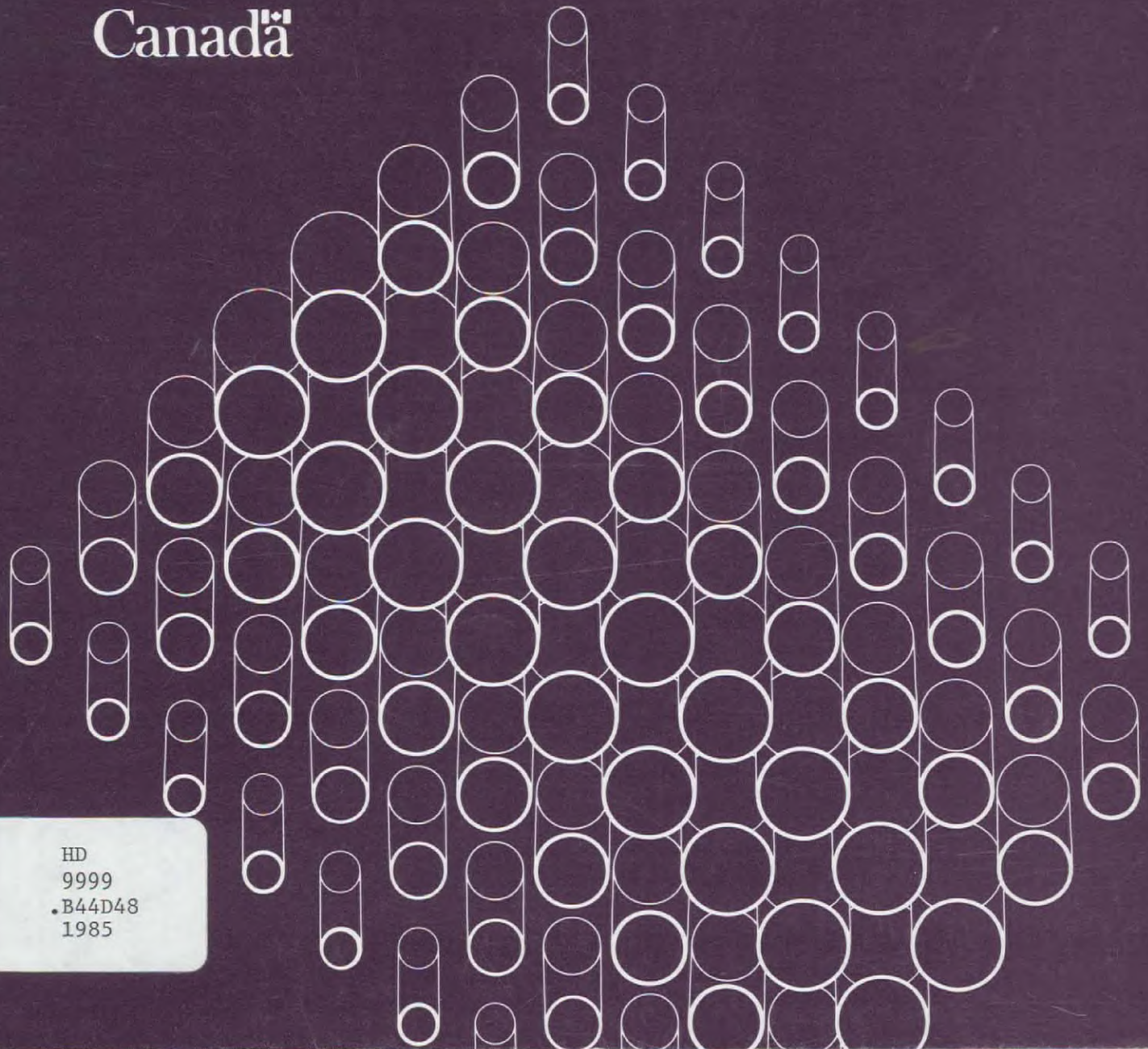


National
Biotechnology
Advisory
Committee

1985 Survey of Canadian
Fermentation Industry and
Facilities for Scale Up and
Process Development

Canada



HD
9999
•B44D48
1985

HD
9999
1344D48
1985



Ministry of State

Ministère d'État

Science and Technology
Canada

Sciences et Technologie
Canada

Ottawa, Canada
K1A 1A1

1985 Survey of Canadian
Fermentation Industry and
Facilities for Scale Up and
Process Development

Prepared for the National Biotechnology Advisory
Committee by:

*diversified
research*

Diversified
Research
Laboratories Ltd.

1047 Yonge Street
Toronto, Ontario
M4W 2L3

Telex: 065-28057

Telephone: 416-922-5100

CONSULTANTS TO INDUSTRY

38791

For more information contact:

Dr. David B. Shindler
Secretary, National Biotechnology
Advisory Committee
Strategic Technologies Branch
Ministry of State for Science and Technology
235 Queen Street (8th floor west)
Ottawa, Ontario
K1A 1A1

Tel: (613) 990-6322

Telex: 053-4123

MINISTRY OF STATE
MINISTÈRE D'ÉTAT
BIBLIOTHÈQUE

SEP 12 1988

LIBRARY
SCIENCE AND TECHNOLOGY
SCIENCES ET TECHNOLOGIE

Canada

TABLE OF CONTENTS

	<u>Page</u>
Introduction.....	1
Inventory of the Canadian Fermentation Industry.....	2
Inventory of Pilot Scale Fermentation Facilities.....	4
R & D Activity Related to Fermentation Engineering.....	5
Section A. Canadian Industrial Fermentation Activity....	6
Section B. Pilot Scale Fermentation Facilities.....	12
Section C. Government Organizations and Private Sector Companies Involved in Fermentation R & D Activity.....	21
Section D. List of Organizations Contacted.....	31

INTRODUCTION

In Vancouver in March 1984, a report entitled "Survey of Canadian Fermentation Industry and Facilities for Scale Up and Process Development" was presented at the National Biotechnology Advisory Committee workshop on Engineering and Fermentation Aspects of Industrial Biotechnology. The present report is intended as a follow up study to the original report, and provides an updated assessment of biotechnological activity in the industrial, university and government sectors. The information contained in this report was collected through limited telephone, personal and site contacts, and is felt to provide a reasonably accurate assessment of the Canadian situation.

The report concentrates on three main topics: the identification of organizations involved in the industrial scale exploitation of biotechnological methods, the existence of pilot scale fermentation equipment in Canada and private/public sector and university R & D interests related to fermentation engineering and scale up.

As is the case with all surveys of this kind, it is very difficult to ensure that it is complete. Should the reader have any suggestions, additions or corrections to what is presented, please contact Andris Ortmanis of Diversified Research Laboratories, 1047 Yonge Street, Toronto, Ontario M4W 2L2. Information received will be recorded and used as a contribution for future updates of the report.

This report was prepared for the National Biotechnology Advisory Committee, as part of its continuing responsibility to assess biotechnological development in Canada, and to promote commercial biotechnology. For further information on the committee and its activities, please contact the secretary, Dr. David B. Shindler, 235 Queen Street, 8th Floor West, Ottawa, Ontario, K1A 1A1. (613) 990-6322

INVENTORY OF THE CANADIAN FERMENTATION INDUSTRY

An inventory of industrial fermentation activity in Canada has been made, and the results are compiled in Table A.1 of Section A. Several different types of industrial scale fermentations exist, and not all are included in this list. For example, while it is recognized that the wastewater treatment industry represents by far the greatest application of biological processing on a large scale, the types of technology employed are quite different from those used in the production industries, and therefore excluded from the listing. However, processes which utilize a specific industrial effluent as a feedstock for the fermentation of a specific valuable product, such as that used by Ontario Paper Co., are included.

A secondary category of fermentation technology which does not appear in this compilation, involves fermentations carried out by breweries, alcoholic beverage distillers, wineries and dairy product manufacturers. These are well established industries in Canada, and for the most part, do not yet rely on highly technical, innovative fermentation processes. However for the sake of completeness, separate diagrams which document the distribution of these industries across Canada appear in Figures A.1 - A.4 of Section A. These diagrams are reprinted as they appeared in the previous 1984 report, as significant changes have not occurred in these industries in the past 18 months, except for the introduction of microbreweries, small scale privately financed brewing companies, in several provinces.

The listing compiled in Table A.1 is very similar to that presented 18 months ago, in that very few additions have been made. Thus, it consists primarily of fermentation industries producing yeast, fuel alcohol, alcohol for vinegar production, vinegar and dextran products. Two additions to this category are a vinegar manufacturer and a producer of alcohol destined for vinegar production.

Two major vaccine and fine biochemical compound producers in Canada are Connaught Laboratories and the Institute Armand Frappier. However, this listing includes an increasing number of small manufacturers producing a specific or limited range of products. This is demonstrated by the addition of Helix Biotech Ltd. and ABI Biotechnology to the list of companies such as Langford Laboratories, Research Foods, Rhizotech Laboratories, and Vetrepharm, which produce high value medicinal, veterinary, agricultural or diagnostic compounds.

INVENTORY OF THE CANADIAN FERMENTATION INDUSTRY (cont'd)

Three plants utilizing large scale immobilized enzyme/whole cell technology are currently operating in Ontario, producing high fructose syrup. Located in Port Colborne, London and Cardinal, they are a joint venture between John Labatt Limited and Canada Starch Company Limited and are operated under the name of CASCO Inc.

INVENTORY OF PILOT SCALE FERMENTATION FACILITIES

In establishing criteria for an inventory of Canadian fermentation pilot scale facilities, it has been assumed that the facility should be capable of providing an intermediate process capacity for the evaluation of technical and economic feasibility. Based on this premise, a minimum fermentation capacity of 100 L was used in the previous report, and has been accepted as a reasonable capacity for this follow up survey. The compilation of scale up facilities is presented in Table B.1 in Section B of this report. Additional information on the nature of the facilities was collected and is also presented. Both upstream and downstream processing capabilities of the facilities are indicated whenever this information was available, and a list of current/past projects, staffing and present status of the facilities is briefly summarized. It is often the case, especially in the fermentation of high value biomolecules, that a production facility may be the same scale or smaller than a 100 L facility. Thus, many "pilot scale" facilities serve as production facilities some fraction of the time, but to have redefined the scale of a pilot facility to below 100 L, would have resulted in a listing containing predominantly lab scale equipment.

R & D ACTIVITY RELATED TO FERMENTATION ENGINEERING

Table C.1 in Section C provides an indication of private sector and government activity in the area of fermentation engineering, while highlights of university projects which involve fermentation are summarized in Table C.2. The breadth of activity which has emerged over the past few years, indicates the rapid evolution of many R & D programs adopting the new technology.

Section A. Canadian Industrial Fermentation Activity

Table A.1 Industrial Fermentation Activity in Canada

<u>FACILITY/LOCATION</u>	<u>PRODUCTION INTERESTS</u>
ABI Biotechnology Winnipeg, Manitoba	Produce high value medicinal products by fermentative processes for domestic/export markets.
Canvin Products Ltd. Wolfeville, N.S. Toronto, Ont. Chatham, Ont. Saskatoon, Sask.	Produce vinegar using packed generators and submerged process licenced from Frings, Germany.
Connaught Laboratories Willowdale Ont.	Produce vaccines for domestic and export markets. Products include tetanus, diphtheria, pertussis and acellular pertussis vaccines prepared in 20 L - 1500 L batches. In-house R & D program with pilot plant scale up/production facilities.
Dextran Products Ltd. Div. of Polydex Pharma Ltd. Scarborough, Ont.	Produce dextran, approximately 35 tonnes annually, in two 10,000 L fermentation vessels. Perform in-house R & D to develop process and products.
Fleischmann Ltd. Montreal, Que. Calgary, Alberta	Produce yeast. R & D, product and process development done either in-house, or by parent company, Nabisco Brands Limited.
Heinz Company Ltd. Leamington, Ont.	Produce vinegar using classical packed generators and submerged process licenced from Frings, Germany, in 6000 gallon batches. Do in-house R & D on developing strain tolerance to vinegar, ability to use alternate substrates and faster fermentation time.
Helix Biotech Ltd. Richmond, B.C.	Small scale producer of veterinary products and clinical diagnostic kits, although not exclusively by fermentative techniques.
Institute Armand Frappier Laval, Quebec	The Institute Armand Frappier produces vaccines in 150 L - 190 L batches for domestic and export markets. In-house R & D program to develop fermentative transformation/synthesis capabilities.

Lallemand Ltd. Montreal, Que.	The production of yeast for breweries, bakeries, wineries and distilleries performed in 60000 L - 80000 L stirred tank fermentors. The addition of a 150000 L vessel and two 2000 L vessels, has recently expanded both production and in-house R & D capabilities. Research centres on the development of wine yeasts, distillers yeasts and resistance of yeasts to cryogenic processing and ethanol.
Langford Laboratories Guelph, Ontario	Produce bacterins and vaccines for veterinary applications. Products include rabies and distemper vaccines, which are batch fermented in new 250 L facility. Active R & D work in area of tissue culture.
Mohawk Oil Ltd. Minnedosa, Man.	Converted old distillery to produce fuel alcohol using standard yeast fermentation technology. Produce 21000 L alcohol daily with ten 14000 L fermentors. R & D work centres on lignocellulytic technology development, upon which the alcohol process is based.
Northwest Food and Fuels. Kerrobert, Sask.	Produce alcohol using standard yeast technology from distillers dry grains at 600 gal/day, primarily as feedstock for vinegar manufacturers. Will expand production capability in fall 1985 with addition of 7000 gallon fermentor. R & D work centres on process development with Saskatchewan type grains and reducing the fermentation times to increase productivity.
Ontario Paper Co. Ltd. St. Catherines, Ontario	Fermentation facility producing 5000m ³ alcohol annually from spent sulfite liquor of paper manufacturing process. Alcohol process operates at a loss, but is beneficial to downstream vanillin productions. Little R & D work on alcohol process - emphasis on paper production.

Reinhart Vinegar Ltd. Produce vinegar using submerged process
Stayner, Ont. licenced from Frings in Germany. R & D
Chambly, Que. work is carried out in-house, but also
rely on process developments by group
in Germany.

Research Foods Small scale production of vomitoxin
Downsview, Ontario standards with technology developed by
Agriculture Canada.

Rhizotech Produce Rhizobium for use as fertilizer
Laboratories Inc. on 2 L scale. Producer of "Frankia"
St. Jean Crysostome, bacteria used for nitrogen fixation in
Quebec shrubs and land reclamation operations.
Involved in plant tissue culture for
forestry service and developing
production methods for microbial
insecticide.

Rosell Institute Produce bacteria for dairy, food,
St. Laurent, Que. hygenic and therapeutic uses. Also
involved in R & D work on nitrogen
fixing bacteria. Production and R & D
fermentors include aerobic 2000 L and
1500 L vessels while have anaerobic
300 L vessel. Plans to supplement
these with 1500 L vessel exist.

Schwartz Inc. Produce vinegar using packed generator
Halifax, N.S. licenced from Frings, Germany.
Candiac, Que.

St. Lawrence Starch Produce 15000 USG/day potable alcohol
Co. (97%) using standard yeast fermentation
Mississauga, Ont. of starch/hemicellulose. Also involved
in the sale of reactors for production
of fermentable sugars, glucose and corn
syrups.

Vetrepharm Inc. Produce bacterins and nutritional
London, Ont. pharmaceutical hormone and vaccine
preparations for veterinary use.
Production runs are in small scale
fermentation equipment, up to 10 L, and
R & D work concentrates on development
of commercial products as needs of
veterinary care change.

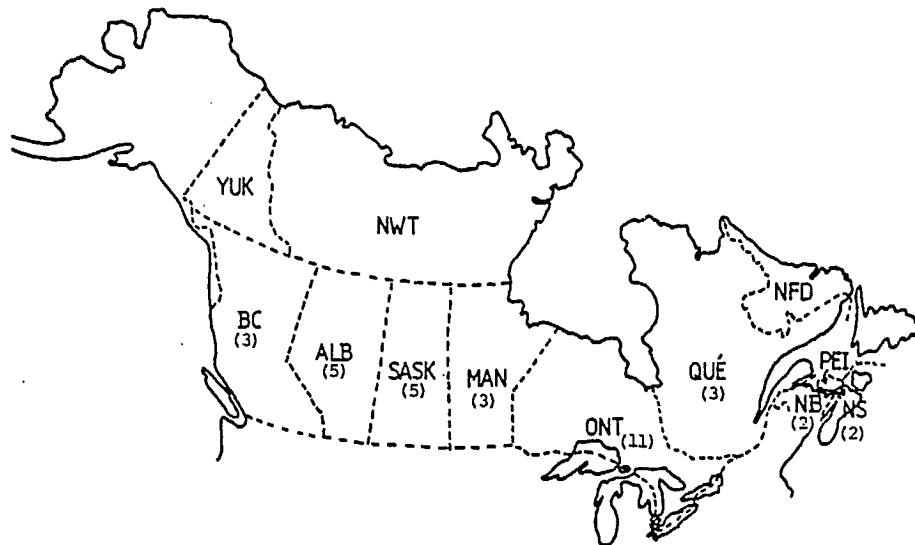


FIGURE A1.1: Distribution of breweries by provinces

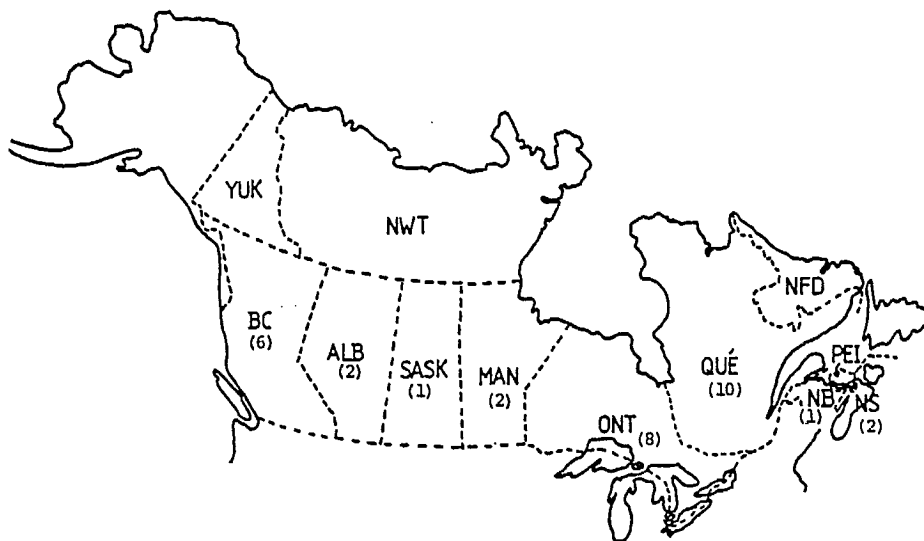


FIGURE A1.2: Distribution of wineries by provinces

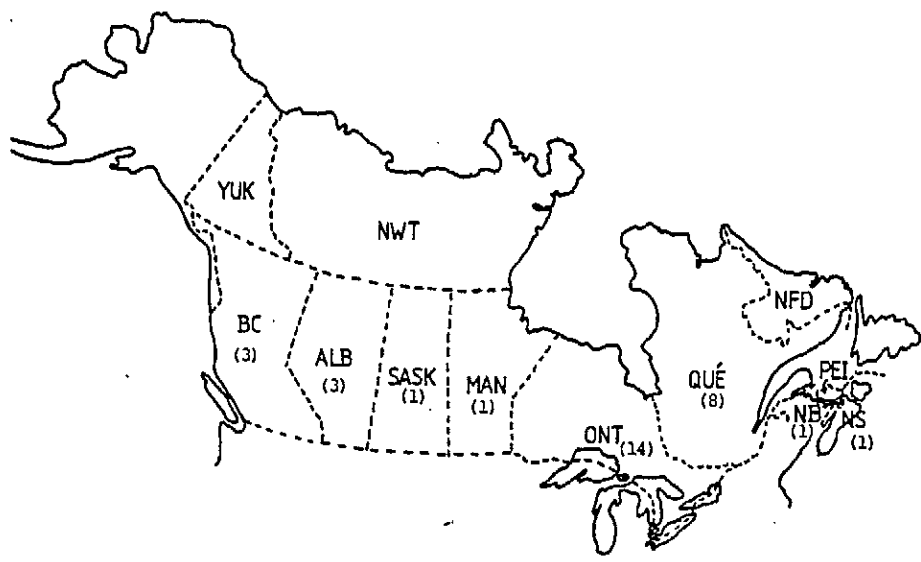


FIGURE A1.3: Distribution of potable alcohol distilleries by provinces.

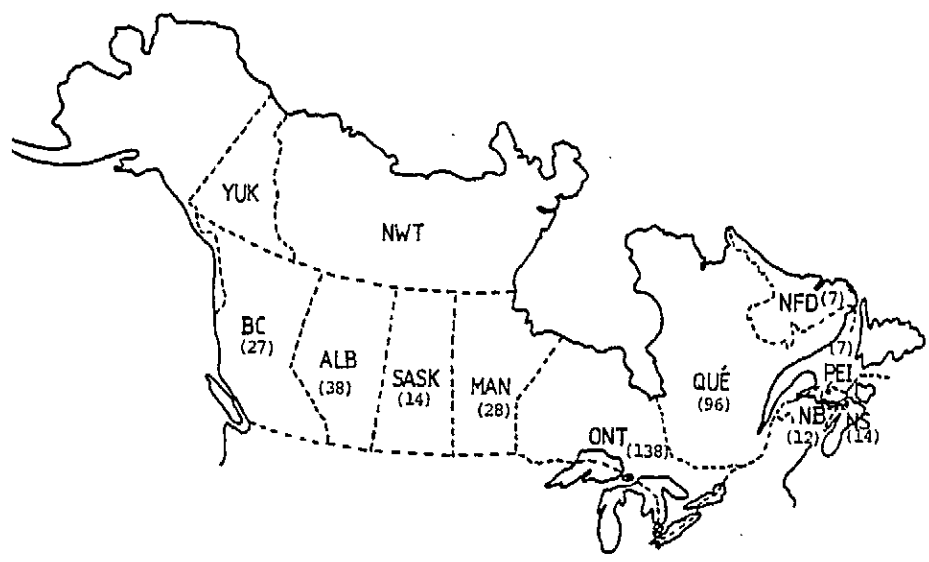


FIGURE A1.4: Distribution of dairy product manufacturers by provinces.

Section B. Pilot Scale Fermentation Facilities

Table B.1 Existing Fermentation Pilot Scale Facilities

<u>FACILITY/LOCATION/CONTACT</u>	<u>FERMENTATION EQUIPMENT</u>	<u>ASSOCIATED FACILITIES</u>	<u>COMMENTS</u>
Alberta Environmental Centre Vegreville, Alberta A. Van Roodselaar	250 L instrumented fermentor with smaller support vessels. The batch vessel has micro-processor control capabilities.	DOWNSTREAM processing equipment includes electrical incineration of fermentor gaseous effluent, a filter press, centrifuge and a hammer mill.	Primarily a support facility for lab scale R & D work. Staffed by 3 biochemists, 2 technologists and a mechanical engineer. Unavailable for private sector contract research under present administrative arrangement.
Alberta Research Council Edmonton, Alberta M. Kole	Fully instrumented 1500 L batch stirred tank/airlift fermentor with instrumented 250 L and 150 L batch stirred tank fermentors. A 250 L airlift and two 150 L stirred tank fermentors will be on stream in the near future. Support fermentors (10) in 15-28 L range now operating or in planning stages. Interface of major fermentors to VAX computer system for data-logging/process control.	UPSTREAM processing facilities consist of storage vessels (375-1000 L). DOWNSTREAM equipment includes continuous centrifuges, spray drier, lyophilization unit and pilot scale gel filtration column capability.	The pilot facility has been constructed to maximize flexibility vital for contractual research and consulting services. A full analytical laboratory services the unit. Current work centres on the development of ice inducing bacteria.
Bio-hol Developments Weston Research Centre Downsview, Ontario G.R. Lawford	Fully instrumented micro-processor control based 250 L, 400 L and 500 L stirred tank fermentors for batch and continuous fermentations. Media sterilization/holding vessels with 1000 L and 3000 L capacities are convertible to fermentors.	UPSTREAM processing equipment include a biomass hydrolysis extrusion system with centrifugal separation and purification equipment, filter press and evaporator. DOWNSTREAM processing consists of continuous centrifugation, filter pressing, evaporation, ultrafiltration and reverse osmosis unit operations.	Pilot plant manned by Biotechnology Department staff as required. Full lab scale R & D and analytical back-up facilities. Plant formerly used to demonstrate the production of fuel alcohol from biomass residues, but currently operates intermittantly on in-house R & D projects. Contractual R & D pilot scale projects sought.

FACILITY/LOCATION/CONTACTFERMENTATION EQUIPMENTASSOCIATED FACILITIESCOMMENTS

Connaught Laboratories Ltd.
Willowdale, Ontario
K. Phillips

Several fully instrumented
150 L and 100 L stirred tank
fermentation vessels.

UPSTREAM processing equip-
ment consists of media prep-
aration facilities, medium
filter and autoclavable
400 L medium storage tanks.
DOWNSTREAM processing equip-
ment includes ultrafil-
tration membrane facilities,
continuous Dynamill for cell
breakage, continuous centri-
fuges and large scale column
chromatography for protein
separation/preparation.

Since the pilot facility is
housed in the same area as
the production facility, a
containment area licensed
for the production of bio-
logical compounds for clinical
trials limits the nature of
pilot plant work in some cases.
The unit is used exclusively as
a testing facility for in-house
R & D projects.

Envirocon Limited
Vancouver, B.C.
R. MacDonald

Fully controlled 1000 L and
10,000 L fermentors operable
in batch or continuous mode.
Specifically designed for
both stirred tank and airlift
fermentation modes.

UPSTREAM processing equip-
ment consists of screening
and continuous sterilization
equipment while DOWNSTREAM
processing equipment in-
cludes rotating drum filter
and rotating drum drier.

Equipment specifically designed
for pilot scale evaluation of
fungal SCP production from
pulp mill sludge (cellulose),
to provide product for feeding
trials. Presently unused, it
is available for contract
research work.

Institute Armand Frappier
Montreal, Quebec
G. Vezina

Two 50 gallon (190 L) and
one 150 L stirred tank fer-
mentation vessels. These are
fully instrumented reactors.

UPSTREAM processing facil-
ities are limited to culture
medium preparation equip-
ment, but DOWNSTREAM pro-
cessing has biomass separ-
ation facilities.

Since the facility serves as
both an R & D and production
tool, strict security limit-
ations imposed by the federal
government on process equip-
ment used to produce vaccines
limits the use of the equip-
ment. Available on contract
with experienced operating
personnel.

Iotech Corp.
Ottawa, Ontario
S. McGuire

Computer interfaced 2000 L
and 200 L stirred batch fer-
mentors.

UPSTREAM processing consists
of lignocellulose degradation
equipment. DOWNSTREAM sep-
aration operations.

In-house R & D on production
of sugars, alcohol and other
chemicals from lignocellulosic
feedstocks.

National Research Council
Halifax, N.S.
A. Taylor

250 L instrumented computer
controlled stirred tank.

DOWNSTREAM processing equip-
ment consists of filtration
and extraction facilities,
specifically designed for
mycotoxin handling.

Facility used for vomitoxin
standard production and for
R & D in products for the
agriculture industry.

FACILITY/LOCATION/CONTACT

FERMENTATION EQUIPMENT

ASSOCIATED FACILITIES

COMMENTS

National Research Council
Ottawa, Ontario
D. Armstrong

Fully instrumented 250 L batch fermentor with incipient plans to interface to micro-processor for central and data-logging operations.

DOWNSTREAM processing capabilities include biomass harvest by continuous centrifugation, ultrafiltration apparatus and facilities for low temperature trapping of volatile components of the fermentation broth.

The facility is used exclusively for collaborative projects on topics such as utilization of low alcohol waste streams and fermentation of fine biological products.

National Research Council
Saskatoon, Saskatchewan
J. Grootwassink

130 L batch/continuous instrumented fermentor.

UPSTREAM processing equipment consists of wet and dry milling equipment and sieving equipment for grain preparation. DOWNSTREAM equipment consists of batch/continuous centrifuges, UF filtration apparatus, spray drier, multiple effect plate evaporator, drum drier, homogenizer, pilot scale lyophilization apparatus and pilot scale pressure cooker.

The centre's activity focuses on plant biotechnology, and the equipment is used for ongoing projects. The facility is manned by 2 Ph.D's and 4 technical staff, and is available to external users on a contractual basis.

POS
Saskatoon, Sask.
D. Hrytzak

2600 L custom made stirred tank reactor with pH and temperature control with capability of aseptic operation.

UPSTREAM equipment consists of 6-8 wet mills for grain processing. The DOWNSTREAM equipment consists of 3 continuous centrifuges, filter press, spray, flash, microwave and tunnel driers, and lyophilization apparatus.

This pilot scale research facility is provided to the client to aid scale up and production viability testing of processes. Although currently has limited fermentation capabilities, the acquisition of additional fermentation equipment is being considered. Facility operates at 100% capacity on contractual basis.

FACILITY/LOCATION/CONTACT

FERMENTATION EQUIPMENT

ASSOCIATED FACILITIES

COMMENTS

St. Lawrence Starch Co.
Mississauga, Ontario
P. Assarsson

Designed a 240 gal (900 L) batch reactor for yeast alcohol fermentation. Low instrumentation. Smaller vessels for solid state fermentation.

UPSTREAM processing equipment consists of hydrolyzation unit. DOWNSTREAM equipment consists of screens, filter press and belt press.

Facility in 100% usage by in-house and contract R & D projects. Engineering/microbiology consulting staff concerned with the hydrolysis of starchy substrates, pectin, hemicellulose and cellulose for fermentation to potable alcohol (St. Lawrence Starch) production. Have collaborated with POS on alcohol projects.

University of Alberta
Dept. of Biochemistry
Edmonton, Alberta
R. Iwonika

Instrumented 450 L batch fermentor.

DOWNSTREAM processing consists of a continuous centrifuge.

The facility is operated to produce approximately 40 batches/year of Escherichia coli for enzyme and other biomolecule isolation.

University of British Columbia
Dept. of Microbiology
Vancouver, B.C.
D. Kilburn

Microprocessor controlled 150 L batch stirred tank fermentor.

DOWNSTREAM processing equipment consists of continuous centrifuge and ultrafiltration units.

Activity in animal cell culture to produce lymphokines and interferon. Work with cellulolytic organisms as well. NSERC Infrastructure grant sought to provide full time staffing.

FACILITY/LOCATION/CONTACTFERMENTATION EQUIPMENTASSOCIATED FACILITIESCOMMENTS

University of British
Columbia
Dept. of Chemical Engineering
Vancouver, B.C.
R. Branion

Small aseptic (60 L) batch stirred tank/airlift fermentation vessel. Also open 150 gal (570 L) and three 35 gal (130 L) temperature controlled agitated fermentation tanks.

DOWNSTREAM processing includes membrane filtration, flash evaporation and drum drier equipment.

Work has included high temperature agricultural waste treatment and lactic acid fermentation.

University of Calgary
Faculty of Science
Calgary, Alberta
M. Gaucher

Instrumented 500 L batch stirred tank and microprocessor interfaced with instrumented 150 L batch/continuous fermentor with conversion to airlift capability. Smaller fermentor and support vessel facilities as well.

DOWNSTREAM processing capabilities include cell harvest by continuous centrifugation, UF membrane filtration and cell disruption in homogenizer.

The larger fermentor used to produce cell batches. The 150 L vessel used in immobilized cell work and continuous penicillin production studies. Computer control studies in progress by L. Behie of Chemical Engineering Department. Equipment available on contractual basis to interested parties.

University of Laval
Dept. of Chemical Eng.
Laval, Quebec
A. LeDuy

Two 1500 L batch stirred tanks with limited instrumentation. Not operated aseptically.

Developing non-aseptic fermentation processes with little upstream or downstream biomass processing.

University of Ottawa
Dept. of Biochemistry
Ottawa, Ontario
I. Altosaar

150 L batch/continuous instrumented stirred tank fermentor.

DOWNSTREAM processing equipment consists of continuous centrifuge and pilot scale protein separation/purification unit.

Presently seeing little use. Formerly used by industrial clients but currently available on a contractual basis. Staffed by members of Biotechnology unit.

Universite du Quebec a
Trois Rivieres
Trois Rivieres, Quebec
M. Lapointe

Open air 2200 L plastic stirred tank fermentor operating as activated sludge system, with associated control facilities. Both batch and continuous operation possible.

UPSTREAM processing equipment consists of continuous sterilizer and DOWNSTREAM capabilities include continuous centrifugation and spray drying.

The facility is involved with spent sulphite liquor conversion to SCP, but seeks contractual R & D engagements.

FACILITY/LOCATION/CONTACTFERMENTATION EQUIPMENTASSOCIATED FACILITIESCOMMENTS

University of Toronto
Dept. of Biochemistry
Toronto, Ontario
H. Lawford

250 L stirred tank fermentor with basic control systems.

DOWNSTREAM processing consists of continuous centrifuge.

Fermentor used to grow cell batches as required by departmental staff and research associates.

University of Toronto
Faculty of Medicine
Toronto, Ontario
M. Paull

250 L stirred tank fermentor with basic control systems.

UPSTREAM processing consists of a 200 L medium supply tank, and DOWNSTREAM processing consists of a continuous centrifuge.

Fermentation facility used to provide batches of organisms. One technician involved in this process.

University of Waterloo
Institute for Biotech Res.
Waterloo, Ontario
M. Moo-Young

1200 L computer coupled airlift fermentor.

UPSTREAM equipment consists of continuous sterilizer, feed preparation, holding and pretreatment tanks. DOWNSTREAM equipment consists of continuous centrifuge and drier.

Current work includes development of fungal SCP production from pulp mill sludge in cooperation with Envirocon. Facility operates at 50-60% usage and is staffed by fermentation and computer technicians and academic staff. Used as teaching facility within university, but available for contract use.

University of Western Ont.
Faculty of Engineering
Science
London, Ontario
A. Margaritis

Two 1000 L batch/continuous stirred fermentors. Plans to scale up existing 26 L airlift vessel to 250 L or 1000 L are possible.

UPSTREAM processing equipment includes mill for cellulosic material degradation. DOWNSTREAM equipment consists of continuous centrifuge, ultrafiltration units and homogenizer.

Intermittent work on the continuous fermentation of ethanol by immobilized yeast. Production of biosurfactants studied. Cyclosporin A fermentations conducted in airlift fermentation equipment. Available for use on contractual basis.

Woodside, R.
Halifax, N.S.

Custom built 125 L airlift fermentor with basic instrumentation.

Equipment originally at the Technical University of Nova Scotia where the yeast production of fuel alcohol from waste potato starch was investigated. Currently seeking commercialization opportunities.

Table B.2

PROPOSED PILOT SCALE FERMENTATION FACILITIES

<u>ORGANIZATION/LOCATION</u>	<u>PROPOSED FACILITY</u>
ABI Biotechnology Winnipeg, Manitoba	Plan 6000 ft ² facility with 10 L, 20 L, 150 L and 500 L fermentation vessels. Downstream processing would concentrate on pilot scale protein purification facilities - column chromatography. Fermentation on line in Fall 1986.
Agriculture Canada Ottawa, Ontario	Intended to provide industrial clients with an opportunity to draw on expertise and facilities of planned Food Research Institute in Ste. Hyacinthe, Quebec. Will have 1500 L, 200L, 150 L and 20 L computer controlled fermentation apparatus with upstream UHT processing and 600 L media storage facilities. Proposed downstream facilities would include continuous centrifuge, homogenizers and protein separation columns.
Allelix Inc. Mississauga, Ontario	Currently writing specifications for pilot facility which is to include 200 L airlift and 1000 L tank fermentor. These facilities will be designed to meet the production requirements of specific compounds.
Cangene Corp. Mississauga, Ontario	Plan to acquire a fully instrumented 120 L fermentor which would support on-going research projects.
Fermtech R&D Inc. Mississauga, Ontario	Plan to occupy 4000 ft ² pilot/testing/production facility with instrumented 500 L stirred tank fermentor, for probiotic production.
Forintek Canada Corp. Ottawa, Ontario	Plan to supplement facilities with a 100 L fermentation pilot plant. Upstream processing to include steam explosion gun.

PROPOSED PILOT SCALE FERMENTATION FACILITIESORGANIZATION/LOCATIONPROPOSED FACILITY

National Research Council
Montreal, Quebec

The Biotechnology Research Institute is in the process of selecting and designing equipment for its pilot plant. Will have 1500 L stirred tank fermentor and several fermentors in range of 100 L - 1000 L. Planned upstream processing facilities include grinders, mixers and continuous sterilizers while downstream equipment to consist of continuous centrifuges, filters, UF/RO membrane filters and driers.

Pulp and Paper Research
Institute of Canada
Pointe Claire, Quebec

The PPRIC plans to develop facility to complement lab scale facility. Investigating 75-100 L scale vessels with undetermined schedule to acquire 250 L fermentation capacity.

University of British
Columbia
Vancouver, B.C.

The Campus of the University of British Columbia is the site for the construction of a \$31 million biotechnology facility, \$8 million of which is slated for pilot plant construction. Unit will be designed for medicinal product synthesis i.e. lymphokines, interferon.

University of Western
Ontario
London, Ontario

The University of Western Ontario has plans to construct 250 L or 1000 L airlift fermentor for scale up studies.

Section C. Government Organizations and Private Sector
Companies Involved in Fermentation R & D
Activity

Table C.1 Private/Government Biotechnological and Fermentation Activities

<u>COMPANY/LOCATION</u>	<u>BIOTECHNOLOGICAL INTERESTS</u>
ABI Limited Winnipeg, Manitoba	A new biotechnology company currently involved in the fermentation and purification of biological molecules such as Interleukan-2. Also produce human blood clot factor-VIII. Have in-house fermentation R & D program, and accept contract research work. A fermentation pilot facility is planned.
Agriculture Canada Ottawa, Ontario Ste. Foy, Que. Ste. Hyacinthe, Que.	Involved in a wide range of agricultural biotechnology. Research and development interests include waste utilization to produce ethanol, flavours and other metabolites, membrane process for nitrogen fixation, plant breeding, the development of gene transfer techniques, plant cell culture to produce flavours and enzymes and mycotoxin and SCP production. Also interested in fermentation of lactic acid, specific enzymes and fermented food products. Pilot plant facilities are under construction in Ste. Hyacinthe, by the Food Research Institute.
Alberta Environmental Centre Vegreville, Albta.	The Alberta Environmental Centre conducts research for the Alberta provincial government and ARC. Now 5 years old, it currently concentrates on wastewater technology, involved primarily in decolourization and deodorization of municipal and pulp mill effluent. The microbiology of fungal processes is also investigated. They have a pilot scale fermentation support facility in-house.

Alberta Research
Council
Edmonton, Alberta

The Alberta Research Council undertakes work in three broad areas; fermentation technology and scale up, plant cell culture and crop cold hardiness improvement and genetic engineering. The first fermentation scale up project in a new pilot plant facility is the production of an ice inducing bacteria. Crop frost tolerance work is being conducted on wheat and alfalfa plants using tissue culture techniques. The genetic engineering work to date has been a joint project with Biologicals, and involves the synthesis of vectors for gene transfer in yeast and bacteria. Some gene cloning work is also on-going.

Allelix Inc.
Mississauga, Ont.

Active in the development of diagnostic reagent kits, plant and animal cell culture research, and the development of fermentative processes to produce high value biochemical compounds. Currently operating on lab scale capacity with computer interfaced equipment, but plan to scale up to pilot scale production in in-house facility.

B.C. Research
Vancouver, B.C.

Biotechnological interests span several areas of application. Have over 30 years of experience in biohydrometallurgy and biological leaching of ores. These projects involve industrial research contract work. Also involved in production of biological polymers for tertiary oil recovery, methanation of residual hydrocarbons in spent oil reservoirs and production of biopolymers from methanol. Produce test kits for aquaculture and produce carotinoid containing yeasts as aquaculture feed. Also involved in microbial treatment of leachate, pulp and paper industry wastewater and oil refinery effluent.

Cangene Corp.
Mississauga, Ont.

Cangene conducts contractual development of proprietary, product independent expression systems using recombinant DNA, genetic engineering and applied and industrial microbiological techniques. Work relates to products in the food and medicinal areas, the latter being composed of enzyme, antigen and secondary metabolite production. Small scale in-house fermentation system is planned to be supplemented with 120 L batch/continuous facility.

Centre de recherche
industrielle du
Quebec
Ste. Foy, Que.

The Centre de recherche industrial du Quebec has an in-house R & D program investigating the fermentative production of biofungicides, biopesticides and polyols. Involved in fermentor and immobilized fermentor design and development. Additional on-site projects include the production of methane from animal wastes as well as anaerobic digestion systems and materials.

Connaught
Laboratories
Willowdale, Ont.

Involved in the production of vaccines for the domestic and export markets. Research work centres on the development of production systems for human insulin and carrier hapten vaccines. Have R & D fermentation facilities as well as production facilities.

Forintek Canada Corp.
Ottawa, Ont.

Research and development program centres on the conversion of ligno-cellulosic material into solvents and fuels such as butanol, butanediol, acetone and ethanol. Future plans include the possibility of complementing existing laboratory fermentation facilities with pilot scale equipment for economic and technical feasibility studies.

Institute Armand
Frappier
Montreal, Que.

The Institute Armand Frappier conduct research into the production of microbial enzyme complexes. They have a pilot scale facility to complement their R & D fermentation lab scale work. Currently involved in a wood to ethanol bioconversion project. Accept research contracts to conduct basic R & D projects or feasibility studies for external clients.

Iotech Corp.
Ottawa, Ont.

Conduct in-house R & D work on the conversion of lignocellulosic material to fermentable sugars, alcohol and other chemicals. Have pilot scale fermentation capabilities.

John Labatt Ltd.
London, Ont.

R & D work centres on genetic manipulation of brewing yeasts, to develop alcohol tolerance and temperature resistance characteristics. Yeasts with alternate substrate specificities and increased amylase levels are also investigated. Scale up of brewing processes possible in specialized in-house pilot facility.

Lallemand Inc.
Montreal, Que.

Conduct applied R & D program in-house aimed at the production and development of yeast strains for both domestic and foreign breweries, wineries, distilleries and bakeries. Investigate yeast resistance to freezing and tolerance to ethanol among other projects. Have pilot facility in which to study different fermentation control strategies before implementing these on production lines.

National Research
Council
Halifax, N.S.

The National Research Council is involved in R & D work centring on vomitoxin and its derivatives and the study of isocyanide metabolites in fungi. Pilot plant facilities complement the lab scale fermentation work.

- National Research Council
Ottawa, Ontario
- The National Research Council conducts work in various areas, including nitrogen fixation and anaerobic waste digestion. Current work centres on the conversion of low alcohol waste streams into higher value ester and aldehyde solvents, and the fermentation of high value biological compounds.
- National Research Council
Montreal, Que.
- The National Biotechnology Institute have formed a bioprocess engineering group, and will be equipping themselves with state of the art fermentation facilities.
- National Research Council
Saskatoon, Sask.
- The Plant Biotechnology Institute, has a diverse research program in several areas of herbarian studies. The Plant Product Technology group has three major interests, alkaloids from cell culture, crop quality improvement and enzyme technology such as yeast lytic enzymes, inulase, lactase and oxoprolinase. The genetics, physiology and fermentation of alkaloid containing plants such as Catarantus roseus (Periwinkle) have been investigated, as has enzyme production, by employing plant suspension tissue culture.
- Nova Husky Research Corp. Calgary, Alberta
- Involved in petroleum microbiology. Research interests include biodegradation, bacterial corrosion of metals and biological in situ agents for enhanced oil recovery. Plan to develop extensive fermentation program with methanol feedstocks.
- Ontario Research Foundation
Mississauga, Ont.
- The Ontario Research Foundation was set up to perform lab scale contract research work. Expertise lies in alternate fuels from biomass, the production of fermentable substrates from wastes by wet oxidation, the recovery of fermented products from fermentation broths and the microbial leaching of ores.

Pulp and Paper Research Institute of Canada Pointe Claire, Que.	The Pulp and Paper Research Institute of Canada has recently constructed an addition onto its existing facilities, specifically for the Biotechnology Group. In-house R & D concentrates on the enzymology of lignin degradation and enzymatic means to increase the strength of mechanical pulps. Some recombinant DNA work done in-house. Plans for a 250 L pilot fermentation facility are in progress.
Roselle Institute Montreal, Que.	The Roselle Institute under Rougier Inc. conduct in-house R & D on bacterial strain development. Recently involved in nitrogen fixing bacterial studies. Have pilot/production scale facilities for lab work scale up.
St. Lawrence Starch Co. Mississauga, Ont.	Conduct in-house research centred on the yeast digestion of starch and hemicellulose and the production of potable alcohol. Operate a versatile 250 L batch fermentor and pilot facility as integral part of this R & D commitment.
Wastewater Technology Centre Environment Canada Burlington, Ontario	Work centres on anaerobic digestion of high strength, high temperature industrial effluent. In-house evaluation of effluents performed before design of "in situ" treatment facilities.
Weston Research Centre Div. of George Weston (Diversified Research) Toronto, Ontario	Conduct biotechnological R & D program concentrating on food, pulp and paper and energy industry applications. Current work involves microbial exopolysaccharide and microbial lipid fermentation and the conversion of waste streams to higher value biological products. Formerly involved in the Bio-hol demonstration of fuel alcohol production from biomass residues. Full pilot plant facilities available.

Table C.2 Highlights of University Biotechnology R & D
Activities Which Involve Fermentation Engineering

McGill University
Montreal, Que.

A multidisciplinary biotechnology group has been set up within the University. The Department of Chemical Engineering (B. Volesky, R.J. Neufeld, D.G. Cooper, W.I. Patterson) are engaged in the development of the acetone butanol ethanol (ABE) fermentation, the production of microbial surfactants, the development of immobilized enzyme reactors and the development of biosorbents. Dr. T.M.S Chang of the Department of Artificial Cells and Organs is actively involved with enzyme immobilization systems, particularly encapsulation in artificial membranes. Dr. D.P Verma of the Department of Biology works on symbiotic nitrogen fixation and the molecular genetics of both the host plant and the bacterial component.

Queens University
Kingston, Ont.

The Department of Chemical Engineering, (A. Daugulis, D. Bone, M.F.A. Goosen, R.H. Clark) is involved in research work covering the following topics: design and scale up of immobilized whole cell reactors, enzyme and solvent production by multistage fermentation, extractive fermentation, fermentation of DNA recombinants, and the encapsulation of animal cells. Fermentation work is generally performed on a laboratory scale, but 70 L fermentation capability exists. The Department of Microbiology, (A.M.B. Kropinski) is involved in strain and fermentation medium development for the ABE (acetone, butanol, ethanol) fermentation.

- University of British Columbia
Vancouver, B.C.
- The University of British Columbia has significant involvement in biotechnological R & D work. The Department of Microbiology (D.Kilburn) does work in animal cell culture to produce interferon and lymphokines, and conducts genetic engineering on cellulolytic organisms. R. Branian of the Department of Chemical Engineering is involved with high temperature agricultural waste digestion and plant cell culture. The Department of Chemistry (J. Kutney) is involved in plant tissue culture for anti-cancer agents, fungal fermentation of pulp and paper wastes to produce oral contraceptive ingredients and research into biobasin development (environmental technology). A \$31 million complex including a pilot fermentation facility will be built on campus for medicinal bioproduct R & D.
- University of Calgary, Calgary, Alberta
- The Department of Biochemistry (M. Gaucher) and Chemical Engineering (L. Behie) conduct research into the production of monoclonal antibodies and the continuous production of penicillin as well as the computer control of these operations. They have also recently run immobilized cell systems in their pilot scale fermentation facility.
- University of Laval
Quebec, Que.
- Production of algae in photobioreactors and anaerobic digestion of algae to biomass are the R & D interests of A. Leduy. Work also centers on cellulase production.

- University of Toronto H.G. Lawford of the Biochemistry
Toronto, Ontario Department is involved in small scale
continuous culture research under
contract to the food industry. The
Plant Biotechnology Centre of the
Botany Department (N. Straus, F.
Dicosmo) are involved in small scale
plant tissue culture, extracting
secondary metabolites with medicinal
value. The Department of Chemical
Engineering (M. Wayman) is involved in
the fermentation of lignocellulosic
wastes to fuels.
- Universite de Quebec The Pulp and Paper Research Centre (M.
a Trois Riveres Lapointe) has long been involved with
Trois Riveres, biomass production from spent sulfite
Quebec liquor in their own 2200 L open stirred
tank reactor.
- University of The Institute for Biotechnological
Waterloo, Research (M. Moo-Young) conducts
Waterloo, Ontario research in fermentation and enzyme
technologies, with a pilot plant
support facility. Work is done to
develop new biological processes with
regard to waste management.
- University of The Department of Chemical and
Western Ontario Biochemical Engineering (A. Margaritis,
London, Ontario N. Kosaric) has research interests in
fuel ethanol, cyclosporin A and
hydrogen production. Other R & D
interests include immobilized cell
technology, bioreactor design,
thermostable cellulases and wastewater
treatment. Pilot plant facilities.

Section D: List of Organizations Contacted

ABI BIOTECHNOLOGY LTD.

Dr. A. Friesen
200-5 Donald Street
Winnipeg, Manitoba
R3L 2T4

(204) 477-6413

ADI LTD.

Mr. Bob Landine
P.O. Box 44
Fredrickton, N.B.
E3B 4Y2

(506) 452-9000

AGRICULTURE CANADA

Dr. Ian de la Roche
Ottawa Station/CBRL
Ottawa, Ontario
K1A 0C6

(613) 995-5222

ALBERTA ENVIRONMENTAL CENTRE

Mr. A. van Roodselaar
Bag 4000
Vegreville, Alberta
T0B 4L0

(403) 632-6761

ALBERTA RESEARCH COUNCIL

Dr. Duncan Currie
11315 87th Avenue
Edmonton, Alberta
T6G 2C2

(403) 439-5916

ALLELIX INC.

Dr. Derek Burke
6850 Goreway Drive
Mississauga, Ontario
L4V 1P1

(416) 677-0831

BC RESEARCH

Dr. Joe Mueller
3650 Wesbrook Mall
Vancouver, B.C.
V6S 2L2

(604) 224-4331

BIOLOGICALS LTD.

Dr. F. Asculai
20 Victoria Street #304
Toronto, Ontario
M5C 2N8

(416) 366-4863

BIOMEGA

Dr. David Marshall
2100 Cunard Street
Laval, Quebec
H7S 2G5

(514) 682-4640

BIOTECHNOLOGY RESEARCH INSTITUTE (Montreal)

Dr. Gerald Andere
National Research Council
Royal Victoria Hospital
Hersey Pavillion, 687 Pins. O.
Montreal, Quebec
H3A 1A1 (514) 283-3832

BOEHRINGER-INGLEHEIM LTD.

Mr. A. Schincariol
977 Century Drive
Burlington, Ontario
L7L 5J8 (416) 639-0333

BOEHRINGER-MANHEIM LTD.

Mr. George Frenette
11450 Cote de Liesse
Dorval, Quebec
H9P 1A7 (514) 636-6760

CAMPBELL SOUP CO. LTD.

Mr. Robert McGregor
60 Birmingham Street
Toronto, Ontario
M8V 2B8 (416) 251-1131

CANADA PACKERS INC.

Research Centre
Mr. Ross Donovan
2211 St. Clair Ave. West
Toronto, Ontario
M6N 1K4 (416) 761-4049

CANGENE CORP.

Mr. Robert Garvin
3403 American Drive
Mississauga, Ontario
L4V 1T4 (416) 673-0200

CANVIN PRODUCTS LIMITED

Mr. Fred Gundard
409 Evans Avenue
Toronto, Ontario
M8Z 1L1 (416) 251-2261

CENTRE QUEBECOIS POUR LA VALORISATION
DE LA BIOMASSE

M. Marcel Risi
Pavillion Paul Comptois
no. 1316 Cité Universitaire
Ste. Foy, Quebec
G1K 7P4 (418) 657-3853

CENTRE RECHERCHES INDUSTRIELLES DU QUEBEC

Dr. F. Dugal
333 Rue Franquet PO 9038
C.P. 9038
Ste. Foy, Quebec
G1V 4C7 (418) 659-1550

CHAMPLAIN INDUSTRIES LIMITED

Mr. G. Keller
176 rue Principal
Stanbridge Stn, Que.
JOJ 2J0 (514) 248-3376

CHEMBIOMED

Dr. Murry Ratcliffe
11145 87th Ave. 16th Floor
Edmonton, Alberta
T6G 0Y1 (403) 432-2053

CONNAUGHT LABORATORIES

Mr. Kim Phillips
1755 Steeles Avenue West
Willowdale, Ontario
M2R 3T4 (416) 667-2819

DEXTRAN PRODUCTS LIMITED

Mr. George Usher
421 Cormstock Avenue
Scarborough, Ontario
M1L 2H5 (416) 725-2231

ENVIROCON LIMITED

Mr. Robert McDonald
300-475 West Georgia Street
Vancouver, B.C.
V6B 4M9 (604) 687-7588

FERMTECH R & D INC.

Dr. H.G. Lawford
2383 Edenhurst Drive
Mississauga, Ontario
L5A 2L1 (416) 279-5337

FORINTEK CANADA CORP.

Dr. Ernest Yu
800 Montreal Road
Ottawa, Ontario
K1G 3Z5 (613) 744-0963

HEINZ COMPANY LIMITED

Mr. Murray Pennel
250 Bloor Street East
Toronto, Ontario
M4W 1G1 (416) 964-7057

HELIX BIOTECH LIMITED

Dr. Terry Owen
217-7080 River Road
Richmond, B.C.
V6X 1X5

(604) 270-7468

INSTITUTE ARMAND FRAPPIER

Dr. G. Vezina
531 Boulevard des Prairies CP 100
Laval des Rapides, Quebec
H7V 1B7

(514) 687-5010

IOTECH CORP.

Dr. Brian Foody
400 Hunt Club Road
Ottawa, Ontario
K1V 8S8

(613) 733-9830

JOHN LABATT LIMITED

Mr. D.W. Murray
P.O. 5870
London, Ontario
N6A 5L3

(519) 673-5059

JOHN LABATT LIMITED

Dr. G.G. Stewart
150 Simcoe Street P.O. 5050
London, Ontario
N6A 4N3

(519) 673-5326

LALLEMAND INC.

Mr. Richard Degree
1620 Prefontaine
Montreal, Quebec
H1W 2N8

(514) 522-2133

LANGFORD LABORATORIES

Dr. Charles Povey
131 Malcolm Road
Guelph, Ontario
N1H 6H8

(519) 823-5490

MANITOBA RESEARCH COUNCIL

Dr. Magdy Dawood
1329 Niakwa Road
Winnipeg, Manitoba
R2J 3P4

(204) 945-6162

MCGILL UNIVERSITY

Dr. R.J. Neufeld
Dept. Chem. Eng.
3480 University Street
Montreal, Quebec
H3A 2A7

(514) 392-5435

MOHAWK OIL CO.
Mr. Chris Smith
Box 335
Minnedosa, Man.
ROJ 1E0 (204) 867-2763

NABISCO BRANDS LTD
(Fleischmans)
Dr. G. Micklea
1 Dundas Street, West
Suite 2800
Toronto, Ontario
M5G 2A9 (416) 252-6131

NATIONAL RESEARCH COUNCIL
Biotechnology Research Inst.
Dr. Gerald Andere
Royal Victoria Hospital
Hersey Pavillion, 687 Pins. O.
Montreal, Quebec
H3A 1A1 (514) 283-3832

NATIONAL RESEARCH COUNCIL
Dr. D. Armstrong
100 Sussex Drive
Ottawa, Ontario
K1A 0R6 (613) 993-9101

NATIONAL RESEARCH COUNCIL
Plant Biotechnology Institute
Dr. Jan Grootwassink
110 Gymnasium Road
Saskatoon, Sask.
S7N 0W9 (306) 975-5285

NATIONAL RESEARCH COUNCIL
Plant Biotechnology Institute
Dr. Wolf Kurz
110 Gymnasium Road
Saskatoon, Sask.
S7N 0W9 (306) 975-5248

NATIONAL RESEARCH COUNCIL
Dr. Allan Taylor
1141 Oxford Street
Halifax, N.S.
B3H 3Z1 (902) 426-8332

NORTHWEST FOODS AND FUELS

Mr. John Henderson
Box 728
Kerrobert, Sask.
SOL 1R0

(306) 834-5433

NOVA HUSKY RES. CORP.

Dr. Tom Jack
1411 25th Avenue NE
Calgary, Alberta
T2E 7L6

(403) 291-4544

ONTARIO PAPER CO. LTD.

Dr. Tony Yau
80 King St., Box 3026
St. Catherines, Ont.
L2R 7G2

(416) 688-5030

ONTARIO RESEARCH FOUNDATION (ORF)

Dr. John Christom
Sheridon Park Research Comm.
Mississauga, Ontario
L5K 1B3

(416) 822-4111

PHILOM BIOS

Dr. John Cross
15 Innovation Blvd
Saskatoon, Sask.
S7N 2X8

(306) 665-6211

POS

Pilot Plant Corporation
Mr. Don Hrytzak, Dr. Paul Fedec
118 Veterinary Road
Saskatoon, Sask.
S7N 2R4

(306) 665-7791

PULP & PAPER RESEARCH
INSTITUTE OF CANADA

Mr. Michael de Roger
570 St. John's Blvd
Pointe Claire, Que.
H9R 3J9

(514) 630-4100

QUEENS UNIVERSITY

Dr. Andrew Daugulis
Dept. of Chem. Eng.
Kingston, Ontario

(613) 547-5520

REED LIMITED

Mr. J.V. Benko
Lignin Prod. Div.
P.O. Box 2025
Quebec, Quebec
GLK 7N1

(418) 647-4266

REINHART VINEGAR LTD.

Mr. Dennis Bell
214 King St. N., Box 30
Stayner, Ontario
LOM 1S0

(705) 428-2422

RESEARCH FOODS LIMITED

Mr. Sohil Mana
77 Champagne Drive
Downsview, Ontario
M3J 2C6

(416) 635-8434

RHIZOTECH LABORATORIES

M. Pierre Perinet
753 Commercial Street
St. Jean Crysostome, Quebec
G6Z 2L9

(418) 839-5931

ROSELL INSTITUTE

M. Edouard Brochu
8480 Boul St. Laurent
Montreal, Quebec
H2P 2M6

(514) 381-5631

SCHWARTZ INC.

P.O. Box 490
Halifax, N.S.
B3J 2R9

(902) 425-8282

SEAGRAM DISTILLERIES LTD.

Mr. Art Peterson
Lasalle Plant
1430 Peel Street
Montreal, Quebec
H3A 1S9

(514) 366-2410

ST. LAWRENCE STARCH COMPANY

Dr. P. Assarsson
1141 Lakeshore E. P.O. 1050
P.O. 1050
Port Credit Postal Stn.
Mississauga, Ontario
L5G 1E8

(416) 274-3671

TECHNICAL UNIV. OF NOVA SCOTIA
Dr. David Mackay
Center for Energy Studies
Halifax, N.S.
B3J 2X4

(902) 429-8300

UNIVERSITY OF ALBERTA
Dr. R. Iwonika
Dept. of Biochemistry
Edmonton, Alberta
T6G 2J9

(403) 432-2411

UNIVERSITY OF BRITISH COLUMBIA
Dr. R. Barnion
Dept. of Chemical Engineering
Vancouver, B.C.
V6T 1W5

(604) 228-3217

UNIVERSITY OF BRITISH COLUMBIA
Dr. Doug Kilburn
Dept. of Microbiology
Vancouver, B.C.
V6T 1W5

(604) 228-4182

UNIVERSITY OF BRITISH COLUMBIA
Dr. James Kutney
Dept. of Chemistry
Vancouver, B.C.
V6T 1W5

(604) 228-2710

UNIVERSITY OF CALGARY
Dr. Morris Gaucher
Biochemistry Division
Calgary, Alberta
T2N 1N4

(403) 220-6240

UNIVERSITE LAVAL
Dr. A. LeDuy
Dept. de la genie chimique
Quebec, Quebec
GLK 7P4

(418) 656-2131

UNIVERSITY OF OTTAWA
Dr. J. Altosaar
Dept. of Biochemistry
Ottawa, Ontario
K1N 6N5

(613) 564-2953

UNIV. DU QUEBEC A TROIS RIVIERES

Dr. Marcel Lapointe
C.P. 500
Trois Rivières, Que.
G9A 5H7

(819) 376-5431

UNIVERSITY OF TORONTO

Dr. H.G. Lawford
Dept. of Biochemistry
Toronto, Ontario
M5S 1A8

(416) 978-7096

UNIVERSITY OF TORONTO

Dr. Michael Paull
Facility of Medicine
Toronto, Ontario
M5S 1A8

(416) 978-8912

UNIVERSITY OF TORONTO

Dr. Neil Strauss
Dept. of Botany
Toronto, Ontario
M5S 1A1

(416) 978-2086

UNIVERSITY OF TORONTO

Dr. Morris Wayman
Dept. of Chemical Eng.
Toronto, Ontario
M5S 1A4

(416) 978-4905

UNIVERSITY OF WATERLOO

Dr. Murry Moo Young
Dept. of Chemical Eng.
Waterloo, Ontario
N2L 3G1

(519) 885-1211

UNIVERSITY OF WESTERN ONTARIO

Dr. A. Margaritis
Dept. of Chem & Biochem Eng
London, Ontario
N6A 5B9

(519) 679-2111

VETRAPHARM INC.

Mr. Rick Colbert
69 Besemer Road, Unit 27
London, Ontario
N6E 2V6

(519) 685-5800

WASTEWATER TECHNOLOGY CENTRE
Environment Canada - CCIW
Dr. Bruce Jank
P.O. Box 5050
Burlington, Ontario
L7R 4A6

(416) 637-4374

WESTON RESEARCH CENTRE
Dr. R. Lawford
1047 Yonge Street
Toronto, Ontario
M4W 2L2

(416) 922-5100

