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C.I.C. SURVEY

# REPORT OF COMMITTEE 06
# PHARMACEUTICALS AND NATURAL PRODUCTS

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## SUMMARY

This Report presents a survey of research and development in the area of pharmaceuticals and natural products in Canadian industrial, academic and government laboratories. Emphasis has been placed on replies to a questionnaire sent to each laboratory carrying out relevant R. and D.

Canadian chemists have often excelled in natural products research and this field represents one of the strongest divisions of organic chemistry in the country; the emphasis has, however, been placed on relatively few classes of compounds. Many of the natural products chemists in the university and government laboratories are highly regarded. The amount of pharmaceutical research carried out in industry has grown considerably in recent years as a result of government incentive programmes. The role of such research is discussed. Related work in schools of pharmacy is uneven but there are a few laboratories carrying out important work in medicinal chemistry and natural products.

Several suggestions are offered to improve the state of R. and D. Basically these relate to means of improving awareness of, and collaboration between workers in related fields, and means of increasing financial support for their work. Amongst the proposals are a Drug Research Institute and various equipment service centres to serve all workers. The need for Canadian laboratories to select, specialize and concentrate on certain well-defined problems is stressed.

A Directory of workers and their principal interests indicates the relative effort in the different fields.

# SECTION I.

## INTRODUCTION

This report presents a survey of Canadian research and development in the fields of pharmaceuticals and natural products carried out in industrial, academic and government laboratories. The topics include natural and synthetic medicinals, toxicants, antibiotics, alkaloids, terpenes and steroids.

It is obvious that the selection of the subject matter has been to some extent arbitrary and that there exists a problem of overlapping interests between this Committee and certain others (e.g. 04 and 17). We have attempted to minimize these overlaps and yet avoid significant omissions. For such errors of omission we ask the indulgence of the parties concerned.

The survey has been conducted largely by means of a questionnaire distributed to selected individuals who could represent the views of their respective institutions. It was hoped to gain a perspective of different opinions and to obtain as complete a coverage as possible. The committee wishes to thank those who gave their time to answer the difficult questions and who offered well-considered suggestions for the betterment of the state of Canadian research and development. Their incisive and cogent replies have helped to offset the lack of response from other institutions. Other material for the survey has been gathered from statistical data furnished by the C.I.C., D.B.S., N.R.C. and related sources as well as from articles and reviews in several chemical news journals. Interested parties also provided informal but highly useful discussions.

The report is presented as follows:

Section II. General survey of the fields under review with an appreciation of the current efforts in R and D.

Section III. Review of pertinent replies to the questionnaire with emphasis on means to improve the state of R and D in the different categories.

Section IV. Future trends.

Section V. Recommendations of Committee 06.

## SECTION II.

## PERSPECTIVE OF CURRENT EFFORT

### (i) Industrial Laboratories:

The sector of industry carrying out most of the research and development which falls within the scope of this report is the ethical pharmaceutical industry; a limited amount of related work is also undertaken by a few food and fermentation concerns. The major part of the basic and "objective basic" (1) chemical research is in the area of medicinal chemistry, i.e. the preparation of novel compounds having potential biological utility. These compounds encompass many classes of organic chemicals including alicyclics, terpenes, steroids, alkaloids and numerous types of heterocyclics. Research is also carried out in kinetics and the chemistry of isotopically labelled compounds. Applied or development work is performed in the area of fine chemical production, i.e. adapting laboratory procedures to a commercial scale. Other applied research is in pharmaceutics or product development which involves studies of formulation, stability and assay procedures. Many firms, however, leave the applied research to their parent companies abroad. The importance of chemistry to the pharmaceutical industry is evidenced by the fact that in the U.S. at least 20% of its total research and development expenditures is devoted to chemical research (2); a similar figure of 17% was reported for Canada (3).

In Canada, industrial pharmaceutical research grew relatively slowly until the early part of the current decade. The obvious rewards to be gained from research were clearly shown in the 1950's - the years when press publicity on the industry dealt not with allegedly high prices but with the benefits of another "miracle drug". Aided by the Federal Government's tax incentive (IRIDA) programme and by research grants from the NRC, several firms either expanded their existing laboratories or established entirely new ones. Many of these laboratories are, incidentally, located in the Montreal area and the city is regarded as the centre for Canadian pharmaceutical research. An informative review of these developments has been published (4).

A brief description of those firms carrying out chemical research follows:

Ayerst Laboratories operates the most extensive pharmaceutical research laboratories in Canada; it has been carrying out research since 1931. In 1943 it was acquired by American Home Products Inc. but continues to perform the research for the Canadian, U.S. and International Divisions of Ayerst - a unique position for a domestic company. The chemical research department is active in the fields of steroid hormones, central nervous system (CNS) and cardiovascular agents, anti-inflammatory and anti-infective agents as well as drugs affecting lipid metabolism. There are also some investigations on natural products. Certain well-recognized advances have been made especially in the hormone field. The chemists also work closely with the Biochemistry Department on studies of drug metabolism and in vitro screening of compounds. The Fine Chemicals Group operates a well-equipped pilot plant where quantities of chemical intermediates and potential drugs are produced.

Chas. E. Frosst and Co. was until recently the largest Canadian-owned company performing its own research, its original laboratory having been established in 1923. Its acquisition in 1965 by Merck, Sharp and Dohme Ltd. has led to integration of the research activities of the two concerns. Chemical research is directed towards the finding of new hormones, CNS drugs and anti-cancer agents. The company's commercial interest in isotopically-labelled compounds is reflected by their research activity in this field. There are also investigations carried out on reaction mechanisms and kinetics, and in pharmacy.

Frank W. Horner Ltd., since 1962 a division of Carter Products Inc., carries out medicinal chemistry research in the field of CNS drugs including hypnotics and psychopharmacological agents, and in antidiabetic and cardiovascular drugs. A basic chemical project on the synthesis of polypeptides is supported by an NRC research grant. The company also carries out applied research in pharmaceutical development.

Pharma Research Canada Ltd. is a research subsidiary of C.H. Boehringer Sohn, Germany. Established in 1964, the group is investigating the preparation and properties of new cardiovascular and CNS drugs.

Bristol Laboratories Ltd., a leading U.S. company in the field of antibiotics, established independent laboratories in Japan and in Canada. The local institution, completed in 1963 just outside Montreal, has concentrated on the field of CNS agents and has developed a new class of potent inactivators of adrenergic alpha-receptors. The compounds have CNS activity comparable to the major tranquilizers of the phenothiazine class. Bristol, as well as those companies cited above, carries out its own pharmacological testing programme.

Abbott Laboratories Ltd. undertook medicinal chemistry research in Montreal in 1963. Their interests are in new cardiovascular drugs including antihypertensives, diuretics and anti-anginal agents. Another programme is directed towards compounds useful in veterinary helminthology.

Smith, Kline and French Canada Corp. has carried out research in pharmacy since 1960 and the Pharmaceutical Development Division has been successful in developing several drugs for the Canadian market. In 1964 the company opened its new R and D laboratories in Western Montreal. Here, in addition to more biologically oriented problems, a group is investigating polypeptide and polynucleotide synthesis. Facilities for pilot scale organic synthesis are available.

Delmar Chemicals Ltd. carries out work in process development for its line of custom-produced organic chemicals, pharmaceutical intermediates and agricultural chemicals. In 1963 the company undertook medicinal chemistry research with the objective of finding new coronary vasodilators and CNS agents. Delmar's parent company, John Labatt Co. (London, Ont.) also carries out pharmaceutical research.

Bio Research Laboratories Ltd. is a Canadian-owned consulting laboratory offering a programme of pharmacological and toxicological services to the pharmaceutical industry. In 1968 the company will establish a group to carry out research in medicinal chemistry.

Canada Packers Ltd. (Toronto), carries out research directed towards the utilization of the raw materials found in a packing house. It has developed methods for the processing of

bile acids, pancreatic enzymes and heparin and is the only Canadian producer of these items. The research group has investigated phosphatides from animal brain which markedly affect the blood clotting mechanism.

R. and L Molecular Research Ltd. (Edmonton) is a Canadian-owned company involved in synthetic organic research in the field of antibiotics on a custom basis for Bristol Myers Inc. (U.S.A.). An affiliated concern, Raylo Chemicals Ltd. provides custom research and custom chemicals, and has facilities for pilot scale organic syntheses.

Many Canadian pharmaceutical firms carry out their own quality control and analytical work; there are also independent testing laboratories. Such activities are not considered within the scope of this report.

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The Pharmaceutical Industry is very much part of the "Canadian situation" whereby most of the larger companies are foreign-owned. The often cited problem of a small domestic market coupled with ready access to the parent company's existing research and technology has tended to inhibit the commitment of research expenditures. Nonetheless, when compared to the amounts spent by the chemical industry in general, the pharmaceutical houses have a noteworthy record.

In 1965, the industry spent $6.9 million on intramural R and D or 4.2% of net volume; for other chemical industries combined the figure was 2.4% (3,5). Of the amount, 27% was spent for basic research, 41% for applied and 32% for development. For 1966, the D.B.S. survey indicated $8.3 million for intramural R and D. If the capital ($1.5 million) and extramural ($2.9 million) expenditures are considered, the total is $12.7 million or 5% of the industry's annual sales, a proportion exceeded by very few other Canadian manufacturing industries. The figure represents 28% of the total amount spent by the chemical and chemical process industries* on R and D in that year (6). In comparison, the U.S. drug industry spent a total of $416.1 million in 1966 on R and D, over 96% of this coming from its own funds; the amount forecast for 1967 was $476.2 million (7). These values represent about 10% of total ethical drug sales.

Some 16% of the total expenditure was designated for basic research as compared to an overall total for industry of only 4% (8).

The difficulties incurred in the development of new drugs should also be noted. In the U.S., for example, over 5,000 compounds are synthesized for each one reaching the market. The cost per new drug has been estimated as being in excess of over $5 million. The more stringent regulations introduced in the last few years have considerably added to the cost and effort involved in the acceptance of new drugs to the point where companies are sometimes reluctant to develop new drug leads. Despite these difficulties the industry has a good record and deserves recognition for building and maintaining a corps of highly trained and respected researchers. These included 112 Ph.D.'s, 50 M.Sc.'s and 137 B.Sc.'s (total personnel 569) according to a 1965 survey; of these 157 were chemists (3).

(ii) Universities:

(a) Natural Products and Related Fields:

Natural products chemistry, at least in the fields of alkaloids and terpenes, has long been an area of strength in Canada, stemming from the pioneering work of L. Marion and R.H.F. Manske at the N.R.C., and then vigorously stimulated by the work of K. Wiesner.

As pointed out by several respondents to the Committee's questionnaire, a natural products chemist is in fact an organic chemist who uses naturally occurring compounds as a means for carrying out basic research in organic chemistry. As far as university chemists are concerned the goals of basic research are (i) to furnish new scientific information and, (ii) to produce a body of scientists who can continue in the quest for new knowledge or who can derive practical applications from new principles. Scientific education and basic research go hand-in-hand. The long-term goals of basic research in natural products chemistry are (i) the improvement of our knowledge of the processes which result in the formation of naturally occurring compounds and of their function - if any, (ii) the development of new synthetic methods and the improvement of existing ones, (iii) the improvement of the techniques available for the study of the structure and conformation of organic

molecules, (iv) the discovery of new naturally occurring compounds, the study of which will enrich the field of organic chemistry and/or which may have interesting and valuable biological properties.

No attempt has been made to provide an exhaustive survey. The institutions selected are those which the respondents to the questionnaire considered to be the leading Canadian schools in the field.

University of New Brunswick (Fredericton). Outstanding work has come from this school in the field of alkaloids and terpenes, both from the structural and synthetic side. Particularly noteworthy are the structural and synthetic studies on the diterpene alkaloids, both of the Atisine and Aconite classes, and on the Lycopodium alkaloids. In both cases the structural work opened the way to a very rapid growth in the body of knowledge concerning these groups of compounds, and the synthetic work has led to several valuable new methods, e.g., the allene photoaddition reaction.

University of British Columbia (Vancouver). Very valuable work has emerged on both the synthesis and biosynthesis of indole alkaloids. Important advances have been made in the biosynthesis of polyacetate compounds, and notable contributions to the chemistry of the tetracycline antibiotics have come from these laboratories.

University of Western Ontario (London). Noteworthy advances in the chemistry of several sesqui- and triterpenes have been made in these laboratories, as well as with the Ceanothus and Amaryllidaceae alkaloids. Of special interest has been the elucidation of the structure and the synthesis of helminthosporal, the toxin produced by a type of wheat rust, work which was carried out in collaboration with Agriculture Research Institute in London.

Several valuable synthetic methods involving photochemical reactions have been developed and applied to the synthesis of natural products.

University of Alberta (Edmonton). A total synthesis of several indole alkaloids of the Ajmaline type has been developed and important advances in the chemistry of the Lycopodium alkaloids have been recorded. Important contributions to the chemistry of the amino sugar antibiotics have also been reported from these laboratories.

McMaster University (Hamilton). Here also pioneering work in the field of Lycopodium alkaloids has been carried out and important studies of the mode of biosynthesis of several types of alkaloids have been recorded.

University of Toronto (Toronto). Important structural and synthetic studies on alkaloids, terpenes, and pigments have been carried out and interesting work of a biochemical nature on steroids has been reported. The work on lipid chemistry at the Banting and Best Institutes is world renowned.

McGill University (Montreal). Interesting mechanistic studies on steroids have been reported from these laboratories, and a very important synthesis of prostaglandin has recently been achieved.

Université de Laval (Quebec). Many valuable structural and synthetic studies on steroids and alkaloids have been reported by members of the Laval Chemistry Department.

As may be seen from the Directory this is by no means an exhaustive survey of the work in natural products being carried out in Canadian universities. It may be seen, however, that natural products chemistry is in a healthy state in Canada, although it is also obvious that the research efforts are concentrated on a relatively few groups of natural products.

(b) Pharmacy:

From modest beginnings academic research in pharmacy has grown considerably in the past 10-15 years. There are 8 schools or faculties of pharmacy of whom Alberta, Toronto, Montreal and Laval award the doctorate degree. Total staff numbers 65 teachers and 75 graduate students. Comprehensive surveys of education and research in pharmacy schools have been compiled (9, 10); only a brief review is presented here.

Pharmacy curricula necessarily embrace several chemical and biological disciplines and the research projects fall within four interdisciplinary areas:

(i) pharmaceutical or medicinal chemistry: synthesis and isolation of compounds with potential biological activity; study of relation between chemical structure and physiological activity.

(ii) pharmacognosy: study of drugs from plant sources; factors relating to plant growth.

(iii) pharmaceutics or biopharmaceutics: study of formulations (dosage forms), stability and assay procedures; availability and distribution of drugs in vivo.

(iv) pharmacology: effects of drugs on microorganisms, animals and man.

In addition, newer areas under investigation include drug metabolism and molecular pharmacology - the application of physico-chemical approaches to the study of drug reactions at a molecular level.

A good part of the work on pharmaceutics could be considered as analytical or physical-organic chemistry. The work in pharmacognosy (natural products) and medicinal chemistry is, however, directly relevant for the present report. There is an unfortunate lack of communication with scientists in the pharmaceutical industry with the result that some of the research activity is of mediocre quality. A similar situation appears to exist in U.S. Schools. There are, however, certain institutions where high-calibre work is being done. These include U.B.C., Alberta and Montreal (medicinal chemistry); Manitoba (drug metabolism and phytochemistry); Toronto (natural products, medicinal chemistry and chemotherapy). A more comprehensive list is given in the Directory (II b). Other university departments carrying out related research, e.g. Ottawa (molecular pharmacology and Laval (cancer chemotherapy) are listed in II a.

(iii) Government Laboratories:

This section briefly reviews those areas of research in government laboratories which come under the terms of reference of Committee 06. By far the best known of these laboratories are

those of the N. R. C. which carries out considerable basic research of a kind traditionally associated with the universities. The N,R.C., however, is by no means typical of government laboratories due to the freedom it enhoys in its research projects. Other government departments and agencies such as Agriculture, National Health and Welfare, Forestry and Rural Development, Defence, Fisheries and the R.C.M.P. bear the responsibility of applying scientific knowledge to the problems associated with their respective departments. This work is mainly applied together with some objective basic research, the latter being taken as providing the background knowledge which will assist in maintaining a state of current awareness in a particular field. The proportion of applied to basic research is dependent on how each research director interprets the terms of reference of his directorate. The Royal Commission on Government Organization has made a detailed study of the function and work carried out by government laboratories (11).

In the field of natural products chemistry, the contributions made by the N.R.C. Ottawa Laboratories have been outstanding. It has long been known for its work on alkaloids which developed under R.H. Manske and L. Marion. In the Division of Pure Chemistry there is currently less emphasis on this field although work is carried out on structure elucidation, possible total syntheses and biosynthetic studies of the aconitine-type alkaloids. Other work includes cyclisation of terpenes and structural studies of mould metabolites (e.g. myxin). The work in pyrroles and porphyrins has concerned the reactions of dipyrrylmethanes, porphyrin synthesis and biosynthesis. X-ray crystallographic studies of complex alkaloids are also carried out. The fatty acid components of seed oils and related materials are investigated. In the Division of Biosciences there is related work on the chemistry of lipids, notably those from halophilic bacteria, and on the biosynthesis of phosphatides in plants. The group dealing with food chemistry is investigating the fatty acid composition of all the major triglycerides in complex fats (e.g. egg triglycerides). Other projects in this Division include work on the toxin in blue-green algae and studies of protein and lipoprotein structure.

N.R.C. has two regional laboratories which do both basic and objective basic research. At the Atlantic Regional Laboratories (Halifax) this includes work on fungal and plant toxins (sporidesmin, fusaric acid) and pigments as well as biosynthesis of antibiotics (gliotoxin, chetomin, chloramphenicol) and lichen metabolites. An aim of this work is to enable better control of fermentation processes.

Other work includes studies of the chemical composition of seaweed, marine algae, certain fish sterols and a programme directed to the synthesis of potentially physiologically active indole compounds. The latter also covers studies on psychotomimetic aminochromes and catecholamines.

Work at the Prairie Regional Laboratories (Saskatoon) is concerned with the study of plants and microorganisms with a view to promoting their economic use. The research includes work on plant constituents, in particular structural studies on oil and proteins from rapeseed. There is also work on fungal metabolites and biosynthetic studies of antibiotics (chloramphenicol, valinomycin) phenolic coumarins, flavonoids, phenazines, isothiocyanates, terpenes, and aromatic amino acids. The microbial metabolism of aromatic compounds and amino acids is also studied. In addition to carbohydrates, the Natural Products group investigates chemotaxonomic relationships in spruce species, terpene compositions of leaf oils (mint, conifers), fatty acids from animals and plants, phospholipids of rapeseed gum and constituents of leaf surface waxes from wheat. Engineering and process development work in fermentation chemistry is also carried out.

In the Department of Agriculture, the Cell Biology Research Institute (Ottawa) does work in the fields of fungal toxins and antibiotics, e.g. the isolation and characterization of myxin, a potent, broad spectrum antibiotic. Studies on microbial metabolism (amino acid metabolism, protein synthesis, enzymology) with reference to tumor-inducing microorganisms are also carried out, as are studies of chemical determinants of plant disease and frost resistance. The Food Research Institute (Ottawa) studies plant-growth factors (indoles, phenols, ethylene, gibberelic acids); sterols, glycolipids, phospholipids and neutral lipids of plant and animal tissue as well as the carotenoid pigments and natural antioxidants of plant tissue; and the chemistry of cheese flavour (ketones, ethers, peptides and amino acids). The long-term goal of the Research Institute at London is to aid in crop protection and its research includes studies of the mode of action of toxicants (fungicides, herbicides and insecticides) and the isolation and characterization of certain biologically active materials such as the fungal toxins, helminthosporal and the hordatines. In addition they carry out structure-activity studies with organophosphorous compounds to help develop new agents of low mammalian and high insect toxicity.

The Defence Research Board has two establishments carrying out chemical research in the area. At the Defence Chemical

Biological and Radiation Establishment (D.C.B.R.E.) (Ottawa) the main interests are the study of therapeutics for anticholinesterase poisoning, radioprotective drugs and the nature of the active site of cholinesterase. The Defence Research Establishment, Suffield (D.R.E.S.) is known for its preparations of compounds containing a high level radioactive phosphorus ($^{32}P$), the structure-activity correlation of irritants (sternutators, lachrimators, etc.) and bacteriostats, and the chemistry of conjugated heteroenoid compounds.

The Fisheries Research Board operates three laboratories. The Vancouver Technological Station studies chemical products of marine phytoplanktons and the chemistry of flavour components, sex attractants and moulting hormones in marine fauna. The recently established Fresh Water Research Institute (Winnipeg) studies fish muscle proteins, chemical indices of fish quality and the chemical control of lampreys. A group at the Halifax Technological Station is well known for its work on the chemistry of marine oils and lipids and their fatty acid components. The main adrenal cortical hormones in salmon have been identified with a view to understanding the life cycle and the possibility of rearing them commercially. A novel steroid shown to have androgenic action has been implicated in the spawning mechanism. There are also investigations of the macromolecules in fish-muscle protein and of hormone-protein bindings.

The chemical research effort by the Department of Forestry and Rural Development is small. The Forest Products Laboratory (Vancouver) has been working on extracts of Western Canadian woods and barks. This has resulted in the identification of the phenolics responsible for sapwood stains and the characterization of thujaplicatins found in Western red cedar.

The programme of the Research Laboratories of the Food and Drug Directorate, Department of National Health and Welfare (Ottawa) reflects the functions of the Directorate in administration and enforcement of the various food and drug acts. Scientists of many disciplines are engaged in a variety of projects and chemical research is carried out in the Divisions of Pharmaceutical Chemistry, Food, and Pharmacology. This includes important work in molecular structure-biological activity relationships in steroids (sex hormones, adrenocortical steroids) as well as metabolic studies on drugs, pesticides and carcinogens. There are also programmes on the development of assay methods for drugs, pesticides and fungicides as well as psychoactive natural products (e.g. opium and ergot alkaloids, peyote, and marihuana) together with some work on the chemistry of alkaloids, terpenoids and glycosides. This is related to studies on biogenetic and biosynthetic processes in drug-bearing plants with a view to

developing chemotaxonomic calssifications. Other projects in pharmaceutics include studies of drug stability and availability in vivo. and the use of spectroscopic, chromatographic and polarographic methods for analyses (13).

Finally, the R.C.M.P. have a small section investigating the application of analytical methods to forensic chemistry.

Certain Provincial Governments undertake research. At the Ontario Research Foundation (Toronto) relevant chemical studies are undertaken on fatty acids, the chemistry of insect attractants and development of methods for determination of pesticide residues. The Saskatchewan Research Council (Saskatoon) has investigated the chemistry of oilseeds including the protein, phenolic and saponin constituents.

There is no doubt that the calibre of work at the N.R.C. in the field of natural products is excellent. In other government laboratories, where more applied and objective basic research is carried out, it is more difficult to assess the standards. The usual criteria such as the number of publications reveal only a small part of the story. Success, or the lack of it, can only be measured by the effect which the work has on the nation's health, economy or defence.

Continue on p. 14.

iv C.I.C. Survey Data. The foregoing discussion of current efforts in industry, universities and government was based largely on D.B.S. statistics and information collected by Committee 6. The D.B.S. data on industry was convenient since one category of the manufacturing industries was entitled "Drugs and Medicines" and corresponded approximately to the area of the committee.

Some selected data from the C.I.C. Survey, Section 18, are given in Tables III and IV of this report. In comparing these data with those of Tables I and II, allowance should be made for the fact that the C.I.C. survey endeavoured to restrict its attention to R. and D. whose objective was largely chemical or related thereto. Thus, the total intramural Chemistry[1] operating R. and D. under Committee 6 for industry is given as $4,817,800 in Table III. The D.B.S. figures for all intramural "Drugs and Medicines" R. and D., quoted on p. 6 of this report, is $8.3 million. However, in Table 12, 13-527 (1965), D.B.S. classify only $6.9 million as related to chemistry, of which $4.0 million is ascribed to medical science. The classification of an R. and D. project as medical or biochemical is difficult, and it appears that the C.I.C. survey took in about one-half the R. and D. that D.B.S. classified as medical.

The classification of industrial R. and D. into basic, applied, and development is approximately the same in Table III and p. 6 of this report.

Table I. Current Expenditures of the Federal Government on R and D, by Department or Agency and by Performer, 1966-1967 (1)

| Department or Agency | Federal Government | Canadian Industry | Canadian Educational Institutions |
|---|---|---|---|
| | thousands of dollars | | |
| Agriculture ..... | 32,826 | - | 450 |
| Fisheries Research Board ..... | 9,985 | - | 250 |
| Industry (2) ..... | - | 29,500 | 1,500 |
| Medical Research Council ..... | 68 | - | 10,234 |
| National Health and Welfare ..... | 2,810 | - | 2,409 |
| National Research Council ..... | 37,751 | 4,400 (3) | 28,785 |
| Defence Research Board ..... | 33,611 | 6,080 | 3,100 |

(1) Selected from "Federal Government Expenditures on Scientific Activities, Fiscal Year 1965-66;" D.B.S. Daily Bulletin Supplement No. 4 (1967); figures are forecasted.

(2) Of the $31 million total, $25 million was allocated for military science.

(3) For 1967 the amount was $6.21 million; cf Appendix D.

Table II. Personnel Employed on Intra-mural R and D by the Federal Government, by Department or Agency, 1966(1)

(full-time equivalent)

| Department or Agency | Scientists and Engineers | | | Supporting Personnel |
|---|---|---|---|---|
| | Bachelors | Masters | Doctors | |
| Agriculture ..... | 160 | 261 | 558 | 3,291 |
| Fisheries ..... | 136 | 77 | 99 | 626 |
| Forestry and Rural Development ..... | 108 | 111 | 138 | 815 |
| National Health and Welfare ..... | 261 | 58 | 178 | 462 |
| National Research Council ..... | 198 | 169 | 397 | 2,007 |
| Defence Research Board ..... | 307 | 220 | 177 | 2,098 |

(1) Source: Table I, ref. 1; only those Departments covered by this Report are included.

Table III Intramural Chemistry[1] Operating R. and D. Expenditures by Performer and Character of R. and D. for C.I.C. Area 061 Pharmaceuticals[2]. 1966 or 1966-67. (in thousands of dollars, % by character in brackets)

| Character / Performer | Basic | Applied | Development | Totals |
|---|---|---|---|---|
| Government | 125.0(10.9) | 957.5(83.6) | 62.5(5.5) | 1,145.0 |
| Industry | 1,570.4(32.6) | 2,218.2(46.0) | 1,029.2(21.4) | 4,817.8 |
| University (Institutes) | 486.7(73.2) | 170.8(25.7) | 7.4(1.1) | 665.0 |
| Totals | 2,182.1(32.9) | 3,346.5(50.5) | 1,099.1(16.6) | 6,627.8 |

(1) Including chemical engineering, and other related disciplines.

(2) Source: C.I.C. Survey - Section 18, Tables 11a, 26 and 39.

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Table IV Manpower Effort on Intramural Chemistry[1] R. and D. by performer and Educational Level for C.I.C. Area 061 - Pharmaceuticals[2] 1966 or 1966-67. (man-years)

| Level / Performer | Dr. | Ma. | Ba. | Techn. | Totals |
|---|---|---|---|---|---|
| Government | 43.5 | 11.0 | 3.0 | 62.0 | 119.5 |
| Industry (estimate) | 84.0 | 28.0 | 98.0 | 137.0 | 347.0 |

| | Academic | P.D.F.'s | Grad. Students | Techn. | Totals |
|---|---|---|---|---|---|
| University (Institutes) | 44.0 | 19.0 | 95.0 | 40.0 | 198.0 |

(1) Including chemical engineering and other related disciplines.

(2) Source: C.I.C. Survey - Section 18, Tables 16, 27A and 38.

## SECTION III.

## OPINIONS REVIEWED

Over 70 replies to the Committee's questionnaire were received representing a cross section of current opinions. As expected, divergent and often contradictory views were presented, some with considerable vigour. While it has not been feasible to discuss each reply we have attempted to present a representative sample of the suggested means for improving the state of Canadian R and D in the areas under consideration.

### (i) Balance of Basic and Applied Research

Several polemics were received either deploring the lack of applied research or the near-frivolous wastage of funds on an excess of basic studies. Some respondents reflected the view of the Engineering Institute's Report (14) that too great a proportion of the country's R and D expenditures were devoted to basic research. A strong case for increasing the amount of support for basic studies was made, however, by a former Vice-President of N.R.C. (15). Through its work in basic research (accounting for about 15% of the total N.R.C. budget) the Council has gained a prestigious scientific reputation and has been instrumental in its success in obtaining from the Government ever increasing financial support for scientific research in the universities. The Committee agrees with this view but notes that every effort must be extended to maintain the quality of basic research; it can easily become inbred and trivial. Those centres of excellence in Canada should be actively supported and encouraged.

The values of applied research to the country's economy are obvious. Several respondents stressed that Canada cannot possibly compete in all fields and must carefully select and concentrate the efforts on a project basis. Most industrial representatives felt that more funds should be given over to applied research and an annual expenditure of $60 million for the pharmaceutical and related fields was (optimistically) suggested.

(ii) Research in University, Government and Industrial Laboratories

(a) Universities:

The most frequently mentioned problem facing academic institutions in Canada is the lack of graduate students of adequate capabilities. Suggested solutions to this problem were (i) increased government and industrial support in the form of scholarships, (ii) increased efforts to keep Canadian students in this country, perhaps by further encouraging exchange of students among Canadian universities and (iii) an increased effort to attract high school students into chemistry.

Industrial and government respondents stressed the need for the universities to maintain a programme for the continuous retraining of scientists in the form of extension courses, lecture series and seminars. Apart from activities arranged by the C.I.C., little is being done in this regard. For the fields under review by this Committee, scientific developments move very rapidly and the universities should be the main centres for maintaining current awareness.

After a period of active growth, research in schools of pharmacy has reached a turning point. Some respondents even questioned the continued existence of pharmacy schools as such. Granted the desirability of maintaining them, it has been suggested that they should create interdisciplinary centres of excellence at the post-doctorate level. The research workers would first be trained in one specific field. An organic chemist, for example, would come to these centres as such and would then learn medicinal chemistry in collaboration with specialists in other disciplines. The particular need for pharmaceutically oriented scientists to collaborate with their counterparts in industry is discussed below. Even in those institutions where the formation of multidisciplinary research teams would be impracticable, individual workers should be encouraged to carry out research in different but related fields.

Mention was made of the difficulties incurred in obtaining grants for certain interdisciplinary projects. In cases which for example, involve the preparation of a series of compounds for biological evaluation, the synthetic problems are often of a routine nature. Chemists in granting bodies tend to evaluate such projects on the basis of chemical interest and fail to understand that the importance of the work lies in the correlation of structure with biological

activity. A broader view of this type of research should be taken by granting agencies. The recent decision to have the Medical Research Council allocate grants to the schools of pharmacy is to be commended.

The U.S. pharmaceutical industry spent about $4 million in 1967 on academic research, much of it on chemistry[8]. The universities should seek to attract at least a proportionate amount from the Canadian industry, who should, in turn, be less conservative in their policy of grants to acacemic institutions.

A study of the future requirements for support of research in science and engineering on Canadian universities has been published (16).

(b) Government:

Some reservations have been expressed about research carried out by government laboratories. First, the research effort covers too many fields and as a result is often lacking in depth. Perhaps the time has come to consider restricting the areas covered and to concentrate more on a limited number of fields. The recent establishment of the Winnipeg Laboratory by the Fisheries Research Board to concentrate several disciplines on one general problem is an attempt to correct this point. Other respondents felt that there should be an increase in research contracts (not grants) to industrial and university laboratories. The objectives should be clearly defined and the progress should be reviewed by highly qualified committees. The work would thus be conducted by specialists in the field and liason between the different institutions would be facilitated.

Secondly, the amount of routine and applied research in some laboratories prevents sufficient objective basic research from being carried out. It is believed that this is a mistake in view of all the benefits that work of this nature can produce. An amount of 15 to 20% of the total effort is not unreasonable. And finally, greater use should be made of multidisciplined research teams. This in turn requires high calibre research directors, preferably those well versed in the various disciplines associated with such a group.

The very important role played by government in promoting university research can be seen from Table I.

(c) Industry:

In 1968 the U.S. pharmaceutical industry will spend an estimated $40 million on R and D in foreign countries (8). Canada should be able to attract an increasing amount from this and from European industries provided that a favourable climate for research is maintained. To this end the economic advantages should be increased by abolition of all taxes and tariffs on scientific equipment and chemicals used for research. The Federal Government has established several policies to encourage Canadian R and D. These include the Industrial Research and Development Incentives Act (March 1967), the Programme for the Advancement of Industrial Technology (PAIT) under the Department of Industry and the Industrial Research Assistance Programme through which the N.R.C. gave grants of $6.2 million in 1967 (cf Appendix D). These policies have been vital in attracting new laboratories and have been most important factors for the increased R and D in recent years. They should be maintained and where possible, increased. Provincial Governments should also apply similar programmes through their own Research Councils. The proposed legislation regarding the weakening of patent protection for drugs will hardly induce more companies to undertake research here and is to be deplored.

Several respondents have stressed the need for Canadian industry to specialize in its research efforts. A recent survey (8) showed that in the U.S. the pharmaceutical industry concentrated 80% of its research expenditures in only 30 out of 128 possible therapeutic classifications. Of the remainder there are doubtless several in which Canadian companies could concentrate and create specialist research groups.

Finally, in Canada the per capita expenditure on research in general, and medical research in particular, is much lower than in U.S., U.K. and many European countries. This must be increased if Canada is to maintain its economic status. The area thought to be in greatest need of stimulation is industrial research and development, since these efforts which will confer the greatest benefits to the Canadian economy.

(iii) Collaboration of Efforts

Nearly all respondents agreed that increased collaboration between the three types of institutions was desirable but the

suggested means to achieve this varied considerably. Many felt that for practical reasons a person-to-person basis was the most realistic since government and industrial laboratories have restrictive terms of reference. A suggested way to promote collaboration amongst different university departments was to encourage the various workers to submit joint grant applications and to form joint groups. An immediate way of achieving better contact between industrial and academic laboratories was to have industry increase its number of university affiliates, chosen especially from among the younger staff members. This could be followed, hopefully, by increased support of their research. Many academics desired closer cooperation but felt that industry cared little for their help. In order to compete effectively Canada cannot affort to waste its resources and it is most unfortunate that the pool of available talent is not better used. This is especially apparent with respect to the schools of pharmacy and certain groups active in natural products research. Here industry could benefit greatly from sources of new compounds and fresh ideas. Examples of collaboration between different types of organizations include those of Canada Packers Ltd. and the Prairie Regional Laboratory of the N.R.C. on the processing of rapeseed oil to an edible form, and initiation of joint research with a number of universities by the Warner-Lambert Research Institute (Toronto) (18). Ideally, a close collaboration of industrial, academic and government laboratories on certain well-defined problems could achieve dramatic results.

There is a strong feeling amongst government scientists that universities do not make use of the talent available in government institutions. Many people would like to see more government scientists employed as extra-mural professors giving courses in their special fields. This would make universities more aware of the work being done by the government. In addition, use could be made of government laboratories by students doing their graduate studies. This approach is already being tried out at A.R.L. and Dalhousie University and at P.R.L. and the University of Saskatchewan, among others. University workers pointed out, however, that this can lead to double standards, both financially and academically and cited occasions where the experiment has been unsuccessful.

The value of sabbatical leaves which are usually granted only to University and Government personnel was also questioned. As a means of re-training, where knowledge of a new field is required, they appear to have some merit. They also afford university workers the time to write and develop fresh ideas. However, more benefits may be gained from the use of

short-term leaves, whereby people could visit laboratories for periods of up to two or three months and collaborate in fields of mutual interest. Every effort should be made to dispense with the archaic idea of allowing attendance at only one scientific meeting per year, and visits between individual workers throughout Canada should be promoted.

There is often a lack of awareness of the many different groups working in a general area; this is quite apparent in the pharmaceutical field. It is suggested that the C.I.C. establish a national Division of Medicinal Chemistry to be run along the lines of the highly successful Montreal Group and the Medicinal Chemistry Division of the American Chemical Society. This would provide a common forum for university workers in the fields of pharmacy and natural products together with their counterparts in government and industry. The leading journals, e.g. Canadian Journal of Chemistry, should actively solicit papers dealing with relationships between chemical structure and biological activity.

(iv) Facilities

In addition to numerous suggestions about individual pieces of equipment, considerable interest was shown in the formation of new institutes such as a Drug Research Institute and Technical Service Centres.

The most popular of these institutes was a Drug Research Institute (or Institute of Pharmaceutical Sciences) which would be organized along the lines of the National Institutes of Health (N.I.H.) in the U.S. or the National Institute for Medical Research, Mill Hill, England. Staffed by the best scientists available, it would have centres of excellence in departments of biology, organic chemistry, biochemistry, pharmacology and molecular pharmacology, biopharmaceutics and microbiology and should be associated with a hospital for clinical trials. This institute could operate as part of N.R.C. and have members of its Board drawn from industry and the universities. Alternatively it could be operated as a Crown Corporation affiliated with the Department of National Health and Welfare. Following the example of the N.I.H., the Institute could be used as a postgraduate training centre and visiting scientists would be encouraged to take up appointments for short periods, two to six months, in order to provide a flow of

new ideas. The Institute could also provide, on a contract basis, biological assay procedures such as antiviral screening which are difficult and expensive for a smaller institution to maintain. It may be noted that there are many scientists in Canadian laboratories who are well qualified to staff the Institute. The idea of a Drug Research Institute is by no means new, mention of it being made in the Harley Report, together with means of financing it.

It was pointed out that such an institute, properly directed and staffed with chemists and biologists could successfully compete with the largest pharmaceutical laboratories. Canada could, in fact, become a world leader in new drug discoveries. Reference can be made to the notable successes of the Institute of Pharmacy and Biochemistry in Prague.

It is very apparent that a need exists for the coordination of research services, particularly for expensive instruments. This would be a great assistance to small research groups who cannot justify the need for the more sophisticated instruments which are necessary for present day research. The formation of "Service Centres" in various parts of Canada would fill this need. These centres should be operated on a fee basis and be available to universities, government and industry alike. Apart from services such as elemental analysis, IR, ORD, NMR ($^{1}H$, $^{31}P$ and $^{19}F$), EPR, scintillation counters, amino acid analysers, they would provide 100 mc/s NMR spectra, mass spectrograms and X-ray crystallographic data, together with related computer services. Highly skilled personnel would be required to operate these instruments and provide interpretations if required. These service centres should be financed by the government and could be located at the three N.R.C. establishments in Halifax, Ottawa and Saskatoon. Alternatively, the centres could be commercial operations associated with universities and possibly a more logical distribution would be Halifax, Ottawa and Edmonton. Initially, it probably would be necessary for the government to guarantee a minimum income for such a private venture. (There is a commercial laboratory in Montreal carrying out mass spectometry analyses).

In areas such as Ottawa where there are numerous research laboratories, there is merit in the idea of combining some existing services. Examples of such services are animal breeding and elemental analyses.

Specialized facilities like 200 mc/s NMR and controlled aquatic environments, which are costly in terms of initial expense and maintenance, should be associated with only one centre. The Fisheries Research Board (Halifax) is a logical choice for the latter and possibly N.R.C. (Ottawa) for the former. These centres should form specialized research groups using these facilities, but also be prepared to assist other laboratories in using them.

Natural products chemists mentioned the difficulty of obtaining plant material and suggested the establishment of a central government agency to handle requests for the collection of such material. This agency might also screen Canadian flora for interesting natural products and report their findings to Canadian scientists who could then proceed with a thorough investigation of promising species. The Departments of Agriculture and Forestry already classify Canadian flora and could establish effective collaborative efforts with university scientists.

A potential source of new medicinals is the large number of novel compounds produced by organic chemists, especially those in natural products laboratories. Grants should be made available to enable biological testing of representative compounds to be carried out. If promising leads are uncovered further work could be undertaken by a suitable industrial or government laboratory. The entire project could, of course, be carried out by the proposed Drug Research Institute. There is at present a commercial laboratory offering pharmacological assays [see Section II (i)].

### (v) Personnel

Although there is a high proportion of natural products research in Canadian universities, the work is directed towards relatively few classes of compounds. There is, for example, a shortage of workers trained in lipid chemistry; this was stressed by those government laboratories where important research is being carried out. Other relatively neglected areas are steroids, antibiotic and polypeptide chemistry.

There is an acute need for adequately trained biologists to evaluate physiologically active compounds. If pharmaceutical research is to develop, the universities must train more pharmacologists, especially at the Ph.D. and post-doctoral levels. The need by the U.S. industry for bioscientists has been discussed (19).

A problem common to all laboratories is the shortage of competent technicians. Technical Colleges such as Ryerson in Toronto and the Southern Alberta College of Technology in Calgary do a good job in training technicians but many more such institutions are needed. Related solutions have recently been put forth (20).

The need for scientists trained in both chemical and biological disciplines has been discussed above.

## SECTION IV.

## FUTURE TRENDS

Due to the variety of topics and institutions surveyed it is difficult to give overall predictions. Funding for research, for example, is related to the national prosperity - or lack of it - and an ability for accurate economic prognostication is not one of the Committee's main attributes. Given, however, a measure of economic growth we have discerned several patterns of future developments.

(1) There will be an increasing awareness by those involved in the allocation of research funds to more clearly define long range scientific policies. The undertaking of this C.I.C. - and related surveys is evidence of this.

(2) More federal funds will be given for research but not necessarily at the same rate of increase as in recent years. Scientific activity, while still considered beneficial, is not held in the same unquestioned view as it once was and administrators are being held more accountable for their distribution of funds. This situation exists now in the U.S. to a marked degree.

(3) There will be keener competition from the three types of institutions for the funds which are made available.

(4) If the economic incentives are maintained or increased and if restrictive patent legislation is not enacted, more industrial pharmaceutical research will be undertaken in Canada.

(5) Pharmaceutical research as such will shift towards more basic studies where increased collaboration with university departments will be essential. Research in pharmacy schools will be more coordinated with that being carried out in government and industrial laboratories.

(6) Basic research will continue to flourish in university and government.

(7) The increasingly complex and specialist nature of chemical research will lead to the formation of more interdisciplinary groups in the universities. Likewise certain government laboratories will merge or be reorganized along interdisciplinary lines.

(8) The government will increase its research in areas where there is little interest for universities or industry. One such area is food chemistry where the government carries out nearly all the research in the field. Interest will also develop in the toxic nature of man's environment, far beyond the restricted fields of foods and drugs, as at present. This will include atmospheric and water pollution.

(9) The following appreciation of the future of natural products research offers specific examples of some of the above points:

The nature of natural products chemistry is changing and will continue to do so. Methods such as mass- and NMR spectroscopy and advances in the application of X-ray diffraction methods have greatly simplified the task of structural elucidation. It seems likely that the chemist interested in natural products will be moving more and more into either the area of organic synthesis or into the more biological aspects of chemistry.

In the area of synthesis the emphasis will be on the development of new synthetic methods, the intellectual stimulus resulting either from the desire to construct a very complex molecule, or to provide an efficient and economical synthesis of a biologically active compound. These methods can then be applied to general organic synthesis, permitting the preparation of entirely novel compounds. Such developments will be of particular interest in pharmaceutical research, where a new class of compounds can have completely new biological activity. Since many new organic reactions have resulted from structural studies on natural products it is to be hoped that the use of X-ray diffraction methods will not entirely supplant attempts to solve structures by chemical methods. Structural studies also will continue to serve as an excellent means of training graduate students in the methods of research.

The role of the natural products chemist will increase in the area of molecular biology. The challenge is now upon us to detail all the processes involved in the construction of natural products by living organisms. The natural products chemist must align himself more closely with the biochemist, the molecular biologist, the enzymologist, the plant scientist, etc., since his intimate knowledge of chemistry at the molecular level will allow him to make extremely important contributions in these areas. This is already being done by a number of chemists concerned with alkaloid biosynthesis. A few workers in departments of chemistry and schools of pharmacy are investigating tissue culture of plant materials and the enzymatic processes involved. If successful, one can forsee the application of fermentation techniques developed by the microbiologists with the exciting possibility of producing "tailor-made" alkaloids in vitro.

## SECTION V.

## RECOMMENDATIONS

We submit the following recommendations concerned with Area 061:

(1) The establishment in Canada of a Drug Research Institute comparable in scope to that of the N.I.H. but with added facilities for drug synthesis and discovery.

(2) The establishment of regional service centres making available to all the expensive but necessary equipment for the conduct of modern chemical research.

(3) Increased incentives and support by government for industrial research.

(4) Increased industrial support for basic research in the universities.

(5) Increased collaboration between (a) workers in the various disciplines and (b) government, university and industrial personnel.

(6) The increased use of interdisciplinary research grants.

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(4) D. W. Emmerson, Chemistry in Canada, Nov. 1965, p. 23.

(5) ibid., Sept. 1967, pp 59, 60.

(6) Ref. 3: quoted in Chemistry in Canada, Aug. 1967, p. 39.

(7) Chemical and Engineering News, Nov. 20, 1967, p. 23.

(8) ibid., Supplement, Sept. 4, 1967, pp. 93A et seq.

(9) Mémoire Presenté à la Commission D'enquête sur la Santé et le Bien-être Social, Faculté de Pharmacie, Université de Montréal, 1967.

(10) Submission of the Canadian Association of Deans of Pharmacy Relative to the Health Resources Fund, 1965.

(11) Ref. 1, pp. 198 et seq.

(12) cf NRC 1966 Review: NRC No. 9017, Ottawa.

(13) cf "Research Laboratories, Food and Drug Directorate"; FDD, Ottawa.

(14) Quoted in Chemistry in Canada, March 1967, p. 9.

(15) L. Marion, personal communication.

(16) Expenditures on Research in Science and Engineering at Canadian Universities, NRC No. 9166, Ottawa, 1966.

(17) Discussed briefly in introduction to Ref. 3.

(18) Chemistry in Canada, July 1966, p. 12.

(19) "Resources for Medical Research"; Report No. 8, U.S. Dept. Health, Education and Welfare; Washington, 1966.

(20) C.J.L. Cook, Chemistry in Canada, Dec. 1967, p. 15.

## ACKNOWLEDGEMENT

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# APPENDIX B

## C.I.C. SURVEY

## QUESTIONNAIRE FOR COMMITTEE 06

1. Outline the developments leading to the choice of your research projects. What do you consider to be the long-term goals of this work?

2. Indicate any recent advances made at your institution in general knowledge and/or developmental techniques which might promote significant advances in your field.

3. What are the areas of strength and weakness of the field in Canada; what laboratories or individuals do you consider to be particularly distinguished?

4. Outline the increases in equipment, facilities and trained personnel which you consider necessary for the continued advance of research in your field.

5. Do you consider it desirable for increased collaboration between industrial, academic and government laboratories? If so, suggest means for achieving this.

6. Discuss any points not covered above which you consider relevant to the work of this Committee.

## APPENDIX C

## STATISTICAL SUMMARY - GRADUATE DEPARTMENTS OF CHEMISTRY[1]

| NAME OF SCHOOL | Full-time Staff as of Oct. 1966 | Part-time Staff as of Oct. 1966 | Number P.D.F.'s Oct. 1966 | Graduate Enrollment Oct. 1966 | Ph.D. degrees granted | | M.Sc. degrees granted | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1964-65 | 1965-66 | 1964-65 | 1965-66 |
| Acadia University | ** | | | | | | | |
| Alberta, University of | 34 | - | 40 | 134 | 11 | 11 | 2 | 2 |
| Bishop's University | 6 | - | - | 1 | - | - | - | - |
| Brandon College Inc. | * | | | | | | | |
| British Columbia, University of | 42 | 6 | 18 | 125 | 12 | 14 | 12 | 10 |
| Brock University | 6 | 4 | - | - | - | - | - | - |
| Calgary, University of | 17 | 5 | 5 | 43 | 3 | 4 | 2 | 5 |
| Carleton University | 12 | 8 | 6 | 25 | - | - | 2 | 4 |
| Dalhousie University | ** | | | | | | | |
| Guelph, University of | 14 | - | - | 14 | - | - | 2 | 1 |
| Lakehead University | 5 | - | - | - | - | - | - | - |
| Laurentian University | * | | | | | | | |
| Laval University | 20 | 1 | 6 | 30 | 3 | 2 | 2 | 2 |
| Lethbridge, University of | * | | | | | | | |
| Loyola College | * | | | | | | | |
| MacDonald College of McGill | ** | | | | | | | |
| McGill University | 17 | 1 | 25 | 134 | 15 | 20 | - | 2 |
| McMaster University | 28 | - | 18 | 78 | 8 | 5 | - | 1 |
| Manitoba, University of | 18 | 2 | 5 | 36 | 2 | 4 | 13 | 15 |
| Marionapolis College | * | | | | | | | |
| Memorial University | 11 | - | 1 | 18 | - | - | 3 | 4 |
| Moncton, Université de | 6 | 1 | - | 7 | - | - | 1 | 3 |
| Montréal, Université de | 19 | 6 | 6 | 66 | 3 | 7 | 8 | 13 |
| Mount Allison University | ** | | | | | | | |
| Mount St. Vincent University | * | | | | | | | |
| New Brunswick, University of | 9 | - | 6 | 32 | 4 | 6 | 1 | 1 |
| Notre Dame University of Nelson | * | | | | | | | |
| Nova Scotia Agricultural College | ** | | | | | | | |
| Ottawa, University of | 12 | 2 | 9 | 38 | 2 | 7 | 1 | 3 |
| Prince of Wales College | * | | | | | | | |
| Queen's University | 21 | - | 6 | 66 | 8 | 7 | 8 | 7 |
| Royal Military College | 12 | 2 | 5 | 1 | - | - | - | - |
| Collège Militaire Royal | ** | | | | | | | |
| St. Dunstan's University | ** | | | | | | | |
| St. Francis Xavier University | 6 | 7 | 1 | 9 | - | - | 2 | 5 |
| Saint Mary's University | ** | | | | | | | |
| Saint Paul's College | * | | | | | | | |
| Saskatchewan (Regina) | 12 | - | 1 | 11 | - | - | - | - |
| Saskatchewan (Saskatoon) | 21 | 2 | 5 | 64 | 3 | 7 | 6 | 11 |
| Sherbrooke, Université de | 11 | - | - | 13 | - | - | - | - |
| Simon Fraser University | 22 | - | 4 | 25 | - | - | - | 1 |
| Sir George Williams University | 10 | 4 | - | 1 | - | - | - | - |
| Toronto, University of | 30 | 5 | 28 | 160 | 13 | 18 | 21 | 19 |
| Trent University | ** | | | | | | | |
| United College | * | | | | | | | |
| Victoria, University of | 11 | 1 | - | 5 | - | - | - | - |
| Waterloo, University of | 24 | - | 2 | 53 | - | - | 3 | 9 |
| Waterloo University College | ** | | | | | | | |
| Western Ontario, University of | 22 | - | 16 | 79 | 4 | 8 | 0 | 2 |
| Windsor, University of | ** | | | | | | | |
| York University | 7 | - | 8 | 9 | - | - | - | - |

[1]Compiled by Mrs. D. Budd, University of Alberta.

* No graduate department.

** Statistical summary not available.

APPENDIX D

# THE NATIONAL RESEARCH COUNCIL

## INDUSTRIAL RESEARCH ASSISTANCE PROGRAM

(Selected Companies: 1967/68)

| COMPANY | GRANTS |
|---|---|
| Abbott Laboratories Ltd. (2 projects) | $ 97,100 |
| Ayerst Laboratories Ltd. (2 projects) | 249,000 |
| Bell-Craig Pharmaceuticals | 43,000 |
| Canada Packers Ltd (4 projects) | 124,700 |
| Delmar Chemicals Ltd. | 72,000 |
| Frank W. Horner Ltd. (2 projects) | 76,100 |
| John Labatt Ltd. (2 projects) | 135,100 |
| Merck, Sharp and Dohme of Canada Ltd. (2 projects) | 75,600 |
| Raylo Chemicals Ltd. | 33,500 |
| Warner Lambert Research Institute of Canada | 53,000 |
| TOTAL FOR ABOVE GROUP | $ 959,100 |
| TOTAL GRANTS DISTRIBUTED (to Aug. 1967) | $ 6,212,150 |

# REPORT OF COMMITTEE 7

## POLYMERS, ETC.

| | | |
|---|---|---|
| Chairman | - | H.L. Williams |
| Members | - | H.C. Clark |
| | - | R.J. Gillespie |
| | - | A.G. Brook |