

REPORT OF COMMITTEE 17

BIOCHEMISTRY

March 1968

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C.I.C. SURVEY OF BIOCHEMISTRYS U M M A R Y

Biochemistry is a new science intimately related to the physical sciences, while being at the same time an integral part of the biological sciences. It plays an important role in Industry, Medicine and Agriculture. Biochemistry teaching and research in Canada began primarily in the Medical Schools of Canadian Universities, and the concentration of biochemistry in medical faculties has continued until the present time, although some biochemistry is associated with Departments of Chemistry or Biology. This has led to an orientation of Canadian biochemistry mainly towards basic medical problems. Biochemical research is also done in other university departments and government laboratories. Close to one thousand five hundred biochemists of all levels of competence are engaged in teaching or research. The teaching of biochemistry in Canada is adequate but not outstanding. For the future it seems desirable that the teaching be broadened with greater emphasis on basis training in physical sciences. The output of biochemistry graduates is not excessive and should be increased. By international standards, Canada has no strong centres of biochemistry and a few outstanding groups in research.

Biochemical research has played a prominent part in the overall program of government research laboratories since their establishment in Canada. Much good research has been carried out in these laboratories but perhaps greater emphasis should be placed on research more directly related to the products and basic industries of the country.

In recent years, government support has also played an important role in building up research facilities within the university, and this is a desirable activity which should be continued, with increased emphasis on research in non-medical biochemistry. The support of biochemical research done outside the medical field is meagre and should be increased if we want to develop important areas which are now neglected: instrumentation, toxicology, comparative biochemistry, molecular biology, etc. Most of the biochemical research undertaken in Canada is aimed at the solution of fundamental problems. However this work has not produced spectacular achievements due to the fact that Canadian biochemistry is too diffuse. Support to date has been largely on an individual basis and it is recommended that consideration be given to the formation of interdisciplinary units in the university environment to provide integrated units which can compete more effectively on an international level at the frontiers of biochemical research.

There is a serious imbalance in Canada between university and government research on the one hand and industrial research on the other. The failure of industrial companies to carry out more biochemical research seems not to be primarily due to lack of facilities and equipment or of available personnel, but rather to inadequate incentives, to the high percentage of foreign controlled industry, and to the fact that many companies are too small to develop independent research programs. To correct this imbalance, government might try to encourage companies associated with particular industries to set up and finance co-operative research laboratories, either by providing tax incentives or by direct

collaboration, and might modify the patent laws to stimulate more industrial research. To correct the mutual lack of respect between university and industrial biochemists, the provision of funds for interchange of personnel between university, government and industrial laboratories might benefit the country by stimulating increased collaborative research between these groups.

Canada cannot hope to compete on an international basis in all aspects of biochemical research and development, but there are several areas of biochemistry which seem to be relatively neglected. Two of these are plant biochemistry and clinical biochemistry. In view of the importance to the economy of agricultural and forest products, it seems desirable that more attention should be given to teaching and research in plant biochemistry. In spite of the emphasis on medical biochemistry in Canada, teaching and research in biochemistry applied to medical problems seem to have lagged, and with increasing emphasis on health programs, such as medicare, a greater proportion of the available resources should perhaps be devoted to this area.

BIOCHEMISTRY IN CANADA1967FOREWORD

The survey of Biochemistry in Canada was conducted by Committee 17. This committee was formed early in 1967 and met four times in Montreal. Its membership was as follows:

Louis BERLINGUET, Département de Biochimie, Université Laval,
Québec (Chairman)

Ken CARROLL, Collip Medical Research Laboratory, University of
Western Ontario, London

Alec SEHOW, Department of Chemistry, McGill University, Montréal

Leo VINING, Atlantic Regional Laboratory, National Research
Council of Canada, Halifax

Information presented in this report was obtained from the following sources:

1) The committee conducted a survey by questionnaires to biochemists working in various sectors.

Industry: Dr. Carroll sent a questionnaire to forty-two Canadian Industries to inquire about the number of biochemists employed, and thirty-two replies (76%) were received. A second letter was sent to twenty-eight individual industrial biochemists asking their opinion on a number of questions relevant to this report, and eleven replies (39%) were received. A third letter was sent to thirteen Heads of Biochemistry Departments of Canadian Universities to inquire about the number of their graduates obtaining employment in industrial research laboratories. Eight replies (62%) were received to this letter.

Government Laboratories: Dr. Vining sent a questionnaire to ninety-eight biochemists working in government laboratories. Fifty-five answered (56%)

Departments of Chemistry: Dr. Schon sent a questionnaire to fifty-eight biochemists in Canadian universities who are employed in departments other than the Biochemistry Departments of Medical Faculties. Most were located in Departments of Chemistry. Forty answers (69%) were received.

Medical Schools: Dr. Berlinguet sent a questionnaire to one hundred eighteen biochemists working in Departments of Biochemistry in the medical schools of Canadian universities. Eighty-three (70.2%) answered.

2) The committee met with Dr. J. A. McCarter, Cancer Research Unit, University of Western Ontario, London, who conducted in 1967 an intensive survey of biochemistry in medical schools on behalf of the Medical Research Council of Canada. Part of his report was made available to us by the Medical Research Council. We wish to acknowledge the collaboration of the chairman, Dr. Malcolm Brown, in this matter.

3) A leading article on Canadian biochemistry "The Story of Biochemistry in Canada" written by Dr. E. Gordon Young and published in Chemistry in Canada (January 1967) served as reference for the historical section.

4) A survey of the facilities offered to graduate students in all Canadian universities made by Dr. D.R. Whitaker on behalf of the Canadian Biochemical Society in 1966. This very intensive survey listing the research projects of most Canadian biochemists was consulted.

5) Data from various questionnaires prepared by the Chemical Institute of Canada and the Manpower Department has been used.

PREAMBLE

1. Boundaries of Biochemistry

Etymologically biochemistry means "the chemistry of life". It comprises the study of all chemical compounds and reactions that are to be found in living things from viruses to man. This relatively new science is intimately related to the physical sciences (chemistry, physics and mathematics) while being at the same time an integral part of the biological sciences.

The boundaries of biochemistry therefore touch and usually overlap those of other disciplines such as chemistry, biology, medicine, agriculture, forestry, oceanography, pharmacology, physiology, bio-engineering, pharmaceutical chemistry, food chemistry, etc.

2. Interactions between Biochemistry and Industry, Medicine and Agriculture

Knowledge of the chemical reactions that take place in living things obviously has wide application in the applied sciences and in industry.

In Industry, biochemical reactions form the basis of manufacturing and processing operations in several fields : beverages (beer, wine, etc.), food (meat, cereals, dairy, etc.), pharmaceuticals (drugs, cosmetics, etc.), and fermentations (production of antibiotics and fine chemicals) are obvious examples.

In Medicine, biochemistry has played such an important role that the more recent advances are largely attributed to this basic science. Better knowledge of the fundamental chemistry of living cells has resulted in new chemotherapeutic agents and new treatments for metabolic disorders. The discovery of some of the secrets of life is offering vast new areas where biochemistry can help mankind; recent advances in our knowledge of the genetic code, mental disease, cancer and transplantation immunology can be cited here.

Finally, basic knowledge of the biochemistry of plant and animal cells has an important bearing on developments in Agriculture, Forestry and Fisheries. Better crops, elimination of parasites and insects, increases in yield and disease resistance by selecting desirable genetic properties of plants and animals, improvements in food conservation and preservation; all of these are made possible through applied biochemistry.

This rapid survey, which is by no means extensive, indicates the beneficial effects of biochemistry on various sectors of the economy of the country. There is more than coincidence in the fact that countries with a high standard of living, excellent medical care programmes and efficient agriculture have developed biochemistry in their universities, in their industries, and in government research laboratories.

3. History

Biochemistry evolved as a separate discipline in the latter part of the nineteenth century, when the study of biological or physiological reactions began to develop independently of those in organic chemistry. Whereas the latter discipline has become restricted to the chemistry of carbon compounds, biochemistry undertakes to explain all chemical phenomena peculiar to living organisms.

In Canada, although the first practical course in biochemistry was taught as early as 1883 at McGill University, it was not until 1907 that a Department of Biochemistry was established. This was organized by Prof. A. B. Macallum in the Medical Faculty at Toronto University, and was preceded elsewhere only by departments in the University of Liverpool in Great Britain (1902) and in a few universities in Germany and the United States. Departments of Biochemistry were subsequently established by other medical schools in Canada.

In several Canadian universities courses in biological chemistry have been developed within the Department of Chemistry, or by collaboration between Departments of Chemistry and Biology. This has occurred predominantly where there is no medical school on the campus, and in some cases the establishment of a medical school and its constituent Department of Biochemistry has postdated the teaching of biochemistry in this manner. Occasionally the establishment of a separate department of Biochemistry has resulted in the discontinuation of biochemistry courses given elsewhere. There is only a single example in Canada of the co-existence of two Departments of Biochemistry in one University. In this instance a Department was founded in the Science Faculty at Laval University prior to the establishment of a similar department in the medical school.

Waterloo University has recently introduced courses on biochemical engineering in its Department of Chemical Engineering. This interdisciplinary field, which applies engineering principles to biological and medical problems has not hitherto been developed in Canada.

The history of applied biochemistry in Canada is, to a large extent, the history of biochemical research in laboratories operated by the Federal Government. When the National Research Council opened its first central laboratory in 1932, a Division of Biology and Agriculture was established. Out of this grew the present Divisions of Biosciences and Radiation Biology and the two Regional Laboratories at Saskatoon and Halifax which conduct a large amount of biochemical research. In this period also biochemists were employed in increasing numbers by the Federal Government in Departments of Agriculture, Forestry and Fisheries to solve important economic problems.

The application of biochemistry to industrial problems has not kept pace with these developments, although there are a few notable exceptions. A control and research laboratory was organized at Chas. E. Frosst and Company in Montreal in 1923, and was followed in 1931 by a research laboratory at Ayerst McKenne and Harrison Ltd. in that city. In recent years some expansion of industrial research in biochemistry has been evident, but companies which have large parent organizations outside Canada still depend mainly upon imported technology.

STATUS OF BIOCHEMISTRY

Tables I and II summarize the man-power data and the expenditures on Biochemistry in universities, government and industrial laboratories during 1966-1967.

1. Location of Research and Teaching Centers

For more details on the various research projects, the reader is referred to the article by Dr. Young and the Whitaker report from which most of the following information has been obtained.

2. Industry

Although biochemistry is important to the pharmaceutical, tobacco, beverage and food industries, and to some aspects of the chemical industry, Canadian research in most of these fields is just beginning.

TABLE 1
MAN POWER
(man-years)

1966-1967

UNIVERSITY *

	<u>Academic</u>	<u>Post-doctoral fellows</u>	<u>Graduate students</u>	<u>Technicians</u>	<u>Total</u>
Biochemists	204	58	270	217	749
Total of all chemists	1,042	378	2,187	598	4,205
%	19.6	15.3	12.3	36.3	17.8

GOVERNMENT **

	<u>Doctors</u>	<u>Masters</u>	<u>Bachelors</u>	<u>Technicians</u>	<u>Total</u>
Biochemists	67.6	14.6	18.1	75	175
Total of all chemists	471.7	115.5	224.7	833	1,637
%	14.3	12.6	8.1	9.0	10.7

INDUSTRY ***

Biochemists	42	14	45	74	175
Total of all chemists	686	442	1,694	2,919	5,741
%	6.1	3.2	2.7	2.5	3.0

Total of Biochemists: 1,099

Total of Chemists: 11,583

% 9.5

* C.I.C. data: Table 38

** C.I.C. data: Table 14 and 15

*** C.I.C. data: Table 27 and 28

TABLE 2
EXPENDITURES
1966

UNIVERSITY *

	<u>Basic</u>	<u>Applied</u>	<u>Development</u>	<u>Total</u>
Biochemistry	\$ 4,744,300	\$ 868,600	\$ 516,100	\$ 6,129,000
Total: Chemistry	17,000,500	2,954,700	881,700	20,837,000
%	27.9	29.4	58.5	29.4

GOVERNMENT **

Biochemistry	\$ 1,616,300	\$ 937,900	\$ 156,600	\$ 2,710,800
Total: Chemistry	7,892,300	9,920,100	6,611,200	24,423,600
%	20.5	9.5	2.4	11.1

INDUSTRY ***

Biochemistry	\$ 599,100	\$ 800,000	\$ 387,400	\$ 1,786,600
Total: Chemistry	8,299,200	40,293,800	42,210,600	90,803,100
%	7.2	2.0	0.92	2.0

Total for Biochemistry: \$ 10,626,400

Total for Chemistry: \$136,063,700

% 7.8

* C.I.C. data: Table 39

** C.I.C. data: Table 11-A

*** C.I.C. data: Table 26

i) Pharmaceutical Industries

Companies engaged in the manufacture of pharmaceuticals are exceptional in having appreciated early the need for research in applied biochemistry to maintain their competitive position. Laboratories at Chas. E. Frosst and Company and at Ayerst, McKenna and Harrison Ltd. in Montreal have expanded greatly over the past few years. The latter company now has a separate Department of Biochemical Research.

In recent years several pharmaceutical firms, mainly in the Montreal area, have established research groups that work in fields directly or indirectly related to biochemistry. These include Frank Horner Ltd.; Merck, Sharp and Dohme Ltd.; Abbott; Bristol; Pharmacia; Smith, Kline and French; Warner Lambert; and BioResearch Laboratories.

Connaught Laboratories at Willowdale, Ontario and the Institut de Microbiologie in Montreal prepare sera, vaccines and related chemicals of importance in preventive medicine.

ii) Food Industries

In the meat packing industry, Canada Packers has a large research laboratory to which a \$1 million addition was made in 1966. The rest of this industry, as well as the fishing and other food processing industries have very limited research facilities. Food and beverages industries spent as current intra-mural R & D expenditures in 1965 \$6,097,000 as compared to \$247,983,000 for all other industries or less than 2.4%.

iii) Tobacco and Alcohol Industries

The Imperial Tobacco Company has recently opened a new \$1.6 million Research and Development Centre in Montreal.

Most of the brewing and distilling industries operate control laboratories but only a few, such as Canadian Breweries and Labatt's carry on some research related to biochemical problems. Although food and beverages industries list 231 scientists and engineers and 477 supporting personnel engaged in R & D in 1965, biochemical research is nonexistent in most Canadian food and beverage industries.

b) Government Laboratories

The Government of Canada has laboratories across the country in which there are intensive research programmes involving biochemistry. It is difficult to arrive at precise figures but the total number of professional and technical staff engaged in biochemical problems is probably around two hundred.

i) National Research Council

The Division of Biosciences in Ottawa, the Division of Radiation Biology in Ottawa, the Atlantic Regional Laboratory in Halifax, and the Prairie Regional Laboratory in Saskatoon have a total of more than one hundred and forty professional staff members. Of these approximately forty-five are biochemists.

ii) Fisheries Research Board

A total of about 65 professional biochemists or chemists are engaged in biochemical problems. The major biochemical investigations are being done at Halifax (twenty-six biochemists and four chemists), Vancouver (fourteen biochemists and six chemists) and Winnipeg (six biochemists and four chemists). Other stations have only one or two biochemists each.

iii) National Health and Welfare

The laboratories of this department have expanded rapidly over the past few years. The Food and Drug Directorate alone now has a professional staff of more than forty, of whom about one half have biochemical interests.

iv) Federal Department of Agriculture

Much good biochemical research is being done at the various Institutes of this department: the Animal Research Institute, Food Research Institute, Microbiology Research Institute, Plant Research Institute, and Soil Research Institute in Ottawa, the Agricultural Research Institute in London, and the Grain Research Laboratory in Winnipeg.

v) Forestry Department

In the Forest Products Laboratories at Ottawa and Vancouver little of the research is of a biochemical character.

vi) Atomic Energy of Canada

The laboratories at Chalk River have a relatively small group engaged in radiation biochemistry.

vii) Defence Research Board

A few biochemists are employed on problems related to biological and chemical warfare.

viii) Provincial Research Laboratories

Some biochemical research is in progress in the laboratories of the British Columbia, Alberta and Saskatchewan Research Councils, the New Brunswick Research and Productivity Council and the Ontario Research Foundation.

c) Universities

Quoting Dr. Young , "It must be admitted that the critical Abraham Flexner Report in 1910 on the medical schools of North America, was responsible for the birth of most Departments of Biochemistry in the universities of Canada under pressure of conformity". In 1967, the twelve Canadian medical schools have Biochemistry Departments which, in most cases, are responsible for the training of honours students in biochemistry, as well as of M.Sc. and Ph.D. students. Their combined staffs include approximately one hundred and sixty scientists, eighty postdoctoral fellows, two hundred and eighty graduate students, and one hundred and seventy-five technicians, giving a total of approximately seven hundred persons.

Laval University has a second department of Biochemistry in the Faculty of Science, and in most Canadian universities, some research in biochemistry is done outside the Medical Faculty. Usually this is in Departments of Chemistry and Biology (e.g. at Simon Fraser, Calgary, McGill, Ottawa, McMaster, Montreal and Ottawa Universities). Some biochemical research is also being done in the Faculties of Agriculture and Forestry, and Waterloo University has introduced a degree course in biochemical engineering which is the first in Canada. The number of biochemists employed in all of these departments would probably increase the figure of seven hundred for Biochemistry Departments by about 35%, i.e. to approximately one thousand persons.

On Canadian university campuses research institutes such as the Cancer Research Institutes at Vancouver, Edmonton, Saskatoon, London, Toronto, Montreal and McGill, are also conducting biochemical research.

d) Hospitals

Although most hospitals now maintain diagnostic laboratories for biochemical analyses, only a few prosecute biochemical research. These are located mainly in Toronto and in Montreal.

2. Extent and Quality

In 1967, the Canadian Biochemical Society, established in 1957, has a membership of around four hundred, and the Division of Biochemistry in the Chemical Institute of Canada approximately six hundred. Our country has its Canadian Journal of Biochemistry, published by the National Research Council of Canada and containing an average of two thousand pages yearly. However much of the best Canadian research in biochemistry is published in foreign or international journals.

From the extent of the present Canadian effort in biochemistry it is apparent that university Biochemistry Departments have produced a fair number of biochemists, despite their recent origin. Their output has been supplemented by extensive immigration of foreign graduates. At a rough guess^{in 1968}, the number of biochemists at all levels of competence in Canada would probably total one thousand five hundred. It is the impression of Committee 17 that this represents an appreciably lower commitment of manpower, when related to gross national product, than is found in other scientifically advanced countries such as the United States, United Kingdom, Sweden, Germany or France. If only the number of biochemists in industrial laboratories is considered Canada is certainly at the bottom of the totem pole.

a) Teaching

When asked about the quality of biochemistry teaching in Canada

members of university Biochemistry Departments answered :

Excellent	:	5%
Good	:	74%
Mediocre	:	19%
Poor	:	2%

Like their university colleagues biochemists in government laboratories felt that training of biochemists in Canadian universities is adequate but not outstanding. Even by those who think biochemistry teaching is generally sound, it was noted that there are small departments with few biochemists on staff, heavy teaching loads, and narrow curricula which do

not offer a satisfactory training. Of those who consider the teaching of biochemistry in Canada to be inadequate, a strong segment believes the basic sciences are not well taught; another considers the training provided to be generally "old-fashioned" and a poor preparation for modern research. It was suggested that this may be the cause of much mediocre research in Government Laboratories.

On the whole biochemists working in government laboratories were not enthusiastic about the qualifications and ability of personnel at present being recruited into biochemical research in their organizations. When asked about this, they answered:

Satisfactory	: 40%
Unsatisfactory	: 40%
No opinion	: 20%

Many of those who considered current appointees to be satisfactory pointed out that a high proportion of these receive their training abroad. Others expressed satisfaction with graduates at the Ph.D. level but considered B.Sc. graduates to be both inadequately trained and in very scarce supply. It was noted that high-calibre scientists with experience are also difficult to obtain and it is generally believed that this is because of the better salaries, opportunities, and facilities available for such people in the United States.

The existence of areas of biochemistry in which no Canadian university provides an adequate training represents a serious weakness; some of these areas are plant biochemistry, toxicology and forensic chemistry, radiation biochemistry, immunochemistry, clinical biochemistry, and comparative

animal biochemistry. The relevance of statistical and computing procedures to biochemistry also seems to be generally ignored. These deficiencies are ascribed, in part, to inadequate facilities for training non-medical biochemists due to the location of most Biochemistry Departments in Medical Faculties. The ~~too~~-rigid course requirements of most University departments, which prevent students from acquiring an interdisciplinary graduate degree, may also be responsible.

b) Research

It is significant to note that when members of university Biochemistry Departments were asked about the quality of biochemical research in Canada, the answers given were :

Excellent	:	5%
Good	:	65%
Mediocre	:	28%
Poor	:	2%

Among biochemists working in government laboratories the consensus was that, by international standards, Canada has no strong centres of biochemistry, and few outstanding groups.

Canada's weakness in the field of biochemistry is also illustrated by the small number of Canadian^s on the editorial boards of international scientific journals.

Four out of two hundred and twenty-four review articles in the Annual Review of Biochemistry from 1958 to 1967 came from Canadian addresses; only four out of one hundred and seventy-one in the Annual Review of Plant Physiology during the period 1958-1966.

In the survey conducted by the Medical Research Council in Canada, the position of Canadian biochemistry is summarized by the statement that, when judged by the best international standards, notably the quality of biochemical research in the United States, it is mediocre, or at the very best average.

Fortunately this somewhat pessimistic judgment of the overall quality of biochemistry does not apply to all its fields. The survey conducted among biochemists reveals that protein biochemistry in Canada is considered to be "excellent". Of the various fields of biochemistry, work on proteins was considered to be the best, while lipid and nucleic acid biochemistry were, respectively, second and third in degree of excellence.

The few good biochemists in Canada, by international standards, are not found exclusively in one type of institution but are working in university departments, government laboratories and in some private research institutes.

Fundamental studies account for by far the greatest volume of biochemical research in Canada. Most of this is being done in Departments of Biochemistry in medical schools. but biochemists working in Departments of Chemistry and Biology, in Faculties of Agriculture and Forestry, in Research Institutes, and in government laboratories also contribute their share. Despite this emphasis on fundamental studies the overall quality of the Canadian output is not outstanding.

Although the raison d'être for most government laboratories and Institutes such as the Cancer Research Institutes was initially to do applied biochemistry, most have tended to shift towards basic biochemistry. Ideally the main effort in applied biochemistry should be centres in industrial laboratories and hospitals. As seen before, very little is being done in this domaine. In fact it is disheartening to see how small is the volume of applied biochemistry done in a country where a large part of the economy depends on agriculture and forests and in a country which furnishes food to the world and which claims a very high standard of medical care.

3. Neglected Areas

Biochemists in university Departments of Biochemistry considered "Clinical Biochemistry" to be the most neglected area (43% Mediocre and 23% Poor). "Medicinal Chemistry" was also felt to be neglected (34% Mediocre and 13% Poor) as was "Comparative Biochemistry". The fields of "Microbiological Biochemistry", "Metabolism" and "Physical Biochemistry" were rated from 'Good' to 'Mediocre'.

The request to government biochemists to name neglected areas produced a long list which includes :

1. Instrumentation
2. Toxicology
3. Radiation effects - especially metabolism of radionuclides in humans
4. Clinical biochemistry
5. Comparative animal biochemistry
6. Biophysics - especially the area between biophysics and biochemistry
7. Molecular biology
specifically : protein structure and function muscle biochemistry
X-ray crystallography
nucleic acid structure and function
biochemical genetics, especially of plants and animals
8. Pollution - especially biochemical engineering aspects
9. Plant biochemistry
10. Chemical embryology
11. Oxidative and photophosphorylation
12. Biochemistry of differentiation
13. Biochemical cytology

14. Biochemical pharmacology
15. Cryobiology
16. Membrane structure and function - lipid biochemistry
17. Biochemistry of reproduction
18. Enzymology
19. Immunochemistry

It was apparent that most scientists felt that their own particular field was receiving too little attention and unquestionably the length of this list would have been longer if more biochemists had been questioned.

It is also apparent that one very neglected area is industrial research in biochemistry.

4. Effects on the Canadian Scene

In view of the impact which biochemistry has on applied sciences the lack of centers of biochemical excellence raises serious questions about our ability to maintain high quality research in such fields as medicine, agronomy, fish and food processing. Absence of stimulation, advice, and guidance from eminent Canadian biochemists, and failure to attract and retain the best young graduates will mean that new biochemical knowledge will be applied only slowly and ineptly in these areas.

Past shortages of biochemistry graduates have also had their harmful effects. The limited number produced by Canadian universities have been hired mainly by universities or government laboratories. Industrial laboratories have failed to compete for the available talent, and, partly as a result of this, biochemical research ^{in industry} is practically absent from the Canadian scene. The situation would have been much worse had it not been for our ability to attract well-trained scientists from economically less favoured countries.

The very few industrial research laboratories which exist have not attracted young Canadians, and our secondary industries have failed to display the innovation and efficiency which would allow them to expand against competition in national as well as international markets.

This also applies to medicine. With very few clinical biochemists doing research in our hospitals and a lack of well trained analytical biochemists in hospital laboratories, the quality of medical care has suffered. First rate medical services are only made possible by the work of a team of specialists of which the biochemist is an important member.

WAYS AND MEANS OF IMPROVING BIOCHEMISTRY IN CANADA

1. Teaching

The training of biochemists in Canada is largely done in the thirteen existing Departments of Biochemistry, twelve of which are in Faculties of Medicine and only one in the Faculty of Sciences. Some Faculties (e.g. Agriculture and Forestry) do have specialized biochemistry lectures although no diploma is awarded, and degree courses in biochemistry are given in the Chemistry and/or Biology Departments of a few Arts and Science Faculties. However the present location of biochemistry teaching in Canada results in the training of biochemists who are, by and large, oriented towards medical science.

Modern biochemistry is inherently a multidisciplinary branch of the natural sciences, leaning heavily on the molecular and mechanistic concepts of pure chemistry. It is generally agreed that specialized training in biochemical programmes and the necessary knowledge of purely biological matters are more easily acquired than the fundamental and more abstract physicochemical concepts based on mathematical derivations. Consequently, it would seem advisable to expose students as early as possible to organic chemistry, physical chemistry, and the cognate subjects of physics, mathematics and genetics. It is more difficult to establish a soundly integrated undergraduate biochemistry curriculum in Departments of Biochemistry located in Faculties of Medicine.

Most

of the courses offered by these departments are dealing with the applied aspects of biochemistry with a more biological orientation being emphasized. As a result, the more physicochemically inclined students are not recruited and join instead classical Departments of Chemistry postponing development of an interest in biochemistry at least until the graduate level.

A well-coordinated and rigorous undergraduate programme in biochemistry could be organized within a Department of Chemistry provided biochemistry is given divisional status on a par with the classical divisions of organic, inorganic, physical-chemistry; this would necessitate the appointment of a minimum, critical number of biochemists to the staff of a Chemistry Department to develop an integrated programme leading to an honours degree in biochemistry or to an honours chemistry degree with a number of biochemistry options.

An alternative would be to establish an independent Department of Biochemistry in the Faculty of Science, or Arts and Science, or as part of a School of Biological Sciences. This development is likely to be more feasible in sizeable Universities which have no medical school and in which no Department of Biochemistry now exists, or in very large Universities which can afford two strong Biochemistry Departments. Such departments should be broadly based to provide advanced training in special areas in which Canadian biochemistry is now weak or deficient, and of sufficient size to provide an adequate variety of courses without imposing a heavy teaching load on the staff. They should not be organized alongside existing departments in Medical Faculties unless the latter are

already large enough not to be impoverished by the competition for money and students. A Biochemistry Department with less than ten professional staff should be considered below critical size to conduct an adequate training programme in undergraduate and graduate biochemistry.

It is of interest that biochemists working outside existing Departments of Biochemistry favour strong Departments or sub-departments of Biochemistry in the Science Faculty. On the other hand, 60% of biochemists in Medical Schools would prefer that biochemistry be taught in a Biochemistry Department under the responsibility of both Science and Medical Faculties. Only 20% of those now working in medical schools believe that the Biochemistry Department should be located with the Sciences, and about the same proportion (18%) consider it should remain exclusively with Medicine.

In summary, biochemistry should be taught in Biochemistry Departments where strong emphasis is given to chemistry, physics and mathematics. Existing departments in medical schools should be strengthened, and teaching programmes coordinated with those of other science departments through interdisciplinary curriculum committees. Where there is no medical school on the campus it is recommended that a separate Department of Biochemistry be established in the Faculty of Science.

In order to keep a good balance between teaching and research, Departments of Biochemistry should try to recruit staff members not solely for their publication records but also for their ability to teach and to be interested in students. Since the quality of teaching is highly dependent on the excellence of the staff, every means available must be

used to attract and retain a first rate staff. Adequate remuneration, good facilities, funds for research and reasonable teaching loads (an average of thirty hours lecturing per year is recommended) are necessary. To keep staff members abreast of recent developments refresher courses, exchange of personnel between universities, and regular Sabbatical leaves should be instituted.

Another means of increasing contact between universities and industrial laboratories might be to institute scholarships for students to work during the summer on research projects in industrial laboratories, as many of them currently do now in university laboratories. This might be easier to set up and organize than exchange visits between staff members.

2. Research

At the present time most of the biochemical research undertaken in Canada is aimed at the solution of fundamental problems. By and large, however, this work has not achieved spectacular achievements. Since Canadian resources in qualified personnel are limited, and a large expansion is needed in applied biochemistry, it seems appropriate to consider first how the quality of this basic research might be improved with, at the most, only modest expansion of the present effort.

Perhaps the most important factor contributing to poor quality is that Canadian biochemistry is too diffuse. Scientists are working as individuals or as small groups in virtual isolation. Today the rate of advance in new areas of biochemistry is such that they have difficulty in keeping pace with large and dynamic teams in other countries. This has several unfortunate consequences. Scientists doing first rate work are frequently 'scooped' and fail to achieve the international recognition they deserve for their accomplishments. Many investigators tend to work in scientific backwaters where competition is less intense. Important but difficult problems are not attempted, particularly those which require the combined efforts of experts from several disciplines. Expensive facilities necessary for rapid advances in many biochemical fields are not available, or when they are provided, are not efficiently utilized. Canada would see a better return for its investment in basic research if some of the money it now spends were used to build up areas of strength in particular institutions.

The number of top-notch people in Canada is very limited. If we can retain these people and attract others the standards of biochemical research in Canada will become high with comparatively little effort by the Government and the granting authorities in general. Every effort should be made to appoint the best scientists we can possibly get by offering the greatest possible academic freedom and the highest possible financial support in terms of salaries and other research expenditure.

The problem of isolation is particularly serious in small institutions, though not absent from larger ones. Many University departments prefer to hire staff with diverse interests in order to cover the field for teaching purposes. While desirable in some respects, this policy should not be carried too far and, once an efficient teaching staff and supporting facilities have been built up, departments should select appropriate areas of specialization and aim to achieve excellence. The provision of funds for postdoctoral appointments in these areas is a relatively economic means to this end. Money should also be provided for travel to scientific meetings and exchange of personnel with other leading institutions in order to keep the staff abreast of new developments.

There seemed to be a general feeling among industrial respondents that it would be desirable to strengthen biochemical research in industrial laboratories. Committee 17 wholeheartedly agrees with this view. As one correspondent pointed out, the food business is the largest business in Canada and there should be many opportunities in it for biochemists. Canadian industries are often foreign owned and the research is carried out in laboratories outside the country. This is a difficult situation to change at the present time, since there are obvious advantages in centralizing research effort. Although some industrial correspondents commented on lack of expensive items of research equipment, this does not seem to be the major handicap in industrial biochemical research at the present time.

In government laboratories, which at present carry the main responsibility for applied biochemical research, the proportion of "mission-oriented" work should be increased. University professors should also think seriously about the value of their research effort to the economy of the country which provides the funds for their work. There has been a tendency to over-emphasize basic research, and the Canadian taxpayer is entitled to see some practical benefits from the biochemists he supports.

It seems that there is a mutual lack of respect between university biochemists and industrial biochemists. Industrial biochemists tend to think that the problems under investigation in university departments are too esoteric and divorced from practical problems relating to the basic products and industries of the country, whereas university biochemists tend to think of industrial biochemistry as second class research, which does not really merit support from any outside agency. Increased collaboration between industrial, academic and government research centers may be one way of increasing the respect of each group for the other. Perhaps this might be encouraged by providing a mechanism whereby industrial biochemists could work for short periods of time in university or government laboratories and vice versa. Exchange visits, along the line of the Medical Research Council visiting professorships, might also be considered. Universities should consider, where possible, the appointment of industrial scientists as visiting or sessional lecturers. At the same time, industry could make better use of the expertise of university scientists and at the same time promote collaboration by offering consultantships. University biochemists feel that one of the barriers between industrial and university biochemists is the lack of free exchange of information in industrial laboratories.

3. Personnel

The creation of new universities has revealed in a dramatic manner the shortage of good and well-trained biochemists. It is safe to assume that at least 40% of the biochemists now in Canada are immigrants. Until ten years ago, our universities had produced only a small number, and the increased demand has led to an influx of biochemists, mostly from the United Kingdom but also from Asia, Europe, and more recently from the United States.

The demand for well-trained biochemists at all levels of proficiency, i.e. B.Sc., M.Sc., Ph.D., and those with postdoctoral experience, will increase with the establishment of new and enlarged facilities in medical schools and hospitals, in industrial and government laboratories, in the agricultural, food and pharmaceutical fields, and with the establishment of new research institutes in specialized areas, such as cancer, multiple sclerosis and other chronic diseases. Canada is one of the largest food producing countries and abounds in natural products. This area is obviously capable of absorbing large numbers of well-trained biochemists. In order to preserve our economic independence and to maintain our high standard of living, we must develop our scientific and technological talents, so that we can compete in international markets by exporting finished products and not only our raw materials. To achieve this aim, we must be prepared to invest more in research. In the long run it will be to our advantage to devote more of our resources to training professional men who will help develop and exploit our natural resources.

The Medical Research Council survey of Biochemistry Departments in universities has indicated that these will undergo a relatively small expansion requiring about fifty new staff appointments over the next few years. In many government laboratories, such as those of the Department of Agriculture, growth has now levelled off after a period of rapid expansion. An average recruitment of about ten to fifteen Ph.D. biochemists and an equal number of B.Sc. graduates yearly. However other government research organizations, notably the Department of National Health and Welfare, and the Fisheries Research Board are still expanding rapidly and may absorb eighty-five to one hundred new M.Sc. and Ph.D. graduates over the next five years 1967-1972, with a concomitant demand for less qualified personnel as technicians.

Canadian universities are now (1967) training some two hundred and eighty graduate students in their Biochemistry Departments, and the number is increasing each year. Assuming an average of three years for graduate training it would appear that, even allowing for the fact that some of these students are from overseas and will return to their homeland after graduation, the current output of graduate students is sufficient to meet the present limited demand in academic and government institutions.

At present the future of graduates in biochemistry is partly obscured by the uncertainty regarding opportunities for employment in industrial laboratories over the next few years. It is apparent that industrial biochemical research is woefully weak in Canada at the present time, and there seems to be little expectation in the companies concerned that the situation will change very much over the next five years, 1967-1972. We

were unable to locate a single instance of a graduate from a biochemistry department of a Canadian university having been employed in an industrial laboratory, and one correspondent indicated that most biochemists employed in industrial laboratories at the present time come from outside the country,

A substantial number of the biochemists surveyed were convinced that, unless a change occurs, Canada will not be able to absorb any substantial increase in biochemistry graduates. Most assumed that any surplus that develops will be absorbed by the United States; others pointed out that this flow will occur, regardless of the opportunities in Canada, as long as a more attractive research environment and higher salaries are to be found in the United States. In general, it was expected that Government and Universities will continue to provide most of the employment opportunities.

This Committee believes, however, that Canada's present output of biochemistry graduates is not excessive and should be increased. The advent of Medicare will create a need for more clinical biochemists in hospitals and emphasis should be given to training students in this area of specialization. Other peripheral disciplines are likely to absorb increasing numbers of biochemists--fields such as pharmacology, physiology, immunology, nutrition, and genetics, where research at the molecular level becomes progressively more important, will benefit from this spillover, and some thought should be given to interdisciplinary training at the graduate level. A higher output of Canadian biochemists will mean that native graduates will fill the available jobs and increased competition will make it more difficult for scientists from

underdeveloped countries to find employment. Many of those who now tend to stay on in Canada will be obliged to return to their homeland, with beneficial effects on the economy of these countries. There seems little likelihood that the demand for well-trained technicians with a B.Sc. or technical college diploma will be satisfied in the foreseeable future.

Since a sufficient number of the most talented students must be trained and recruited to University appointments to maintain (or attain) a high standard of teaching in the future, a flow of good graduate students into biochemistry is vital.

The National Research Council lists 11,472 graduates students in Sciences and Engineering in 1967-1968. Of these only 183 (1.6%) are classified under Biochemistry. In the Biochemistry departments located in the medical schools, approximately 280 graduates students are being trained. Although it is difficult to evaluate the overlapping between the two lists, the graduates in Biochemistry represent at the most 2-3% of all graduate students in Science and Engineering.

When asked about the availability of graduate students 24% of university biochemists answer that the supply was adequate; 76% said it was inadequate. The quality of these students as appraised by their supervisors as follows :

Poor quality	:	21%
Average	:	61%
Good quality	:	18%

When asked to place in order of priority several of the factors which might be expected to attract more graduate students to biochemistry 32% of the university professors surveyed favoured an increase in the number of fellowships available, 27% more space, 21% better teaching and 20% more jobs for graduates. It is somewhat surprising to learn that the university biochemists are about evenly divided on what constitutes the main attraction for graduate students. It is even more surprising that they do not place more emphasis on the availability of jobs for their students after graduation.

4. Funding

a) Salaries

Salaries in biochemistry are comparable to those in other branches of chemistry. In universities, the salaries have improved greatly over the past years and have now reached if not surpassed the salaries paid in government laboratories. The gap between salaries in industrial and academic jobs is now narrowing to the point where most biochemists would prefer to remain on the campus after graduation so that there is even less incentive to seek industrial positions. There is also a salary differential within universities in favour of the medical faculty in which most biochemists are employed.

However, although adequately paid at the outset of their career professional biochemists receive only modest remuneration for experience and proven ability. It is relatively easy for other countries which are willing to offer more attractive rewards to senior personnel, to induce the most competent Canadian scientists to emigrate. The most serious shortage in Canada appears to be not of young biochemists, but of experienced people who can direct and plan. If this situation persists the establishment in future of new laboratories of high caliber may be nearly impossible

b) Operating Expenses

Funds available for research in biochemistry vary according to the location of the biochemist. In industry, they are almost nonexistent due to the fact that most of the research that should be done in our industrial firms is carried on in the parent firm, either the United States, the United Kingdom or Switzerland.

In government laboratories, funds are now levelling off after rapid expansion over recent years.

In Universities, the support for research has increased tremendously since the last war. Biochemistry has gained in stature with the availability of new sources of funds. The National Research Council, which once supported most of the research in biochemistry, has been superceded since 1960 by the Medical Research Council as the main funding agency. The Medical Research Council budget has grown from a few hundred thousands of dollars in 1961 to more than twenty millions in 1967. The private agencies (National Cancer Institute, Muscular Dystrophy Association, Heart Foundation, Life Insurance Companies, etc.) have also contributed their share to the budgets of the research biochemist.

The survey conducted in 1965-1966 by the Canadian Biochemical Society mentioned that in 1964-1965 a total of \$3,212,000 was awarded for biochemical research in Canada. Of this amount, 13% or \$423,000 was provided by the N.I.H. of U.S.A.. Of all the money given to biochemical research, 41% or \$1,316,920 was awarded directly to the Biochemistry Departments, the rest going to other departments.

More recently, in the publication on Medical Research in Canada ("Reference List of Medical Research Projects in Canada 1967-1968") which divides projects into forty categories, some four hundred and thirty-two (10.2%) out of a total of four thousand two hundred and twenty-five are classified as biochemistry. Biochemistry leads the field, followed closely by physiology. The funds awarded for these four hundred and thirty-two projects total \$5,962,925.00. From these figures, the average grant for biochemical research oriented in the medical field is \$14,803. Despite this increase, 71% of the biochemists in departments located in Medical Schools consider that they do not have adequate financial support. However, these biochemists when asked what should be done to develop biochemistry, listed "more time for research" as the most important priority. "More money to hire staff" to reduce the teaching load and give more time for research was given second priority, and "space" third priority. Only in fourth place did they list "more money for supporting personnel", followed by "more money for equipment" and, finally, "more money for graduate students".

We conclude that there is no critical lack of funds in Departments of Biochemistry located in medical schools. The tangible expression of public sympathy in terms of financial support is probably one of the main reasons why this privileged area of biochemistry has flourished.

The picture is completely reversed for biochemists who are working in other Faculties. They receive their grants^{to} mainly from the National Research Council, with a small contribution from private agencies. From the list published by the National Research Council, in 1966-1967, we have classified as "biochemical research": one hundred projects totaling \$747,320 in the section Biology; forty projects totaling \$250,359 in the section Chemistry and fifty seven projects totaling \$300,230 in the section on Agriculture. The grand total of support is \$1,297,909 for the 197 projects. The average grant is therefore \$6,588.

In spite of increasing federal and provincial budgets for support of research in the biosciences, the funds provided are still not adequate to sustain strong research centres which can retain and attract the best scientists against competition from similar centres in the United States. As a result, some of our more gifted students are inclined to go for their training to the United States. An enquiry done by the NRC has shown that 1/3 of these return to Canada. Nowadays, for efficient teaching and research, highly expensive items of major equipment and physical installations are required, in addition to adequate numbers of academic and technical staff. At the present time some university staff are overworked and have not time and energy left to develop the new areas (e.g. molecular biology). The overall support received by all branches of science in Canada is meagre representing about one quarter to one third of the contributions made by other developed countries with comparable gross national products. The support of biochemical research in science departments is much below that received by the faculties of medicine from the Medical Research Council. This tendency if not converted could prevent the developments of biochemistry in some important area.

Although a fair proportion of government scientists appear satisfied that their own personal research is being adequately supported, only about 20% consider that their field of interest is receiving the attention it deserves. Many feel that they are working as individuals or small isolated groups with little prospect of catching up with active groups elsewhere, or of maintaining the slim lead they may now hold. Expansion to groups of three or four scientists with adequate technical and service support and a steady investment in new instrumentation appears to be the ideal which most would like to attain. Several biochemists cited a need for additional staff in supporting disciplines; some of these e.g. biochemical geneticists and cytologists are unobtainable. Many of the needs could be met at relatively small cost by an expanded postdoctoral fellowship programme. A brief has been presented from the Cell Biology Institute, Canada Department of Agriculture, Ottawa pointing out the advantages of increasing the number of postdoctoral fellowships tenable at government research institutions.

5. Centers of Excellence

Primarily because of lack of adequate funds, there are very few strong centres in Canada which can claim to have original investigators of world-wide reputation who could provide the expertise to act as consultants to government and industry. It is clear that research cannot be pursued in the biophysical sciences without any concern to industrial productivity. After all, without a supporting industry there would be neither the money nor the need for sophisticated research programmes. For a more economical and efficient utilization of our human and technical resources, it would be desirable to establish interdisciplinary units in

our universities. These should function as integrated biochemical institutes. A number of such institutes should be established in different geographical areas, preferably pursuing different fields of specialization. In general, in Canada, the older academic staff members object to the establishment of organizationally autonomous research centres, which might be classified as institutes, on rather debatable grounds, i.e. that they create two classes of citizens, those who teach and those who do research. In contrast, in some highly developed countries, such as Sweden, Germany, Belgium and Switzerland, specialized institutes have been shared ventures between university professors and research investigators, on the one hand, and scientists from industry and government, on the other. Obviously, the key people in such a multi-disciplinary and multi-departmental research institute must command not merely the scientific respect, but also the personal trust and admiration of their colleagues.

Our present research funding policies do not encourage cooperative research programmes between individuals in a university, and clearly there are too many investigators who would be better off, in the long run, within a coordinated research programme under the guidance of a senior colleague of sounder judgment, rather than working away on trivial problems in "free" isolation. Only large integrated research centres can justify the expenditure of large budgets required for the purchase of highly specialized items of equipment, their costly maintenance and the salaries of the supporting technical staff. Considering the successful execution of some of the venturesome multi-disciplinary research programmes in bio-science in some other centres, e.g. the Medical Research Council units in

the United Kingdom, the Max-Planck Institutes in Germany, the Centre Nationale de Recherche Scientifique (C.N.R.S.) groups in France, the National Institutes of Health laboratories and private research centres in the United States, it is clear that these programmes run into several million dollars and not into the few hundred thousand which is the more common magnitude appropriated in Canada.

It is difficult, if not impossible, to legislate collaboration between individuals in our freely-organized universities. Nevertheless, some way must be sought to encourage cooperative efforts within the university, and between university professors, industry and government. Joint appointments from industrial and government research laboratories to the graduate faculty of the university appear to be one way of inducing these sectors of our economy to provide their experts for cooperative programmes. These programmes could be performed either within research centres on a university campus or in an industrial or government laboratory setting. Promotion of harmony and cooperation among these three sectors of our scientific community will not be solved by our cautious habit of referring all ventures to committees for a democratically acceptable recommendation. The moving force must come from industry or government through the establishment of a multi-million dollar budget for interdisciplinary research centres, such as was the case for the establishment of the Pulp and Paper Research Institute in Montreal, and the most successful Polymer Corporation in Sarnia.

It is clear that universities, being the home of experts in different fields, provide an ideal setting for some interdisciplinary research, on condition that the right people are appointed to the appropriate positions in the first place. Moreover, universities can still provide the centres for study of problems of long-term interest which would not be done in industry or government. The important thing is to find means of promoting mutual awareness between government, industrial and academic personnel at the level of the working scientist. One way of achieving this might be to encourage a programme of visiting speakers and exchange scientists. In this connection, universities should be more outgoing in making the faculty easily available to industry for lectures, refresher courses and consultation. In turn, industry should be willing to underwrite the cost of more academic research, and industrial and government laboratories should be made available for graduate research on the basis of carefully regulated agreements between the organization in question and the supervising university.

6. Role of Government

It is generally agreed that the funds needed to promote the development of biochemistry in Canada will have to be provided by government. The problem is simply to discover where the money be applied to create the most beneficial effect. In earlier sections Committee 17 has considered the present status of biochemistry and outlined various areas of special need. The most serious deficiencies are considered to be the lack of industrial research on which new and expanding secondary industries should be based, the mediocrity of much of the teaching and

basic research at our universities and government laboratories, and the absence of any strong centres of biochemistry to attract and retain high-calibre scientists within Canada. It is clear that these deficiencies will not be overcome without a balanced investment of funds in various sectors. Biochemists in the Department of Biochemistry believe that these efforts should be directed towards university (39.2%), research institute (26.4%) and industry (15.0%).

a) Government Laboratories

We concur with the overwhelming majority of professional biochemists employed in government laboratories who believe that their role should be to undertake research problems which are of a long-term interdisciplinary nature, which serve a broad national interest, and which are too expensive or too specialized for universities or industry to attempt. Superimposed on this required role is a variety of other functions which may be expected to promote the economic development of the country:

- (1) Applied research aimed at the establishment of new industrial processes but beyond capabilities or outside the interests of existing companies. Development of new methods or products on a semi-industrial scale to prove their value may often be required here. Although this is a job for industry itself where facilities and investment are already available, social or economic considerations may require Government participation. Under some circumstances sponsorship, collaboration or limited financial support may be all that is necessary to foster the necessary research.

- (2) Any research, fundamental or applied, needed to solve assigned problems (e.g. enforcing the Food and Drug Act, crop protection or improvement, etc.).
- (3) Fundamental research that is multidisciplinary and in the national interest but unlikely to be done in Universities because of their tendency to maintain a fairly rigid departmental structure for teaching purposes.
- (4) Fundamental research of a long-term nature, which requires extensive preliminary exploration, development of instrumentation, and continuity of staff, and which is related to the economic development of the country. This is frequently unsuited to the thesis-oriented typical University research unit of a professor, technician and 3 or 4 graduate students.
- (5) Any neglected or "unfashionable" area of research, particularly when it requires large engineering capabilities and supporting staff. Government Laboratories should provide and maintain such facilities for use by Universities and Industry.

This committee considers that there is little need for new government laboratories devoted to problems in basic biochemistry at the present time. There is a need to strengthen and coordinate the programmes in existing organizations. Government research groups should be "mission-oriented", and strongly directed, but within the National Research Council there should be scope for talented individuals who have no interest in teaching to develop pioneering research units in fields of their own choosing.

b) Interdisciplinary Institutes

Although there is considerable unanimity among biochemists on the desirability of organizing interdisciplinary research institutes to provide an opportunity for collaboration between specialists, few can agree on the form these should take and how they should be operated. The biochemists in the Medical Faculties are in favor (66%) of these institutes as compared to 17.7% that oppose and 16.5% who are indifferent. These biochemists overwhelmingly (80%) also favor active collaboration between university and both government and industry. Our committee believe that such institutes should be associated with a University and participate in the graduate training programme. The most suitable method of promoting excellence and guiding the expansion of biochemistry in Canada would be to develop "cells" around men of proven ability within existing organizations. Beside the various models already in existence --i.e. the scheme for interdisciplinary "cells" operated by the Medical Research Council in Great Britain, and in the United States the Career Scientist scheme and the loosely organized "Institute for Advanced Studies" composed of separate disciplines able to interact flexibly, an even more flexible scheme based on 1-2 year fellowships that would bring together distinguished scientists in different disciplines and provide them with facilities, supporting staff and a small permanent cadre for continuity, should be considered.

c) Industrial Research

The volume of industrial biochemical research in Canada at the present time is very small in comparison to that carried out in university and government laboratories. The following reasons may be given for the relative lack of industrial biochemical research :

- (1) Companies are foreign-owned or controlled, and research is carried out in centralized laboratories located outside of Canada;
- (2) Companies are too small to afford laboratory research facilities;
- (3) Company management does not consider biochemical research a profitable investment;
- (4) Recruitment of personnel may present some problems since many biochemists feel that they have more freedom to follow their individual research interests and to publish their results when working in a university or government laboratory.

This committee feels that the imbalance between research activity in university and government laboratories on the one hand and industrial laboratories on the other, is undesirable for the economy of the country and for the future development of biochemistry in Canada. Increasing the volume of industrial biochemical research would, we believe, make it possible for Canadian companies to make better use of our natural resources in agriculture, fisheries and forest products, and to compete more effectively in international markets. It would also provide more opportunities for employment of biochemists in Canada, thus reducing the "brain drain" to other countries and perhaps at the same time attract trained personnel to settle in Canada.

Government has been and is attempting to stimulate industrial research, but the efforts to date do not seem to have had a very significant effect on industrial biochemical research and some new approaches are perhaps desirable. The following suggestions are based on comments received in response to questionnaires and on the deliberations of the Committee in the course of preparing this report: (1) Some better incentives to engage in industrial biochemical research in Canada should be offered to Companies who are foreign owned or are too small to support independent research laboratories. Perhaps a group of Companies associated with some particular industry (e.g. the food industry) could be induced to collaborate in setting up centralized laboratory facilities for the solution of common problems. It is our feeling that such laboratories should be financed primarily by industry but Government might act as a catalyst in attempting to initiate such activities either by direct collaboration or by providing tax incentives. (2) Consideration might be given to modifying the patent laws to provide further incentive for industrial biochemical research. (3) A number of people commented on the desirability of promoting increased contact and collaboration between biochemists in university, government and industrial laboratories. Government might help to promote this by (a) providing funds for exchange visits and lectures along the lines of the current Medical Research Council arrangements for exchange of personnel between different universities; (b) providing scholarships for students to work in industrial research laboratories during the summer; and (c) organizing conferences or symposia with the aim of bringing together personnel from university, government and industrial laboratories and perhaps industrial management

as well, to discuss subjects which might benefit from increased biochemical research activity. (An example of this type of conference was organized in 1967 by the Fats and Oils Committee of the National Research Council).

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C.I.C. SURVEY OF BIOCHEMISTRYRECOMMENDATIONS

We recommend :

1. That efforts be made to foster applied research in biochemistry, particularly in industrial and clinical laboratories.
2. That centres of excellence in biochemical teaching and research be developed.
3. That interdisciplinary institutes associated with a University be established.
4. That government laboratories direct more of their attention to mission-oriented research, by organizing strong interdisciplinary groups with realistic goals that would benefit the Canadian economy.
5. That means for promoting mutual awareness between government, industrial and academic personnel be established by a program of visiting and exchange scientists.
6. That the teaching of biochemistry in Canadian Universities be broadened with greater emphasis on basic training in chemistry, physics and mathematics and better coordination with other science departments.
7. That support to biochemistry outside the Medical Faculties should be increased.