THE SWEDISH BIOTECHNOLOGY ENGINE: FINISHING THE FINAL LAP

Marisa Castronova

Introduction

It may seem unbelievable; but with a population of only nine million people, Sweden has had a profound impact on medical and biological science in the world. For instance, in the 1940s Arne Tiselius discovered electrophoresis, a method of protein analysis with great importance and practicality used in medical and biological research today. In 1950, Inge Edler and Hellmuth Hertz devised echocardiography, a non-invasive method for examining the heart. This medical technology revolutionized cardiovascular diagnostics throughout the world. Also, such products as the dialysis machine, the world famous ulcer medicine omeprazole (Losec®), and the acid pump inhibitor esomeprazole magnesium (Nexium®) are all worldwide contributions adding to Sweden's scientific clout. ("Swedish Inventions and Discoveries")

In the 21st century, a high priority is placed on biotechnology as a means to foster economic growth and scientific discovery. While the world usually looks toward the United States, the United Kingdom, Germany, and France to take the lead within this biotechnological race, should Sweden be ignored as one of the favorites? The answer is "No." Currently, the Swedish biotechnology industry enjoys high international status. It comprises more than 200 companies, ranking fourth in Europe in terms of total number of biotech companies and ninth in the world. ("Biotechnology and Pharmaceuticals in Sweden," p. 1) Thus, despite Sweden's small population, it has still managed to contribute substantially to the field of biotechnology. With such success, it is no surprise that Sweden's intent is to support the emergence of its new sector consisting of smaller, more innovative biotech companies. However, although the Swedish biotechnology industry has great potential, many of these smaller companies are currently stuck in the start-up phases of development, slowing down the Swedish biotech engine. Employing strate-

gies that lead to better early seed financing and strengthened ties between industry and academia will prove helpful in overcoming this problem. Only then will Sweden be able to make it through the final lap.

I begin this article by highlighting the importance of the biotechnology industry in Sweden. Next, I provide statistical evidence illustrating the industry's problems with early seed financing and the need for strengthened ties between industry and academia. Finally, I discuss strategies to help alleviate these problems and conclude with thoughts on the future of this potential industrial powerhouse.

What Is Biotechnology?

According to Sandstrom and Norgren, biotechnology is defined as the application of science and technology to living organisms in order to alter living or non-living materials for the production of knowledge, goods, and services. (Sandstrom and Norgren, p. 9) The Swedish biotechnology companies that produce knowledge, goods, and services are divided among six industrial sectors. Modern biotechnology is used mainly in the pharmaceutical/medical subsector of the industry where more than 50 percent of the companies and employees in the biotech industry are found. This subsector aids in drug discovery, development, diagnostics, and medical technology. Also, the subsectors of bioproduction and biotech tools and supplies have shown impressive scientific advancements in recent years. For example, BioInvent International AB, a firm in the bioproduction subsector, produces biologic molecules and microorganisms such as monoclonal antibodies and fusion proteins for use by other biotech firms. In addition, Pyrosequencing, a firm in the biotech tools and supplies subsector, produces equipment such as DNA-sequencing instruments for use by biotech companies and universities. Finally, scientific applications of the subsectors of environmental biotechnology, agrobiotechnology, and functional food and feed result in products for plant improvement, waste disposal, and increased nutrition, respectively. (Sandstrom and Norgren, pp. 51–52)

Why Is Biotechnology Important to Sweden?

The Applications of Biotechnology

Speaking at a 2003 conference in Washington, DC, Jan Eliasson, Swedish ambassador to the U.S., stated, "Biotech is promising not only because it can help develop our industries but also because biotech can contribute solutions to many of society's challenges." (Eliasson) With increasing knowledge in genomics and proteomics, biotechnology companies are finding useful applications for improving the quality of life. For example, the health care sector can enjoy the development of new drugs, diagnostic tools, and treatments. In 2001 the Swedish company Biovitrum was founded as a spin-off from the Pharmacia Corporation. With approximately 575 employees, it is one of the larger biotech firms in Sweden and focuses on various stages of drug discovery for prevalent metabolic diseases such as obesity, type 2 diabetes, and certain types of cancers. ("Biovitrum") Biotechnology also can improve the use of biologic processes for developing food with increased nutritional value. The biotech company Biogaia uses the microorganism *Lactobacillus Reuteri* as a probiotic (food that contains living microorganisms) for humans and animals in hopes that it will have beneficial health effects in the gastrointestinal tract. Finally, biotechnology can help improve the environment with new methods for soil treatment, waste disposal, and water treatment. For example, ANOX AB develops methods for testing levels of toxic substances and microorganisms in sewage. After analysis, bacterial strains may be used from dunghills and swamps to transform waste products into methane gas. Thus, much of the driving force behind the biotechnology industry stems from the industry's trans-sectoral nature. (Sandstrom and Norgren, pp. 53–54)

Economic Growth

In addition to a wide range of applications, a second reason biotech is important for Sweden is the industry's promising rate of

growth.[1] From 1997 to 2001, the total number of Swedish biotech companies in all sectors of the industry increased by 36 percent (from 135 to 183). In addition, the total number of employees in the industry increased over this period from 2,677 to 3,975. Annual turnover, the ratio of company sales to inventory, is another indicator of economic growth. All subsectors except one within the industry showed growth in annual turnover between the years 1997 and 2000. The pharmaceutical sector of biotech in Sweden grew by 31 percent and environmental biotechnology grew by 100 percent, while the remaining sectors of bioproduction, biotech tools and supplies, and functional food and feed enjoyed a growth in annual turnover between 60 percent and 80 percent. Agrobiotechnology, however, showed a 13 percent decrease. (Sandstrom and Norgren, pp. 65–68)

A Strong Science Base

In addition to its strong economic growth in the biotech sectors, Sweden also has a reputation for possessing a strong science base. To date, eight Swedes have received the Nobel Prize in physiology and medicine. Sweden also has received recent attention — even notoriety — from its pioneering research on adult and embryonic stem cells. Finally, Sweden ranks third in Europe (after Switzerland and Denmark) on a per capita basis in the total number of biotechnology and applied microbiology scientific publications. (Bergstrand, p. 5)

A strong science base is a necessity for achieving a successful biotech industry. The higher the quality of research and knowledge that a country produces, the more likely it is that the country will attract prominent scientists and collaborate with successful science companies. The data compiled by VINNOVA (see footnote 1) reveals that the Swedish share of the world's total number of scientific publications increased in five of seven life science fields from 1987 to 2001, with the fields of immunology, neuroscience/behavior, and biochemistry/biophysics showing the three largest totals.

Signs of Trouble for Swedish Biotechnology

Indicators of Economic Trouble[2]

All evidence points to recent growth in the Swedish biotechnology industry. The number of companies, the number of employees, and the rate of turnover all have increased. However, the continued economic growth of an industry through the launching of new products and services is a costly process. In order to maintain financial strength, stability, and growth, these industrial endeavors must be financed through the infusion of profits and not by loans or continued venture capital (VC). But, according to two measures of economic strength, the equity/assets ratio and net profits/losses ratio, the situation is somewhat disappointing.

The equity/assets ratio is one measure of financial strength. However, an equity/assets ratio between 30 percent and 50 percent indicates that the owners of the company have funded only 30 percent to 50 percent of the assets, leaving more than half of the company's assets funded by debt. Therefore, the company is highly leveraged and is a riskier investment for outside creditors. Equity/assets ratios within this range were observed for all sectors of the biotech industry in Sweden between 1997 and 2000. (Sandstrom and Norgren, pp. 67) Another way of analyzing this situation is by using the debt/equity ratio. Using the equity/assets ratio of 30 to 50 percent as a baseline, this translates into a debt/equity ratio between 1 and 2.333, indicating that between 50 percent and 70 percent of the company's assets are financed by debt. This is further evidence that companies within the Swedish biotech industry are highly leveraged.

In addition, the trend of growing net losses does not present an image of a prosperous industry. At the sectoral level, net losses were seen in four of six sectors between 1998 and 2001, with only the agrobiotechnology and

[1]The biotech companies described in this section are small and medium-sized with up to 500 employees. Much of the statistical data in this section was derived from a recent analysis by VINNOVA, the Swedish agency for innovation systems.

[2]The author would like to thank Dr. Parveen Gupta for assistance with this section.

environmental biotech sectors showing net profits. Net losses over time combined with high and increasing debt/equity ratios indicate that the activities of many companies within the biotech industry have been financed by the infusion of VC and not by net profits. However, with so many companies dipping into the same pool of financial resources, companies are now being halted in their start-up phases of development. (Sandstrom and Norgren, pp. 67–71) With many old and new companies relying heavily on seed financing, the question is whether sufficient capital will be available to support the development of Sweden's promising biotech industry.

Lack of Venture Capital

A look at Sweden's VC industry will help determine whether sufficient capital currently exists. Between 1995 and 2000, Sweden enjoyed a fast growing VC industry, and VC firms specializing in biotech and life sciences frequently provided start-up and expansion capital to the industry. However, this trend has been changing. As outlined in Table 1, the percentage of investments in both the seed and start-up phases decreased from 2000 to 2001; investments in the later, more stable expanding phase of companies increased dramatically. ("The Development …")

In addition, a survey by the Swedish Venture Capital and Private Equity Association (SVCA) and the Swedish Business Development Agency (NUTEK) conducted every quarter since the first financial quarter of 2001 reveals some other interesting trends within the VC industry. The most dramatic trend is the decline in the number of seed-phase investments: the number of investments decreased for six quarters in a row, from 27 seed investments totaling 125 million Swedish krona (SEK) (c. $15.6 billon) during the first quarter of 2001 to only four seed investments totaling 13 million SEK during the second quarter of 2002. (Berggren) Thus, while the total amount of financing available is shrinking, the distribution of financing is changing as well. According to a PricewaterhouseCoopers MoneyTree survey, the U.S. also experienced a dry spell in VC activity during 2001, with such activity in the VC sector falling from approximately $106 billion total investments made in 2000 to only about $40 billion in 2001. Furthermore, most investments were made in the later stages of company development. The declining U.S. trend also characterized VC investments within the life sciences, which totaled $6.9 billion in 2000 and $5.3 billion in 2001. Thus, although this dry spell is not unique to Sweden, the country must still find a way to address this problem in order to help its biotechnology industry grow. It is significant that during the first six months of 2002, several industries, including information technologies (39 percent), communications (26 percent), and Internet technology (19 percent), have attracted larger percentages of total investments available than the biotech industry (18 percent), thus creating increased competition for financial resources. ("The Development…")

Considered altogether, this evidence reflects a problem for small Swedish biotech companies. Johan Lembke, Senior Project Manager, Science and Technology, Embassy of Sweden, eloquently summarized the sentiments of Swedes and Americans: "The provision

Table 1
Distribution of Investments Made by the Swedish Venture Capital Industry

Phase of Company Development	2000 (%)	2001 (%)
Seed	14.3	9.3
Start-up	49.6	33.0
Expansion	30.1	46.6
Replacement	1.1	4.4
Buyout	4.0	6.7

Source: "MoneyTree™ Survey."

of and access to early-stage funding is becoming an even more difficult task in a time when promise and products, rather than promise alone, often are favored." (Lembke, p. 3) Many venture capitalists are taking fewer risks and investing in later stages of company development, making it difficult for new companies to get started. Sweden must address this problem in order for the industry to continue to grow.

Lack of Early Public Seed Financing

Public seed financing is available to biotech companies from government agencies such as NUTEK and the Swedish Innovation Centre (SIC). However, in a questionnaire sent in June 2000 to the managing directors of 139 biotech companies, criticism was voiced regarding the support of this current government funding system. Namely, the responding managing directors complained that government agencies such as NUTEK and SIC have become prone to taking fewer risks and are acting more like the venture capitalists discussed previously who are demanding later-stage, lower risk options for investment. (Backlund et al., pp. 45–46) This criticism is not without merit. Starting in 2002, Industrifonden, another government agency, was to take over much of the early seed financing of NUTEK. However, few investments have come out of this collaboration. In addition, NUTEK and other government agencies can only finance half of the total investment needed to start a company, with the other half being matched by non-governmental investors. Thus, the amount of public early seed financing available to biotech companies is small. (Sandstrom and Norgren, p. 77)

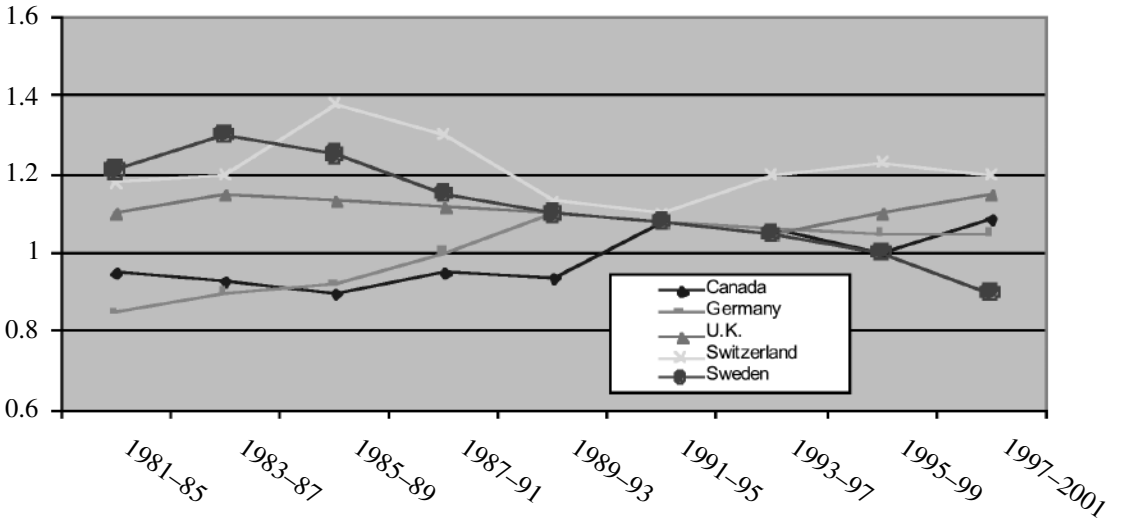
Citation Trends

Scientific research articles are an important resource for biotech companies. These companies draw on research, most of which is done at the academic level, in order to develop new ideas and products. Thus, with university researchers authoring 96 percent of life science articles, employing strategies to help strengthen the ties between industry and academia might prove beneficial to the success of smaller biotech companies.

One indication of the quality of published articles is the extent to which they are cited in later articles. However, over the last twenty years, there has been a decline in the relative citation level of Swedish research articles compared to the relative citation level of research done in other countries. Between 1981 and 2001, the relative citation levels for Swedish articles within the life science fields of neuroscience/behavior and biochemistry/biophysics have fallen below the global average (indicated as 1.0 in Figures 1 and 2). The relative citation level for Swedish articles within the life science field of cell/developmental biology has also decreased. On the other hand, for biotechnology/applied microbiology, molecular biology/genetics, and microbiology, the citation trend is increasing beyond the global average while within the field of immunology there is no clear trend. (Sandstrom and Norgen, p. 22) However, Sweden publishes the largest percentage of its total number of research articles from the fields of neuroscience/behavior and biochemistry/biophysics. Thus, what becomes disheartening is that within these two fields, Sweden is losing ground in citation levels relative to several other countries despite Sweden's beginning at a higher-than-global average. Figure 1 shows that within the field of neuroscience/behavior, Germany, Canada, the U.K., Switzerland, and the U.S. all have now surpassed Sweden in relative citation levels, while Sweden has actually dropped below the global average. The situation is similar in the field of biochemistry/biophysics, as Figure 2 shows.

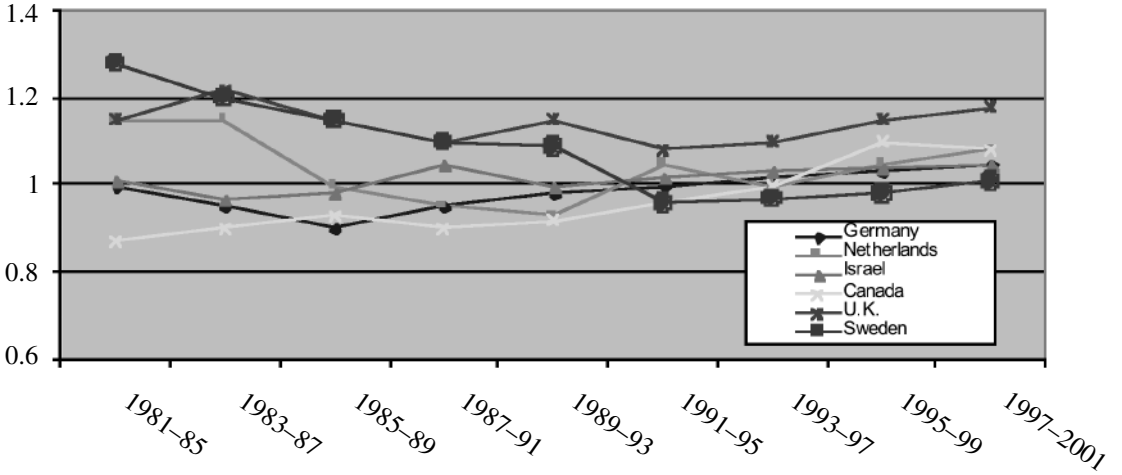
Some argue that these decreasing trends are inconsequential for the Swedish biotechnology industry. Although the number of Sweden's publications and relative citation levels in the field of biotechnology/applied microbiology is on the rise, this field covers only a small part of the total publication volume. The significance of this overall decreasing citation trend, though, is that biotech companies do not rely on knowledge from just one life science discipline. Rather, they rely heavily on knowledge in many fields in order to generate ideas that will enable them to take off and move beyond the start-up phase. For example, Biovitrum is one of Europe's largest biotech companies; it

Figure 1
Relative Citation Levels for Articles within the Field of Neuroscience/ Behavior, 1981–1997 (World Index=1)*



Source: Sandstrom, Anna and Lennart Norgren.
* The values listed along the y-axis indicate whether a country's citation level is above, below, or at the world average citation level shown as 1.0.

Figure 2
Relative Citation Levels for Articles within the Field of Biochemistry/ Biophysics, 1981–1997 (World Index=1)*



Source: Sandstrom, Anna and Lennart Norgren.
* The values listed along the y-axis indicate whether a country's citation level is above, below, or at the world average citation level shown as 1.0.

produces recombinant protein products and plasma products. In order to research and develop such products, scientific knowledge from the fields of molecular biology/genetics, biochemistry, and immunology is used. ("Biovitrum")

Strategies to Improve the Biotech Industry

Increasing Venture Capital Investments

Sweden already has begun to employ several methods to try to overcome the lack of VC available to small biotech companies. For example, the largest Nordic VC company, HealthCap, with locations in both Sweden and Switzerland, has created new funds of 3 billion SEK. The HealthCap fund will invest globally in pharmaceutical, biotechnology, and medical technology companies. It remains to be seen how such a new fund will be distributed among the stages of company development, but the new fund promises to give small Swedish biotech companies a chance to move beyond the seed and start-up phases. (Sandstrom and Norgren, p. 80)

Creandum is a new Nordic VC firm created by the Sixth Swedish National Pension Fund and Skandia Liv. Creandum is one of the few Nordic venture capital companies to focus its investments exclusively on early-stage technology. The fund will manage approximately 400 million SEK. Creandum admits that there is almost no early-stage venture capital available in Sweden today. It also acknowledges that there are companies with roots in universities and science parks that need competent early-stage investors with a long-term commitment to help them get off the ground. In a 2003 press release, Creandum described its excitement to be one of those players. For its first investment opportunity, Creandum plans to make 10 to 15 investments in scientific sectors where there are opportunities to create internationally competitive companies, where there are companies that have the potential for dramatic growth, and where there are companies that service markets of considerable size. With these criteria, Creandum is a good candidate to help several companies within the biotech industry. ("Creandum")

Increasing Government Investments

Swedish government agencies have heard the complaints voiced by many small and medium-sized biotech companies and have begun to employ methods to increase the amount of government investment. For example, NUTEK, ALMI Business Partner, and VINNOVA initiated a contest in 2002 where the most interesting new technology-based business enterprise could win grants. Of the 429 contenders, 20 received grants of 300,000 SEK each, with three of the winners having innovative ideas in the field of biotechnology. Although the number is small, it nonetheless represents Sweden's acknowledgement of the lack of government investment and its attempt to make some improvement. (Sandstrom and Norgren, pp. 77–78) In addition, seed funds are being launched at universities, such as the KTH Seed Capital Fund at the Royal Institute of Technology. This fund was created by Industrifondem, W Capital Management, SEB Foretagsinvest and KTH Holding. The fund's investments, totaling 127 million SEK, will help support high-tech companies in the early phases of their development. "KTH is the leading institute of technology in the Nordic region today," says Jan Sundberg, chairman of KTH Seed Capital. "KTH has in recent years spun off a number of companies with an aggregate value exceeding 20 billion SEK. By creating KTH Seed Capital, we hope to develop the potential that resides in KTH." ("KTH Seed Capital Gets MSEK 127," p. 1)

Strengthening Ties between Industry and Academia

When universities have completed high quality research, this knowledge must be transferred to industry quickly and efficiently. A weakness in this transfer process can slow the cycle and keep biotech companies in the start-up phases of development for much longer than desirable. In order to improve the transfer of knowledge, Sweden already has certain initiatives in place.

To stimulate the development of small and medium-sized biotech companies, Sweden has created science and technology parks with the

purpose of facilitating technology transfer between industry and academia. The majority of the Swedish science and technology parks are linked to universities and organized in the Swedepark association. Swedepark is a non-profit association founded in 1989 to offer a supportive environment for the establishment of new firms, product development, and cooperation between companies and academia. Swedepark currently has 31 members from both established science and technology parks and parks in the planning stages. Spin-off companies in the early stages of development typically set up camp within these parks in order to have access to new knowledge and educated personnel. ("Swedepark…") An investigation performed by Linkoping University shows that companies located within these parks have a tendency to grow faster than other companies in the same business. (Backlund et al.)

The Swedish Institute for Food and Biotechnology (SIK) was founded in 1996 when the Biotechnology Research Foundation (SBF) merged with the Institute for Food and Research. Approximately 120 companies, mainly from the food sector and the biotechnology sector, belong to the SIK. The SIK offers many services to its company members, such as a pilot program in which researchers from biotech companies are stationed at academic institutions. The researchers devote half their time to company activity and half to academic activity. This arrangement gives the biotech industry access to new knowledge through an established pipeline and allows a larger outflow of ideas from academia into the industry. The knowledge gained can be particularly beneficial to smaller companies in early stages of development, giving them a better chance to produce new and innovative products. (Backlund et al., pp. 97–99)

Strategies to Improve Swedish Biotechnology

Building Business Competence

Of the methods Sweden is beginning to employ, many involve the creation of new VC funds. However, this alone may not be sufficient to shift the focus from late-stage to early-stage investment. Because of Sweden's increasing number of biotech start-ups, there is fierce competition for early investments. Thus, the problem of lack of VC requires the attention not only of the VC industry but also the attention of the biotech companies.

In order to attract investment and move out of the start-up phase, Swedish biotech companies must prove to VC investors that they possess both clear-cut technologic and commercial advantages. They can accomplish this task by showing investors that they are leaders within their fields of research and can produce products with sustainable, long-term growth. Also, these biotech companies must show their investors that they have good internal organization, stability, and scientific experience. ("Elements to Consider When Seeking Capital") Without good company management and personnel, investors will not provide companies with financing. Thus, scientists in biotech companies need to have expertise in the business world. Biotech companies must be aware that investors wish to gain a profit just as much as the company does. Thus, it is important for companies to market themselves as best as they can by showing investors how they will make their money grow with products that can reach a large market. The solution to overcoming a lack of venture capital is two-sided, one that requires the contributions of both the VC industry and biotech industry.

The same strategy holds true in order to gain more public seed financing. Increasing the amount of financial investment made by government agencies is not enough to help biotech companies move past their early stages of development. Respondents to the 2000 VINNOVA survey also mentioned the need for competent business advice and support. Thus, in addition to providing increased financial assistance, the Swedish government can help biotech companies become skilled in business practices. (Backlund et al., p. 46)

A 1996 international study conducted by Bo Carlsson, Professor of Industrial Economics at Case Western Reserve University, revealed that start-up biomedical/biotech companies located in the state of Ohio (with 11 million inhabitants and 422 firms) grew much faster, provided twice as many jobs, and generated

much more total revenue ($15.0 billion vs. $6.1 billion) than similar start-up firms in Sweden (with 9 million inhabitants and 230 firms). Carlsson proposed that the reason Ohio biotech companies were more successful was that they possessed more managerial competence. Firms in Ohio were able to recruit experienced management, were superior at commercialization, had better access to financing (especially VC), had better links to scientific advisors, and enjoyed faster technology transfer between industry and academia. Although both Ohio and Sweden both possessed strong science bases, Sweden had too few venture capitalists and weaker managerial skills. Based on this evidence, Swedish government agencies may be well advised to develop databases of individuals with specific competencies regarding business development in the biotechnology field. Individuals within such a database could provide business management and networking skills and help companies seek out VC funds and other possible investors. Another option is for government agencies to develop workshops where scientific personnel within biotech companies can learn about entrepreneurship and business theory and practices. The key is combining capital investments with business skills. New seed capital funds can continue to develop, but without a knowledge of business, biotech companies have a lower chance of moving past the start-up phases of their development.

Strengthening the Scientific Knowledge Base

According to Tim Corless, Senior Associate Director for Science and Technology Ventures at Columbia University, "The main job of a university is to do research. But then, this research should be transferred to society as efficiently as possible so that the money the university research generates for the industry can go back into the university." This statement provides the premise for a strong plan of action to help strengthen ties between the Swedish biotech industry and Swedish academia. Swedish universities must first begin to generate more scientific knowledge with the hope that this knowledge will in turn create novel ideas from which the biotech industry can work.

There are several ways that Swedish universities and secondary schools can strengthen their scientific knowledge base. First, it is increasingly necessary for Swedish secondary and higher education science programs to have a greater multidisciplinary approach. Biotechnology transcends rigid, established delineations between various science fields. (Magnusson, p. 30) For example, companies in the tools and supplies sector of biotechnology sell to customers within the scientific areas of bioseparation, biomolecular analysis, biosensors, genomics, bioinformatics, and fermentation equipment. To use some specific examples of Swedish firms, Amersham Biosciences AB provides systems and products for research into genes and proteins. The firm Biacore develops tools for biomolecular interactions. The firm Gyros produces microlaboratories in the shape of a compact disc, and the firm Pyrosequencing produces DNA-sequencing instruments. Initial development of all these products relied on combining fundamental knowledge from chemistry, biology, physics, and engineering. Refinement of the products required expertise in the fields of software development, optics, mechanics, and electronics. (Sandstrom and Norgren, p. 52)

Another method by which the scientific foundation of Swedish research can be strengthened is offering better incentives to Swedish scientists to return home after doing research abroad. Sweden's Knut and Alice Wallenberg Foundation argues that a country should encourage young researchers to work abroad for the opportunity to gain valuable knowledge and expertise. ("Plugging the Brain Drain") However, the Foundation's director, Erna Möller, realizes that better incentives can be given to return home. For example, the Foundation currently pays for Swedish scientists to work at U.S. institutions such as the Massachusetts Institute of Technology. However, if the researchers return to Sweden, the Foundation also pays for laboratory construction and donates millions of krona in equipment so that researchers have the best work environment they need to succeed. ("Plugging the Brain Drain") In addition to subsidizing education and equipment, Sweden

might also consider providing tax breaks for these individuals as another incentive. (Magnusson, p. 27)

At a recent conference entitled "Sweden and the United States: Excellence in Biotechnology," it was suggested that Swedish universities could enhance the development of the biotech industry if universities were to educate not only students but also the public. Several voices at the conference called for academia to play a larger role in explaining new technologies and scientific information to the public. A constructive dialogue between researchers and the public (patients, physicians, journalists, etc.) could help the Swedish biotech industry reach its full potential. For example, across Europe many consumers have rejected genetically modified foods, and public concern over these products remains high. A European opinion poll published by the European Commission in December 2001 showed that 94.6 percent of EU citizens wanted the right to choose, 85.9 percent wanted to know more before eating genetically modified foods, and 70.9 percent did not want to eat genetically modified foods at all. In November 2000, the Nordic Industrial Fund carried out a survey in Denmark, Finland, Norway, and Sweden on genetically modified foods. The Nordic Industrial Fund found that when a product involved genetic modification, the public viewed this idea negatively, using words such as "unhealthy" and "uncertainty." ("What Europeans Think about GMOs") These statistics suggest that if the public is uninformed on ethical and research issues, the growth of the biotechnology industry may be cut short. If researchers take the time to explain new technology to the public and how these technologies can benefit their lives, there is a better chance for the industry to reach its potential.

Strengthening the Transfer of Knowledge from University to Industry

In addition to the generation of knowledge, competitiveness and the potential for economic growth depend on transferring this knowledge to industry quickly and efficiently. A weakness in the transfer can slow the cycle previously discussed and keep biotech companies in the start-up phases of development for much longer than desired. The following suggestions may help Sweden to strengthen the transfer of information from university to industry.

Large companies such as AstraZeneca have dominated the field of biotechnology in the past. However, if these larger pharmaceutical and biotechnology companies invest more money into university research, smaller spin-off biotech companies may be born and more effectively cross the threshold into later stages of development with continued support from these "mentors." Syngenta is one example of such a spin-off company. After the merger of Astra and Zeneca in 1999, Novartis agribusiness and AstraZeneca's agrochemicals division merged to form Syngenta, which has become a successful agrobiotech company. ("Syngenta")

Finally, Swedish universities might consider requiring undergraduate and graduate students to enroll in courses on entrepreneurship, specifically entrepreneurship within the life sciences and related fields. Within these courses, students can learn ways to finance a newly started company, leadership and negotiation tactics, and the rules and regulations that exist within the industry.

Future Prospects

In this article I have analyzed the strengths and weaknesses of Sweden's biotechnology industry and have offered several suggestions for its improvement. Small and medium-sized Swedish biotechnology companies face an uncertain future. These companies need to devise a plan to cross the threshold into later stages of development in order to enjoy vigorous and sustained growth. There is no doubt that, if more of these companies were able to leave the start-up phases of development, there would then be stronger opportunity for economic growth in the Swedish biotechnology industry. Lena Torell, President of the Swedish Academy of Engineering Sciences, stressed that once the industry enjoys a period of sustained success, its future growth will lie in its ability to foster even newer links between previously separate fields. Coined "The New Industrial

Paradigm" (Torell), the biotech industry will be driven to foster strong ties with the emerging fields of nanotechnology, information technology, materials technology, computing, artificial intelligence, and software. From these partnerships a range of new products, applications, and services will be generated with a great potential for success.

Sweden is well positioned to be a world leader in this emerging paradigm and to reap significant rewards. But first, small biotech companies must cross the boundary into later phases of development so that the whole industry can finish the final lap of the biotech race. By fine-tuning the trouble spots currently hampering Sweden's biotech industry, Sweden has the potential for attaining high international status in future scientific endeavors.

REFERENCES

Backlund, Anna, H. Haggbad, N. Markusson, L. Norgren, A. Sandstrom. *The Swedish Biotechnology Innovation System.* VINNOVA The Swedish Agency for Innovation Systems, 2001.

Berggren, Tom. The Development of the Venture Capital Industry in Sweden. Swedish Venture Capital and Private Equity Association, 2002. Online. www.vencap.se/article_view_e.asp?ArticleID=31. Accessed April 28, 2004.

Bergstrand, Bjorn. Biotechnology: Excellence in All Steps of Drug Discovery and Development. Invest in Sweden Agency, 2002.

"Biotechnology and Pharmaceuticals in Sweden." Stockholm: The Swedish Institute, 2001. Online. www.sweden.se/upload/Sweden_se/ english/factsheets/SI/SI_FS132a_Biotechnology_and_Pharmaceutical_in_Sweden/fs132B.pdf. Accessed April 28, 2004.

"Biovitrum." Online.www.biovitrum.com/ main.asp?sub_menu=0&menu=1&menu_item=0&main_menu=0. Accessed January 23, 2004.

Carlsson, Bo. Technological Systems in the Bio Industries: An International Study at the conference Sweden and the United States: Excellence in Biotechnology: The Success of Clusters and Future Challenges, April 3, 2003, Washington, DC.

Corless, Tim. Remarks at the conference Sweden and the United States: Excellence in Biotechnology: The Success of Clusters and Future Challenges, April 3, 2003, Washington, DC.

"Creandum." Press release, March 3, 2003. Online. www.creandum.com/press_030326_en.html. Accessed October 19, 2003.

"The Development of the Venture Capital Industry in Sweden." Online. www.vencap.se/article_view_e.asp?ArticleID=31. Accessed October 19, 2003.

"Elements to Consider When Seeking Capital." Medicon Valley Investment Guide. Online. www.mva.org/composite-288.htm. Accessed October 19, 2003.

Eliasson, Jan. Remarks at the conference Sweden and the United States: Excellence in Biotechnology: The Success of Clusters and Future Challenges, April 3, 2003, Washington, DC.

"KTH Seed Capital Gets MSEK 127." Press release October 7, 2002. Skandinaviska Enskilda Banken AB, 2003. Online. www.taz.vv.sebank.se/cgi-bin/pts3/pow/foretag/riskkapital/press/20021007.html. Accessed October 19, 2003.

Lembke, Johan. Concluding remarks from transcript of the conference Sweden and the United States: Excellence in Biotechnology: The Success of Clusters and Future Challenges, April 3, 2003,Washington, DC.

Magnusson, Leif. *Swedish Technology Foresight: Synthesis Report from Swedish Technology Foresight*. Vasteras, Sweden: Stenby Offset, 2000.

"MoneyTree™ Survey." PricewaterhouseCoopers/Thomson Venture Economics/National Venture Capital Association. Online. www.pwcmoneytree.com/moneytree/index.jsp. Accessed January 23, 2004.

"Plugging the Brain Drain." *Time:* Europe. Online. www.time.com/time/europe/html/040119/brain/story_5.html. Accessed January 23, 2004.

Sandstrom, Anna and Lennart Norgren. *Swedish Biotechnology: Scientific Publications, Patenting and Industrial Development.* VINNOVA The Swedish Agency for Innovations Systems, April 2003.

"Swedepark: Swedish Science and Technology Parks." Online. www.swedepark.se/. Accessed October 19, 2003.

"Swedish Inventions and Discoveries." Swedish Institute, November 2003. Online. www.sweden.se/upload/Sweden_se/english/factsheets/SI/SI_FS91c_Swedish_Inventions_and_Discoveries/FS91d.pdf. Accessed February 9, 2004.

"Syngenta." Online. www.syngenta.com/en/about_syngenta/index.aspx. Accessed January 23, 2004.

Torell, Lena. Remarks at the conference Sweden and the United States: Excellence in Biotechnology: The Success of Clusters and Future Challenges, April 3, 2003, Washington, DC.

"What Europeans Think of GMOs." European GMO Campaign. Online. www.foeeurope.org/GMOs/What_Europeans.htm. Accessed January 23, 2004.