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Modern Biotechnology in New Zealand: Further Analysis of Data from the Biotechnology Survey 1998/99

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Abstract

The New Zealand Government has indicated a strong interest in fostering innovation and aims to concentrate on selected areas where New Zealand may be able to develop a new comparative advantage. One such area is biotechnology, which would build on New Zealand's existing comparative advantage in the primary sector (dairy, forestry, meat, wool and horticulture). This paper aims to fill some of the gaps in our knowledge of biotechnology and innovation processes in New Zealand. It is based on the 1998/99 survey of modern biotechnology activity in New Zealand conducted by Statistics New Zealand in 2000. The survey was commissioned by the Ministry of Research, Science and Technology (MORST) mainly in order to produce statistics on the present position of the industry for planning purposes. The findings reported in this paper are based on further analysis of the survey data conducted by the author on behalf of MORST. Data are presented on the number, type and characteristics of enterprises involved in biotechnology in New Zealand. The paper presents data on enterprises that conduct R&D into modern biotech processes and includes analysis of the rate of innovation by biotech respondents compared to OECD estimates. Comparisons are also made between data from the New Zealand and Canadian biotech surveys.

Keywords

biotechnology; innovation, New Zealand; patents; intellectual property

JEL Classification

L65, L66, O31, O32, O38

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Access to the data used in this study was provided by Statistics New Zealand under conditions designed to give effect to the security and confidentiality provisions of the Statistics Act 1975. Standard Statistics' random rounding to base three has been applied to all output.

Disclaimer

The results presented in this study are the work of the author not Statistics New Zealand.

Contents

Key Indicators of Biotech Activity in New Zealand ii

Executive Summary iii

1. Introduction 1

1.1 Background 1

1.2 What is Biotechnology? 2

1.3 Meaning of Biotech Terms Used in this Report 4

2. Modern Biotech R&D and Use in New Zealand 7

2.1 Enterprises Involved 7

2.2 Biotech Processes 10

2.3 Product and Process Development 14

3. Characteristics of the Biotechnology 'Industry' 17

3.1 Industry Sectors 17

3.2 Strategic Alliances 18

3.3 Intellectual Property Rights 21

3.4 Income, Expenditure and Exports 23

3.5 Human Resources 25

3.6 Problems Affecting Biotech R&D 26

4. International Comparisons 27

5. Modern Biotech Enterprises in New Zealand 29

5.1 Introduction 29

5.2 Enterprises Involved 29

5.3 Biotech Processes 29

5.4 Product and Process Development 29

5.5 Industry Sectors 30

5.6 Strategic Alliances 30

5.7 Intellectual Property Rights 30

5.8 Income, Expenditure and Exports 30

5.9 Human Resources 31

5.10 Problems Affecting Biotech R&D 31

Appendix Tables 32

References 42

Key Indicators of Biotech Activity in New Zealand

	Modern Biotech Enterprises	Traditional Biotech Enterprises	Modern Biotech Users	Traditional Biotech Users	All Biotech Respondents
No. of Respondents and Processes					
No. of Respondents	57	24	36	63	**180**
No. in Private Sector	30	21	21	30	**102**
Biotech Processes per enterprise	19	3	8	4	**9**
No. Involved in DNA Based Processes	42	0	9	0	**51**
Innovation Indicators					
No. New Products last 3 yrs	114	18	27	18	**180**
No. New Processes last 3 yrs	105	21	45	9	**177**
% Introducing New Product or Process	68%	50%	42%	24%	**45%**
New Products & Processes per Enterprise	3.8	1.8	2.0	0.4	**2.0**
No. Processes New to the World last 3 yrs	30	6	3	0	**39**
No. New Products Planned Next 3 years	207	24	42	21	**298**
No. New Processes Planned Next 3 years	219	12	24	30	**288**
New Products & Processes per Enterprise	7.5	1.5	1.8	0.8	**3.3**
No. of Patents Applications Last 5 Yrs	147	6	3	0	**156**
Patents Applications per Enterprise	2.6	0.3	0.1	0	**0.9**
Biotech Income and Exports					
Total Income ($ million)	2,124	1,008	1,647	2,475	**7,254**
Biotech Income ($ million)	236	68	112	59	**475**
Biotech as % of Total Income	11%	7%	7%	2%	**7%**
Biotech Income per Enterprise ($ million)	4.1	2.8	3.1	0.9	**2.6**
Biotech Exports	60	*c*[1]	40	*c*	**170**
Biotech Employment					
Full-time Equivalents (yr to 30 June '99)	1,667	*c*	*c*	155	**2,984**
PhDs	667	*c*	*c*	*c*	**703**
Graduates	1,512	*c*	*c*	*c*	**1,824**
Graduates per Enterprise	27	*c*	*c*	*c*	**10**
Biotech Alliances					
% Reporting Biotech Alliances	90%	50%	42%	24%	**53%**
% Reporting Alliance with CRI	68%	25%	17%	14%	**32%**
% Reporting Alliance with Business	47%	13%	17%	10%	**22%**

[1] *c* indicates cell 'confidentialised' to give effect to the confidentiality provisions of the Statistics Act 1975

Executive Summary

Background

Over the last few years there has been an explosion of interest in Biotechnology in New Zealand. Politicians and policy makers have become increasingly interested in the role that biotech might play in the 'new economy'; and aware of the policy initiatives in support of biotech which have been implemented by many of our competitors. In 1999 the Ministry of Research Science and Technology (MORST) commissioned Statistics New Zealand to undertake a survey to investigate the use of biotechnology in New Zealand. The survey was intended to focus on modern biotechnology because of its perceived importance for New Zealand's future economic development. The 1998/99 survey of modern biotechnology activity in New Zealand was conducted by Statistics New Zealand in 2000 with the results being published in April 2001. The findings reported in this document are based on further analysis of the survey data conducted by the author on behalf of the Ministry of Research, Science and Technology.

This report adopts a rule based definition modern biotechnology as: (1) recombinant DNA technology, (2) use of antibodies (3) protein engineering (4) novel bioprocessing techniques (Eliasson & Eliasson, 1997, p. 145; U.S. Congress, 1991, p. 5). The term "modern" is used to distinguish processes that have been developed in the last 30 years or so, from traditional biotech areas such as fermentation and extraction.

A further distinction has been drawn based on whether respondents used modern or traditional processes and whether they conducted R&D (creators) or were simply *users* of biotechnology processes. These characteristics have been used to define four categories of biotech respondents; those engaged in R&D (or not) and those using modern vs. traditional biotech processes. The term Modern Biotech Enterprise (MBE) is used to describe respondents that are engaged in R&D into at least one modern biotech process. Academics and policy makers have a particular interest in this group, since their innovative performance will be crucial in determining New Zealand's overall performance in the biotech area.

Enterprises Involved

Questionnaires were sent to 426 enterprises that had been identified as possible users of modern biotechnology processes. The survey achieved a 98% response rate with 180 enterprises being identified as users of at least one biotechnology process. The high response rate and wide ranging processes used to identify possible users of modern biotechnology suggest that the survey is likely to have captured almost all significant users of *modern* biotech in New Zealand over the survey period (1998/99).

93 enterprises used modern biotechnology; 57 of these were also engaged in R&D and so were defined as Modern Biotechnology Enterprises.

The survey also included enterprises that use *traditional* biotech processes. 87 survey respondents used traditional biotech processes; 24 of these were also engaged in R&D and so were defined as Traditional Biotech Enterprises.

Estimates on the size of the traditional biotech 'sector' cannot be regarded as being complete since a significant numbers of other users of such processes were not included in the survey, or reported that they did not use modern biotech and so did not fill in the questionnaire.

- 57 Modern Biotech Enterprises (MBEs) were spread across various industrial groups particularly scientific research organisations (24) primary product and manufacturing enterprises (15) and Universities (6). They included 42 enterprises which develop and use DNA based processes and 24 which develop and use genetic engineering.
- 36 Modern Biotech Users (MBU) were spread across most industrial groups with the largest number being hospitals and health providers, around three members of this group also research traditional biotech processes;
- 24 Traditional Biotech Enterprises (TBEs) were concentrated in the food and non-food manufacturing groups;
- 63 Traditional Biotech Users (TBU) include local authorities that use biotech for sewage treatment and food and non-food manufacturers including brewers of wine and beer, bakers etc.

Biotech Processes

Biotech respondents reported use of 1647 processes; universities had by far the most diverse involvement reporting an average of 33 different biotech processes per institution. They were followed by research organisations (including CRIs) with an average of 14 processes per organisation. Modern Biotech Enterprises reported use of 1060 processes – an average of 19 processes per enterprise – compared to 5 per enterprise for biotech users. The survey included 246 respondents that did not use a biotech process in 1998/99; none of these said that they planned to start using specific processes within three years, although three indicated possible use at some stage.

Use of modern biotech in New Zealand is at an early stage of development with many enterprises being involved primarily in R&D. Overall slightly over half (53%) of biotech respondents reported use of at least one biotech process for R&D or process development. 85% reported use of biotech processes as 'part of the production process', while 45% used at least one process 'as part of product sold'.

51 different enterprises were involved in DNA based processes, 81 in environmental processes and 132 and 156 in biochemical and bioprocessing based processes respectively.

24 enterprises reported use of genetic engineering (GE) or recombinant DNA, most of these being research institutions and universities. 21 used GE for R&D, 6 used it as part of the 'production process' while 3 used it in 'production sold'.

Product and Process Development

33% of respondents reported implementation of a new biotech *product* over the last three years, with the innovation rate being lowest for local government (9%) and food manufacturers (27%), around 50% for four other industrial groups and 33% for tertiary organisations. *Process* innovation rates were fairly similar.

42% of enterprises indicated that they were planning to implement a total of 298 new products in the next 3 years, this compares with 180 in the last 3 years. Similarly 40% of enterprises reported plans to implement a total of 288 new processes (compared to 177 in the last 3 years). This suggests a significant increase in the rate of new product and process development.

Modern biotechnology enterprises (MBEs) were far more active than other groups in new product and process development. MBEs introduced a total of 219 new products and processes over the last 3 years (an average of 3.8 per enterprise).

Further work is required before definite conclusions can be reached on the relative innovative output of New Zealand biotech firms relative to similar firms in other countries. The evidence reviewed in this report does not support the idea that New Zealand biotech firms have a particularly high rate of new product or process development.

Industry Sector

Modern Biotech Enterprises were most involved in the ag-bio and human health sectors, followed by food processing, genomics/molecular modelling, aquaculture and the environment. The environment industry sector was reported most frequently by Traditional Biotech Users – reflecting the waste treatment activities of local authorities. Modern Biotech Users most reported sector was human health – reflecting the activities of health services respondents.

Strategic Alliances

52% of biotech respondents reported a partnership/alliance with a total of 303 different organisation types; this suggests that the 93 respondents that had alliances had an average of at least three partners each. 90% of MBEs reported alliances.

The proportion of respondents reporting an alliance varied markedly between industry groups from 100% in tertiary education to a low of 18% for local government. Overall 47% reported at least one New Zealand alliance while 31% reported an overseas alliance. Overseas alliances were most common in the tertiary education, non-food manufacturing and scientific research groups.

- The most commonly reported alliance purposes were product/process development – reported by 81% of respondents who had an alliance and clinical/field trials (48%).
- 32% of respondents reported alliances with CRIs, followed by universities (27%) and other businesses (22%).
- 68% of MBEs reported alliances with CRI's and 47% reported biotech alliances with other businesses.

Intellectual Property Rights

25% of respondents reported at least one IP related problem. Positive responses were concentrated in the MBE category where 47% reported at least one problem - IP rights were clearly a significant problem for this group.

Only a small proportion of biotech respondents had made any patent applications. In the previous five years, 33 enterprises (18% of respondents) had made a total of 156

successful biotech patent applications (147 by MBEs). Nine respondents were responsible for 70% of all biotech patent applications.

Conference and Publishing Activity
At least one member of staff from 70% of respondents had attended a national or international conference 'on a biotechnology subject'. Staff from 22% of respondents had published an article on biotechnology in a refereed journal.

MBEs had a markedly higher rate of conference and publishing activity: 95% of respondents had been involved in a biotech conference and staff from 58% had published a refereed journal article.

Income, Expenditure and Exports
Survey respondents estimated that income of $475 million was attributable to modern biotechnology, in the year ended June 1999 - $326 million from private sector respondents, $149 million from the public sector. This compares to respondents income from all sources of $7.25 billion i.e overall biotech provided around 7% of income for the 180 biotech using enterprises.

Biotech respondents reported total exports of $1.75 billion and biotech exports of the order of $170 million. 42% of biotech respondents reported exports, while biotech exports were reported by 23%.

MBEs estimated that income of $236 million was attributable to modern biotechnology, in the year ended June 1999 - $122 million from private sector respondents, $115 million from the public sector. MBEs reported total exports of $300 million and biotech exports of the order of $60 million.

Human Resources
Survey respondents reported that a total of 3057 (or 2984 full time equivalent) staff supported biotech activity. Around 67% were graduates and 26% had PhD's.

MBEs employed 1667 biotech staff (FTE) – 56% of the total for all respondents. Employment of qualified staff was heavily concentrated in MBEs; they employed 83% of biotech graduates and 95% of PhDs.

Problems Affecting Biotech R&D
Around 59% of respondents reported at least one problem affecting biotech R&D (most of the remainder did not report any R&D activity); 89% of MBEs reported at least one problem. The problems reported most frequently by all respondents were access to capital and regulations.

International Comparisons
The Statistics New Zealand biotech survey was closely modelled on work carried out by Statistics Canada thus enabling some comparisons to be made. New Zealand's biotech revenue per million population (NZ$54 million) is rather lower than Canada's (NZ$94 million). New Zealand has a rather lower mean revenue per biotech firm ($5.3m vs $8.0m); consistent with the predominance of SMEs in the New Zealand economy. New Zealand appears to have a significantly higher rate of biotech employment.

1. Introduction

1.1 Background

Over the last few years there has been an explosion of interest in Biotechnology in New Zealand. Politicians and policy makers have become increasingly interested in the role that biotech might play in the 'new economy'; and aware of the policy initiatives in support of biotech which have been implemented by many of our competitors. The biotech industry has begun to achieve critical mass and has been increasingly effective in lobbying for policy changes that would make the New Zealand environment more supportive of biotech R&D and innovation. At the same time, increasing levels of popular concern over the safety of some modern biotechnologies culminated in the setting up of the Royal Commission on Genetic Modification that spent over $6 million and 14 months listening to all sides of the debate. In October 2001 the government announced its response to the Royal Commission report, including permission for field trials to restart and a two-year ban on commercial release of genetically modified products. These factors have combined to ensure that there is a high level of interest in data and analysis on development and use of modern biotechnologies in New Zealand.

In 1999 the Ministry of Research Science and Technology (MORST) commissioned Statistics New Zealand to investigate the use of biotechnology in New Zealand. The main purpose was to "produce statistics concerning the present position of this industry in New Zealand" in order to "take stock of the current situation for planning purposes"(Statistics New Zealand, 2000b, p. 1). The survey was intended to focus only on modern biotechnology since it was thought that "the contribution to future economic development resulting from modern biotechnology is likely to be much greater than the potential contribution by its traditional counterpart". The objectives[2] of the survey were:

- To understand the present status, the structure and the future progression of the biotechnology industry in New Zealand.
- To assess the present status of strategic alliances, the links with the public / private research system and the potential for cluster development for the biotechnology industry.
- To provide a baseline on the utilisation of resources including the knowledge in the biotechnology industry against which progress could be compared at a future date.
- To identify the enabling factors and constraints facing the biotechnology industry in New Zealand.

The 1998/99 survey of modern biotechnology activity in New Zealand was conducted by Statistics New Zealand in 2000 with the results being published in April 2001[3].

[2] Source: Ministry of Research, Science and Technology (2000) *Draft Objectives for the Biotechnology Survey*.
[3] Statistics New Zealand. (2001). *Modern Biotechnology Activity in New Zealand*. Wellington.
[4] Marsh, D. (2001) *Modern Biotechnology in New Zealand: Methodological Issues and Analysis of Free Text Responses from the Biotechnology Survey 1998/99.*

Relationship of this Report to 'Modern Biotechnology Activity in New Zealand' (Statistics New Zealand, 2001)

This report is based on further analysis of the survey data conducted by the author on behalf of the Ministry of Research, Science and Technology. This included preparation of additional tables and cross tabulations; presentation and analysis of the data in alternative formats; and breakdowns based on four new respondent categories (see Figure 1). Some of the results presented here may appear to conflict with those published by Statistics New Zealand. This is mainly explained by different treatment of multiple responses from single enterprises[5].

1.2 What is Biotechnology?

The term biotechnology was coined in 1919 by Karl Ereky, a Hungarian engineer to refer to "all the lines of work by which products are produced from raw materials with the aid of living organisms"(Bud, 1989, p. 10). Since then "the word biotechnology has been re-developed at least four times and its definition changed on each occasion" (Kennedy, 1991, p. 218). For much of the twentieth century it has been a broad term applied to technologies ranging from the fermentation of products such as wine and beer through extraction and sewage treatment to the selective breeding of plants. However in recent years the term has become increasingly synonymous with genetic modification so for example, the recent Pew report on agricultural biotechnology states:

> For the purposes of this report … the term "biotechnology" refers to the use of recombinant DNA technology to take genes from one organism and insert them into the DNA of another plant or animal. (Pew Initiative on Food and Biotechnology, 2001, p.4)

Modern biotechnology is usually traced back to the development of the recombinant DNA technique in 1973 and hybridoma technology in 1975 (Orsenigo, 1989, p. 37). Government, business, academic and media interest has tended to focus on modern biotechnology because it has the potential to transform large parts of the global economy and to have a major impact on the way we live. Indeed the rapid pace and widespread impact of developments in biotechnology since the 1970s has often been referred to as the biotechnology revolution.

In New Zealand there has been strong resistance to redefinition of biotechnology to mean genetic modification. For example, Biotenz (2001, p. 9) suggests that this "will seriously undermine the ability of the New Zealand economy and New Zealanders to benefit from new knowledge and new technologies in traditional industries". Similarly, the New Zealand Biotechnology Association (NZBA) "represents the interests of people with an interest in biotechnology, and the biotechnology industry

[5] A number of universities and hospitals returned multiple questionnaires each referring to the activities of a different part of the organisation. In many of the report tables Statistics New Zealand treated these organisation subunits as equivalent to a separate response from an individual survey respondent. This had the effect of increasing the number of responses from 'biotech using enterprises' from 180 to 218. In the current analysis multiple responses from single organisations have been aggregated in order to create the single responses that would have been sent in had such organisations submitted only one questionnaire. See also Marsh, D. (2001) *Modern Biotechnology in New Zealand: Methodological Issues and Analysis of Free Text Responses from the Biotechnology Survey 1998/99.*

in its broadest sense" and defines biotechnology as "the application of scientific and engineering principles to the processing of material by biological agents and the processing of biological materials to improve the quality of life[6]". NZBA membership includes a spectrum of organisations engaged in activities ranging from traditional biotechnology through to genetic modification.

The 1998/99 Statistics New Zealand survey adopted a dual approach to the definition of biotechnology. The stated purpose was to collect statistics on *modern* biotechnology and the second page of the questionnaire started with the New Zealand Biotechnology Association definition[7] of modern biotechnology:

> the application of scientific and engineering principles to the processing of material by biological agents and the processing of biological materials to improve the quality of life by isolating, modifying and synthesising the genetic instructions responsible for actual biological processes (Statistics New Zealand, 2000a, p. 2)

Respondents were then asked to review a list of biotechnology processes (see Table 1) and indicate which if any were used by their business. This was based on a list of technologies developed by Statistics Canada. An expert panel also added several processes in order to develop a definition appropriate to New Zealand.

While the stated intention of the survey was to focus on modern biotechnology it included a fairly wide list of processes, many of which have been around for quite some time. As a result many of the enterprises that reported use of biotech processes were involved in traditional rather than modern biotechnology.

Table 1: Statistics New Zealand's List Based Definition of Biotechnology

Main Category	**Sub Categories**
DNA Based Technology	*Genetic engineering, Gene Probes, Bio-informatics, Genomics, Pharmacogenetics, Gene Therapy, Rational Drug Design, DNA Sequencing, Synthesis, Amplification*
Biochemistry or Immunochemistry based	*Vaccines, Immune Stimulants, Drug Design and Delivery, Combinatorial Chemistry,* Diagnostic Tests, *Peptide/Protein Synthesis and Sequencing, Cell Receptors and Cell Signalling,* Bio-Sensing, Pheromones, *Molecular Modelling, Structural Biology, Antigens, Antibodies,* Microbiology, Biomaterials
Bio Processing	Cell, *Tissue and Embryo Culture, Cell, Tissue and Embryo Manipulation, Somatic Embryo genesis,* Fermentation, Bio processing, Bio transformation, Bio leaching, Bio pulping, Bio bleaching, Bio desulphurisation, Bio pesticide Manufacturing, Extraction, concentration, purification, separation, Natural Products Chemistry, Bio filtration, Bio indicators, *Micro-selected Breeding of Plants and Animals,* Microbio inoculants, Bio Sensing
Environmental Biotechnology	Bio augmentation, Bio reactors, Biological Gas Cleaning, Bio remediation, Phyto remediation

Source: Statistics New Zealand (2000a, p. 39) and author's calculations
For the purposes of this report, processes in italics are 'modern', other processes are 'traditional'
See Table A13 for a more detailed breakdown.

In an attempt to extract more meaning from the survey data, this report adopts specific rule based definitions of traditional and modern biotechnology (see below). Our

[6] http://www.biotech.org.nz/objectives.htm
[7] This definition appears to be open to alternative interpretations depending on whether the reader considers that the specifications before and after the 'and' must both be fulfilled.

definition of modern biotechnology follows authors such as Eliasson and Eliasson (1997, p. 145) who state that: "the biotech field is thought of as consisting of three or four sub-areas: (1) recombinant DNA technology, (2) use of antibodies including phage display, and (3) protein engineering…" and the U.S. Congress, Office of Technology Assessment (1991, p. 5) which defined 'new' biotechnology as: "the industrial use of rDNA, cell fusion and novel bioprocessing techniques". It should be recognised that any definition of modern biotech will be somewhat arbitrary since there is a continuum from the most traditional biotechnologies e.g. fermentation through to the most modern e.g. proteomics (see Figure 1).

The list of processes in Table 1 has been divided into 'modern' (processes in italics) and 'traditional' processes with the aim of separating enterprises involved in processes that have been developed in the last 30 years or so, from those involved in traditional areas e.g. fermentation, extraction etc (see Appendix Table A13 for further details).

A further distinction has been drawn between *users* of biotechnology processes and *creators* who conduct R&D and are active in developing new processes and products[8]. These characteristics have been used to define four categories of biotech respondents; modern and traditional biotech enterprises and modern and traditional biotech users (defined below). Academics and policy makers have a particular interest in modern biotech enterprises (MBEs), since their innovative performance will be crucial in determining New Zealand's overall performance in the biotech area.

1.3 Meaning of Biotech Terms Used in this Report

Biotechnology
"the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services" (Bull, Holt, & Lilly, 1982)
This is the definition used by the OECD.

Modern Biotechnology
For the purposes of this report, *modern* biotechnology is defined as: (1) recombinant DNA technology, (2) use of antibodies (3) protein engineering (4) novel bioprocessing techniques (Eliasson & Eliasson, 1997, p. 145; U.S. Congress, 1991, p. 5). The term "modern" is used to distinguish processes that have been developed in the last 30 years or so, from traditional biotech areas such as fermentation and extraction.

Biotech Respondent
- Any enterprise which uses at least one biotech process (as listed in Table 1)

Modern Biotech Enterprise (MBE)
- Uses at least one modern biotech process (see Table 1);
- Conducts R&D involving at least one modern biotech process;

[8] It may also be useful to think of a continuum in this area ranging from the most creative/innovative enterprises through to users that have no innovative or development input.

- At least one (FTE) graduate 'supports biotechnology activity'[9];
- May also be a TBE and/or MBU or TBU (see below).

Figure 1: Classification of Biotech Respondents

	Modern	**Traditional**
Creators ↓ ↓	Modern Biotech Enterprises (MBEs)	Traditional Biotech Enterprises (TBEs)
↓ ↓ **Users**	Modern Biotech Users (MBUs)	Traditional Biotech Users (TBUs)

Traditional Biotech Enterprise (TBE)

- Uses at least one traditional biotech process (but no modern processes);
- Conducts R&D involving at least one biotech process;
- At least one (FTE) graduate 'supports biotechnology activity'.
- May also be a TBU.

Modern Biotech User (MBU)

- Uses at least one modern biotech process;
- Does not conducts R&D into modern processes, or does not have at least one (FTE) graduate 'supporting biotechnology activity';
- May also be a TBE.

Traditional Biotech User (TBU)

- Uses at least one traditional biotech process;
- Does not conducts R&D, or does not have at least one (FTE) graduate 'supporting biotechnology activity'.

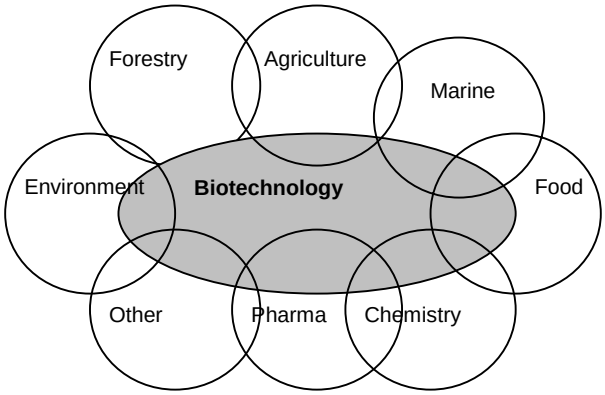
[9] A number of enterprises reported that they conducted R&D into modern biotech processes but had less than one FTE graduate working in the biotech area. It is assumed that such R&D must be very small scale so these enterprises are defined as biotech users.

[10] A number of enterprises reported that they conducted R&D into modern biotech processes but had less than one FTE graduate working in the biotech area. It is assumed that such R&D must be very small scale so these enterprises are defined as biotech users.

Biotech Industry/Sector

Modern biotechnology is used in a number of different economic sectors ranging from food and non-food manufacturing through various primary industries to health, diagnostic and environmental applications (see Figure 2). The terms 'biotech industry' and 'biotech sector', although not strictly 'correct' may be used to denote the group of industries and sectors that use biotechnologies.

Figure 2: Sectors Contributing to the Biotechnology 'Industry'



2. Modern Biotech R&D and Use in New Zealand

2.1 Enterprises Involved

Questionnaires were sent out to 426 enterprises that had been identified as possible users of modern biotechnology processes. The survey achieved a 98% response rate with 180 enterprises being identified as users of at least one biotechnology process. In the remainder of this paper these are referred to as 'biotech(nology) respondents', although it should be noted that this does not necessarily imply that biotechnology is their main activity. The high response rate and wide ranging processes used to identify possible users of modern biotechnology suggest that the survey is likely to have captured almost all significant users of *modern* biotech in New Zealand over the survey period (1998/99).

The survey also included enterprises that use *traditional* biotech processes (TBU). Estimates on the size of the traditional biotech 'sector' cannot be regarded as being complete since a significant numbers of other users of such processes were not included in the survey, or reported that they did not use modern biotech and so did not fill in the questionnaire. For example 33 'local authority' enterprises reported use of biotech processes – primarily for treatment of sewage and wastewater but around 20 reported no involvement.

Table 2: Number of Enterprises Involved in Biotechnology, by Industrial Grouping

Industrial Group	No. Enterprises Involved in Biotech Activity	Total No. Enterprises in each Industrial Group	No. of Biotech Processes Used	No. Processes per Enterprise
Primary Products	6	8,122	33	6
Food Manufacturing	33	1,268	207	6
Non-Food Manufacturing	24	591	153	6
Scientific Research	36	5,404	513	14
Local Government Administration	33	201	150	5
Tertiary Education	9	76	297	33
Health Services	24	3,536	237	10
Other	12	25,036	57	5
Total	**180**	**44,234**	**1,647**	**9**

Note: Other includes water supply, sewerage and drainage services, veterinary services, parks and gardens.

The 180 biotechnology respondents were spread fairly evenly over five main industrial groups: food and non-food manufacturers, scientific research, and local

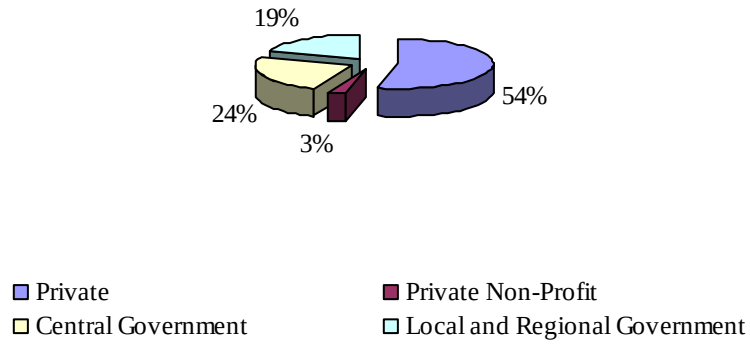
government and health services. Overall, fewer than half of one per cent of enterprises in the above industrial groupings made any use of biotech. See Table 2[11]

Biotech respondents were concentrated in a small number of industrial groups; 120 of the 180 respondents falling under 8 ANZSIC categories (at the 5 digit level), see Table 3. A more detailed breakdown by ANZSIC category is included in the Appendix as Table A1.

Table 3: Number of Biotech Enterprises in Selected ANZSIC Categories

Dairy Product Manufacturing	6
Wine Manufacturing	9
Medicinal and Pharmaceutical Product Manufacturing	15
Scientific Research	24
Technical Services nec	6
Local Government Administration	33
Higher Education	12
Hospitals (except psychiatric)	15
Total No of Respondent in above categories	*120*
Other ANZSIC Categories	*60*

Figure 3: Institutional Breakdown of Biotech Respondents



Around 60% of biotech respondents were from the private sector (including manufacturers, research enterprises and laboratories), the remainder being mainly comprised of local and regional authorities, universities, crown research insititutes and health providers[12] (see Figure 3 and appendix Table A2 for more details). Modern biotech enterprises were split fairly evenly between the private sector (30) and the public sector (27).

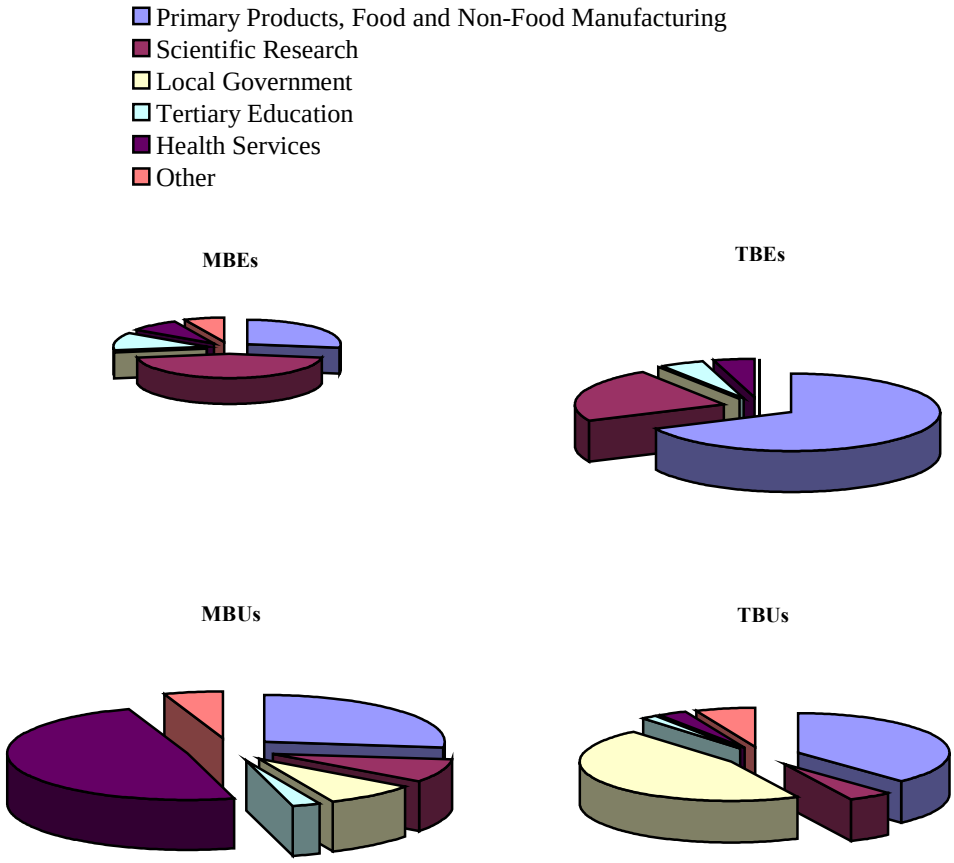
It is also useful to distinguish between enterprises engaged in modern biotech (i.e. processes developed in the last 30 years) rather than traditional biotech and between *users* of biotech processes and those which conduct R&D and are active in the development of new processes and products (see section 1.3). Around 80 biotech

[11] All tables are based on analysis of data from the Biotechnology Survey 1998/99 unless otherwise stated.
[12] Formerly known as Crown Health Enterprises

respondents conducted R&D; 57 of these conducted R&D into modern processes; these are classified as Modern Biotech Enterprises (MBEs). A further 36 respondents *used* modern biotech processes but were not engaged in a significant level of R&D, while 63 respondents used traditional processes e.g. fermentation, extraction, diagnostic tests etc. and were not engaged in R&D.

- 57 MBEs were spread across various industrial groups particularly scientific research organisations (24) primary product and manufacturing enterprises (15) and Universities (6). They include 42 enterprises which develop and use DNA based processes and 24 which develop and use genetic engineering.
- 24 Traditional Biotech Enterprises (TBEs) were concentrated in the food and non-food manufacturing groups;
- 36 Modern Biotech Users (MBU) were spread across most industrial groups with the largest number being hospitals and health providers, around three members of this group also research traditional biotech processes;
- 63 Traditional Biotech Users (TBU) include local authorities that use biotech for sewage treatment and food and non-food manufacturers including brewers of wine and beer, bakers etc.

Figure 4: Respondent Category vs Industrial Group



Note: This figure is based on data in Table A3

2.2 Biotech Processes

Respondents were asked to review a list of 54 biotech processes and indicate whether "each process was used in operations by this business during the accounting year". They also had the option of recording any other biotech process not included in the questionnaire[13]. Respondents were then asked whether the process was used:

- in "research & product/process development";
- as "part of the production process"; or
- as "part of the product sold".

In the case of processes which were *not* used, respondents were asked:

- "does this business plan to use this process in the next three years?". If they had no plan to use they were asked whether this was because "it has no application to this business" or "it is not cost effective"14.

Number of Processes Used

Biotech respondents reported use of 1647 processes[15]; universities had by far the most diverse involvement reporting an average of 33 different biotech processes per institution. They were followed by research organisations (including CRIs) with an average of 14 processes per organisation. Local government and private sector organisations were involved in far fewer processes – an average of five or six per respondent.

87 respondents used 5 biotech processes or less; they tended to be food or non-food manufacturers (36) or local authorities (21); 70% of this group did not carry out biotech R&D.

57 Modern Biotech Enterprises reported use of 1060 processes – an average of 19 processes per enterprise – compared to 5 per enterprise for biotech users (see Table 4).

Table 4: Frequency Distribution for Number of Biotech Processes Used

	All Biotech Respondents	Modern Biotech Enterprises
1	18	
2	24	
3	18	6
4	15	
5	12	
6 to 10	48	12
More than 10	45	39

[13] A total of 15 'other' processes were recorded by respondents, many of these are not considered to be modern biotech, other responses will assist with improved process definitions in future surveys.

[14] Most respondents reported that processes that they did not use 'had no application to this business'. 8 processes were reported not cost effective by 9 respondents, 19 by 6 respondents, 23 by 3 respondents, 8 by 0 respondents (see Table A4). No clear pattern could be discerned as to which processes were reported to be not cost effective vs. not applicable.

[15] This is the sum of the number of processes used by each organisation. This number is different to that reported by SNZ for reasons discussed under methodology (in the supporting report).

Figure 5 and Table A4 record the number of respondents reporting use of each biotech process (broken down by stage of use). The most frequently used processes were microbiology[16] (105 respondents), cell culture (69), bioindicators (69) and diagnostic tests (66). Several of these processes were defined in fairly general terms, none are specific to *modern* biotechnology. Several processes were used by very small numbers of enterprises (less than 8), namely gene therapy, pharmacogenetics, biopulping, biobleaching, bioleaching and biodesulphurisation.

Stage of Use

Use of modern biotech in New Zealand is at an early stage of development with many enterprises being involved primarily in R&D. Overall slightly over half (53%) of biotech respondents used at least one biotech process for R&D or process development (Table 5). 85% reported use of biotech processes as 'part of the production process', while 45% used at least one process 'as part of product sold[17]'.

There is significant variation between the different biotech areas, for example:

- 76% of enterprises using DNA based processes conducted R&D in this area while only 24% used these processes as 'part of product sold'
- Results for enterprises using biochemistry and bioprocessing are fairly similar – around 55% conducted R&D in these areas, 68/77% used processes as part of the production process and around 40% used processes as 'part of the product sold.
- Enterprises using environmental biotech processes were least likely to conduct R&D in this area (37%) and most likely to use these processes as 'part of the production process' (particularly use of bio-reactors and bioaugmentation for sewage treatment).

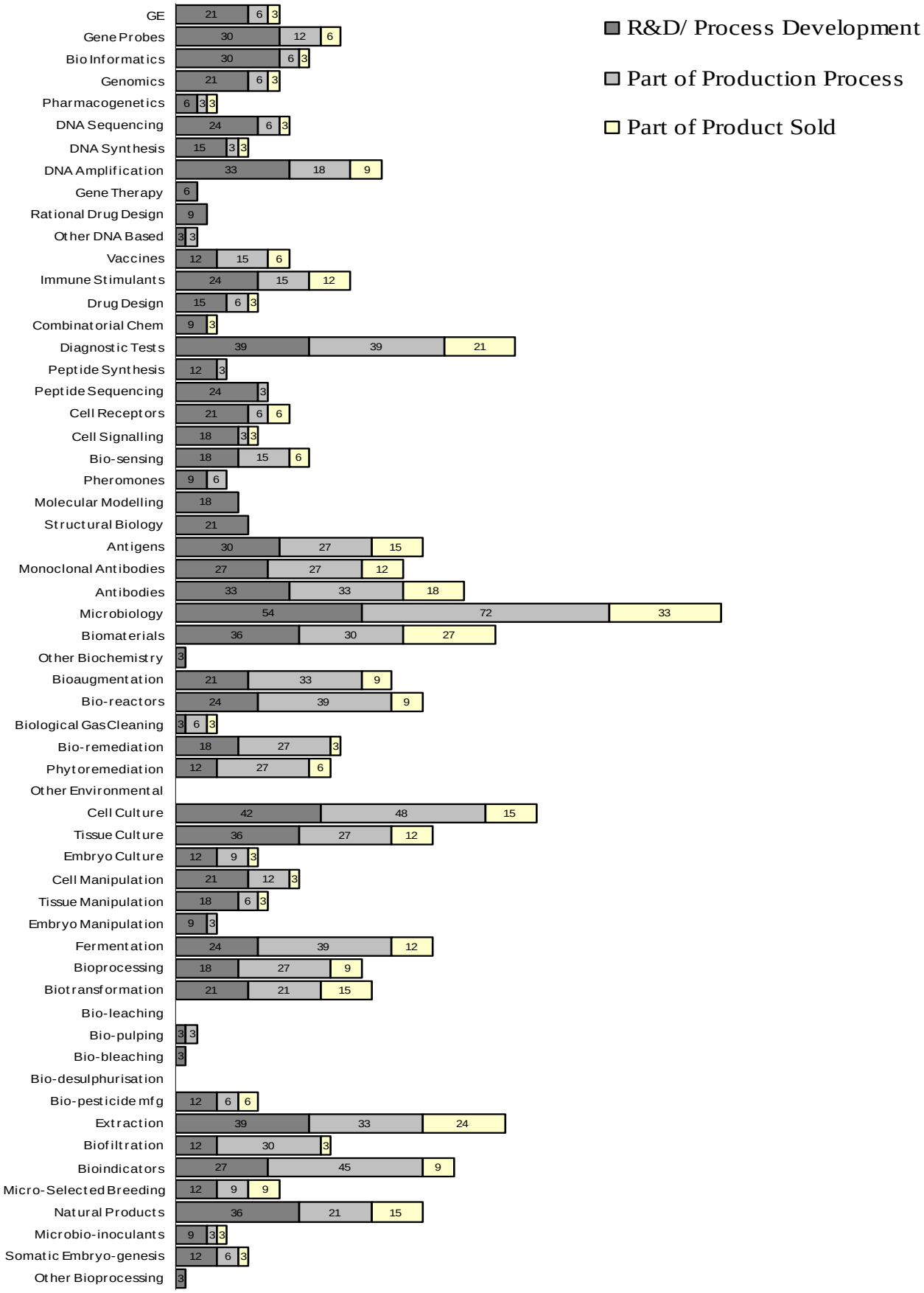
Table 5: Percentage of Enterprises Involved in Different Biotech Areas by Stage

Biotech Area	No. of Enterprises Involved at any stage	% Using Processes in R&D/ Process Development	% Using Processes as 'Part of the Production Process'	% Using Processes as 'Part of Product Sold	No. Planning to Use in next 3 years (not using now)
DNA Based Processes	51	76%	35%	24%	9
Biochemistry Based	132	57%	68%	43%	3
Environmental Biotech	81	37%	78%	19%	9
Bioprocessing Based	156	54%	77%	37%	3
Enterprises Involved in each Stage	**180**	**53%**	**85%**	**45%**	

Note: Percentages are expressed as a proportion of the number of enterprises involved in each area e.g. '76% of the 51 firms that used DNA based processes used DNA based processes for R&D'. Enterprises may use the same process in more than one stage.

[16] The definition of each of these terms is provided in the Statistics New Zealand (2000a) questionnaire.
[17] This apparently contradictory statement is derived directly from the questionnaire. It is used because an enterprise might report, for example, that genetic engineering is researched, is part of the production process or is part of the product sold e.g. the enterprise sells genetically engineered product.

Figure 5: No. of Respondents Using Biotech Processes in R&D, as Part of the Production Process and as Part of Product Sold



It is useful to distinguish the number of enterprises involved in different biotech areas. Around 51 different enterprises were involved in DNA based processes, 81 in environmental processes and 132 and 156 in biochemical and bioprocessing based processes respectively (see Table 5).

Given the current interest in genetic modification it is relevant to note that 24 enterprises reported use of genetic engineering (GE) or recombinant DNA- most of these being research institutions and universities. 21 used GE for R&D, 6 used it as part of the 'production process' while 3 used it in 'production sold'[18] (see Table A4).

Many organisations carry out biotech processes falling under more than one of the above categories e.g enterprises using DNA based processes may well also use biochemistry and bioprocessing. The converse is less likely to be true; there were a number of enterprises that use biochemistry and bioprocessing that were not involved in any DNA based processes.

Enterprises Involved in Different Biotech Areas

Estimation of the number of processes used per enterprise (Table 6) allows some conclusions to be drawn about which types of enterprise were involved in different biotech areas:

- The primary products, manufacturing and health services groups were mainly involved in biochemistry and bioprocessing based processes.
- Scientific research and tertiary education enterprises were involved in all areas
- Local government involvement was mainly confined to environmental and bioprocessing based biotech.

Table 6: Number of Processes per Enterprise, by Biotech Area and Industrial Grouping

Industrial Group	DNA Based	Bio-chemistry based	Environ-mental biotech	Bio-processing based	Main Bio-Industry Sector
Primary Products	1.0	1.5		2.5	Agricultural biotech, Bio-informatics, Forest Products, Mining/energy etc
Food Manufacturing	0.2	2.0	1.0	3.1	Food Processing
Non-Food Manufacturing	0.3	2.6	0.8	2.8	Agricultural biotech, Food processing, environment
Scientific Research	3.3	5.4	0.9	4.6	All Bio-Industry Sectors
Local Government Administration		0.5	2.1	2.0	Environment
Tertiary Education	7.0	12.0	2.3	11.7	All Bio-Industry Sectors
Health Services	1.3	6.3	0.1	2.4	Human health biotech
Other	0.5	1.5	1.0	2.0	Environment, agricultural biotech

[18] As noted on the title page; all numbers are subject to random rounding to base 3 - so 3 may mean 1, 2, 3, 4, or 5.

2.3 Product and Process Development

One indication of the rate of innovation by biotech respondents is provided by questions such as: "In the last 3 years, has this business implemented a new or significantly improved bio-industry sector product/service?"

Overall, 33% reported implementation of a new *product* with the innovation rate being lowest for local government (9%) and food manufacturers (27%) around 50% for four other industrial groups and 33% for tertiary organisations (see Table 7).

Process innovation rates were fairly similar except for local government and non-food manufacturers that implemented significantly more new process (rather than new products). 42% of enterprises indicated that they were planning to implement a total of 298 new products in the next 3 years, this compares with 180 in the last 3 years. Similarly 40% of enterprises reported plans to implement a total of 288 new processes (compared to 177 in the last 3 years). This suggests a significant increase in the rate of new product and process development.

Some respondents that were already using biotech processes planned to move into new areas or to implement additional processes:

- 9 enterprises that did not use any DNA based process indicated that they planned to use at least one of these processes in the future; similarly
- 9 enterprises that did not use any environmental process indicated that they planned to use at least one of these processes in the future (see last column Table 5).

The survey included 246 respondents that did not use a biotech process in 1998/99; none of these said that they planned to start using specific processes within three years, although 3 indicated possible use at some stage.

The frequency distribution for new products and processes is fairly skewed; for example 67% had not introduced any new products, 17% had introduced one, 15% had introduced two to five new products and 3% had introduced more than five (see Table 9.

Modern Biotechnology Enterprises

Modern biotechnology enterprises (MBEs) were far more active than other groups in new product and process development:

- 57 MBEs introduced a total of 219 new products and processes over the last 3 years (an average of 3.8 per enterprise); 61% of the total for all groups.
- 99 Biotech Users (MBU and TBU) introduced a total of 102 new products and processes (an average of 1 per enterprise).
- 68% of MBEs introduced a total of 117 new products and 105 new processes.

Table 7: Innovative Output of Biotech Respondents

Industrial Group	No. of Biotech Respondents	% Reporting Any R&D	% Implementing New Product Last 3 Yrs	% Implementing New Process Last 3 Yrs	% Planning to Implement New Product Next 3 yrs
Primary Products	6	50%	50%	50%	50%
Food Manufacturing	33	55%	27%	18%	36%
Non-Food Manufacturing	24	75%	50%	63%	63%
Scientific Research	36	92%	42%	50%	58%
Local Government Administration	33	18%	9%	18%	18%
Tertiary Education	9	100%	33%	33%	33%
Health Services	24	13%	50%	38%	50%
Other	12	50%	50%	25%	25%
Total	**180**	**55%**	**33%**	**33%**	**42%**

Note: these percentages should be interpreted with caution because of small cell numbers and random rounding.

Table 8: Number of New Products and Processes

Industrial Group	No. of New Products Last 3 Yrs	No. of New Products Planned in Next 3 Yrs	No. of New Processes Last 3 Yrs			
			New to the Business	New to New Zealand	New to the World	Total
Primary Products	4	6	6	6	2	11
Food Manufacturing	12	26	6	4	0	6
Non-Food Manufacturing	33	48	36	19	9	42
Scientific Research	44	84	30	17	15	36
Local Government Administration	4	9	6	1	0	6
Tertiary Education	24	66	21	14	13	27
Health Services	44	50	33	1	0	38
Other	15	9	12	2	0	11
Total	**180**	**298**	**144**	**64**	**39**	**177**

Source: (Statistics New Zealand, 2001)

Table 9: Frequency Distribution for Number of New Products and Processes

Number of Products/ Processes Planned	New Product Last 3 Yrs		Planning New Product Next 3 yrs		New Process Last 3 Yrs		New to Business	New to New Zealand	New to World
0	120	67%	105	58%	120	67%	129	147	156
1	30	17%	18	10%	30	17%	24	18	15
2-5	27	15%	48	27%	24	13%	18	12	9
More than 5	6	3%	9	5%	6	3%	9	0	0

Innovation rate data is included in OECD and EU innovation surveys but has not been systematically collected in New Zealand. An innovation survey commissioned by MORST in 1994 asked, "how many completely new product lines have you introduced in the last 5 years?" It was found that the average company had introduced 16 completely new products over that period (Frater, Stuart, Rose, & Andrews, 1995, p. 74). This is a significantly higher level than reported by biotech respondents, (averaging one new product per enterprise over the last three years) although this may be partly attributable to differences in the survey populations, question formats and timeframe.

The OECD has used 'the share of firms introducing at least one new or improved product or process onto the market over a given period' to compare the innovative output of firms in different member countries. The OECD average proportion of manufacturing firms that introduced a new product or process in 1994-96 was 56% (data from 21 OECD members). For firms with 20-49 employees the share was significantly lower – averaging 41% of firms (OECD, 2001, p. 174)– similar to the rate of 45% reported by biotech respondents in New Zealand[19].

It should be possible to draw further comparisons with other New Zealand industry groups once the results of the Business Practices Survey 2000[20] become available. Further work is required before definite conclusions can be reached on the relative innovative output of New Zealand biotech firms – although the evidence reviewed above does not support the idea that New Zealand biotech firms have a particularly high rate of new product or process development.

[19] The mean for a group of small OECD countries that New Zealand might wish to emulate (Austria, Belgium, Denmark, Finland, Ireland, Netherlands, Portugal, Sweden, Switzerland) was 62% for all firms and 50% for small firms.

[20] a Statistics New Zealand survey commissioned by the Ministry of Economic Development that includes questions on the percentage of enterprises introducing new products/processes over the last 3 years.

3. Characteristics of the Biotechnology 'Industry'

3.1 Industry Sectors

Modern biotechnology is used in a number of different economic sectors ranging from food and non-food manufacturing through various primary industries to health, diagnostic and environmental applications.

Table 10: Percentage of Respondents Involved in Different Industry Sectors by Biotech Category

Industry Sector	Modern Biotech Enterprises	Traditional Biotech Enterprises	Modern Biotech Users	Traditional Biotech Users	All Groups
Human Health	53%	13%	49%	5%	30%
Food Processing	42%	38%	8%	29%	33%
Aquaculture	37%	13%	0%	5%	13%
Mining/Energy/Petroleum etc	5%	13%	0%	0%	4%
Forest Products	21%	0%	8%	5%	8%
Environment	37%	25%	8%	48%	35%
Ag-Bio	63%	25%	24%	10%	32%
Genomics & Molec' Modelling	42%	0%	0%	0%	12%
Custom Synthesis	21%	0%	0%	5%	8%
Other	21%	0%	16%	10%	13%

Modern Biotech Enterprises reported that they were researching and developing products, processes and services for use in the ag-bio and human health sectors, followed by food processing, genomics/molecular modelling, aquaculture and the environment. Food manufacturers were generally classified as MBEs because of their use of non-DNA based processes e.g. peptide sequencing, immune stimulants, antigens and antibodies etc.

Other biotech categories exhibit a similar pattern while being influenced by the industry group of some respondents; so for example:

- the environment industry sector was reported most frequently by Traditional Biotech Users – reflecting the waste treatment activities of local authorities;
- Modern Biotech Users most reported sector was human health – reflecting the activities of health services respondents.

A similar pattern emerges when 'end use sector' is tabulated against industry group (Table A7). The main end use sector is in many cases 'self defined':

- Food manufacturers reported food processing as the main end use sector;
- Non-food manufacturers were mainly involved in ag-bio, human health and food processing[21];
- Scientific research organisations were involved in most sectors, ag-bio being the most common;

[21] Presumably this is because enterprises were assigned to industry groups based on their primary activity so 'non-food manufacturers' may also be engaged in food processing.

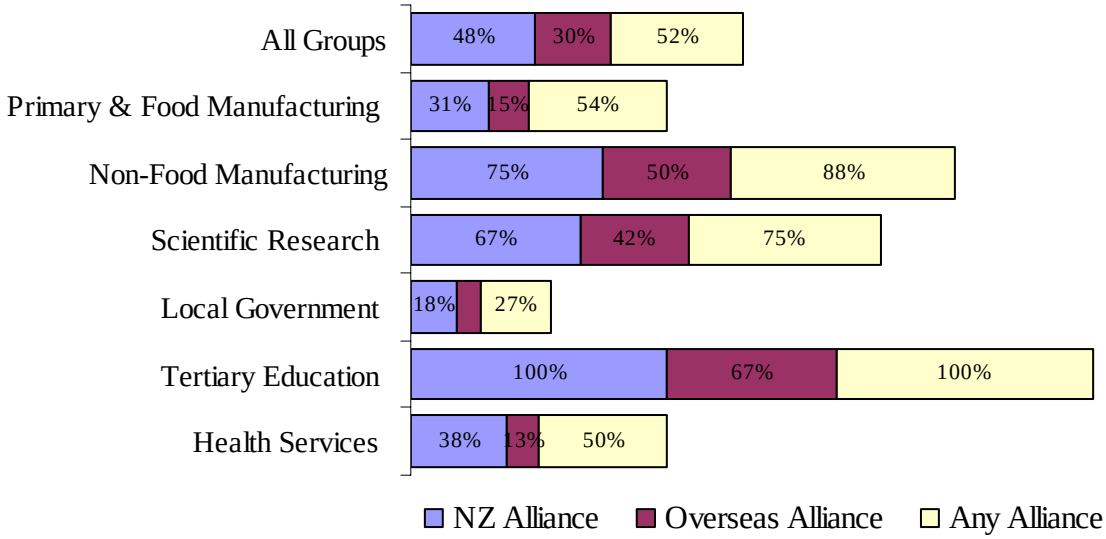
- Local government was mainly involved in environmental processes (water and waste treatment)
- The university and polytechnic group were involved in all areas; human health being the most common;
- Health services organisations were all involved in human health and have some involvement in ag-bio and the environment.

3.2 Strategic Alliances

Respondents were asked[22] about partnerships and alliances for biotechnology activity over the last 3 years. Further questions focussed on the purpose of any alliances and the types of New Zealand and overseas organisations involved.

52% of biotech respondents reported a partnership/alliance with a total of 303[23] different organisation types; this suggests that the 93 respondents that had alliances had an average of at least three partners each.

Figure 6: Percentage of Respondents Reporting Biotech Alliances



The proportion of respondents reporting a biotech alliance varied markedly between industry groups from 100% in tertiary education to a low of 18% for local government (Figure 6). Overall 48% reported at least one New Zealand alliance while 30% reported an overseas alliance. Overseas alliances were most common in the tertiary education, non-food manufacturing and scientific research groups.

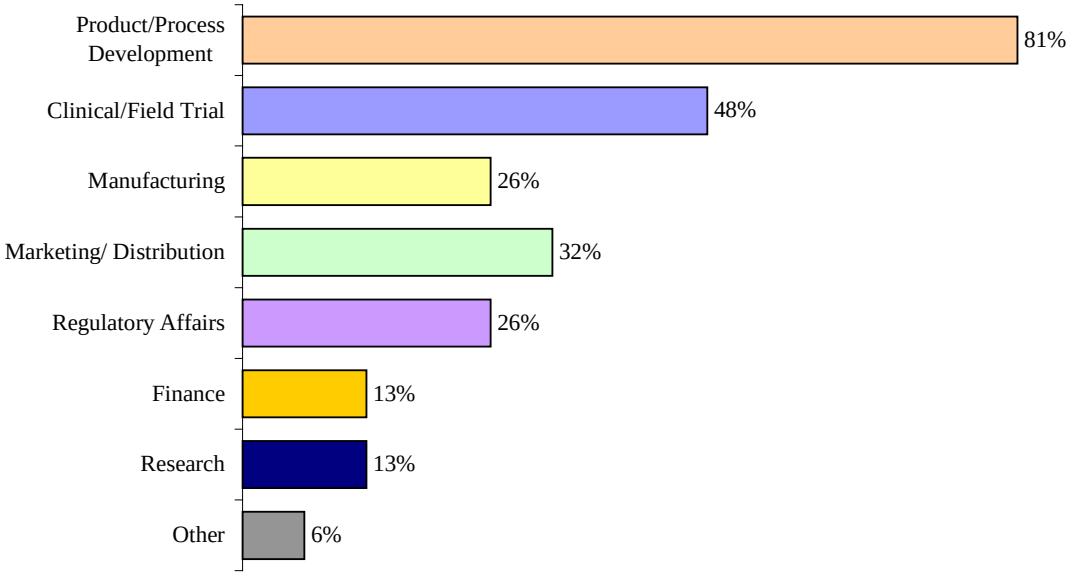
A breakdown of alliance frequency by biotech category reveals that 90% of MBEs reported alliances falling to 42% for MBUs and 24% for TBUs.

The most commonly reported alliance purposes were product/process development – reported by 81% of respondents who had an alliance and clinical/field trials (48%). 13% reported alliances for the purpose of undertaking basic research[24].

[22] "In the last 3 years did this business have any partnership/alliance for undertaking biotechnology activity (research or production)?"

[23] Respondents were not asked how many different organisations they had partnerships with. Data was collected on the different *types* of organisations with which they formed alliances e.g. CRI's businesses, universities etc both in NZ and overseas.

Figure 7: Purpose of Biotech Alliances



Note: this Figure differs from SNZ (2001, p. 19) because from Table 2.06 includes multi unit responses – for example the number of (whole) enterprises reporting an alliance for the purpose of 'product/processs development' is 75 (not 96)

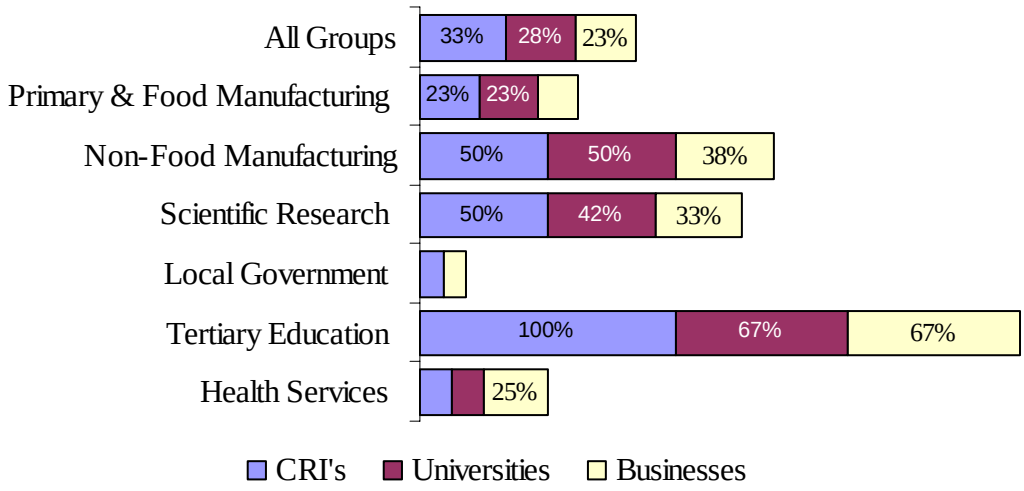
Overall 33% of respondents reported alliances with CRIs, followed by universities (28%) and other businesses (23%). Alliances with CRIs were most common in the tertiary education, non-food manufacturing and scientific research groups (Figure 8). The relative *frequency* of the different alliance types seems to be fairly similar across the main industry groups. However, further data would be required before any conclusion could be drawn as to the relative *importance* of the different alliance types.

There was a marked difference in the frequency of biotech alliances with other businesses and with CRI's between the different biotech categories:

- 68% of MBEs reported alliances with CRI's and 47% reported biotech alliances with other businesses.
- For the TBE, MBU and TBU groups; the percentage reporting alliances with other businesses was 10% to 17%, while the percentage reporting alliances with CRI's was 14% to 25%.

[24] Based on answers in the 'other' category - this may be an underestimate since the questionnaire did not include a basic research option.

Figure 8: Percentage of Respondents with Different Types of NZ Alliance Partners

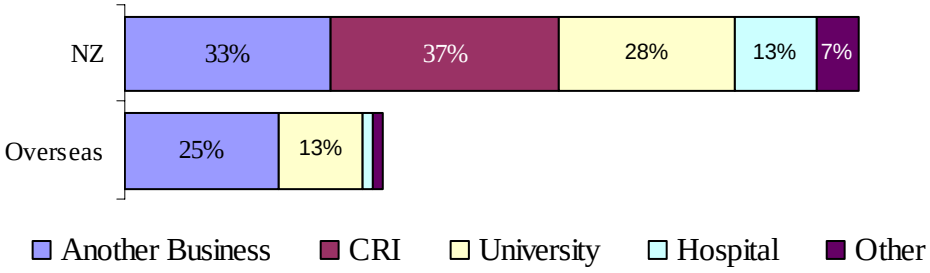


Note: Base data for Figure 8 is included in Table A8

Respondents were asked whether they had entered into any informal information sharing arrangements in the previous three years.

- 58% of respondents had informal agreements (89% of MBEs)
- 68% of respondents reported either a strategic alliance or an informal agreement or both.
- Most respondents reporting strategic alliances also entered informal agreements, however10% reported strategic alliances but not informal agreements and 15% reported informal agreements but not strategic alliances.
- The pattern of informal agreement partner types is very similar to that for strategic alliances (see Figure 9)

Figure 9: Percentage of Respondents with NZ/Overseas Informal Agreements to Share Information



This Figure is based on Table 2.072 in SNZ (2001) adjusted for multi unit responses

3.3 Intellectual Property Rights[25]

The Biotechnology Survey included eight questions relating to intellectual property (IP) rights and patents covering the following topics:

- Lack of access to IP as a constraint on biotech activities.
- IP disputes and litigation in the previous three years.
- Information sharing arrangements.
- IP acquisition.
- Patent applications.

15 respondents reported that IP rights issues had hindered development activities[26]. This problems was largely confined to MBEs within the scientific research and tertiary education industry groups where 26% -11 out of 43 respondents reported problems[27].

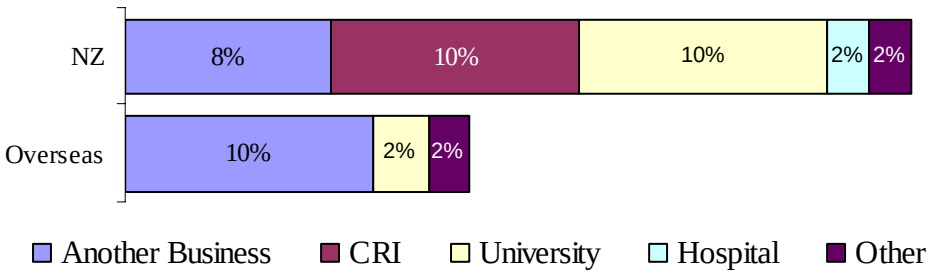
Projects were abandoned because the enterprise was unable to purchase the IP (9), the enterprise was unable to licence the IP (6) or 'other reasons' (9).

The survey also collected data on IP related disputes and litigation:

- 12 respondents had been involved in 16 cases of 'litigation relating to patent infringements'; and
- 15 respondents had been involved in 41 disputes 'relating to access to research information'.

Overall 45 respondents reported at least one IP related problem[28]. Positive responses were concentrated in the MBE category where 47% reported at least one problem. While not a major issue for the overall respondent population, IP rights are clearly a significant problem for organisations involved in R&D using modern biotech processes (MBEs).

Figure 10: Percentage of Respondents Acquiring Intellectual Property Rights from NZ/Overseas by Source



This Figure is based on Table 2.073 in SNZ (2001) adjusted for multi unit responses

[25] This report section covers material similar to Section 2.07 in Statistics New Zealand (2001) adjusted for multi-unit responses.
[26] "Has this business ever had to abandon or not start a biotechnology development activity because further work was blocked by IP rights or some knowledge protected by another organisation?"
[27] Problems were reported by 21% (12 out of 57) of Modern Biotech Enterprises
[28] Blocked by IP rights, lack of access to research data, patent litigation, access to research data (Q. 23, 25, 26, 27) or access to biotech research data reported as a problem (Q. 34).

Overall, 25% of respondents acquired the right to use IP in the last accounting year (47% of MBEs). The main sources were other businesses (NZ and overseas), universities and CRI's (see Figure 9).

Patents

Only a small proportion of biotech respondents had made any patent applications

- In the year to June 1999, 21 enterprises (12% of biotech respondents) made a total of 56 successful patent applications.
- Nine respondents made 80% of all biotech patent applications in the year to June 1999.
- In the previous five years, 33 enterprises (18% of respondents) had made a total of 156 successful patent applications (147 by MBEs).
- Nine respondents made 70% of all biotech patent applications in the previous five years.

See Marsh (2001a) and van Beuzekom (2001) for a comparison of New Zealand's biotech patenting rate with that of other OECD countries.

Biotech Related Conference and Publishing Activity

Survey respondents were asked whether any staff member had been involved in biotech related conference and publishing activity in the 12 months to June 1999.

- At least one member of staff from 70% of respondents had attended a national or international conference 'on a biotechnology subject';
- Staff from 32% of respondents had presented a research paper at a biotech conference;
- Staff from 22% of respondents had published an article on biotechnology in a refereed journal.

A breakdown of respondents by biotech category (Table 11) shows that there are marked differences between the different groups:

- MBEs have a markedly higher rate of conference and publishing activity: 95% of respondents had been involved in a biotech conference and staff from 58% had published a refereed journal article;
- Only 43% of TBUs had staff attending a biotech conference and there were no refereed journal articles.

Table 11: Percentage of Respondents with Staff Attending Biotech Related Conferences and Publishing Refereed Journal Articles

Activity	Modern Biotech Enterprises	Traditional Biotech Enterprises	Modern Biotech Users	Traditional Biotech Users	All Groups
Attend Conference	95%	63%	92%	43%	70%
Present Conference Paper	68%	13%	25%	10%	32%
Publish Ref'd Journal Article	58%	13%	8%	0%	22%

This Table differs from Table 2.075 in SNZ (2001) because of adjustment for multi-unit responses

3.4 Income, Expenditure and Exports

Survey respondents estimated that income of $475 million was attributable to modern biotechnology, in the year ended June 1999 - $326 million from private sector respondents, $149 million from the public sector. This compares to respondents income from all sources of $7.25 billion i.e overall biotech provided around 7% of income for the 180 biotech using enterprises.

Various difficulties associated with the data on income and expenditure mean that these estimates should be treated with caution. Enterprises were asked to estimate the proportion of their total income and expenditure that could be attributed to biotechnology. Such an instruction is open to widely varying interpretations[29], so for example dairy product manufacturers estimates varied between zero and 100% of their income.

15% of enterprises which use biotech processes reported that they received no income attributable to biotechnology. 73% received less than 50% of their income from biotech, while 15% attributed *all* of their income to biotech (see Table 12 below).

Within the MBE group 53% received 0 > 25% of their income from biotech, while 15% (around 9 enterprises) received *all* of their income from biotech – such firms are commonly termed Dedicated Biotechnology Firms (DBF) in the international literature (see Table 12 below).

Table 12: Biotech Income as a % of Total Income

Industrial Group	**0**	**0 > 25%**	**25 > 75%**	**75 > 100%**	**100%**
Food Manufacturing & Primary Products	29%	50%	7%	0%	7%
Non-Food Manufacturing	13%	13%	25%	13%	38%
Scientific Research	8%	54%	15%	8%	15%
Local Government Administration	36%	45%	18%	0%	0%
Health Services	0%	38%	38%	13%	25%
Other	25%	25%	25%	0%	0%
Modern Biotech Enterprises	*5%*	*53%*	*16%*	*11%*	*16%*
All Groups	**15%**	**47%**	**17%**	**5%**	**15%**
Number of Respondents	**27**	**84**	**30**	**9**	**27**

Biotech respondents reported total exports of $1.75 billion and biotech exports of the order of $170 million. 42% (75) of biotech respondents reported exports, while biotech exports were reported by 23% (42).

The value of biotech exports was generally less than $1 million (57% of those reporting exports). 29% reported biotech exports of $1 to $10 million while 14% (around 6 enterprises) reported biotech exports of $10 to $100 million.

[29] depending on interpretation of 'attributable' and whether the respondent concentrated only on *modern* biotech. Based on a broad interpretation it could be said that *all* dairy manufacturing income is attributable to biotech. Separation of the proportion of this attributable to *modern* biotech would be very difficult. These issues are also discussed in Statistics New Zealand (2001).

Table 13: Biotech Respondents Income, Expenditure and Exports by Industrial Group

Industrial Group	Total Income	Biotech Income	Total Exports	Biotech Exports
Primary Products	*c*	*c*	*c*	*c*
Food Manufacturing	3,954	109	1,691	*c*
Non-Food Manufacturing	685	110	0	*c*
Scientific Research	669	88	31	*c*
Local Government Administration	556	11	*c*	*c*
Tertiary Education	330[30]	29	c	*c*
Health Services	188	74	*c*	*c*
Other	*c*	*c*	c	*c*
Sum of Confidential Cells (c)	*873*	*55*	*33*	*168*
Total	**7,254**	**475**	**1,755**	**168**

Note: *c* indicates cell 'confidentialised' to give effect to the confidentiality provisions of the Statistics Act 1975

Some key points derived from Table 13 include:

- 80% of biotech income was attributable to four industrial groups (food and non-food manufacturers, research and health services);
- The relative importance of biotech to respondents varies from 40% in the health services group (mainly laboratories which *use* biotech processes) to less than 3% for food manufacturers (e.g. dairy product manufacturers).
- The food manufacturing group contains a number of very large enterprises that account for over 96% of respondents total exports.

The estimated value of biotech exports should be viewed with considerable caution (see Footnote[31] below). Confidentiality requirements mean that a breakdown of biotech exports by industrial group cannot be published.

[30] This is an underestimate since it is partly based on aggregation of multi-unit responses rather than single responses for 'whole' institutions.

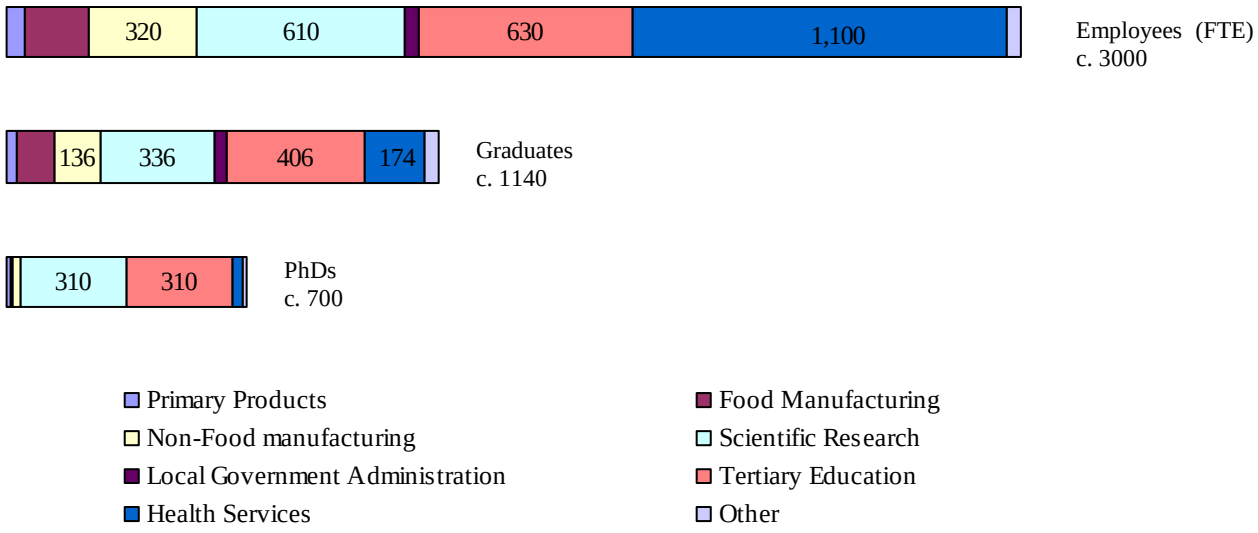
[31] This estimate should be viewed with considerable caution – hopefully it is of the right order of magnitude. Total and biotech exports have been estimated based on the assumption that 'total production of goods/services' is approximately equal to total income – thus Q.21 (exports as a % of total production) * total income = total exports and Q. 22 (biotech exports as a % of total production) * total income = biotech exports. In certain cases the resultant value of biotech exports exceeds reported biotech income. In these cases biotech exports were taken to be the same as biotech income. This had the effect of reducing the estimated level of biotech exports from $325 million to $168 million.

3.5 Human Resources

Survey respondents were asked to provide data on their employees 'supporting biotech activity' including:

- a headcount as at 30 June 1999, broken down by staff qualification; and
- Full time equivalents in the year to 30 June.
- they were specifically asked *not* to include staff performing indirect support to biotech activities e.g. central finance or personnel or other similar centralised support services.

Figure 11: Number of Biotech Employees by Qualification and Industrial Group



Survey respondents reported that a total of 3057 (or 2984 full time equivalent) staff supported biotech activity. Around 67% were graduates and 26% had PhD's.

- The largest employee group came from the health services industrial group, followed by the tertiary education and research groups (see Figure 10).
- Most graduates were employed by the tertiary education and research groups (most health services biotech employees are not graduates). The concentration of qualified staff is most marked for staff with PhDs – 88% of these were employed within these two groups.
- MBEs employed 1667 biotech staff (FTE) – 56% of the total for all respondents.
- Employment of qualified staff was heavily concentrated in MBEs; they employed 83% of biotech graduates and 95% of PhDs

3.6 Problems Affecting Biotech R&D

The survey questionnaire included a question on "constraints to biotechnology research and development activities faced by this business over the accounting period". 'Catch-all' question of this type do not attempt to measure the seriousness of each issue and so may overstate problems. Nonetheless they can provide a valuable snapshot on the relative importance of various problems facing the industry.

- Around 59% of respondents reported at least one problem affecting biotech R&D (most of the remainder did not report any R&D activity);
- Around 79% of respondents involved in R&D reported at least one problem;
- 89% of MBEs reported at least one problem.
- Enterprises engaged in R&D tended to report a wider range of problems (3.5 per enterprise for MBEs, 2.4 for TBEs, 1.2 for MBUs and 0.5 for TBUs).

The problems reported most frequently by all respondents were access to capital and regulations. Problems were reported most widely in the tertiary education and research industrial groups, where again access to capital and regulations were cited most frequently.

Table 14: Problems Affecting Biotech R&D, by Industrial Group

	Primary Products	Food Manuf'	Non Food	Scientific Research	Local Gov't	Tertiary Education	Health Services	All Groups
Access to Capital	0%	18%	38%	58%	0%	67%	63%	35%
Access to Management Experts	0%	0%	25%	25%	9%	0%	13%	13%
Access to Trained Biotech Experts	100%	18%	25%	33%	0%	67%	25%	23%
Experienced Biotech Experts	50%	18%	38%	25%	9%	67%	25%	22%
Access to Biotech Research Data	0%	9%	25%	17%	9%	33%	13%	10%
Acess to Technology	0%	18%	25%	25%	0%	33%	25%	20%
Lack of Market Information	0%	9%	25%	25%	0%	67%	13%	17%
Regulations	50%	9%	50%	58%	0%	67%	13%	28%
Implications of Treaty of Waitangi	0%	0%	13%	8%	0%	67%	0%	8%
Other Problems	0%	9%	0%	8%	9%	67%	13%	10%

Table 15: Problems Affecting Biotechnology, by Category

	Modern Biotech Enterprises	Traditional Biotech Enterprises	Modern Biotech Users	Traditional Biotech Users	All Groups
Access to Capital	63%	38%	42%	10%	35%
Access to Management Experts	26%	25%	0%	5%	13%
Access to Trained Biotech Experts	42%	25%	17%	5%	23%
Experienced Biotech Experts	42%	38%	17%	5%	22%
Access to Biotech Research Data	16%	13%	8%	5%	10%
Acess to Technology	37%	38%	8%	5%	20%
Lack of Market Information	32%	13%	8%	5%	17%
Regulations	63%	25%	17%	10%	28%
Implications of Treaty of Waitangi	21%	0%	8%	0%	8%
Other Problems	16%	0%	17%	5%	10%

4. International Comparisons

National statistics on biotechnology use are available from some governments and various private sector reports[32]. Five OECD members collect data on biotech expenditure and human resources as part of their national R&D surveys. Only three countries have undertaken specific biotech surveys – Canada, France and New Zealand. International comparisons are difficult because of wide variation in data collection methods and definitions. The Statistics New Zealand biotech survey was closely modelled on work carried out by Statistics Canada thus enabling some comparisons to be made. However there are some important differences; the New Zealand definition of biotech included several additional processes and so was somewhat wider than that used in Canada; the number of biotech firms is also not directly comparable since the Canadian survey excluded firms that had less than 5 employees and less than C$100,000 R&D expenditures[33].

An approximate comparison between the two data sets is included as Table 16. It is based on application of the Statistics Canada definition of a biotech enterprise to the New Zealand data set – namely enterprises which conduct R&D, have a minimum of five biotech employees and biotech expenditure of at least NZ$150,000. Data for Australia is also included although based on a narrower definition (see footnote 34).

Table 16: Biotechnology in New Zealand, Canada and Australia

	Canada 1999	Australia 1998/99	NZ 1998/99
Population (1997)	30.3	18.5	3.8
No. of biotech enterprises	358	120[34]	39
Total Biotech revenue[35] (NZ$ m)	2850	1077	205
Biotech revenue per million population (NZ$ m)	94	58	54
Revenue per firm (NZ$ m)	8.0	9.0	5.3
Biotech related employees (Headcount)	7695	3801	1708
Biotech related employees per million population	254	205	449
% of products and processes in R&D stage	49%	47%[36]	72%

Data for Canada is extracted from McNiven (2001) and Ernst & Young (1999)

New Zealand's biotech revenue per million population (NZ$54 million) is rather lower than Canada's (NZ$94 million), but the difference is fairly small considering Canada's higher per capita income and proximity to the United States. New Zealand has a rather lower mean revenue per biotech firm ($5.3m vs $8.0m); consistent with

[32] Pattinson, Van Beuzekom, & Wyckoff (2001) provide a useful summary of existing sources of national statistics on biotechnogy.
[33] These firms were responsible for less than 1% of biotech R&D expenditure.
[34] No. of 'core' biotech firms whose business is entirely or substantially biotechnology related and that have a significant commitment to technological innovation, excludes traditional biotech operations and not for profit enterprises. See Ernst & Young (1999) and van Beuzekom (2001).
[35] Based on an exchange rate of NZ$1.5= C$1
[36] Includes 'under development' (33%) and 'clinical/field trial stage' (14%), see Ernst & Young (1999, p. 17)
[37] Based on an exchange rate of NZ$1.5= C$1

the predominance of SMEs in the New Zealand economy. New Zealand appears to have a significantly higher rate of biotech employment; further investigations will be undertaken to try and confirm this. There is some evidence that use of biotech processes in New Zealand is at an earlier stage with 72% being at the R&D stage against 49% in Canada[38].

[38] Some of this difference may result from differences in variable definition

5. Modern Biotech Enterprises in New Zealand

5.1 Introduction

Policy makers and academics have a particular interest in modern biotech enterprises since their performance will be crucial in determining New Zealand's overall performance in the biotech area. Much of the international biotech literature focuses on this group so a separate description should be useful, both for international comparison and for domestic policy makers.

This section describes the characteristics of Modern Biotech Enterprises (MBEs) that use at least one modern biotech process (see Table 1); conduct R&D involving at least one modern biotech process; and employ at least one (FTE) graduate that 'supports biotechnology activity'. Such a definition is broadly consistent with the Statistics Canada definition of a biotechnology firm (see chapter 4 above).

5.2 Enterprises Involved

New Zealand had 57 MBEs in 1998/99, spread across various industrial groups particularly scientific research organisations (24) primary product and manufacturing enterprises (15) and Universities (6). They included 42 enterprises which developed and used DNA based processes and 24 which developed and used genetic engineering or recombinant DNA.

45 of the 57 MBEs fall under 6 ANZSIC categories (at the 5 digit level): Scientific Research, Higher Education, Medicinal and Pharmaceutical Product Manufacturing, Dairy Product Manufacturing, Technical Services nec and Hospitals (except psychiatric). Modern biotech enterprises were split fairly evenly between the private sector (30) and the public sector (27).

5.3 Biotech Processes

57 Modern Biotech Enterprises reported use of 1060 processes – an average of 19 processes per enterprise – compared to 5 per enterprise for biotech users (see Table 4).

69% of MBEs use DNA based processes, almost all used bioprocessing and biochemistry based processes, around half used environmental biotech (Table A6).

5.4 Product and Process Development

Over the previous three years:

- 68% of MBEs had introduced a new product or process.
- MBEs had introduced 114 new products and 105 new processes.
- 26% of MBEs introduced a total of 30 'New to the World' processes.

In the next three years:

- 67% plan to introduce a new product and 74% plan to introduce a new process.

- MBEs plan to introduce 207 new products and 219 new processes.

5.5 Industry Sectors

Modern Biotech Enterprises were most involved in the ag-bio (63% of MBEs) and human health sectors (53%), followed by food processing (42%), genomics/molecular modelling (42%), aquaculture and the environment (Table 10).

5.6 Strategic Alliances

90% of MBEs reported alliances with a total of 227 different organisation types; this suggests that the 51 MBEs that had alliances had an average of at least 4 partners each.

89% of MBEs reported informal information sharing agreements.

5.7 Intellectual Property Rights

47% of MBEs reported at least one IP related problem[39]. While not a major issue for the overall respondent population, IP rights are clearly a significant problem for organisations involved in R&D using modern biotech processes (MBEs).

Patents

- In the year to June 1999, 21 enterprises (37% of MBEs) made a total of 54 successful patent applications (no patent applications were made by other respondent groups)
- In the previous five years, 27 enterprises (47% of MBEs) had made a total of 147 successful patent applications (94% of patent applications by all respondent groups).

Biotech Related Conference and Publishing Activity

- 95% of MBEs had been involved in a biotech conference.
- Staff from 58% of MBEs had published a refereed journal article.

5.8 Income, Expenditure and Exports

MBEs estimated that income of $236 million was attributable to modern biotechnology, in the year ended June 1999 - $122 million from private sector respondents, $115 million from the public sector.

This compares to MBE income from all sources of $2.1 billion i.e overall biotech provided around 11% of income for the 57 MBEs.

[39] Blocked by IP rights, lack of access to research data, patent litigation, access to research data (Q. 23, 25, 26, 27) or access to biotech research data reported as a problem (Q. 34).

Within the MBE group 53% received 0 > 25% of their income from biotech, while 15% (around 9 enterprises) received *all* of their income from biotech – such firms are commonly termed Dedicated Biotechnology Firms (DBF) in the international literature.

MBEs reported total exports of $300 million and biotech exports of the order of $60 million. 47% of MBEs reported exports, while biotech exports[40] were reported by 26% (around 9 had exports up to $1million, while 6 had exports in the range $1-$10 million).

5.9 Human Resources

MBEs employed 1667 biotech staff (FTE) – 56% of the total for all respondents.

Employment of qualified staff is heavily concentrated in MBEs; they employed 83% of biotech graduates and 95% of PhDs.

5.10 Problems Affecting Biotech R&D

The problems most frequently reported by MBEs were access to capital, regulations, and access to trained/experienced biotech experts.

- 89% of MBEs reported at least one problem affecting biotech R&D.
- MBEs tended to report a wider range of problems (3.5 per enterprise for MBEs compared to 2.4 for TBEs, 1.2 for MBUs and 0.5 for TBUs).

[40] The estimated value of biotech exports should be viewed with considerable caution (see Footnote on page 23).

Appendix Tables

Table A1: Breakdown of Biotech Respondents by ANZSIC Classification

A021900 Services to Agriculture A030100 Forestry B120000 Oil and Gas Extraction	6
C212900 Dairy Product Manufacturing	6
C211200 Poultry Processing C212100 Milk and Cream Processing C212200 Ice Cream Manufacturing C213000 Fruit and Vegetable Processing C215200 Cereal Food and Baking Mix Manufacturing C216100 Bread Manufacturing C217300 Seafood Processing C217900 Food Manufacturing nec	12
C218200 Beer and Malt Manufacturing C218400 Spirit Manufacturing	6
C218300 Wine Manufacturing	9
C233100 Pulp, Paper and Paperboard Manufacturing C253400 Organic Industrial Chemical Manufacturing C253500 Inorganic Industrial Chemical C254400 Pesticide Manufacturing C254600 Cosmetic and Toiletry Preparation Manufacturing C254900 Chemical Product Manufacturing C272200 Aluminium Smelting	9
C254300 Medicinal and Pharmaceutical Product Manufacturing	15
F451200 Cereal Grain Wholesaling F452300 Chemical Wholesaling F471700 Liquor Wholesaling F479600 Pharmaceutical and Toiletry Wholesaling	3
L781000 Scientific Research	24
L782900 Technical Services nec	6
M811300 Local Government Administration	33
N843100 Higher Education	12
O861100 Hospitals (except Psychiatric hospitals)	15
O863100 Pathology Services O863900 Health Services nec O864000 Veterinary Services	9
P923900 Recreational Parks and Gardens Q952500 Gardening Services Q963400 Waste Disposal Services D370100 Water Supply D370200 Sewerage and Drainage Services M811100 Central Government Administration L785500 Business Management Services L782300 Consultant Engineering Service	9
Total	180

Table A2: Industrial Grouping vs Institutional Type

Industrial Group	Private	Private Non-Profit	Central Govern-ment	Local and Regional Govern-ment	Total
Primary Products	6	0	0	0	6
Food Manufacturing	36	0	0	0	36
Non-Food Manufacturing	24	0	3	0	27
Scientific Research	24	6	9	0	36
Local Government Administration	0	0	0	33	33
Tertiary Education	0	0	9	0	9
Health Services	6	0	18	0	24
Other	6	0	3	3	9
Total	**99**	**6**	**45**	**36**	180

Note Private includes 'Corporate and Non-Corporate Enterprises'. Central Government includes 'Producer Enterprises' and 'Non-market Organisations'

Table A3: Biotech Category vs Industrial Group

Industrial Group	Modern Biotech Enterprises	Traditional Biotech Enterprises	Modern Biotech Users	Traditional Biotech Users	All Biotech Respondents
Primary Products	3	0	0	3	6
Food Manufacturing	3	9	6	18	36
Non-food Manufacturing	9	6	3	3	24
Scientific Research	24	6	3	3	36
Local Government Administration	0	0	3	30	30
Tertiary Education	6	0	3	3	9
Health Services	6	0	18	0	27
Other	3	0	3	6	12
Total	57	24	36	63	180

Table A4: Details of Respondents Using Biotech Processes and Stage of Use

Process	Used	Stage of Use			Plan to Use in Next 3 Years	If no plan .. because	
		R&D/ Process Develop-ment	Part of Production Process	Part of Product Sold		No application to this business	Not cost effective
DNA Based							
GE	24	21	6	3	9	144	6
Gene Probes	42	30	12	6	12	126	9
Bio Informatics	30	30	6	3	9	141	6
Genomics	24	21	6	3	9	147	3
Pharmacogenetics	6	6	3	3	9	162	3
DNA Sequencing	27	24	6	3	9	141	6
DNA Synthesis	18	15	3	3	3	150	9
DNA Amplification	45	33	18	9	3	132	3
Gene Therapy	3	6	0	0	3	168	6
Rational Drug Design	9	9	0	0	6	165	3
Other DNA Based	3	3	3	0	0	36	0
Biochemistry Based							
Vaccines	24	12	15	6	6	147	3
Immune Stimulants	33	24	15	12	3	144	3
Drug Design	18	15	6	3	9	159	3
Combinatorial Chem	9	9	0	3	9	165	3
Diagnostic Tests	66	39	39	21	3	111	6
Peptide Synthesis	9	12	3	0	6	162	9
Peptide Sequencing	24	24	3	0	3	150	6
Cell Receptors	27	21	6	6	6	150	3
Cell Signalling	21	18	3	3	9	156	3
Bio-sensing	30	18	15	6	15	132	9
Pheromones	12	9	6	0	6	165	3
Molecular Modelling	18	18	0	0	6	156	3
Structural Biology	21	21	0	0	6	156	6
Antigens	51	30	27	15	6	126	0
Monoclonal Antibodies	48	27	27	12	6	126	6
Antibodies	54	33	33	18	3	123	6
Microbiology	105	54	72	33	3	75	3
Biomaterials	57	36	30	27	3	120	3
Other Biochemistry	0	3	0	0	0	39	0
Environmental Biotechnologies							
Bioaugmentation	48	21	33	9	3	126	6
Bio-reactors	51	24	39	9	6	120	9
Biological Gas Cleaning	9	3	6	3	3	165	6
Bio-remediation	39	18	27	3	6	132	9
Phytoremediation	36	12	27	6	6	138	6
Other Environmental	3	0	0	0	0	30	0
Bioprocessing Based							
Cell Culture	69	42	48	15	3	99	9
Tissue Culture	51	36	27	12	3	126	9
Embryo Culture	15	12	9	3	0	156	6
Cell Manipulation	30	21	12	3	3	147	6
Tissue Manipulation	18	18	6	3	0	159	3
Embryo Manipulation	9	9	3	0	3	165	6
Fermentation	54	24	39	12	3	123	6
Bioprocessing	36	18	27	9	3	141	3
Biotransformation	42	21	21	15	0	138	3
Bio-leaching	0	0	0	0	3	174	3
Bio-pulping	3	3	3	0	6	171	0
Bio-bleaching	3	3	0	0	3	174	0
Bio-desulphurisation	0	0	0	0	0	177	3
Bio-pesticide mfg	18	12	6	6	3	159	3
Extraction	54	39	33	24	3	126	0
Biofiltration	42	12	30	3	9	126	6
Bioindicators	69	27	45	9	3	108	3
Micro-Selected Breeding	15	12	9	9	6	153	6
Natural Products	45	36	21	15	9	126	3
Microbio-inoculants	9	9	3	3	3	168	3
Somatic Embryo-genesis	12	12	6	3	0	162	6
Other Bioprocessing	3	3	0	0	0	36	0

Table A5: Number of Enterprises Involved in Different Biotech Areas by Industrial Group

Biotech Area	Primary, Food & Non-Food Manufact-urers and Other	Research Organ-isations	Univers-ities etc	Health Organ-isations	Local Auth-orities	**No. of Enter-prises Involved in each stage**
DNA Based Processes	9	24	9	12	0	**51**
Biochemistry Based	57	30	12	24	9	**132**
Environmental Biotech	33	15	6	3	27	**81**
Bioprocessing Based	69	33	6	21	27	**156**
Total No of Enterprises involved at any stage	**75**	**36**	**9**	**24**	**33**	**180**

Table A6: Number of Enterprises Involved in Different Biotech Areas by Biotech Category

Biotech Area	Modern Biotech Enterprises	Traditional Biotech Enterprises	Modern Biotech Users	Traditional Biotech Users	All Biotech Respondents
DNA Based Processes	42	0	9	0	51
Biochemistry Based	57	12	33	30	132
Environmental Biotech	27	9	9	36	81
Bioprocessing Based	54	18	33	51	156
Total No of Enterprises involved at any stage	**57**	**21**	**36**	**63**	**180**

Table A7: Percentage of Respondents Involved in Different Industry Sectors by Industry Group

	Food Manufact-uring	Non Food	Scientific Research	Local Govern-ment	Tertiary Educ-ation	Health Services	All Groups
Human Health	0%	38%	33%	0%	100%	100%	28%
Food Processing	91%	38%	25%	0%	67%	0%	32%
Aquaculture	9%	13%	25%	0%	67%	0%	13%
Mining/Energy/Petroleum etc	0%	0%	0%	0%	33%	0%	2%
Forest Products	0%	13%	8%	0%	33%	0%	8%
Environment	9%	13%	42%	82%	67%	13%	35%
Ag-Bio	9%	63%	58%	18%	67%	13%	32%
Genomics & Molec' Modelling	0%	0%	33%	0%	67%	0%	12%
Custom Synthesis	0%	13%	17%	0%	33%	0%	8%
Other	9%	13%	25%	9%	67%	0%	15%

Table A8: Alliance Frequency by Industry Group

Industrial Group	No. in Group	% of respondents with			% of respondents reporting alliance with		
		Any Strategic Alliance	NZ Alliance	Overseas Alliance	CRI	University or Polytech	Business
Primary & Food Manufacturing	39	54%	31%	15%	23%	23%	15%
Non Food Manufacturing	24	88%	75%	50%	50%	50%	38%
Scientific Research	36	75%	67%	42%	50%	42%	33%
Local Government Administration	33	27%	18%	9%	9%	0%	9%
Tertiary Education	9	100%	100%	67%	100%	67%	67%
Health Services	24	50%	38%	13%	13%	13%	25%
Other	12	50%	25%	25%	25%	25%	0%
All Groups	180	52%	48%	30%	33%	28%	23%

Table A9: Informal Agreements to Share Information

Classification of Partner	Partner in New Zealand		Partner Outside New Zealand	
	Number	Percentage of Respondents	Number	Percentage of Respondents
Another Business	60	33%	45	25%
University	51	28%	24	13%
Crown Research Institute	66	37%	0	
Hospital	24	13%	3	2%
Other	12	7%	3	2%

This Table is based on Table 2.072 adjusted for multi unit responses

Table A10: Income, Expenditure and Exports by Biotech Category ($ millions)

Industrial Group	Modern Biotech Enterprises	Traditional Biotech Enterprises	Modern Biotech Users	Traditional Biotech Users	*Sum of Confidential Cells (c)*	All Biotech Respondents
Total Income	2,124	1,008	1,647	2,475	0	**7,254**
Biotech Income	236	68	112	59	0	**475**
Total Exports	301	c	c	c	1,454	**1,755**
Biotech Exports	60	c	40	c	70	**170**

Table A11: Breakdown of Biotech Employees by Qualification and Industrial Group

	RD Headcount	**RD FTE**	**PhD**	**MSc**	**BSc**	**Certificate**	**Other Qualification**
Primary Products	55	50	12	3	12	6	0
Food Manufacturing	230	190	6	15	80	55	25
Non-Food manufacturing	370	320	25	30	90	35	100
Scientific Research	780	610	310	110	210	60	20
Local Government Administration	95	40	0	3	15	65	6
Tertiary Education	700	630	310	210	180	45	15
Health Services	800	1,100	30	18	140	310	150
Other	45	40	12	9	18	12	3
Total	**3057**	**2984**	**703**	**388**	**733**	**588**	**315**

Table A12: Breakdown of MBEs by ANZSIC Classification

A021900 Services to Agriculture A030100 Forestry	3
C212900 Dairy Product Manufacturing	6
C254300 Medicinal and Pharmaceutical Product Manufacturing	9
L781000 Scientific Research	21
L782900 Technical Services nec	3
N843100 Higher Education	6
O861100 Hospitals (except Psychiatric hospitals)	3
L785500 Business Management Services	3
C218200 Beer and Malt Manufacturing C254600 Cosmetic and Toiletry Preparation Manufacturing D370100 Water Supply L782300 Consultant Engineering Service M811100 Central Government Administration O863900 Health Services nec P923900 Recreational Parks and Gardens	6
Total	57

Table A13: Definition of 'Modern' and 'Traditional' Processes DNA Based

SNZ Q No.	Process	Definition in Biotechnology Survey 1998/99	Stat's Canada Categ'y
	DNA Based Processes: Technology using chemistry of DNA as a major component		
5.1	Genetic Engineering/Recombinant DNA	The manipulation of an organism's genetic material by introducing or eliminating specific genetic changes through modern molecular biology techniques.	1140
5.2	Gene Probes	A section of DNA or RNA of known structure or function which is marked with a radioactive isotope, dye or enzyme that can be used to detect the presence of a similar sequence from any biological material	1110
5.3	Bio Informatics	Computer-based analysis of biological information (bio-info), especially genomics and molecular modelling (eg DNA/RNA/ protein sequencing and databases for genes of humans, plants, animals and micro-organisms)	1120
5.4	Genomics	The use and organisation of information of biological interest, including the construction and analysis of genes that may be used to search for new genes of interest, matching existing genes etc.	1140
5.5	Pharmacogenetics	The study of the genetics of drug production, action or assimilation	1140
5.6	DNA Sequencing	A method to determine the order of nucleotides on a gene or DNA fragment	1140
5.7	DNA Synthesis	Design and synthesis of a DNA molecule from existing information of its constituent bases	1140
5.8	DNA Amplification	Process of increasing the number of copies of a particular gene of chromosomal sequence	1140
5.9	Gene Therapy	Replacement of a defective gene in an organism suffering from a genetic defect	*1140* *
5.10	Rational Drug Design	Analysis of the structures of active sites of enzymes and receptors in order to design pharmocologically active synthetic molecules	*1160*
5.11	Other DNA Based		

Notes:

i. 'Modern' biotech processes (for the purpose of this report) are represented in normal font, white background.

ii. 'Traditional' biotech processes in italic, grey background.

iii. Statistics Canada categories refer to 1999 questionnaire in McNiven (2001).

iv. * indicates allocation to Statistics Canada category is probably correct but needs to be reviewed.

Table A13 (cont): Definition of 'Modern' and 'Traditional' Processes Biochemistry/Immunochemistry Based

SNZ Q No.	Process	Definition in Biotechnology Survey 1998/99	Stat's Canada Categ'y
	Biochemistry/Immunochemistry Based: Technology which utilises immunochemistry/antibodies or enzymes as a major compnent		
6.1	Vaccines	The agent containing antigens produced from killed, attenuated or live pathogenic micro-organisms or their genetic material used to stimulate the immune system to protect the host	1150
6.2	Immune Stimulants	Compounds that induce the immune system to produce antibodies or antibody containing lymphocytes	1150
6.3	Drug Design and Delivery	Development of drugs where the raw materials and/or processes involve the use of biotechnology	1160
6.4	Combinatorial Chemistry	An approach to chemical synthesis that enables the creation of large numbers of organic compounds by putting chemical building blocks together in every possible combination. It is used to synthesise novel compounds, which are screened, or tested, against biological targets as part of the drug discovery process	1200
6.5	*Diagnostic Tests*	A test used to determine the source of a problem or a method of determining the nature of a disease by analysing the symptoms	*1170*
6.6	Peptide/Protein Synthesis	Procedure to link two or more amino acids joined by a linkage called a peptide bond	1180
6.7	Peptide/Protein Sequencing	The process of determining the sequence of a polypeptide or cluster of polypeptides, or the process of creating a new substance from precursor molecules	1180
6.8	Cell Receptors	Functional proteinaceous structures found in the membrane (surface) of cells that tightly bind specific molecules (organic, protein or viruses).	1190
6.9	Cell Signalling	The mechanism used by cells to induce or trigger events at remote sites within cells	1190
6.10	*Bio-sensing*	Use of biological molecules (eg enzymes, antibodies) in conjunction with a transducer to low level detection of substances such as sugars and proteins in body fluids, pollutants in water etc.	*none*
6.11	*Pheromones*	Compounds emitted by insects and spread through the air for the purpose of attracting the opposite sex	*1190*
6.12	Three Dimensional Molecular Modelling	Description of the characteristics of molecules through a 3D spatial representation	1200
6.13	Structural Biology	The study of the three dimensional structures of biological molecules(such as proteins) and their mutual interactions as a means of understanding the functions of these molecules within the cell	1190
6.14	Antigens	A substance that stimulates the production of specific neutralizing antibodies in an immune response. Any chemical substance, usually protein that interacts with an antibody	*1170* *
6.15	Monoclonal Antibodies	A monoclonal antibody is a highly specific antibody which is derived from a line of specialised cells and which recognises only one specific complimentary antigen	1170
6.16	Antibodies	Proteins that circulate in the blood stream and bind to foreign invading substances (antigens eg bacteria, toxins, certain viruses) with a great deal of specificity	1170
6.17	*Microbiology/Microbial Ecology*	Study of organisms that are too small to be seen with the naked eye	*1220*
6.18	*Biomaterials*	Any biologically derived material which is used for its material properties rather than its biological properties	*none*
6.19	*Other Biochemistry*		

Notes:

'Modern' biotech processes (for the purpose of this report) are represented in normal font, white background.

'Traditional' biotech processes in italic, grey background.

* indicates Statistics Canada category is probably correct but needs to be reviewed.

Table A13 (cont): Definition of 'Modern' and 'Traditional' Processes Environmental Biotechnologies

SNZ Q No.	Process	Definition in Biotechnology Survey 1998/99	Stat's Canada Categ'y
	Environmental Biotechnologies: Biotechnologies used for pollution control		
7.1	*Bioaugmentation*	The process of increasing the efficiency of the naturally occurring microbial population to concentrate or accumulate specific com-pounds. This is usually achieved by adding nutrients, oxygen or water	*none*
7.2	*Bio-reactors*	Enclosed containers in which micro-organisms are maintained under controlled conditions for the purpose of creating or destroying specific compounds	*none*
7.3	*Biological Gas Cleaning*	The use of micro-organisms to break down or degrade hazardous substances in a gas stream into less hazardous or non-toxic substances	*none*
7.4	*Bio-remediation*	The use of naturally occurring or genetically modified micro-organisms to breakdown or degrade hazardous substances into less hazardous or non-toxic substances	*1270*
7.5	*Phytoremediation*	The use of plants to treat or clean environmental pollution	*1270*
7.6	*Other Environmental*		

Notes:
'Modern' biotech processes (for the purpose of this report) are represented in normal font, white background.
'Traditional' biotech processes in italic, grey background.
* indicates Statistics Canada category is probably correct but needs to be reviewed.

Table A13 (cont): Definition of 'Modern' and 'Traditional' Processes Bioprocessing Based

SNZ Q No.	Process	Definition in Biotechnology Survey 1998/99	Stat's Canada Categ'y
	Bioprocessing Based: Processing of any natural material of biological origin		
8.1	*Cell Culture*	A population of cells grown for microbiological testing, cell culture development or in fermenters to study their biology or to manufacture products	*1230*
8.2	Tissue Culture	A technique for growing cells from multi-cellular organisms in a artificial medium	1230
8.3	Embryo Culture	A technique for growing embryos from multi-embryo organisms in an artificial medium	1230
8.4	Cell Manipulation	Ability to grow and modify a range of cell types under laboratory conditions	1230
8.5	Tissue Manipulation	Ability to grow and modify a range of tissue types under laboratory conditions	1230
8.6	Embryo Manipulation	Ability to grow and modify a range of embryo types under laboratory conditions	1230
8.7	*Fermentation*	Micro-organic process in which the metabolism of sugars for energy is accompanied by the formation of alcohol and/or lactic acid and solvents. Include processes such as wine, cheese and youghurt making, brewing, yeast production etc.	*1250*
8.8	*Bioprocessing*	Production stages that include fermentation, recovery and purification	*1250*
8.9	*Biotransformation*	Conversion of one chemical or material into another using a biological catalyst	*1250*
8.10	*Bio-leaching*	Use of micro-organisms to leach metals from ore	*1260*
8.11	*Bio-pulping*	The use of enzymes to degrade wood structures to produce pulp for paper making purposes	*1260*
8.12	*Bio-bleaching*	The use of enzymes to bleach paper fibre	*1260*
8.13	*Bio-desulphurisation*	The removal of organic or inorganic sulphur from coal by bacterial or soil micro-organisms	*1260*
8.14	*Bio-pesticide manufacturing*	Biological pest control through the use of naturally occurring microbes or bacteria	*none*
8.15	*Extraction/Concentration/ Purification/Separation*	The retrieval of a compound of interest from a raw material	*1240*
8.16	*Biofiltration*	The treatment of sewage or industrial wastewaters using active biomass growing on a solid support	*none*
8.17	*Bioindicators*	The use of organisms to indicate the status of an environment	*none*
8.18	Micro Selected Breeding	Using modern biotechnological tools to acelerate selection	*none*
8.18	*Natural Products Chemistry*	The study of a biological material or a biologically-derived material using analytic methods, normally being the isolation and identification of the novel chemicals within a biological material	*1250*
8.20	*Microbio-inoculants*	Naturally occurring bacterial inoculates used to promote plant growth	*none*
8.21	Somatic Embryo-genesis	Propagation of genetically desirable plant and tree lineages by tissue culture methods	*1230* *
8.22	*Other Bioprocessing*		

Notes:
'Modern' biotech processes (for the purpose of this report) are represented in normal font, white background.
'Traditional' biotech processes in italic, grey background.
* indicates Statistics Canada category is probably correct but needs to be reviewed.

References

BIOTENZ. (2001). *Biotech21: A Biotenz Strategy for the New Zealand Biotechnology Sector in the 21st Century*.

Bud, R. (1989). History of 'Biotechnology'. *Nature, 337(6202)* 5 January, 10.

Bull, A., Holt, G., & Lilly, M. (1982). *Biotechnology: International Trends and Perspectives*.: OECD, Paris.

Eliasson, G., & Eliasson, Å. (1997). The Pharmaceutical and Biotechnological Competence Bloc and the Development of Losec. In B. Carlsson (Ed.), *Technological Systems and Industrial Dynamics* (Vol. 10). Dordrecht: Kluwer.

Frater, P., Stuart, G., Rose, D., & Andrews, G. (1995). *The New Zealand Innovation Environment*. Wellington: The Berl Foundation.

Kennedy, M. J. (1991). The Evolution of the Word Biotechnology. *Trends in Biotechnology, 9(7)* July, 218-220.

Marsh, D. (2001a, 7-9 February). *Does New Zealand Have an Innovation System for Biotechnology?* Paper presented at the The R&D Management Conference 2001: Levering Research and Technology, Wellington, NZ.

McNiven, C. (2001). *Biotechnology Use and Development 1999*. Statistics Canada. (88F006XIE No. 7)

OECD. (1999). *OECD Science, Technology and Industry Scoreboard 1999 Benchmarking Knowledge-Based Economies*. Paris: OECD.

Orsenigo, L. (1989). *The Emergence of Biotechnology*. New York: St Martin's Press.

Pattinson, W., Van Beuzekom, B., & Wyckoff, A. (2001). *Internationally Comparable Indicators on Biotechnology: A Stocktaking, A Proposal for Work and Supporting Material*. Statistics Canada. (88F0017MIE No. 9)

Pew Initiative on Food and Biotechnology. (2001). *Harvest on the Horizon: Future Uses of Agricultural Biotechnology*.

Statistics New Zealand. (2000a). *Biotechnology Survey 1998/99*. Wellington: Statistics New Zealand.

Statistics New Zealand. (2000b). *Draft Objectives for the Biotechnology Survey*. Statistics New Zealand.

Statistics New Zealand. (2001). *Modern Biotechnology Activity in New Zealand*. Wellington.

U.S. Congress. (1991). *Biotechnology in a Global Economy* (OTA-BA-494). Washington, DC: Office of Technology Assessment,.

van Beuzekom, B. (2001). *Biotechnology Statistics in OECD Member Countries: Compendium of Existing Statistics*. OECD, Paris. (STI Working Papers 2001/6)