
e) Medicine
f) Food Sciences
g) Pollution—Environment
h) Veterinary medicine
i) Wildlife
j) Resource management
k) General
l) Other

If "other", specify orientation on the *answer* sheet.

Your teaching

Coded answers to questions 33 to 46 are to be entered on the *brown* scan sheet.

In order to produce a composite picture of the Canadian biologist, it is necessary to know your commitment, not only to research, but also to formal teaching.

In general it is only those who are employed in Universities who have such commitments. It is important, however, to record the teaching of all who do participate in this activity.

33. How many hours of lectures did you give in the last twelve months?

34. How many different courses (undergraduate and graduate) did you give in the last twelve months?

Count shared courses as full courses.

35. What is the total enrollment in all of your courses?

36. How many laboratory hours are you responsible for in each twelve months?

37. What fraction of the hours in 36 must you personally supervise?

a) none
b) one quarter
c) one half
d) three quarters
e) all

38. What is the total enrollment in all of the laboratory sessions associated with your courses?

39. What is the longest uninterrupted period of time, to the nearest month, during which you have no responsibility for formal courses (i.e. lectures and/or laboratory sessions) and that is therefore available solely for research and direction of graduate students?

40. What percentage of the total time associated with your position in the university is devoted to undergraduate teaching and associated activities, including committee work on curricula, and advising students?

a) 10 or less
b) 20
c) 30
d) 40
e) 50
f) 60
g) 70
h) 80
i) 90
j) 100

41. How many of your postgraduate students are registered for each of the following degrees?

a) Masters
b) Doctors
c) Other

If "other", specify degree on the *answer* sheet.

42. How many of your postgraduate students received their first degree in each of the geographical areas in 8?

If "other", specify country on the *answer* sheet.

43. How many of your postgraduate students receive stipends from the following sources?

a) Your personal research grants
b) Scholarships
c) Bursaries
d) Teaching or research assistantships
e) Commonwealth governments
f) Other Foreign governments
g) External Aid Office
h) Other

If "other", specify source on the *answer* sheet.

44. What percentage of the total research grants that you personally receive is used to provide stipends to support postgraduate students?

a) 10 or less
b) 20
c) 30
d) 40
e) 50
f) 60
g) 70
h) 80
i) 90
j) 100

Your opinions

45. Is your research work and/or the number of postgraduate students you can supervise limited by inadequacies in any of the following?

Indicate the most urgent by marking the left-hand column, the next most urgent in the second column, and so on.

a) Space
b) Equipment
c) Funds (for supplies and travel)
d) Supporting professional staff
e) Supporting technical staff
f) Services (shops, library, animal rooms, etc.)
g) Stipends for graduate students
h) Land for experimentation
i) Other

If "other", specify inadequacy on the *answer* sheet.

46. Given your present involvement in university affairs, how many postgraduate students could you personally supervise if the inadequacies in 45 were overcome?

51. Taking a broad view of biology in Canada, give your opinions on the following four points in the space provided on the *answer* sheet.

In parts b, c and d do not limit your remarks to your own specific research interest.

a) What will be the development in terms of direction and emphasis in your specific field of interest in the next decade?

b) What direction will the major areas of applied biology of interest to you take in the next decade?

c) What areas of specialization are presently most neglected?

d) What will be the major changes in basic biology in the next decade?

A Survey of Research in Agricultural Engineering

Note: The questions asked in this survey are the same as for the Biology survey with the exception of Nos. 25, 26 and 32, which were not appropriate.

Entity list

100	*Machinery General*
110	Field production
120	Crop harvesting
130	Horticultural
140	Spraying and dusting
150	Lawn, garden, etc.
200	*Power General*
210	Mobile tractor
220	Stationary engine
230	Airborne vehicle
240	Electrical
250	Truck
300	*Structures General*
310	Livestock production
320	Storage
330	Bridges
340	Fence, common corral
350	Service
360	Foundations
370	General purpose and exhibit
400	*Environmental Control General*
410	Ventilation
420	Heating
430	Refrigeration
440	Air conditioning
450	Pest control
500	*Crop and Food Processing General*
510	Crop drying
520	Silage
530	Crops processing
540	Food processing
600	*Materials General*
610	Systems layout
620	Data processing
630	Systems programming
640	Control units
650	Equipment operation
700	*Water Resource General*
710	Hydrology
720	Irrigation
730	Drainage
740	Water Supply
750	Water reclamation
760	Waste disposal

800 *Soils General*
810 Conservation
820 Reclamation
830 Erosion control
840 Land clearing and improvement

900 *Research Equipment General*
910 Instrumentation
920 Prototype machine
930 Equipment calibration and testing

Approach List

0100 *Theoretical Engineering General*
0101 Fluid mechanics
0102 Heat mass transfer
0103 Solid mechanics
0104 Electronics
0105 Materials

0200 *Design General*
0201 Mechanical
0202 Structural
0203 Systems

0300 *Experimental General*
0301 Laboratory
0302 Field

0400 *Developmental General*
0401 Laboratory
0402 Field

0500 *Testing General*
0501 Durability —laboratory
0502 —field
0503 Performance—laboratory
0504 —field
0505 Suitability —laboratory
0506 —field

A Survey of Research in Agricultural Economics

Note: The questions asked in this survey are the same as for the Biology survey with the exception of Nos. 25, 26, 27, 32, 36, 37, and 38, which were not appropriate.

Subject list

100 *Economics of Production*
101 Farm management
102 Farm organization and structure
103 Farm accounting
104 Farm credit
105 Budget analysis
106 Business arrangements and contracts
107 Linear programming
108 Production function analysis
109 Simulation techniques and procedures
110 Risk, uncertainty and insurance
111 Electronic data processing

200 *Marketing, Distribution and Trade*
201 Market Organization
202 Market structure analysis
203 Supply analysis
204 Demand analysis
205 Price analysis
206 Marketing efficiency
207 Commodity marketing
208 Market margins
209 Marketing boards
210 Food consumption studies
211 International agriculture and trade
212 Market location analysis
213 Transportation
214 Storage
215 Market development

300 *Resource Use and Development*
301 Land classification and utilization
302 Conservation
303 Land tenure, expropriation and leasing
304 Water
305 Forestry
306 Outdoor recreation
307 Land appraisal, valuation and assessment
308 Legislation
309 Zoning and land use controls
310 Fisheries
311 Irrigation
312 Taxation
313 Land settlement
314 Part-time farming
315 Labour

400 *Agricultural Policy*
500 *Co-operatives*
600 *Methodology and Theory*
700 *Econometrics*
800 *Inter-Regional Competition*
900 *Rural Sociology*
010 *Economic Development*

A Survey of Research in Rural Sociology

Note: The questions asked in this survey are the same as for the Biology survey with the exception of Nos. 25, 26, 27, 32, 36, 37 and 38, which were not appropriate.

Subject list

100 *Anthropology*
110 Applied Anthropology
120 Ethnography/Ethnology
130 Culture and Personality
140 Linguistics
150 Physical Anthropology
160 Social Anthropology
170 Cultural Anthropology
180 Other Anthropology (specify)

200 *Social Psychology*
210 Personality
220 Other social psychology (specify)

300 *General Sociology*
311 Theory
312 Methodology
313 Collective Behaviour
314 Community Studies
315 Comparative Institutions
316 Criminology
317 Deviance
318 Ecology
319 Formal Organizations
320 History of Social Thought
321 Industrial Sociology
322 Juvenile Delinquency
323 Marriage and Family
324 Mass Communications
325 Mass Culture
326 Mathematical Sociology
327 Medical Sociology
328 Minority Groups and Race Relations
329 Occupations and Professions
330 Political Sociology
331 Population and Migration
332 Small Groups
333 Social and Cultural Change
334 Social Control
335 Social Organization
336 Social Problems
337 Social Stratification
338 Sociology of Education
339 Sociology of Knowledge
340 Sociology of Religion
341 Statistics
342 Urban Sociology
343 Values and Attitudes
344 Other (specify)

400 *Rural Sociology*
410 Co-operatives
420 Diffusion of Innovations
430 Evaluation Research
440 Land Tenure
450 Rural-Urban Differences
460 Social Participation
470 Other (specify)

500 *Extension*
510 Surveys
520 Evaluation of Programs
530 Other (specify)

600 *Economics*
610 General
620 Agricultural
630 Other (specify)

700 *Political Science*
800 *Other (specify)*

Appendix A2

A Survey of Research in Biology for Science Council of Canada and the Science Secretariat, Privy Council Office, by the Biological Council of Canada and the Canadian Federation of Biological Societies

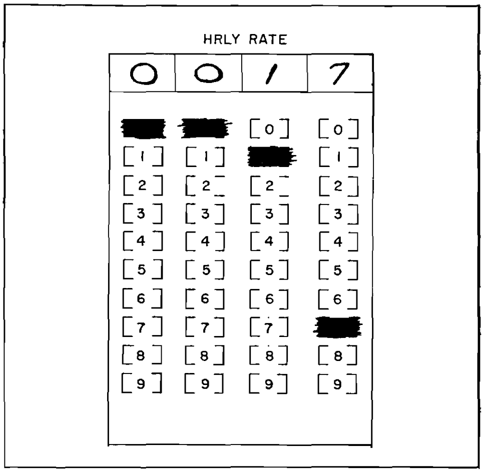
Please Read the following before Proceeding
The answers you are asked to give will be in two forms; those written on the answer sheet and those coded on the scan sheets. The scan sheet is the most efficient means of transmitting information from the originator to the computer. Your coded answers will be "read" by an optical scanner and transferred directly to magnetic tape. In this way no errors can be introduced between you and the computer.

The spaces provided for answers on the scan sheets are identified by the question numbers. Indicate your response by a single, dark horizontal stroke through the appropriate letter or digit, keeping the mark within the block, as shown in the example.

For many of the questions spaces are provided at the top of the code columns on the scan sheets. These are for you to write in the answer prior to coding it. Where these spaces are provided, please write in your response as shown in the example.

It is important to use the utmost care in your responses. Therefore, please:

1. Print your name on each scan sheet.
2. Mark the scan sheet only where directed. Do not make any unnecessary marks.
3. Use an ordinary lead pencil only (preferably an H or HB). Make sure marks are dark, and extend across the response blocks but not beyond them. Do not use a pen or ballpoint.
4. If you make a mistake, erase thoroughly and correct.
5. Do not separate the scan sheets.
6. Always include leading zeros if they exist, e.g. 17 in a four-digit code is recorded as 0017 as in the example.
7. If your answer is zero, mark it as such.
8. Return your *answer* sheet and all scan sheets in the envelope provided.



Note: The questions asked in this booklet are taken from a longer list which is being used for several closely-related surveys. The list was intended to include the activities of all government, industry, and university, etc., research workers. Some questions do not apply to all three groups. The obviously inappropriate questions have been omitted from the version of the questionnaire here presented to you. For this reason there are breaks in the numerical sequence of the questions.

Your name appears on the scan and answer sheets only so that the total response may be determined. Thereafter, your coded answers will become part of a computer memory from which your name will have been excluded.

At all stages the information you supply will be treated confidentially. The report of the committee will contain no references to individuals but will deal only with totals.

Questionnaire

You and your profession

Coded answers to questions 8 to 22 are to be entered in the appropriate numbered boxes on the *blue* scan sheet. Written answers go on the *answer* sheet.

1. Print your name in the space provided on the *blue* scan sheet: *surname first.*

2. Write your name and the name and address of your company in the space provided on the *answer* sheet.

8. What degrees do you hold and when were they awarded?

Give the last two digits of the year in which each of your degrees was awarded under the appropriate heading ("B"—bachelor, "M"—master, "V"—DVM, "MD", "D"—doctor; if your actual degrees are not among these use an equivalent heading) *and* in the adjacent column headed "C" indicate the geographical area (see list below) in which the degree was awarded.

Example; If you received a bachelor's degree in France in 1954 and a Ph.D. in Canada in 1960, mark 54 in the "B" column, and mark "e" in the adjacent "C" column. Then mark 60 in the "D" column and "a" in the adjacent "C" column.

a) Canada
b) Africa
c) Asia
d) Australia or New Zealand
e) France
f) Germany
g) United Kingdom
h) United States
i) India or Pakistan
j) Other

If "other", specify country on the *answer* sheet.

10. To what Faculty did the Department belong in which you specialized for your final degree?

a) Agriculture or Veterinary Medicine
b) Arts and/or Science
c) Engineering
d) Forestry
e) Medicine or Dentistry
f) Other

If "other", specify Faculty on the *answer* sheet.

11. What was the major discipline of your final degree?

a) Biological sciences
b) Chemical sciences
c) Earth sciences
d) Economics
e) Engineering
f) Food sciences
g) Mathematical sciences
h) Medical sciences
i) Physical sciences
j) Sociology
k) Other social sciences
l) Other

If "other", specify discipline on the *answer* sheet.

13. If you have ever spent a period of six months or more in formal postdoctoral work, including sabbatical leave or transfer of work, in what country were you working immediately before you started this period?
Use the geographic area code provided for 8.

(Boxes 13, 14 and 15 are repeated on the scan sheet so that up to 3 such periods may be reported.)

14. In what country did you spend the period(s) in 13? Use the geographic area code provided for 8.

15. If you have answered "Canada" to either 13 or 14, when was it and how was it financed?

Enter the last two digits of the year the period started in the double column and the agency in the adjacent "c" column.

a) financed by a Canadian agency
b) financed by a U.S. agency.
c) financed by a foreign agency other than U.S.

19. How many people in the following categories report directly to you as project leader and are actively involved in your research project(s), development or service activities?

a) Postdoctorate trainees, visiting scientists with Ph.D., Postdoctorate Fellows, those on sabbatical leave and on transfer of work
b) Professionals
c) Technicians (*not* general service personnel)
d) Clerical and stenographic staff
e) Other

20. How much time do each of these categories contribute to Development, Research, Service, and Teaching?*

Report the time in tenths of a man-year. Enter the postdoctoral time in box "20a", the professional time in box "20b", and so on, apportioning these man-years to Development, Research, Service, and Teaching in the double columns headed "D", "R", "S", "T/E", respectively.

21. How many professionals on your staff (those in 19b) received their final degree in each of the following major disciplines?

Select the letter representing the number of professionals:

n) 0
o) 1
p) 2
q) 3
r) 4–10
s) 11–20
t) 21–30
u) 31–40
v) 41–50
w) over 50

and mark in the column indicating the discipline, as follows:

a) Biological sciences
b) Chemical sciences
c) Earth sciences
d) Economics
e) Engineering
f) Food sciences
g) Mathematical sciences
h) Medical sciences
i) Physical sciences
j) Sociology
k) Other social sciences
l) Other

If "other", specify discipline on the *answer* sheet.

22. How many of these professionals received their final degree in each of the geographical areas listed in 8?

Select the letter representing the number of professionals from the list in Question 21, and mark in the column indicating the geographical area.

If "other", specify country on the *answer* sheet.

*Teaching is not generally a responsibility of the scientist in industry. However, it is important to record the teaching of those in industry who do participate in this activity.

Your research

It is understood that in many instances the specific details of research and development in industry are confidential. In no way is this questionnaire intended to intrude on this confidentiality. For this reason, your response to questions on the research projects in your unit may be as general and unspecific as you wish: titles such as "Studies on the efficacy of pesticides", "Development and comparison of inorganic fertilizers", or "Clinical study of antibiotic pharmaceuticals" are entirely appropriate.

Coded answers to questions about your research are to be entered in the numbered boxes on the *green* scan sheet.

Information about one project is to be entered on one side of the *green* scan sheet. If you are responsible for two projects, use the reverse side to report the second. If you are responsible for more than two projects, use the extra sheets supplied.

Print your name on the *green* scan sheet.

23. Write the project title(s) on the *answer* sheet and number the *green* scan sheets in the same order.

24. What is the entity on which this project is centered?

Select the code number from the following list and enter it in the first triple column in box 24. There are four triple columns. Therefore, up to four entities may be entered. If more than three entities in any one major category are involved, use the appropriate general classification.

Entity List

Note: Animal and plant products, exclusive of foods which are listed separately, should be listed under the taxonomic entities from which they are derived.

100	*Animals General*
110	Mammals general
111	Rodents (includes rabbits)
112	Carnivores
113	Ungulates (includes swine, horses, cattle)
114	Humans
115	Primates (other than humans)
116	Cetaceans
117	Other (specify)
120	Birds general
121	Anseriformes (includes ducks, geese)
122	Galliformes (includes chickens, turkeys, grouse)
123	Passeriformes
124	Raptores
125	Other (specify)
130	Amphibians
140	Reptiles
150	Fishes general
151	Salmonids
152	Pleuronectids
153	Gadoids
154	Cyprinids
155	Other (specify)
160	Invertebrates general
161	Helminths
162	Insecta
163	Arachnida
164	Crustacea
165	Mollusca
166	Other (specify)
200	*Plants General*
210	Gymnosperms
220	Angiosperms general
221	Gramineae
222	Leguminosae
223	Solanaceae
224	Cruciferae
225	Compositae
226	Rosaceae
227	Other (specify)
230	Other Vascular plants
240	Mosses, Liverworts, and Lichens
250	Algae general
251	Marine
252	Fresh water
260	Fungi general
261	Basidiomycetes
262	Ascomycetes
263	Phycomycetes
264	Fungi imperfecti
265	Myxomycetes
300	*Protozoa*
301	Parasitic
302	Free-living
400	*Bacteria*
450	*Viruses*
500	*Soil*
600	*Fossils*
700	*Water*
710	Fresh
720	Marine
800	*Air*
900	*Food Products*

26. At what level of organization is this study carried out?

Mark one only.

a) geographical area
b) community of species
c) single species
d) population—individuals
e) cell—tissue
f) subcell—molecule

27. What approach is used in this research?

Every project may appropriately have elements of several of the approaches listed below. If you must record more than one, do so in descending order of importance to this project. Confine your answer to this moment in time and stage of evolution of your project and to the approaches that genuinely are *central* to the present main themes of your research. If more than 4 subcategories in any major category apply, use the "general" category.

You should examine the entire list before making your selection.

Approach list

Biochemical
0100 General biochemistry
0101 Amino-acids, peptides, proteins
0102 Antimetabolites
0103 Biochemical mechanisms
0104 Carbohydrates
0105 Endocrines
0106 Enzymes-coenzymes
0107 Technology
0108 Lipids
0109 Organic acids
0110 Pigments
0111 Nucleic acids
0112 Vitamins
0113 Photosynthesis
0114 Physical biochemistry
0115 Steroids
0116 Pheromones
0117 Methodology
0118 Other (specify)

Biomathematical
0200 General biomathematics
0201 Systems analysis and design
0202 Models
0203 Biometrics-statistics
0204 Cybernetics-management systems
0205 Demography-life tables
0206 Sampling theory
0207 Methodology
0208 Other (specify)

Biophysical
0300 General biophysics
0301 Structure and design
0302 Bioacoustics (incl. communications)
0303 Bioelectricity
0304 Bio-optics
0305 Biosystems and control
0306 Biothermics
0307 Biotransport, membranes
0308 Radiation biology
0309 Isotopes
0310 Geochronology
0311 Meteorology
0312 Climatology
0313 Methodology
0314 Other (specify)

Ecological
0400 General ecology
0401 Ecosystems
0402 Productivity
0403 Community or population dynamics
0404 Control—chemical
0405 Control—other
0406 Behaviour
0407 Phenology
0408 Life history
0409 Physical factors
0410 Epidemiology
0411 Human ecology
0412 Biogeography—distribution
0413 Bioclimatology
0414 Host-parasite relations
0415 Methodology
0416 Other (specify)

Genetical/Breeding
0500 General genetics and breeding
0501 Population genetics
0502 Molecular genetics
0503 Breeding, hybridization, testing
0504 Cytogenetics
0505 Mutations
0506 Linkage, segregation, transmission
0507 Development
0508 Genetics and control
0509 Radiation
0510 Immunogenetics
0511 Biochemical genetics
0512 Physiological genetics
0513 Behavioural genetics
0514 Psycho-genetics
0515 Methodology
0516 Other (specify)

Immunological
0600 General immunology
0601 Allergies
0602 Antibody formation
0603 Antibody structure
0604 Antigens; antibodies
0605 Antigen-antibody reaction
0606 Blood groups
0607 Cell culture
0608 Complement
0609 Hypersensitivity
0610 Enumeration and identification of macromolecules
0611 Immunogenetics
0612 Infection, resistance
0613 Tissue antibodies, auto-antibodies
0614 Transplantation antigens

0615 Vaccines
0616 Methodology
0617 Other (specify)

Morphological
0700 General anatomy-morphology
0701 Comparative
0702 Embryology-developmental
0703 Gross
0704 Microscopic anatomy
0705 Ultrastructure
0706 Cell-tissue culture
0707 Cyto-histochemistry (incl. autoradiography)
0708 Methodology
0709 Other (specify)

Nutritional
0800 General nutrition
0801 Cell; tissue culture
0802 Clinical
0803 Digestion
0804 Energy metabolism—intermediary
0805 Nutritional diseases
0806 Nutrients; nutrient values
0807 Requirements; deficiencies
0808 Methodology
0809 Other (specify)

Pathological
0900 General pathology
0901 Epidemiology
0902 Diagnostic services
0903 Disease control, chemical
0904 Disease control, other
0905 Host resistance
0906 Non-infectious diseases
0907 Host-parasite relations
0908 DNA-RNA virus relations
0909 Interferon, interference
0910 Synergism
0911 Latency
0912 Vaccines
0913 Toxins
0914 Cardiovascular
0915 Cell; tissue culture
0916 Clinical pathology
0917 Hematology
0918 Immunopathology
0919 Oncology; carcinogenesis
0920 Radiation
0921 Anatomical-structural pathology
0922 Infective processes
0923 Parasitology
0924 Methodology
0925 Other (specify)

Pharmacological-Toxicological
1000 General pharmacology-toxicology
1001 Phytotoxicity
1002 Mutagenic compounds
1003 Autonomic
1004 Biochemical
1005 Cardiovascular
1006 Cellular
1007 Chemotherapy
1008 Clinical
1009 Drug metabolism
1010 Antimetabolites
1011 Endocrines
1012 Neuropharmacology
1013 Pharmacodynamics
1014 Renal
1015 Psychopharmacology
1016 Narcosis—anesthesiology
1017 Methodology
1018 Other (specify)

Physiological
1100 General physiology
1101 Altitude, environment, stress, space, exercise
1102 Narcosis—anesthesiology
1103 Cardiovascular
1104 Cell-tissue culture
1105 Central nervous system
1106 Water balance—electrolyte
1107 Endocrines
1108 Gastrointestinal (incl. digestion)
1109 Hematology
1110 Energy metabolism
1111 Muscle and physiology of locomotion
1112 Lactation
1113 Host-parasite relations
1114 Neurophysiology
1115 Radiation
1116 Renal
1117 Reproductive system
1118 Development, growth
1119 Senescence, gerontology
1120 Post-harvest physiology
1121 Growth substances
1122 Respiratory system
1123 Behaviour
1124 Transport
1125 Sensory processes
1126 Photosynthesis
1127 Photoperiodism
1128 Bioengineering
1129 Methodology
1130 Other (specify)

Taxonomical/Classification

1200 General taxonomy—classification
1201 Description, discrimination—fine categories (e.g. species)
1202 Description, discrimination—broad categories (e.g. families)
1203 Phylogeny, evolution, adaptation
1204 Numerical taxonomy
1205 Experimental taxonomy
1206 Chemical taxonomy—palaeobiochemistry
1207 Survey
1208 Identification services
1209 Methodology
1210 Other (specify)

Technological/Biological Products

1300 General

Food Products

1401 Food preservation
1402 Food processing
1403 Evaluation of quality
1404 Other (specify)

Forest Products

1500 General
1501 Pathology
1502 Entomology
1503 Wood anatomy
1504 Other (specify)

30. How much time was devoted to this project in the last twelve months by each of the following?

Report time in tenths of a man-year.

a) manager
b) postdoctorate trainees and others as in 19a
c) professionals
d) graduate students (only those assigned on a formal basis as part of their training)
e) technicians
f) others

32. To which problem areas, if any, do you as project leader feel that this project is oriented?

If there is more than one orientation, indicate primary orientation in the first column, secondary in the second column, and so on.

a) Agriculture
b) Dentistry
c) Fisheries
d) Forestry
e) Medicine
f) Food Sciences
g) Pollution—Environment
h) Veterinary medicine
i) Wildlife
j) Resource management
k) General
l) Other

If "other", specify orientation on the *answer* sheet.

Your space and cost

Coded answers to questions 47 to 50 are to be entered on the *brown* scan sheet.

47. How much laboratory and other research space is used in your R & D program?

a) <500 sq. ft.
b) 500-100 sq. ft.
c) 1000-2000 sq. ft.
d) >2000 sq. ft.

48. What is the average total financial support in *thousands* of dollars for each project under your supervision (salaries, services, expenses, equipment)?

Include costs of services received from other units in your company as well as those purchased outside.

49. How much, in *thousands* of dollars, does your unit budget for co-operative research with scientists outside your company?

50. If your administrative unit budgets for university grants and/or scholarships, specifically in the field of biology in Canada, how much, in *thousands* of dollars, is given to departments in the following faculties:

a) Agriculture
b) Dentistry
c) Engineering
d) Forestry
e) Medicine
f) Science
g) Other

Your opinions

51. Taking a broad view of biology in Canada, give your opinions on the following four points in the space provided on the *answer* sheet. In parts b, c and d do not limit your remarks to your own specific research interest.

a) What will be the development in terms of direction and emphasis in your specific field of interest in the next decade?

b) What direction will the major areas of applied biology of interest to you take in the next decade?

c) What areas of specialization are presently most neglected?

d) What will be the major changes in basic biology in the next decade?

A Survey of Research in Agricultural Engineering

Note: The questions asked in this survey are the same as for the Biology (Industry) survey, with the exception of Nos. 26 and 32 which were not appropriate.

Entity List

100 *Machinery General*
110 Field production
120 Crop harvesting
130 Horticultural
140 Spraying and dusting
150 Lawn, garden, etc.

200 *Power General*
210 Mobile tractor
220 Stationary engine
230 Airborne vehicle
240 Electrical
250 Truck

300 *Structures General*
310 Livestock production
320 Storage
330 Bridges
340 Fence, common corral
350 Service
360 Foundations
370 General purpose and exhibit

400 *Environmental Control General*
410 Ventilation
420 Heating
430 Refrigeration
440 Air conditioning
450 Pest control

500 *Crop and Food Processing General*
510 Crop drying
520 Silage
530 Crops processing
540 Food processing

600 *Materials General*
610 Systems layout
620 Data processing
630 Systems programming
640 Control units
650 Equipment operation

700 *Water Resource General*
710 Hydrology
720 Irrigation
730 Drainage
740 Water Supply
750 Water reclamation
760 Waste disposal

800 *Soils General*
810 Conservation
820 Reclamation
830 Erosion control
840 Land clearing and improvement

900 *Research Equipment General*
910 Instrumentation
920 Prototype machine
930 Equipment calibration and testing

Approach list

0100 *Theoretical Engineering General*
0101 Fluid mechanics
0102 Heat mass transfer
0103 Solid mechanics
0104 Electronics
0105 Materials

0200 *Design General*
0201 Mechanical
0202 Structural
0203 Systems

0300 *Experimental General*
0301 Laboratory
0302 Field

0400 *Developmental General*
0401 Laboratory
0402 Field

0500 *Testing General*
0501 Durability —laboratory
0502 —field
0503 Performance—laboratory
0504 —field
0505 Suitability —laboratory
0506 —field

A Survey of Research in Agricultural Economics

Note: The questions asked in this survey are the same as for the Biology (Industry) survey, with the exception of Nos. 26, 27, and 32, which were not appropriate.

Subject list

100 *Economics of Production*
101 Farm management
102 Farm organization and structure
103 Farm accounting
104 Farm credit
105 Budget analysis
106 Business arrangements and contracts
107 Linear programming
108 Production function analysis
109 Simulation techniques and procedures
110 Risk, uncertainty and insurance
111 Electronic data processing

200 *Marketing, Distribution and Trade*
201 Market Organization
202 Market structure analysis
203 Supply analysis
204 Demand analysis
205 Price analysis
206 Marketing efficiency
207 Commodity marketing
208 Market margins
209 Marketing boards
210 Food consumption studies
211 International agriculture and trade
212 Market location analysis
213 Transportation
214 Storage
215 Market development

300 *Resource Use and Development*
301 Land classification and utilization
302 Conservation
303 Land tenure, expropriation and leasing
304 Water
305 Forestry
306 Outdoor recreation
307 Land appraisal, valuation and assessment
308 Legislation
309 Zoning and land use controls
310 Fisheries
311 Irrigation
312 Taxation
313 Land settlement
314 Part-time farming
315 Labour

400 *Agricultural Policy*
500 *Co-Operatives*
600 *Methodology and Theory*
700 *Econometrics*
800 *Inter-Regional Competition*
900 *Rural Sociology*
010 *Economic Development*

Appendix A3

A Survey of Institutional Support in Biology, Agricultural Engineering, Agricultural Economics, Rural Sociology in connection with the Agriculture and Biology Research Studies for Science Council of Canada and the Science Secretariat, Privy Council Office

Please Read the following before Proceeding

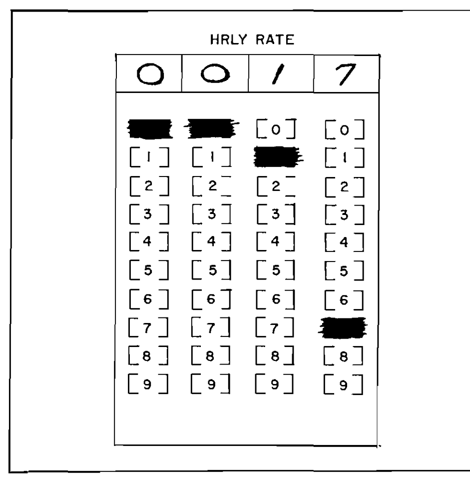
The answers you are asked to give will be in two forms; those written on the answer sheet and those coded on the scan sheets. The scan sheet is the most efficient means of transmitting information from the originator to the computer. Your coded answers will be "read" by an optical scanner and transferred directly to magnetic tape. In this way no errors can be introduced between you and the computer.

The spaces provided for answers on the scan sheets are identified by the question numbers. Indicate your response by a single, dark horizontal stroke through the appropriate letter or digit, keeping the mark within the block, as shown in the example.

For many of the questions spaces are provided at the top of the code columns on the scan sheets. These are for you to write in the answer prior to coding it. Where these spaces are provided, please write in your response as shown in the example.

It is important to use the utmost care in your responses. Therefore, please:

1. Print your name on each scan sheet.
2. Mark the scan sheet only where directed. Do not make any unnecessary marks.
3. Use an ordinary lead pencil only (preferably an H or HB). Make sure marks are dark, and extend across the response blocks but not beyond them. Do not use a pen or ballpoint.
4. If you make a mistake, erase thoroughly and correct.
5. Do not separate the scan sheets.
6. Always include leading zeros if they exist, e.g. 17 in a four-digit code is recorded as 0017 as in the example.
7. If your answer is zero, mark it as such.
8. Return your *answer* sheet and all scan sheets in the envelope provided.



Note: The questions asked in this booklet are intended to include the activities in both government and university establishments in which research and/or development is carried out. If any question does not apply to you simply do not answer.

Your name appears on the scan and answer sheets, only so that the total response may be determined. Thereafter, your coded answers will become part of a computer memory from which your name will have been excluded.

At all stages the information you supply will be treated confidentially. The report of the committee will contain no references to individuals but will deal only with totals.

Questionnaire

1. Print your name in the space provided on the scan sheet: *surname first.*

2. Write the name and address of the unit for which you are reporting (Department, Faculty, University or Unit location and Government Department) in the space provided on the *answer* sheet.

3. How many academic or professional staff members were in your budget in 1962, and in 1967, and are expected to be in it in 1972?

(Do *not* include postdoctorate students, visiting scientists or graduate students.)

Count part-time appointees as the appropriate fraction of a "full time equivalent."

Consider a staff member holding a joint appointment in another department or institution as a fraction of a full time equivalent, the fraction being the proportion of his total salary that appears in your budget. If no portion appears in your budget, do not report this person.

a) in January 1962
b) in January 1967
c) in January 1972

4. How many students were registered in your unit in January 1962?

a) for Masters
b) for Doctors

5. How many students were registered in your unit in January 1967?

a) for Masters
b) for Doctors

6. How many students do you expect to be registered in your unit in January 1972?

a) for Masters
b) for Doctors

7. How many of your present students conduct their research in facilities, such as institutes, etc., not controlled by your unit?

8. What is the maximum number of graduate students that can be directed by your present staff?

a) with existing funds and resources
b) with all necessary funds and resources

9. In your unit what is the average number of contact hours teaching per full-time academic staff member per week throughout the academic session of two semesters?

10. In your opinion what is the optimum number of contact hours for a full-time faculty member per week through an academic session?

11. How many service personnel (clerical, library, animal room, shop, etc.) are there in your unit?

a) assigned to a project leader
b) not assigned to a project leader

12. What is the total net assignable space in square feet (excluding hallways, washrooms, stairways, boiler rooms, etc.) administered by your unit?

Pro rate shared facilities.

a) for greenhouses and growth chambers
b) for classrooms and seminars
c) for all other research and graduate work, including offices, services, shops, library, animal rooms, etc. (Do *not* include farm buildings, garages.)

13. How much additional space in square feet have you requested for your unit by 1972?

14. If you show additional space in 13, how much has been definitely committed by the administration?

15. How much land for experimental use is managed by your unit for each of the following purposes?

Give area in *acres*.

a) Agriculture
b) Forest
c) Resource management
d) General
e) Other

16. (a) How many research vessels do you operate?

(b) What is the gross tonnage of these vessels?

Questions 17 to 27 involve financial data. Give all sums in *thousands* of dollars.

What budgetary allocation for the following did your unit receive from parent sources during the year 1967–68 (do *not* include "grants" received individually and directly by your project leaders from sources outside your unit)?

17. project leaders' salaries

18. other teaching and academic or professional salaries

19. graduate student teaching assistantships

20. salaries of technicians assigned to project leaders

21. other non-academic non-professional salaries

22. operating expenses and supplies

23. equipment

24. any items not specified in 17 to 23

25. What was the total sum received as grants-in-aid during the year 1967–68 by the project leaders of your unit in their own right as individuals, from sources outside the unit?

26. What was the total sum available to your unit from *non-parent* sources during the year 1967–68? Do *not* include funds reported in 25.

a) from Federal government
b) from Provincial government
c) from industry
d) from other sources
If "other", specify source on the *answer* sheet.

27. Total inventory value (e.g. as used for insurance purposes) of research equipment in your unit.

28. In your opinion as unit head, is the research and/or graduate training programme of your department limited at present by lack of any of the following?

Indicate greatest urgency or need in the left-hand column, the next most urgent in the second column, and so on.

a) Academic or professional staff
b) Technical staff
c) Equipment
d) Space
e) Funds
f) Services
g) Land for experimentation
h) Other
If "other", specify limiting factor on the *answer* sheet.

29. Taking a broad view of the field with which your unit is associated, give your opinion on the following three points in the space provided on the *answer* sheet.

a) What fields are most neglected at present?
b) What direction will the major areas of interest to your unit take in the next decade?
c) What will be the major changes in your discipline in the next decade?

NAME/NOM

3. a b

4. a b

5. a b c d e f g h i

7.

1	2	3	4	5
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8.

B.		c	M.		c	V.		c	M.D.		c	D.		c
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9. a b c d e f

10. a b c d e f

11. a b c d e f g h i j k l

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16.

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UTILITY FORM 3053 OP 6

2. Your name:
   Employer's name and address:
6. Second employer's name and address:
7. Organization
8. Country
9. Faculty
10. Faculty
11. Discipline
12. Discipline
17. Developmental work:
18. Service work:
21. Discipline
22. Country
23. Project title
    1.
    2.
    3.
    4.
    5.
24. Other entity
    Proj. 1.
    2.
    3.
    4.
    5.
25. Common name
    1.
    2.
    3.
    4.
    5.

27. After each "other approach"	
entered here, put the number of the	
project to which it applies.	
0118	
0208	
0314	
0416	
0516	
0617	
0709	
0809	
0925	
1018	
1130	
1210	
1404	
1504	
31. Support	
Proj. 1.	
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32. Orientation	
1.	
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5.	
41. Degree	
42. Country	
43. Source	
45. Inadequacy	
51. a)	
b)	
c)	
d)	

Considering your current professional employment, please give us a title for the area of science in which your greatest professional competence lies. Be as specific as you feel is desirable but do not use more than three words.

To those concerned:
Grants-in-aid of research have been made in Canada, typically, for periods of 1 year only. Would you prefer to have the grants made for periods of 3 to 5 years? Would your opinion be changed if it was impossible to negotiate an increase in the grant part-way through the 3- to 5-year period?

Appendix B

Interviews

Canada Department of Agriculture
Mr. S. B. Williams, Deputy Minister

a) Research Branch
Dr. J. A. Anderson, Director-General (Retired July 31, 1968).
Dr. B. B. Migicovsky, Assistant Director-General (Institutes) (Appointed Director-General, August 1, 1968).
Dr. J. C. Woodward, Associate Director-General (Appointed Assistant Deputy Minister (Research), August 1, 1968).
Dr. K. Rasmussen, Assistant Director-General (Western) (Appointed Associate Director-General, August 1, 1968).
Dr. D. G. Hamilton, Assistant Director-General (Eastern).
Dr. R. A. Ludwig, Assistant Director-General (Administration).
Dr. J. E. Andrews, Director, Research Station, Swift Current.
Dr. T. H. Anstey, Director, Research Station, Lethbridge (Appointed Assistant Director-General (Western), April 1, 1969).
Dr. Bryan P. Bierne, Director, Research Institute, Belleville.
Mr. H. W. R. Chancey, Director, Research Station, St. John's West.
Dr. R. E. Fitzpatrick, Director, Research Station, Vancouver, and staff.
Dr. J. E. R. Greenshields, Director, Research Station, Saskatoon.
Dr. A. A. Guitard, Director, Research Station, Beaverlodge.
Dr. G. P. Holland, Director, Entomology Research Institute.
Mr. T. M. MacIntyre, Superintendent, Experimental Farm, Nappan.
Dr. W. B. Mountain, Director, Research Station, Vineland, and staff.
Dr. R. P. A. Sims, Director, Food Research Institute.
Dr. E. Y. Spencer, Director, Research Institute, London.
Mr. J. G. Stothart, Director, Research Station, Lacombe, and staff.
Dr. F. Whiting, Director, Research Station, Fredericton.

b) Economics Branch
Dr. S. C. Hudson, Director-General and staff.

c) Health of Animals Branch
Dr. J. F. Frank, Director, Animal Pathology Division.
Dr. R. Avery, Director, Animal Diseases Research Institute, Lethbridge.

Provincial Departments of Agriculture
British Columbia
Dr. A. H. Turner, Deputy Minister, and staff.
Alberta
Dr. E. R. Ballantyne, Deputy Minister, and staff.
Saskatchewan
Mr. W. H. Horner, Deputy Minister.
Manitoba
Mr. W. E. Jarvis, Deputy Minister, and staff.
Ontario
Mr. E. Biggs, Deputy Minister, and staff.
Dr. J. A. Archibald, Director, Research Station, Vineland, and staff.
Quebec
Dr. Benoit Lavigne, Assistant Deputy Minister.
Dr. Bertrand Forest, Director, Research Service.
New Brunswick
Mr. R. Gilbert, Deputy Minister.
Nova Scotia
Mr. D. L. Parks, Deputy Minister.
Prince Edward Island
Mr. S. Wright, Deputy Minister.
Newfoundland
Mr. P. Murray.

Universities
University of British Columbia
Dr. J. B. MacDonald, President.
Dr. B. A. Eagles, Dean, Faculty of Agriculture, and staff.
University of Alberta
Dr. W. H. Johns, President.
Dr. A. G. McCalla, Dean, Faculty of Graduate Studies.
Dr. C. F. Bentley, Dean, Faculty of Agriculture, and staff

University of Saskatchewan
Dr. J. W. T. Spinks, President.
Dr. W. J. White, Dean, Faculty of Agriculture, and staff.
Dr. L. Smith, Dean, Western College of Veterinary Medicine.
University of Manitoba
Dr. H. E. Duckworth, Vice-President (Academic).
Dr. L. H. Shebeski, Dean, Faculty of Agriculture, and staff.
University of Guelph
Dr. N. R. Richards, Dean, Ontario Agricultural College, and staff.
Dr. T. L. Jones, Dean, Ontario Veterinary College, and staff.
Brock University
Dr. B. M. Millman, Head, Department of Biology.
Carleton University
Dr. D. Whyte, Faculty of Social Sciences.
Laval University
Dr. L. P. Bonneau, Rector.
Dr. R. Poirier, Dean, Faculty of Agriculture, and staff.
Dr. M. A. Tremblay, Faculty of Social Sciences.
Mr. Gérald Fortin, Faculty of Social Sciences.
Mr. Napoléon Leblanc, Faculty of Social Sciences.
Dr. Gabriel Filteau, Department of Biology.
Dr. André Lafond, Faculty of Forestry.
Macdonald College
Dr. H. G. Dion, Dean, Faculty of Agriculture, and staff.
University of Montreal
Dr. Roger Gaudry.
Agricultural Institute, La Pocatière
Mr. Charles Gagné.
Dalhousie University
Dr. I. L. McLean, Dean, Faculty of Graduate Studies.
University of California, Berkeley
Dr. M. L. Peterson, Dean, Faculty of Agriculture.
Dr. G. Alcorn, Director, Extension Services.

Other Government Departments and Agencies
Canada Department of Fisheries
Dr. W. L. Ford, Director, Bedford Institute.
Canada Department of Forestry
Dr. M. L. Prebble, Assistant Deputy Minister.
Dr. Lionel Daviault, Director, Forest Research Laboratory, Laval.
Canada Department of Industry
Dr. B. Weinberg.
External Aid Office
Mr. J. A. Arsenault and staff.
Fisheries Research Board of Canada
Dr. F. R. Hayes, Chairman, and staff.
National Research Council of Canada
Dr. W. H. Cook, Vice-President.
Dr. P. R. Gorham, Director, Division of Biosciences.
Quebec Council of Education
Mr. J.-M. Martin.
Quebec Department of Fisheries
Dr. Yves Jean.
United States Department of Agriculture
Dr. T. Byerly, Director, Cooperative State Research Services.
United States National Science Foundation
Dr. D. D. Keck and staff.
Dr. T. D. Fontaine and staff.
Australia Commonwealth Scientific and Industrial Research Organization
Dr. D. F. Waterhouse, Chief, Division of Entomology.

Industry and Producer Organizations
Aluminum Company of Canada
Mr. Clément Montgrain.
Canadian Agricultural Chemicals Association
Mr. Lloyd Miller, (Shell), President.
Dr. George Cooper (Cyanamid).
Mr. Jacques Chevalier (CACA).
Dr. D. Dever (Niagara Brand).
Dr. Marian Norman (Fisons).
Canadian Chemical Association
Dr. E. J. Jones, President, and colleagues.
Canadian Federation of Agriculture
Mr. David Kirk, Executive Secretary.
Coopérative fédérée
Mr. L.-P. Poulin.
Saskatchewan Wheat Pool
Mr. E. A. Boden, Vice-President, and colleagues.
United Grain Growers, Ltd.
Mr. A. M. Runciman, President, and staff.
Union catholique des cultivateurs (UCC)
Dr. Roger Perreault.
Mr. J.-M. Proulx.
Winnipeg Grain Exchange
Mr. J. E. McCannel, President, and colleagues.

Appendix C

Table 1–Financial Support, Natural Sciences (in $ Thousands)

Agency	No. Professional Staff	Expenditures: Prof. Salaries	Graduate Student Salaries	Other Salaries	Supplies and Equipment	Budget Total	$ per Capita	Budget Adjusted for Teaching	Grants Received	Grand Total (excl. teaching)	$ per Capita (whole time)
University:											
agricultural units	533	6 508	340	3 038	3 144	13 030	24 446	8 795	4 870	13 665	33 583
non-agricultural units	209					5 109	24 446	3 162	2 166	5 328	34 808
Provincial Government	202	1 936	0	1 621	1 464	5 021		5 021	0	5 021	24 856
Federal Government	1 023	11 667	0	13 735	9 672	35 074		35 074	0	35 074	34 285
Industry	109					2 509		2 509	0	2 509	23 018
Total	**2 076**	**20 111**	**340**	**18 394**	**14 280**	**60 743**		**54 561**	**7 036**	**61 597**	**32 648**

Note: All university budgets adjusted for teaching by deducting from the total for each discipline a percentage equal to the reported percentage of time spent on teaching as follows:

	Agr. Units	Non-Agr. Units
Life Sciences	32.5	38.1
Agr. Engineering	44.3	39.3
Agr. Economics	38.9	38.8
Rural Sociology		45.2

Table 2–Financial Support, Agricultural Engineering (in $ Thousands)

Agency	No. Professional Staff	Expenditures: Prof. Salaries	Graduate Student Salaries	Other Salaries	Supplies and Equipment	Budget Total	$ per Capita	Budget Adjusted for Teaching	Grants Received	Grand Total (excl. teaching)	$ per Capita (whole time)
University:											
agricultural units	56	764	25	212	195	1 196	21 357	666	234	900	25 535
non-agricultural units	9					192	21 357	117	44	161	26 222
Provincial Government	51	347	0	253	343	943			0	943	18 490
Federal Government	35	260	0	442	260	962			0	962	27 485
Industry	25					2 282			0	2 282	91 280
Total	**176**	**1 371**	**25**	**907**	**798**	**5 575**			**278**	**5 248**	**33 255**

Note: All university budgets adjusted for teaching as in Table 1.

Table 3–Financial Support, Agricultural Economics (in $ Thousands)

		Expenditures									
Agency	No. Professional Staff	Prof. Salaries	Graduate Student Salaries	Other Salaries	Supplies and Equipment	Budget Total	$ per Capita	Budget Adjusted for Teaching	Grants Received	Grand Total (excl. teaching)	$ per Capita (whole time)
University:											
agricultural units	53	643	84	169	100	996	18 792	609	324	933	24 905
non-agricultural units	5					94	18 792	58	19	77	22 600
Provincial Government	95	860	0	519	467	1 846			91	1 937	20 389
Federal Government	125	1 425	0	1 090	950	3 466			0	3 466	27 728
Industry	22					673			0	673	30 590
Total	**300**	**2 928**	**84**	**1 778**	**1 517**	**7 075**			**434**	**7 086**	**25 030**

Note: All university budgets adjusted for teaching as in Table 1.

Table 4–Financial Support, Rural Sociology (in $ Thousands)

Agency	No. Professional Staff	Expenditures: Prof. Salaries	Graduate Student Salaries	Other Salaries	Supplies and Equipment	Budget Total	Budget Adjusted for Teaching	Grants Received	Grand Total (excl. teaching)	$ per Capita (whole time)
University:										
agricultural units										
non-agricultural units	44	489	45	99	112	745	408	215	623	21 818
Provincial Government	0	0	0	0	0	0		0	0	
Federal Government	5	85	0	12	17	114		0	114	22 800
Industry	0	0	0	0	0	0		0	0	
Total	**49**	**574**	**45**	**111**	**129**	**859**		**215**	**737**	**21 918**

Note: All university budgets adjusted for teaching as in Table 1.

Appendix D

Table 1–Allocation of Time of Staff Components (Man-Years)
Totals of All Disciplines

Staff Components	Federal	Provincial	University	Other	Total
Project Leaders:					
Development	107.6	33.7	26.9	0.9	169.1
Research	632.1	72.0	266.5	6.6	977.2
Service	96.3	50.1	55.7	1.2	203.3
Teaching	9.4	18.5	234.5	0.5	262.9
Other	80.0	27.7	70.7	1.3	179.7
Total	**925.4**	**202.0**	**654.3**	**10.5**	**1 792.2**
Postdoctorate Fellows:					
Development	5.8	0.5	8.7	0	15.0
Research	66.3	3.5	104.3	0	174.1
Service	1.0	0.6	6.7	0	8.3
Teaching	0.8	0	6.7	0	7.5
Total	**73.9**	**4.6**	**126.4**	**0**	**204.9**
Professionals:					
Development	61.5	28.4	19.3	0.7	109.9
Research	236.1	56.6	98.3	1.9	392.9
Service	56.8	56.9	42.3	0.4	156.4
Teaching	8.4	23.7	68.0	0	100.1
Total	**362.8**	**165.6**	**227.9**	**3.0**	**759.3**
Technicians:					
Development	217.1	42.8	51.3	1.1	312.3
Research	881.5	86.4	504.0	17.2	1 489.1
Service	238.1	102.4	121.8	0.9	463.2
Teaching	7.6	13.0	100.2	0.1	120.9
Total	**1 344.3**	**244.6**	**777.3**	**19.3**	**2 385.5**
Others:					
Development	89.6	39.9	30.8	0.2	160.5
Research	272.5	68.4	191.5	6.2	538.6
Service	173.9	97.0	119.1	1.0	391.0
Teaching	20.9	36.8	120.8	0	178.5
Total	**556.9**	**242.1**	**462.2**	**7.4**	**1 268.6**
Grand Total	**3 263.3**	**858.9**	**2 248.1**	**40.2**	**6 410.5**

Table 2—Allocation of Time of Industry Staff Components in Man-Years

Personnel	Life Sciences	Agricultural Engineering	Agricultural Economics	Total
Professionals:				
Development	61.9	20.9	4.1	86.9
Research	32.9	1.7	16.5	51.1
Service	12.9	3.1	1.4	17.4
Teaching	1.8	0.8	0	2.6
Total	**109.5**	**26.5**	**22.0**	**158.0**
All Other Staff:				
Development	60.7	95.8	21.7	178.2
Research	46.2	7.7	18.8	72.7
Service	50.6	34.9	13.0	98.5
Teaching	1.4	0	0	1.4
Total	**158.9**	**138.4**	**53.5**	**350.8**
Grand Total	**268.4**	**164.9**	**75.5**	**508.8**

Appendix E

Table 1–Distribution of Project Leaders by Provinces

Province	Sector: Fed. Agric.	Fed. Other	Fed. Total	Prov. Agric.	Prov. Other	Prov. Total	Univ. Agric.	Univ. Other	Univ. Total	Industry	Other	Total
British Columbia	73	6	79	22	3	25	28	30	58	0	1	163
Alberta	94	11	105	29	0	29	39	19	58	9	0	201
Saskatchewan	97	13	110	8	0	8	49	27	76	2	0	196
Manitoba	69	15	84	5	1	6	57	14	71	4	0	165
Ontario	362	50	412	66	5	71	162	112	274	39	5	801
Quebec	43	5	48	53	5	58	72	28	100	6	5	217
New Brunswick	29	8	37	1	0	1	0	5	5	0	0	43
Nova Scotia	31	5	36	3	2	5	1	10	11	0	1	53
Prince Edward Island	17	0	17	1	0	1	0	2	2	0	0	20
Newfoundland	6	1	7	0	0	0	0	3	3	0	0	10
Total	**821**	**114**	**935**	**188**	**16**	**204**	**408**	**250**	**658**	**60**	**12**	**1 869**

Table 2—Distribution of Project Leaders with Canadian or Foreign Bachelor's Degrees*

	Location of Undergraduate Training: Canada	Foreign
	%	%
Federal	79.4	20.6
Provincial	89.6	10.4
University	70.9	29.1
Other	81.8	18.2
Total	77.5	22.5
Total number	1 315	381

*Industry not included.

Table 3–Distribution and Numbers of Project Leaders

Sector	Discipline: Life Sciences	Agricultural Engineering	Agricultural Economics	Rural Sociology	Total
Federal Agriculture	766	18	36	1	821
Federal Other	102	1	8	3	114
Federal Total	868	19	44	4	935
Provincial Agriculture	129	20	38	1	188
Provincial Other	12	1	1	2	16
Provincial Total	141	21	39	3	204
University Agriculture	345	29	34	0	408
University Other	209	9	5	27	250
University Total	554	38	39	27	658
Industry	34	14	12	0	60
Other	7	1	3	1	12
Total	**1 604**	**93**	**137**	**35**	**1 869**

Table 4–Educational Background of Research Project Leaders

Sector	Degree: No. Degree Reported	Doctor of Veterinary Medicine	Doctor of Philosophy
Federal Agriculture	7	31	487
Federal Other	2	2	83
Total Federal	9	33	570
Provincial Agriculture	5	3	23
Provincial Other	1	1	2
Total Provincial	6	4	25
University Agriculture	0	50	305
University Other	0	10	214
Total University	0	60	519
Industry	0	0	20
Other	0	2	7
Total	**15**	**99**	**1 141**

Table 5–Numbers of Project Leaders by Country of Graduate Training*

Country	Federal	Provincial	University	Other	Total
Canada	318	78	188	6	590
Africa	2	0	3	0	5
Asia	7	0	5	0	12
Australia, New Zealand	4	0	6	0	10
France	0	0	4	0	4
Germany	5	1	0	0	6
United Kingdom	68	3	77	0	148
United States	349	25	278	4	656
India, Pakistan	9	0	5	0	14
Other	8	2	10	1	21
Total	**770**	**109**	**576**	**11**	**1 466**

*Industry not included.

Table 6–Frequency of Postdoctoral Experiences of Project Leaders

Sector	Frequency		
	0	1	2 or more
	%	%	%
Federal	72.1	21.6	6.3
Provincial	92.0	8.0	0
University	62.4	26.8	10.8
Industry	80.0	20.0	0
Other	71.4	14.3	14.3
Total	68.2	23.6	8.2

Table 7–Previous Employment History of Project Leaders*

Type of Previous Employment	Type of Present Employment: University	Government: Provincial	Government: Federal	Other	Total
None	332	122	565	6	1 025
University		24	213	3	240
Government:					
provincial	68		47	1	116
federal	143	27		1	171
municipal	3	3	5	0	11
Industry	48	15	54	1	118
Private Institutions	23	6	14	0	43
Other	41	7	37		85
Total	**658**	**204**	**935**	**12**	**1 809**

*Industry not included.

Table 8–Number of Graduate Students by Country of First Degree

Country	Discipline: Life Sciences	Agricultural Engineering	Agricultural Economics	Rural Sociology	Total	Horizontal Percentage
Canada						
number	673	37	46	75	831	57.5
(percentage)	(55.9)	(53.6)	(51.7)	(76.5)		
Africa	34	4	3	3	44	3.0
Asia	160	7	7	2	176	12.2
Australia, New Zealand	16	0	0	1	17	1.2
France	4	0	0	0	4	0.3
Germany	3	0	0	0	3	0.2
United Kingdom	65	3	5	4	77	5.3
United States	66	1	3	5	75	5.2
India, Pakistan	105	5	3	2	115	8.0
Other	78	6	12	6	102	7.1
Total	**1 204**	**69**	**89**	**98**	**1 444**	**100.0**

Table 9–Graduate Students Receiving Stipends from Professor's Research Grants

Discipline	Not Receiving	Receiving	Percentage Receiving
Agriculture:			
Life Sciences	166	360	68.4
Agricultural Engineering	15	31	67.4
Agricultural Economics	24	22	47.8
Rural Sociology	0	0	0
Other:			
Life Sciences	84	240	74.1
Agricultural Engineering	7	3	30.0
Agricultural Economics	5	0	0
Rural Sociology	18	16	47.1
Total	**319**	**672**	**67.8**

Table 1–Man-Years Devoted to Research Projects by Project Leaders in Natural Sciences–Major Entity Analysis

Major Entities	Fed. Agric.	Fed. Other	Fed. Total	Prov. Agric.	Prov. Other	Prov. Total	Univ. Agric.	Univ. Other	Univ. Total	Industry	Other	Total
Mammals	15.2	3.1	18.3	1.7	0.3	2.0	15.5	6.9	22.4	1.2	0	43.9
Rodents	18.3	1.2	19.5	1.3	0.2	1.5	7.1	5.9	13.0	1.0	0.8	35.8
Ungulates	33.3	1.2	34.5	1.3	0.3	1.6	20.1	1.2	21.3	1.5	0	58.9
Birds	1.3	1.2	2.5	0.1	0	0.1	3.3	0.8	4.1	0	0	6.7
Galliformes	13.1	0	13.1	1.3	0	1.3	11.0	0.6	11.6	1.7	0.2	27.9
Amphibians, Reptiles, Fishes	0.8	0.5	1.3	0.5	0	0.5	4.6	1.2	5.8	0	0.4	8.0
Invertebrates, General	3.3	0.4	3.7	0	0	0	1.3	0.7	2.0	1.2	0	6.9
Helminths	6.7	0	6.7	0	0	0	2.2	1.1	3.3	0	0	10.0
Insecta and Arachnids	115.3	11.0	126.3	4.5	0.4	4.9	9.8	13.1	22.9	1.0	0.2	155.3
Plants, General	33.1	6.6	39.7	5.9	0.2	6.1	6.2	8.4	14.6	1.5	0.3	62.2
Gymnosperms	4.4	4.6	9.0	0.7	0	0.7	0.7	0.9	1.6	0	0	11.3
Angiosperms, General	11.3	1.3	12.6	2.8	0	2.8	5.6	5.1	10.7	0	0	26.1
Graminae	68.7	0.6	69.3	3.0	0	3.0	13.2	5.2	18.4	1.6	0	92.3
Leguminosae	17.2	0	17.2	0.9	0	0.9	2.9	4.1	7.0	0	0	25.1
Solanaceae	26.9	0	26.9	3.0	0	3.0	3.3	0.6	3.9	0	0	33.8
Cruciferae	6.6	3.0	9.6	0	0	0	0.4	0.6	1.0	0.6	0	11.2
Compositae	3.9	1.0	4.9	0	0	0	0.3	0.5	0.8	0	0	5.7
Rosaceae	17.5	0	17.5	2.4	0	2.4	1.9	0	1.9	0	0	21.8
Other	11.2	3.8	15.0	2.0	0.6	2.6	2.7	1.5	4.2	0	0	21.8
Algae	0	0.5	0.5	0	0	0	0	0.8	0.8	0	0	1.3
Fungi	30.4	6.9	37.3	0.7	0.4	1.1	4.4	4.4	8.8	2.0	0	49.2
Protozoa	0	0	0	0	0	0	1.1	0.3	1.4	0	0	1.4
Bacteria	10.4	12.3	22.7	0.7	0	0.7	6.6	2.4	9.0	3.0	0.5	35.9
Viruses	19.0	0.8	19.8	0.4	0	0.4	1.8	1.6	3.4	0	0	23.6
Soil	67.3	0.6	67.9	5.7	1.0	6.7	9.4	0.9	10.3	1.1	0	86.0
Water	0.6	0.3	0.9	0	0.2	0.2	0.4	0	0.4	0.3	0	1.8
Air	0.9	0.3	1.2	0	0	0	0.1	0	0.1	0	0	1.3
Food Products	12.5	1.8	14.3	3.2	0	3.2	6.1	0.1	6.2	9.6	0	33.3
Total	**549.2**	**63.0**	**612.2**	**42.1**	**3.6**	**45.7**	**142.0**	**68.9**	**210.9**	**27.3**	**2.4**	**898.5**

Table 2–Man-Years Devoted to Research Projects by Postdoctoral Students, Professionals, and Technicians in Natural Sciences–Major Entity Analysis

Major Entities	Fed. Total	Prov. Total	Univ. Agric.	Univ. Other	Univ. Total	Industry	Other	Total
Mammals, General	58.2	8.0	54.5	20.0	74.5	4.1	0	144.8
Rodents	32.5	1.6	16.5	24.5	41.0	12.0	2.5	89.6
Ungulates	84.8	5.9	68.2	3.3	71.5	7.9	0	170.1
Birds, General	5.3	0.1	7.1	0.3	7.4	0	0	12.8
Galliformes	22.5	5.1	40.5	9.0	49.5	9.7	0.4	87.2
Amphibians, Reptiles, Fishes	2.5	0.7	12.2	2.9	15.1	0	0.6	18.9
Invertebrates, General	3.4	0	1.2	2.3	3.5	4.8	0	11.7
Helminths	7.7	0	3.6	3.2	6.8	0	0	14.5
Insecta and Arachnids	163.8	6.9	17.0	21.4	38.4	0	0.4	209.5
Plants, General	70.0	10.5	12.1	24.5	36.6	4.0	0.3	121.4
Gymnosperms	13.8	2.1	3.3	4.3	7.6	0	0	23.5
Angiosperms, General	20.2	3.9	17.2	11.1	28.3	0	0	52.4
Graminae	150.1	6.1	46.2	14.1	60.3	4.3	0	220.8
Leguminosae	28.0	1.9	6.2	3.7	9.9	0	0	39.8
Solanaceae	35.0	1.9	7.6	3.2	10.8	0	0	47.7
Cruciferae	16.9	0	4.1	1.4	5.5	1.0	0	23.4
Compositae	4.5	0	1.0	0.9	1.9	0	0	6.4
Rosaceae	35.8	5.1	2.3	0	2.3	0	0	43.2
Other	16.7	4.7	2.3	4.5	6.8	0	0	28.2
Algae	3.3	1.1	0	0.2	0.2	0	0	4.6
Fungi	38.9	3.1	5.7	8.4	14.1	6.0	0	62.1
Protozoa	0	0	1.2	0.9	2.1	0	0	2.1
Bacteria	53.1	0.3	17.2	7.3	24.5	18.4	4.4	100.7
Viruses	36.6	0	3.4	2.1	5.5	0	0	42.1
Soil	105.5	9.9	26.6	1.1	27.7	8.8	0	151.9
Water	5.4	0.7	1.8	0	1.8	5.8	0	13.7
Air	5.0	0	0.1	0	0.1	0	0	5.1
Food Products	33.2	2.2	17.2	0.5	17.7	69.9	0	123
Total	**1 052.7**	**81.8**	**396.3**	**175.1**	**571.4**	**156.7**	**8.6**	**1 871.2**

Table 3–Man-Years Devoted by Project Leaders in Natural Sciences–Study Approach Analysis

Approaches	Fed. Total	Prov. Total	Univ. Agric.	Univ. Other	Univ. Total	Industry	Other	Total
Biochemical	104.6	2.1	27.8	21.4	49.2	4.3	0.5	160.7
Biomathematical	12.7	0.8	1.6	1.8	3.4	1.1	0	18.0
Biophysical	16.4	1.8	5.5	2.9	8.4	0	0	26.6
Ecological	145.6	19.8	19.4	8.0	27.4	6.3	0.9	200.0
Genetical/Breeding	77.5	3.4	18.0	6.9	24.9	1.0	0	106.8
Immunological	10.0	0.1	5.3	1.9	7.2	0	0.2	17.5
Morphological	11.9	0.4	5.0	5.4	10.4	0	0	22.7
Nutritional	46.7	3.7	18.6	2.2	20.8	3.1	0	74.3
Pathological	61.0	4.1	10.0	3.7	13.7	0.2	0.8	79.8
Pharmacological-Toxic.	8.2	0.4	1.3	2.8	4.1	1.0	0	13.7
Physiological	48.8	1.5	19.7	9.6	29.3	0.6	0	80.2
Taxonomical-Classific.	57.7	4.7	4.5	2.3	6.8	0	0	69.2
Tech./Biological Prod.	1.6	0.4	0.8	0	0.8	0.5	0	3.3
Food Products	8.7	2.6	5.4	0.1	5.5	9.2	0	26.0
Forest Products	1.4	0.5	0.1	0	0.1	0	0	2.0
Total	**612.8**	**46.3**	**143.0**	**69.0**	**212.0**	**27.3**	**2.4**	**900.8**

Table 4–Man-Years Devoted to Projects by Postdoctoral Students, Professionals, and Technicians in Natural Sciences–Study Approach Analysis

Approaches	Fed. Total	Prov. Total	Univ. Agric.	Univ. Other	Univ. Total	Industry	Other	Total
Biochemical	177.1	1.6	66.9	46.5	113.4	22.4	4.4	318.9
Biomathematical	30.3	1.3	5.2	2.4	7.6	5.0	0	44.2
Biophysical	23.5	2.8	10.3	4.1	14.4	0	0	40.7
Ecological	207.2	30.2	46.9	21.6	68.5	12.1	1.3	319.3
Genetical/Breeding	169.1	11.9	51.3	12.5	63.8	2.0	0	246.8
Immunological	25.4	0	16.5	14.8	31.3	0	0.4	57.1
Morphological	14.1	0.4	7.8	18.2	26.0	0	0	40.5
Nutritional	88.1	8.2	55.4	6.2	61.6	23.6	0	181.5
Pathological	96.6	10.5	48.4	14.8	63.2	0.8	2.5	173.6
Pharmacological-Toxic.	24.8	0.8	3.0	7.4	10.4	12.0	0	48.0
Physiological	72.8	2.1	54.8	20.6	75.4	0.8	0	151.1
Taxonomical/Classifica.	89.1	7.0	12.4	6.0	18.4	0	0	114.5
Tech./Biological Products	4.1	0.2	0.5	0	0.5	4.6	0	9.4
Food Products	29.9	1.8	18.1	0	18.1	72.4	0	122.2
Forest Products	1.7	2.5	0.4	0	0.4	0	0	4.6
Total	**1 053.8**	**81.3**	**397.9**	**175.1**	**573.0**	**155.7**	**8.6**	**1 872.4**

Table 5–Number of Graduate Students assigned to Research Projects in Natural Sciences–Major Entity Analysis

Major Entities	Fed. Total	Prov. Total	Univ. Agric.	Univ. Other	Univ. Total	Industry	Other	Total
Mammals, General	1	1	71	22	93	0	0	95
Rodents	2	0	20	18	38	0	0	40
Ungulates	1	2	100	3	103	0	0	106
Birds, General	0	0	11	7	18	0	0	18
Galliformes	0	0	44	4	48	0	0	48
Amphibians, Reptiles, Fishes	0	0	17	6	23	0	0	23
Invertebrates, General	1	0	3	4	7	0	0	8
Helminths	0	0	9	9	18	0	0	18
Insecta and Arachnids	15	8	68	53	121	0	0	144
Plants, General	5	0	49	46	95	0	0	100
Gymnosperms	1	1	2	4	6	0	0	8
Angiosperms, General	1	1	24	30	54	0	0	56
Graminae	5	0	92	34	126	0	0	131
Leguminosae	0	0	17	21	38	0	0	38
Solanaceae	1	0	11	2	13	0	0	14
Cruciferae	1	0	2	1	3	0	0	4
Compositae	1	0	3	8	11	0	0	12
Rosaceae	2	0	10	0	10	0	0	12
Other	1	2	11	11	22	0	0	25
Algae	0	0	0	0	0	0	0	0
Fungi	20	0	12	15	27	0	0	47
Protozoa	0	0	4	2	6	0	0	6
Bacteria	3	0	39	8	47	0	0	50
Viruses	4	0	4	5	9	0	0	13
Soil	4	1	62	3	65	0	0	71
Water	0	0	3	0	3	0	0	3
Air	0	0	0	0	0	0	0	0
Food Products	2	0	31	1	32	0	0	34
Total	**71**	**17**	**719**	**317**	**1 036**	**0**	**0**	**1 124**

Table 6–Number of Graduate Students Assigned to Projects in Natural Sciences–Study Approach Analysis

Approaches	Fed. Total	Prov. Total	Univ. Agric.	Univ. Other	Univ. Total	Industry and Other	Total
Biochemical	19	1	137	99	236	0	256
Biomathematical	1	1	11	6	17	0	19
Biophysical	2	0	25	8	33	0	35
Ecological	15	9	127	49	176	0	200
Genetical/Breeding	8	0	84	29	113	0	121
Immunological	0	0	20	11	31	0	31
Morphological	2	0	21	25	46	0	48
Nutritional	1	0	90	11	101	0	102
Pathological	9	2	37	16	53	0	64
Pharmacological–Toxic.	3	0	8	10	18	0	21
Physiological	6	0	103	37	140	0	146
Taxonomical/Classific.	5	2	27	17	44	0	51
Tech./Biological Products	0	0	5	0	5	0	5
Food Products	0	0	26	0	26	0	26
Forest Products	0	2	1	0	1	0	3
Total	**71**	**17**	**722**	**318**	**1 040**	**0**	**1 128**

Table 7–Man-Years Devoted to Research Projects by Project Leaders in Agricultural Engineering–Entities

Entities	Fed. Total	Prov. Total	Univ. Total	Industry	Other	Total
Machinery	1.4	1.0	2.4	7.3	0	12.1
Power	0	0.1	0.6	0	0.1	0.8
Structures	0.2	0	0.9	1.0	0	2.1
Environmental Control	0.2	0.2	0.8	0.2	0	1.4
Crop, Food Processing	0	0.2	1.0	0.4	0	1.6
Materials	0	0.1	0.5	0.2	0	0.8
Water Resources	3.5	3.0	4.3	0	0	10.8
Soils	0	0	0.2	0.1	0	0.3
Research Equipment	1.4	0	0.1	0	0	1.5
Total	**6.7**	**4.6**	**10.8**	**9.2**	**0.1**	**31.4**

Table 8–Man-Years Devoted to Projects by Postdoctoral Students, Professionals, and Technicians in Agricultural Engineering–Entities

Entities	Fed. Total	Prov. Total	Univ. Total	Industry	Total
Machinery, General	6.5	1.9	7.1	135.7	151.2
Power, General	0	0.4	1.9	0	2.3
Structures, General	0.8	0	3.1	3.7	7.6
Environmental Control	1.6	1.0	1.1	0.6	4.3
Crop, Food Processing	0	0.3	1.7	1.3	3.3
Materials, General	0	0.4	0.7	0.6	1.7
Water Resources, General	7.8	13.5	7.8	0.0	29.1
Soils, General	0	0	1.0	0.5	1.5
Research Equipment	14.8	0	0.4	0	15.2
Total	**31.5**	**17.5**	**24.8**	**142.4**	**216.2**

Table 9–Number of Graduate Students in Agricultural Engineering–Entities

Entity	No. Graduate Students
Machinery, General	11
Power, General	4
Structures, General	4
Environmental Control	4
Crop, Food Processing	3
Materials, General	2
Water Resources, General	21
Soils, General	2
Research Equipment	0
Total	**51**

Table 10–Man-Years Devoted to Projects by Project Leaders in Agricultural Economics–Major Research Subjects

Subject	Fed. Total	Prov. Total	Univ. Total	Industry	Other	Total
Economic Development	0	1.7	1.1	0.3	0	3.1
Econ. of Production	11.6	7.5	4.8	4.5	0.7	29.1
Marketing, Distribution and Trade	3.4	4.0	3.0	3.5	0	13.9
Resource Use and Development	2.9	2.8	2.4	0	0.5	8.6
Agricultural Policy	0.6	0.5	0.5	0.5	0.8	2.9
Co-operatives	0.2	0.2	0.5	0	0	0.9
Methodology and Theory	0.6	0	0.1	0	0	0.7
Econometrics	0.3	0	0.8	0	0	1.1
Interregional Competition	0	0.5	0.3	0	0	0.8
Rural Sociology	0.4	0	0.1	0	0	0.5
Total	**20.0**	**17.2**	**13.6**	**8.8**	**2.0**	**61.6**

Table 11–Man-Years Devoted to Projects by Postdoctorate Students, Professionals, and Technicians in Agricultural Economics–Research Subjects

Research Subjects	Fed. Total	Prov. Total	Univ. Total	Industry	Other	Total
Economic Development	0	2.0	0.3	0.9	0	3.2
Econ. of Production	26.9	21.4	8.5	20.4	0	77.2
Marketing, Distribution, and Trade	2.7	4.9	3.6	3.0	0	14.2
Resource Use and Development	2.3	4.1	2.4	0	0	8.8
Agricultural Policy	0	0	0.9	12.7	0	13.6
Co-operatives	0	2.0	0.2	0	0	2.2
Methodology and Theory	1.5	0	0.6	0	0	2.1
Econometrics	0.9	0	0	0	0	0.9
Interregional Competition	0	0	2.0	0	0	2.0
Rural Sociology	0.2	0	0.3	0	0	0.5
Total	**34.5**	**34.4**	**18.8**	**37.0**	**0**	**124.7**

Table 12–Number of Graduate Students in Projects in Agricultural Economics

Research Subjects	No. Graduate Students
Economic Development	4
Econ. of Production	33
Marketing, Distribution and Trade	28
Resource Use and Development	12
Agricultural Policy	4
Co-operatives	0
Methodology and Theory	1
Econometrics	2
Interregional Competition	2
Rural Sociology	0
Total	**86**

Note: Twenty-eight graduate students (32.6%) are supervised by project leaders in federal and provincial governments. Most of these are located as follows: CDA, Economics Branch; DBS, FCC, Department of Finance, and Department of Trade and Commerce, all in Ottawa; ODAF, Kemptville, Ontario; and Min. Agric. Colon., Quebec City.

Table 13–Man-Years Devoted to Projects by Project Leaders in Rural Sociology–Research Subjects

Research Subjects	Sectors										
	Fed. Agric.	Fed. Other	Fed. Total	Prov. Agric.	Prov. Other	Prov. Total	Univ. Agric.	Univ. Other	Univ. Total	Other	Total
Anthropology	0	0.2	0.2	0	0	0	0	2.2	2.2	0	2.4
Social Psychology	0	0	0	0	0	0	0	0	0	0	0
General Sociology	0	0.9	0.9	0	1.1	1.1	0	3.9	3.9	0	5.9
Rural Sociology	0	0.2	0.2	0.9	0.3	1.2	0	2.5	2.5	0.1	4.0
Extension	0	0	0	0	0	0	0	1.0	1.0	0	1.0
Economics	0	0	0	0	0	0	0	0	0	0	0
Political Science	0	0	0	0	0	0	0	0	0		0
Total	**0**	**1.3**	**1.3**	**0.9**	**1.4**	**2.3**	**0**	**9.6**	**9.6**	**0.1**	**13.3**

Table 14–Man-Years Devoted to Projects by Postdoctoral Students, Professionals, and Technicians in Rural Sociology–Research Subjects

Subjects	Sectors										
	Fed. Agric.	Fed. Other	Fed. Total	Prov. Agric.	Prov. Other	Prov. Total	Univ. Agric.	Univ. Other	Univ. Total	Other	Total
Anthropology	0	0	0	0	0	0	0	1.9	1.9	0	1.9
Social Psychology	0	0	0	0	0	0	0	0	0	0	0
General Sociology	0	2.2	2.2	0	4.0	4.0	0	6.5	6.5	0	12.7
Rural Sociology	0	1.8	1.8	1.5*	0	1.5	0	3.5	3.5	0	6.8
Extension	0	0	0	0	0	0	0	0	0	0	0
Economics	0	0	0	0	0	0	0	0	0	0	0
Political Science	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0
Total	**0**	**4.0**	**4.0**	**1.5**	**4.0**	**5.5**	**0**	**11.9**	**11.9**	**0**	**21.4**

*Co-operatives.

Table 15–Number of Graduate Students in Projects in Rural Sociology–Research Subjects

Subjects	Fed. Total	Prov. Total	Univ. Agric.	Univ. Other	Univ. Total	Other	Total
Anthropology	0	0	0	13	13	0	13
Social Psychology	0	0	0	0	0	0	0
General Sociology	0	0	0	14	14	0	14
Rural Sociology	0	0	0	8	8	2	10
Extension	0	0	0	1	1	0	1
Economics	0	0	0	0	0	0	0
Political Science	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**36**	**36**	**2**	**38**

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