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Selected Results of the Biotechnology Use and Development Survey 2005

by Charlene Lonmo and Chuck McNiven

Science, Innovation and Electronic Information Division (SIEID)
7-A, R.H. Coats Building, Ottawa, K1A 0T6

Telephone: 1-800-263-1136

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Note of appreciation

Canada owes the success of its statistical system to a long-standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued cooperation and goodwill.

The science and innovation information program

The purpose of this program is to develop **useful indicators of science and technology activity** in Canada based on a framework that ties them together into a coherent picture. To achieve the purpose, statistical indicators are being developed in five key entities:

- **Actors**: are persons and institutions engaged in S&T activities. Measures include distinguishing R&D performers, identifying universities that license their technologies, and determining the field of study of graduates.
- **Activities**: include the creation, transmission or use of S&T knowledge including research and development, innovation, and use of technologies.
- **Linkages**: are the means by which S&T knowledge is transferred among actors. Measures include the flow of graduates to industries, the licensing of a university's technology to a company, co-authorship of scientific papers, the source of ideas for innovation in industry.
- **Outcomes**: are the medium-term consequences of activities. An outcome of an innovation in a firm may be more highly skilled jobs. An outcome of a firm adopting a new technology may be a greater market share for that firm.
- **Impacts**: are the longer-term consequences of activities, linkages and outcomes. Wireless telephony is the result of many activities, linkages and outcomes. It has wide-ranging economic and social impacts such as increased connectedness.

The development of these indicators and their further elaboration is being done at Statistics Canada, in collaboration with other government departments and agencies, and a network of contractors.

Prior to the start of this work, the ongoing measurements of S&T activities were limited to the investment of money and human resources in research and development (R&D). For governments, there were also measures of related scientific activity (RSA) such as surveys and routine testing. These measures presented a limited picture of science and technology in Canada. More measures were needed to improve the picture.

Innovation makes firms competitive and we are continuing with our efforts to understand the characteristics of innovative and non-innovative firms, especially in the service sector that dominates the Canadian Economy. The capacity to innovate resides in people and measures are being developed of the characteristics of people in those industries that lead science and technology activity. In these same industries, measures are being made of the creation and the loss of jobs as part of understanding the impact of technological change.

The federal government is a principal player in science and technology in which it invests over five billion dollars each year. In the past, it has been possible to say only *how much* the federal government spends and *where* it spends it. Our report **Federal Scientific Activities, 1998 (Cat. No. 88-204)** first published socio-economic objectives indicators to show *what* the S&T money is spent on. As well as offering a basis for a public debate on the priorities of government spending, all of this information has been used to provide a context for performance reports of individual departments and agencies.

As of April 1999, the Program has been established as a part of Statistics Canada's Science, Innovation and Electronic Information Division.

The final version of the framework that guides the future elaboration of indicators was published in December, 1998 **(Science and Technology Activities and Impacts: A Framework for a Statistical Information System, Cat. No. 88-522)**. The framework has given rise to **A Five-Year Strategic Plan for the Development of an Information System for Science and Technology** (Cat. No. 88-523).

It is now possible to report on the Canadian system on science and technology and show the role of the federal government in that system.

Our working papers and research papers are available at no cost on the Statistics Canada Internet site at http://www.statcan.ca/cgi-bin/downpub/research.cgi?subject=193.

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Highlights

- The number of innovative biotechnology firms grew to 532 in 2005 from 490 in 2003, an increase of 9%, according to new preliminary data from the Biotechnology Use and Development Survey. This was lower than the 31% increase between 2003 and 2001 when there were 375 firms. Between 2005 and 1997, when there were 282 firms, the compound annual growth rate has been 8%.
- An innovative biotechnology firm is a firm that uses biotechnology for the purpose of developing new products or processes.
- Combined, these 532 companies generated revenues of $4.2 billion in 2005. Their spending on research and development was $1.7 billion.
- Large biotech companies, those with at least 150 employees, represented only 10% of the 532 biotech firms in 2005, but accounted for 67% of biotech revenues. Three-quarters of all companies were small firms, that is, they had fewer than 50 employees.
- By contrast, biotechnology related R&D was more equally distributed between the three sizes of firms.
- More than 70% of the innovative biotechnology firms were in three provinces: Quebec, Ontario and British Columbia. These provinces continue to comprise the bulk of Canadian biotechnology activity, accounting for more than 90% of biotechnology revenues in 2005.
- Ontario firms led the way in biotechnology revenues, research and development expenditures and employment, whereas those in Quebec accounted for the largest share of biotechnology firms.
- Biotechnology related to Human Health remained the most significant biotechnology sector in terms of number of firms, employment, R&D and revenues.
- The number of employees with biotechnology responsibilities increased to 13,400 from about 11,900 in 2003.

Introduction

Beginning with the first survey on biotechnology development in 1997, and continuing on a biennial basis since, Statistics Canada has been systematically measuring biotechnology development in Canada. The survey and questionnaire have been regularly updated and improved to reflect the latest developments in biotechnologies and in response to stakeholder requirements and improved methodological techniques. In 1999, the survey was changed to capture the use and development of biotechnology, in 2003 a section on bioproducts was added and in 2005 a nanotechnology component was added. This paper discusses some of the results of the latest survey and enters the discussion of what should come next in the development of information on biotechnology.

The survey was conducted as part of a project to develop biotechnology statistics under the Canadian Biotechnology Strategy. It targets firms that use and develop biotechnology in Canada in 2005. The survey asked the question: What are the characteristics and activities of firms that use or develop biotechnology as an important part of their activities? Data are provided on the firms' revenues, research and development activities, imports and exports, human resources, business strategy, intellectual property issues and on the use and development of biotechnology.

Overview

Between 1997 and 2005, the number of innovative biotechnology firms rose from 282 to 532. Biotechnology in Canada continued to expand between 2003 and 2005, generating revenues of over $4 billion; however the increase is at a slower pace than past years. Biotechnology companies have more than quadrupled their revenues since 1997, making biotechnology a fast growing activity. The number of biotechnology products on the market has risen from a level of 1,758 in 1997 to 2,438 in 2005. For each dollar invested in biotechnology R&D, firms generated $2.64 in biotech revenue, compared to $1.65 in 1997, $2.36 in 1999 and $2.67 in 2001 and $2.57 in 2003.

The population studied in this document is *biotechnology innovative firms*. They are also referred to in the document as biotechnology companies. These are firms that use biotechnology to develop new products or processes[1]. Biotechnology is defined using both a single definition as well as a list-based definition (OECD, 2005). Because the single definition is broad, and therefore "covers all modern biotechnology but also many traditional or borderline activities, it is recommended that this definition be accompanied by the list-based definition". Biotechnology can be defined as *"the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services"* (OECD, 2005). Biotechnology is a dynamic activity found in many industries, characterized by diverse applications in a broad range of sectors: Human Health, Agriculture, Natural Resources, the Environment, Aquaculture and Food Processing. The following list of biotechnologies can be used as interpretative guidelines to the single definition[2]:

1. The Biotechnology Use and Development Survey (BUDS) is a study of the use of a technology in which innovation occurs at the level of the process of creation. Innovation Surveys (IS) are generally based on the definition of innovation contained in the OECD/Eurostat Oslo Manual. BUDS differs from the Oslo Manual in three respects: i) the reference period: in the Oslo manual, a new product is a product that has been introduced into the market during the previous three years; BUDS instead uses the current period; ii) In an IS, innovation implies that a product has been introduced into the market. In BUDS, an innovative firm has products in development that are not necessarily on the market; iii) an innovative biotechnology product is based on a particular new technology; iv) there is also a difference in terms of the questions. While the IS refers to a product that is new or improved in a significant way, BUDS does not use that terminology for two reasons: the "new" aspect is covered by the reference period and the "significant" aspect is replaced by the link between the development of products or processes and the use of biotechnology.

2. This list of biotechnologies can be found in question 1 of the Biotechnology Use and Development Survey 2005. The list is "indicative rather than exhaustive and is expected to change over time as data collection and biotechnology activities evolve" (OECD, 2005).

The list-based definition of biotechnology techniques

DNA/RNA: Genomics, pharmacogenomics, gene probes, genetic engineering, DNA/RNA sequencing/synthesis/amplification, gene expression profiling, and use of antisense technology.

Proteins and other molecules: Sequencing/synthesis/engineering of proteins and peptides (including large molecule hormones); improved delivery methods for large molecule drugs; proteomics, protein isolation and purification, signaling, identification of cell receptors.

Cell and tissue culture and engineering: Cell/tissue culture, tissue engineering (including tissue scaffolds and biomedical engineering), cellular fusion, vaccine/immune stimulants, embryo manipulation.

Process biotechnology techniques: Fermentation using bioreactors, bioprocessing, bioleaching, biopulping, biobleaching, biodesulphurisation, bioremediation, biofiltration and phytoremediation.

Gene and RNA vectors: Gene therapy, viral vectors.

Bioinformatics: Construction of databases on genomes, protein sequences; modelling complex biological processes, including systems biology.

Nanobiotechnology: Applies the tools and processes of nano/microfabrication to build devices for studying biosystems and applications in drug delivery, diagnostics, etc.

This document is a descriptive analysis of the results of the 2005 Biotechnology Use and Development Survey. The analysis is accompanied by data tables presented for all of Canada according to size of firm, activity sector and the region/province of location.

Appendix 1 provides readers and users of the data with information on the methodology of the Survey.

Distribution of firms

There were 532 biotechnology firms in Canada an increase of 8% over the 490 biotechnology firms in Canada in 2003, compared to 375 in 2001, 358 in 1999 and 282 in 1997. Most of the increase in the number of firms between 2003 and 2005 results can be attributed to new entries into the sector. Indeed the sector is characterized by a high entry and exit numbers as firms are acquired or merge with other firms. In general firms can be described as small, with less than 50 employees, engaged in human health related biotechnology, and located in Ontario or Quebec.

Number of innovative biotechnology firms by region

Results from the 2005 survey indicate the presence of 532 innovative biotechnology firms in Canada, a growth of 9% over 2003 figures (Tables 1 and 2). Quebec, Ontario and British Columbia were once again home to the majority of firms, with Quebec once again being the home to the largest number of biotechnology firms in Canada. The proportion of firms from each region has been fairly consistent since 1999, except for the initial 1999 values when Quebec and Ontario had parity in their respective number of firms.

While the overall 2003-2005 growth rate in the number of biotechnology firms was nine percent, Quebec, Ontario and Alberta saw above average growth, while the other provinces either remained at the same level or saw declines. As can be seen in table 2, provincial growth rates tend to be quite different. The only province with consistent results every year was Quebec, which consistently sees growth in the number of resident firms.

Table 1 Number of innovative biotechnology firms, by region

	1999	2001	2003	2005
Total	**358**	**375**	**490**	**532**
Atlantic	19	23	25	25
Quebec	107	130	146	181
Ontario	111	101	129	144
Manitoba	6	11	21	19
Saskatchewan	16	17	34	18
Alberta	28	24	44	51
British Columbia	71	69	91	94

Source: Canadian Trends in Biotechnology
Statistics Canada, Biotechnology Use and Development Survey 2005

Table 2 Growth rates of firm counts, by region

	1999/2001	2001/2003	2003/2005
	percentage growth, rounded to the nearest integer		
Total	**5**	**31**	**9**
Atlantic	21	9	0
Quebec	21	12	24
Ontario	-9	28	12
Manitoba	83	91	-10
Saskatchewan	6	100	-47
Alberta	-14	83	16
British Columbia	-3	32	3

Source: Canadian Trends in Biotechnology
Statistics Canada, Biotechnology Use and Development Survey 2005

Distribution by sector[3]

Between 2003 and 2005, the number of firms increased in Human Health and Environment sectors. The Human Health sector enjoyed the biggest absolute increase in the number of firms, rising from 262 firms in 2003 to 303 in 2005.

Human Health remained the dominant biotechnology sector, with 57% of all biotechnology firms in this sector in 2005. Agriculture and Food Processing firms accounted for 24% of all biotech firms, while Environment biotech firms accounted for 10%. The number of firms in Environment biotechnology remained fairly constant from 1999 through 2003, but increased by 16, or 42%, between 2003 and 2005.

Table 3 Number of innovative biotechnology firms, by sector

	1999	2001	2003	2005
Total	**358**	**375**	**490**	**532**
Human health	150	197	262	310
Agriculture and food processing	119	113	138	146
Environment	35	33	38	60
Other	54	32	52	16

Source: Canadian Trends in Biotechnology
Statistics Canada, Biotechnology Use and Development Survey 2005

Table 4 Growth rates of firm counts, by sector

	1999/2001	2001/2003	2003/2005
	percentage growth, rounded to the nearest integer		
Total	**5**	**31**	**9**
Human health	31	33	18
Agriculture and food processing	-5	22	6
Environment	-6	15	58
Other	-41	63	-69

Source: Canadian Trends in Biotechnology
Statistics Canada, Biotechnology Use and Development Survey 2005

Distribution by size[4]

Small firms continued to account for the majority of all firms in biotech. In 2005, small firms with fewer than 50 employees accounted for three-quarters of all biotech firms, while medium sized firms with 50 to 149 employees accounted for 16% and large firms with 150 or more employees accounted for the remaining 10%. This represented a continuation of patterns seen in earlier periods such as in 2003 when small firms accounted for 72% of the total number, followed by medium-sized firms (16%) and large firms (13%), and 2001, when small firms represented 71% of the total, medium-sized firms 17% and large firms 12%.

3. Firms are grouped by sector based on their main product. In 2003, sectors are based on the answers to question 12 of the Survey questionnaire.
4. The size of a company is determined by the number of employees. Small firms are those that employ less than 50 employees, medium-sized firms between 50 and 149 and large firms 150 employees and more.

Between 2003 and 2005, the number of firms increased in all size categories the two smaller size categories, but fell somewhat for the largest size category.

Table 5 Number of firms, by size

	1999	2001	2003	2005
Total	**358**	**375**	**490**	**532**
Small (0 to 49 employees)	270	267	352	397
Medium (50 to 149 employees)	51	62	77	83
Large (150 employees and over)	37	46	61	52

Source: Canadian Trends in Biotechnology
Statistics Canada, Biotechnology Use and Development Survey 2005

Table 6 Growth rates of firm counts, by size

	1999/2001	2001/2003	2003/2005
	percentage growth, rounded to the nearest integer		
Total	**5**	**31**	**9**
Small (0 to 49 employees)	-1	32	13
Medium (50 to 149 employees)	22	24	8
Large (150 employees and over)	24	33	-15

Source: Canadian Trends in Biotechnology
Statistics Canada, Biotechnology Use and Development Survey 2005

Financial Data

Total firm revenues and biotechnology revenues

Table 7 Innovative firms with revenues and biotech revenues by sector, region and size, 2005

	All innovative biotech firms	Innovative firms with biotech revenue	Innovative biotech firms with revenue from any source
Canada	**532**	**373**	**438**
Biotechnology sector			
Human health	310	197	232
Agriculture and Food Processing	146	117	133
Environment	60	46	57
Other	16	13	15
Region			
Atlantic	25	22	24
Quebec	181	117	142
Ontario	144	115	125
Manitoba	19	9	13
Saskatchewan	18	13	15
Alberta	51	32	42
British Columbia	94	65	78
Size			
Small (less than 50 employees)	397	273	316
Medium (50 to 149 employees)	83	65	75
Large (150 or more employees)	52	35	47

Source: Statistics Canada, Biotechnology Use and Development Survey, 2005
Preliminary data; subject to revision.

Firms engaged in development of human health biotechnologies dominate the biotechnology sector generally, accounting for over one half (58%) of all innovative biotechnology firms. They account for 53% of all innovative firms with revenues from any source and also 53% of firms with revenues from biotechnology. Of all human health biotech firms, 64% had biotech revenue and 75% had revenue from any source.

The next most significant sector in terms of the number of firms, agriculture and food processing, reported higher levels of firms with biotechnology revenues at 80% and 91% from any source. It is likely that the human health sector lags other sectors due to the complexities of the regulatory process to establish that a product is safe and effective and to determine the appropriate dosing for each product.

While Atlantic Canada did not report a large proportion of biotechnology firms, those they have were most likely to report biotechnology revenues. By contrast firms located on the Prairies and in Quebec were less likely to report any biotechnology revenues, suggesting that these firms were at earlier stages of development of their technologies. Ontario also reported a comparatively high proportion of firms with biotechnology revenues.

Interestingly, the proportion of firms with biotechnology revenues did not vary clearly by size. Two-thirds of both small and large firms reported some biotechnology revenues and almost four in five medium size firms had biotech revenues. By contrast the larger firms were more likely to report revenues from any source, which indicates that the larger firms have other activities from which to draw revenues to fund the development of biotechnology products and processes while the smaller firms may have to rely on other sources of funds such as venture capital, private placement or issuing shares.

Table 8 Biotechnology revenues, 1997 to 2005

	1997	1999	2001	2003	2005
	(millions of 2002 constant dollars)				
Canada	**876**	**2,075**	**3,609**	**3,719**	**3,812**
Biotechnology sector					
Human health	449	1,103	2,488	1,935	2,692
Agriculture and Food Processing	347	755	835	1,680	982
Environment	53	48	271	35	120
Other	27	168	14	70[E]	17[E]
Region					
Atlantic	37	30	22	20	30
Quebec	241	590	1,532	465	417
Ontario	391	676	1,391	1,961	2,513
Manitoba	36	73	100	140[E]	149
Saskatchewan	60	461	21	91	48
Alberta	60	96	123	288	124
British Columbia	51	147	419	754	532[E]
Size					
Small (less than 50 employees)	231	265	527	453	366
Medium (50 to 149 employees)	217	314	858	880	879
Large (150 or more employees)	429	1,495	2,223	2,386	2,567

Note: Implicit chain price index from CANSIM Table 380-0056
Source: Statistics Canada, Biotechnology Use and Development Survey
Data for 2005 is preliminary; subject to revision.

Between 1997 and 2005 real biotechnology revenues have increased four-fold, from $876 million in 1997 to $3,812 million in 2005. The human health sector continued to account for the largest share of biotechnology revenues. Revenues in the agriculture and food processing sector fell between 2003 and 2005, but this sector remained second overall in terms of revenues from biotechnology.

The general distribution of revenues from biotechnology did not change substantially between the provinces from 2003 to 2005. Ontario continued to report the highest levels of biotechnology revenues, followed by Quebec and then British Columbia. Atlantic Canada, Ontario and Manitoba reported somewhat higher levels of biotech revenues in 2005, while Quebec, Saskatchewan, Alberta and British Columbia reported lower biotech revenues in 2005 as compared with 2003.

As in previous years, the majority of biotech revenue was reported by large firms, those with 150 or more employees. Revenues reported by the various size groups did not change substantially between 2003 and 2005.

Table 9 Biotechnology revenue and total revenue by sector, region and size, 2005

	Biotechnology revenues	Revenues from all sources
	(millions of current dollars)	
Canada	**4,201**	**53,614**
Biotechnology sector		
Human health	2,967	7,562
Agriculture and Food Processing	1,082	F
Environment	132	F
Other	19[E]	50[E]
Region		
Atlantic	33	59
Quebec	459	7,774[E]
Ontario	2,769	6,726
Manitoba	164	F
Saskatchewan	53	F
Alberta	137	27,747[E]
British Columbia	586	F
Size		
Small (less than 50 employees)	403	716
Medium (50 to 149 employees)	969	1,932
Large (150 or more employees)	2,829	50,966

Source: Statistics Canada, Biotechnology Use and Development Survey, 2005
Preliminary data; subject to revision.

In terms of the levels of biotechnology revenues reported, the innovative firms in human health dominated the biotechnology sectors accounting for 71% of all biotechnology revenues. Agriculture and food processing accounted for a further 26% and environmental biotechnologies accounted for most of the remainder at 3%.

Ontario reported the lion's share of biotech revenues at 66%, followed by British Columbia (14%) and Quebec (11%).

Overall, revenues from biotechnology account for only 8% of all revenues of innovative biotechnology firms. The intensity of reliance on revenues from biotechnology varies by firm size and sector, as well as by geographic region.

Firms in the human health sector reported the highest proportion of revenues from biotechnology at almost 40% of total revenues.

Smaller firms and medium sized firms relied on revenues from biotechnology as they comprised at least half of these firms' total revenues. By contrast, for larger firms biotechnology revenues accounted for only 6% of total revenues.

There were also variations by province. Firms in Atlantic Canada reported the highest proportion of revenues from biotech while those in Alberta reported the lowest.

Amounts of funding for biotechnology firms

Biotechnology firms frequently engage in intensive R&D efforts to create new products and to meet regulatory requirements for these new products. If they have no sales or their sales are not sufficient to cover costs, firms need alternative sources of funds to maintain these activities.

Table 10 Amount of funding raised by biotechnology firms in 2005, by sector and size	
	millions of current dollars
Canada	**1,350**
Biotechnology sector	
Human health	1,129
Agriculture and Food Processing	198
Environment	x
Other	F
Size	
Small (less than 50 employees)	664
Medium (50 to 149 employees)	518
Large (150 or more employees)	167

Source: Statistics Canada, Biotechnology Use and Development Survey, 2005
Preliminary data; subject to revision.

In 2005, biotech firms raised $1.35 billion from sources other than revenues to fund their activities. The vast majority of this funding was directed to firms in the human health sector. This is not surprising given the time it takes to bring a product to market (often more than 10 years) and the amount of research and testing required to meet health and safety regulations. Products in other sectors may require some form of regulatory approval but typically the hurdles are less onerous.

It is interesting to note that small firms raised the most funds, followed closely by medium sized firms. The largest firms raised the least amount of funds, implying that they are largely able to maintain their activities through revenues from sales.

Sources of funding for biotechnology firms

Firms seeking funding have a range of sources that may be available to them ranging from loans to venture capital to sale of shares. Each source has its benefits and costs. Venture capitalists frequently want control of the firm in return for their funding, while trading shares on public markets requires the time and expense of meeting the regulatory disclosure requirements. Traditional loans involve debt instead of equity, but many banks do not fund firms without a reasonably predictable revenue stream.

Table 11 Types of sources of funding raised by biotechnology firms, 1999-2005				
	1999	2001	2003	2005
	(millions of 2002 constant dollars)			
All sources of funding	**2,278**	**991**	**1,640**	**1,225**
Venture Capital	464	507	362	417
Private placement	..	..	484[E]	289
Initial/Secondary Public Offerings	58	..	239	289
Debt	242	20	101	57
Other	1,513	464	455	172

Note: Implicit chain price index from CANSIM Table 380-0056
Note: Data in this table should be interpreted with caution since the sources of funding categories have been modified in every year of the survey. For example, in 1999, the "other" category included private placements, in 2001 it included public offerings, collaborative arrangements and European-based venture capital. Data from 2003 and 2005 are the most directly comparable.
Source: Statistics Canada, Biotechnology Use and Development Survey, 2005
Preliminary data; subject to revision.

In 2005 the largest single source of funding was venture capital, followed by private placement and Initial and Secondary Public Offerings (IPO and SPO).

R&D expenditures by biotechnology firms

Table 12 Biotechnology R&D by sector, region and size, 1997 to 2005

	1997	1999	2001	2003	2005
	(millions of 2002 constant dollars)				
Canada	**532**	**881**	**1,352**	**1,439**	**1,546**
Biotechnology sector					
Human health	441	749	1,190	1,274	1,350
Agriculture and Food Processing	57	78	108	86	151
Environment	11	x	16	36[E]	34[E]
Other	24	x	37	45[E]	11[E]
Region					
Atlantic	15	6	14	7	9
Quebec	142	359	353	474	507
Ontario	237	237	399	439	589
Manitoba	13	21	31	54[E]	76
Saskatchewan	20	30	10	22	13
Alberta	22	86	119	85	93
British Columbia	83	140	425	358	259
Size					
Small (less than 50 employees)	208	273	438	479	524
Medium (50 to 149 employees)	134	113	608	677	446
Large (150 or more employees)	191	687	306	284	576

Note: Implicit chain price index from CANSIM Table 380-0056
Source: Statistics Canada, Biotechnology Use and Development Survey
Data for 2005 is preliminary; subject to revision.

Biotechnology-related R&D expenditures continued to grow between 2003 and 2005, representing 11% of total industrial R&D[5] in 2005. The human health sector accounted for by far the largest component of biotechnology-related R&D. This is likely due to the substantial expenditures required to demonstrate the safety and effectiveness of any product proposed for human health use. The agriculture and food processing sector reported a substantial increase in R&D, while firms in the environment sector reported little change in biotechnology-related R&D expenditures.

Most provinces and Atlantic Canada reported increases in biotechnology-related R&D spending, with the exceptions of Saskatchewan and British Columbia.

When examined by firm size, there were shifts in the patterns of biotech R&D expenditures between 2003 and 2005. In 2003 medium sized firms reported the highest biotechnology-related R&D expenditures, followed by small firms and lastly larger firms. In 2005, the largest firms reported the highest levels of biotechnology-related R&D expenditures, followed by small firms and lastly the medium sized firms. Generally, the distribution between the three size groups was more equal in 2005 than 2003.

5. Science Statistics, November 2007, Statistics Canada, Catalogue No.88-0001-X, vol.31, no.6, Table 1-1, p.9

Table 13 Biotechnology R&D and total R&D by sector, region and size, 2005

	Biotech R&D expenditures	Total R&D expenditures
	(millions of current dollars)	
Canada	**1,704**	**2,529**
Biotechnology sector		
Human health	1,488	1,993
Agriculture and Food Processing	166	200
Environment	38	317
Other	12[E]	19[E]
Region		
Atlantic	10	11
Quebec	559	909
Ontario	649	940
Manitoba	84	93
Saskatchewan	14	16
Alberta	103	251
British Columbia	285	309
Size		
Small (less than 50 employees)	577	606
Medium (50 to 149 employees)	492	562
Large (150 or more employees)	635	1,361

Source: Statistics Canada, Biotechnology Use and Development Survey, 2005
Preliminary data; subject to revision.

Once again, firms in human health dominated innovative firms in the biotechnology sector in Canada in 2005, this time in terms of expenditures for biotechnology research and development. Almost nine in ten (87%) biotech R&D dollars were spent by human health firms. The next most significant sector was agriculture and food processing at 10%.

Ontario reported the highest level of biotechnology-related R&D spending with 38% of all such expenditures. Ontario was followed closely by Quebec which reported 33% of all biotech R&D spending in Canada. British Columbia accounted for a further 17%, so that the top three provinces accounted for 88% of all biotechnology-related R&D spending in Canada.

Unlike figures for biotech revenues, the estimates for biotech R&D are much more evenly distributed by firm size, with small firms accounting for 34%, medium sized firms 29% and large firms 37% of the total. This is consistent with the view that many of the smaller firms are in earlier stages of development with less revenues, but very intense R&D efforts.

Consistent with the greater diversification of revenues for larger firms, larger firms reported a lower proportion of their R&D expenditures that were devoted to development of biotechnologies. For the small firms 95 cents of every R&D dollar was spent on biotechnology-related R&D, while for large firms the figure was 47 cents. This is still much more biotechnology-focused than their respective shares of biotechnology-related revenues.

Human Resources

Biotechnology-related employment grew by 13% between 2003 and 2005, from 11,863 to 13,433 employees. This growth occurred in the human health and environment sectors. Biotechnology employment growth occurred in Ontario, Quebec and Alberta, while the other provinces reported decreases in biotechnology-related employment. In terms of firm size, growth in biotech employment occurred in small firms, which reported growth of 23% between 2003 and 2005.

Table 14 Biotechnology employees by sector, region and size, 1997 to 2005

	1997	1999	2001	2003	2005
Canada	**9,019**	**7,695**	**11,897**	**11,863**	**13,433**
Biotechnology sector					
Human health	6,280	5,433	8,675	9,255	10,865
Agriculture and Food Processing	1,542	1,323	2,264	1,832	1,755
Environment	291	323	709	246	719
Other	906	616	249	531[E]	94
Region					
Atlantic	490	181	402[E]	206	132
Quebec	2,722	2,557	4,710	3,700	4,554
Ontario	3,416	2,547	3,346	3,508	5,203
Manitoba	209	257[E]	936[E]	1,213[E]	491
Saskatchewan	351	289	262	337	167
Alberta	789	574	494	727	944
British Columbia	1,042	1,191	1,746	2,173	1,942
Size					
Small (less than 50 employees)	2,895	2,902	3,144	3,619	4,460
Medium (50 to 149 employees)	2,299	1,323	3,230	3,746	3,613
Large (150 or more employees)	3,825	3,470	5,523	4,498	5,360

Source: Statistics Canada, Biotechnology Use and Development Survey, 2005
Data for 2005 are preliminary; subject to revision.

Table 15 Biotechnology employees and total employees of biotechnology firms by sector, region and size, 2005

	Employees with biotechnology-related responsibilities	Total employees
Canada	**13,433**	**86,889**
Biotechnology sector		
Human health	10,865	26,158
Agriculture and Food Processing	1,755	13,758
Environment	719	46,668
Other	94	306
Region		
Atlantic	132	374
Quebec	4,554	22,935
Ontario	5,203	14,252
Manitoba	491	5,215
Saskatchewan	167	654
Alberta	944	32,323
British Columbia	1,942	11,137[E]
Size		
Small (less than 50 employees)	4,460	5,809
Medium (50 to 149 employees)	3,613	6,160
Large (150 or more employees)	5,360	74,920

Source: Statistics Canada, Biotechnology Use and Development Survey, 2005
Preliminary data; subject to revision.

The human health sector accounted for the vast majority of all employees with biotechnology-related responsibilities. Eighty percent of all employees with biotechnology-related responsibilities were employed by innovative human health biotechnology firms. The concentration of employees with biotechnology-related responsibilities is also higher in the human health sector than in either agriculture and food processing or environment sectors. In fact, the proportion of employees in the environment sector with biotech-related responsibilities is quite low, while the overall number of employees is quite high. This suggests that there are some large firms which are developing environmental biotechnologies, but that these environmental biotechnologies are not central to the activities of the firm.

As with many of the other biotechnology statistics, Ontario and Quebec accounted for most of the biotechnology-related employment. Ontario accounted for 39%, Quebec 34% and British Columbia 14%.

The figures on biotech employment largely mirrored those for biotech R&D, with the distribution of employment between small, medium and large firms fairly equal. Small firms accounted for 33% of biotechnology employment, medium firms 27% and large firms 40%. This is likely to some degree due to two facts: researchers have traditionally been a large component of biotech personnel and the largest single component of R&D expenditures is typically wages and salaries[6] of those engaged in research.

As with revenue and R&D expenditures, the intensity of focus on biotechnology is greatest amongst the small firms. In these firms, almost eight in ten employees has biotechnology-related responsibilities, while in the large firms the figure is less than one in ten.

6. Industrial Research and Development 2005 intentions, Statistics Canada, January 2006, 88-202-XIE, Science, Innovation and Electronic Information Division, pages 27 and 55 (Table 6).

Other firm characteristics

Average age of biotechnology firms

Innovative biotechnology applications are fairly recent in origin and many of the firms established to exploit these technologies are also new.

Table 16 Average age of biotechnology firms as of 2005, by sector and size

	years
Canada	**14**
Biotechnology sector	
Human health	10
Agriculture and Food Processing	18
Environment	24
Other	13
Size	
Small (less than 50 employees)	9
Medium (50 to 149 employees)	19
Large (150 or more employees)	44

Source: Statistics Canada, Biotechnology Use and Development Survey, 2005
Preliminary data; subject to revision.

Overall, the average age of biotech firms in Canada was 14 years, as of 2005. Not surprisingly, small firms were also the youngest firms, averaging 9 years of operation, while the largest firms averaged 44 years of operation. This is typical of firms in the economy at large as it usually takes many years to grow a firm to a larger size.

The average age of biotech firms also varied by biotechnology sector. Firms in the human health sector were youngest and those in environmental biotechnologies were oldest. This may indicate that large, established firms are seeking to mitigate the environmental impacts of their traditional activities. Firms in agriculture and food processing averaged 18 years of operation.

Publicly traded biotechnology firms

Biotechnology firms may choose to seek funding through listing on stock exchanges, granting equity in the form of tradable shares to multiple shareholders. This strategy typically requires that the particular technology being pursued by the firm is developed to a point where it would be of interest to potential shareholders and that the firm is prepared to commit the resources to meet the listing requirements of the particular exchange where the shares are traded.

Table 17 Proportion of biotechnology firms which are publicly traded, by sector and size

	percent
Canada	**25**
Biotechnology sector	
Human health	33
Agriculture and Food Processing	12
Environment	18
Other	0
Size	
Small (less than 50 employees)	20
Medium (50 to 149 employees)	32
Large (150 or more employees)	49

Source: Statistics Canada, Biotechnology Use and Development Survey, 2005
Preliminary data; subject to revision.

Overall, one quarter of all biotechnology firms in Canada were publicly traded in 2005. As with average age, the proportion of firms which were publicly traded varied by both size and sector. Biotechnology firms in the human health sector where more likely to be publicly traded than those in other sectors, possibly due to the need for income streams from activities other than sales in order to maintain operations while a product is under development and testing for compliance with health standards and regulations. Not surprisingly, larger firms were most likely to be publicly traded, while smaller firms were least likely to be publicly traded.

Country of control of biotechnology firms

Biotechnology firms are typically small and small firms in the broader economy are more likely to be Canadian-controlled. Data from the Biotechnology Use and Development Survey is consistent with the larger economy.

Table 18 Proportion of biotechnology firms which are Canadian-controlled, by sector and size

	percent
Canada	**84**
Biotechnology sector	
Human health	81
Agriculture and Food Processing	88
Environment	89
Other	88
Size	
Small (less than 50 employees)	89
Medium (50 to 149 employees)	81
Large (150 or more employees)	46

Source: Statistics Canada, Biotechnology Use and Development Survey, 2005
Preliminary data; subject to revision.

The vast majority of biotechnology firms in Canada are Canadian-controlled. This proportion did not vary greatly by sector, with only Human Health firms somewhat less likely to be Canadian-controlled, but it did vary significantly by size. Larger biotech firms were less likely to be Canadian-controlled, while the smallest firms were the most likely to be Canadian-controlled.

Future Directions and Challenges

The biotechnology surveys have provided a clear, consistent and comparable picture of the biotechnology sector in Canada. This is currently unique in the world. However, many questions remain outstanding, not the least of which is: what are the social and economic impacts of biotechnology?[7]

To begin to answer these questions the Statistics Canada has undertaken surveys on firms producing novel bioproducts and functional foods and/or nutraceuticals. These surveys, combined with the Biotechnology survey, provide a partial picture of the state of uptake and the direction of impacts these technologies may have. Currently the Biotech survey provides some measures of impacts but is focused primarily on the development of new products and processes. It does not measure the full impact in terms of revenues or employment of all firms which use, but do not develop biotechnology. As these technologies become more accepted and understood by industry they become more broadly applied as a means for production, often involving transformation of biomass to bioproducts.

Biotechnology has been labelled an "enabling technology". Enabling technologies (ICT, biotechnology and nanotechnology) were identified by the federal government in ***Mobilizing Science and Technology to Canada's Advantage*** as "underpinning many of the most transformative advances in science and technology". These advances form the foundation for opportunities to build strategic advantages for Canada in a competitive global marketplace. The potential impact of these enabling technologies touches all four of the government's stated priorities: environment; energy; health and life sciences; and information and communications technologies.

Two[8] of these enabling technologies are also "emerging" technologies, that is, they are scientific foundations are comparatively recent and their impacts have not yet been realized. Emerging technologies share a number of characteristics but most notably they are technologies which have a broad range of potential applications and their incorporation into market production systems is in the earliest stages. These technologies are assumed to follow a path from discovery to incremental improvement and diffusion as they move out of the laboratories and into the factory.

The transition of biotechnology from the lab to the market was first brought to the general public's attention in the March 1981 edition of Time, when the magazine put Herbert Boyer, co-founder of Genentech one of the first pure biotechnology firms in the world, on its cover. Since that time Genentech has grown from a firm with no revenues to anticipated revenues of $9.28 billion (US) in 2006 and global biotech firms reported over $70 billion (US) in revenues in 2007.[9]

There are also some modifications of the trajectory for enhanced regulatory obligations that apply to all human health products and to any genetically modified life form that will be released into the environment. These technologies continue to be actively developed in university laboratories but have also begun the shift into the marketplace, with new products for treatment of disease, production of bio fuels and new techniques for environmental remediation for a variety of traditional resource industry activities.

The Life Sciences statistics program, based on the Emerging Technologies Survey, provides measures of science-based activities and their transition to the marketplace for the first three of these priority areas, through statistics on firm active in biotechnologies, bioproducts and functional foods and nutraceuticals.

7. For complete discussion of this topic see Rose and McNiven.
8. While ICTs have transformed society and will continue to have profound impacts, both economic and social as the ever increasing power of computing systems is combined with more sophisticated software for specialized and general applications, they are sufficiently well developed that they are no longer truly "emerging". Biotechnology and nanotechnology, by contrast, are in much earlier stages of development.
9. http://reuters.com/article/mergerNews/idUSL1534079120070415

This enables an understanding of the current state of the sector and its technologies. But if the surveys are continued over time it also the ability to begin to determine the trajectory of development of biotechnology in Canada and the impacts of government policies on these firms. By providing regular, consistent snapshots of the biotechnology sector, Statistics Canada surveys provide an important means of measuring impacts over time. Through the Emerging Technologies Survey, the potential has been developed to provide similar statistics for nanotechnology firms as well.

Researchers from the academic community rely on biotechnology databases and the knowledge of Statistics Canada staff in support of their research. Changes in the program would have repercussions since they would then be unable to fulfill commitments to their major funding agencies.

Biotechnology is an important transformative technology, and some biotechnology applications, existing or potential, raised important and legitimate public concerns. This makes policy choices more difficult to make and to sell. Political support is uneven across capitals. Meanwhile, as exemplified by the number of firms participating and the level of investment in R&D, biotechnology keeps making progress and is diffusing through the economy. This requires monitoring. Increasing our knowledge of living mechanisms, biotechnology allows for the transformation of existing processes but, more important, for a substitution of inputs towards the use of biomass, a renewable resources, therefore with a potential to also become sustainable.

Existing surveys, such as the Biotechnology Use and Development Survey and the Federal S&T Expenditures on Biotechnology, provide important information on the biotechnology related activities performed by the industrial sector and, to some extent, government departments. More information could be obtained on the activities of the higher education sector.

The progressive switch towards more use of biomass, new product and process innovation may have important substitution effects in the economy that requires monitoring if countries wish to minimize losses, and maximize benefits to their population. As often observed, large substitution effects in the economy trigger employment and capital losses in some industrial sectors, with potential for job creation and capital formation in others. An important motive for the monitoring of these changes is the need to minimize the costs associated with this possible shift.

Other members of the OECD are in the process of building biotechnology statistics programs and some data are now available to permit comparisons between countries.

Table 19 Key biotechnology statistics from selected OECD member states, 2003

Selected OECD members	Biotechnology revenues	Biotechnology R&D	Biotechnology employment
	millions PPP dollars		
Canada	3,842	1,488	11,864
France	2,146	671	8,923
Germany	3,222	1,353	17,277
United Kingdom	5,701	2,007	22,406
United States	51,655	16,834	130,305

Source: OECD Biotechnology Statistics – 2006[10]

The data indicate that Canada has a sizeable biotechnology sector in comparison with larger countries in Europe, such as France and Germany. They also show that the Canadian biotechnology sector is comparatively R&D intensive with a ratio of sales to R&D that is lower

9. © OECD 2006, www.sourceoecd.org/9264015825, pp.41-43

than all but Germany, while the United States and France report higher levels of sales per unit of R&D.

Historically, Statistics Canada's biotechnology statistics program has been funded solely through the Canadian Biotechnology Secretariat, a coordinating agency which is now defunct. In order to continue to produce statistics on biotechnology firms other funding sources will need to be secured. The implications to relationships with others would not be confined to Canada. Statistics Canada has been very active on the international scene, for example chairing the OECD Ad Hoc Committee on Biotechnology Statistics and leading in the development internationally comparable statistics for biotechnology, as well as development work on bioproducts and nanotechnology. This ongoing process that demonstrates Canada's leadership in biotechnology statistics would be jeopardized, potentially harming Canada's credibility in other areas. The Statistics Canada biotechnology statistics program regularly provides assistance to other countries, who view Canada as a leader in the world, in the development of biotechnology statistics. Should the Biotechnology statistics program be unable to secure alternative support, these activities would cease.

Appendix 1 - Methodology

The Biotechnology Use and Development Survey (BUDS), administered by the Science, Innovation and Electronic Information Division (SIEID), provides information on companies developing innovative products or processes using biotechnologies**.** The 2005 version of the survey also provides information about the key characteristics of firms that are using or developing nanotechnology.

The survey's target population includes all firms, in Canada, in selected NAICS codes, supplemented by other sources of information from industry associations, etc. The establishments of an enterprise located in the same province and industry were grouped to form the statistical unit. Excluded from the survey were not-for-profit organizations, universities, government laboratories, hospitals. In addition, respondents had at least $100,000 in R&D expenditures or at least 5 employees according to the Business Register.

The questionnaire was prepared with active input from partners and in consultation with a group of biotechnology experts with a variety of specialties and interests. Following the initial design work, the questionnaire was presented to a sample of potential respondents, whose comments on the design and content were incorporated into the final version. The 2005 survey questionnaire included a section on nanotechnology.

The survey was conducted in two stages. First, the Emerging Technology Survey, a simple questionnaire with five Yes/No questions was mailed to 11,800 firms. The list of recipients was compiled from the list of firms identified in previous Biotechnology Use and Development Surveys, from the set of firms identified by the Business Register as belonging to a predetermined list of NAICS codes and finally firms identified by other means as involved in biotechnology or nanotechnology.

A section on nanotechnologies was also included in the questionnaire. Stratification was made using these 3 variables: NAICS, province and size. Size is based on the number of employees of the provincial enterprise: i) 0-49 employees; ii) 50-149 employees and iii) 150 employees and more.

A challenge facing the survey and indeed all research into the nature of an emerging technology is the fact that these technologies are not a single product or process, nor a single group of products or processes. They are a broad spectrum of products and processes spanning Human Health, Agriculture, the Environment and other industries and classifications. The sampling techniques are consistent with this situation, and the sample reflects not a single well-defined industry but developing sectors with a variety of characteristics, some known and some unknown.

Responding to this survey was mandatory. Data were collected directly from survey respondents. Data were collected through respondent completed questionnaires in paper format (mail or fax) and electronic format (e-mail) which were then returned by mail or fax.

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Catalogued publications

Science, Technology and Innovation statistical publications

88-001-XIE Science statistics
88-003-XIE Innovation analysis bulletin
88-202-XIE Industrial research and development, intentions (annual)
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