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Trends in Canadian Biotechnology Activity: 1997 to 2001

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Symbols

The following standard symbols are used in Statistics Canada publications:

.	not available for any reference period
..	not available for a specific reference period
…	not applicable
0	true zero or a value rounded to zero
0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the Statistics Act
^{E}	use with caution
F	too unreliable to be published

Note: Due to rounding, components may not add to totals

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.

Table of Contents

List of tables:

List of figures:

List of appendixes:

Highlights:

- In 2001, Canada had 375 innovative biotechnology firms, up 5% from 1999 and up 33% from 1997. More than 70% of these firms are small, and nearly half are in the Human Health sector.
- Between 1999 and 2001, some small firms moved into higher size categories. Also, some biotechnology firms moved from one sector of activity to another.
- Together, Quebec, Ontario and British Columbia account for 80% of the Canadian population of innovative biotechnology firms in 1999 and 2001.
- Between 1999 and 2001, the revenues generated by biotechnology firms grew by 83% in Canada, an increase reflected in all size categories. This growth rate exceeded that for biotechnology R&D expenditures (62%).
- Together, Quebec, Ontario and British Columbia accounted for more than 90% of biotechnology revenues in 2001.
- Even though small firms generated a smaller proportion of total revenues in 2001 (15%), their situation improved in relation to previous years, doubling their revenues compared to 1999.
- The ratio of biotechnology exports to imports was 3 to 1 in 1999 and appeared to stabilize at 2 to 1 in 2000 and 2001.
- Whereas until 1999, the Human Health sector accounted for the largest share of biotechnology exports (57% in 1997 and 1999), the Agriculture and Food Processing sector led the way (58%) in 2001.
- Between 1997 and 2001, biotechnology R&D expenses almost tripled, going from $494 million to $1.3 billion.
- In 2001, the biotechnology revenues-to-R&D ratio for the Agriculture and Food Processing sector was 7.72, approximately four times higher than in the Human Health sector.
- In 2001, innovative biotechnology firms together raised capital totaling approximately $980 million. While down 54% from the 1999 level, this amount is twice as large as in 1997.
- Among small firms, only one company in two managed to meet its financing target, compared to four companies in five for medium-sized firms and two companies in three for large firms.
- Whereas biotechnology employment was found to have declined 15% between 1997 and 1999, it increased by more than 50% between 1999 and 2001.

Introduction

Although a recent phenomenon, biotechnology in Canada is booming. The number of innovative biotechnology firms grew by 33% between 1997 and 2001, going from 282 to 375. Together, these firms generated $3.6 billion in revenues, up more than 300% compared to 1997. The number of biotechnology products on the market went from 1,758 in 1997 to more than 9,600 in 2001. For every dollar invested in biotechnology R&D, companies generated $2.67 in biotechnology revenues in 2001 compared to $1.65 and $2.36 respectively in 1997 and 1999. Also, whereas biotechnology employment was found to decline between 1997 and 1999 (-15%), it increased by more than 50% in the more recent period.

However, to support this growth, firms need capital. And despite a 100% increase in the total amount of capital raised between 1997 and 2001, the situation for some firms—especially small ones—remains a challenge that is often difficult to overcome. In 2001, of the 109 small firms reporting that they had succeeded in raising capital, only one in two reported reaching its target; the ratio was four in five among medium-sized firms and two in three among large firms.

In this paper, the population studied consists of "*innovative biotechnology firms*." They are referred to as "biotechnology firms" in the rest of the paper. These are firms that use biotechnology to develop new products or processes.[1] Biotechnology is not limited to a particular industry. It is a dynamic activity characterized by various applications in a varied range of sectors: Human Health, Agriculture, Natural Resources, Environment, Aquaculture and Food Processing.

There have been three previous biotechnology surveys. The first, the Biotechnology Use Survey - 1996, examined the use of biotechnology in selected Canadian sectors. The second, the Biotechnology Firm Survey – 1997, focused on firms actively engaged in research and development and seen as innovative in biotechnology. The third, the Biotechnology Use and Development Survey – 1999, had the same objectives as the 2001 survey; both combine elements of the previous surveys (1996 and 1997) in order to provide statistics on biotechnology. They provide data on Canadian biotechnology firms from two perspectives: as biotechnology users and as biotechnology innovators. This article includes data tables and a brief descriptive analysis, designed to help readers and data users better understand and interpret the concepts and the context of the data. Readers are strongly encouraged to acquaint themselves with the concepts and context in order to have a good understanding of the data and interpret them accurately.

1. The Biotechnology Use and Development Survey (BUDS) examines the use of technology that entails innovation in the creative process. Surveys of innovation (SIs) are generally based on the definition of innovation provided in the Oslo Manual of the OECD/Eurostat. BUDS differs from the Oslo Manual in three respects: i) the reference period: in the Oslo Manual, a new product is one that was brought onto the market in the past three years; BUDS instead uses the current period; ii) in SIs, innovation means that a product has been brought onto the market, whereas in BUDS, an innovative firm has products in development that are not necessarily on the market; iii) an innovative biotechnology product is considered innovative on the basis of a specific new technology; iv) there is also a difference with respect to the questions asked. Whereas SIs refer to a new or significantly improved product, this terminology is not used in BUDS, for two reasons: the newness aspect is covered by the reference period, and the significance aspect is replaced by the link between the development of products or processes and the use of a new technology.

This article aims at providing a portrait of the evolution of some key indicators of the Canadian biotechnology innovators from 1997 to 2001[2]. The analysis is based on the results of the Biotechnology Firm survey – 1997 and the Biotechnology Use and Development Survey 1999 and 2001. The data and analyses are presented for Canada and distributed by the size of the firm, its sector and the province in which it is located. Section 1 describes the change over time in the number of innovative biotechnology firms. Section 2 looks at key financial indicators for these firms, including the change over time in total revenues from biotechnology activities, export revenues and biotechnology R&D expenditures. Section 3 focuses on the financing characteristics of innovative biotechnology firms. Lastly, Section 4 examines the change over time in human resources devoted to biotechnology.

I- Distribution of firms

In 2001, Canada had 375 innovative biotechnology firms, compared to 358 in 1999 and 282 in 1997. However, between 1999 and 2001, the increase in the number of firms slowed, with a 5% rise in the total number of such firms (Table 1).

Table 1: Change in number of biotechnology firms by size, sector and province, 1997 to 2001

	Number of biotechnology firms			Change (Number)		
	1997	1999	2001	1999-1997	2001-1999	2001-1997
A) Size						
Small (Less than 50 employees)	214	270	267	56	-3	53
Medium (50-149 employees)	37	51	62	14	11	25
Large (150 or more employees)	31	37	46	6	9	15
Total	**282**	**358**	**375**	**76**	**17**	**93**
B) Sector						
Human Health	136	150	197	14	47	61
Agriculture and Food Processing	74	119	113	45	-6	39
Environment	31	35	33	4	-2	2
Other	41	54	32	13	-22	-9
Total	**282**	**358**	**375**	**76**	**17**	**93**
C) Province						
British Columbia	52	71	69	19	-2	17
Alberta	19	28	24	9	-4	5
Saskatchewan	19	16	17	-3	1	-2
Manitoba	6	6	11	0	5	5
Ontario	87	111	101	24	-10	14
Quebec	79	107	130	28	23	51
Atlantic	20	19	23	-1	4	3
Total	**282**	**358**	**375**	**76**	**17**	**93**

Source: Statistics Canada

[a] The "Other" sector consists of Bioinformatics, Aquaculture, Mining/Energy/Petroleum/Chemicals and Forest Products.

Note: Due to rounding, components may not add to totals

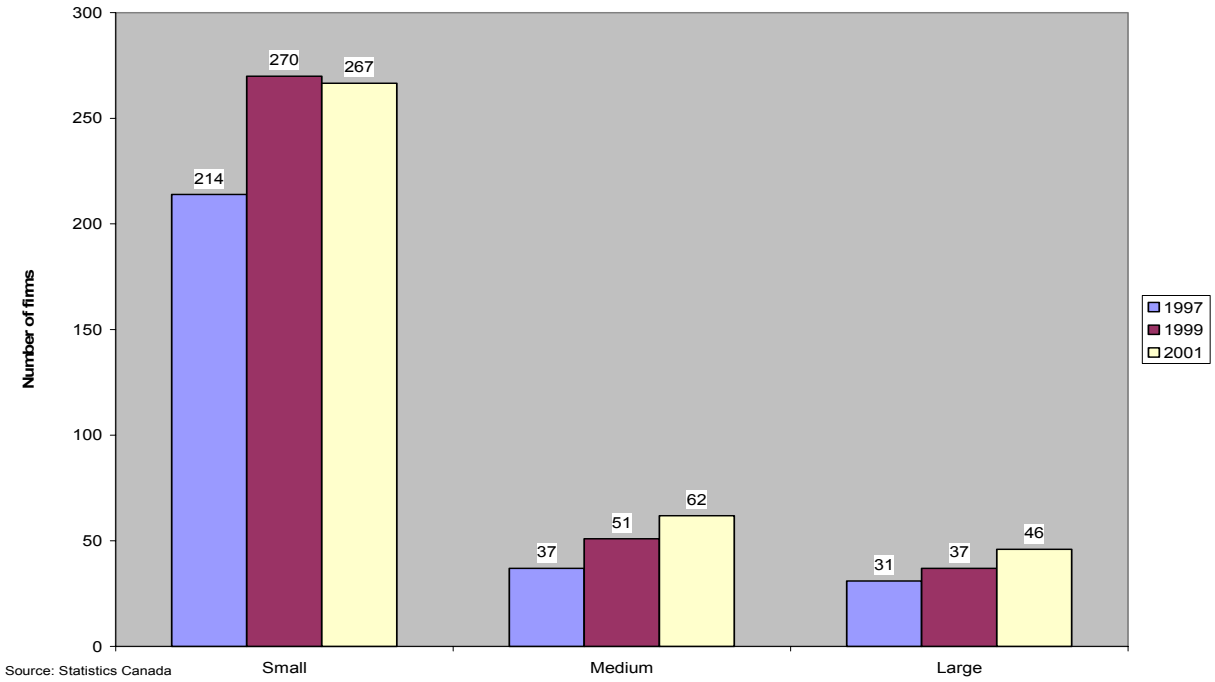
2. The actual impact of the change in the 1997 and 1999 survey methodology on the change in any biotechnology activity indicator is 9%. For more details on the impacts of the survey methodology changes please refer to Traore (2004a).

1.1- Change over time by size

Small firms[3] continue to be numerically dominant; they account for more than 70% of all biotechnology firms in Canada. Between 1997 and 1999, there was an increase of 56 firms in this size category, accounting for 74% of the total increase in the number of firms in Canada between those two years. However, between 1999 and 2001, the number of small firms declined, whereas medium-sized firms accounted for 65% of the increase in the total number for this period.

While the distribution of biotechnology firms by size category was fairly stable between the three years (Chart 1), small firms lost a little ground to medium-sized firms.

Chart 1: Distribution of biotechnology firms by size, 1997 to 2001



The decrease in the number of small firms between 1999 and 2001 may be explained by three factors:

- Movement of some firms from the "small" to the "medium" category: the increasing maturity of some small firms has begun to show up in the data (McNiven et al., 2003). Among the units *commonly selected* from both surveys, some 15% of the firms that were classified as small in 1999 reported as medium-sized or large in 2001.

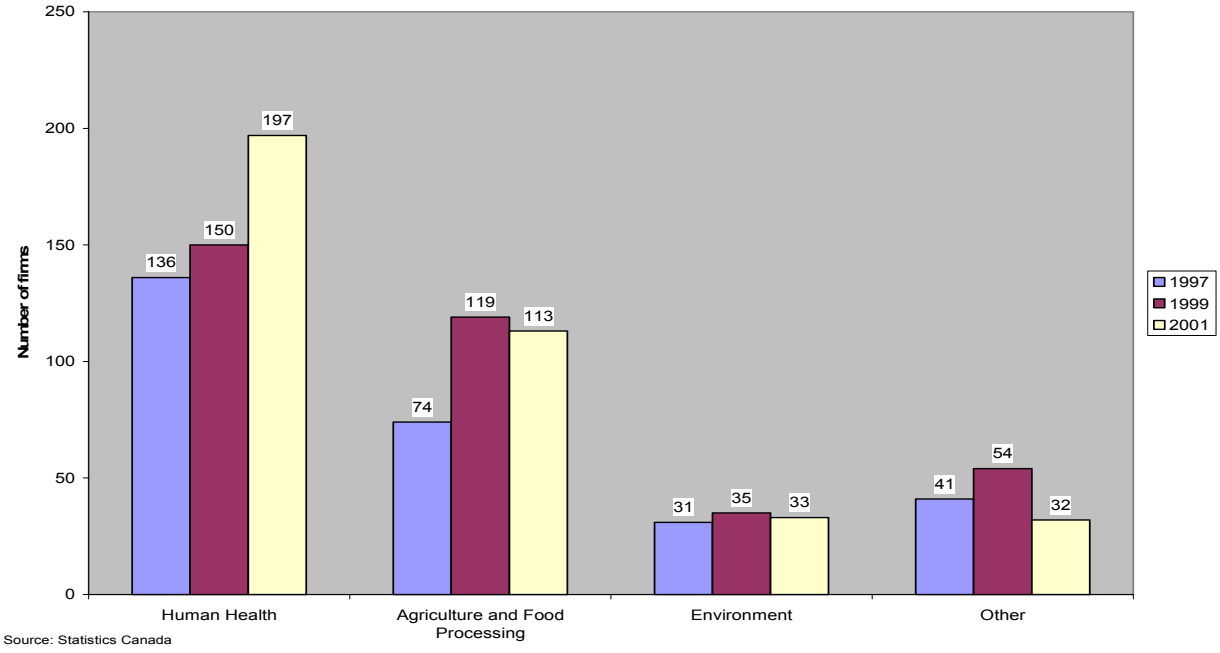
3. Size is defined in terms of the number of employees in the firm: a small firm has fewer than 50 employees, a medium-sized firm has between 50 and 149 employees, and a large firm has at least 150 employees.

- Disappearance of some small firms: in 2001, among the units *commonly selected* from both surveys, 27% of the small firms that were present in 1999 had become out of scope, either because they were no longer in business or because they were no longer part of the group of innovative biotechnology firms.
- Mergers and acquisitions with larger firms: among the units *commonly selected* from both the 1999 and the 2001 surveys, some 6% of innovative biotechnology firms from 1999 had merged with other firms or been acquired by them.

1.2- Change over time by sector

Canadian biotechnology firms are concentrated in the Human Health sector,[4] followed by the Agriculture and Food Processing sector. In 2001, 57% of the firms in the Human Health sector were operating in the therapeutics field, followed by the diagnostics field (34%).

Chart 2: Distribution of innovative biotechnology firms by sector, 1997 to 2001



Between 1997 and 1999, the number of biotechnology firms increased in all sectors—especially the Agriculture and Food Processing sector, which experienced an increase of 45 firms during this period. These firms were "beginning to emerge around new technologies coming off the laboratory benches" (Traore et al., 2003).

4. Firms are assigned to their sector on the basis of their primary product. For 2001, the sectors are based on Question 10 of the survey questionnaire; for 1999, on Question 9 of the questionnaire; and for 1997, on Question 3. The questionnaires are available online at the following address: http://www.statcan.ca/english/sdds/instrument/4226_Q1_V2_E.pdf

Between 1999 and 2001, the number of firms declined in all sectors except Human Health (Table 1). Some firms in the Bioinformatics sector shifted to the Human Health sector[5]. For the other sectors, the decline in the number of firms may be attributed either to some firms going out of business, shifting to another sector or even ceasing to be an innovative biotechnology firm.

The number of firms in the Agriculture and Food Processing sector declined overall (with a reduction of six firms). When this sector is examined in detail, it may be seen that the food processing component saw an increase of 19 firms between 1999 and 2001, whereas the agriculture biotechnology component lost 25 firms. This decrease is attributed to a consolidation of firms, a shift of some firms from agriculture to food processing[6], and to a lesser extent, the disappearance of some firms (see McNiven et al., 2003).

The Natural Resources sector lost eight firms between 1999 and 2001. In fact, some firms in this sector stopped developing new biotechnology products or processes, thereby shifting from the category of innovative biotechnology firms to the category of biotechnology user firms.

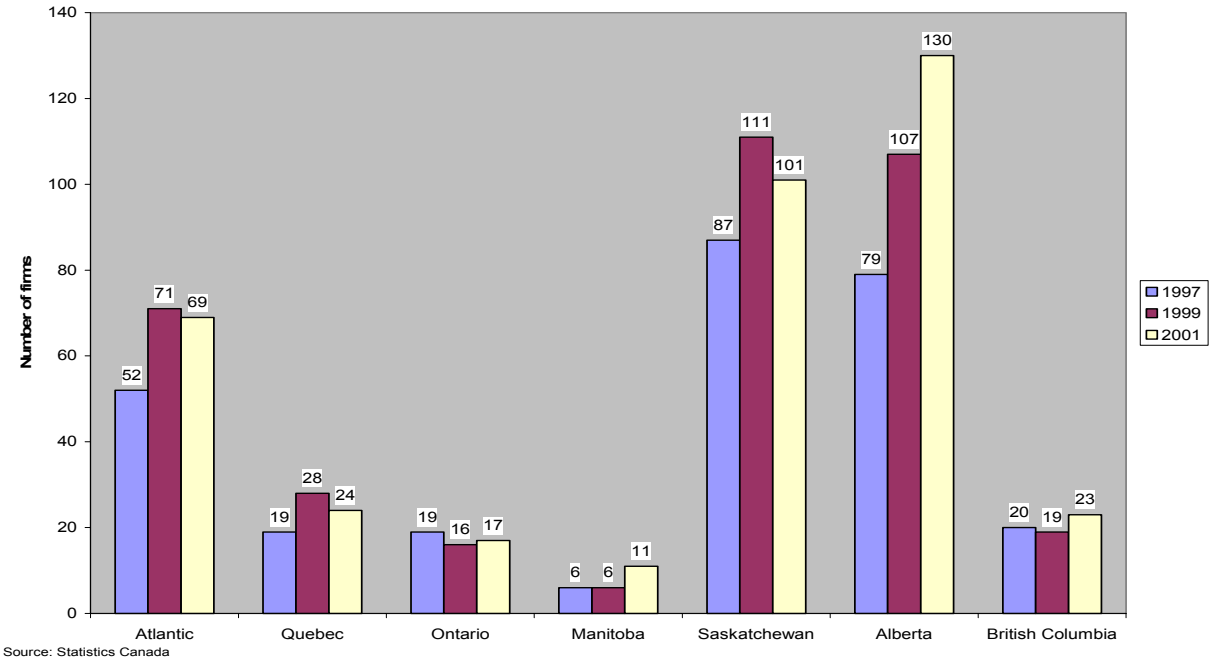
1.3- Change by province

Geographically, Canadian biotechnology activity is concentrated in three provinces: Quebec, Ontario and British Columbia. Together, these three provinces account for approximately 80% of all biotechnology firms in Canada. Between 1999 and 2001, most of the increase in the number of biotechnology firms occurred in Quebec.

Whereas Ontario, British Columbia and Alberta lost firms between 1999 and 2001, Quebec added 23 firms and Manitoba, and the Atlantic regions registered an increase of 5 and 4 respectively for this period. The number of firms in the province of Saskatchewan remained stable during this period. Between 1997 and 1999, the Saskatchewan and Atlantic regions were the only ones to see their numbers decline. Thus, some stability has been established in the distribution of biotechnology firms among the provinces. However, Quebec continues to see its number of firms increase. In fact, the number of innovative biotechnology firms in that province is continuing to grow, to the point that Quebec is now seen as the third-ranking region in North America in terms of the number of firms, after California and Massachusetts (Ernst & Young, 2003).

5. Among the units *commonly selected* from both the 1999 and the 2001 surveys, approximately 5 out of 10 firms shifted from the Bioinformatics to the Human Health sector.
6. Among the units *commonly selected* from both the 1999 and the 2001 surveys, approximately 3 firms shifted from the Agricultural biotechnology to the Food Processing sector.

Chart 3: Distribution of innovative biotechnology firms by province, 1997 to 2001



Source: Statistics Canada

II- Financial indicators

Despite the uncertainty and economic instability that characterized the period 2000 and 2001, the key indicators for Canadian innovative biotechnology firms remained fairly strong. Biotechnology revenues grew by 83% between 1999 and 2001, going from $1,948 million to $3,569 million. The growth rate for biotechnology revenues exceeded the growth rate for biotechnology R&D expenditures (62%), indicating that research efforts were beginning to pay off. Indeed, between 1999 and 2001, the number of products/processes that reached the Canadian biotechnology market went from 6,597 to 9,661, an increase of 3,064 (Appendix 1). Table 2 shows that the ratio of biotechnology revenues to biotechnology R&D expenditures increased for Canada during this two-year period, despite a drop in the ratio of total revenues (from all sources) to total R&D expenditures.

In 2001, large firms as a group spent less on biotechnology-oriented R&D than the others but had much more success generating revenues.

Table 2: Change in financial indicators, Canada and by size, 1997 to 2001

	1997 (000,000)	1999 (000,000)	2001 (000,000)	Change (%) 1999-2001
Canada				
Total revenues	14,452	18,730	27,066	45
Total R&D spending	926	1,210	2,241	85
Revenues / R&D ratio	15.61	15.48	12.08	
Biotechnology revenues	813	1,948	3,569	83
Biotechnology R&D spending	494	827	1,337	62
Revenues / R&D ratio	1.65	2.36	2.67	
Size				
Small				
Biotechnology revenues	214	249	521	109
Biotechnology R&D spending	193	256	433	69
Revenues / R&D ratio	1.11	0.97	1.20	
Medium				
Biotechnology revenues	201	295	849	188
Biotechnology R&D spending	124	106	601	467
Revenues / R&D ratio	1.62	2.78	1.41	
Large				
Biotechnology revenues	398	1,404	2,199	57
Biotechnology R&D spending	177	465	303	-35
Revenues / R&D ratio	2.25	3.02	7.26	

Source: Statistics Canada

2.1- Change in biotechnology revenues

The biotechnology revenues generated by innovative Canadian biotechnology firms grew steadily between 1997, 1999 and 2001. During this period, those revenues more than doubled, going from $813 million to $3.6 billion. It may also be observed that between 1997 and 2001, the share of total revenues represented by biotechnology revenues also rose, going from 6% to 10% to 13% for 1997, 1999 and 2001 respectively. Firms are beginning to draw earnings from their R&D investments, and this is reflected in the biotechnology revenues-to-R&D ratio shown in Table 2, which went from $1.65 to $2.67 between 1997 and 2001[7and 8].

Between 1999 and 2001, the number of biotechnology products/processes brought onto the market increased by 3,064, whereas the number of products in development declined by 2,618 (see Appendix 1). The primary objective of innovative biotechnology firms is to develop new biotechnology products/processes and eventually bring them onto the market. This is a long and costly process, and a number of products never succeed in reaching the production and marketing

7. In this section, the biotechnology revenues-to-R&D ratio is used as a financial indicator. It is different from the R&D-to-revenues ratio which is often used in the literature related to innovation (Bernier, 1997). The latter is an R&D intensity measure and it establishes a link between the importance of the firm's R&D activity and its size.
8. The revenues-to-R&D ratio should be interpreted with caution. In theory, we expect there to be a causal relation between biotechnology R&D spending and revenues. However, this relation has not been empirically tested with our data: three reference years (1997, 1999 and 2001) do not allow an accurate testing of the significance of this relation.

stage. However, it would appear that between 1997 and 2001, a great number of firms in Canada managed to achieve this objective, which is both a lead indicator of the success of Canadian biotechnology firms and an indication that biotechnology activity in Canada is likely to grow in the years to come.

Table 3: Change in total revenues and biotechnology revenues by size, sector and province, 1997 to 2001

	Total revenues (000,000)				Biotechnology revenues (000,000)			
	1997	1999	2001	Change (%) 1999-2001	1997	1999	2001	Change (%) 1999-2001
A) Size								
Small (Less than 50 employees)	1,756	590	1,169	98	214	249	521	109
Medium (50-149 employees)	685	849	1,504	77	201	295	849	188
Large (150 or more employees)	12,011	17,291	24,392	41	398	1,404	2,199	57
Total	**14,452**	**18,730**	**27,066**	**45**	**813**	**1,948**	**3,569**	**83**
B) Sector								
Human Health	3,397	3,185	5,074	59	417	1,036	2,461	138
Agriculture and Food Processing	9,792	7,153	12,998	82	322	709	826	17
Environment	1,090	287	8,900	3,001	49	45	268	496
Other	173	8,105	94	-99	25	158	14	-91
Total	**14,452**	**18,730**	**27,066**	**45**	**813**	**1,948**	**3,569**	**83**
C) Province								
British Columbia	118	1,880	7,118	279	47	138	414	200
Alberta	248	392	132	-66	56	90	122	36
Saskatchewan	5,644	..	F	..	56	433	21	-95
Manitoba	1,908	123	759	517	33	69	99	43
Ontario	2,665	8,121	3,485	-57	363	635	1,376	117
Quebec	3,805	3,960	10,511	165	224	554	1,515	173
Atlantic	61	..	F	..	34	28	22	-21
Total	**14,452**	**18,730**	**27,066**	**45**	**813**	**1,948**	**3,012**	**55**

Source: Statistics Canada

F: too unreliable to be published

.. : not available for the reference period

Note: Due to rounding, components may not add to totals

[a] The "Other" sector consists of Bioinformatics, Aquaculture, Mining/Energy/Petroleum/Chemicals and Forest Products.

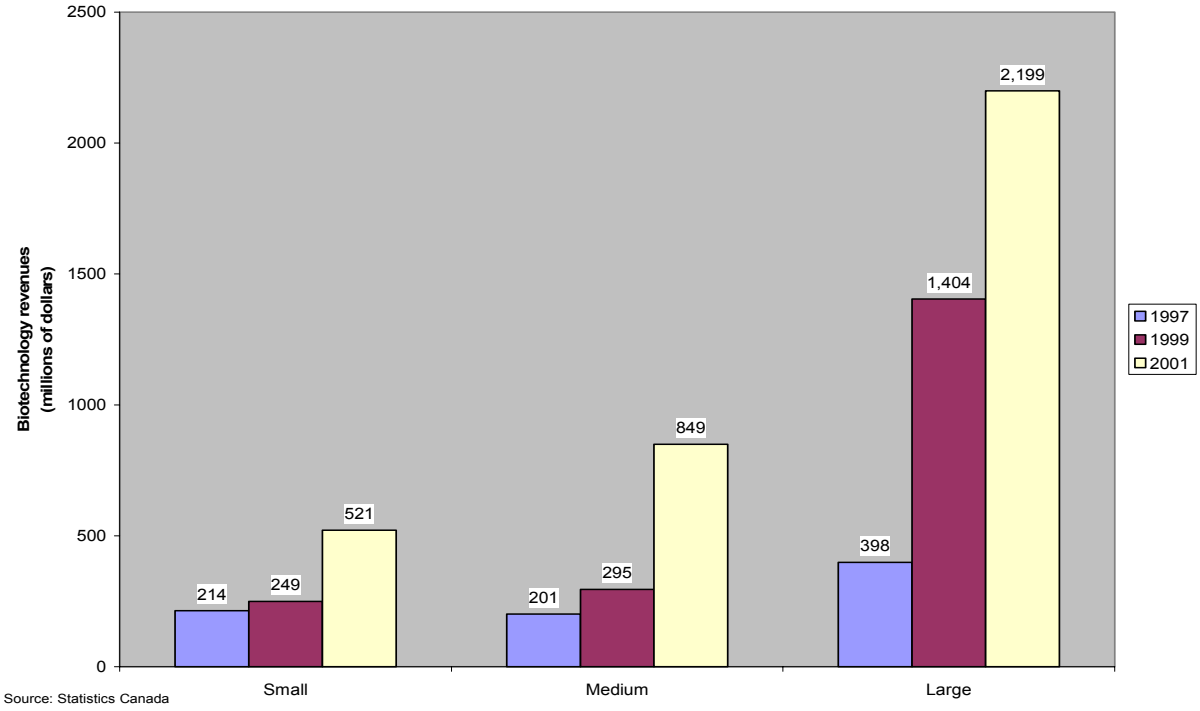
A- Change in revenues by size

Biotechnology revenues increased for all size categories. As may be seen, for small and medium-sized firms, the growth rate for biotechnology revenues is higher for the period 1999-2001 than for 1997-1999. It is not clear how much of this growth in revenues is due to the entry of new firms with products, to existing firms that released products on the market in 2001 or to existing firms that already had revenues that they increased. This investigation is crucial and will help us better explain the change in revenues and understand the behaviour of biotechnology innovators.

Medium-sized firms in particular stood out in terms of increased biotechnology revenues. Whereas in 1997 and 1999, their revenues were close to those of small firms, in 2001 they were nearly twice as high. As Chart 4 shows, large firms continue to generate more biotechnology revenues; medium-sized firms, a distant second, follow slowly but surely. While small firms were more numerous in reporting biotechnology revenues in 2001, it was the large firms that reported the largest amount of biotechnology revenues in 2001. Fewer large firms report such revenues because they might tend to diversify their activities, whereas small firms tend to concentrate their

efforts on biotechnology (McNiven et al., 2003). They continue to have the lowest revenues, but their situation marks an improvement compared to previous years.

Chart 4: Change in biotechnology revenues by size, 1997 to 2001



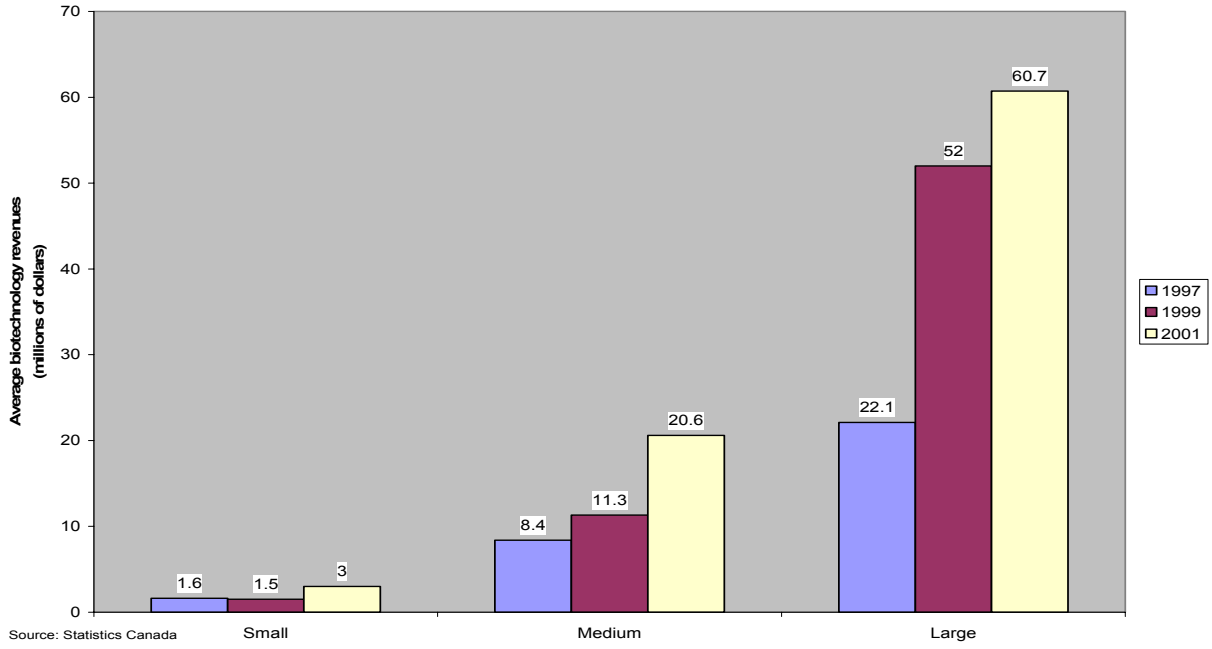
In 2001, 28 more firms reported revenues than in 1999. Among them, 15 were medium-sized firms. All size categories saw their average biotechnology revenues increase between 1999 and 2001. This indicates a real increase in revenues, that is, an increase that is not due solely to an increase in the number of firms reporting revenues.

Small firms are still the ones that on average generate the least biotechnology revenues. Correlation analysis indicates that a statistically significant and positive linear association exists between firm size and biotechnology revenues. Thus, large firms are more likely to generate biotechnology revenues than small firms (Appendix 2).

The biotechnology environment is characterized by the entry of a great number of small firms (Mangematin et al., 2003) intensively engaged in scientific research (McNiven et al., 2003). These small firms tend to transfer their research and discoveries to large firms, which incorporate them into their products (Mangematin et al., 2003). Because of the newness of biotechnology and the risk associated with it, large, already-established biotechnology firms tend to conduct part of their biotechnology research externally, either by contracting it out or by forming alliances or joint ventures with small firms. In turn, the latter tend to take advantage of these relationships to obtain the financial capital and management expertise of the large firms in order to test or commercialize their products (Teece, 1986). Hence, the ability of small firms to commercialize their innovations and thus generate revenues initially depends on their ability to form business

relationships with larger firms. This explains in part why small firms continue to generate, on average, less revenue than the others.

Chart 5: Average biotechnology revenues by size, 1997 to 2001



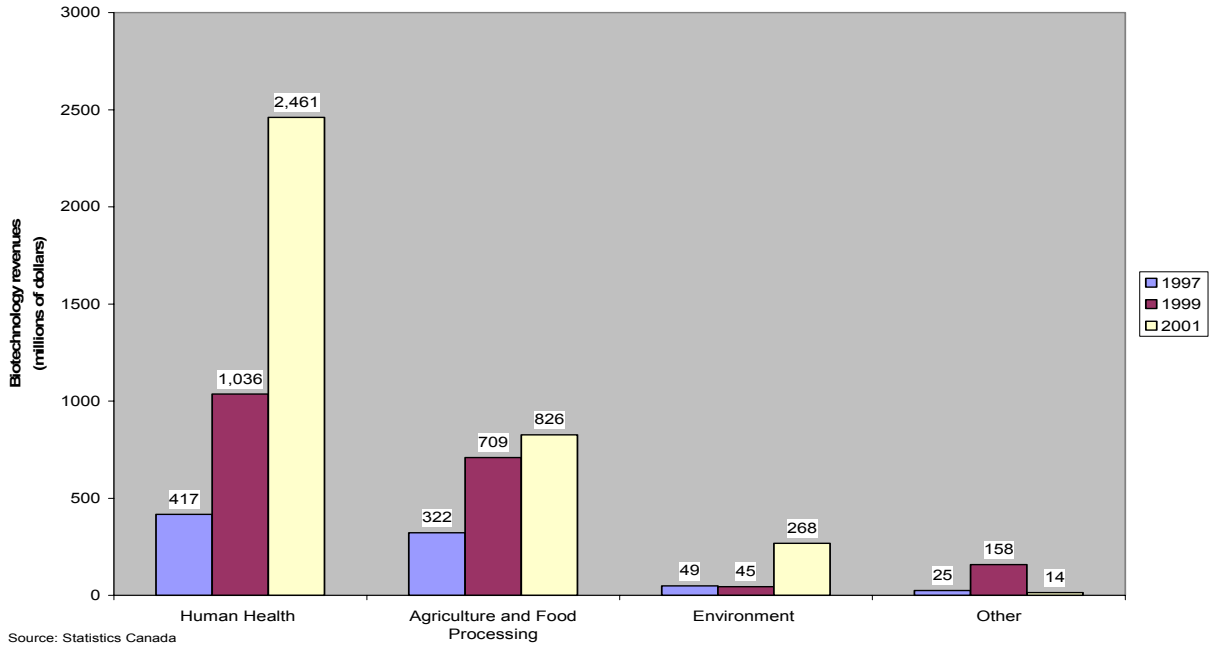
B- Change in revenues by sector

In 2001, the Human Health sector continued to dominate in terms of revenue generated, accounting for 69% of biotechnology revenues for that year. Biotechnology firms in that sector saw their revenues grow 138% between 1999 and 2001 (Chart 6).

An examination of average revenues indicates that over the periods 1997-1999 and 1999-2001, they grew by 100% in each period. The strong growth of revenues in the Human Health sector thus appears to be real and not due solely to the increased number of firms reporting revenues.

The Agriculture and Food Processing sector follows, with a 23% share of total biotechnology revenues. However, whereas the revenues of this sector grew by 120% between 1997 and 1999, the increase between 1999 and 2001 was only 17%. This trend is maintained when average revenues are examined: these went from $9 to $9.4 million during the same period.

Chart 6: Change in biotechnology revenues by sector, 1997 to 2001



Compared to firms in other sectors, those in the Human Health sector continue to have more biotechnology-oriented activities, since in 2001, 49% of their total revenues came from the sale of biotechnology products. This sector also continues to have the greatest number of firms reporting biotechnology revenues, namely 115 out of the total of 252[9] in 2001, compared to 88 in the Agriculture and Food Processing sector, 27 in the Environment sector and 23 in the "Other" sector.[10] Firms in the Human Health sector generally have greater success in boosting their revenues. A study conducted by Niosi (2000) showed that having activities in the Human Health sector is one of the factors that increases the probability of rapid growth for biotechnology firms. It would therefore appear that growth (defined by the author in terms of revenues or human resources) is faster when the biotechnology firm is involved in the Human Health sector. Correlation analysis (Appendix 2) shows that the probability of generating biotechnology revenues is not related to the sector in which the firm operates. Thus, being in a particular sector does not in itself increase the ability to generate biotechnology revenues. On the other hand, that probability is instead related to factors such as i) the total number of patents; ii) biotechnology-related exports; iii) biotechnology R&D expenditures; and iv) strategic alliances.

In 2001, firms in the Human Health sector held 86% of all patents obtained by innovative Canadian biotechnology firms. Patents may be a way to measure a biotechnology firm's scientific value and are considered by some authors as an indicator of its innovative capacity (George et al., 2001). Patents are, in a sense, a benchmark used by potential investors to determine the value of a

9. In 2001, out of 375 innovative biotechnology firms, 252 reported biotechnology revenues.
10. The "Other" sector consists of Bioinformatics, Aquaculture, Mining/Energy/Petroleum/Chemicals and Forest Products.

biotechnology firm's research, and they can thus facilitate its access to financing. Such access is often a condition of survival for biotechnology firms. These firms, to achieve the objective of marketing their new products and starting to generate revenues, must generally put them through a quite costly process, each stage of which calls for developing new financial resources.

In Canada, in 2001, some 57% of biotechnology revenues came from the therapeutics sector (e.g., vaccines, immunostimulants, biopharmaceutical products). In 2001, firms in the Human Health sector had 6,619 products on the market, representing 69% of the total for Canada. Of these, 9% (or 600) were therapeutic products. Because of the positive externalities of biotechnology research in the Human Health field (use of biotechnology in the manufacture of products for the health care system to save lives and improve Canadians' quality of life), the demand for biotechnology products in the health field will continue to outpace the demand in other sectors. According to "Canada's Research-Based Pharmaceutical Companies,"[11] the current benefits of biotechnology in the health care field include i) "medicines to treat cancers, AIDS, diabetes, hormonal disorders and other diseases; vaccines, antibiotics, interferon, insulin and growth hormones; ii) diagnostic products to help doctors identify disease, screen blood, and perform other life-saving tests." According to the same organization, biotechnology will make even greater contributions to health care in the future by creating: i) "new vaccines for common diseases such as flu, tuberculosis, malaria and cholera; ii) pharmaceutical products tailored to respond to the genetic characteristics of individual patients; and iii) products to regenerate damaged spinal cord/brain tissues."

Although the Agriculture and Food Processing sector contributed the most to biotechnology-derived exports each year (1997, 1999 and 2001), firms in the Human Health sector in 2001 generated around 38% of export-derived biotechnology revenues. And quite often, firms that succeed in exporting their products or research manage to obtain rapid growth rates because they tapped much larger markets" (Niosi, 2000: 19).

In the Agriculture and Food Processing sector, the drop in biotechnology revenues came mainly from the agriculture component. There, revenues fell 53% whereas those in the food processing component surged 214% between 1999 and 2001. This trend is borne out when the change in average revenues for these two components is compared. For agriculture biotechnology, average revenues dropped by 49%, whereas those for food processing rose 93%.

A change was observed in 2001 in the structure of the agriculture component; some firms had moved over to the food processing component while others, fewer in number, had disappeared (McNiven et al., 2003). Firms in the Agriculture and Food Processing sector have more difficulty marketing their products, since they constantly face a problem of public perception and acceptance but also and more importantly a lack of access to venture capital. However, there is growing government support through different programs oriented toward this sector, especially in Saskatchewan and, more recently, Alberta. In October 2000, a private venture capital fund (Foragen Technologies Limited Partnership) was specially created to target biotechnology firms

11. Canada's Research-Based Pharmaceutical Companies, November 2001, "The Value of Medicines from Biotechnology," http://www.canadapharma.org/Industry_Publications/Value_Medecine/ValueBiotech_e.pdf.

engaged in high tech agriculture and food processing. This signals a need for venture capital in this sector and perhaps also a good start for such firms.

Biotechnology also has applications in sectors such as Natural Resources, Aquaculture and Bioinformatics. Between 1997 and 1999, biotechnology revenues in the "Other"[12] sector increased six-fold, going from $25 million to $158 million. However, this sector's revenues subsequently dropped drastically to $14 million in 2001. For the Natural Resources sector, a decrease is observed both in biotechnology revenues and in the number of firms reporting such revenues. However, for the Bioinformatics and Aquaculture sectors, the number of firms reporting biotechnology revenues grew by 79% and 103% respectively. Thus, for these two sectors, despite an increase in the number of firms reporting revenues, the amount of revenue obtained from the sale of biotechnology products declined, with the result that average revenues were less than $1 million in 2001. For a period (1997-1999), Bioinformatics was considered a highly attractive biotechnology sector. Bioinformatics (genomics/molecular modeling and gene therapy) is a sector that has grown in importance in recent years owing to scientific advances that have made it possible to determine the genome sequence or the coded model of complex organisms (genomics). As a result, an enormous quantity of information and data has been created. Bioinformatics is concerned with collecting, managing, exploring and analysing these biological data. Because of scientists' interest in this promising field, many new biotechnology firms were created during the period 1997-1999, and an increasing number of firms reported biotechnology revenues. However, in absolute terms, the amount of revenue reported in biotechnology dropped between 1999 and 2001, contrary to expectations (see Traore et al., 2003: 23). This may be related in part to a sizable drop in the number of products/processes brought onto the market in this sector between 1999 and 2001. It is also important to note that a number of bioinformatics firms are rather service-related and are therefore not included in our target population.

C- Change in revenues by province

Ontario, Quebec and British Columbia continue to generate the most biotechnology revenue of all Canadian provinces. Together, these three provinces accounted for 78%, 68% and 93% of Canadian biotechnology revenues in 1997, 1999 and 2001 respectively.

In 1999, Ontario led the way with 33% of Canada's biotechnology revenues, followed by Quebec with 28%. In 2001, the trend reversed and Quebec had the largest share of total biotechnology revenues (42%), with Ontario following closely (39%) and then British Columbia (12%). As regards the intensity of biotechnology revenues (i.e., the ratio of biotechnology revenues to total revenues from all sources), it was higher in Ontario (39%) than in Quebec (14%) in 2001. The industrial structure being different for those 3 regions, there is a strong probability that the portfolio of activities of Ontario firms consists primarily of biotechnology products which, having reached the marketing stage, generate more revenue than other products.

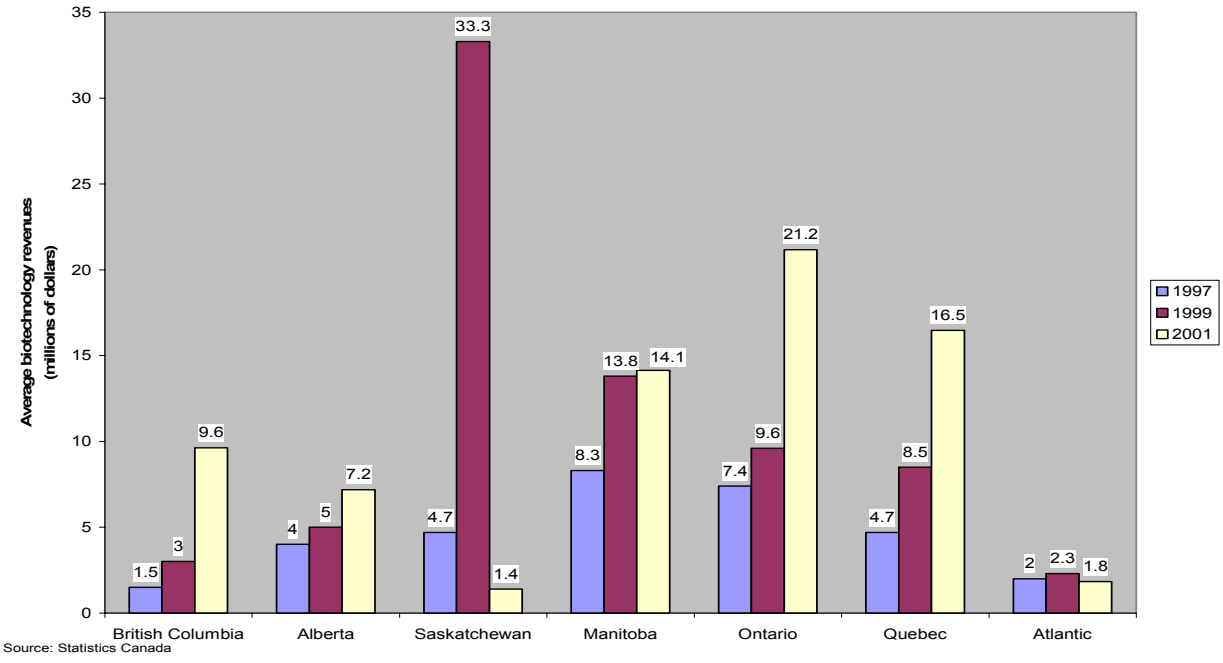
Between 1997 and 1999, one-third of the increase in biotechnology revenues was registered by Saskatchewan firms. However, between 1999 and 2001, that province experienced a 95% drop in

12. *Idem* as footnote 10.

reported biotechnology revenues. Quebec accounted for more than half of the growth in biotechnology revenues reported by all Canadian firms for this period, followed by Ontario with a 46% share. In 1999, the boom observed in Saskatchewan was due in part to the creation of an agriculture cluster in Saskatoon (Traore et al., 2003) which made that city, in only a few years, a major centre for agri-biotechnology.

An examination of the change in average revenues by province (Chart 7) shows that between 1999 and 2001, increases were registered for all provinces except Saskatchewan and the Atlantic region. The decrease in average revenues was especially sizable for Saskatchewan (from $33.3 million in 1999 to $1.4 million in 2001). The drop in biotechnology revenues for that province is therefore real, since despite a small increase in the number of firms reporting biotechnology revenues (from 13 to 15 between 1999 and 2001), the amount of revenues reported fell 95%. This decrease in biotechnology revenues may be explained by a plunge in export revenues (from $208 million to $5 million) between 1999 and 2001 (see Section 2.1-D) rather than a decrease in sales of biotechnology products, since in 2001 that province brought seven more biotechnology products onto the market than in 1999.

Chart 7: Average biotechnology revenues by province, 1997 to 2001



Source: Statistics Canada

D- Biotechnology export revenues

Given the size of the domestic market, Canadian firms are often driven by international trade. Since Canada's domestic market being relatively small, firms probably have to turn to the external market to ensure a return on their development costs and to make their projects feasible. In 2001, 76% of Canadian exports of biotechnology products went to the United States, 4% to

Europe, 3% to Asia and 18% to countries in other regions. The ratio of biotechnology exports to imports, which was 3 to 1 in 1999, appears to stabilize at 2 to 1 in 2000, 2001 and 2004.[13]

Despite a drop in total export revenues of Canadian biotechnology firms, export revenues from biotechnology activities grew between 1999 and 2001 (Table 4). In Canada, 21% of biotechnology revenues in 2001 were obtained from exports. This is a lower percentage than in 1999 (37%). Between 1999 and 2001, the increase in biotechnology revenues in general was much greater than the increase in revenues from biotechnology exports: biotechnology revenues grew by 83%, whereas revenues from biotechnology exports grew by only 4% between 1999 and 2001.

While biotechnology export revenues continue to increase over time for Canada, their growth is no longer as great as in previous years: between 1997 and 1999, they grew by 131%. At the time, this finding was seen as underlining "the vitality of Canadian biotechnology," since the expansion of international markets and exports was found to be a source of rapid growth for biotechnology firms (Niosi, 2000; Traore et al., 2003).

An analysis of correlation (based on 2001 data) between biotechnology exports and different characteristics of firms indicates that biotechnology export revenues are positively and significantly correlated with the size of the firm, its sector and the number of products/processes at the commercialization stage (Appendixes 2 and 3).

Table 4: Change in total export revenues and biotechnology export revenues by size, sector and province, 1997 to 2001

	Total export revenues				Biotechnology export revenues			
	1997 (000,000)	1999 (000,000)	2001 (000,000)	Change (%) 1999-2001	1997 (000,000)	1999 (000,000)	2001 (000,000)	Change (%) 1999-2001
A) Size								
Small (Less than 50 employees)	810	150	110	-27	67	78	99	27
Medium (50-149 employees)	183	131	220	68	77	51	96	88
Large (150 or more employees)	2,338	2,249	1,286	-43	167	589	551	-6
Total	**3,331**	**2,530**	**1,616**	**-36**	**311**	**718**	**746**	**4**
B) Sector								
Human Health	484	578	929 E	61	177	410	280	-32
Agriculture and Food Processing	2,073	1,433	645 E	-55	101	284	432 E	52
Environment	750	..	35	..	24	..	28	..
Other[a]	24	..	..	..	9	..	..	..
Total	**3,331**	**2,530**	**1,616**	**-36**	**311**	**718**	**746**	**4**
C) Province								
British Columbia	26	290	25	-91	24	60	24	-60
Alberta	52	101	F	..	49	..	F	..
Saskatchewan	441	763	66 E	-91	2	208	5	-98
Manitoba	1,130	53	X	..	2	43	X	..
Ontario	540	709	79	-89	153	164	63	-62
Quebec	1,116	612	1,272 E	108	59	227	591 E	160
Atlantic	26	2	5	150	22	..	2	..
Total	**3,331**	**2,530**	**1,616**	**-36**	**311**	**718**	**746**	**4**

Source : Statistics Canada

E: use with caution

.. : not available for the reference period

X: suppressed to meet confidentiality requirements of the *Statistics Act*

Note: Due to rounding, components may not add to totals

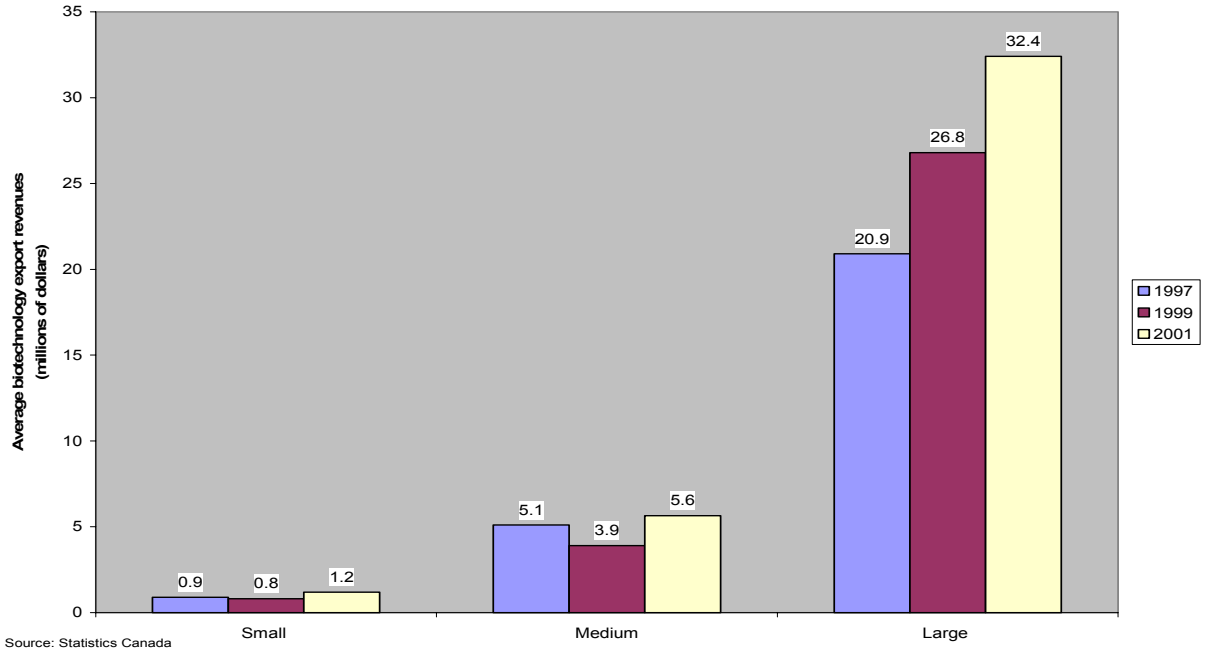
[a] The "Other" sector consists of Bioinformatics, Aquaculture, Mining/Energy/Petroleum/Chemicals and Forest Products.

13. The information for 2004 is based on forecasts made by respondents to the Biotechnology Use and Development Survey – 2001.

The existence of a significant and positive linear relationship between firm size and biotechnology exports suggests that large firms are more likely than small biotechnology firms to generate export revenues. Between 1997 and 1999, large firms contributed the most to export growth (with an increase of 253%). However, these same firms saw their biotechnology exports decline 6% between 1999 and 2001, and they expected a further decrease in their biotechnology exports in 2004 ($150 million). Biotechnology exports are correlated with the number of products/processes at the production and marketing stage. Between 1999 and 2001, large firms experienced a 24% drop (from 353 products in 1999 to 267 in 2001) in biotechnology products marketed, whereas small and medium-sized firms saw an increase of respectively 127% and 32% in products commercialized during this period (Appendix 1). This decrease in the number of products commercialized by large firms may have contributed in part to the decrease in biotechnology export revenues.

However, if we look at average export revenues by size (Chart 8), we can see that while large firms generated less biotechnology export revenue, average exports increased.

Chart 8: Average biotechnology export revenues by size, 1997 to 2001



Until 1999, the export revenues of Canadian innovative biotechnology firms consisted primarily of products in the Human Health sector; in 1997 and 1999, 57% of Canadian biotechnology export revenues came from this sector, with the Agriculture and Food Processing sector ranking second. This trend seemed to reverse in 2001. For that year, products in the Agriculture and Food Processing sector accounted for the largest share of biotechnology exports with 58% of total exports, while health products were a distant second with a share of 38% ($280 million), down 32% from 1999. This finding is surprising, since the number of biotechnology products commercialized by the Human Health sector increased twelve-fold between 1999 and 2001, from 542 products to 6,619 products respectively for those two years.

From a geographic standpoint, Quebec and Ontario are the two provinces that generated the most biotechnology export revenues in 2001, followed by British Columbia. Whereas in 1999, Saskatchewan accounted for 29% of total biotechnology export revenues ($208 million), its firms generated only $5 million in export revenues from biotechnology products in 2001, representing only 1% of total biotechnology exports for that year. This is surprising, since more than half of that province's biotechnology activities are in Agriculture and Food Processing, and overall exports for that sector grew significantly (52%) between 1999 and 2001.

2.2- Change in biotechnology R&D expenditures

In theories on the growth of small firms, it has often been proposed that growth is explained by factors internal to the firm, including R&D (Baldwin, 1996; Foss, 1997). Between 1997 and 2001, biotechnology R&D expenditures almost tripled, from $494 million in 1997 to more than $1.3 billion in 2001. This trend is confirmed when average R&D expenditures are considered; these went from $1.8 million in 1997 to $2.3 million in 1999 and $3.6 million in 2001. This is a sign of vitality and success for biotechnology firms. Nearly 60% of total R&D expenditures in the group of innovative Canadian biotechnology firms were devoted to biotechnology in 2001, compared to 53% in 1997. However, this is down from 1999, when biotechnology R&D expenditures accounted for 68% of total R&D expenditures.

The biotechnology revenues-to-R&D ratio was 2.67 in 2001, compared to 2.36 in 1999 and only 1.65 in 1997. Biotechnology firms can rely increasingly on their internal resources to finance their R&D activities, since capital from external sources is not always easy to obtain (see Section III).

Table 5: Change in biotechnology R&D expenditures and ratio of biotechnology R&D expenditures to total R&D expenditures by size, sector and province, 1997 to 2001

	Biotechnology R&D expenditures				Ratio of biotechnology R&D over total R&D		
	1997 (000,000)	1999 (000,000)	2001 (000,000)	Change (%) 1999-2001	1997	1999	2001
A) Size							
Small (Less than 50 employees)	193	256	433	69	0.63	0.87	0.67
Medium (50-149 employees)	124	106	601	467	0.73	0.58	0.87
Large (150 or more employees)	177	465	303	-35	0.40	0.63	0.34
Total	**494**	**827**	**1,337**	**62**	**0.53**	**0.68**	**0.60**
B) Sector							
Human Health	409	703	1,177	67	0.56	0.77	0.78
Agriculture and Food Processing	53	73	107	47	0.57	0.59	0.34
Environment	10	..	16	..	0.24	..	0.05
Other[a]	22	..	37	..	0.39	..	0.41
Total	**494**	**827**	**1,337**	**62**	**0.53**	**0.68**	**0.60**
C) Province							
British Columbia	77	131	420	221	0.88	0.83	0.73
Alberta	20	81	118	46	0.71	0.79	0.99
Saskatchewan	19	28	10	-64	0.54	0.65	0.24
Manitoba	12	20	31	55	0.86	0.65	0.94
Ontario	220	223	395	77	0.60	0.53	0.69
Quebec	132	337	349	4	0.34	0.75	0.39
Atlantic	14	6	14	133	1.00	1.00	0.93
Total	**494**	**827**	**1,337**	**62**	**0.53**	**0.68**	**0.60**

Source: Statistics Canada

.. : not available for the reference period

Note: Due to rounding, components may not add to totals

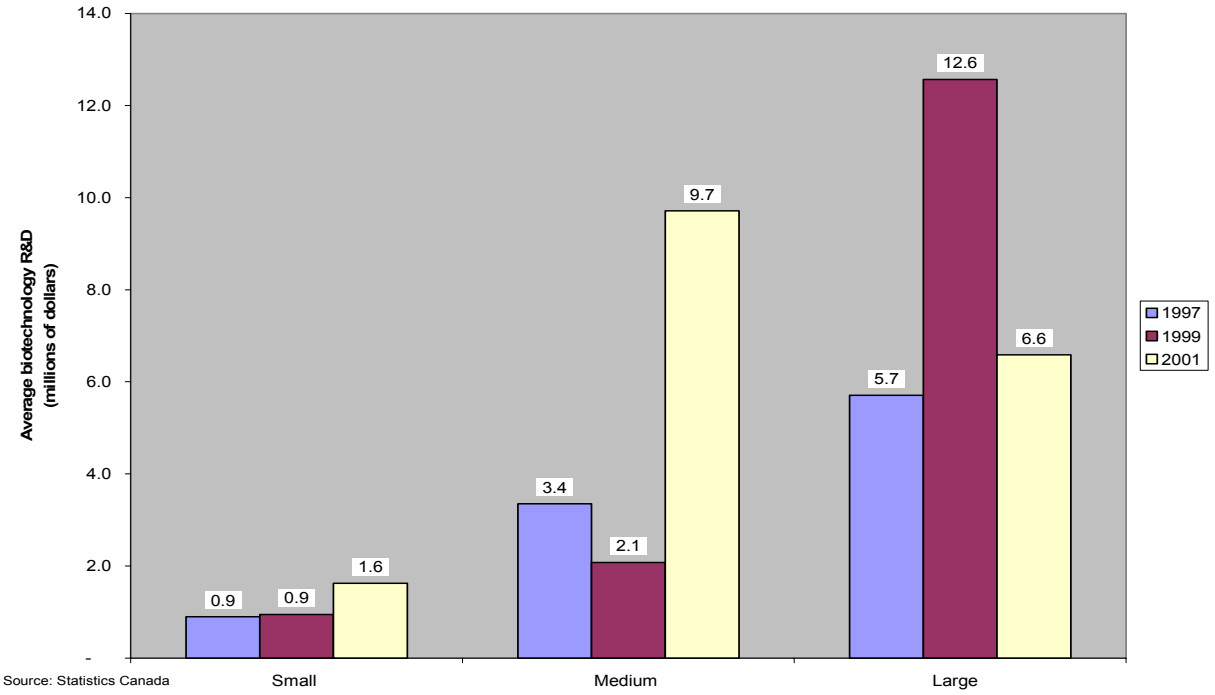
[a] The "Other" sector consists of Bioinformatics, Aquaculture, Mining/Energy/Petroleum/Chemicals and Forest Products.

A- Change in biotechnology R&D by size

Whereas the increase in R&D expenditures between 1997 and 1999 was to a great extent attributable to large firms, which accounted for 86% of the overall increase, it was medium-sized firms that led the way in 2001, accounting for 97% of the overall increase owing to a 467% increase in their R&D expenditures. In 2001, the R&D expenditures of large firms were down 35% from their 1999 level. Once again, medium-sized firms stood out from the other size categories. The increase in biotechnology R&D expenditures by medium-sized firms appears to have been real and not merely due to an increase in the number of firms in this size category, since average R&D expenditures per firm grew significantly between 1999 and 2001, going from $2.1 million to $9.7 million, roughly five times their 1999 level (Chart 9).

Small biotechnology firms continued to increase their biotechnology R&D expenditures, from $193 million in 1997 to $256 million in 1999 and $433 million in 2001. Between 1997 and 1999, the increase in R&D was mainly due to an increase in the number of firms covered by the survey, whereas between 1999 and 2001, it was a real increase, since R&D expenditures per firm also rose (Chart 9).

Chart 9: Average biotechnology R&D expenditures by size, 1997 to 2001



Small and medium-sized firms allocate a larger share of total R&D expenditures to biotechnology R&D. This is not surprising, since the main objective of these firms is to develop biotechnology products and processes. Large firms are involved in a range of activities other than biotechnology. Because they diversify their activity portfolio, the share of their R&D expenditures that they devote to biotechnology tends to be smaller.

The correlation analysis in Appendix 2 shows that biotechnology R&D expenditures are positively and significantly correlated with the size of the firm and the amount of capital raised by it. Thus, large firms are more likely to raise capital to finance their projects than small firms and can therefore afford to devote larger amounts to biotechnology R&D. In 1997 and 1999, average R&D expenditures were much higher for large firms than for the other two size categories. In 2001, medium-sized firms spent, on average, three times more on R&D than large firms. The future looks promising for them.

B- Change in biotechnology R&D by sector

Human Health continues to be the sector that accounts for the largest share of biotechnology R&D expenditures in Canada. Over the period 1997 to 2001, each sector's share of total investments in R&D remained fairly stable. Firms in the Human Health sector accounted for just over 80% of overall investment, while the Agriculture and Food Processing sector accounted for approximately 9% and the other two sectors for between 1% and 4%. The increase in R&D expenditures in the Human Health sector is real and is not merely due to an increase in the number of firms in this sector, since average R&D expenditures increased constantly over the study period (Chart 10).

A Human Health product/process entails relatively higher research costs (including R&D, regulation, etc.) than the products/processes of other biotechnology sectors. Very often, a product from this sector has to go through a regulatory process before reaching the market that is less important in other biotechnology sectors. In 2001, the Human Health sector accounted for 67% of Canada's total costs of taking the main biotechnology product/process from the initial development stage to the marketing stage. According to estimates made in the United States, in order for a single health-related biotechnology product to go from the initial R&D stage in the laboratory to marketing, it takes on average twelve years of investments on the order of US$359 million, with no guarantee of ever reaching the market.[14]

Even though the biotechnology revenues-to-R&D ratio in the Human Health sector is greater than 1, it was lower in 1999 and 2001 than the ratio for the Agriculture and Food Processing and Environment sectors and the overall average for Canada (Tables 2 and 6). This reflects the importance of R&D in this biotechnology sector.

Table 6: Ratio of biotechnology revenues to biotechnology R&D by sector, 1997 to 2001

	1997	1999	2001
Human Health	1.02	1.47	2.09
Agriculture and Food Processing	6.08	9.71	7.72
Environment	4.9	..	16.75
Other[a]	1.14	..	0.38
Total	**1.65**	**2.36**	**2.67**

Source: Statistics Canada

.. : not available for the 1999 reference year

[a] The "Other" sector consists of Bioinformatics, Aquaculture, Mining/Energy/Petroleum/Chemicals and Forest Products.

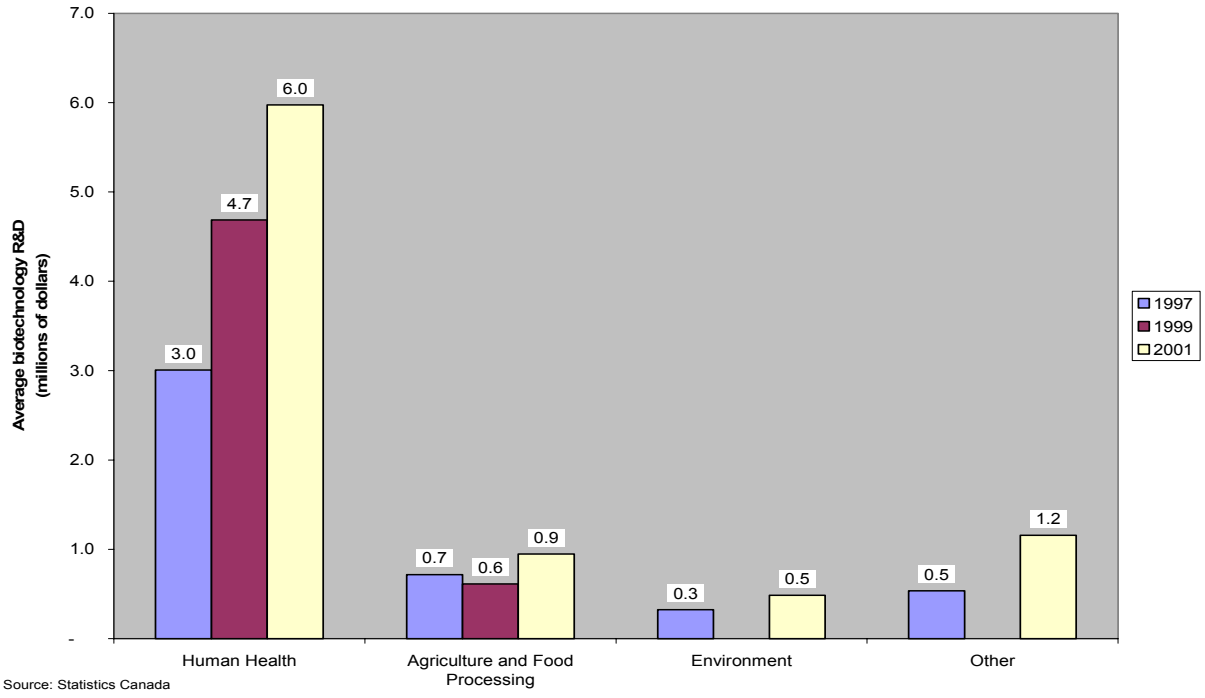
14. Office of Technology Assessment, Pharmaceutical R&D: Costs, Risks and Rewards, Washington (1993).

Between 1999 and 2001, the revenues-to-R&D ratio almost doubled for the Human Health sector. This was due to a 138% increase in revenues for this sector. In fact, during this period, firms in this sector succeeded in bringing roughly twelve times more biotechnology products onto the market.

The year 2000 was an important year for firms in the Human Health sector, since it was in June of that year that the decoding of the human genome was completed. Biological information derived from the human genome decoding helps create preventive therapies, vaccines and therapeutic products that will improve the duration and quality of life. In the years to come, firms in the Human Health sector will be engaged even more intensively in research, and some believe that these firms are still at the beginning of their technology curve (Ernst & Young, 2003).

Although R&D expenditures in the Agriculture and Food Processing sector are much lower than in the Human Health sector, they nevertheless increased by 43% between 1999 and 2001. Unlike in the period 1997-1999, this gain was due not only to the increased number of firms in this sector, but also to real growth. While average biotechnology R&D expenditures were low, they grew between 1999 and 2001 (Chart 10).

Chart 10: Average biotechnology R&D expenditures by sector, 1997 to 2001[15]



In 2001, the biotechnology revenues-to-R&D ratio for this sector was 7.72, some four times higher than for the Human Health sector. Thus, each dollar devoted to biotechnology R&D in the Agriculture and Food Processing sector generated four times more biotechnology revenues than in the Human Health sector. Firms in Agriculture Biotechnology do not face costs as high as

15. Average R&D spending for the "Environment" and the "Other" sectors is not available for 1999.

those in the Human Health sector. But this does not mean that these firms do not invest in R&D. In 1999 and 2001, Agriculture Biotechnology ranked second in R&D expenditures after Human Health.

C- Change in biotechnology R&D by region

Between 1999 and 2001, all provinces registered increases in their biotechnology R&D expenditures except Saskatchewan. The latter province, which had experienced a 47% increase in biotechnology R&D expenditures between 1997 and 1999, ranked at the same level as the Atlantic regions in 2001 and accounted for only 1% of overall biotechnology R&D expenditures for that year. Considering the increase in the number of biotechnology products/processes in the stages preceding commercialization[16] in Saskatchewan (from 80 products/processes in 1999 to 126 in 2001), one would have expected an increase in its R&D expenditures. This result is all the more surprising because a major share of Canadian agriculture biotechnology activity had taken place in Saskatchewan, and more than half of that province's biotechnology activity is in Agriculture Biotechnology (67% of that province's biotechnology R&D expenditures were in agriculture and 10% in food processing in 2001); a concentration of biotechnology firms targeting the agricultural field has been noticed in the city of Saskatoon. This is underlined by the fact that between 1999 and 2001, biotechnology R&D in the Agriculture and Food Processing sector increased by 43%.

In Saskatchewan, whereas biotechnology R&D expenditures fell 64% between 1999 and 2001, total R&D expenditures registered a relatively small decline of 5%. It appears that firms in Saskatchewan have decided to diversify their research activities by orienting their R&D expenditures toward sectors other than biotechnology. This may also be seen in the change in that province's figures for total human resources and biotechnology human resources: whereas total human resources increased 11% between 1999 and 2001, human resources in biotechnology-related activities declined 9%.

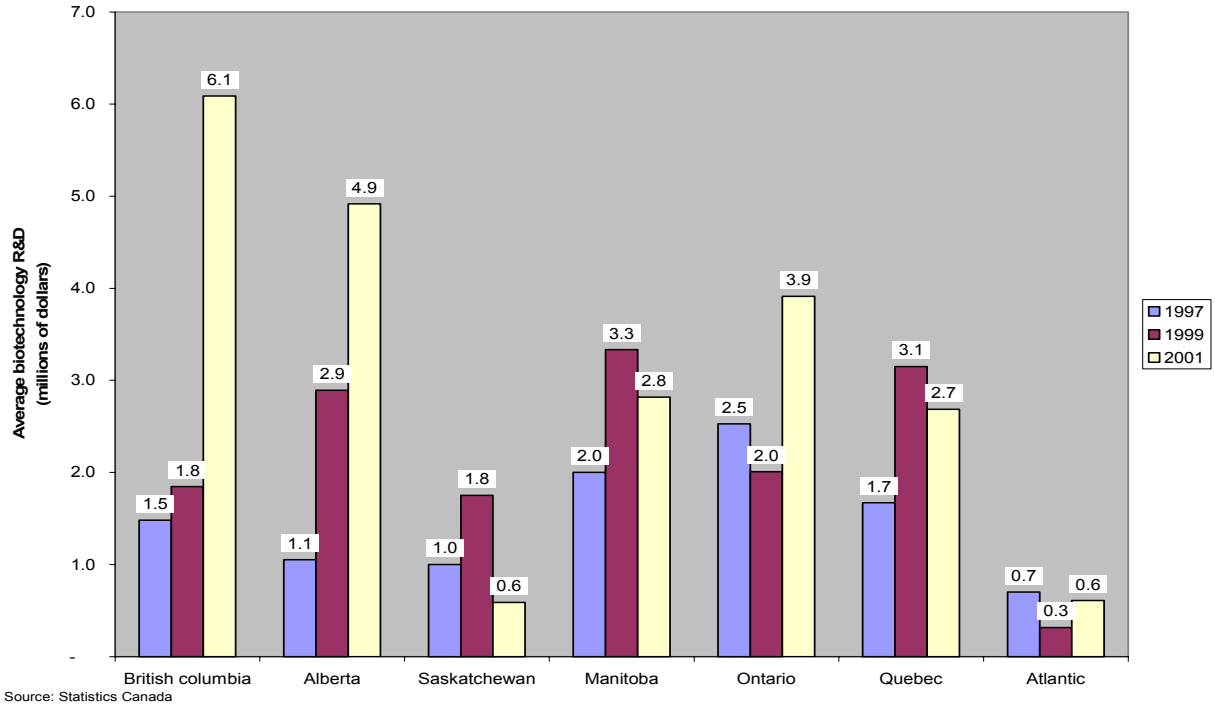
Quebec, Ontario and British Columbia led the way in biotechnology R&D expenditures over the entire study period. However, whereas in 1997 and 1999, British Columbia ranked third after Quebec and Ontario, it moved into first place in 2001 with 31% of all biotechnology R&D expenditures, or $420 million (up 221% from 1999). It was closely followed by Ontario. This upward trend persists when average expenditures are considered; these went from $1.8 million in 1999 to $6.1 million in 2001. A sectoral analysis of biotechnology R&D expenditures shows that in all sectors (except the "Other"[17] sector), these expenditures increased for British Columbia. Expenditures in Human Health and Agriculture and Food Processing doubled, while those in the Environment sector increased significantly during this period because they had been very low in 1999. Of the three main Canadian provinces (i.e., Ontario, Quebec and British Columbia), British Columbia devoted the largest share of its total R&D to biotechnology (73%). In 2001, Quebec ranked third in this comparison (with 40%). These findings suggest that Quebec firms have a more diversified R&D portfolio that is not concentrated exclusively in biotechnology activities.

16. These stages are research and development, pre-clinical trials/confined field trials, and regulatory phase/unconfined release assessment.
17. *Idem* as footnote 10.

In fact, out of the total of 46 large biotechnology firms in 2001, 43% were in Quebec. It is generally large firms that diversify their R&D activities (see Section 2.2 A). British Columbia firms appear to have an R&D portfolio that is concentrated in biotechnology activities. British Columbia therefore has an increasingly active research base in biotechnology. A large number of that province's firms were spin-offs from local universities (see Byrd, 2002).

Ontario firms outspent Quebec firms in 2001: their outlays in biotechnology R&D totalled $395 million, up 77% from 1999. Between 1999 and 2001, biotechnology R&D expenditures in Quebec remained fairly stable, with only a 4% increase.

Chart 11: Average biotechnology R&D expenditures by region, 1997 to 2001



Source: Statistics Canada

III- Financing

Access to capital is a critical factor for the success of biotechnology firms (Traore, 2004b; Niosi, 2000). In order to maintain their success, these firms (especially small ones) need continuous inputs of funds to finance each of the stages in the development of their products, since their revenues are often insufficient.

To access financial capital, biotechnology firms turn to different sources, ranging from conventional sources (such as banks or government), friends/family or venture capital funds. The need for financing will differ depending on the stage of development of the product/process and the firm's past success rate in raising capital (McNiven, 2001).

Table 7: Percentage of capital raised from each source, Canada, 1999 and 2001[18]

	1999	2001
Canadian based venture capital (%)	..	37
American based venture capital (%)	..	6
Total venture capital (%)	30	43
Conventional sources (%)	7	7
Angel investors/family (%)	27	15
Government sources (%)	7	13
Initial public offering (%)	2	..
Collaborative arrangements , alliances (%)	4	..
Other[a] (%)	19	23

Source: Statistics Canada, Biotechnology use and development survey - 1999 and 2001

[a] In 2001, the "Other" category includes European Venture Capital, Initial Public Offering and collaborative arrangements. In 1999, this category includes mainly private investments.

.. : not available for the reference period.

Venture capital (especially Canadian venture capital) continues to be the main source of financing for Canadian biotechnology firms. Between 1999 and 2001, the portion of all capital raised that came from this source went from 30% to 43%. This suggests that despite an unstable economic environment and a decrease in confidence in markets (with the burst of the speculative bubble in 2000), markets appear to be maintaining their confidence in biotechnology firms. Sources in the "Other" category, which in 2001 consisted mainly of initial public offerings, collaborative alliances and European venture capital, rank second as a source of financing. The results for 1999 indicate that initial public offerings are not often used as a source of financing. This is not surprising, since young firms that are still at an early stage in their development, such as biotechnology firms, often have problems raising capital through this type of financing. Patents and collaborative arrangements with the academic sphere (and with larger firms) "appear to be positive signals of competencies for potential investors when the firm enters into the stock market" (Mangematin, 2003). Despite increases in biotechnology revenues, R&D spending, the number of patents and the number of products/processes on the market between 1999 and 2001, biotechnology firms seem to have problems raising capital using initial public offerings and conventional sources. In general, the explanation for this situation is that firms lack assets to secure their loans.

18. The 1997 data are not available.

3.1- Amount of capital raised

In 2001, Canadian biotechnology firms together raised capital totalling $980 million. Despite a 54% drop in comparison to 1999, this amount is two times greater than in 1997. Medium-sized firms were the only ones to increase the amount of capital raised, from $160 million to $374 million between 1999 and 2001 (Table 8).

Table 8: Change in amount of capital raised by size, sector and province, 1997 to 2001

	Amount of capital raised			
	1997 (000,000)	1999 (000,000)	2001 (000,000)	Change (%) 1999-2001
A) SIZE				
Small (Less than 50 employees)	333	1,690	517	-69
Medium (50-149 employees)	87	160	374	134
Large (150 or more employees)	47	297	89	-70
Total	**467**	**2,147**	**980**	**-54**
B) SECTOR				
Human Health	332	867	858	-1
Agriculture and Food Processing	62	87	72	-17
Environment and Other[a]	74	1,193	50	-96
Total	**467**	**2,147**	**980**	**-54**
C) PROVINCE				
British Columbia	125	545	127	-77
Alberta	40	50	139 E	178
Saskatchewan	36	..	F	..
Manitoba	X	..	X	..
Ontario	184	175	216	23
Quebec	69	1,301	467	-64
Atlantic	X	63 E	11 E	-83
Total	**467**	**2,147**	**980**	**-54**

Source: Statistics Canada

E: use with caution

F: too unreliable to be published

.. : not available for the 2001 reference period

Note: Due to rounding, components may not add to totals

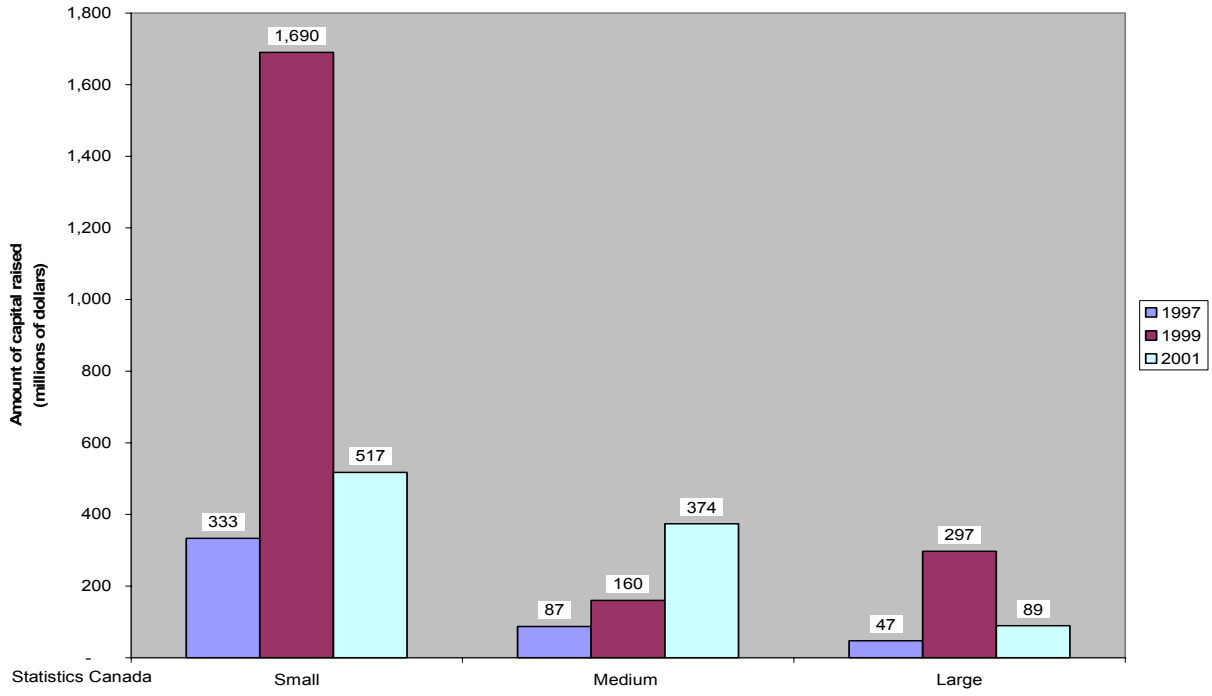
[a] For confidentially reasons, the sectors "Environment" and "Other" are grouped under one category.

Despite the decrease in the amount of capital raised between 1999 and 2001, the success rate of firms that managed to raise capital was very similar in the two years, and in both cases it was greater than 70%. In 1999, out of 178 firms that attempted to raise capital, 138 were successful. The corresponding figures were respectively 188 and 134 in 2001.

A- Change in amount of capital raised by size

In 2001, small firms accounted for 53% of the total capital raised. However, this result does not mean that small firms were more successful raising funds. In comparison to large firms, which tend to have a more diversified portfolio of activities, small firms concentrate more on biotechnology. Therefore, they are going to devote a larger share of the capital that they raise to this activity.

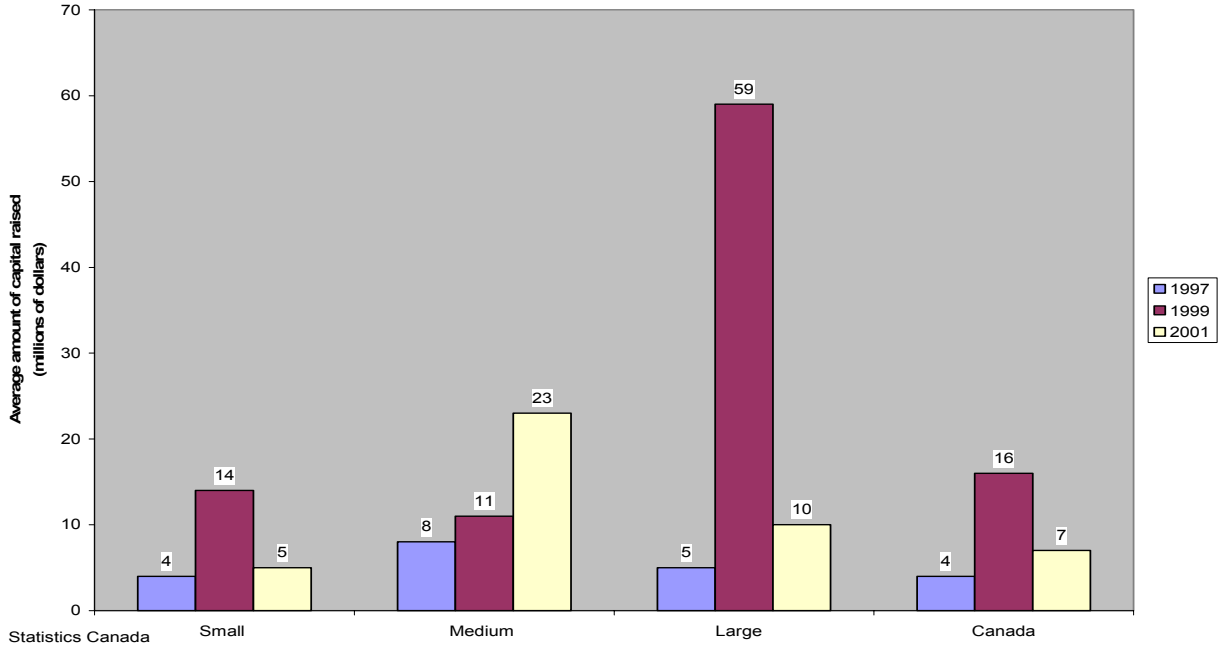
Chart 12: Change in amount of capital raised by size, 1997 to 2001



Whereas small firms' share of capital raised has declined over time (it was 71% and 79% respectively for 1997 and 1999), that of medium-sized firms has increased, rising from 7% in 1999 to 38% in 2001. The increase in the amount of capital raised for biotechnology by medium-sized firms is real and is not related to the number of firms in this size category. In fact, the number of firms that raised capital remained almost unchanged, going from 15 firms to 16 between 1999 and 2001.

For small firms, the change over time in the *average* amount of capital raised (Chart 13) indicates that in 1997, they raised two times less capital than medium-sized firms. Compared to large firms, they raised on average four times less capital in 1999 and two times less in 2001. Hence, the large amount of capital raised for biotechnology by small firms is related to the fact that there is a larger number of firms in this category that raised funds, which in turn is related to the fact that firms in the "small" category account for a large proportion (more than 70%) of biotechnology firms in Canada.

Chart 13: Change in *average* amount of capital raised by size, 1997 to 2001



Small firms had the lowest success rate in raising capital in 2001. For those firms, only one company in two succeeded in meeting its capital requirements, whereas the rate for medium-sized firms was four in five and for large firms, two in three (McNiven et al., 2003; Traore, 2004b). In 2001, the main reasons given by lenders for limiting or refusing loans to small firms were i) unfavourable market conditions; ii) further product development or proof of concept required, and iii) biotechnology product/process not sufficiently developed.

The first reason given (instability of the market) applies generally to all biotechnology firms. When the speculative bubble in the technology sector and the Internet burst in 2000, markets became unstable and reluctant to lend to firms. This might explain in part the decreased amount of capital raised by biotechnology firms, both small and large.

According to an analysis of correlation between the number of products/processes at each development stage and the amount of capital raised in 2001, there is a positive and monotonic association between the number of products at the production/marketing stage and the amount of capital raised. Indeed, this is the only development stage that is significantly associated with the financial capability of biotechnology firms (Appendix 3). This means that the more products that a firm has on the market, the more likely it will be to raise capital for biotechnology. In 2001, medium-sized firms put 2,727 products on the market, up 127% from 1999. Because of the instability of markets during this period, lenders would appear to have become more selective in their loans and more risk-averse. In fact, a biotechnology product/process must go through several development stages before it reaches the market; for some types of products/processes, each stage requires some level of financing, and it may take several years before the product goes on to the next stage. Often, for a variety of reasons, the product will "die" before even reaching

the market. For these reasons, lenders will insist on further development of the product and proof of concept in order to minimize their risk.

B- Change in amount of capital raised by sector

In 2001, firms in the Human Health sector raised capital totalling $858 million for biotechnology, which accounts for 88% of the total for Canadian biotechnology activity (Table 8). Whereas all biotechnology sectors experienced a drop of at least 17% in the amount of capital raised between 1999 and 2001, the Human Health sector remained at a fairly stable level during that period (with a decrease of 1%).

The number of firms in the Human Health sector that tried to raise capital increased between 1999 and 2001, from 104 firms to 126. This was the only sector which, between 1999 and 2001, saw an increase in the number of firms obtaining funds. Even though firms in this sector experienced a drop in their *success rate* (the percentage of firms that succeeded in raising capital out of the total number of firms that attempted to do so) between 1999 and 2001 (from 81% to 75%), that rate was still higher than the rate for firms in other sectors. Firms in the Human Health sector appear to have more success raising capital for biotechnology. To evaluate a firm's performance, investors usually look at factors such as the number of patents (Coombs and Deeds, 2000; George et al., 2001), the number of products in development or on the market (Stalk and Hout, 1990; Schoonhoven, Eisenhardt and Lyman, 1990) or the number of strategic alliances (Dyer and Singh, 1998; Gulati, 1998). And the fact is that nearly 87% of the patents held by Canadian biotechnology firms in 2001 belonged to firms in the Human Health sector; furthermore, these firms also accounted for 69% of all products marketed and more than half of strategic alliances established in Canada in 2001.

C- Change in amount of capital raised by province

From a geographic standpoint, Quebec, Ontario and British Columbia together account for at least 80% of the total amount of capital raised in Canada. In 2001, Quebec's biotechnology firms led the way with $467 million worth of capital raised, representing half of all capital raised for biotechnology in Canada. Quebec also had the highest rate of firms attaining their capital-raising objectives for that year (64%).

Between 1999 and 2001, all provinces experienced a decrease in the amount of capital raised, except Ontario and Alberta. Quebec and British Columbia experienced a decrease of 64% and 77% respectively between those two years. For British Columbia, the decrease in the level of capital raised is due in part to the fact that fewer firms attempted to raise capital in 2001. In fact, whereas 43 firms had tried to raise funds in 1999, only 26 did so in 2001.

While the total level of capital raised was also down for Quebec, that province's firms succeeded in raising more capital on average in 2001. Since the success rate of Quebec firms was relatively high in 2001 (64%), the drop in the amount of capital raised may be related to a reduced need for biotechnology funding among Quebec biotechnology firms.

IV- Change in human resources

Human resources in biotechnology are characterized by a very high skill level. Nearly half of the biotechnology personnel in a biotechnology firm are concentrated in scientific research/direction and technician/engineer positions.[19] This is not surprising, since for any knowledge-based activity, the competition between innovative biotechnology firms is in the realm of intellectual property and ideas. Thus, highly skilled human resources are becoming the means by which these firms acquire their competitive edge.

Table 9: Change in human resources in biotechnology by size, sector and province, 1997 to 2001

	Number of biotechnology employees			
	1997	1999	2001	Change (%) 1999-2001
A) Size				
Small (Less than 50 employees)	2,895	2,902	3,144	8
Medium (50-149 employees)	2,299	1,323	3,230	144
Large (150 or more employees)	3,825	3,470	5,523	59
Total	**9,019**	**7,695**	**11,897**	**55**
B) Sector				
Human Health	6,280	5,433	8,675	60
Agriculture and Food Processing	1,542	1,323	2,264	71
Environment	291	323	709	120
Other[a]	906	616	249	-60
Total	**9,019**	**7,695**	**11,897**	**55**
C) Province				
British Columbia	1,042	1,191	1,746	47
Alberta	789	574	494	-14
Saskatchewan	351	289	262	-9
Manitoba	209	357	936 E	162
Ontario	3,416	2,547	3,346	31
Quebec	2,722	2,557	4,710	84
Atlantic	490	181	402 E	122
Total	**9,019**	**7,695**	**11,897**	**55**

Source: Statistics Canada

E: use with caution

Note: Due to rounding, components may not add to totals

[a] The "Other" sector consists of Bioinformatics, Aquaculture, Mining/Energy/Petroleum /Chemicals and Forest Products.

The change in human resources in biotechnology is not constant over time. In 1999, even though the main economic indicators were on the rise, biotechnology employment was down 15% compared to 1997. The 2001 employment data indicate a 55% increase in biotechnology personnel compared to 1999. This increase in employment has a real component, since the number of employees engaged in biotechnology-related activities continued to increase proportionally to the total workforce in the firm. The intensity of biotechnology employment (the ratio of biotechnology jobs to total jobs) went from 12% to 19% between 1999 and 2001.

19. For a more detailed description of the characteristics of human resources in innovative biotechnology firms in 2001, see McNiven et al., 2003, page 23.

In a study conducted jointly by Statistics Canada and Industry Canada (Traore et al., 2003: 32) special attention was paid to the evolution of human resources between 1997 and 1999. That study sought to grasp the factors explaining the drop in biotechnology employment, a surprising phenomenon given that the number of Canadian biotechnology firms had increased and most economic variables were on the rise during that period. The drop in employment occurred primarily in medium-sized and large firms, in all biotechnology sectors (except Environment) and in all provinces (except British Columbia and Manitoba). Correlation analyses led to two conclusions: first, science- and R&D-intensive jobs were not affected by this loss of employment. Second, given the strong correlation between contacting out and loss of employment between 1997 and 1999, it was argued that "the loss of personnel was more a transfer of service personnel which may have taken place between biotechnology firms and service companies."

The employment growth observed between 1999 and 2001 was mainly among full-time employees,[20] whose numbers increased 72%, while the number of part-time biotechnology employees declined 40%. While scientific research/direction and technician positions together made up some 50% of total biotechnology employment in 2001, employment in related services accounted for most of the increase in full-time employment. Most of the increase came from the management/administration/licensing category, which grew 153%, followed by production (152%) and regulation and clinical affairs (117%);[21] these are types of jobs associated with commercialization, which suggests that increasing numbers of firms are moving into the commercialization stage. Thus, whereas the decrease in biotechnology employment in 1999 was attributable to a possible transfer of human resources to services, and whereas the biotechnology personnel whose numbers declined that year were mainly involved in marketing/distribution and regulation/clinical affairs, much of the growth in biotechnology human resources in 2001 appears to have been in these types of jobs.

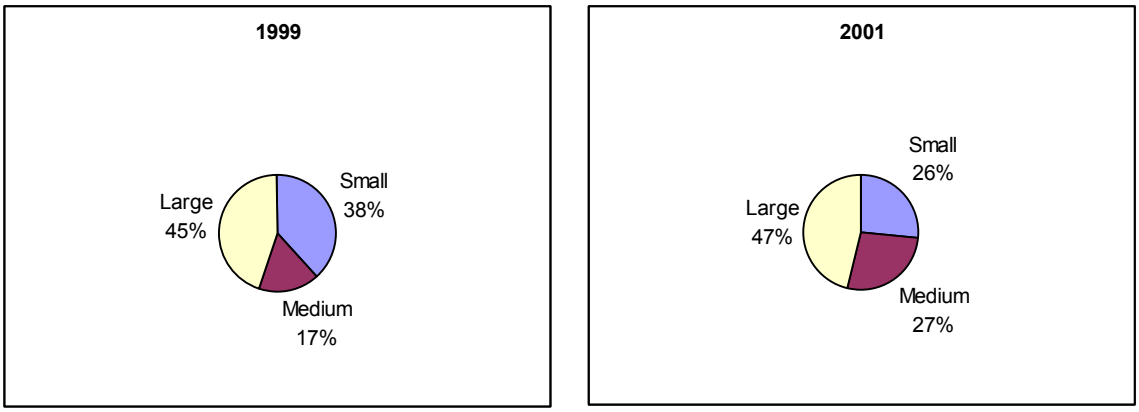
Between 1999 and 2001, employment was up in firms of all sizes. But there was a reversal of trend in the evolution of employment by firm size, compared to the period 1997-1999. During that period, employment had remained stable for small firms (zero growth) and dropped 42% and 9% respectively for medium-sized and large firms. Between 1999 and 2001, a similar comparison showed that employment increased slightly for small firms (8%) but jumped 144% and 59% respectively for medium-sized and large firms.

Thus, it was mainly the medium-sized and large firms that absorbed the increase in human resources between 1999 and 2001, accounting for respectively 45% and 49% of overall growth. Among medium-sized firms, the scientific research and technician/engineer categories accounted for more than 60% of the increase in the number of employees.

Chart 14 shows that the distribution of biotechnology jobs by firm size was almost unchanged for large firms, while differences emerged for small and medium-sized firms. The proportion of employees working in small firms declined (from 38% to 26%), while the proportion working in medium-sized firms increased (from 17% to 27%).

20. These are employees who spend at least 50% of their time on biotechnology activities. Part-time employees are those who spend less than 50% of their time on biotechnology activities.
21. Source: Biotechnology Use and Development Survey – 2001.

Chart 14: Distribution of biotechnology employment by size, 1999 and 2001



Younger firms are starting to show increasing maturity. Some small firms have changed from one size category to another. Among the units commonly selected from both surveys, some 15% of the firms that were classified as small in 1999 reported as medium-sized or large in 2001. The biotechnology firms' maturity is also reflected in the human resources composition that has changed between 1999 and 2001. There is an increase in biotechnology employees with production-related responsibilities. For example, in Canada, the ratio of employees with production-related responsibilities to the overall biotechnology employment went from 0.02 in 1999 to 0.16 in 2001.

In general, employment rose in all sectors between 1999 and 2001. The Human Health sector continued to employ the lion's share of biotechnology human resources in Canada (73% in 2001), followed by the Agriculture and Food Processing sector (19%). Whereas between 1997 and 1999, employment in Human Health declined by 847, this sector added 3,242 jobs between 1999 and 2001, accounting for 77% of the increase in biotechnology employment in Canada.

From a geographic standpoint, all provinces except Alberta and Saskatchewan experienced employment gains in 2001. Quebec firms led the way with a gain of 2,153 jobs, moving ahead of Ontario in terms of the number of employees in 2001. In Saskatchewan, the number of biotechnology employees declined 9% between the two years, while firms' total employment rose 11%. Firms in that province appear to have decided to diversify their activity portfolios and concentrate less on biotechnology.

Conclusion

The objective of this study was to analyse how innovative Canadian biotechnology firms have evolved in recent years by comparing data from the 1997, 1999 and 2001 surveys of biotechnology use and development.

The analysis shows that most indicators of Canadian biotechnology activity were up over the period 1997 to 2001. Firms succeeded in bringing approximately 9,660 biotechnology products onto the market in 2001, up considerably in relation to the other years. Also, the biotechnology revenue-to-R&D ratio increased in 2001, indicating that research was beginning to pay off.

However, the size of a firm continues to be a factor that can limit its ability to raise capital and its success in doing so. In 2001, only one small firm in two reached its financing target, whereas the ratio was higher for the other two size categories.

In 2001, medium-sized firms seemed to stand out. First, there was an increase in the number of firms in this size category, owing in part to the fact that some small firms moved into higher size categories. Medium-sized firms accounted for nearly 60% of the total change in the number of firms between 1999 and 2001. They also posted the highest rate of growth of total revenues generated by biotechnology as well as export revenues and biotechnology R&D. Furthermore, the amount of capital raised declined for all size categories except for medium-sized firms between 1999 and 2001. The maturation of biotechnology firms is starting to show up in the data, and medium-sized firms are playing an increasingly important role in Canadian biotechnology activity.

The Human Health sector continues to dominate the biotechnology field in Canada. This sector accounted for more than half the population of Canadian biotechnology firms in 2001. This group also accounted for the largest share of revenues (69% of the total), and it invested the largest amount in biotechnology R&D (88% of total R&D). Furthermore, whereas in 1999, firms in this sector had fewer products on the market than those in other sectors, they accounted for nearly 69% of all products commercialized by Canadian firms in 2001; in next place were firms in the Agriculture and Food Processing sector.

Most of the biotechnology activity in Canada takes place in Quebec, Ontario and British Columbia. However, in 2001, Quebec stood out, since its firms succeeded in commercializing more than 8,000 products, or 84% of the total number marketed that year. Whereas between 1997 and 1999, nearly one-third of the increase in biotechnology revenues was reported by firms in Saskatchewan, that province experienced a 95% drop in biotechnology revenues reported in 2001. Also, between 1999 and 2001, all provinces registered increases in their biotechnology R&D spending except Saskatchewan. While R&D spending declined in Saskatchewan, it increased by 47% in Alberta, offsetting the decrease in R&D spending in the region.

Despite the economic uncertainty that prevailed in 2000-2001, key biotech indicators remained stable, and Canadian biotechnology activity appeared to outperform the economy as a whole. The year 2000 was an important year for science and for biotechnology in particular. Let us recall that in June of that year, the gene structure was decoded, marking the beginning of understanding of human life. This understanding of the structure and map of the human genome will have major consequences for the research conducted by biopharmaceutical firms. In the years to come, firms in the Human Health sector will further intensify their research efforts, and some observers believe that these firms are at only the beginning of their technology curve.

This study has shed light on how biotechnology activity in Canada has evolved. Statistics Canada is developing its 2003 Biotechnology Use and Development Survey; the results should come out in the fall of 2004. This will enable us to contribute further to the evolving analysis of biotechnology activity in Canada and gain a better understanding of the characteristics of biotechnology firms.

References

Baldwin, J. (1996). "Innovation and success in Canada: Small and medium-sized enterprises" in J. de la Mothe and G. Paquet (Eds.): Evolutionary economics and the new international political economy, London, Pinter, 1996, pp: 238-256.

Bernier, R. (1997). "The effect of country of control on industrial research and development (R&D) performance in Canada, 1993". Service Bulletin, Science Statistics, Catalogue No. 88-001, Vol. 21, No. 2, SIEID, Ottawa: Statistics Canada.

Byrd, C. (2002). "Profile of spin-off firms in the biotechnology sector: results from the Biotechnology Use and Development Survey - 1999". Working Paper No. 04, Catalogue No. 88F0006XIE, SIEID, Ottawa: Statistics Canada.

Ernst and Young. (2003). "Resilience: Americas Biotechnology Report 2003".

Foss, N. (1997). Resources, firms and strategies, New York, Oxford University Press, 1997.

George, G., Zahra, S.A., Wheatley, K.K. and Khan, R. (2001). "The effects of alliance portfolio characteristics and absorptive capacity on performance. A study of biotechnology firms". *Journal of High Technology Management Research*, Vol. 12, pp: 205-226.

Canada's Research-Based Pharmaceutical Companies, November 2001, "The value of medicines from biotechnology", http://www.canadapharma.org/Industry_Publications/Value_Medecine/ValueBiotech_e.pdf.

Mangematin, V., Lemarié, S., Boissin, J.P., Catherine, D., Corolleur, F., Coronini, R. and Trommetter, M. (2003). "Development of SMEs and heterogeneity of trajectories: the case of biotechnology in France", *Research Policy*, Vol. 32, pp: 621-638.

McNiven, C. (2001). "Practices and activities of Canadian biotechnology firms: results from the Biotechnology Use and Development Survey - 1999". Working Paper, No. 11, Catalogue No. 88F0006XIE, SIEID, Ottawa: Statistics Canada.

McNiven, C., Raoub, L. and Traore, N. (2003). " Features of Canadian biotech innovative firms: results from the Biotechnology Use and Development Survey - 2001", Working Paper, No. 5, Catalogue No. 88F0006XIE, SIEID, Ottawa : Statistics Canada.

Niosi, J. (2000). "Explaining rapid growth in Canadian biotechnology firms", Working Paper, No. 8, Catalogue No. 88F0017MIB, SIEID, Ottawa: Statistics Canada.

Statistics Canada. (1997). "Biotechnology Firm Survey – 1997", SIEID, Ottawa: Statistics Canada.

Statistics Canada. (1999). "Biotechnology Use and Development Survey – 1999", SIEID, Ottawa: Statistics Canada.

Statistics Canada. (2001). "Biotechnology Use and Development Survey – 2001", SIEID, Ottawa: Statistics Canada.

Teece, D. (1986). "Profiting from technological innovation: implications for integration, collaboration, licensing and public policy, *Research Policy*, Vol. 15, pp: 285-305.

Traore, N. (2004a). "Biotechnology Use and Development Survey: methodology, issues and responses", Working Paper, No. 6, Catalogue No. 88F0006XIE, SIEID, Ottawa: Statistics Canada.

Traore, N. (2004b). "Canadian innovative biotechnology firms' access to financing capital: extent and success factors", *Forthcoming*, SIEID, Ottawa: Statistics Canada.

Traore, N., Tourigny, D., St-Louis, M.H. and Ouimet, C.A. (2003). "How is the Canadian biotechnology evolving: a comparison of the 1997 and 1999 Biotechnology Use and Development surveys", Working Paper, No. 3, Catalogue No. 88F0006XIE, SIEID, Ottawa: Statistics Canada.

Appendix 1: Total number of biotechnology products/processes in development and number of biotechnology products/processes on the market, by size, sector and province, 1997, 1999 and 2001

	1997		1999		2001	
	In development	Approved/ On market / In production	In development	Approved/ On market / In production	In development	Approved/ On market / In production
	(Number)	(Number)	(Number)	(Number)	(Number)	(Number)
A) Size						
Small (Less than 50 employees)	1,480	1,040	6,164	5,041	3,477 E	6,667 E
Medium (50-149 employees)	5,482	470	4,502	1,203	2,351 E	2,727 E
Large (150 or more employees)	204	248	323	353	2,531	267
Total	**7,166**	**1,758**	**10,989**	**6,597**	**8,359**	**9,661**
B) Sector						
Human Health	767	943	2,893	542	2,484 E	6,619
Agriculture and Food Processing	5,814	454	4,220	2,123	5,535	1,011
Environment	318	82	59	174	162	102
Other[a]	267	279	3,805	3,758 E	..	..
Total	**7,166**	**1,758**	**10,977**	**6,597**	**8,359**	**9,661**
C) Province						
Atlantic	119	223	X	X	101	38
Quebec	5,391	443	3,741	4,162	2,985 E	8,087 E
Ontario	935	540	2,083	808	1,971	405
Manitoba	37	4	X	X	2,322 E	24 E
Saskatchewan	120	204	80	34	126 E	41 E
Alberta	90	18	143	22	113	18
British Columbia	474	326	4,843	1,537	741	1,048
Total	**7,166**	**1,758**	**10,989**	**6,597**	**8,359**	**9,661**

Source: Statistics Canada

Note 1: In this table, the number of products/processes in development is the number of products/processes that did not reach the market or the production phase and includes the R&D, pre-clinical and regulatory stages.

Note 2: Due to rounding, components may not add to totals

E: use with caution

F: too unreliable to be published

.. : not available for the 2001 reference period

X: suppressed to meet confidentiality requirements of the *Statistics Act*

[a] The "Other" sector consists of Bioinformatics, Aquaculture, Mining/Energy/Petroleum/Chemicals and Forest Products.

Appendix 2: Correlation table, 2001

	Size	Sector	Province	Biotech revenues	Amount of capital raised	Biotech R&D	Biotech Exports	Total patents	Alliances
Size	1								
Sector	N.R.	1							
Province	N.R.	N.R.	1						
Biotech revenues (2001)	0.42*	0.002	-0.08	1					
Amount of capital raised (2001)	0.1	-0.16	-0.001	-0.003	1				
Biotech R&D expenditures (2001)	0.26*	-0.17	0.09	032*	0.18*	1			
Biotechnology exports (2001)	0.25*	0.14**	-0.08	0.48*	0.01	-0.02	1		
Total number of patents (2001)	0.25*	-0.12***	-0.02	0.53*	0.03	0.33*	0.62	1	
Alliances and collaborative arrangements (2001)	0.19*	-0.09	0.11***	0.23*	0.15**	0.25*	0.11***	0.18*	1

* Correlation coefficient is significant at the 1% level (2-tailed)

** Correlation coefficient is significant at the 5% level (2-tailed)

***Correlation coefficient is significant at the 10% level (2-tailed)

N.R. Not Relevant

Appendix 3: Correlation between number of products at each development stage and selected variables, 2001

	Research and development	Pre-clinical trials/ Confined field trials	Regulatory phase	On the market/ in production
Biotech revenues (2001)	-0.02	0.13**	0.01	0.004
Amount of capital raised (2001)	0.07	-0.01	-0.02	0.20*
Biotech R&D expenditures (2001)	-0.04	0.05	-0.008	-0.02
Biotechnology exports(2001)	0.03	-0.01	-0.01	0.11**
Total patents (2001)	-0.02	0.09	-0.004	0.002

* Correlation coefficient is significant at the 1% level (2-tailed)

** Correlation coefficient is significant at the 5% level (2-tailed)

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Volume 27

No. 1 Biotechnology Scientific Activities in Selected Federal Government Departments and Agencies, 2001-2002

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No. 5 Industrial Research and Development, 1999 to 2003

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No. 7 Research and development (R&D) personnel in Canada, 1991 to 2000

No. 8 Federal government expenditures on scientific activities, 2003-2004[p]

Volume 28

No. 1 Estimation of research and development expenditures in the higher education sector, 2001-2002

No. 2 Total spending on research and development in Canada, 1990 to 2003[p], and provinces, 1990 to 2001

No. 3 Distribution of federal expenditures on science and technology by province and territories, 2001-2002

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No. 5 The provincial research organizations, 2001

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