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Technology and the Competitive Advantage of Regions: A Study of the Biotechnology Industry in New York State

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All responsibility for the material in this report, of course, lies with the author.

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Technology and the Competitive Advantage of Regions: A Study of the Biotechnology Industry in New York State

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Introduction and Summary

The research for this project was conducted during 1991 under the auspices of the Center for Biotechnology, in Stony Brook, New York, with the primary objective of constructing an accurate profile of New York's commercial biotechnology organizations, and documenting the size, scope, structure, character, and competitive position of the state's biotechnology industry. The project, including its theoretical perspective and methodology, however, grew out of earlier work conducted by the author on the biotechnology industry in California. That work was conducted as part of a long-term research project with colleagues in the *Biotechnology Industry Research Group*, directed by Professor Edward Blakely, in the Institute of Urban and Regional Development, at the University of California at Berkeley.

California is home to the single largest concentration of biotechnology firms in the world. It is also the focus for much of the popular interest in biotechnology since the state is home to many of the early high-profile companies in the industry— such as Genentech, Cetus, or Chiron— and to path-finding scientific discoveries —such as that which led to the Cohen-Boyer patent for recombinant DNA. As a consequence, many policy analysts and economic development specialists have looked to California for insights into the economic potential of biotechnology. This has often involved a search for the elusive list of factors which would attract biotechnology firms to relocate from one place to another. The hope has been that, if civic and commercial leaders from other areas could identify the factors that could attract footloose California biotechnology firms to their town, then economic renewal would somehow follow. At the same time, policymakers and industry leaders in California have been seeking assurance that the lead held by the state in biotechnology would not be lost through inattention to environmental or regulatory factors inhospitable to the fledgling industry.

With these factors in mind, the research of the *Biotechnology Industry Research Group* has aimed to both identify the factors driving the locational dynamics of California's biotechnology firms, and the factors that determine the industry's competitive position in California *vis-à-vis* other U.S. states and emerging international rivals. The Group's findings (see Willoughby and Blakely, 1989; Willoughby and Blakely, 1990; Blakely and Nishikawa, 1989; and Blakely and Willoughby, 1990) have demonstrated that, in contrast to popular belief, biotechnology is not a footloose industry; rather, successful firms have tended to remain in certain —mainly urban —locations, in order to thrive. More specifically, the best firms have appeared to operate as part of strong local biotechnology indus-

try clusters characterized by strong inter-organizational relations, and exhibiting distinctive technological and product competencies related to their localities. It has appeared, furthermore, that such clusters have evolved primarily from the emergence and growth of locally based firms rather than from industrial relocation. This has given support to the application of incubation-oriented policies rather than attraction-and-relocation policies as tools for gaining economic benefits from biotechnology.

The work of Willoughby and Blakely (1990) has also suggested that local biotechnology industry clusters containing firms making strongest use of local institutions and resources tend also to exhibit the strongest international orientation. In other words, in the more successful biotechnology clusters, a parochial and global orientation tends to occur simultaneously. Interestingly, this phenomenon appears to occur even when locational factors, such as a stringent regulatory environment or high business costs (e.g., due to taxation, land prices, or wages), make a location otherwise unattractive. Finally, the competitive strength of California in biotechnology was found to be particularly interesting in view of the fact that the state does not have a strong presence of complementary industries, such as pharmaceuticals or chemicals, often seen as a stimulus to biotechnology through both R&D funding and through the purchase of intellectual property and biotechnology end-products.

Following the publication of the above findings, it became apparent that, as a comparison with California, New York was an important region to study, *vis-à-vis* biotechnology competitiveness, because of its historical role as a leader in biomedical research. The New York region is extremely well endowed with "resources" appropriate to the biotechnology industry (hospitals, research universities, pharmaceutical firms, scientific and medical instrument suppliers, and financial institutions), and it appeared to have a substantial biotechnology industry in place. Would the substantial base of "biomedical resources" enjoyed by the New York region give that state's biotechnology industry a competitive edge? Would the general economic, social, and regulatory context of New York significantly affect the competitive position of the state's biotechnology industry? Would the principles which had begun to emerge from the research of the *Biotechnology Industry Research Group* at Berkeley on the California biotechnology industry be applicable in New York too, or ought they to be interpreted as being of parochial interest only? If the principles of biotechnology competitiveness identified in California were found to be generally applicable across regions, could policy insights be identified that would enable New York to capture the full commercial potential of its strengths in basic biomedical research? Could some general principles for technology-based regional competitive advantage be derived from a comparison of New York and California? These questions lay behind the more practical concerns that led to the establishment of this present study of New York's biotechnology industry.

The study of New York's biotechnology industry is published here in attempt to present the value of adopting a regional approach to the analysis of advanced technology industries, and to explore the extent to which distinctive economic policies are required, by both commercial and government organizations, to nurture the growth of industries based on knowledge rather than tangible

resources. It presents evidence for the importance of focusing on the "region" as the unit of analysis in studies of industrial competitiveness, in addition to those of the nation or the individual firm.

This report summarizes the results of the comprehensive study of the biotechnology industry across the whole of New York state. A great deal of care was directed towards ensuring that organizations included in the study were properly classified and accurately documented; this has resulted in a body of information and an analytical framework which may serve as a benchmark for future studies of the industry and assessments of its evolving economic performance. The study has revealed a substantial, complex, and changing industry that is emerging with the potential to play a key role in the evolution of New York's economy. There are a number of distinctive local biotechnology industry clusters within the state, each of which has special strengths, needs, and relationships to the surrounding community. Public initiatives or cooperative industry efforts to strengthen the position of biotechnology in New York will need to be tailored to the specific conditions that apply in each of the local clusters.

The most notable conclusion that has emerged from the analysis in this report is that the relative performance of the organizations studied appears to be driven primarily by the patterns of communication and collaboration within the biotechnology industry and between dedicated biotechnology businesses and organizations in complementary industries such as health care, pharmaceuticals, higher education, food production and processing, environmental management, and technical instrumentation. The more that New York's biotechnology businesses engage in informal communication or formal collaboration with other organizations, the better they perform and the more satisfied they appear to be with New York as a location for doing business. The businesses that exhibit vigorous interaction with other organizations simultaneously, in *both* the local geographical area where they are located *and* internationally, appear to be the most competitive. In other words, building "local embeddedness" and "global connectedness" simultaneously within local biotechnology clusters appears to be the best way of improving the overall competitiveness of New York's biotechnology industry. This study has shown that communication and collaboration factors are far more important than locational factors, such as the cost of doing business or the regulatory environment, in shaping the dynamics of the biotechnology industry.

The main policy implication of the above two insights is that primary effort ought to be placed on indirect measures to nurture the development of *local biotechnology industry clusters* based on local knowledge, local people, local institutions, and local information networks— while simultaneously encouraging global activities and associations by biotechnology businesses rooted in those local industry clusters. Measures that enhance the quality of the "technological milieux" associated with these clusters, by such means as enriching their levels of inter-organizational communication and collaboration, will make the most productive use of limited resources earmarked for biotechnology industry support. A strategy based upon this perspective will lead to better results than a

strategy based upon the idea of attracting firms to relocate to New York with various cost-lowering incentives and subsidies.

Chapter One discusses the basic economic function of biotechnology and makes a case for viewing the biotechnology industry as a strategic industry for New York. It explores what may be at stake should New York not manage to maintain an internationally competitive position in biotechnology.

Chapter Two sets out the details of the classification system used in this study, showing how precise definitions and the thoughtful use of conceptually consistent categories may make a significant difference to the results of inquiries into commercial biotechnology. The methodology and procedures of the study are also explained.

Chapters Three and Four together constitute the basic profile of New York's biotechnology industry. In addition to the comprehensive picture they provide of the industry during mid-1991 they also give a sense of its origins and history. Chapter Three covers the primary information on industry size, scope, finance, corporate structure, personnel, technology, market orientation, and economic-cum-demographic context. Chapter Four then extends the profile by documenting the regional variations in these data throughout New York state; in doing so it characterizes the state's nine local biotechnology industry regions.

Chapters Five, Six, and Seven explore the questions of what it is that "drives" New York's biotechnology industry and whether or not the industry is "competitive". Chapter Five compares New York's biotechnology industry with the industry throughout the rest of the United States, paying special attention to New York's main competitors, California and Massachusetts. Chapter Six examines the questions of whether or not New York is a good location for doing business in biotechnology, and what kind of influence New York's locational factors have on the behavior of biotechnology businesses and on the attitudes of their managers. Chapter Seven then presents statistical analyses which reveal the underlying dynamics of the performance of biotechnology businesses and indicate the factors most critical to the future competitiveness of New York's biotechnology industry.

The last two chapters provide information and an analytical approach for identifying tangible measures for building up the biotechnology industry in New York. Chapter Eight documents the distribution of various industries in New York that are complementary to biotechnology and which present attractive opportunities for fruitful collaboration with the state's dedicated biotechnology businesses. The historical trends and relative strengths of these complementary industries in each of the nine biotechnology industry regions are analyzed. Finally, Chapter Nine reflects on the prospects for New York succeeding in the task of building and sustaining a distinctive internationally competitive position in biotechnology, and outlines a simple model for interpreting the role of biotechnology in economic development.

Chapter One

What's at Stake Here?

The New Economic Golden Goose

As the lead in microelectronics held by the United States appears to many observers to be slipping under the pressure of foreign competition, biotechnology has been promoted as the new economic "golden goose" to replace the role previously played by defense-related industries. Recent changes in the U.S./Soviet strategic relationship, furthermore, have created uncertainty for American industries dependent upon defense subcontracting, and this has stimulated even greater interest in the commercial and industrial potential of biotechnology.

Since its emergence as a commercial activity during the 1970s, biotechnology has evolved from being an experimental outgrowth of modern biological science into a new industry. While at one level biotechnology is a collection of techniques (e.g., for recombinant DNA, cell culture, monoclonal antibody production, or microbial fermentation of enzymes) for application in existing industries (such as the pharmaceutical, chemical, agricultural, and food-processing industries), the collection of firms and other organizations involved with these techniques constitutes an industry in its own right—which many communities are seeking to cultivate as a regional economic asset.

In the wake of this trend, almost every federal and provincial government in the industrialized world has established some kind of agency or program to facilitate the development of biotechnology. Competitiveness in biotechnology is seen as a key to future economic competitiveness. While it is not clear exactly how the economic benefits of biotechnology will be realized, and how they may be appropriated by investors, most industrialized countries (and a significant number of less industrialized countries) are competing with each other to develop a strong national biotechnology industry. While the United States has been the clear leader in this industry, massive public-sector investment and growing private-sector involvement in biotechnology in other countries—particularly in Europe and in Japan — threatens to undermine this lead.

In the above context, the policy challenge for state governments, local governments, and local industry bodies is to identify strategies for building a competitive local biotechnology industry, and to gain regional economic rewards from the application of biotechnology in other industries. In order to meet this challenge effectively, it is necessary to understand the economic dimensions of biotechnology on at least two levels: the ways in which firms commercialize knowledge in biotechnology and make the transition to manufacturing activities; and the essential processes for nurturing the growth of clusters of successful firms in communities and regional economies.

The attention which entrepreneurs, investors, industrialists, and government economic development specialists have given to biotechnology has been accompanied by a boom in academic research oriented towards the field. In addition to the growth of scientific work in modern biology and complementary fields, and a recent tendency for some institutions to place attention on relevant process engineering dimensions, there has also been a expansion of social-science, economic, and policy studies associated with biotechnology. Most of these studies do not focus directly on the issues relevant to local economic development from biotechnology.

There are a great many biotechnology-related publications now available dealing with regulatory-cum-legal issues, ethics, public attitudes and responses, environmental impact issues, intellectual property factors, and public education and information. More recently, researchers from business schools have joined the fray with studies about the financial and organizational aspects of biotechnology firms; however, on the whole, these studies take the firm itself as the unit of analysis, and do not yield useful results to aid in initiatives to facilitate the development of biotechnology industries in particular regions (such as New York State, or more locally, Long Island, New York City, Albany, or the Buffalo region). Some business-oriented publications have appeared that adopt a much wider perspective than that of the individual firm, but instead tend to examine questions of international competitiveness in biotechnology (e.g., the growing threat to the United States from Japan). While the insights gained from such work can be helpful to national policymakers, they do not offer much guidance for decision-makers who are concerned with questions such as "what can I do for my town?" or "how can we stop jobs disappearing from our community and migrating to other states?"

This study is designed to rectify this situation and to provide policymakers in New York with the kind of information that is useful for forging local economic development initiatives relevant to the state's biotechnology industry.

Can New York Compete in Biotechnology?

New York's stakes in biotechnology are significant. In absolute terms, the level of biotechnology activity in the region is substantial, but this provides no guarantee that New York will be able to appropriate major economic advantages from its existing accomplishments in biotechnology.

The New York region (especially when nearby New Jersey is included) appears to exhibit all the features that one would expect to lead to it being pre-eminent in industrial biotechnology. The state is replete with high-class medical and biological research centers, and universities with excellent teaching and research in the biomedical sciences. In addition, the concentration of pharmaceutical and chemical firms in the region should provide marvellous opportunities for rapid downstream development of New York's biotechnology research-and-development ventures into manufacturing and marketing; and the diversity and concentration of processing and manufacturing industries in the

region provides a potentially rich set of opportunities for industrial linkages and spin-offs from biotechnology activities. Finally, the premier status of New York City as a financial center should add an even greater fillip to the cash-hungry biotechnology industry. There is evidence that New York is not pre-eminent in biotechnology, however, despite the significant advantages the region appears to offer. This raises some important challenges for policymakers, managers, and those who provide professional and financial services to the industry.

This project has sought to identify the reasons for this enigma, and to propose ways in which strong biotechnology industry clusters in New York may be developed.

What's at Stake Here?

Why does New York need to be competitive in biotechnology? What is at stake if New York does not maintain a competitive position in this industry?

1. New York's status as a "high-technology" region.

If New York does not manage to build and maintain a strong biotechnology industry, its image as a place where technological entrepreneurs may set up ventures and succeed, where investors may take risks on technological companies and win, and where scientists and technologists may develop their careers with a bright future before them, will all be threatened. If this image is weakened too much, then there will probably be a spill-over of lack of confidence into other technological industries. If New York cannot succeed in a field of technology where it has an abundance of scientific resources, where then could it succeed? In advanced technology industries, a strong image in one field can enhance the prospects of another; but the converse, that a weak image in one field can damage the prospects of another, is also true. Success in biotechnology is probably necessary to feed success in other advanced technologies, because of the subtle but powerful influence of "image" on economic performance in technological ventures.

2. The future economic competitiveness of a range of other industries in New York.

Because biotechnology is an enabling technology having applications in a range of existing and emerging industries, many of these industries need to master biotechnology in order to remain competitive. These industries include health care, pharmaceuticals, fine chemicals, food processing, environmental management, agriculture, horticulture, and even forensics. Companies representing these industries but located elsewhere in the world will increasingly utilize biotechnology in their processes during the next couple of decades, and will therefore provide increased competition for firms based in New York.

In principle, New York companies within these other industries may get access to biotechnology from anywhere in the world, but there are at least three reasons why the presence of strong local clusters of biotechnology businesses in New York are important.

There is a tacit dimension to technology transfer, which means that many aspects of biotechnology cannot be successfully transferred from one organization to another without considerable direct and informal communication. Such communication is aided immensely by close geographical proximity between biotechnology businesses and firms in other industries.

For technology (biotechnology in this case) to successfully increase the effectiveness and efficiency of the organization where it is adopted it needs to be tailored to fit the peculiar needs and conditions of the local context [Willoughby, 1990]. For this to occur, it is often necessary to have complex layers of local communication between organizations so that local knowledge can be incorporated into the technological design and implementation process.

Being able to sustain a "competitive" advantage for the long term requires, in essence, being the best in the world at something. Being best in the world at something— technological or otherwise —requires a degree of specialization. It is necessary to be very good at doing something distinctive. To be able to sustain distinctive technological competence globally requires, in turn, differential access to some resources, such as special people, specialized technical supplies, unusual institutional support, or being part of a distinctive local intellectual milieu. It is difficult, if not impossible, to develop those kinds of conditions without having a strong local technological and industrial network in which to participate.

For the above reasons, it is necessary for there to be a strong local presence of the biotechnology industry in New York to enable various "downstream" and "supplier" industries to be in an adequate position to take advantage of trends in biotechnology sufficiently to maintain an internationally competitive position. New York needs to compete in biotechnology, not just by duplicating the kind of work done elsewhere, such as in California or Massachusetts, but by developing its own distinctive local technological competency.

3. New York's biotechnology industry itself.

The two arguments just presented asume that New York has stakes in the biotechnology industry because it is *instrumental* to other industries. In addition to its usefulness to other sectors of the economy, however, New York's biotechnology industry is now substantial in its own right. The competitiveness of the industry now matters irrespective of its usefulness to other interest groups in the state. As this report will document, there is now a body of people, companies, and associated services established in New York as part of the biotechnology industry which has gone a long way past being a simple passing fashion or experiment. Despite immense challenges, New York's presence in this global industry cannot be ignored.

What's at stake here? New York's position as a globally competitive economy during the twenty-first century is at stake.

Chapter Two

Definitions, Classifications, Procedures

It is important to begin this study with clear definitions of the concepts and terminology it has employed. While this may seem a little pedantic, imprecision or ambiguity in what is classified as "biotechnology," or as a "biotechnology firm," can lead to wide divergence in claims as to the relative sizes of the biotechnology industry in different places, and to dangerous errors-of-judgment about the economic or political issues at stake.

Problems with Classifying the Biotechnology Industry

There are now quite a number of directories, catalogues, and databases on biotechnology firms available —some at exorbitant prices —and virtually all of these were consulted as part of this study. As most serious commentators and observers of the biotechnology industry have discovered, however, all kinds of organizations appear in these directories which either can't be located, don't exist, or turn out upon investigation to be either not doing any biotechnology or perhaps just "dabbling" in it. Some are only just thinking about pursuing biotechnology! In other cases, there are organizations which may have a very important role to play— such as the corporate headquarters of global pharmaceutical corporations — but which themselves ought not to be classified as biotechnology firms. The "accidental" inclusion of just one such firm in a study such as this could distort the financial stakes by many millions of dollars, and exaggerate employment figures by thousands, particularly if interstate or foreign operational divisions were included. The majority of published studies of "the biotechnology industry," even some in respectable scholarly journals, tend to have used databases which are flawed or so loose in their criteria for including firms, that their results may be rather questionable. Without a clear definition of what constitutes a biotechnology firm, however, it is difficult to be discriminating.

For example, one widely quoted publication on the biotechnology industry in Philadelphia (Sosland, 1991: 58) pointed to over 31,000 employees in 157 "biotech start-ups" by 1990, whereas another widely respected annual publication (Burrill & Lee, 1990: 88-89) reported 1,041 employees in 28 biotechnology companies in the Philadelphia region during the same year! The larger of the two numbers comes from a very generous definition of a "biotech start-up" which includes, amongst other things, a variety of companies involved in "high-technology" medical equipment and related areas —but not all readers may bother to examine the "fine print."

A similar example may be found for New York. A widely publicized database of "Biotechnology Companies" in the United States, published in mid-1990 (North Carolina Biotechnology Center, 1990), was analyzed by the author of this study to compare the biotechnology industry in

New York and California (see Table 2.1). Over 19 percent of the U.S. organizations in the database turned out not to be valid biotechnology firms (over 32 percent in the case of New York, and 13 percent for California); and if these are excluded from the results of the analysis, the total biotechnology employment level for the United States is reduced by over 96 percent (99.8 percent in the case of New York, and about 90 percent for California). In other words, the minority of organizations in the database which are not dedicated biotechnology businesses account for the vast majority of the employment! The same is true for the financial figures (see Table 2.1). Most of the "extraneous" organizations included in this database are large pharmaceutical corporations, many of which are indeed engaged, in some way, in biotechnology. To ignore them would be unwise, but to include them in a biotechnology study along with the "biotech start-ups" grossly distorts the figures.

This study has minimized the kinds of problems illustrated by the above examples by three accomplishments: articulation of a precise and conservative definition of biotechnology; careful and explicit application of a detailed and logical classification framework; and rigorous efforts to identify and individually assess each candidate organization for inclusion in the population of biotechnology firms in New York.

The classification framework involves two parts. First, a classification system for biotechnology as a *scientific and technological arena*, and, second, a system for classifying *organizations* concerned with biotechnology. The first classification system includes 31 market or product categories (see Table 2.2) and 17 technological-cum-scientific categories (see Table 2.3). These two classification systems, while developed especially for this study, have been designed so that they are compatible with other commonly used classification systems, to enable meaningful comparisons across data sets. In particular, they are compatible with the general categories used by the Ernst & Young group in its annual survey of the national biotechnology industry (Burrill and Lee, 1990), and the general categories used by the North Carolina Biotechnology Center in its databases (North Carolina Biotechnology Center, 1990).

The second classification system involves grouping biotechnology organizations into three basic organizational categories: *dedicated biotechnology businesses*, *nascent biotechnology businesses* (i.e., businesses involved in biotechnology but not yet dedicated to it), and *biotechnology complementary organizations*. Each of these types of biotechnology organizations may be classified into further sub-categories according to their organizational structure, particularly whether or not they are a separate "stand-alone" firm ("discrete" organization) or part of a larger organization ("non-discrete" organization). An independent "biotech startup" company (e.g., Oncogene Science, Inc., or NYGene Corporation) would be classified as a "discrete" biotechnology business; and a group which is part of a larger corporation (e.g., Lederle-Praxis Biologicals, Division of American Cyanamid, or the Biotechnology Group in the Industrial Division of Bristol-Myers Squibb Company) would be classified as a "non-discrete" biotechnology business. By these means, outlined in more detail

Table 2.1

Scale of Biotechnology Industry: United States, New York, California, June 1990
Derived from Biotechnology Companies Data Base of North Carolina Biotechnology Center

Industry Measure	United States	New York	California	NY/US	CA/US
A. # biotech-related firms	744	37	164	5%	22%
B. # Biotechnology firms	602	25	142	4%	24%
C. Ratio of "B" over "A"	80.9%	67.6%	86.6%		
D. # biotech-related jobs	2,791,980	617,580	259,988	22%	9%
E. # biotechnology jobs	100,306	1,174	25,443	1%	25%
F. Ratio of "E" over "D"	3.6%	0.2%	9.8%		
G. Average size of firms (#jobs): "A"	3753	16691	1585	445%	42%
H. Average size of firms (#jobs): "B"	167	47	179	28%	108%
I. Ratio of "H" over "G"	4.4%	0.3%	11.3%		
J. Revenue from firms in "A" ($M)	$430,522,551,000	$77,789,753,000	$57,935,078,000	18%	13%
K. Revenue from firms in "B" ($M)	$22,215,793,000	$54,903,000	$3,075,190,000	0%	14%
L. Ratio of "K" over "J"	5.2%	0.1%	5.3%		
M. Average revenue in "A" firms	$578,659,343	$2,102,425,757	$353,262,671	363%	61%
N. Average revenue in "B" firms	$36,903,311	$2,196,120	$21,656,268	6%	59%
O. Ratio of "N" over "M"	6.4%	0.1%	6.1%		

Source: Biotechnology Companies Data Base, North Carolina Biotechnology Center, Research Triangle Park, North Carolina, 6/18/90.

Table 2.2

Dedicated Biotechnology Businesses
Classified by Product/Market Orientation or Function

1 Diagnostics

1.1 Human diagnostics
1.2 Diagnostics (other than human or animal health)

2 Therapeutics

2.1 Human therapeutics
2.2 Drug delivery systems (biological)
2.3 Transgenics
2.4 Other therapeutics

3 Agri-bio

3.1 Plant agriculture
3.2 Food processing
3.3 Biological pest control
3.4 Biological fertilizer
3.5 Animal production and breeding
3.6 Animal health - diagnostics
3.7 Animal health - therapeutics
3.8 Other "agri-bio" or food

4 Suppliers (specialized-for-biotechnology only)

4.1 Instrumentation and controls
4.2 Production equipment
4.3 Bio-separations systems
4.4 Biological materials
4.5 Chemicals
4.6 Software
4.7 Other supplies

5 Other

5.1 Aquaculture
5.2 Environmental management
5.3 Forestry
5.4 Mineral extraction
5.5 New materials
5.6 Industrial feedstocks
5.7 Energy
5.8 Forensic
5.9 Basic science
5.10 Other

Table 2.3

Dedicated Biotechnology Businesses
Classified by Technological Specialization

Technological Categories

1 Recombinant DNA
2 Fermentation
3 Biological separation/purification (laboratory scale)
4 Biological separation/purification (industrial scale)
5 Cell/tissue culture
6 Hybridoma/cell fusion
7 Protein synthesis
8 Enzymology
9 Sequencing
10 Bioprocessing
11 Monoclonal antibodies
12 Polyclonal antibodies
13 Liposomes
14 Imaging and biosensors
15 Process monitoring/control
16 Specialized software
17 Other technological specialization

Note: "technological specialization" refers to technology which is either developed or employed by the organization being classified.

below, this study has avoided either understating or overstating the size of New York's biotechnology industry. All four of the organizations just cited are examples of a "dedicated biotechnology business." Dedicated biotechnology businesses are commercial organizations that either use biotechnology in the manufacture of a product or the provision of a service, produce biotechnology, conduct research and development towards the production of biotechnology, or supply specialized biotechnology inputs for biotechnology organizations; *and which devote at least half of their effort to such activities*. This definition will be discussed in more detail below.

While all three types of basic organizational categories (dedicated biotechnology businesses, nascent biotechnology businesses, and biotechnology complementary organizations) are important to the biotechnology industry, in this study primary attention has been placed upon *dedicated biotechnology businesses*. When the phrase "biotechnology business" is used in this study it refers only to "dedicated" biotechnology businesses. The phrase "New York's biotechnology industry" will normally refer only to the population of dedicated biotechnology businesses (DBBs) in New York state, and not to extraneous organizations such as nascent biotechnology businesses and biotechnology complementary organizations.

In short, the information presented in this study of New York's biotechnology industry is conservative, conceptually consistent, and thoroughly checked for validity. The terminology used throughout this study will now be defined.

Definition of Biotechnology

Biotechnology, construed very broadly, is technology in which biological systems are employed as means towards the attainment of practical ends. Defined in this way it is as old as cheese-making, yoghurt-making, brewing, composting, pickling, or agriculture. Advances in modern biological science during the last two decades, however, have led to the development of some new biotechnologies which present potentially radical changes in the scope for artificial manipulation of biological systems. It is this particular set of modern biotechnologies which has generated the recent flurry of commercial experiments more popularly known as "biotechnology," and which has created the need for a more restrictive definition than the one based on the ancient crafts of fermentation or food cultivation.

Modern biotechnology, as popularly understood, draws upon a number of distinct fields of scientific and technical endeavor, of which the three most commonly discussed are recombinant DNA technology (often known as "genetic engineering"), cell culture technology (or in vitro cell manipulation technology), and monoclonal antibody technology; but it also draws upon others such as protein engineering, advanced microbial fermentation (sometimes known as "bioprocess" technology), and various other disciplines concerned with aspects of micro-organisms or cells (such as their taxonomy, morphology, physiology, biochemistry, or genetics). Techniques derived from

such science may find applications in a variety of practical fields such as medicine, environmental management, agriculture, veterinary care, food processing, energy supply, pest control, advanced materials, mineral extraction, or forensic investigations. The distinctive feature of the scientific fields underlying biotechnology is that they create knowledge about how biological systems may be controlled precisely through the artificial manipulation of micro-organisms, living cells, and sub-cellular structures or processes.

While much debate exists over what exactly constitutes "biotechnology," the term is restricted in this study to the narrower spectrum of technologies that have been derived from modern biological science within the last 20 years or so, typified by the fields of endeavor just listed. It does not necessarily exclude conventional technology relevant to biological, agricultural, or medical fields, but it does not include such technology unless it may independently be classified as "biotechnology" according to the above principles. That is, biotechnologies (as defined here) must be based upon scientific knowledge about how biological systems may be controlled precisely through the artificial manipulation of micro-organisms, living cells, and sub-cellular structures or processes.

Thus, a restrictive definition of biotechnology may be stipulated as follows: *biotechnology is technology in which biological systems, established and controlled through the application of molecular biology, cell biology, or microbiology, are employed as means towards the attainment of practical ends.*

Only organizations involved primarily in biotechnology, according to this definition, have been included in the population of biotechnology businesses analyzed in this study.

Corporate Categories of Biotechnology Organizations

In the same way that general agreement on the exact meaning of "biotechnology" is difficult to reach, general agreement on what constitutes a biotechnology organization is elusive. All of the following definitions, therefore, are stipulative definitions provided by the author of this study to ensure analytical consistency; they may or may not concur with the definitions used in other studies.

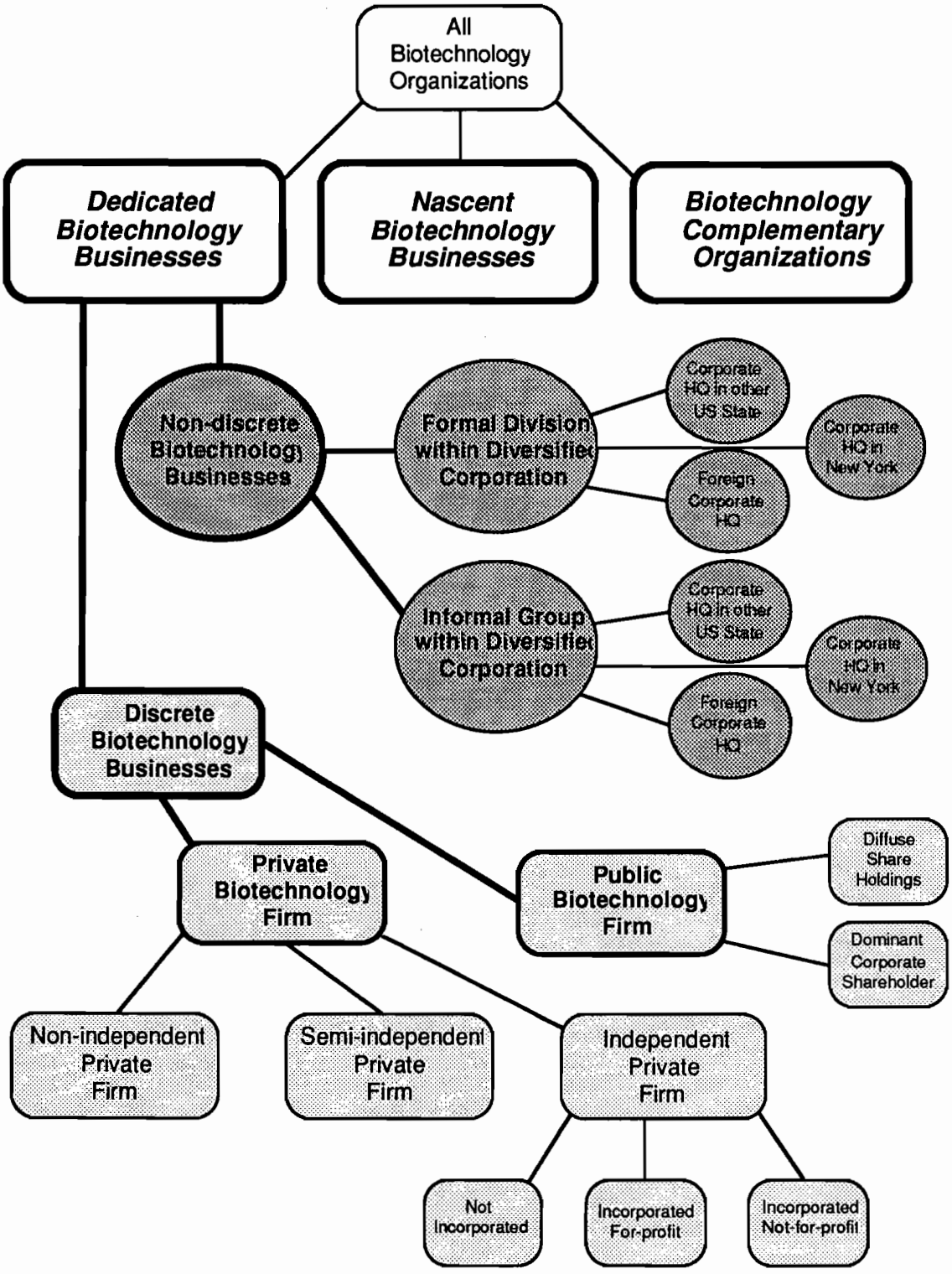
The organizational classification scheme explained below is summarized pictorially in Figure 2.1.

Biotechnology Organizations

Biotechnology organizations are all organizations which play a significant role in the development, support, practice, or maintenance of biotechnology as a field of technology or industry, or which conduct observable biotechnology activities.

A "significant role" in biotechnology is played by an organization when either of the following conditions apply: at least half of its activities are dedicated to or complementary to biotechnology; or, its activities have important implications for organizations which satisfy the first condition.

Figure 2.1
Biotechnology Organizations
Classified by Corporate Status



Source: K. W. Willoughby, 1991.

Biotechnology organizations include dedicated biotechnology businesses, nascent biotechnology businesses, and biotechnology complementary organizations. Each of these three categories will now be explained.

Dedicated Biotechnology Businesses

A dedicated biotechnology business is a commercial organization which uses biotechnology in the manufacture of a product or the provision of a service, produces biotechnology, conducts research and development towards the production of biotechnology, or supplies specialized biotechnology inputs for biotechnology organizations; and, in addition, which devotes at least half of its effort to such activities.

Specialized biotechnology inputs are: specialized technologies that are dedicated for use within biotechnology activities, or specialized materials that are dedicated for use within biotechnology activities, or other inputs that have been produced by the application of biotechnology. Specialized biotechnology inputs must be artefacts or tangible products, and may include specialized software dedicated to use in biotechnology activities, intellectual property of a scientific or technical kind, or biological materials such as enzymes, but may not include services such as technical consulting.

The term "business," in "dedicated biotechnology business," is used in preference to "firm" or "company" because it allows for dedicated biotechnology groups (which might not be formally incorporated bodies) within larger companies to be included in their own right, without having to include the whole parent company. To illustrate how this definition may be applied, some examples will be discussed.

A typical example of a dedicated biotechnology business is Enzo Biochem, Inc., a public company based in New York City. Enzo Biochem, with more than one location in New York state, is engaged primarily in the chemical modification of nucleic acids to create research reagents and diagnostic reagents, and in the development of DNA-based human therapeutic reagents. The company is relatively easy to classify as a *bona fide* New York biotechnology business.

In the case where the executive office only of a dedicated biotechnology business was located in New York, it would be included in the study, but only where it was the office of a *dedicated* biotechnology business, and not of a diversified corporation which happened to engage in some biotechnology. A good example is BioTechnology General Corporation, a dedicated biotechnology business involved in genetically engineered human health products, particularly growth hormones, which is based in New York City but has most of its operations located in Israel. Only the people actually employed in the New York office count as biotechnology personnel in New York. Another good example of people employed by a New York-based biotechnology business but located elsewhere is the company Genencor International, Inc. This is an international biotechnology company (specializing in industrial and diagnostic enzymes and specialty chemicals) based in Rochester,

New York, but with a significant proportion of its operations in the San Francisco Bay Area. In this study, Genencor's New York facility and its employees count as part of the New York biotechnology industry, while the California facility and its employees count as part of the California biotechnology industry.

Likewise, employees of a New York division of a biotechnology business based elsewhere would be included as part of the New York industry, but the employees of the parent business would not. An example of this may be found in Life Technologies, Inc. This is an international company with its corporate headquarters in Maryland but with a major facility located in Grand Island, New York (in the Buffalo region), and which specializes in research, development, and manufacturing in cell culture technology. The Grand Island facility, previously known as "Gibco Laboratories" and at one time an independent New York company, is classified here as a dedicated biotechnology business in New York, whereas the operations and personnel in Maryland and elsewhere are excluded. A final interesting example of this general type lies with Gemini Science, Inc., which pursues biotechnology research and development in haematology, immunology, vascular biology, osteology, nephrology, and oncology. This dedicated biotechnology business, with headquarters in New York City, is a subsidiary of Kirin Brewery Co., Ltd., in Japan, but locates most of its research in San Diego, California. Both the parent business and the main operations of Gemini Science are located outside of New York; nevertheless, formally, its office in New York qualifies as part of the New York biotechnology industry. This is an exceptional case, however, and most of the biotechnology businesses included in the New York population closer to the type discussed above.

In keeping with the strict definition adopted here, many well established companies which appeared to be obvious candidates for a biotechnology directory, and which have clear "biotech" names, were excluded from this study. For example, one of the largest suppliers of specialized biotechnology equipment in New York, Sulzer Biotech Systems, was excluded from the study because it was only a distributor of equipment produced elsewhere. This was no reflection on the quality of the company, only an indication that it did not fit within this study's conservative definition of a dedicated biotechnology business.

On the other hand, a specialized biotechnology supplier does not have to be engaged primarily in the biological sciences in order to be classified as a "dedicated biotechnology business," so long as its products are *specialized* biotechnology inputs (i.e., they are specialized for technologial applications based upon the pertinent fields of biological science). For example, most biotechnology businesses use a range of standard scientific laboratory equipment, but just because a scientific instrument producer supplies the biotechnology market (e.g., Mixing Equipment Company, of Rochester, New York) it does not thereby qualify as a dedicated biotechnology business. It would only do so if its instruments were especially developed for biotechnology applications and were not capable of being readily applied elsewhere. NYGene Corporation, of Yonkers in New York,

however, is an excellent example of a technical supplier which is specialized for biotechnology. The company is a leader in membrane-affinity separation systems and ion exchange-based laboratory and downstream processing technology for the purification of monoclonal antibodies and other biomolecules. Its use of derivatized membranes differentiates itself from other, much larger suppliers of membrane technology, such as the Pall Corporation, of East Hills in New York, where the membranes have a much broader scope for application than biotechnology.

Nascent Biotechnology Businesses

A nascent biotechnology business is a commercial organization which has a small amount of biotechnology activity, which may be mixed or embedded within its other activities, but that has the potential to lead to the formation of a dedicated biotechnology business. A nascent biotechnology business may be either a discrete business or a unit of a diversified corporation. "A small amount" means that less than half of the organization's activities are devoted to biotechnology business. "Biotechnology business" is the use of biotechnology in the manufacture of a product or the provision of a service, the production of biotechnology, research-and-development towards the production of biotechnology, or the supply of specialized inputs for biotechnology.

An interesting example of a nascent biotechnology business is American Genevac, Inc., of West Nyack, New York. It is a private U.S. company, formed in 1986, with about one dozen employees and annual sales of over $1 million. It is a manufacturer of biomedical laboratory apparatus, including vacuum pumps, fittings, and valves used with laboratory equipment. American Genevac is interesting because the company claims that all of its products are highly specialized for life-science research. They are not just general scientific equipment suppliers. For example, its vacuum pumps are specially designed to extract specific vapors often produced in microbiology research, vapors for which other pumps are not very well adapted. The company also makes specialized biological research products such as centrifugal concentrators and gel driers for DNA science. Only about ten percent of the company's sales, however, go directly to dedicated biotechnology businesses. This kind of company is essential for the effective development of the biotechnology industry, and its existence means that there is expertise in the community for future development of specialized biotechnology equipment needed by biotechnology firms in the region. Because it is still mostly a "life science" supplier at this stage rather than a "biotechnology supplier," the company has been classified here as a "nascent biotechnology business," even though it would easily qualify for inclusion in many biotechnology directories as a biotechnology supplier.

Biotechnology Complementary Organizations

A biotechnology complementary organization is any biotechnology organization other than a dedicated biotechnology businesses or a nascent biotechnology business. A significant propor-

tion (at least half) of its activities play a role in supporting or complementing biotechnology, or have important implications for dedicated biotechnology businesses.

Biotechnology complementary organizations do not in themselves engage in a significant amount of biotechnology business; rather, their activities enrich the capacity of other organizations to conduct biotechnology business.

Their functions may include generating a knowledge or human-resource base necessary to the development of biotechnology; providing a market for biotechnology products; developing or constraining the environment directly surrounding the biotechnology industry; providing financial, technical, or organizational services to biotechnology firms; and/or supplying non-specialized technical equipment or non-specialized raw materials. Examples may include hospitals, pharmaceutical companies, technical instrument suppliers, universities, scientific research laboratories, specialized regulatory agencies, or specialized financiers. Examples of a biotechnology complementary organization, as defined here, are the Center for Biotechnology, in Stony Brook, New York; the New York Biotechnology Association, Inc.; and the Cornell University Biotechnology Program.

Non-Discrete Biotechnology Businesses

A non-discrete biotechnology business is a dedicated biotechnology business which is a unit of another organization.

It may take the form of either a formal division within a diversified corporation or an informal group within a diversified corporation. A biotechnology subsidiary of a diversified corporation may be treated as a non-discrete biotechnology business within the "formal division" category, if it is not legally constituted as a separate corporation; a dedicated biotechnology business that is legally constituted as a separate corporation and that is wholly owned by another organization should be treated as a non-independent private firm. A biotechnology research-and-development laboratory within a diversified corporation, so long as it did not contravene one of the pertinent criteria specified above, should be treated as a non-discrete biotechnology business, within the "informal group" category.

The corporate headquarters of a non-discrete biotechnology business may be either distant from the business or co-located with it.

Discrete Biotechnology Businesses

A discrete biotechnology business is a dedicated biotechnology business which is not a sub-unit of another organization. It may be either a private biotechnology firm or a public biotechnology firm.

Private Biotechnology Firms

A private biotechnology firm is a discrete biotechnology business which is not traded in public. It may be independent, semi-independent, or a non-independent private firm.

A non-independent private biotechnology firm is one in which at least half of it is owned-externally by a single organization or person (i.e., owned by an organization or person other than the firm's entrepreneur or entrepreneurs).

A semi-independent private biotechnology firm is one in which no one organization or person owns half or more of the firm, but where the greatest single share of the firm is owned externally by an organization or person other than the firm's entrepreneur or entrepreneurs.

An independent private biotechnology firm is one in which the single largest proportion of the firm is owned internally by the firm's entrepreneur or entrepreneurs.

Independent private biotechnology firms may be incorporated for-profit organizations, incorporated not-for-profit organizations, or organizations of any size which are not incorporated.

Public Biotechnology Firms

A public biotechnology firm is a discrete biotechnology businesses which is traded in public.

It should be treated as having diffuse share-holdings when no one external shareholder owns a greater proportion of shares than the entrepreneur, entrepreneurs, or other members of the firm.

It should be treated as having a dominant corporate shareholder when at least one external shareholder owns a greater proportion of shares than the entrepreneur, entrepreneurs, or other members of the firm.

All of the dedicated biotechnology businesses surveyed in this study were classified according to their corporate status, using the above categories. The main results are summarized in the next chapter.

Study Procedures

The first major task in this study was to develop the classification system for describing organizations relevant to the biotechnology industry in New York state, and to articulate assessment criteria for discriminating between those organizations to be included in the study and those to be excluded or studied in less detail. The results of this exercise have just been summarized.

It should be added here that the geographical boundary selected for the study coincides with the boundary of New York state. In some respects this is an artificial boundary, as many of the organizations which make up the state's biotechnology industry operate across state borders, and because the relevant market factors, together with many of the forces and resources upon which the industry is dependent, may certainly not be so tightly proscribed.

Despite these problems, however, there were good reasons for limiting the study in this manner. The first was the objective of providing useful data and advice to the Center for Biotechnology, a New York organization. The second was to provide a solid base of information to assist the State of New York in its policymaking processes concerned with science, technology, and economic development. The third was that, notwithstanding the general openness of the New York economy, there are certain factors that unite businesses operating within the state, such as the regulatory and fiscal policies of the state government, or common access to certain resources of the state, including the university system. The fourth was that the project was sponsored by New York-based organizations, and there was therefore a need to tailor the investigations to the primary sphere of interest of those organizations. Finally, in all good studies there is a need to place limits on the work to be done, otherwise it will lack coherence or take too long to complete.

The above considerations, together with the practicalities of data collection, made a compelling case for keeping the study within New York state. Nevertheless, while restricting the detailed data collection to organizations in New York, a great deal of care was taken to document the interstate and international linkages of those organizations, to take account of the wider context of commercial biotechnology, and to make comparisons with the biotechnology industry elsewhere. While the study has indeed exhibited a tight geographical focus, it has also been imbued with a global perspective.

The second major task was to identify the total population of candidate organizations to be considered for classification within the biotechnology industry in New York state. This turned out to be a major task. The first step was to examine the computer database maintained by the Center for Biotechnology in Stony Brook, New York; over one thousand potentially relevant records were obtained from this source. The second step was to consult all the publicly available directories of the biotechnology industry in the United States, including several electronic databases. The third step was to contact all of the organizations in New York state, both industry-based and in the public sector, which were likely to have knowledge of extant biotechnology organizations. To ensure good coverage of the upstate regions, each of the ten Regional Technology Development Organizations sponsored by the New York State Science and Technology Foundation, were contacted; these were particularly good sources of information on the small, new, or informal businesses outside of metropolitan New York that do not often get covered in formal national surveys. Following the above three steps, a master list was assembled of organizations which either purported to be biotechnology organizations or were described as such by others. The final list comprised over 1,400 references.

After having assembled the master list of "candidate" New York biotechnology organizations, a preliminary scan was conducted to delete all those organizations which obviously did not fit the assessment criteria. This reduced the master list to just over one thousand organizations. Each one of these remaining organizations was then contacted directly by telephone to confirm whether it

still existed, whether it appeared likely that it really was involved in biotechnology, whether it really was based in New York state, and to confirm that accurate identifying information had been obtained. This process, which continued for many weeks (with some assistance from graduate students in the Harriman School of the State University of New York at Stony Brook), eventually reduced the master list down to about 130 organizations in New York that seemed likely to match the predetermined criteria of a *dedicated biotechnology business*.

Each one of the remaining 130 provisional dedicated biotechnology businesses was then contacted again to further ascertain its status, to obtain more complete identifying information, and to seek the cooperation of senior management in this study. A letter from the Director of the Center for Biotechnology (see Appendix 2.1 for a sample copy) was sent to the CEO of each organization, and further telephone conversations ensued. This process reduced the list down to 110 organizations which still appeared to be *bona fide* dedicated biotechnology businesses.

A survey questionnaire was then administered to the businesses. This was done either by telephone or in person, and in almost all cases the interview was conducted with the CEO or a senior officer of the business very close to the CEO. At the completion of the survey, and after examination of the information gained from the interviews, the final population of dedicated biotechnology businesses in New York was determined to be exactly 90 organizations (see Appendix 2.2 for a complete list). Valid survey questionnaires were completed for 66 of these dedicated biotechnology businesses, yielding a sample size of 73 percent of the total population. The final interviews took place during June 1991 and represented the observed population of dedicated biotechnology businesses as of May 1991. Data was provided by each of the businesses under a promise of confidentiality; that is, except for the basic descriptions published in the directory of New York's biotechnology industry (Center for Biotechnology, 1991), a commitment was made that only aggregated data would be publicly released. The large sample size gives strong credibility to the results of the survey.

The immensity of the task of reducing down the list of candidate biotechnology organizations to the final list of validated dedicated biotechnology businesses confirmed the degree to which observers of the biotechnology industry often employ rather vague notions of what constitutes biotechnology. To some extent this reflects the desire of many companies to benefit from the "reflected glamor" of biotechnology (e.g., a of toilet paper manufacturer with the name "Biotech Mills, Inc."). It also reflects that the number of "complementary biotechnology organizations" and "nascent biotechnology organizations" in New York state is probably very large indeed. Much of the potential economic benefit to New York from biotechnology will lie in the development of linkages between dedicated biotechnology businesses and these other two classes of organizations. While this study does not directly analyze these organizations, their economic importance ought not to be underestimated.

Unless otherwise stated, all the data reported in this report comes from the questionnaire survey of dedicated biotechnology businesses conducted by K. W. Willoughby for the Center for Biotechnology, in Stony Brook, New York. Two other sources of data were also very important.

Because of the objective of this study to provide insight into the potential for local economic benefits of biotechnology, it was necessary to develop a scheme for dividing up the state of New York into a number of sub-regions for analysis. Three criteria were used to set the boundaries of these "biotechnology industry regions": (1) maximum consistency with the State of New York "economic development region" boundaries; (2) maximum consistency with the regional boundaries used by other authorities for the collection and analysis of economic and demographic statistics; and (3) meaningful concurrence with the actual locations of clusters of dedicated biotechnology businesses. The ten regions in criterion (1), which correspond to the jurisdictions of the ten Regional Technology Development Organizations mentioned above, are: Capital Region, Southern Tier, Western New York, Mid-Hudson, Long Island, New York City, North Country, Finger Lakes, Central New York, and Mohawk Valley. The regions which correspond best with criterion (2) are the Metropolitan Statistical Areas (MSAs) or Standard Metropolitan Statistical Areas (SMSAs), but which, unfortunately, do not cover the rural areas very well, and do not coincide neatly with the boundaries of the New York State "economic development regions." After analyzing the locations of the whole population of biotechnology businesses in New York, nine "biotechnology industry regions" were defined as set out in Table 2.4. Because of low counts in some of the MSAs and NYS economic development regions, it was necessary to amalgamate a couple to enable meaningful analysis of the biotechnology industry. Table 2.4 indicates the New York counties in each biotechnology industry region, and the correspondence between them and the MSAs. The regions correspond as close as is practicable to the boundaries used in New York State planning. A map of the regions is provided in Chapter Four.

To supplement the Center for Biotechnology survey data on the financial dimensions of the businesses, additional financial data was kindly provided by the Manufacturing/High Technology Industry Services Group of Ernst & Young in San Francisco. The Ernst & Young group extracted aggregated data on basic financial indicators for the sample of New York biotechnology companies in their national database of biotechnology companies, as used in the production of the annual Ernst & Young survey of the U.S. biotechnology industry (Burrill and Lee, 1990). This data enabled financial comparisons to be made between the New York biotechnology industry and that in California, Massachusetts, and the United States as a whole. A test was conducted to see whether the Ernst & Young sample was broadly compatible with the survey sample from this study (the Center for Biotechnology study), with results in the affirmative (see Appendix 2.3).

Data were also required on a range of industries in New York complementary to biotechnology. These include health services, pharmaceuticals, food processing, agriculture, and various fields

Table 2.4
Biotechnology Industry Regions, New York State

New York City (NYC)

Bronx County	*Portion of*
Kings County (Brooklyn)	*New York,*
New York County (Manhattan)	*NY-NJ*
Queens County	*MSA*
Richmond County (Staten Island)	

Long Island (LI)

Nassau County	*Nassau-Suffolk MSA*
Suffolk County	

Lower Hudson (LH)

Putnam County	*Portion of*
Rockland County	*New York,*
Westchester County	*NY-NJ MSA*

Capital (CAP)

Albany County	*Albany-*
Montgomery County	*chenectady-*
Rensselear County	*Troy*
Saratoga County	*MSA*
Schenectady County	

North (NO)

Herkimer County	*Combined*
Madison County	*Syracuse MSA*
Oneida County	*and*
Onondaga County	*Utica-Rome*
Oswega County	*MSA*

Clinton County
Essex County
Franklin County
Fulton County
Hamilton County
Jefferson County
Lewis County
St. Lawrence County
Warren County
Washington County

Mid West (MW)

Livingston County	*Rochester MSA*
Monroe County	
Ontario County	
Orleans County	
Wayne County	

Allegany County
Cattaraugus County
Chautauqua County
Genesee County
Wyoming County

Buffalo (BUF)

Erie County	*Buffalo-Niagara*
Niagara County	*Falls MSA*

Southern Tier (ST)

Broome County
Cayuga County
Chemung County
Chenango County
Cortland County
Delaware County
Otsego County
Schohare County
Schuyler County
Seneca County
Steuben County
Tioga County
Tompkins County
Yates County

Upper Hudson (UH)

Columbia County
Dutchess County
Greene County
Orange County
Sullivan County
Ulster County

of instrumentation, scientific equipment, and high-technology manufacturing. Data for these industries covering employment, wages, and number of units (i.e., units of "firms" or "employers") from 1975 to 1990, disaggregated by county within New York state, were kindly provided by the Division of Research and Statistics of the New York State Department of Labor (New York State Department of Labor, 1991). The data originated in the ES-202 series, and had been recoded by the New York State Department of Labor staff to be consistent with the most recent definitions of the Standard Industrial Classification (SIC) Codes. These data were then analyzed by the author of this study aggregated within the sub-regions in New York state corresponding to the distribution of dedicated biotechnology businesses. The results of this exercise (presented in Chapter Eight) are intended to enable investigations of the potential for linkages *at the local level* between biotechnology businesses and organizations in complementary industries.

In summary, an unusually rich array of data has been assembled in this study, and it has been made possible not only by a careful analytical approach to the selection of organizations to be studied and information to be sought, but also by the excellent support from a range of participating organizations. First, each of the New York biotechnology businesses that provided time and information made an invaluable contribution. It would also not have been possible to assemble the data without the practical cooperation of Center for Biotechnology, State University of New York at Stony Brook; New York Biotechnology Association, Inc.; Ernst & Young, Long Island Office; Ernst & Young, National Manufacturing/High Technology Services Office; New York State Department of Labor; New York State Science and Technology Foundation; and the ten Regional Technology Development Organizations of New York State.

Chapter Three

Profile of New York's Biotechnology Industry

Salient Facts

The first significant observation we may make about commercial biotechnology in New York is that, even by the very conservative definition used in this study, the industry is substantial in scale. Despite the relative youth of most of the firms, the industry is a number of times larger than most commentators have previously indicated. One widely cited database (North Carolina Biotechnology Center, 1990), for example, put the mid-1990 population of biotechnology companies in New York at 37 (and at only 25, if the biotechnology complementary organizations were excluded). With 90 dedicated biotechnology businesses, worth over $1.3 billion, and responsible for over 6,000 employees world-wide, the industry may no longer be thought of as a fledgling experiment. It is here to stay. The overall scale of the industry, for 1990-1991, is summarized in Table 3.1.

As can be seen from this table, there is a global dimension to the industry, with one-third of the employees of New York's dedicated biotechnology businesses located in another country or elsewhere in the United States. Forty-one percent of the businesses have multiple facilities. There are over 150 facilities globally, over 70 percent of which are located within New York State. While having developed a global spread, the industry's activities are nevertheless located predominantly within New York.

The second significant observation is that the industry is diffused spatially throughout the state. As revealed in Table 3.2 (which was calculated entirely from data collected directly from the organizations themselves, as part of this study), the dedicated biotechnology businesses cluster in nine different regions. Only 18 percent are located in New York City (the boroughs of Manhattan, Brooklyn, the Bronx, Queens, and Staten Island), and the region with the single largest share is Long Island (with 28 businesses), accounting for one-third of the total. Metropolitan New York as a whole (New York City, Long Island, and Lower Hudson— the latter including Westchester County —and the three regions together accounting for about 62 percent of the human population of the state) accounts for 62 percent of the whole population of biotechnology businesses, 57 percent of the total commercial biotechnology employment within the state, and 48 percent of the New York biotechnology industry's global employment.

The nine biotechnology industry clusters differ considerably in the average size of their businesses, ranging from 10 people per unit in the Southern Tier (the large region in the center of New York surrounding Ithaca and Cornell University), to 108 people per unit in the North (the even larger region extending north-east from Syracuse). Long Island's businesses, with 28 people per

Table 3.1

New York Biotechnology Industry

Basic Facts, 1990-1991

Total industry assets	**$1,340 million**
Global industry turnover	**$750 million**
Total expenditure in New York State	**$490 million**
Total industry revenue	**$525 million**
Number of dedicated biotechnology businesses	**90**
Number of biotechnology facilities in New York State	**110**
Global number of NY-based biotechnology facilities	**153**
Number of people employed in New York State	**4,100**
Number of people employed by NY businesses globally	**6,300**

Source: K.W. Willoughby (estimates based upon data from the Center for Biotechnology1991 survey of the New York biotechnology industry and extracts from the Ernst & Young 1990 survey of the US biotechnology industry).

Table 3.2

Employment and Facilities of Dedicated Biotechnology Businesses in New York Regions, 1991

Biotechnology Industry Region	New York City NYC	Long Island LI	Lower Hudson LH	Upper Hudson UH	Capital CAP	North NO	Mid West MW	Buffalo BUF	South -ern Tier ST	New York State **NY**
Number of businesses located in region	*16*	*28*	*12*	*5*	*6*	*4*	*4*	*8*	*7*	***90***
Estimated number of facilities in region	*20*	*32*	*15*	*6*	*6*	*12*	*4*	*8*	*7*	***110***
Estimated number of jobs in region	**527**	**826**	**981**	**281**	**99**	**432**	**318**	**544**	**73**	**4081**
Estimated global number of jobs based in region	*781*	*957*	*1264*	*361*	*107*	*432*	*978*	*1270*	*113*	***6263***
Estimated mean number of jobs (locally) per facility	26	26	65	47	17	36	80	68	10	**37**
Estimated mean number of jobs (globally) per business	49	34	105	72	18	108	245	159	16	**70**
Estimated mean number of jobs (locally) per business	33	30	82	56	17	108	80	68	10	**45**
Estimated number of NY jobs based in region	565	789	981	281	99	432	318	544	73	**4081**
Estimated mean number of jobs (NY) per business	35	28	82	56	17	108	80	68	10	**45**
Estimated number of facilities (globally)	24	37	26	8	8	12	12	13	14	**152**
Net proportion of jobs located in region	13%	22%	26%	9%	2%	4%	5%	16%	2%	100%
Net proportion of facilities in each region	19%	32%	13%	8%	5%	4%	3%	9%	6%	100%
Proportion of businesses based in region	18%	33%	12%	8%	6%	2%	3%	11%	8%	100%

Source: K. W. Willoughby, Center for Biotechnology, New York, Survey of the Biotechnology Industry, June 1991.

unit employed within New York, are smaller on average than the "typical" business statewide (which has 45 people per unit).

The single largest cluster of employees occurs in Lower Hudson, and this is accounted for largely by the concentration of biotechnology research and development carried out there by groups within large pharmaceutical companies, such as Lederle Laboratories' Medical Research Division. Lower Hudson is also the home base for the largest number of biotechnology facilities globally (i.e., locations throughout the world where activities of New York biotechnology businesses are situated). The region with the lowest total commercial biotechnology employment locally is Southern Tier (with 73 people, est. June 1991) followed by the Capital region (with 99, est. June 1991).

The urban part of metropolitan New York (i.e., New York City) contains only one-third as many biotechnology employees (just over 500 people) as the suburban part of metropolitan New York (i.e., Long Island and Lower Hudson), which are home to over 1,800 employees. It appears that New York's biotechnology industry is something of a suburban phenomenon, rather than either an urban or a rural one. It should also be recognized, however, that there is great diversity in the geographical character of the industry; that is perhaps the main message which should be read from Table 3.2.

A few other salient facts will provide a picture of the industry's present status. Over three-quarters (77 percent) of the businesses in New York have begun to generate revenue from the sale of products or services based upon biotechnology. An even higher majority (84 percent) claim to have commenced manufacturing operations already (and plan to continue manufacturing for the next five years) or plan to commence manufacturing within the next five years. Interestingly, 14 percent say that they plan to rely exclusively upon means other than manufacturing, such as the sale of intellectual property or services, for the generation of revenue; a further 5 percent are undecided about whether they intend to exclude manufacturing from their strategy for generating revenue.

History and Origins of the Industry

New York's role as an international center for biomedical research has evolved over a long period of time. Despite recent fears voiced about the region declining from its previous pre-eminent position, New York's biomedical research endeavors are still very substantial in absolute terms, having only recently been surpassed financially by those of the Boston region (Sturman, 1988; Aries, 1990). Although somewhat overshadowed by the public success of California in leading the "genetic engineering revolution," New York's scientists and institutions played a pioneering role in the development of the scientific foundations of biotechnology one generation ago. The critical role of institutions such as the Cold Spring Harbor Laboratory or the Rockefeller Institute (now Rockefeller University), to name only two, should not be overlooked; and the Cold Spring Harbor Laboratory, in particular, plays an extremely important role at present, leading programs such as the Human

Genome Research Project. The New York region was also quite active (even if not attracting wide media attention) during the embryonic phases of the biotechnology industry in the early 1980s (Peters, 1983). But what has happened during the last decade?

Figure 3.1 plots, over the last two decades, the number of biotechnology start-up companies each year in New York. Figures are taken only from the 1991 population of 90 dedicated biotechnology businesses, and exclude any start-ups that may have failed, or relocated outside the state, prior to 1991. The data in Figure 3.1 are therefore conservative.

A number of interesting observations may be drawn from the figure. First, 13 percent (12 businesses) were formed before the 1970s. This reflects the fact that a number of New York's biotechnology businesses grew out of long-established pharmaceutical and medical research enterprises —consistent with the region's historical role in biomedical research. The fact that these businesses still survive suggests that there is some basic resilience and maturity in the industry.

Second, the peak year for start-ups was 1988 — the year following the infamous stock market crash (of October 1987)! The overwhelming majority of commentators during that period were pessimistic about the likely effects of the crash, noting that the "honeymoon" was over and that the consequent shortage of capital from the public market would radically impede the growth, or even precipitate the decline, of the emergent biotechnology industry. Despite these problems and concerns, the long-term cyclic pattern of new start-ups (fluctuating over an average period of about three years) has continued, suggesting that the industry is not quite so wedded to the cyclic fortunes of the public capital market as is popularly thought. A similar phenomenon has been documented for the California biotechnology industry (Willoughby and Blakely, 1989).

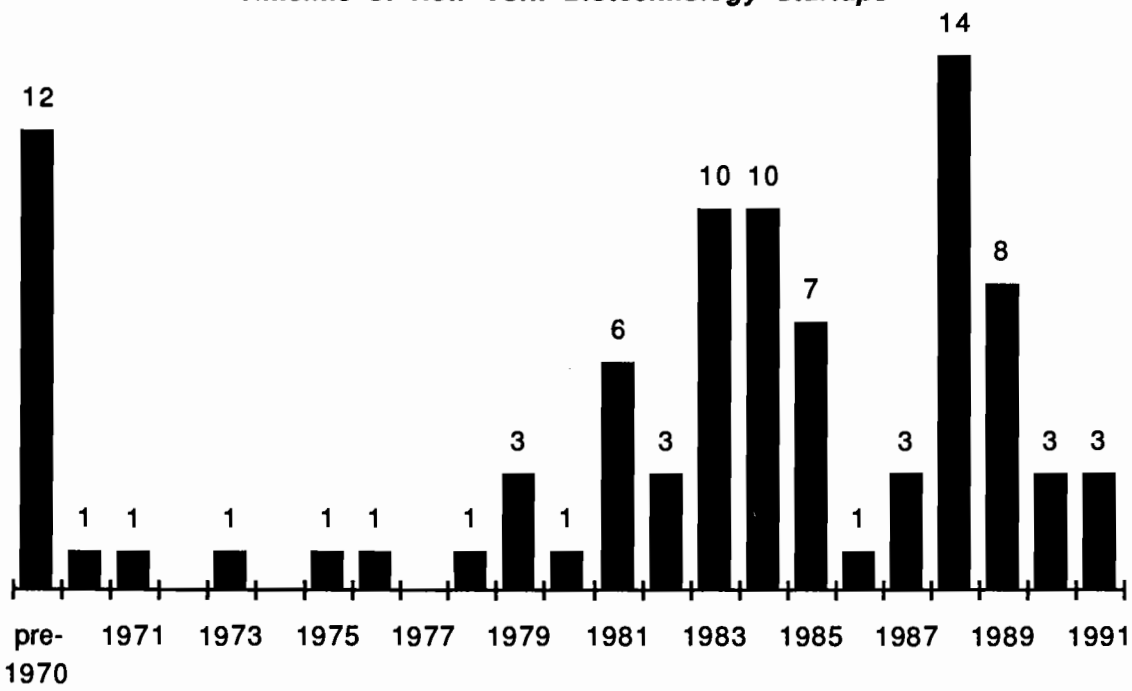
Third, Figure 3.1 shows that the majority of the businesses are quite young. Thirty percent of start-ups from the 1991 population happened within the previous four years, and three-quarters happened within the previous decade. The industry is therefore made up of an interesting mixture of both mature and immature organizations. The overall youth of the industry is probably what underlies the size distribution of firms.

Figure 3.2 sets out the distribution of New York's biotechnology businesses across size categories, based upon the number of employees in each unit (i.e., in each "firm" or "business"). These size categories are consistent with those used in the biotechnology studies of the Ernst & Young group, except that in the Ernst & Young publications, "small" refers to all companies with 50 employees or less. In this study, these organizations have been broken down further into three sub-categories: "small" (26-50 people), "mini" (6-25 people), and "micro" (1-5 people), an exercise which, as will be demonstrated later, has been quite fruitful in revealing the underlying dynamics of the industry.

In general, the size distribution of biotechnology businesses in New York appears roughly similar to that of the whole U.S. industry, as indicated by Ernst & Young's *Biotech 91* analysis of

Figure 3.1

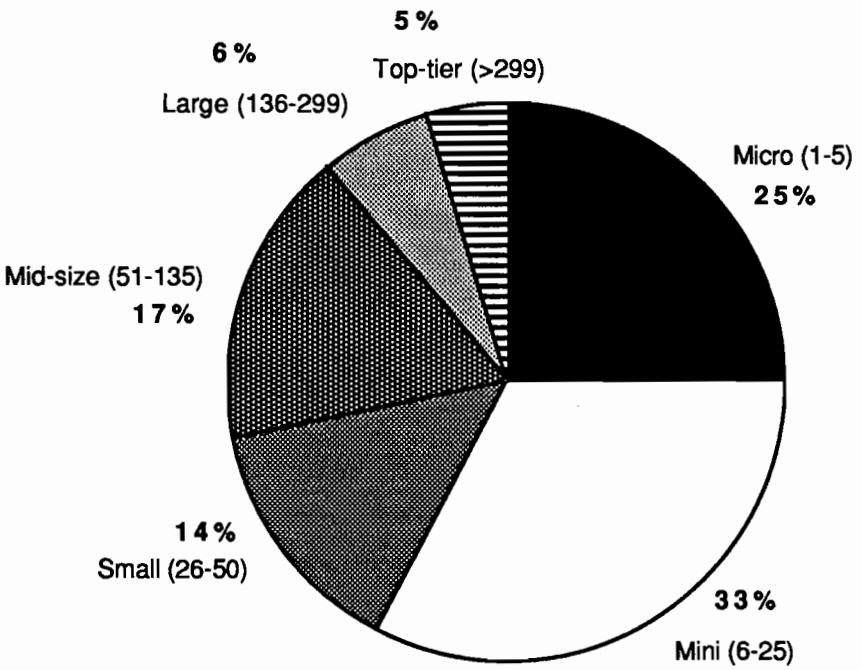
Timeline of New York Biotechnology Startups



Estimated number of startups each year of 1991 population

Figure 3.2

Size Distribution of New York Biotechnology Businesses



Percentage of State Total in Each Size Range
(figures in brackets indicate number of employees per business)

the national population of companies (Burrill & Lee, 1990: 15). According to Ernst & Young, 76 percent of biotechnology companies in the United States had 50 or less employees (72 percent of the businesses in Figure 3.2 match this criterion), while 15 percent were mid-size (New York, 17 percent), 6 percent were large (New York, 6 percent), and 3 percent were "top-tier" (New York, 5 percent). The particularly interesting discovery of this present study, however, is that fully one-quarter of New York's dedicated biotechnology businesses consist of five people or less. These organizations face significantly different challenges and strategic opportunities than their larger cousins, and probably also possess distinctive expectations as to the appropriate role of the public sector. As will be shown later, proportionally, they also draw more heavily upon the public sector for financial support (in the form of grants) than do larger firms. The fact that they are very small does not mean that they should not be taken seriously; the micro firms often play a critical role in providing services and support to the larger firms, they help vitalize the local milieu in which all the firms operate, and a good proportion grow into larger firms. The large number of small biotechnology businesses in New York probably means that the industry has certainly not yet stabilized.

Over three-quarters (79 percent) of the total sample of businesses in the survey commenced operations at their present primary location in New York. Only 60 percent of the founders of the businesses have ever engaged in a significant planning exercise involving investigation of alternative locations for the business and the articulation of locational criteria. Of those who have engaged in such an exercise, only 38 percent have actually relocated the business (21 percent of the total sample), and of those, 69 percent relocated from *elsewhere in New York State*. Hence, less than 8 percent of all the businesses (or 31 percent of those which did relocate) relocated from out-of-state. Most of the relocations were relatively local, aimed at such objectives as improving facilities rather than gaining fundamental changes in the environment.

When asked where the geographical location of the primary founder (or founders) was at the time of the formation of the business, almost 80 percent responded that it was at or nearby the present primary location of the business, and another 6 percent indicated a location elsewhere in New York State. Of the remaining founders, 8 percent were located elsewhere in the United States and 6 percent were located outside the United States.

These results are interesting because much of the policymaking of state governments intended to create local "high-technology" industries (such as biotechnology), and much of the promotional activity of private (or quasi-private) regional industry organizations with similar policy objectives, is based upon the premise of seeking to entice "footloose" high-tech/biotech firms to relocate to "our" state or region. While such initiatives may indeed pay off from time to time (as may have been the case with the few firms mentioned above which did relocate from out-of-state), this study suggests that other approaches are more likely to be fruitful. Biotechnology businesses

are basically not footloose. While a minority may make geographical shifts, it is hardly a strong enough phenomenon to form the foundation of an industrial development strategy.

As indicated by the above data and as suggested by other studies (Willoughby & Blakely, 1990), *the prime determinant of the location of biotechnology businesses is the prior location of the founders of the business*. Biotechnology companies emerge out of places in which suitably motivated, and suitably competent, people (where "competent" includes competence in getting access to necessary resources) already exist. This suggests that policies aimed at nurturing the pool of such people within a region would be more likely to lead to industrial growth in biotechnology than would industrial attraction efforts.

In the course of this study, a couple of ex-New York firms were identified that have relocated to other states (e.g., Marrow-Tech to California, and American Diagnostica to Connecticut), but these are exceptions to the rule, and while there appeared to be good reasons in these two cases, relocations generally also involve considerable cost. Despite inadequacies that may be associated with the original location, most firms will relocate only when there are significant advantages intrinsic to the new location beyond those which may be "packaged" by governments as inducements, and sufficient to outweigh the transitional costs (human, organizational, and financial) associated with relocation (Blakely and Willoughby, 1990).

The growth of the biotechnology industry in New York continues apace, despite widely discussed stringent circumstances. From 1990 to 1991 employment levels increased by an average of 51 percent, and the annual rate of employment growth averaged 53 percent over the previous five years. The annual rate of employment growth internationally from 1990 to 1991 was greater than the rate of employment growth within New York for 12 percent of the biotechnology businesses, and was equal for about 85 percent. If measured over the previous five years instead, the annual rate of employment growth globally was greater than the rate within New York for 13 percent of the businesses. This suggests that as the industry continues to grow it is gradually becoming more international in scope, while remaining firmly rooted locally in the places where it has emerged.

Eighty-six percent of the organizations interviewed in this study were dedicated biotechnology businesses at the time they were formed. Most of the rest were previously either hospital laboratories, medical diagnostic laboratories, or consulting/contract research organizations. When asked what kind of employment status the primary founder had at the time the business was formed, 19 percent responded that they were a member of another biotechnology business, 39 percent were university academics or members of a research institution, 22 percent were members of a business other than a biotechnology business, 8 percent were employees of a government agency (other than an educational or research institution), and 12 percent were self-employed.

Most of New York's dedicated biotechnology businesses (76 percent) were formed as a completely new business, but 18 percent were "spun-off" from an existing business, and 5 percent were formed by merging more than one existing business.

The manager of each business was also asked whether or not use had ever been made of the services of a state-funded support agency (such as a biotechnology center, a local economic development agency, or a university-industry liaison office) in either the establishment or the continuation of the business in its present location. Sixty-two percent responded that they had; of those which did make use of the services, 65 percent found them to be very useful, 22 percent did not find them to be very useful, and 13 percent were not sure of their usefulness.

Given that the majority of biotechnology businesses are "generated" locally rather than "transferred" from a distant location, and that this process is very people-intensive (with almost half of the founders being located in academic institutions or public agencies), it is not surprising that the majority have taken positive advantage of support services backed by the public sector. Almost 60 percent of the businesses, as mentioned above, have 25 or less employees, and 25 percent have no more than a "handful" of employees. This suggests that there is a perceived need for public sector assistance to the industry of a kind other than financial hand-outs or general management of the economic environment.

Technological Specialization and Research Focus

In many publications on commercial biotechnology there is confusion between the market focus and the scientific or technological focus of biotechnology companies. In this study a clear distinction is made between these things.

As indicated in the previous chapter, biotechnology is a series of technologies that may be applied in a range of existing or emerging industries or markets. For example, a particular technique such as "gene splicing" may be used as one of the processes in the development of drugs for human health-care (the so-called "therapeutics" market), it may be used to develop a new plant hybrid for agriculture (the so-called "agri-bio" market), it may be used in the production of a special protein for use in identifying disease states (the so-called "diagnostics" market), or it may find application in the production of enzymes to supply the food-processing or industrial chemicals markets.

In view of the above complexities, many commentators claim that there really is no such thing as a "biotechnology industry," only other industries to which biotechnology may be applied. With this logic, however, it would not be possible to speak of the "computer industry" just because computers are now tools in virtually every other industry! It is true that "biotechnology" itself is a field of technology rather than an industry; but an *industry of organizations* has indeed formed, based upon research, development, manufacturing, and services in this field of technology, and it is therefore quite appropriate to speak of the "biotechnology industry." The biotechnology industry

is an industry which interacts in complex ways with other industries, and in this sense there is nothing particularly unusual about it. The biotechnology industry in one community may be usefully differentiated from the industry in other communities by its distinctive mixture of both technological specializations and relationships with other industries (i.e., its market orientation). The businesses analyzed in this study have been classified from both vantage points.

The organizations interviewed were presented with the list of scientific and technological categories in biotechnology, as documented in Table 2.3 (see the previous chapter). Each business was asked to indicate whether it had engaged during the previous year in activities oriented towards each of the categories, and then to rank the three most important. From the answers to these questions it was possible to classify each business with both a primary technological specialization and a secondary technological specialization. These results were then aggregated across the whole New York biotechnology industry to produce Figure 3.3.

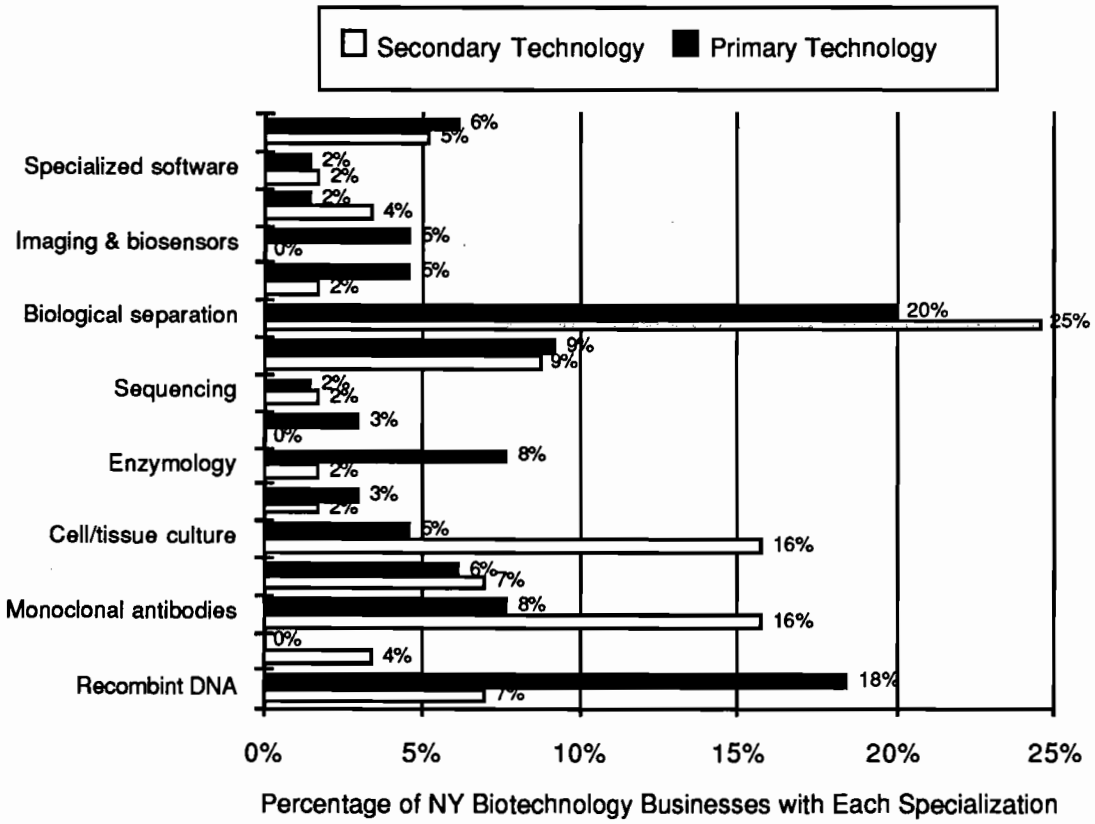
It is important to recognize that most biotechnology businesses engage in a wide variety of technologies; so while virtually all might have used recombinant DNA techniques (even school children can do this nowadays), not all would necessarily focus their business around this technique. Figure 3.3 is an attempt to emphasize the *relative importance* of the individual specializations. It shows that biological separation and purification techniques (e.g., derivatized membrane affinity bioseparations systems, amongst others) represent the single most dominant field for both primary specializations (20 percent of businesses) and secondary specializations (25 percent of businesses). This is followed by recombinant DNA techniques, which represent 18 percent of the primary specializations and 7 percent of the secondary specializations. Interestingly, except for these two fields, none of the technological fields represent more than 10 percent of the primary specializations of the businesses. Cell culture or tissue culture technology, and monoclonal antibody technology, follow as the next most prominent specializations when both the primary and secondary specializations are taken into account; monoclonal antibody technology appears slightly more prominent, with 8 percent of the primary specializations. On the basis of primary specializations, fermentation technology is also somewhat prominent, followed by enzymology.

Market Orientation

Using the classification system outlined in Table 2.2 (from the previous chapter), each business surveyed was asked to indicate in which market orientations or areas of product application it had engaged during the previous year. As with the technological specializations, it was asked to rank the three most important. From this it was possible to classify each business using the same five-category system as that employed by Ernst & Young (Burrill & Lee, 1990) in its studies, derived from the system originally used in the "BioScan" database (BioScan, 1991). The general market/pro

Figure 3.3

Technological Specialization of New York Biotechnology Businesses



duct categories, with which most observers of the biotechnology industry are very familiar, are therapeutics, diagnostics, agri-bio, supplies, and "other." Figure 3.4 presents the results of this analysis.

Figure 3.4 shows that the majority (63 percent) of New York's dedicated biotechnology businesses have as their primary market orientation one of the two human-health-oriented applications, therapeutics or diagnostics. This conforms roughly to the general pattern of the whole U.S. industry, as indicated by Ernst & Young's *Biotech 91* analysis of the national population of companies (Burrill & Lee, 1990: 16), with the main exception that New York businesses place more emphasis on diagnostics applications of biotechnology and less on therapeutics applications than is the norm at the national level. According to Ernst & Young, 35 percent of the nation's biotechnology companies were placed in the therapeutics segment of the market (30 percent of the businesses in Figure 3.4 match this criterion), while 28 percent were in the diagnostics segment (New York, 33 percent), 18 percent were in the supplies segment (New York, 17 percent), and 11 percent were in "other" (New York, 12 percent). The New York sample and the Ernst & Young national sample coincide in the case of the agri-bio market category, each with 8 percent oriented primarily towards this segment.

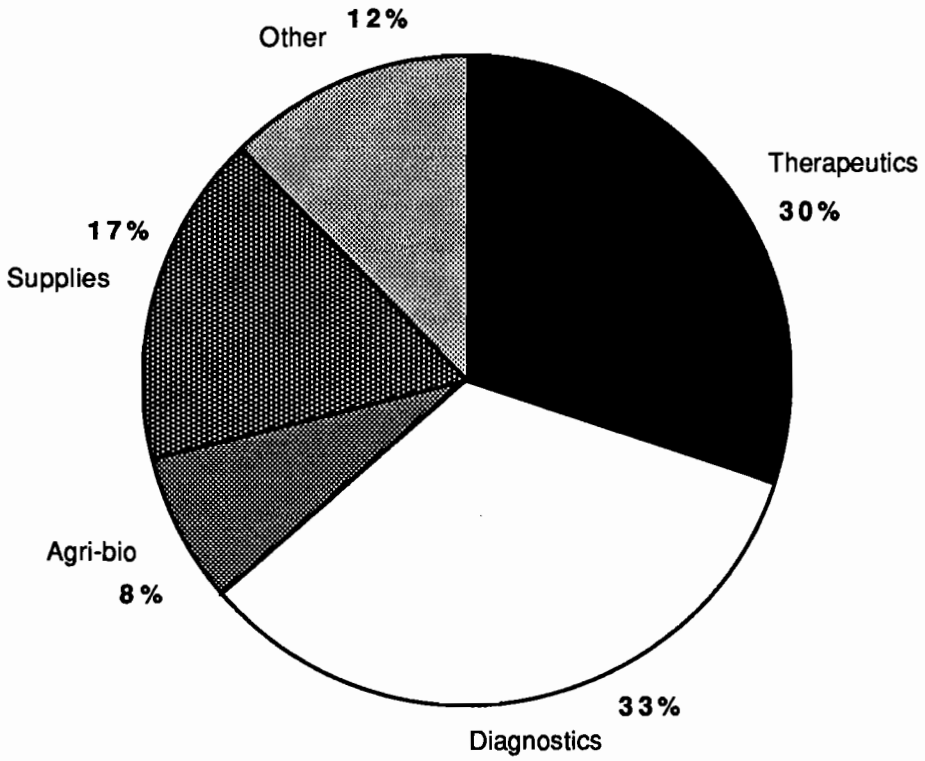
The distinctions between the market orientations of the biotechnology businesses are important for a number of reasons. Each market segment is subject to different kinds of regulatory constraints, public perceptions, and financial challenges. The choice of market orientation can therefore frame a firm's whole approach to financing and regulatory affairs; for example, developing a completely new drug for human use would require a lot of "patient" capital and a great deal of skill in managing relationships with federal regulatory authorities, and it may consequently require the formation of new strategic alliances.

Choice of market orientation can also be important for other reasons. Even though many of the basic biotechnology methods are applicable across a wide range of applications and final industries, some are nevertheless more important to some product markets than others. Conversely, the prior competence of a firm in one technological or scientific field may determine which markets it is adequately equipped to enter. No matter how attractive a product/market segment may appear on financial grounds, if the firm does not possess the requisite knowledge or skills it may be unable to take advantage of new opportunities which emerge in the market, possibly thereby also reducing its prospects of access to adequate capital. While biotechnologies may be versatile, in summary, they are not infinitely versatile; firms therefore need to choose technological specializations taking into account both the capabilities of their core personnel and the wider market environment.

These principles are illustrated by Tables 3.3 and 3.4. Table 3.3 sets out the cross-specialization of New York's biotechnology businesses by *primary* technological specialization and primary market orientation, and Table 3.4 sets out the cross-specialization of New York's biotechnology businesses by *secondary* technological specialization and primary market orientation. They both reveal a great deal of variation in the technological mix between each market segment.

Figure 3.4

Primary Market Orientation of New York Biotechnology Businesses



Proportion of State Total with Each Market Orientation

Table 3.3

Primary Technology and Primary Market of Biotechnology Businesses
New York, 1991

Primary Technology	Primary Market					*Total*	*N*
	Agri-bio	Diagnostics	Therapeutics	Supplies	Other		
Biological separation	20%	5%	32%	36%	13%	*20%*	*13*
Bioprocessing	0%	9%	0%	9%	0%	*5%*	*3*
Cell/tissue culture	0%	9%	0%	9%	0%	*5%*	*3*
Enzymology	0%	14%	5%	9%	0%	*8%*	*5*
Fermentation	20%	0%	11%	9%	25%	*9%*	*6*
Hybridoma/cell fusion	0%	0%	0%	0%	0%	*0%*	*0*
Imaging & biosensors	0%	9%	5%	0%	0%	*5%*	*3*
Liposomes	0%	5%	5%	0%	0%	*3%*	*2*
Monoclonal antibodies	20%	14%	0%	0%	13%	*8%*	*5*
Other	0%	9%	0%	9%	13%	*6%*	*4*
Polyclonal antibodies	0%	9%	0%	9%	13%	*6%*	*4*
Process monitoring/control	0%	0%	0%	0%	13%	*2%*	*1*
Protein synthesis	20%	5%	0%	0%	0%	*3%*	*2*
Sequencing	0%	5%	0%	0%	0%	*2%*	*1*
Specialized software	0%	0%	0%	9%	0%	*2%*	*1*
Recombinant DNA	20%	9%	42%	0%	13%	*18%*	*12*
No primary technology	0%	0%	0%	0%	0%	*0%*	*0*
Total	100%	100%	100%	100%	100%	*100%*	*65*
N	*5*	*22*	*19*	*11*	*8*	*65*	

Source: K. W. Willoughby, Center for Biotechnology, New York, Survey of the Biotechnology Industry, June 1991.

Table 3.4

Secondary Technology and Primary Market of Biotechnology Businesses New York, 1991

Secondary Technology	Primary Market					*Total*	*N*
	Agri-bio	Diagnostics	Therapeutics	Supplies	Other		
Biological separation	0%	9%	40%	18%	25%	*21%*	*14*
Bioprocessing	0%	0%	0%	9%	0%	*2%*	*1*
Cell/tissue culture	20%	9%	15%	27%	0%	*14%*	*9*
Enzymolology	0%	5%	0%	0%	0%	*2%*	*1*
Fermentation	20%	5%	5%	0%	25%	*8%*	*5*
Hybridoma/cell fusion	0%	0%	5%	9%	0%	*3%*	*2*
Imaging & biosensors	0%	0%	0%	0%	0%	*0%*	*0*
Liposomes	0%	0%	0%	0%	0%	*0%*	*0*
Monoclonal antibodies	20%	18%	5%	18%	13%	*14%*	*9*
Other	20%	5%	5%	0%	0%	*5%*	*3*
Polyclonal antibodies	0%	14%	0%	0%	13%	*6%*	*4*
Process monitoring/control	0%	0%	10%	0%	0%	*3%*	*2*
Protein synthesis	0%	0%	5%	0%	0%	*2%*	*1*
Sequencing	0%	0%	0%	9%	0%	*2%*	*1*
Specialized software	0%	5%	0%	0%	0%	*2%*	*1*
Recombinant DNA	0%	14%	5%	0%	0%	*6%*	*4*
No secondary technology	20%	18%	5%	9%	25%	*14%*	*9*
Total	100%	100%	100%	100%	100%	*100%*	*66*
N	*5*	*22*	*20*	*11*	*8*	*66*	

Source: K. W. Willoughby, Center for Biotechnology, New York, Survey of the Biotechnology Industry, June 1991.

Those businesses oriented towards the therapeutics market, as shown by Table 3.3, exhibit a strong specialization in recombinant DNA, followed by biological separation and purification techniques, and then fermentation technology. When the two tables are examined together they reveal that, beyond these three areas of concentration, the therapeutics businesses also exhibit a very broad scope of technological expertise, covering almost every category. The other group of businesses directly within the human health-care market, the diagnostics specialists, have a quite different mix of technological expertise. As would probably be expected by those familiar with the relevant science, the diagnostics businesses specialize in monoclonal antibody technology and enzymology; but they do so with a broader scope of primary technological expertise and a narrower scope of secondary technological expertise than the therapeutics businesses.

We could speculate on the basis of these figures, and with a bit of allegorical licence, that the therapeutics businesses probably tend to employ prominent specialists in a small number of key areas, but backed-up by solid teams of scientific and technological generalists (i.e., they put most of their eggs in one or two baskets, but ensure that they employ plenty of technically trained basket-holders to stop the baskets from dropping). On the other hand, the diagnostics businesses, we may further speculate, probably tend to employ specialists in a wider range of fields (i.e., they hedge their scientific bets more than do the therapeutics firms), but place less of an emphasis on scientific and technological generalists (i.e., they have more baskets in which to place their eggs, but consequently employ less people to hold the baskets, because if one basket did drop there would still be others containing the rest of the eggs).

The businesses operating in the agri-bio market category, as shown by the tables, cluster tightly in four or five technological fields: recombinant DNA, protein synthesis, monoclonal antibodies, biological separation/purification techniques, and fermentation. This striking pattern probably reflects two things. First, the diversity of prominent primary technologies (five) reflects the fact that this market/product category is in some ways a rather artificial combination of firms operating in fields as diverse as plant agriculture, food processing, livestock industries, and entomology —but united by their general relevance to food and agriculture. Second, when the first explanation is taken into account (the diversity of fields), it appears that each of the component sub-markets within agri-bio is indeed extremely specialized from a technological point of view. This interpretation is reinforced when the data from Table 3.4 is examined. Only one of the secondary technological specializations (cell/tissue culture technology) does not also appear as a primary technological specialization, and two of the primary technological specializations do not appear on the secondary technology list. In the agri-bio market segment, to continue the allegory, it appears that there are tight groups of highly specialized experts, working on unique eggs, and probably having to carry their own baskets as well!

The businesses operating in the biotechnology supplies segment of the market exhibit a distinctive primary emphasis on the technological field of biological separation and purification (see Table 3.3). It is very interesting to note, however, that less than one in ten of these firms have adopted specialized biotechnology software as their primary technology. All of the other categories of suppliers' primary technology, with the possible exception of bioprocessing technology (which also accounts for less than one in ten cases), are in the biological arena. This picture is confirmed by the data in Table 3.4. The specialized suppliers in New York's biotechnology industry, in other words, tend to be suppliers of *biological* supplies and technology rather than specialized suppliers of biotechnology electronics or equipment. This appears to be in contrast to the biotechnology industry in the San Francisco Bay Area, which exhibits a concentration of specialized biotechnology suppliers in the Santa Clara ("Silicon Valley") area, and which operate within the wider Bay Area but draw heavily upon the software, computing, and instrumentation expertise of the local region (Willoughby & Blakely, 1990).

Finally, the biotechnology businesses in New York categorized as part of the "other" market segment exhibit a primary technological specialization in fermentation technology (Table 3.3). This emphasis is repeated in the pattern of secondary technological specialization exhibited in Table 3.4, but reinforced by the complementary secondary field of biological separation and purification technology. This may be interpreted as a positive sign for the future of the state's biotechnology industry, in view of the heavy reliance, reported earlier in this report, which New York biotechnology businesses plan to maintain on manufacturing as a source of revenue. In debates about the future international competitiveness of the American biotechnology industry (e.g., President's Council on Competitiveness, 1991: 9-10), concern has been raised about the capacity of domestic firms to master the transition to efficient larger-scale industrial biotechnology manufacturing. The existence of a market-cluster of firms in New York with primary expertise in the "process" dimensions of biotechnology may prove to be invaluable in future years — particularly if good links may be formed between these firms and those concentrated in other technological specializations.

Corporate Structure

As explained in Chapter Two, the classification system developed for this study divides biotechnology businesses into those which are a free-standing separate company and those which are a part of a larger organization (see Figure 2.1). The first type is called a "discrete biotechnology business" (85 percent of New York's dedicated biotechnology businesses fall into this category), and the second type is called a "non-discrete biotechnology business" (15 percent fall into this category). Although the state's biotechnology industry is geographically part of the conglomeration of large established corporations in the northeast of the United States, New York's biotechnology businesses are nevertheless still predominantly of the individual form popularly associated with "new

biotechnology firms" ("NBFs") in California and elsewhere. The overall corporate structure of the industry is laid out in detail in Table 3.5.

The discrete biotechnology businesses may be further divided into public companies (16 percent of the discrete businesses, and 14 percent of the total population) and private firms (84 percent of the discrete businesses, and 71 percent of the total population). The non-discrete biotechnology businesses may be further divided into those which are a *formal division* within a diversified corporation (63 percent of the the non-discrete group, and 9 percent of the whole population), and those which are an *informal group* within a diversified corporation (38 percent of the non-discrete group, and 6 percent of the total population).

Most of the published financial reports on the biotechnology industry give a quite distorted picture of the reality because of their reliance upon readily available financial data from the public companies. Most private biotechnology companies are reluctant to make their financial structure and performance publicly known, and because the kind of detailed investigations involved in a study like this are so time-consuming and are only possible with the full cooperation of a specialist industry body such as a biotechnology association, most financial journalism on biotechnology is forced to concentrate on the public companies. In the case of New York this can lead to serious misrepresentations of the actual situation because, as this study has identified, only 14 percent of the state's biotechnology businesses are public companies. The balance is made up of private firms (71 percent) and groups or divisions within diversified corporations (15 percent), and it is therefore difficult to locate comprehensive and reliable information about them. This may partly explain the observation made earlier that the historical pattern in biotechnology start-ups in New York does not appear to be linked at all closely to the ebbs and flows of the public stock market (see Figure 3.1). The industry appears to be driven by forces other than purely financial ones.

An important structural issue for the future of the industry is that of *who* owns and manages its firms. If New York's biotechnology businesses are owned primarily by interests located within the state, and are managed primarily by those who have a positive commitment to the industry itself, then the chances of maintaining the industry as a competitive and sustainable *local* industry are probably greater. With this perspective in mind, each of the businesses interviewed in this study were asked a series of questions about its ownership and management. The results are shown in Table 3.5.

The non-discrete biotechnology businesses are those which one would probably expect to be most under the "control" of non-local interests. Table 3.5 reveals, however, that almost three-quarters of these organizations have their corporate headquarters located within New York State, with the remaining quarter accounting for only about 4 percent of the total population.

The private firms were classified into *independent firms* (those owned primarily by people directly involved in the daily operations of the business) and *non-independent firms* (those owned

Table 3.5
Corporate Structure of the Biotechnology Industry, New York, 1991

Organizational Category			Data for Sub-categories		
Parent category	Primary category	Sub-category	Valid proportion of primary category	Projected proportion of parentof category	Projected proportion of survey sample
All biotechnology organizations	Population of dedicated biotechnology businesses	Sample of all dedicated biotechnology businesses	73%	?	100%
All biotechnology organizations	All dedicated biotechnology businesses	Discrete organization	85%	?	85%
		Non-discrete organization	15%	?	15%
All dedicated biotechnology businesses	Discrete biotechnology businesses	Public company	16%	14%	14%
		Private firm	84%	71%	71%
All dedicated biotechnology businesses	Non-discrete biotechnology businesses	Formal corporate division	63%	9%	9%
		Informal group	38%	6%	6%
Discrete biotechnology businesses	Public companies	*Ownership distribution*			
		Diffuse share holdings	56%	9%	8%
		Dominant external shareholder	44%	7%	6%
Discrete biotechnology businesses	Private firms	*Ownership distribution*			
		Internal (independent firm)	67%	56%	48%
		External (non-independent firm)	33%	27%	23%
All dedicated biotechnology businesses	All private firms and public companies	Businesses free of concentrated external ownership	64%	55%	55%
All dedicated biotechnology businesses	Non-discrete biotechnology businesses	*Location of corporate HQ*			
		New York	71%	11%	11%
		Elsewhere in United States	14%	2%	2%
		Another country	14%	2%	2%
Private firms	Non-independent private firms	*Primary external owner's location*			
		New York	64%	21%	15%
		Elsewhere in United States	36%	12%	8%
		Another country	0%	0%	0%
Public companies	Public companies with dominant external shareholder	*Primary external owner's location*			
		New York	33%	15%	2%
		Elsewhere in United States	33%	15%	2%
		Another country	33%	15%	2%
Private firms	Non-independent private firms	*Primary location of planning and management functions*			
		"Parent" organization	0%	0%	0%
		Local organization	100%	33%	23%
		Shared equally between both	0%	0%	0%
Public companies	Public companies with dominant external shareholder	*Primary location of planning and management functions*			
		"Parent" organization	0%	0%	0%
		Local organization	100%	44%	6%
		Shared equally between both	0%	0%	0%
All dedicated biotechnology businesses	Non-discrete biotechnology businesses	*Primary location of planning and management functions*			
		Parent organization	17%	3%	3%
		Local organization	33%	5%	5%
		Shared equally between both	50%	8%	8%

Source: K. W. Willoughby, Center for Biotechnology, New York, June 1991.

primarily by people not directly involved in the daily operations of the business). Two-thirds of the private biotechnology firms in New York turn out to be independent by this definition. A parallel indicator of independence was measured for each of the public companies in the survey: the degree to which shares are either concentrated in the hands of a single dominant external shareholder, or diffused throughout a wider range of stakeholders. The logic to this distinction is that if people involved directly in the day-to-day operations of the business remain the dominant shareholders, even after the company goes public the chances are good that they will exert a fairly strong control over the company. However, if this is not the case, but instead the externally held shares are distributed widely across a range of stakeholders, then the internal stakeholders are more likely to be able to manage the company as they wish. Fifty-six percent of the public companies in the sample turn out not to have a dominant external shareholder. The balance account for about 6 percent of the total population. Combining together the non-discrete businesses, the private firms, and the public companies, we are led to the observation that 64 percent of New York's dedicated biotechnology businesses are free of concentrated external ownership; the balance, 36 percent, are potentially more open to external control (e.g., relocation, amalgamation, down-sizing, et cetera— but in principle such external control might also involve business expansion if the external investor was confident in future prospects within New York).

The dominant external shareholders of the public companies are distributed evenly between New York State, another U.S. state, and another country. This means that 30 percent of the public companies (about 4 percent of the total population) are subject to concentrated external ownership outside of the state of New York. Thirty-six percent of the primary external owners of non-independent private firms (about 12 percent of all private firms and about 8 percent of the whole population) are located outside of New York. Hence, combining the non-discrete businesses, the public companies, and the private firms, we discover that New York's dedicated biotechnology businesses are subject to concentrated external ownership, located out of state in about 12 percent of the cases. It would be reasonable to conclude, therefore, that from a financial (and perhaps legal) point of view the vast majority of New York's commercial biotechnology operations are locally controlled (where "local" means "from within New York").

The corporate structure looks even more attractive, from the vantage point of "local control," if the distribution of actual management and planning functions is examined in addition to ownership patterns. Table 3.5 also shows that, when all of the non-independent private firms and all of the public companies with a dominant external shareholder in the survey sample are combined, in all cases the primary location of the main corporate management-and-planning functions of the business is located in the actual business itself rather than with the primary external owner (parent organization). In other words, the external ownership patterns do not appear to have much influence on the actual planning and management of the businesses themselves. In the case

of the non-discrete businesses, these functions are shared equally between the business and its corporate headquarters in half of the cases, but in one-third of the cases they are based primarily with the business itself.

Putting together all of the above information on corporate structure, it seems reasonable to conclude that, on the whole, the New York biotechnology industry is locally controlled. It does not appear to be reasonable to fear that the industry might decline due to lack of opportunity for local participants in the industry to play a strategic role in setting its future. To put this in colloquial language —*the industry's future is in its own hands.*

Human Resources

It was noted above that New York's biotechnology businesses tend to locate at, or nearby, the prior location of their primary founder or founders. It was also suggested that factors such as the local supply of suitably competent and motivated people were more likely to be important determinants of the emergence of commercial biotechnology in a region than other economic factors. It is therefore important to look at the kind of people biotechnology businesses employ, and from where they tend to come. This kind of information may be useful in guiding exercises in the area of training and human resources planning.

Table 3.6 shows the results of analysis of data from the survey on personnel patterns. Each business interviewed was asked to list all its facilities worldwide and to indicate, for each one, the total number of people employed there and the percentage of full-time-equivalent people devoted primarily to each of the following organizational functions: management and marketing, research and development, technical operations, and other functions. The term "technical operations" was used in preference to "manufacturing" because in most biotechnology firms it is difficult to isolate the activities of people so neatly into manufacturing and non-manufacturing, particularly when the firm is small or when the manufacturing process itself is undergoing research and development. Furthermore, in those firms engaged primarily in research work rather than manufacturing, there are often a good many people who are technically trained and who may conduct quite a bit of technically complex work (e.g., operation or maintenance of sophisticated equipment), but who should probably not be described as "scientists" or "researchers"; the "technical operations" category covers these people. Finally, in both manufacturing-oriented firms and in research-oriented firms there are various tasks, such as stock-taking, cleaning, security, or caring for animals, to name a few, which ought not to be classified as the functions of managers, researchers, or technicians— hence the category of "other." The four personnel classifications used here are therefore based upon the person's *function* within the organization rather than upon either the specialization of the organization or the particular background or qualifications of the person.

Table 3.6
Distribution of Personnel between Organizational Functions of New York's Biotechnology Businesses, 1991

Organizational function	Mean proportion of personnel in businesses devoted to each organizational function		
	Main facility only	All branch facilities combined	All facilities combined
Management and marketing	24.1%	16.8%	21.5%
Research and development	31.2%	47.4%	37.1%
Technical operations	27.0%	27.4%	27.1%
Other	17.7%	8.4%	14.3%
Estimated total # personnel	*3,972*	*2,291*	*6,263*

Source: K. W. Willoughby, Center for Biotechnology, New York, 1991.

Table 3.6 suggests, first of all, that only a small proportion of the people in New York's biotechnology businesses tend to be engaged in low-level or unskilled work. This is indicated by the fact that only just over 14 percent of all personnel are classified as "other," and it accords with popular images of biotechnology being a skill-intensive an knowledge-intensive field— or, put differently, as "high technology." The single largest functional personnel category is "research and development," accounting for almost two-fifths of the total. Management and marketing account for just over one-fifth of the personnel.

It is also interesting to note that over a quarter of the personnel, both in the main facilities and in the branch facilities, are functionally specialized in technical operations. It is important to recognize this because it points to the need for a tier of scientifically and technically trained people other than senior scientists with doctorates. Given that not all, or even most, of the people within the research and development category would need to be of the "hero scientist" kind, it would appear that the employment prospects in biotechnology firms for people with "middle range" and "lower range" scientific and technical backgrounds is at least as large as the prospects for scientists with higher degrees.

Table 3.6 also suggests that the branch facilities of New York's biotechnology businesses tend to be there primarily to further the research and development objectives of the firms rather than to conduct routine manufacturing. This is demonstrated by the fact that the percentage of research and development personnel in the branch facilities (47 percent) is higher than in the main facilities (31 percent); and the percentages of personnel in the branch facilities devoted to either managerial and marketing functions or "other" (routine) functions is lower than in the main facilities. The spatial distribution of the industry is probably therefore related more to knowledge-generating needs and people-related factors than to the pressure for cost reduction often associated with the establishment of branch facilities by companies.

Table 3.7 summarizes the sources from which the businesses in the survey draw their personnel. The personnel categories used here are based upon the person's *qualifications and skills* rather than upon their function within the organization, as was the case for Table 3.6. Support staff (Table 3.7), for example, may be functionally involved in technical operations, in non-technical ("other") functions, or in supporting senior managers. Engineers would probably be involved predominantly in technical operations, but they might also fulfil a critical function in research work toward the development of a new biotechnology manufacturing process (e.g., scaling up fermentation or biological purification systems from laboratory scale to industrial scale).

The information in Table 3.7 shows that there is considerable variety in the recruitment sources between the different personnel categories. The single strongest concentration lies with universities (or similar institutions) as sources of the *junior* scientific staff. The universities and non-commercial research institutions are also the main source for senior scientists, but a fifth of

these come from other biotechnology businesses. The secondary source for the senior scientists (other biotechnology businesses) is possibly an expression of the growing importance the industry itself gains as a source for scientist-entrepreneurs once it becomes established in a region. While universities appear to be the probable initial generators of the human resources pool for biotechnology, the industrial ecology of the industry is somewhat more complex than would be the case if universities were the only "driving force" (as indicated earlier, less than two-fifths of the founders of New York's dedicated biotechnology businesses were located in universities or research institutions at the time they founded the business).

The vast majority of engineers in the biotechnology industry (four-fifths) come from other industries or backgrounds. The fact that they tend not to emerge from within the biotechnology industry may mean that it will be important for links to grow between biotechnology businesses and other "high-technology" firms to ensure that there is a good pool of engineers fluent enough in the language and traditions of biotechnology to make effective contributions when they are needed.

Table 3.7 also shows that over one-third of the support staff come from universities. This reinforces the point made earlier that biotechnology is a knowledge-intensive and skill-intensive industry. Less than one-quarter of the senior management of the biotechnology businesses in the sample come from universities or research institutes, and almost one-half come from industries or backgrounds other than biotechnology. This suggests that the popular "scientist-entrepreneur" model of the emergence of biotechnology firms is not adequate to account for the complexity of the origins of the industry in New York.

Finance

Information cited earlier suggested that the formation of new biotechnology businesses appears not to be closely related to the state of the public stock market. Given the importance which the stock market is normally given in popular discussions of biotechnology, this study has sought to document carefully the range of sources of finance for biotechnology businesses in New York and to determine what proportion of the industry's finances comes from public sources. The results from the survey are summarized in Figure 3.5.

The single most important source of finance for New York's biotechnology businesses is revealed by Figure 3.5 to be revenue (retained earnings), accounting for 44 percent of the total. Private equity, the second most important source, accounts for 2.75 times the amount of finance raised from public sources. Public equity accounts for only 8 percent of the total.

Figure 3.6 is based on the same data, but excludes revenue from the picture to conform with the more conventional way of presenting sources of finance for companies. The share of finance coming from public equity, viewed this way, rises to 15 percent of the total. Both figures also reveal the significant proportion of finance which derives from the principals' personal

Figure 3.5

Sources of Finance, New York Biotechnology Businesses, 1990-91

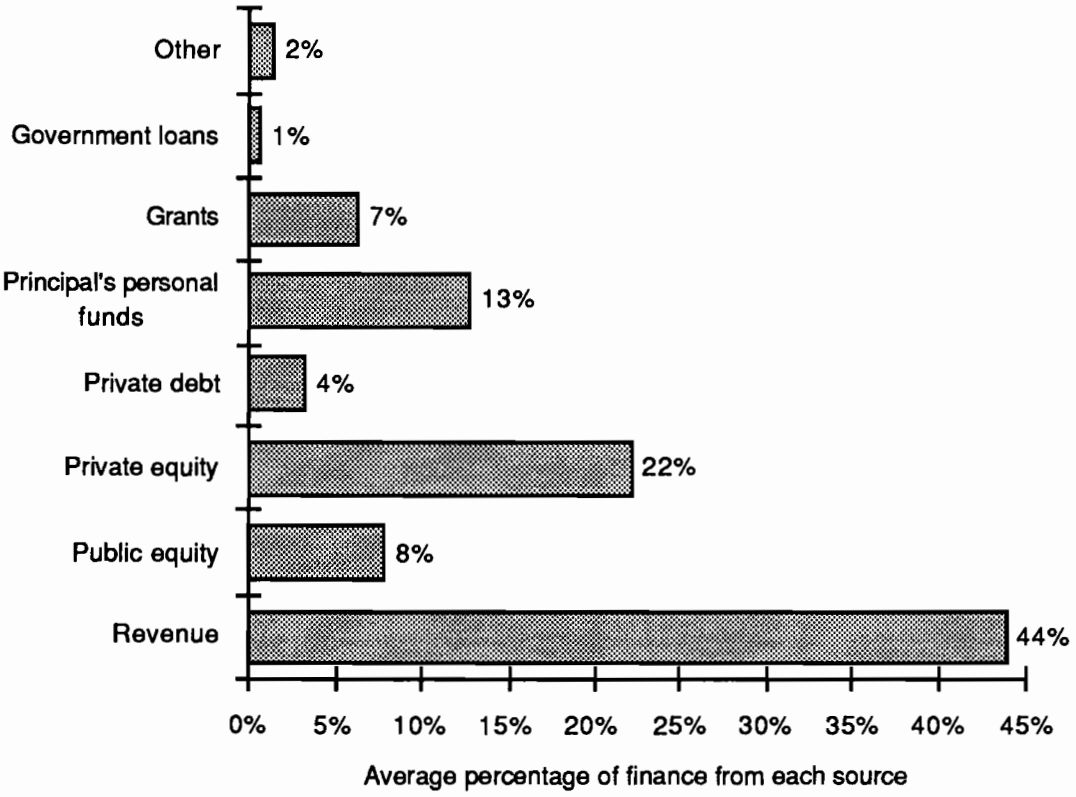
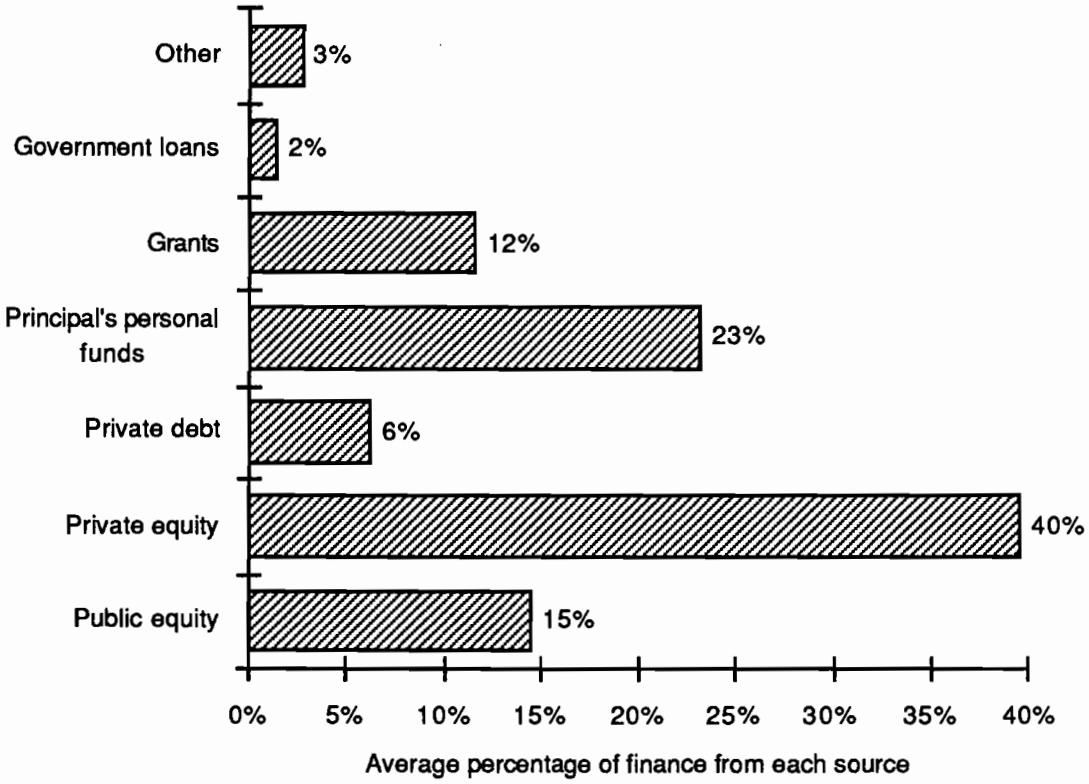


Figure 3.6

Sources of Finance (Excluding Revenue), New York Biotechnology Businesses, 1990-91



funds —almost twice as much as the amount raised through grants, and over one-and-a-half times the amount which comes from public equity.

Figure 3.7 lays out the basic patterns of expenditure of New York's dedicated biotechnology businesses for 1990-91. It reveals that almost two-fifths of the expenditure was devoted to research and development, just over a quarter to the cost of product sales, and about 30 percent to general, administrative, and marketing. This picture conforms with the one we gained through the data on distribution of personnel by function and qualification (Tables 3.6 and 3.7).

Of particular interest is that, up until the time of the survey during mid-1991, only a fraction of one percent of total expenditure was devoted to the purchase of equity in other companies, and less than four percent was devoted to the purchase of licenses and technology rights. The amount spent on research and development is an order of magnitude (ten times) larger than the amount spent on the purchase of intellectual property or rights to use other people's technology. Taken together, *these figures paint a clear picture of the way in which New York's dedicated biotechnology businesses develop technology. It is largely generated locally rather than obtained through the process of formal technology transfer from elsewhere —in other words, it is "home-grown."*

Table 3.8 summarizes the overall shape and size of New York's biotechnology industry from the point of view of its financial accomplishments. The estimates for 1990-1991 in this table are derived from extracts of the data set from the annual survey by Ernst & Young of biotechnology companies in the United States, modified to take into account the data presented in Tables 3.5, 3.6, and 3.7, and to reflect differences between the average size of organizations in the Ernst & Young sample of New York's biotechnology businesses and those of the sample from this study.

Table 3.9 presents a composite statement of operations for New York's biotechnology businesses for both 1989 and 1990. These figures are set alongside the equivalent results for the whole national sample of biotechnology businesses during the same time periods. In a similar manner, Table 3.10 presents a composite balance sheet for New York's biotechnology businesses for both 1989 and 1990, alongside the equivalent national figures.

Highlights of the two tables include the following. The rate of revenue increase for a typical New York biotechnology business was greater than for the typical firm at the national level, but so was the rate of increase of total costs and expenses— a result mirrored in the change in the absolute size of the loss (greater for New York than for the United States as a whole). New York's firms show a shift away from an emphasis on contract research and royalties and towards product sales and interest income as sources of revenue. This pattern also appears at the national level, but to a lesser degree.

The balance sheets show that the size of the total assets for the New York industry grew very rapidly over the year (the 1990 figure is 337 percent of the 1989 figure), and at a greater rate

Figure 3.7

Distribution of Expenditure, New York Biotechnology Businesses, 1990-91

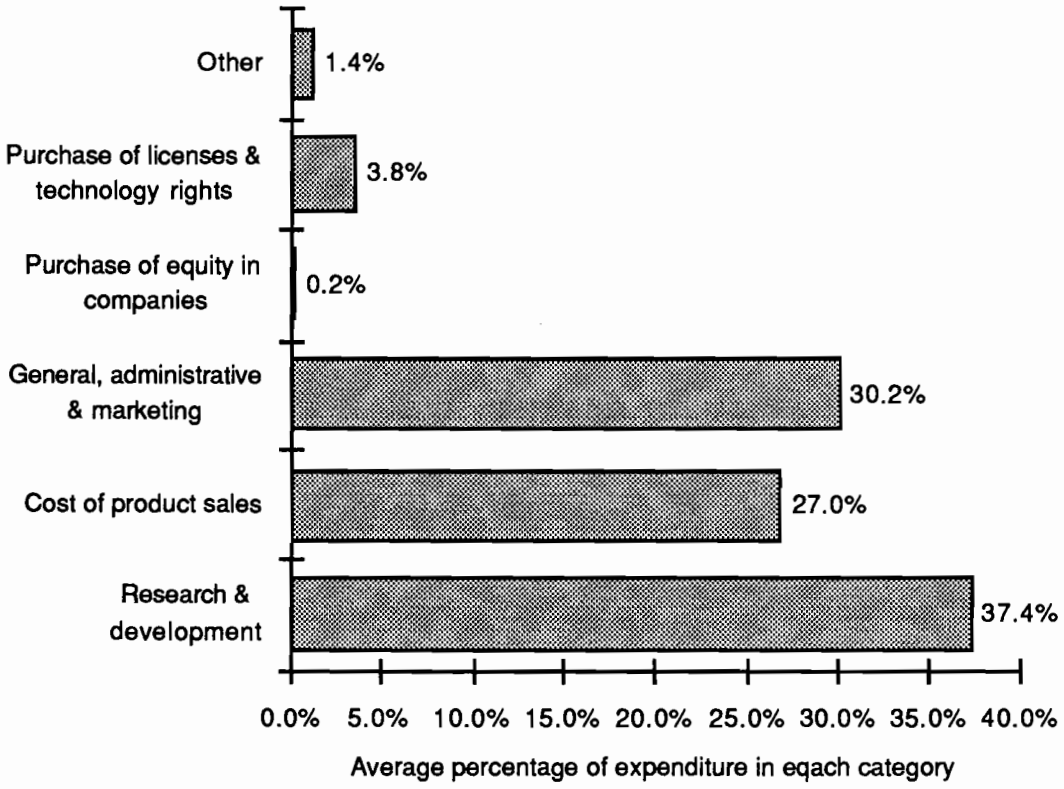


Table 3.7
Source of Personnel in Biotechnology Businesses
New York, 1991

Personnel category	Most frequent previous institutional affiliation of personnel employed in each biotechnology business *(% of firms in each group)*			N
	Other biotechnology business	University or research institution	Other industry or background	
Senior management	30%	23%	48%	61
Senior scientists	20%	64%	16%	61
Junior scientific staff	2%	83%	14%	42
Engineers	3%	17%	79%	29
Support staff	0%	35%	65%	49

Source: K. W. Willoughby, Center for Biotechnology, New York, 1991.

Table 3.8

Basic Financial Summary of New York Biotechnology Industry

Ernst & Young Data, 1990	(thousands of dollars)
Composite total assets	$16,424
Composite expenditure	$9,182
Composite revenue	$6,417
Estimates for 1990-1991	(thousands of dollars)
Composite expenditure	$8,347
Composite revenue	$5,834
Total revenue	$525,027
Total expenditure in New York State	$489,521
Total global expenditure	$751,255
R&D spending	$280,969
Cost of product sales	$202,839
General, administrative & marketing costs	$226,879
Purchase of equity in companies	$1,503
Purchase of licenses and technology rights	$28,548
Other spending	$10,518
Average assets	$14,931
Total industry assets	$1,343,782

Sources: Ernst & Young (primary source); final estimates for 1991 are based upon the Ernst & Young data for 1990, modified to take account of results from the 1991 survey by Center for Biotechnology, New York.

Table 3.9

Composite Statements of Operations, Biotechnology Businesses
New York and United States, 1989 and 1990

(in thousands of dollars)	New York		United States	
	1989	1990	1989	1990
Revenues				
Product sales	$3,856	$4,870	$8,201	$9,455
Contract/collaborative research	$846	$827	$2,724	$2,798
Royalties and license fees	$191	$122	$355	$252
Interest income	$436	$537	$874	$948
Other revenues	$77	$61	$411	$395
Total Revenues	***$5,406***	***$6,417***	***$12,565***	***$13,848***
Costs and Expenses				
Cost of product sales	$2,068	$2,581	$3,571	$4,123
General and administrative	$2,099	$2,630	$4,161	$4,635
Marketing and selling	$102	$140	$386	$309
Research and development	$1,650	$2,694	$5,184	$5,772
Interest	$417	$402	$333	$330
Purchase of R&D Partnership	$0	$0	$0	$63
Other expenses	$325	$734	$432	$637
Total Costs and Expenses	***$6,660***	***$9,182***	***$14,067***	***$15,869***
Income (loss) before taxes	($1,254)	($2,765)	($1,502)	($2,021)
Income tax credit (expense)	($199)	($154)	($408)	($388)
Extraordinary credit (expense)	$27	$12	$21	$12
Other credit (expense)	$2	($85)	($10)	($24)
Net Income (loss)	***($1,425)***	***($2,993)***	***($1,899)***	***($2,421)***
Number of businesses in sample	16	16	480	422

Source: Ernst and Young, 1991.

Table 3.10

Composite Balance Sheets, Biotechnology Businesses
New York and United States, 1989 and 1990

(in thousands of dollars)	New York		United States	
	1989	1990	1989	1990
Assets				
Current Assets				
Cash and short-term investments	$5,168	$5,710	$11,177	$11,175
Accounts receivable, net	$966	$1,308	$2,140	$2,524
Inventory	$779	$981	$1,893	$2,189
Other current assets	$1,191	$847	$842	$730
Total current assets	*$8,105*	*$8,846*	*$16,052*	*$16,618*
Net property, plant and equipment	$2,257	$2,954	$6,713	$7,701
Patents, net of amortization	$172	$205	$133	$218
Goodwill, other intangibles	$149	$2,772	$919	$660
Investments in partnerships & other entities	$37	$26	$203	$276
Long-term cash and marketable securities	$215	$209	$645	$772
Other long-term assets	$974	$1,413	$903	$1,456
Total assets	***$11,909***	***$16,424***	***$25,568***	***$27,701***
Liabilities and Stockholder's Equity				
Current Liabilities				
Accounts payable	$471	$681	$1,088	$1,111
Accrued liabilities	$498	$492	$882	$1,147
Short-term debt	$131	$42	$336	$344
Current portion of deferred revenue	$8	$15	$228	$197
Current portion of long-term debt	$54	$87	$493	$293
Other current liabilities	$81	$285	$591	$497
Total current liabilities	*$1,243*	*$1,602*	*$3,618*	*$3,589*
Long-term debt	$3,948	$5,685	$4,188	$4,937
Deferred revenue	$0	$0	$65	$58
Other non-current liabilities	$37	$345	$517	$611
Total liabilities	**$5,227**	**$7,631**	**$8,388**	**$9,195**
Stockholder's Equity				
Preferred stock	$0	$0	$829	$1,351
Common stock	$108	$119	$2,222	$2,062
Other paid-in capital	$9,708	$14,130	$23,297	$25,416
Other shareholders' equity	$63	($21)	($174)	($145)
Retained earnings (losses)	($3,199)	($5,435)	($8,994)	($10,178)
Total stockholders' equity	**$6,681**	**$8,793**	**$17,180**	**$18,506**
Total liabilities and stockholders' equity	***$11,908***	***$16,424***	***$25,568***	***$27,701***
Number of businesses in sample	16	16	480	422

Source: Ernst and Young, 1991.

than did the typical firm nationally (for which the 1990 figure is 248 percent of the 1989 figure). Total liabilities for the typical New York firm also increased over the year (the 1990 figure is 148 percent of the 1989 figure), but at a lesser rate than the rise of assets. The total liabilities for the typical firm in the United States actually dropped during the period. Stockholders' equity in New York increased by over 70 percent during the period covered by the two tables.

Detailed analysis of the data in these two tables will be presented in a later chapter on the competitive position of the New York biotechnology industry compared with other U.S. states.

Table 3.11 sets out the data on income and expenditure in New York's biotechnology businesses, collected directly from the survey sample in this study, cross-tabulated against variations in the size of the organizations. Amongst other things it shows that, in general, the dependence upon revenue as a source of finance increases with the size of the firm, but that there is a departure from this pattern for the mid-sized businesses that lean more heavily towards public equity. Dependence upon private equity tends to decline with the size of the business, with the exception of mid-size businesses which rely upon private equity slightly more than is the case at the norm. The contribution of principals' personal funds declines sharply from 35 percent for the micro businesses to 10 percent for the mini businesses; the substantial contribution made by this category of finance for the whole industry is explained by the fact that a large proportion of the state's biotechnology businesses have a low number of employees. Grants, as a source of finance, also feature most prominently for the micro and mini businesses, with the former raising 14 percent of their finance from this source, and the latter relying upon it for 8 percent of their finance.

The general story about financing which we might deduce from Table 3.11 is that businesses with less than about 50 people tend to rely upon a diverse range of sources for their finance, gradually increasing the share that comes from revenue as they grow. As firms reach the size of about 50 people, their needs for capital injection appear to increase rapidly, leading to a number of public floats, and to a marginal increase in private equity financing. Once businesses grow significantly beyond the "100 employees" mark, the public equity market appears less attractive (or possibly less important), and there is a shift towards revenue as a main source; however, as the firms grow into top-tier firms (300 people or above), private equity begins to become more important again (presumably signalling their becoming attractive for corporate takeovers). Whether the pattern just described is a standard pathway through which biotechnology firms move, or whether, instead, there are stable niches at each size level and at which firms may remain settled, will require further investigations.

Table 3.11 also shows that, as a general rule, the proportion of expenditure that is devoted to research and development declines as the size of the firms increases; conversely, the proportion devoted to the cost of product sales tends, in general, to increase as the size of the firm increases. This presumably reflects a general trend in the industry for firms to mature into manufacturing

Table 3.11

Variations in Finances of Biotechnology Businesses by Size of Organization, New York, 1991

Size of Business (number of employees per business)	Micro (1-5)	Mini (6-25)	Small (26-50)	Mid-size (51-135)	Large (135-299)	Top-tier (>299)	All sizes
Sources of finance							
Revenue	18%	44%	66%	39%	91%	70%	44%
Public equity	2%	8%	6%	19%	0%	17%	8%
Private equity	31%	22%	22%	24%	6%	0%	22%
Private debt	1%	7%	1%	1%	3%	13%	4%
Principals' personal funds	35%	10%	2%	5%	0%	0%	13%
Grants	14%	8%	3%	1%	0%	0%	7%
Government loans	0%	1%	0%	2%	1%	0%	1%
Other	0%	0%	0%	9%	0%	0%	2%
Distribution of expenditure							
Research & development	41%	41%	37%	42%	12%	14%	37%
Cost of product sales	19%	25%	38%	24%	41%	44%	27%
General, administrative & marketing	31%	32%	20%	31%	36%	35%	30%
Purchase of equity in companies	0%	0%	0%	0%	3%	0%	0%
Purchase of licenses & technology rights	9%	1%	4%	2%	3%	1%	4%
Other	0%	2%	1%	0%	6%	5%	1%
Annual rate of revenue growth	35%	57%	127%	87%	31%	14%	70%
Annual rate of expenditure growth	23%	62%	9%	21%	13%	7%	33%

Source: K. W. Willoughby, Center for Biotechnology, New York, Survey of the Biotechnology Industry, June 1991.

activities as they grow. On the other hand, it may also be that there are niches at each size level and at which firms may remain if they so desire. For example, some firms may choose to remain small and do so by concentrating on doing research work in close collaboration with larger firms better equipped for the manufacture and distribution of final products.

As is the case with financing, the mid-size firms tend to depart from the overall size-related trends in expenditure. They exhibit the highest proportion of expenditure devoted to research and development of all the size-groups in the industry. They also tend to devote less expenditure to the cost of product sales than is typical for the industry. It appears that there is a close link between the form of financing required and the type and scale of activities to be pursued. Those firms which wish to pursue a concentration on research and development activities at more than a modest scale (i.e., more than about 50 people) appear to have a pronounced need to raise capital from the public market. Firms in the smaller size range seem to be able to concentrate on research and development work without "going public," and those in the top end of the size range appear to maintain the research as a subsidiary activity to product manufacturing and marketing, and thus find less need to raise capital through the public market.

The proportion of funds devoted to "general, administrative, and marketing" is fairly uniform across all the size ranges, except that there is a "dip" in the size-range of between 26 and 50 employees per business. It appears that, for some reason yet to be determined, the small (but not tiny) firms have less "overhead" in their budgets.

Finally, the annual rate of growth of revenue rises as the size of businesses rises to the mid-size category, but then tapers off again as the size continues to increase. There does not appear to be a universal pattern to the way in which rate of growth of expenditure varies with size. Table 3.11 does show, however, that the annual rate of growth of expenditure tends to decline as the size of businesses rises above the mid-size category. From these figures we might deduce that the highest degree of volatility in the industry is probably taking place amongst the firms in the general size range of between 50 and 100 employees.

Table 3.12 sets out the same data used to construct Table 3.11, but is cross-tabulated against the primary market orientation of the businesses.

There does not appear to be much variation between the different market segments in the rate at which their annual expenditure grows; but one group, "other" (which includes about 12 percent of the industry population and covers a range of industries including industrial feedstocks, forensics, energy, new materials, mineral extraction, forestry, aquaculture, and environmental management), shows spectacular revenue growth rates (248 percent per annum, as opposed to 66 percent for the industry as a whole, and around 30 percent to 40 percent for the other markets segments if "other" is excluded from the total).

Table 3.12

Variations in Finances of Biotechnology Businesses by Market Orientation, New York, 1991

Market Orientation	Therapeutics	Diagnostics	Agri-bio	Suppliers	Other	All businesses
Sources of finance						
Revenue	27%	50%	74%	43%	54%	44%
Public equity	16%	6%	7%	5%	1%	8%
Private equity	25%	25%	0%	15%	33%	22%
Private debt	1%	3%	10%	8%	1%	4%
Principals' personal funds	17%	7%	7%	22%	10%	13%
Grants	7%	10%	3%	5%	1%	7%
Government loans	1%	0%	0%	3%	0%	1%
Other	5%	0%	0%	0%	0%	2%
Distribution of expenditure						
Research & development	56%	37%	22%	24%	23%	37%
Cost of product sales	13%	29%	47%	39%	29%	27%
General, administrative & marketing	26%	27%	25%	34%	45%	30%
Purchase of equity in companies	1%	0%	0%	0%	0%	0%
Purchase of licenses & technology rights	3%	6%	5%	2%	0%	4%
Other	1%	1%	1%	2%	3%	1%
Annual rate of revenue growth	29%	27%	30%	38%	248%	70%
Annual rate of expenditure growth	96%	-1%	0%	11%	13%	33%

Source: K. W. Willoughby, Center for Biotechnology, New York, Survey of the Biotechnology Industry, June 1991.

Table 3.12 shows that businesses that exhibit an agri-bio market orientation have the greatest reliance upon revenue, and the least reliance upon private equity, as sources of finance. The heaviest reliance upon public equity as a source of finance may be found with the therapeutics businesses. This may be partly explained by the fact that they also exhibit the highest proportion of expenditure devoted to research and development, as well as the highest annual rate of increase of total expenditure of all the market segments. Among all the market segments, they also devote the lowest proportion of their expenditure to the cost of product sales. The image this evokes is of cash-hungry firms pursuing long-term pay-offs (with a low capacity to earn revenue through sales in the short term) —the kind of situation that is typically associated with "high-technology" companies recently floated on the stock exchange.

As a final observation on the influence of market orientation on the finances of biotechnology businesses, it should be noted that there is an association between businesses that are located within the general health care area (therapeutics and diagnostics) and the propensity to emphasize research and development rather than production of products for sale. Whether this is a necessary arrangement for all firms that situate themselves within the health care market, or whether research-oriented biotechnology companies tend naturally to gravitate towards the health care arena for some other reason, remains to be seen.

Summary

This chapter has presented the basic facts on the scale, scope, and structure of New York's biotechnology industry. The profile this has produced may be used as a benchmark against which to monitor the future development of the industry. It also represents a systematic way of organizing information about commercial biotechnology which, if applied to the biotechnology industry in other regions, would make comparative interstate and international discussions about biotechnology competitiveness more meaningful. The balance of this report will be devoted to analysis of the competitive dynamics of New York's biotechnology industry. Such analysis needs to be grounded, however, in the kind of information assembled above.

In summary, this chapter has shown that the biotechnology industry in New York State is substantial, well established, and continuing to grow, as measured by the number of businesses, the number of people employed or the amount of revenue generated. The industry has emerged from a pool of talented people and institutions based in New York, rather than through attracting businesses from elsewhere. Most of the firms have engaged in or are about to engage in manufacturing, but the industry nevertheless remains very research-intensive and draws upon a highly qualified and skilled human resource base. It is growing gradually more global in scope but also appears to be rooted firmly in the local arena; in addition, while the region is home to a number of large biotechnology enterprises and to major enterprises in pharmaceuticals and other complementary industries,

most of New York's dedicated biotechnology businesses are quite small. In the main, the dedicated biotechnology businesses in New York are locally managed and controlled.

The industry is also quite heterogeneous. It clusters in a number of sub-regions throughout New York State, each of which has its own peculiar structure and character. There are also quite distinctive groupings of firms based upon scientific and technological specialization, and upon market orientation. There is no one monolithic "situation" for New York's biotechnology businesses. A series of specialized strategies tuned to the special character of each of the sub-groups within the industry is more likely to be fruitful than a standard set of solutions to perceived common problems.

Finally, the means by which the state's biotechnology businesses generate finance are quite varied and complex. The diversity of funding sources is particularly marked at the early entrepreneurial stages, with businesses drawing heavily upon a number of sources of finance not frequently discussed in the financial press, including personal funds and income generated through the sales of products and services. The dynamics of the industry, furthermore, appear less connected to the fashions and fortunes of the public stock market than is popularly thought. The information presented in this chapter covering the history, employment levels, regional variety, organizational structure, finance, personnel, market orientation, and technological complexity of commercial biotechnology in New York points to an industry which, besides now taking identifiable place in the economic landscape, is undergoing considerable development and change. It appears to be driven more by the resourcefulness and interests of the people forming the foundation of the industry than by the general conditions of the economic environment— and this is a theme to be examined in more detail in the following chapters.

Chapter Four

Regional Profile of the Industry

New York's Biotechnology Industry Regions

In Chapter Two it was explained that New York's biotechnology businesses fall into nine different geographical regions: New York City (NYC), Long Island (LI), Lower Hudson (LH), Upper Hudson (UH), Capital (CAP), Mid-West (MW), Buffalo (BUF), and Southern Tier (ST). These were defined precisely in Table 2.4, and basic data on the population of businesses, facilities, and employment in each region was set out in Table 3.2. The demographic and economic conditions of each of these regions vary a great deal, as do their human and institutional resources pertinent to biotechnology. The groups of dedicated biotechnology businesses that cluster in each of these nine biotechnology regions (sub-regions of New York State) also vary considerably in their character and structure. This chapter will take some of the information presented in Chapter Three and analyze its complexities between regions across the state.

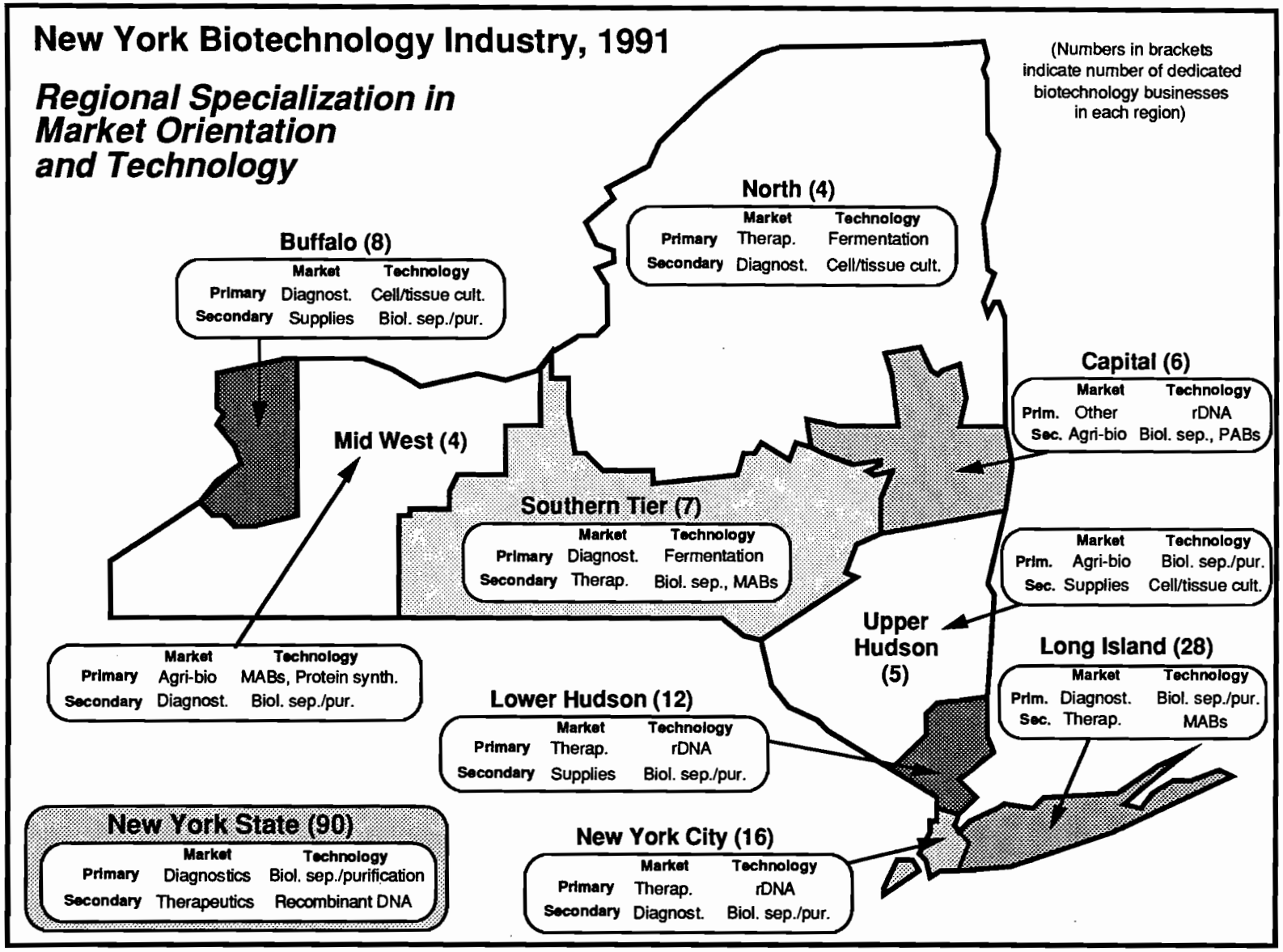
Figure 4.1 is a map of New York State showing the number of dedicated biotechnology businesses in each of the regions. It also summarizes the variations between regions in the primary and secondary market orientations, and primary and secondary technological specializations, of the businesses. The details of the classification schemes used for market and technology were set out in Tables 2.2 and 2.3. There is, as stated previously, a great deal of variety between the regions.

Economic Scale of the Biotechnology Industry Regions

Biotechnology organizations do not operate in a vacuum, and the scale and character of the surrounding economy provides part of the context in which the biotechnology industry clusters operate. Figure 4.2 plots the total numbers persons employed in all classes of industry (services, manufacturing, and all others except government) in each of the nine biotechnology industry regions (averages for 1990). New York City, with 45 percent of the total, is the clear leader in the absolute number of jobs, followed by Long Island, as a distant second, with 14 percent of all New York's non-government employment. The remaining seven regions each contain between 4 and 8 percent of the state total.

New York City accounts for just under 40 percent of the total resident human population of New York State, and Long Island (Nassau and Suffolk counties) accounts for about 15 percent of the population. Lower Hudson, the other main biotechnology region, contains about 7 percent of the human population and 6 percent of non-government employment. The population of the rest of New York State rose above that of New York City during the 1950s, the population of Long Island

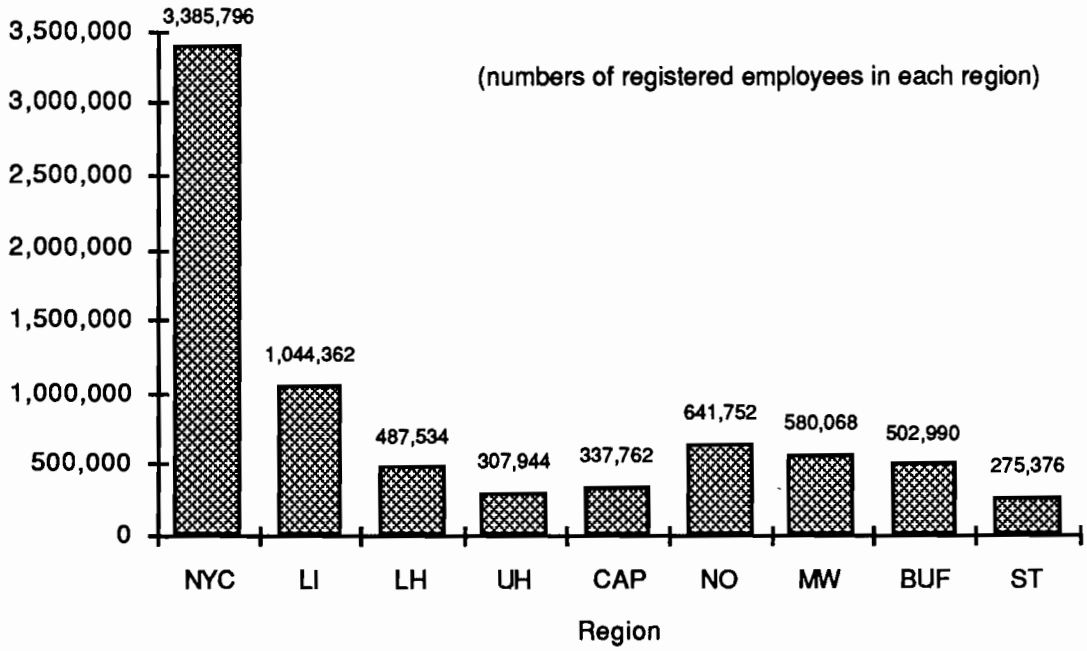
Figure 4.1



Source: Dr. K. W. Willoughby, Center for Biotechnology, June 1991.

Figure 4.2

Distribution of Non-government Employment, New York, 1990



surpassed that of Manhattan by 1960, and by the time of this study the population of Suffolk County alone was about equal to that of Manhattan. The primary source for the industry data cited here is the New York State Department of Labor (ES-202 series); the demographic data come from the *New York State Statistical Yearbook* (Rockefeller Institute of Government, State University of New York).

These economic and demographic data, while reflecting the place of New York City as the single largest region by far (ignoring land area), also point to the growing role which non-metropolitan New York has played in recent decades, and to the growing role of *suburban* population and employment in the economy of metropolitan New York. It would be surprising if these trends did not exert some influence on the geographical distribution of the biotechnology industry. This theme will be taken up later.

Figure 4.3 plots each region's share of both employment and businesses (i.e., employment units) of the total of all non-government industry. In both of the "suburban" biotechnology regions in metropolitan New York — Long Island and Lower Hudson— the share of the state total of businesses is greater than the share of the state total of employment. For New York City, and for virtually all of upstate New York, the opposite is the case. This means, roughly, that the suburban regions tend to emphasize small business, while the urban and upstate regions tend to emphasize big business. This does not mean that the same pattern would be likely to follow with biotechnology (in fact, as Table 2.4 shows, there is no obvious general principle to size distribution of biotechnology firms between regions); however, it does suggest that there is an impetus in suburban New York for the creation of new firms and this, in turn, may reinforce the suitability or convenience of these locations for entrepreneurship in biotechnology.

Emergence of Biotechnology Regions

In Chapter Two it was observed that there is an interesting mixture of both young and relatively mature biotechnology firms in New York. Table 4.1 summarizes the age structure of the industry in each region, revealing both inter-regional differences in the longevity of its businesses and inter-regional variations in the mix of mature and young businesses.

Figure 4.4 ranks the nine regions according to the mean age of its biotechnology businesses. There is no apparent link between the scale of the regional economy and the maturity of the local biotechnology industry.

Figure 4.5 compares the absolute scale of biotechnology employment between the regions. Within metropolitan New York there is a parallel between the amount of employment located within each local region and the corresponding level of global employment for which it is the home. Upstate, however, the parallel is not so close, particularly in the northwestern area where the intra-state employment is greatly surpassed by out-of-state employment.

Figure 4.3

All Industries (Excluding Government), New York, 1991

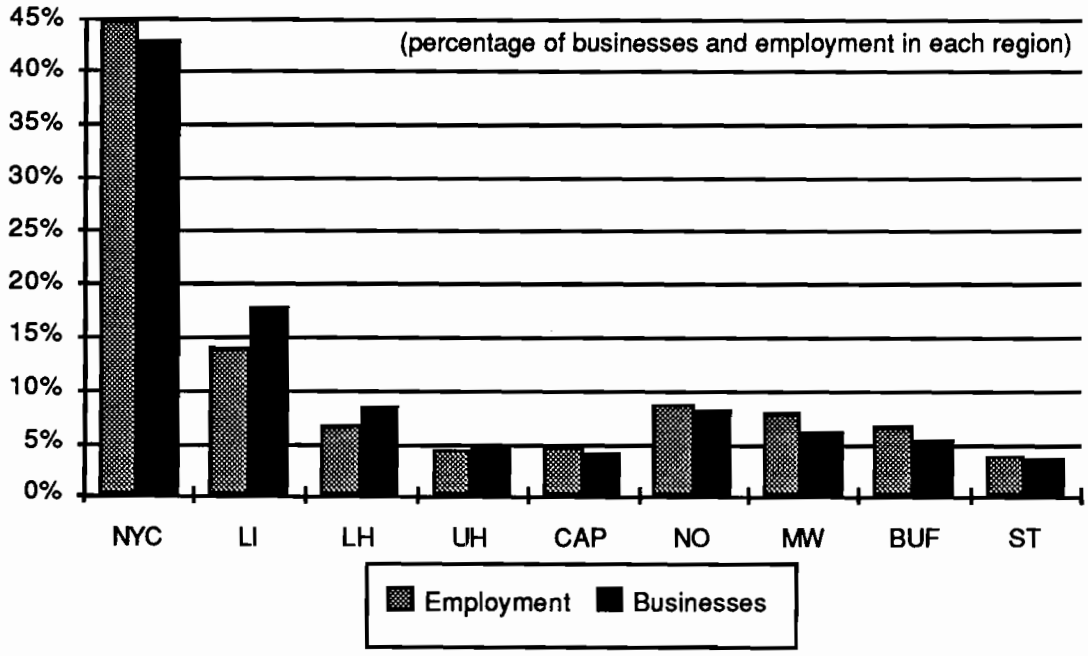


Table 4.1

Number of Years in Operation at Present Location by 1992 New York Biotechnology Businesses

Region	Mean	Std. Dev.	Minimum	Maximum
NYC	8.8	6.6	3	24
LI	7.9	7.4	1	35
LH	15.5	30.6	2	91
UH	21.4	16.3	3	40
CAP	5.0	4.1	2	11
NO	17.0	n.a.	17	17
MW	9.0	2.8	7	11
BUF	6.6	4.0	2	12
ST	7.8	2.9	3	11

Source: K. W. Willoughby, Center for Biotechnology, New York, 1991.

Figure 4.4

New York Regions Ranked According to Mean Age of Biotechnology Businesses by 1991

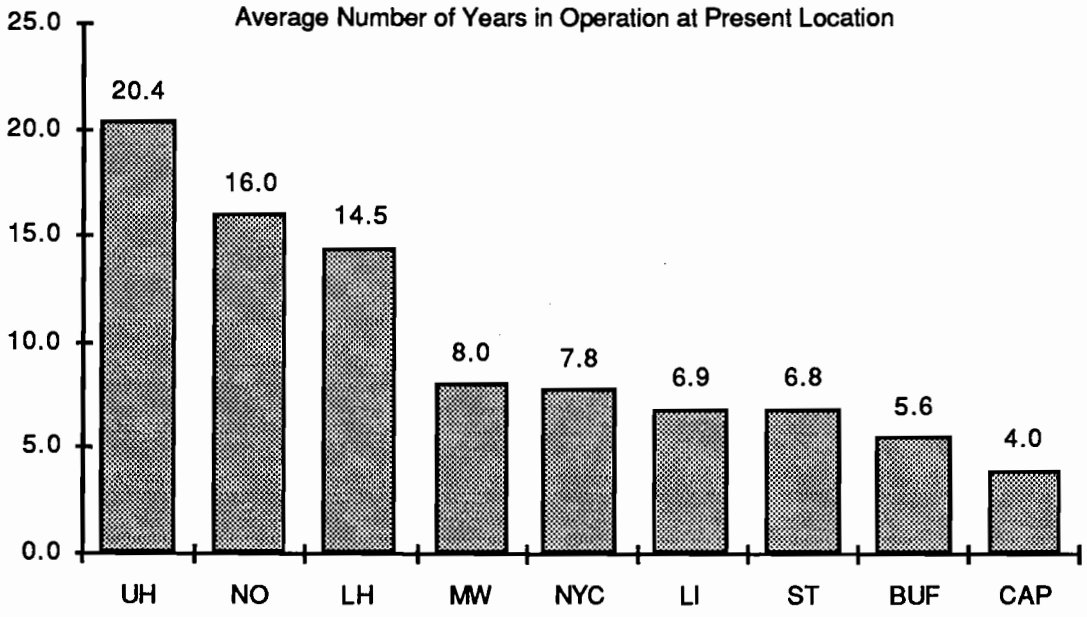


Figure 4.5

Employment In Biotechnology Businesses, New York, 1991

(estimated numbers of people employed in each region)

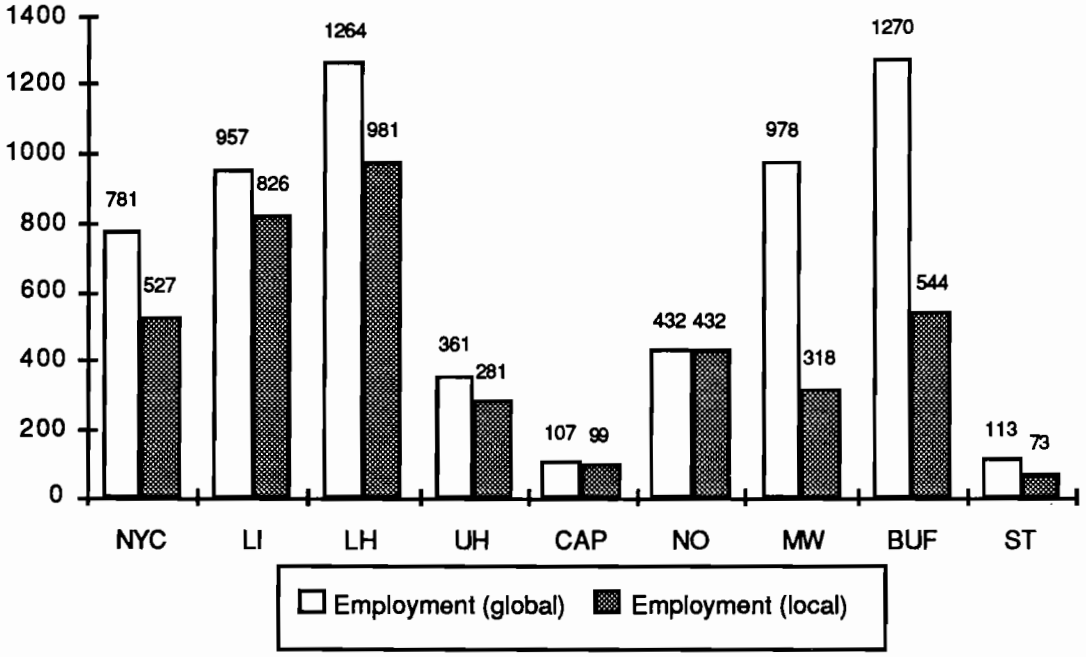


Figure 4.6 plots the regional share of biotechnology industry employment against the regional share of employment in all other industries. It shows clearly that the scale of the biotechnology industry is not a simple reflection of the scale of the local economy. New York City, with a dominant share of the total industrial employment, has only 13 percent of the state's biotechnology employment; while Lower Hudson's share of commercial biotechnology employment is over four times its share of total industrial employment. The conditions which biotechnology firms need in order to thrive do not appear to be identical to those which "business in general" requires. Biotechnology, as a field of technology, generates special locational requirements.

Regional Capacity to Generate New Industry

The biotechnology cluster in each region exhibits a distinctive profile in terms of its scale. While Lower Hudson is home to the largest number of biotechnology personnel, Long Island is home to more than double the number of biotechnology companies of Lower Hudson. Figure 4.7, which juxtaposes employment-share with the share of businesses in each region, creates a profile of the biotechnology industry in which Long Island stands out as the center for entrepreneurship, with its combined volume of biotechnology start-ups and the high ratio of firm-share to employment-share ("firm-share" here means percentage of the state's businesses, or firms, located in the region). The Capital region and Southern Tier also have high ratios of firm-share to employment-share, but the absolute scale of their contribution is small. New York City, while trailing behind Long Island by both measures, is also shown by Figure 4.7 to be a significant entrepreneurial region in biotechnology. A high ratio of firm-share to employment-share indicates that, for a given number of biotechnology personnel in a region, the propensity for that region to generate new firms is relatively high.

Although Figure 4.6 demonstrated that the local scale of a biotechnology industry is not determined simply by the scale of the surrounding economy (i.e., just because a city is large, it doesn't follow that the scale of its commercial biotechnology activity will necessarily also be large), it did not demonstrate that it plays no role at all. Just because Long Island, Lower Hudson, and New York City have the most substantial populations of biotechnology jobs and firms, it does not follow that they are necessarily the most successful regions at generating biotechnology activity, given the relativities of their respective economies. We need a measure that will help us to compare the productivity of local regions at generating commercial biotechnology activity on a "level playing field." Figure 4.7 compares absolute employment and firm levels between the regions.

Figure 4.8 complements Figure 4.7 by presenting two measures of the *density* of the biotechnology industry in each region. They compare the regions from the point of view of their relative capacity to *generate local industries*. The *employment density index* (EDI) for biotechnology expresses the level of industrial biotechnology employment in a region against total state industrial biotechnology employment, total industrial employment for that region, and total industrial employ

Figure 4.6

Regional Distribution of Employment, New York, 1991

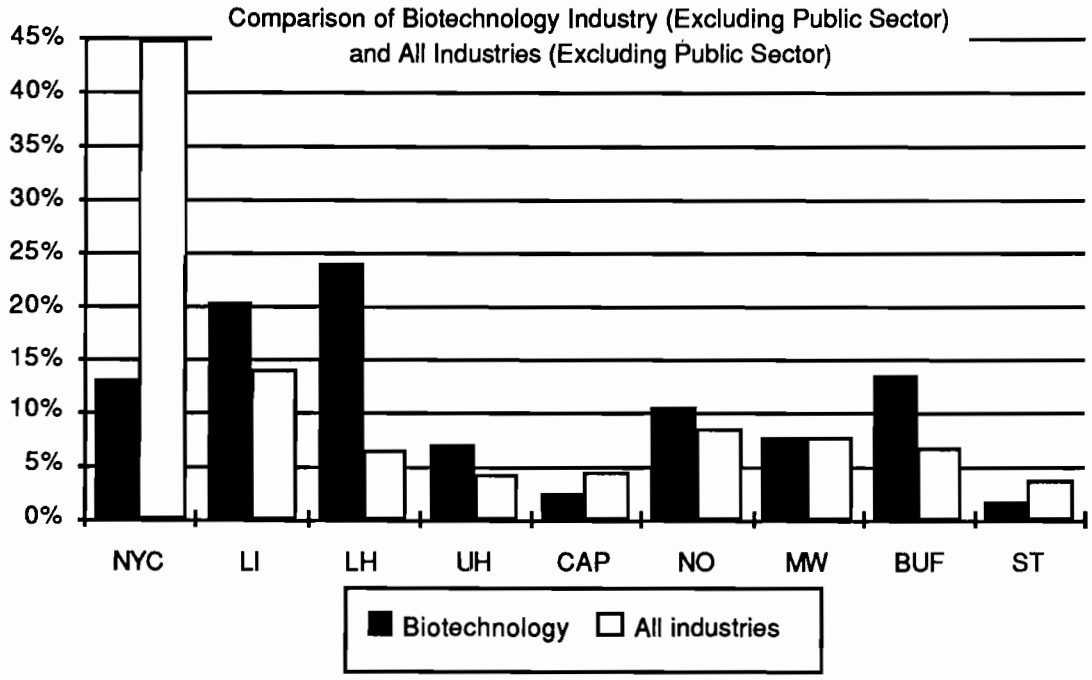


Figure 4.7

Regional Share of Biotechnology Industry, New York, 1991

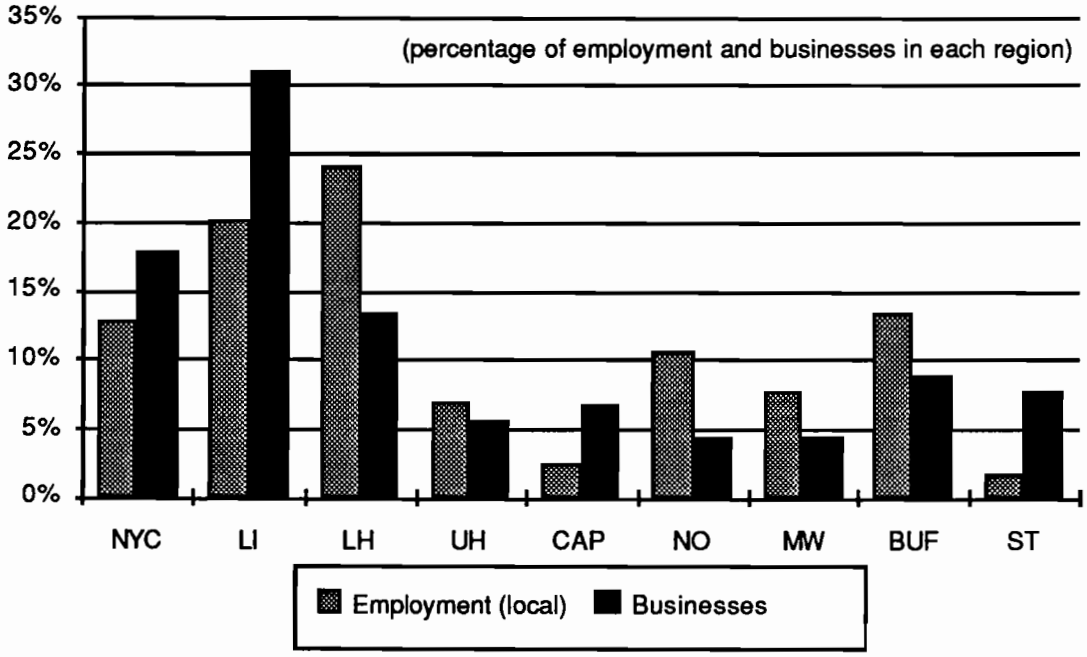
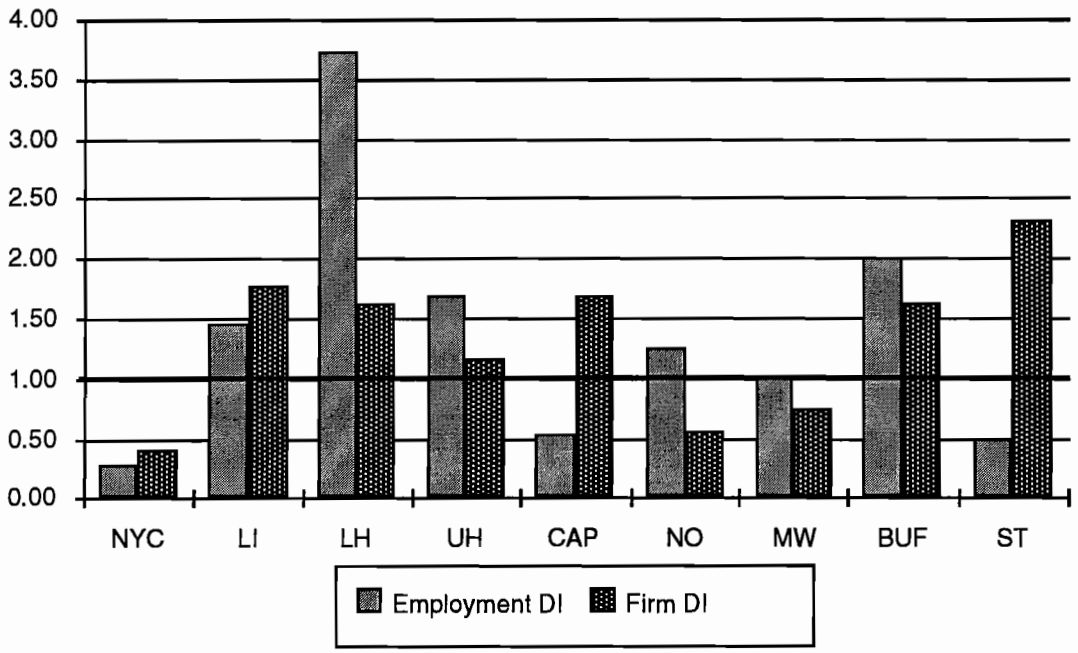


Figure 4.8

Biotechnology Industry Density Indices, New York, 1991



ment for the whole state. The *firm density index* (FDI) expresses the population of biotechnology businesses (firms) in a region against the total population of biotechnology businesses (firms) for the whole state, the total population of all businesses (firms) for that region, and the total population of all businesses (firms) for the whole state. The exact formulae for these two industry density indices are documented in Appendix 4.1.

The employment density indices and the firm density indices in Figure 4.8 are designed so they always compute to "1.0" for the reference region (New York State, in this case). A region with a biotechnology industry density index of less than 1.0 would be considered less productive than normal in generating activity in industrial biotechnology (i.e., it would be considered less competitive); whereas a region with a score of above 1.0 would be considered to have above-average productivity in generating a local presence in the biotechnology industry (i.e., it would be competitive).

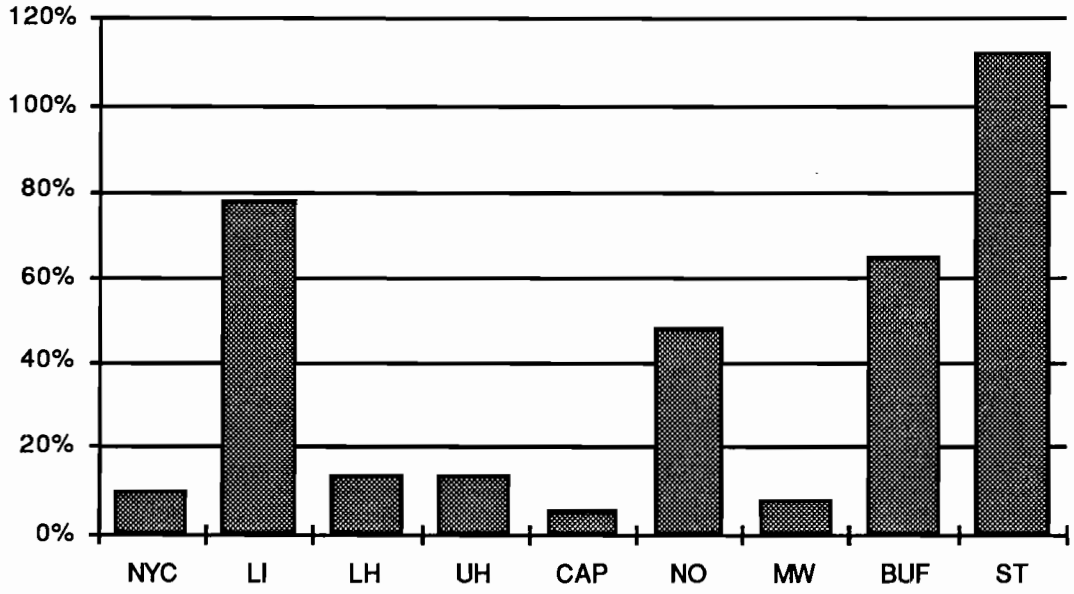
As would be expected, the marked contrast between the performance of the regions in metropolitan New York and upstate is dissipated in Figure 4.8 (by definition). Long Island, Lower Hudson, Upper Hudson, and Buffalo are the only regions which measure up as competitive by both of the two indices. Southern Tier — the smallest of the industry clusters in absolute terms— turns out to be the most productive in generating biotechnology businesses against the backdrop of its total economy (although this does not annul the importance of absolute scale). Lower Hudson, which is the leading region from the point of view of the number of biotechnology jobs, also has the most prominent employment density index (it significantly outranks Long Island on this count because of the relatively smaller size of the economy in Lower Hudson). Finally, New York City, which is second only to Long Island in the *number* of biotechnology businesses it has generated, turns out to be very weak in the *density* of its biotechnology industry by both measures.

These industry density measures are most useful when complemented with other industry data, but they do help to make meaningful economic comparisons between dissimilar local economies. Some useful data to complement Figure 4.8 may be found in Figure 4.9, which illustrates variations in the annual rate of employment growth between each of the nine biotechnology industry regions.

The most significant region here appears to be Long Island. When the existing scale of local employment is taken into account, the relatively high growth rate exhibited by Long Island means that it will probably increase its absolute importance as a biotechnology employment region quite considerably in the future. The Buffalo region, which presently has almost two-thirds the number of biotechnology jobs as Long Island, also has a rapid growth rate and may become an increasingly important player in the field as the industry matures. The high employment density index exhibited by Southern Tier in Figure 4.8 is reinforced by the high employment growth rate it exhibits in Figure 4.9. Despite the variations between them, it is encouraging to notice that all nine regions experienced a positive growth in biotechnology employment from 1990 to 1991.

Figure 4.9

Regional Variations in Rate of Annual Employment Growth by Biotechnology Businesses in New York



Future Plans for the Regions

The vast majority of the dedicated biotechnology businesses in New York (84 percent) expect to either commence or continue manufacturing during the next five years. Figure 4.10 shows that, overall, this propensity appears to be greatest upstate and in the least quantitatively significant regions (from the point of view of the relative scales of the local industries). Firms in metropolitan New York, it appears, probably have plans to place more emphasis on research and development, contract research, and intellectual property revenue than is the case upstate; it may also be that the metropolitan firms are placing their sights on more long-term, high-risk payoffs.

Figure 4.11 qualifies the data from Figure 4.10 by indicating the proportion of businesses in each region which intend to locate a significant amount of their manufacturing activities in New York. Statewide, almost one half intend to do so. The upstate firms appear to be more enamored with New York as a place for biotechnology manufacturing activities than are the metropolitan firms. New York City firms appear to be the most reluctant to locate manufacturing in New York, although this is no reflection on their general intention to engage in manufacturing (over four-fifths either have already commenced manufacturing or intend to do so).

The proportion of dedicated biotechnology businesses on Long Island which plan to locate their manufacturing operations within New York (57 percent) is above the state average (48 percent). When this information is combined together with the data on employment growth trends from Figure 4.9, the relative contribution flowing to the local economy from biotechnology multiplier effects in Long Island may be more significant than those in Lower Hudson, despite Lower Hudson having a higher biotechnology employment density index. Less than one-third of the biotechnology businesses in Lower Hudson intend to locate their manufacturing operations in New York.

Regional Variations in the Character and Structure of the Industry

Figure 4.12 sets out the percentage of biotechnology businesses in each region that have more than one facility. The lowest level of dispersion between facilities is found in Buffalo, followed by Long Island and Capital. Given the high numbers of biotechnology businesses in Long Island, and the low proportion of businesses with multiple facilities, the region should probably be thought of as highly "localized" in its structure.

Figure 4.13 takes some of the key information on corporate structure presented in Table 3.5 and shows how it varies from region to region. The detailed definitions for the terms used are found in Chapter Two. The first interesting observation that may be drawn from the chart is that the public companies tend congregate around metropolitan New York, with a presence also in Buffalo, but with the highest concentration in New York City itself. In Chapter Three it was noted that there is a tendency in firms to simultaneously place emphasis on the therapeutics market orientation, a strong bias towards research rather than manufacturing, and a tendency to rely more heavily than usual

Figure 4.10

Percentage of NY Biotechnology Businesses Expecting to Commence or Continue Manufacturing During the Next Five Years

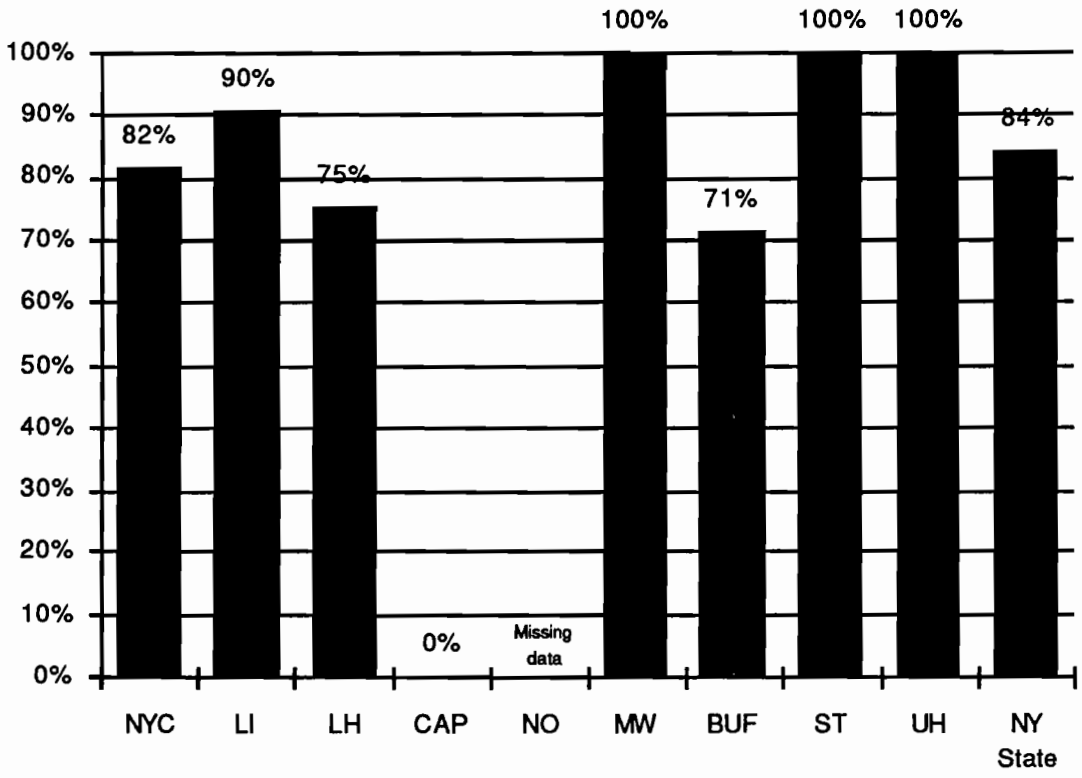


Figure 4.11

Percentage of NY Biotechnology Businesses Intending to Locate their Manufacturing Activities in New York

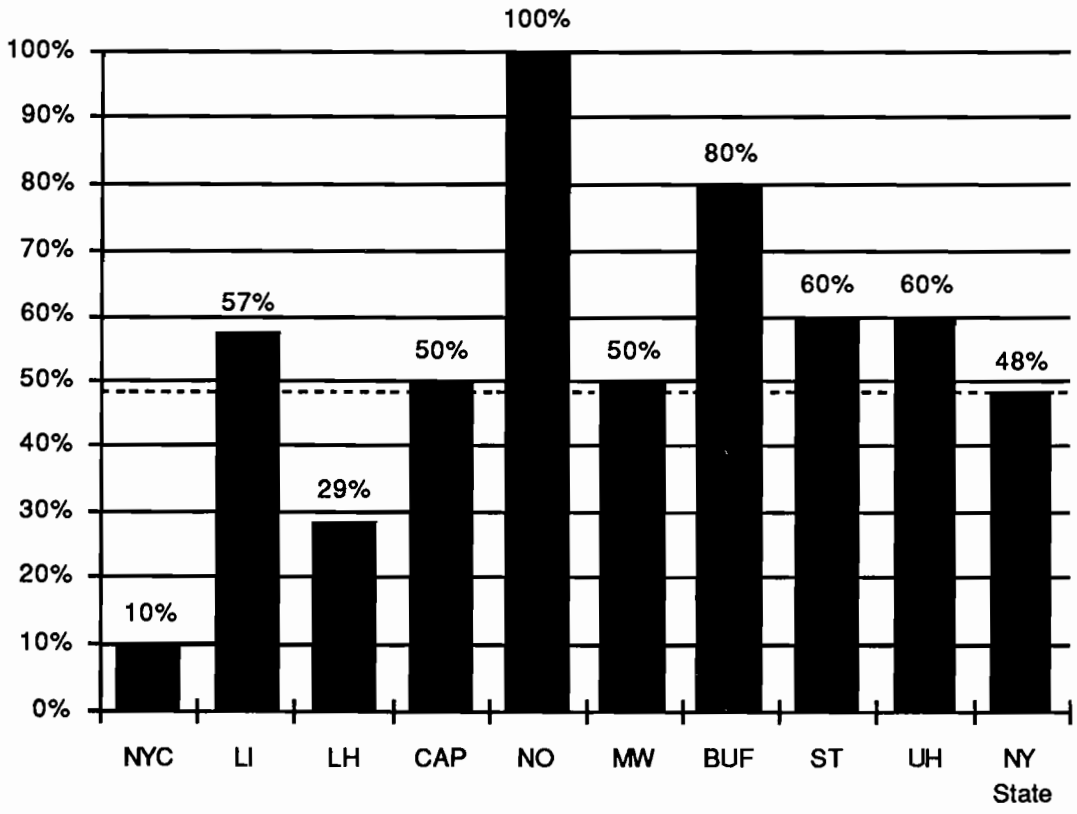


Figure 4.12

Percentage of New York Biotechnology Businesses which have More Than One Facility

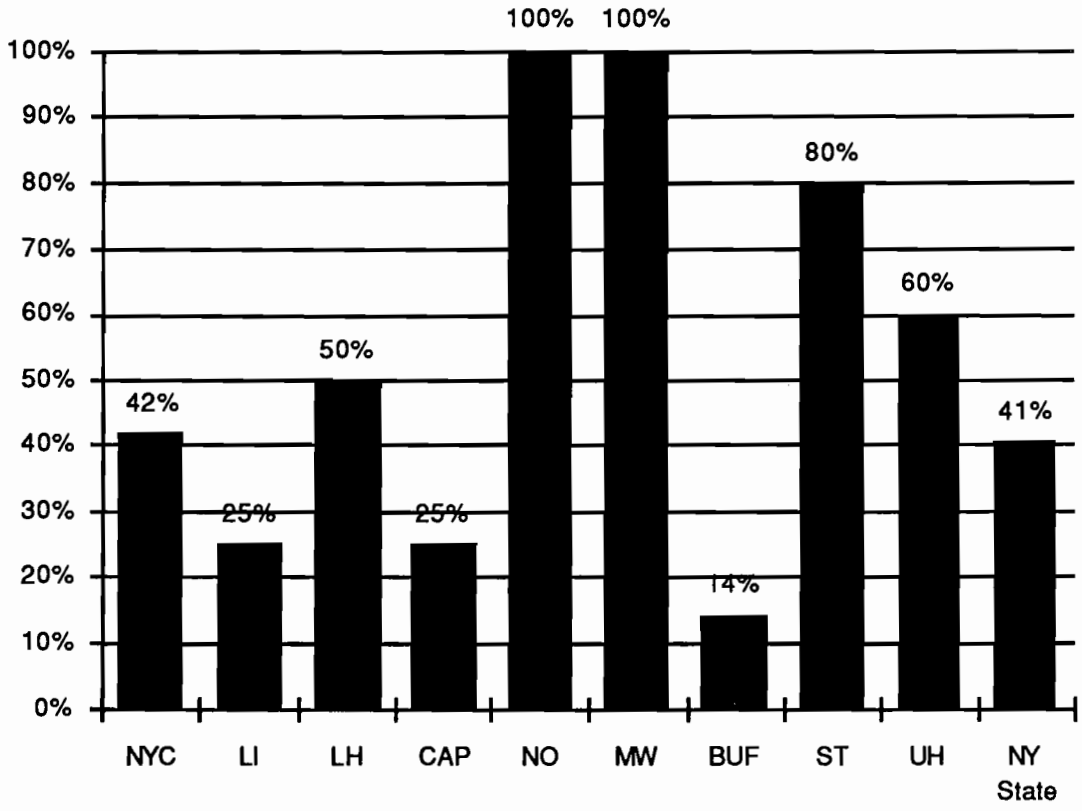
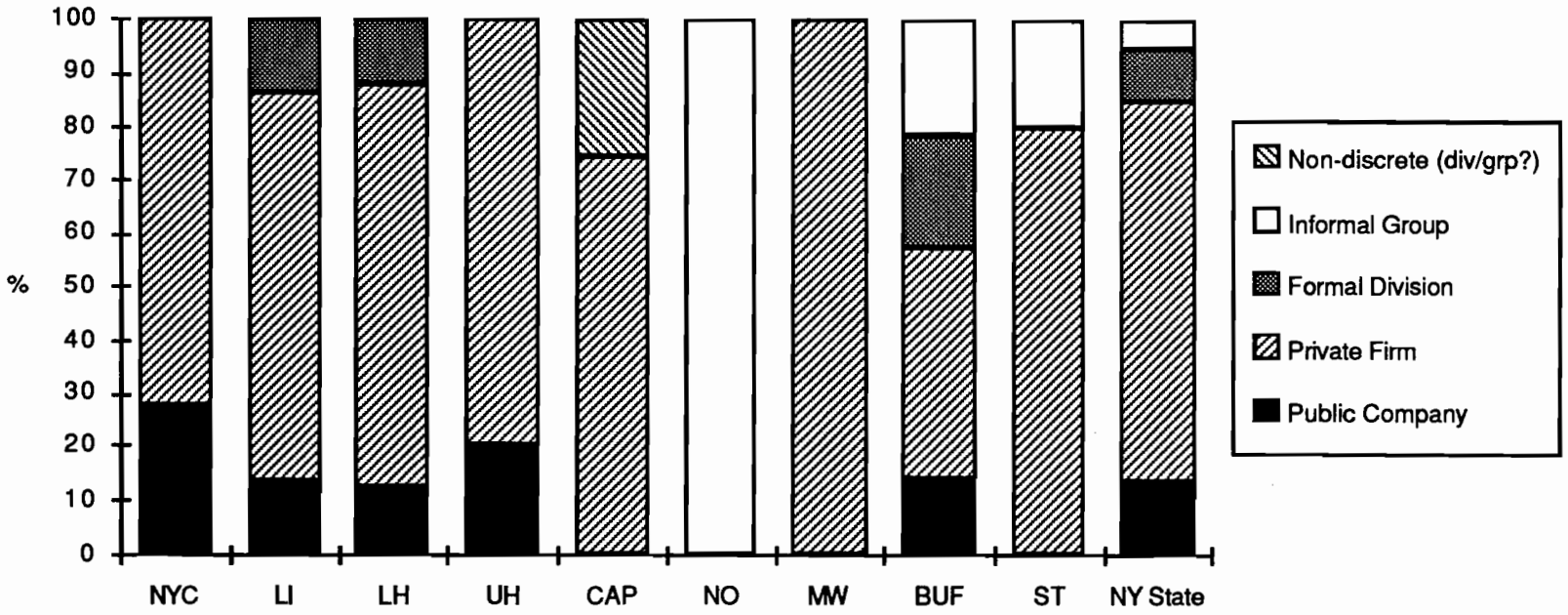


Figure 4.13

Corporate Structure of Regional Biotechnology Industry Clusters, New York, 1991



Percentage of dedicated biotechnology businesses with each type of corporate status

on public equity as a source of finance. Figure 4.13 adds a fourth factor to the list— location in a major metropolitan region. It appears that cities provide the kind of environment needed by that particular kind of biotechnology business in order to thrive. Hence, while the scale of a city itself might not be much of a determinant of the scale of the local biotechnology industry, the city environment itself may create some resources or a milieu greatly assisting *certain kinds* of biotechnology ventures. This theme will be explored further in later chapters.

Figure 4.13 also shows that the non-discrete category of biotechnology businesses (i.e., the branch facility or group) tends to predominate, as a proportion of local businesses, upstate rather than in the metropolitan area, although there is some presence in Long Island and Lower Hudson of formal biotechnology divisions of other organizations.

Table 4.2 outlines the basic financial structure of the biotechnology industry in each of the nine regions. It shows, first of all, that the heaviest reliance upon public equity as a source of capital lies with the businesses in Lower Hudson, followed by Buffalo and New York City. Long Island businesses, on average, raise only one percent of their finance from this source. They also rely quite heavily on revenue and the principals' personal funds as sources of finance. The proportion of funds that Long Island businesses dispense on the cost of product sales is higher than is the case for the other two metropolitan biotechnology regions, yet the proportion devoted to research and development is still quite high (higher than average).

Interestingly, even though Lower Hudson businesses are the most dependent upon public equity, they spend proportionally less than New York City and Long Island businesses on research and development (and less than average for New York State as a whole); this appears to be explained by the unusually high amount spent on the purchase of licenses and technology rights. In other words, biotechnology businesses in Lower Hudson allocate an unusually large of amount of their resources to technology transfer activities, bringing in technology from outside the region. New York City and Long Island businesses, on the other hand, appear to be more self-reliant in the development of technology.

An interesting picture of the Long Island biotechnology industry emerges from the above observations, in keeping with earlier observations of it being a particularly entrepreneurial region. Long Island businesses appear to pursue simultaneously both a research-intensive emphasis and a manufacturing-intensive emphasis. While this may seem somewhat counter-intuitive at first, it may well be a distinctive strategy for entrepreneurial, small-scale, science-based firms. There is some evidence here of a parallel with biotechnology firms in the East Bay area of the San Francisco region and San Diego in California (Willoughby and Blakely, 1990).

Finally, to further emphasize the regional variety of the character of New York's biotechnology industry, Table 4.3 sets out for each of the regions the primary technological specialization, secondary technological specialization, primary market orientation, and secondary market orientation of each

Table 4.2

Variations in Finances of Local Biotechnology Industry Clusters, New York, 1991

Biotechnology Industry Region	New York City NYC	Long Island LI	Lower Hudson LH	Upper Hudson UH	Capital CAP	North NO	Mid West MW	Buffalo BUF	South -ern Tier ST	New York State **NY**
Sources of finance										
Revenue	32%	49%	20%	80%	33%	0%	80%	44%	53%	**44%**
Public equity	13%	1%	22%	12%	8%	0%	0%	14%	0%	**8%**
Private equity	35%	23%	31%	2%	25%	0%	0%	16%	17%	**22%**
Private debt	0%	2%	7%	4%	0%	0%	20%	1%	10%	**4%**
Principals' personal funds	17%	19%	14%	2%	16%	0%	0%	9%	0%	**13%**
Grants	1%	5%	7%	0%	10%	0%	0%	16%	19%	**7%**
Government loans	2%	0%	0%	0%	8%	0%	0%	0%	0%	**1%**
Other	0%	0%	0%	0%	0%	100%	0%	0%	0%	**2%**
Distribution of expenditure										
Research & development	43%	40%	36%	19%	29%	65%	25%	38%	42%	**37%**
Cost of product sales	16%	27%	15%	37%	38%	25%	54%	38%	23%	**27%**
General, administrative & marketing	37%	28%	34%	37%	32%	8%	21%	20%	31%	**30%**
Purchase of equity in companies	1%	0%	0%	0%	0%	0%	1%	0%	0%	**0%**
Purchase of licenses & technology rights	3%	3%	15%	1%	0%	0%	1%	1%	4%	**4%**
Other	0%	1%	1%	5%	2%	2%	0%	2%	0%	**1%**
Annual rate of revenue growth	143%	21%	75%	31%	277%	15%	16%	20%	31%	**70%**
Annual rate of expenditure growth	50%	49%	19%	20%	7%	20%	3%	6%	22%	**33%**

Source: K. W. Willoughby, Center for Biotechnology, New York, Survey of the Biotechnology Industry, June 1991.

Table 4.3

Technological and Market Specializations of Dedicated Biotechnology Businesses New York Regions, June 1991

Region	Primary Technology	Secondary Technology	Primary Market	Secondary Market
NYC	Recombinant DNA	Biological sep./pur.	Therapeutics	Diagnostics
LI	Biological sep./pur.	MABs	Diagnostics	Therapeutics
LH	Recombinant DNA	Biological sep./pur.	Therapeutics	Supplies
UH	Biological sep./pur.	Cell/tissue culture	Agri-bio	Supplies
CAP	Recombinant DNA	Biological sep./pur., PABs	Other	Agri-bio
NO	Fermentation	Cell/tissue culture	Therapeutics	Diagnostics
MW	MABs, Protein synthesis	Cell/tissue culture, Fermentation	Agri-bio	Diagnostics
BUF	Cell/tissue culture	Biological sep./pur.	Diagnostics	Supplies
ST	Fermentation	Biological sep./pur., MABs	Diagnostics	Therapeutics
NY State	Biological sep./pur.	Recombinant DNA	Diagnostics	Therapeutics

of the local biotechnology industry clusters. Incorporating this with evidence from Chapter Three, it would appear that there is a link between some of the regional differences in financial and corporate structure, the regional biotechnology industry "density" just documented, and the technological and market variations between regions.

Having now constructed a basic profile of New York's biotechnology industry in the previous chapter, and extended it in this chapter to reveal the importance of the regional biotechnology clusters over and above the industry as a whole, the balance of the report will address the challenges of building up New York's biotechnology competitiveness *vis-à-vis* the biotechnology industry elsewhere in the United States and internationally.

Chapter Five

Competitiveness Within the United States

In Part Two of this study (Chapters Three and Four), a profile of the biotechnology industry in New York was constructed. In Part Three (Chapters Five, Six, and Seven) the performance of New York as a region for biotechnology will be compared with that of other regions within the country, particularly California and Massachusetts, New York's main rivals.

Comparative Scale of Commercial Biotechnology in New York and Elsewhere

Table 2.1 in Chapter Two presented data derived from the Biotechnology Companies database of the North Carolina Biotechnology Center on commercial biotechnology in New York, California, and the United States as a whole. If we ignore the data on extraneous companies, which are not *bona fide* biotechnology businesses, we learn the following from Table 2.1 about the relative scale of New York's biotechnology industry by mid-1990.

New York was suggested by the North Carolina database to be home to 4 percent of the nation's biotechnology firms (while California was home to 24 percent), to 1 percent of the nation's biotechnology employment (while California was home to 25 percent), and to a minuscule share (significantly less than 1 percent) of the national revenue of biotechnology firms (while California was responsible for 14 percent of the total). The database put the average size of New York's firms at 28 percent of the national average, and the average revenue-per-firm at 6 percent of the national average (while California managed 107 percent of the national average firm-size, and 59 percent of the national average revenue-per-firm). As will be demonstrated shortly, the North Carolina database significantly understates the contribution to the national industry by New York; but it nevertheless does reflect the general order of magnitude of New York's position. While New York has over half the human population of California, its relative contribution to the national biotechnology industry is noticeably less than half of California's.

The absolute disparity between New York and California appears to have widened over the last two decades. At the beginning of the 1970s, California probably had only about three more biotechnology firms than New York, whereas by 1987 it had about 91 more (Hall, et al., 1988). By mid-1990, according to the North Carolina database (see Table 2.1), New York trailed California by 117 firms.

These figures, while conservative in their depiction of New York, suggest that the scale of the state's commercial biotechnology sector is smaller than one would expect, were all other things to be equal, and given its leadership in basic biomedical research during the last several decades.

Historical Pattern in Biotechnology Start-Ups

To explore further the suggestions raised by the North Carolina data, Figure 5.1 was constructed, based upon data from this survey of the New York biotechnology businesses and data from Ernst & Young (Burrill & Lee, 1990: 92) for the national population of firms. Figure 5.1 takes the 1990 population of New York's biotechnology businesses and plots the number of businesses each year in this group over two decades to 1990 as a percentage of the number which were in existence prior to the 1970s. The equivalent figures for the national population of biotechnology businesses are plotted on the same graph.

The graph confirms the impression gained from other data that New York is generating new biotechnology businesses at a slower rate than the national average. The influence of the California population on the national data, however, should not be underestimated (Willoughby and Blakely, 1989). The general shape of the two curves is similar, except that there is an interesting decline in the annual start-up rate in New York for the two years *prior* to the 1987 stock market crash, with a recovery *immediately after* the crash.

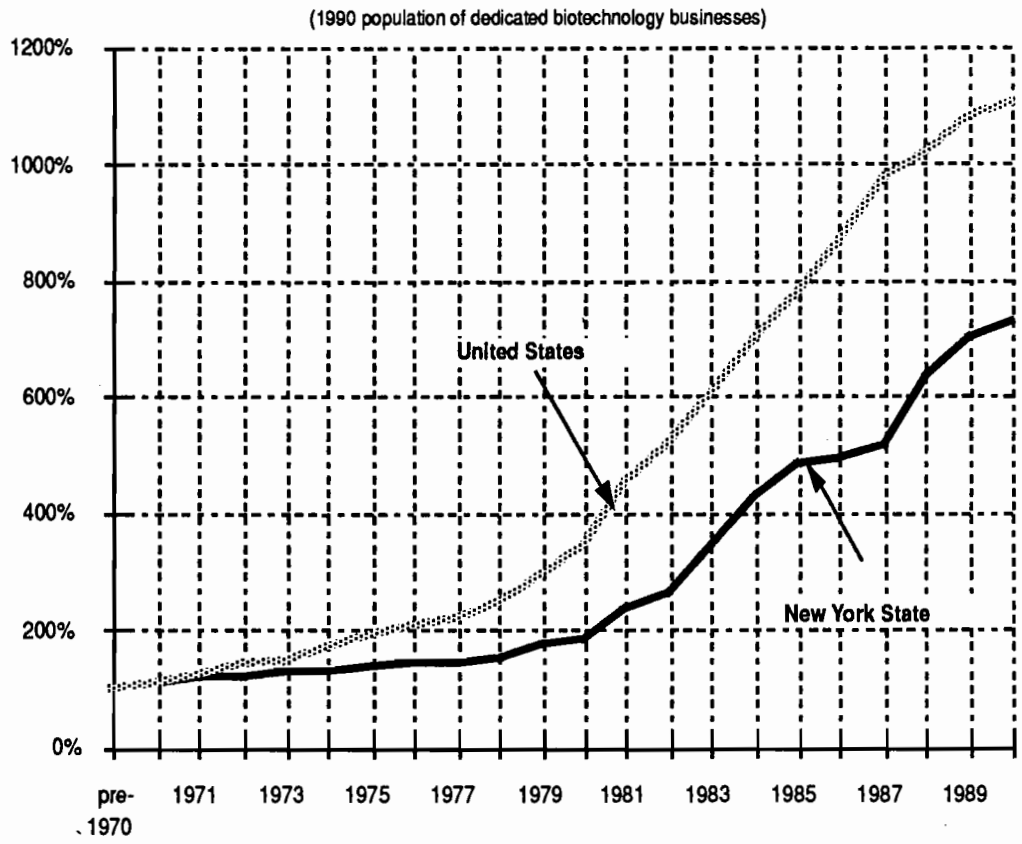
Figure 5.2 is composed of the same data used to construct Figure 5.1, except that it plots each population of businesses as a cumulative percentage of its respective 1990 level. Once again, the general shape of the two curves is similar. Both show an upturn in start-up rates during the late 1970s. An interesting difference, however, is that prior to 1977 New York's cumulative percentage was slightly greater than the national average, but since that date it has been slightly lower. It was in the decade between 1977 and the stock market crash that the "take-off" happened in commercial biotechnology, and it was during this period that New York lost its lead in annual start-up rates. This suggests that California probably gained some kind of first-mover advantage in the new breed of entrepreneurial biotechnology start-ups (e.g., Cetus and Genentech), and that New York hasn't yet been able to catch up with the nation as a whole (heavily influenced by California) in the entrepreneurial dimensions of biotechnology. A caveat must be placed over these surmises, however, that despite the changeover that took place in the late 1970s, the differences over the last two decades in start-up rates between New York and the United States as a whole are not very large, although the cumulative effects of the differences over time are noticeable.

Comparative Productivity in Generating Commercial Biotechnology Activity

Most compendia and directories of the biotechnology industry in the United States place California, in general, and the San Francisco Bay Area, in particular, as the leading biotechnology region. New York, as part of the New York/New Jersey/Connecticut tri-state area, generally ranks second, followed by the Boston area. If New York is separated out from New Jersey and Connecticut, however, it generally ranks behind Boston. Table 5.1 compares New York with California, Massachu-

Figure 5-1

Biotechnology Startups: Percentage of pre-1970 Total



Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), 1991; © K.W. Willoughby 1991.

Figure 5-2

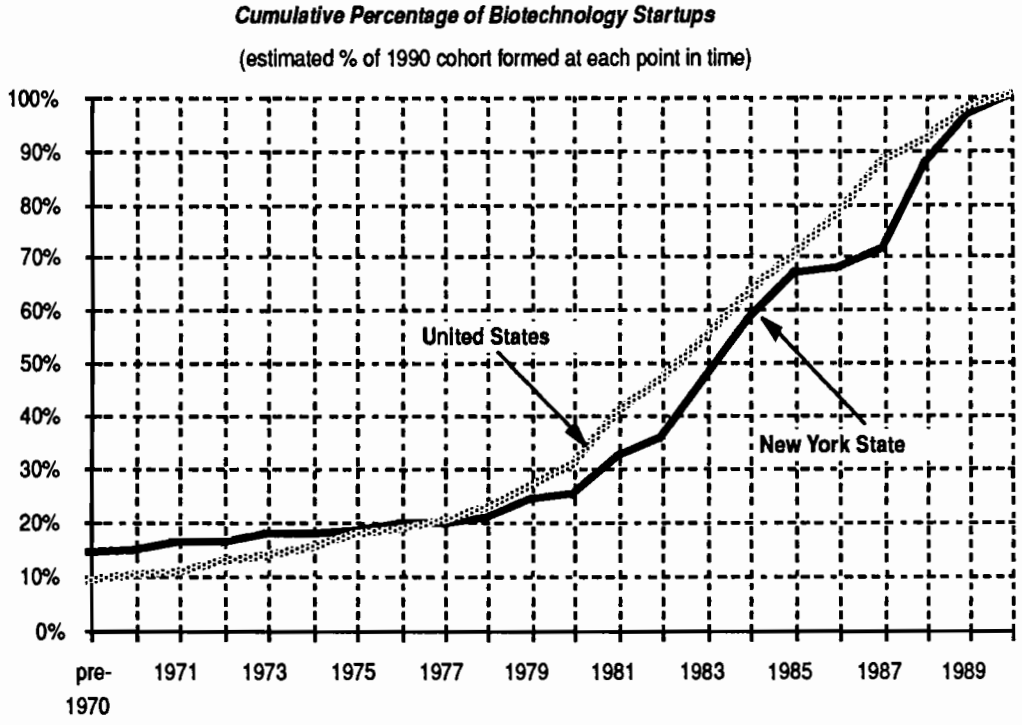

Cumulative Percentage of Biotechnology Startups
(estimated % of 1990 cohort formed at each point in time)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
United States
New York State
pre-1970
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989

Table 5.1

Commercial Biotechnology Industry, 1990
Comparison of New York with Other US States

State	New York	Massachusetts	California	USA
Number of biotechnology businesses	90	116	304	1,147
Number of biotechnology employees	6,263	13,600	17,887	61,449
Mean size (employees/biotech business)	70	117	59	54
Total non-govt. employment (all industries)	6,737,000	2,584,000	10,802,000	92,030,000
% of US non-government employment	7%	3%	12%	100%
% of US biotechnology employment	10%	22%	29%	100%
% of US biotechnology businesses	8%	10%	27%	100%
Biotech Employment Density Index	***1.39***	***7.88***	***2.48***	***1.00***

Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), drawing upon data from US Department of Labor, Genetic Engineering News, Ernst & Young, Massachusetts Biotechnology Council, North Carolina Biotechnology Center, U.C Berkeley Biotechnology Industry Research Group, Bioscan. NY biotech figures are from 1991 data.

setts, and the whole of the United States, on a number of key measures that reflect the relative scales of their respective biotechnology industries.

The data used to construct Table 5.1 were drawn from a range of the best current sources of information on biotechnology in each of the regions: Genetic Engineering News, Ernst & Young, the Massachusetts Biotechnology Council, the North Carolina Biotechnology Center, the Biotechnology Industry Research Group at the University of California at Berkeley, BioScan, and the present study of the Center for Biotechnology in New York. The data on total industrial employment was obtained from the United States Department of Labor (Bureau of Labor Statistics, 1991) and represent averages for 1990. The data for the New York biotechnology industry represent the population of mid-1991, while the data for Massachusetts represents the population of late 1990, and the data for California represent the population for mid-1990. The figures from each data source were studied and cross-checked for consistency. The final figures in Table 5.1 are best estimates produced by the author of this study, drawing upon all of the above sources.

Table 5.1 puts the number of biotechnology businesses in California at almost three-and-a-half times the number in New York, and the number in Massachusetts at just over one-and-a-quarter the number in New York. Because the mean size of New York's businesses is greater than that of California's, the latter's commercial biotechnology employment level is less than three times that of New York's. Massachusetts, however, with just over half the human population of New York, has over twice the biotechnology employment, and its mean firm size is one-and-two-thirds the size of New York's and almost twice that of California. This is even more remarkable in view of the fact that the size of the private sector economy in Massachusetts is less than two-fifths that of New York (as measured by employment levels, Table 5.1). In addition, Massachusetts has over three-quarters the number of biotechnology jobs as California, with a private sector economy less than one-quarter the size of its West Coast competitor. By these figures Massachusetts appears to be very competitive in biotechnology, even if it is out-ranked by California in absolute terms.

To make a more informed judgement about the relative competitiveness of the three states in their capacity to generate commercial biotechnology activity, it is necessary to employ a measure that standardizes each state's biotechnology industry to take into account the differences between the scale of its economy and that of its competitors. That is, we are interested in the *density* of biotechnology employment, not just the absolute level. The *employment density index* (EDI) for biotechnology, as explained in Chapter Four and defined in Appendix 4.1, provides just such a measure. It expresses the level of industrial biotechnology employment in a particular region against total industrial biotechnology employment in a wider reference region, total industrial employment for the particular local region, and total industrial employment for the whole reference region. Whereas in Chapter Four the reference region was New York State, in this exercise it becomes the whole of the United States; furthermore, whereas each local biotechnology region

(e.g., Long Island or Buffalo) was the local region in Chapter Four, each of the three states in question become the "local" regions here.

The employment density index, as explained in the previous chapter, always computes to "1.0" for the reference region (United States, in this case). The biotechnology industry EDIs for New York, Massachusetts, and California are set out in Table 5.1 and also expressed graphically in Figure 5.3. They reveal, first of all, that *all three* states score above 1.0 and are therefore competitive. That is, each state has above-average productivity in generating commercial biotechnology employment, compared with the United States as a whole.

From the point of view of national biotechnology competitiveness, New York is doing well. Even after taking into account the relative sizes of their respective economies, however, New York trails behind both of its main competitor states. The productivity in generating biotechnology jobs achieved by Massachusetts is so unusually large (EDI = 7.88), furthermore, that New York's overall competitiveness should not be taken for granted. Massachusetts is doing something right to nurture biotechnology, and its proportional success is so remarkable that its lead from the point of view of industry density (or productivity) may translate into an absolute competitive advantage.

Comparing each of the states' biotechnology industries using a density index, rather than absolute figures or simple percentages, does reduce the apparent gap between California and New York. While California's biotechnology employment is 285 percent greater than New York's, its EDI is only 178 percent greater; but this is still no cause for complacency.

We may summarize New York's competitive position in commercial biotechnology within the United States with a double-sided statement: the industry should take comfort from the fact that it is out-performing most other states in the country, even discounting variations in the size of the economies of all the other states, but this national competitiveness is fragile, and may be eroded by the outstanding productivity of Massachusetts and California in generating industrial biotechnology activity.

Given this situation of what might be called "ambiguous competitiveness" for New York, it would be valuable to look more deeply into the differences between the performance and structure of the biotechnology industry in each of the three states. We will now do this by comparing key financial indicators.

Financial Comparisons of the Main Competitors

Using the financial data from Tables 3.9 and 3.10 for New York and the United States as a whole, supplemented by equivalent data provided by Ernst & Young for Massachusetts and California, a range of standard financial indicators was calculated (in composite form) for the biotechnology industries in each of the geographical areas included in Table 5.2.

Table 5.2

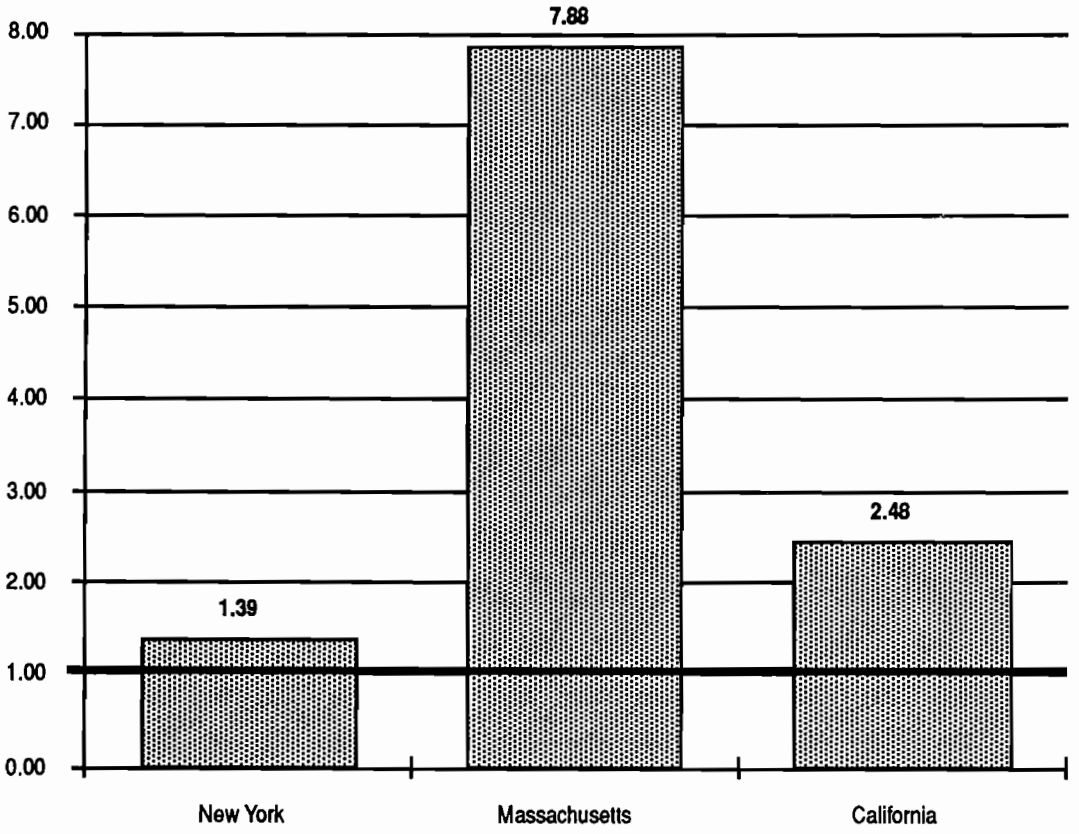
Financial Performance of Biotechnology Businesses, 1990
Comparison of Composite Figures for New York and Other US States

Financial Indicator	**New York**	Massa-chusetts	Southern California	Northern California	*United States*
Total revenues ($000)	**$6,417**	$10,815	$7,704	$42,789	*$13,848*
Net income (loss) ($000)	**($2,993)**	($4,232)	($2,541)	($1,341)	*($2,421)*
% businesses profitable	**13%**	21%	19%	27%	*21%*
Total sales per employee ($000)	**$75**	$80	$75	$122	*$98*
Revenues per employee ($000)	**$83**	$93	$84	$134	*$108*
R&D expenditure per employee ($000)	**$35**	$65	$55	$47	*$45*
Assets per employee ($000)	**$212**	$275	$184	$244	*$216*
Value of patents ($000)	**$205**	$269	$99	$571	*$218*
Patents as % of assets	**1.25%**	0.85%	0.59%	0.73%	*0.79%*
Current ratio	**5.52**	6.98	4.97	4.67	*4.63*
Quick ratio	**4.91**	6.42	4.33	4.05	*4.02*
Total debt-total assets ratio	**0.46**	0.22	0.25	0.37	*0.33*
Total debt-equity ratio	**0.87**	0.28	0.33	0.58	*0.50*
Long term debt-equity ratio	**0.65**	0.11	0.14	0.36	*0.27*
Asset turnover	**0.35**	0.29	0.41	0.50	*0.45*
Profitability (Net income/total sales)	**-51%**	-45%	-37%	-3%	*-19%*
Return on assets before interest (ROI)	**-21%**	-14%	-15%	-3%	*-10%*
Return on equity (ROE)	**-45%**	-24%	-20%	-3%	*-14%*

Source: K.W. Willoughby, Center for Biotechnology; Primary data provided by Ernst & Young, 1991.
Note: "Total sales" = Product sales + contract research income + royalties & license fees.

Figure 5-3

Biotechnology Employment Density Indices, 1990*



* Date of figues: New York (mid 1991), Massachusetts (late 1990), California (mid 1990).

California has been divided into two distinct regions, Northern California (based around the San Francisco Bay Area) and Southern California (which consists mainly of the greater Los Angeles region and the San Diego area). The significant differences between the two regions in California reflected in their respective finances underlines the importance of taking a regional approach to analysis of the biotechnology industry. By almost every performance measure, the biotechnology industry in Northern California surpasses that of Southern California. The composite debt-equity ratio of the industry in Northern California is higher than that of Southern California, but its relatively high performance in revenue generation and capital accumulation probably lessens the importance of this distinction.

Two key financial indicators from Table 5.2, the percentage of biotechnology businesses that are profitable and composite return-on-equity, are presented graphically in Figures 5.4 and 5.5.

According to the Ernst & Young data, 21 percent of biotechnology businesses nation-wide were profitable during 1991. The only regional industry in Figure 5.4 to achieve a proportion higher than this was Northern California. New York, with 13 percent, scored the lowest.

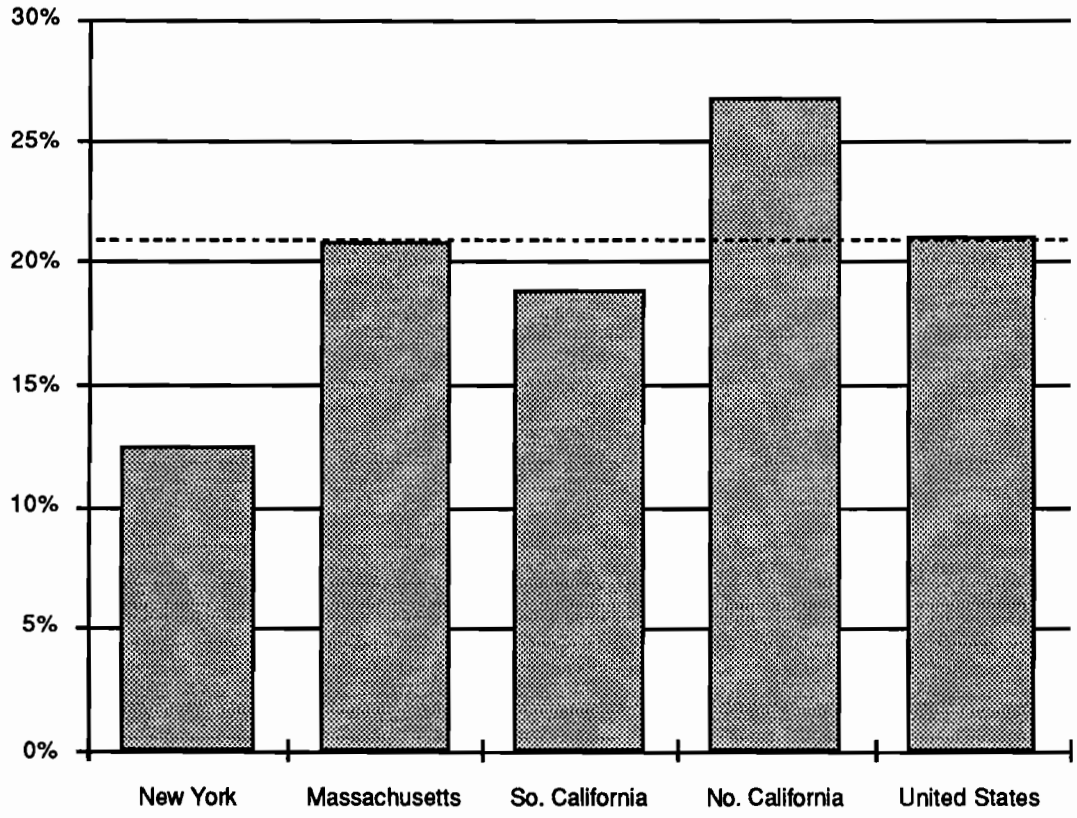
Figure 5.5 shows that all four regional biotechnology industries, and the industry aggregated nationally, scored a negative return-on-equity during 1990. For this reason the title of Figure 5.5 is "total loss as a percentage of equity" (which means the same thing as "return on equity"). This does not mean that no firms made a positive return-on-equity (see Figure 5.4), only that the industry as a whole did not. Northern California came the closest to net profitability with the composite loss accounting for only 3 percent of composite equity. New York's negative return-on-equity (45 percent) is over three times the size of the national figure. While New York achieves above-average competitiveness from the point of view of industry density indices, it is below average according to key financial indicators.

Registering a net loss is not unusual for biotechnology businesses (in fact, it is normal), and it can actually be a sign of strength, because for many firms it is a result of heavy investment in research and development with a sight on substantial profitability in the long-term. The strongest overall biotechnology industry cluster in California, the East Bay cluster in the San Francisco area, has historically incurred relatively high total losses (Willoughby & Blakely, 1989). New York's poorer overall short-term financial performance, however, does not appear to stem from a relatively high level of investment on research and development. As Figure 5.6 shows, New York's biotechnology businesses spent proportionally less money during 1990 on research and development than those of the other states, and less than the national average.

The state with the highest amount spent on research and development per employee was Massachusetts. This suggests that the intensity of research and development spending could be the chief cause for the unusually high competitiveness of Massachusetts' biotechnology industry, as reflected in Figure 5.3. Juxtaposition of Figures 5.4, 5.5, and 5.6, however, indicates that there is

Figure 5.4

Percentage of Biotechnology Businesses which are Profitable, 1990



Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), 1991; source of primary data, Ernst & Young, 1991;

Figure 5.5

Total Loss as a Percentage of Equity, Biotechnology Businesses, 1990

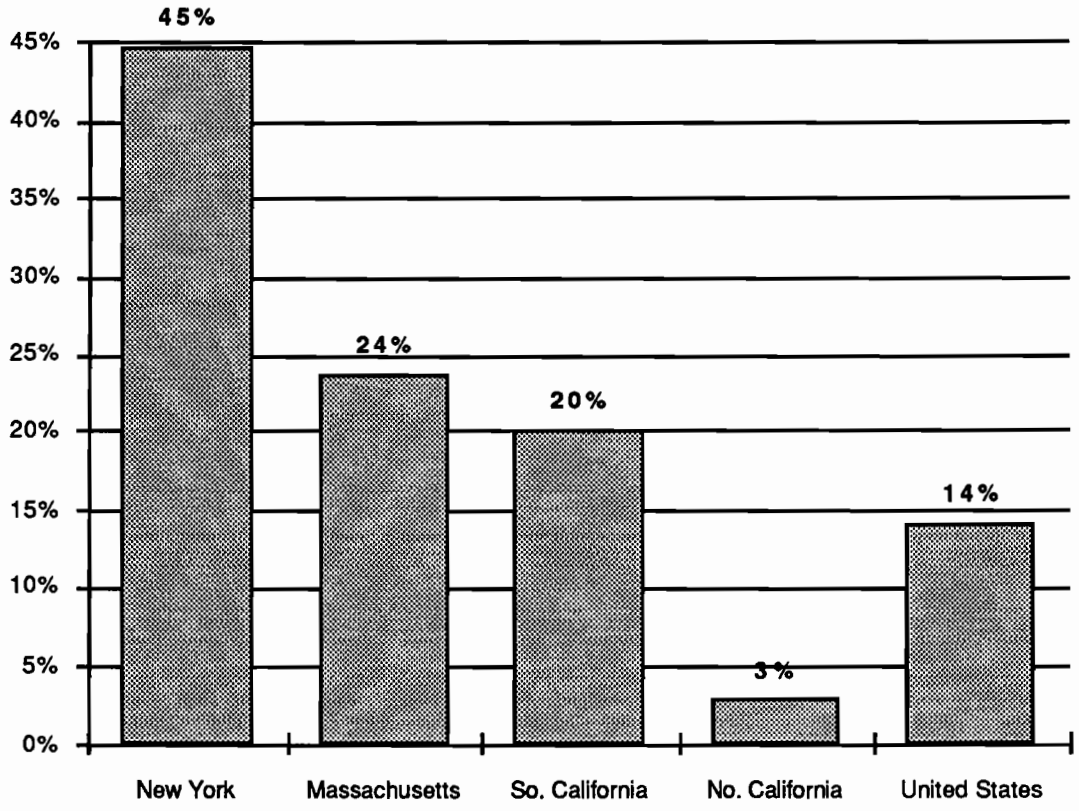
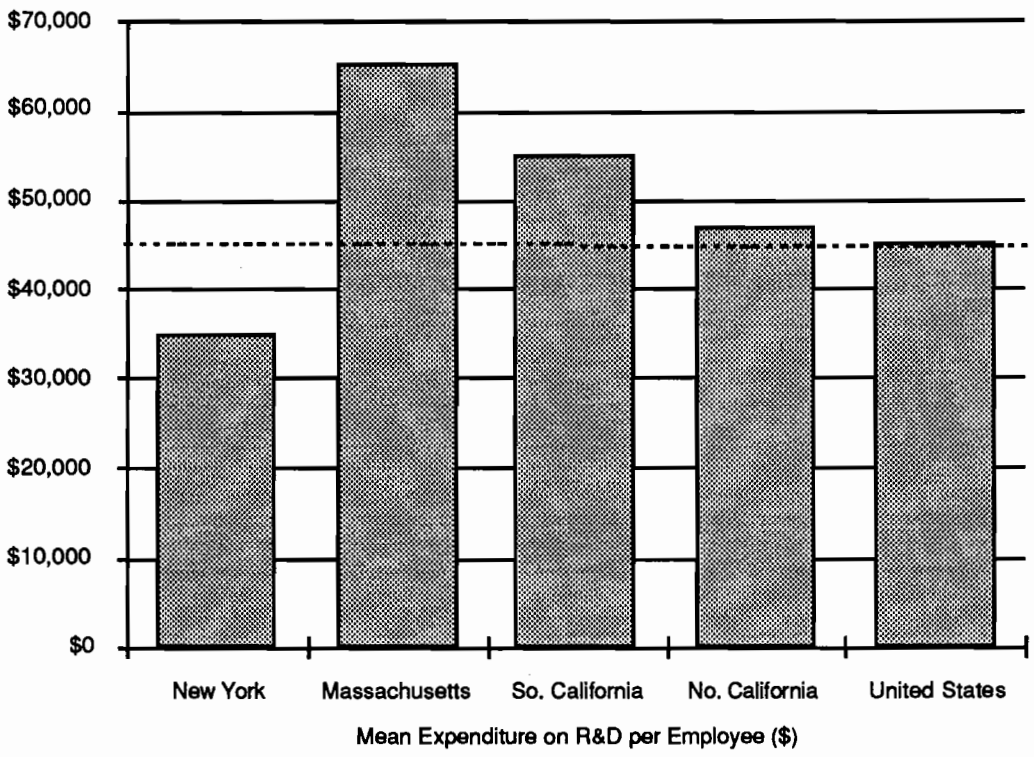


Figure 5.6

Regional Variations in R&D Expenditure by Biotechnology Businesses, 1990



not a simple link between research and development spending and strong financial performance. Firms in Northern California spend only marginally more on a per capita basis than the national average; firms in Southern California, while performing less impressively on the whole than those in Northern California, actually average higher research and development spending per capita than those in Northern California. Although the intensity of research and development spending is almost certainly important for commercial performance, there is clearly something else at work in the industry which is a key to success.

Research and development spending in commercial biotechnology should probably be viewed as playing a similar role for firms as food and exercise play for people. Without a regular intake of food and reasonable exercise people tend not to thrive, but the social or economic success of individuals requires a lot more than heavy eating and heavy exercising! Similarly, substantial research and development spending may be viewed as an essential foundation for economic success in biotechnology, but it is inadequate alone. There is no universal pattern to the relationship between research and development and industrial success. Furthermore, as demonstrated in Chapter Three by financial structure variations in biotechnology clusters within New York, research and development may in fact be a more significant determinant of success for some groups of firms than it is for others.

New York's relatively poor financial performance in biotechnology does not come from extravagant spending on research and development, or even from extravagant spending in general. The data in Table 3.9 indicate that the total spending of a typical firm in the New York industry during 1990 was about 58 percent of that of the typical firm at the national level. Even on a per capita basis, New York firms spent less ($119,250 per employee) than was the case nationally ($123,977 per employee), according to the Ernst & Young data. It is necessary therefore to inquire more deeply into the structure of differences between the biotechnology industry in New York and elsewhere in the United States.

Financial Structure of New York's Biotechnology Industry Compared with Elsewhere in the United States

Table 5.3 takes the data from Table 5.2 and expresses the score for New York on each financial indicator as a percentage of the respective score for each of the other states. Figure 5.7 presents in graph form the ratio of the New York score for each indicator over the equivalent score for the biotechnology industry at the national level.

Table 5.3 and Figure 5.7 show that according to all indicators except liquidity measures, New York's biotechnology firms perform less well than the national average.

The size of composite total revenue for New York's biotechnology businesses is less than half that of the national composite, and the composite net loss is larger than the composite national net

Table 5.3

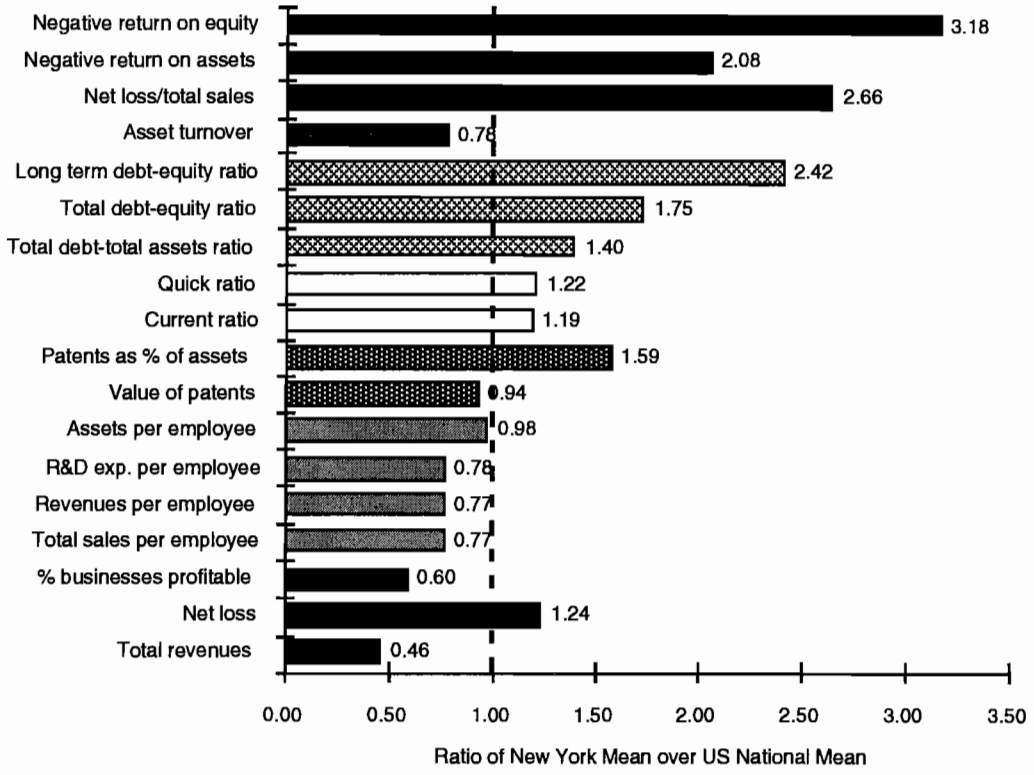
Relative Financial Performance of Biotechnology Businesses, 1990
Comparison of Composite Figures for New York and Other US States

Financial Indicator	Ratio of New York Mean over Mean for Other US States: Massachusetts	So. Calif.	No. Calif.	United States
Total revenues	0.59	0.83	0.15	0.46
Net loss	0.71	1.18	2.23	1.24
Percentage of businesses profitable	0.60	0.66	0.47	0.60
Total sales per employee	0.94	1.00	0.61	0.77
Revenues per employee	0.89	0.99	0.62	0.77
R&D expenditure per employee	0.54	0.64	0.74	0.78
Assets per employee	0.77	1.15	0.87	0.98
Value of patents	0.76	2.07	0.36	0.94
Patents as % of assets	1.48	2.13	1.71	1.59
Current ratio	0.79	1.11	1.18	1.19
Quick ratio	0.76	1.13	1.21	1.22
Total debt-total assets ratio	2.14	1.88	1.27	1.40
Total debt-equity ratio	3.14	2.65	1.50	1.75
Long term debt-equity ratio	5.77	4.58	1.81	2.42
Asset turnover	1.21	0.87	0.71	0.78
"Profitability" (Net loss/total sales)	1.13	1.39	14.99	2.66
Negative return on assets before interest (ROI)	1.43	1.34	7.34	2.08
Negative return on equity (ROE)	1.88	2.24	15.72	3.18

Source: K.W. Willoughby, Center for Biotechnology; Primary data provided by Ernst & Young, 1991.
Note: "Total sales" = Product sales + contract research income + royalties & license fees

Figure 5.7

Relative Performance of New York and US National Biotechnology Industries for a Range of Financial Parameters, 1990



Source: K.W. Willoughby, Center for Biotechnology; Primary data provided by Ernst & Young, 1991.

loss. In all three of the standard measures of profitability— return on equity, return on assets, and net loss as a proportion of total sales — New York's negative score is two to three times larger than is the case nationally. This low profitability does not appear to flow just from a higher cost structure, since New York also exhibits lower sales-per-employee and lower revenues-per-employee.

By both liquidity measures, the current ratio and the "quick ratio" (which discounts for the possibility of slow-moving or obsolescent inventories), New York firms are better off than those based elsewhere; in other words, their supply of cash to meet short-term obligations is relatively good. This may suggest that the state's firms are being very professionally managed from a financial point of view, with careful consideration being paid to cash-flow considerations.

The level of assets-per-employee are roughly on par with the rest of the biotechnology industry in the United States. However, it appears that New York's firms tend to make less efficient use of those assets than firms elsewhere, as indicated by the relatively low asset turnover ratio (78 percent of the national mean).

The relatively poor profitability figures are made more troubling by the fact that, on the whole, New York's firms have weaker leverage than their competitors. All three of New York's measures of leverage —the debt-equity ratio, the long-term debt-equity ratio, and the debt-assets ratio —are higher than the corresponding national mean. On the other hand, the absolute scale of debt compared with assets or equity is quite reasonable (see Table 5.2), so there is no cause for alarm. Nevertheless, the generally lower dependence upon debt financing of the biotechnology firms outside of the state means that there is no cause for complacency for those within New York.

The relatively high proportion of the New York industry's assets that are accounted for by patents (159 percent of the national mean, 171 percent of the Northern California mean, 213 percent of the Southern California mean, and 148 percent of the Massachusetts mean) suggests that the firms in New York may be relying more heavily than their competitors upon fees and income from intellectual property rather than sales of products or services. This strategy does not appear to be paying off. We may speculate that those firms in the biotechnology industry that try to do something practical with their technical knowledge, in addition to "protecting" it through legal mechanisms, are more likely to experience better revenue performance than those which do not.

Finally, on the positive side, the size of composite net loss for New York is less than the size of composite net loss for Massachusetts; however, in view of the heavy investment which Massachusetts' firms do make in research and development, and their significantly lower debt-equity ratios, this large loss ought probably to be viewed as an expression of a strategy of investing with a long-term return in mind. Although Massachusetts is clearly the national leader in terms of "industry density," it lags behind Northern California in terms of financial performance; and New York lags behind these two regions in both industry density terms and financial terms.

To conclude, we should recall that in spite of the weaker financial competitiveness of New York's biotechnology industry as indicated by the Ernst & Young data, this survey has revealed that in *absolute terms* the financial performance of the majority of New York's biotechnology businesses was *improving* during the previous year (see Chapter Three). In addition, while the composite figures for the state appear weaker than those of Massachusetts and Northern California, many individual businesses are doing very well.

Chapter Six

Locational Factors in New York

The previous chapter presented evidence that while the New York biotechnology industry is competitive by some measures, by others it lags behind major competitors such as Northern California and Massachusetts, and to some extent also the nation as a whole. While the fine details of just how competitive one region is compared to others may be argued, it is clear that New York's biotechnology industry needs to increase its competitiveness. It is therefore necessary to identify the chief factors that will facilitate the accomplishment of this goal. With this in mind, an analysis was conducted of the locational factors that make New York attractive or unattractive for commercial biotechnology activities. The results of this analysis are the subject of this chapter.

New York's Legacy of Costs and Regulations

It is commonly believed that New York is not as competitive in biotechnology as would be expected, given the region's remarkable human and institutional resource base. This has to do with the high costs of doing business in the state (high taxes, high real estate costs, high wages, high insurance fees, et cetera) as well as an inhospitable regulatory environment. This image of New York as being burdened by a legacy of such difficulties is certainly common in the news media (e.g., Ungar, 1991). This study has sought to identify the extent to which these factors are truly perceived as problems by managers of the state's biotechnology businesses and the extent to which they are significant determinants of business behavior.

The biotechnology businesses interviewed in this study were presented with a list of ten factors that firms sometimes consider when deciding between alternative locations for research and development facilities. Each business was asked to indicate how important the factor is to them as a determinant of the attractiveness of a location for their main research and development facility. They were then asked to rate their present primary location in New York as advantageous or disadvantageous, compared to potential locations outside New York, and from the point of view of each of the ten factors. The first set of questions asked how important in principle each factor rated as a criterion for decision-making, while the second set of questions assessed the quality of a business's actual location. The same procedure was then repeated for manufacturing facilities. Combining these procedures, each business was asked a total of 40 individual questions about locational factors for biotechnology. The results of this exercise for research and development are summarized in Table 6.1, and the results for manufacturing are summarized in Table 6.2. The data from these two tables are represented graphically in Figures 6.1, 6.2, 6.3, and 6.4.

Table 6.1

Advantageousness of present location in New York for biotechnology research and development compared with other potential locations outside New York

	Percentage of businesses which rate their location in each category			
	Advantageous	**No difference**	**Disadvantageous**	N
Regulatory environment	16%	63%	22%	51
Cost of doing business	37%	17%	47%	60
Availability of good senior staff	53%	29%	17%	58
Availability of good support staff	62%	26%	12%	58
Proximity to universities & res. inst.	75%	16%	9%	55
Proximity to other biotechnology businesses	28%	48%	24%	46
Proximity to major customers	30%	59%	11%	46
Proximity to major technical suppliers	30%	65%	4%	46
Proximity to other facilities of your business	31%	48%	21%	29
Other	71%	0%	29%	7

Advantageousness of present location in New York for biotechnology manufacturing compared with other potential locations outside New York

	Percentage of businesses which rate their location in each category			
	Advantageous	**No difference**	**Disadvantageous**	N
Regulatory environment	20%	48%	33%	46
Cost of doing business	32%	14%	54%	50
Availability of good senior staff	58%	20%	22%	45
Availability of good support staff	62%	24%	13%	45
Proximity to universities & res. inst.	65%	30%	5%	43
Proximity to other biotechnology businesses	32%	45%	23%	31
Proximity to major customers	42%	58%	12%	33
Proximity to major technical suppliers	33%	58%	9%	33
Proximity to other facilities of your business	56%	28%	16%	32
Other	57%	14%	29%	7

Table 6.2

Determinants of the attractiveness of a location for research and development

n=65 Percentage of businesses which rate factor at each level of importance

	Very Important	Important	Somewhat Important	Not at all Important
Regulatory environment	25%	31%	22%	23%
Cost of doing business	43%	29%	18%	9%
Availability of good senior staff	68%	17%	8%	8%
Availability of good support staff	46%	40%	9%	5%
Proximity to universities & res. inst.	54%	23%	18%	5%
Proximity to other biotechnology businesses	9%	18%	35%	37%
Proximity to major customers	15%	12%	23%	49%
Proximity to major technical suppliers	8%	12%	43%	37%
Proximity to other facilities of your business	18%	14%	6%	62%
Other	9%	0%	0%	91%

Determinants of the attractiveness of a location for manufacturing

n=65 Percentage of businesses which rate factor at each level of importance

	Very Important	Quite Important	Somewhat Important	Not at all Important
Regulatory environment	48%	20%	14%	18%
Cost of doing business	65%	22%	11%	3%
Availability of good senior staff	49%	35%	6%	9%
Availability of good support staff	40%	38%	9%	12%
Proximity to universities & res. inst.	31%	14%	28%	28%
Proximity to other biotechnology businesses	11%	14%	23%	52%
Proximity to major customers	8%	25%	18%	49%
Proximity to major technical suppliers	14%	22%	28%	37%
Proximity to other facilities of your business	23%	17%	6%	54%
Other	11%	0%	0%	89%

Figure 6.1

Advantageousness of Present Location for Research and Development (by Various Factors) Compared with Potential Locations Outside New York, 1991

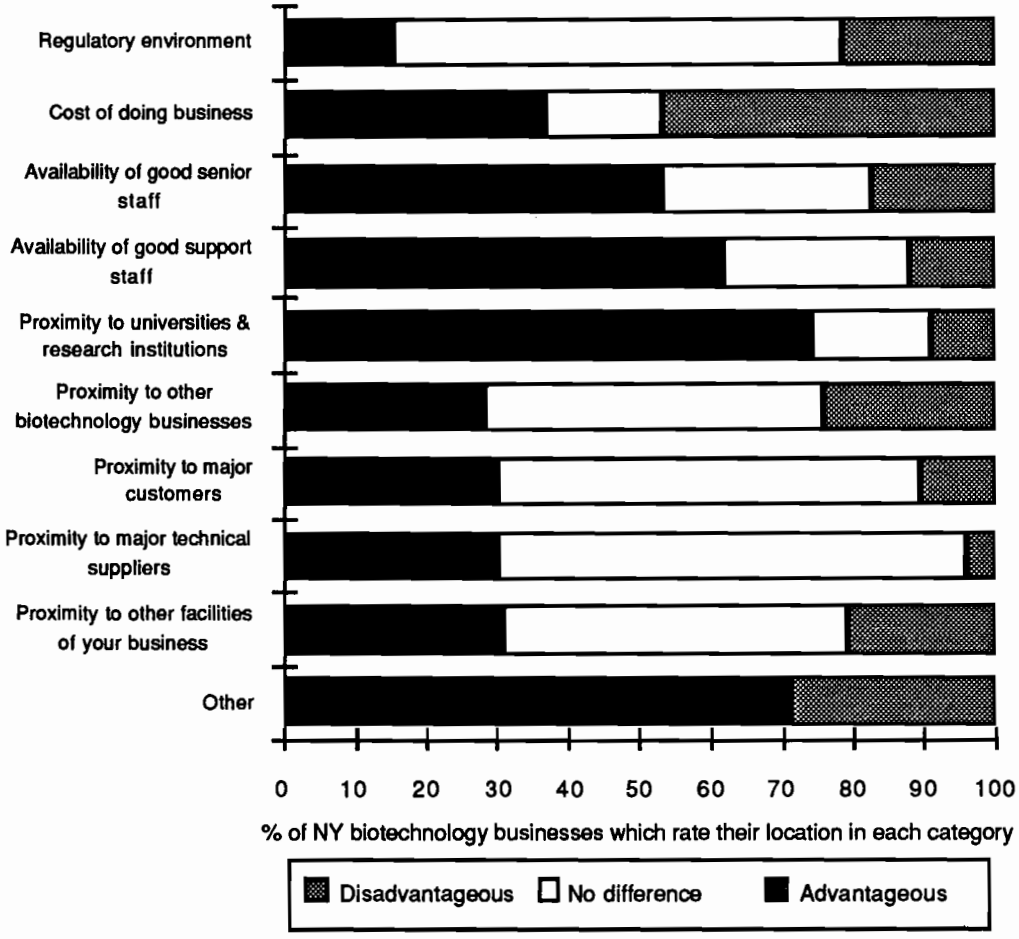


Figure 6.2

Determinants of the Attractiveness of a Location for Research and Development, New York Biotechnology Businesses, 1991

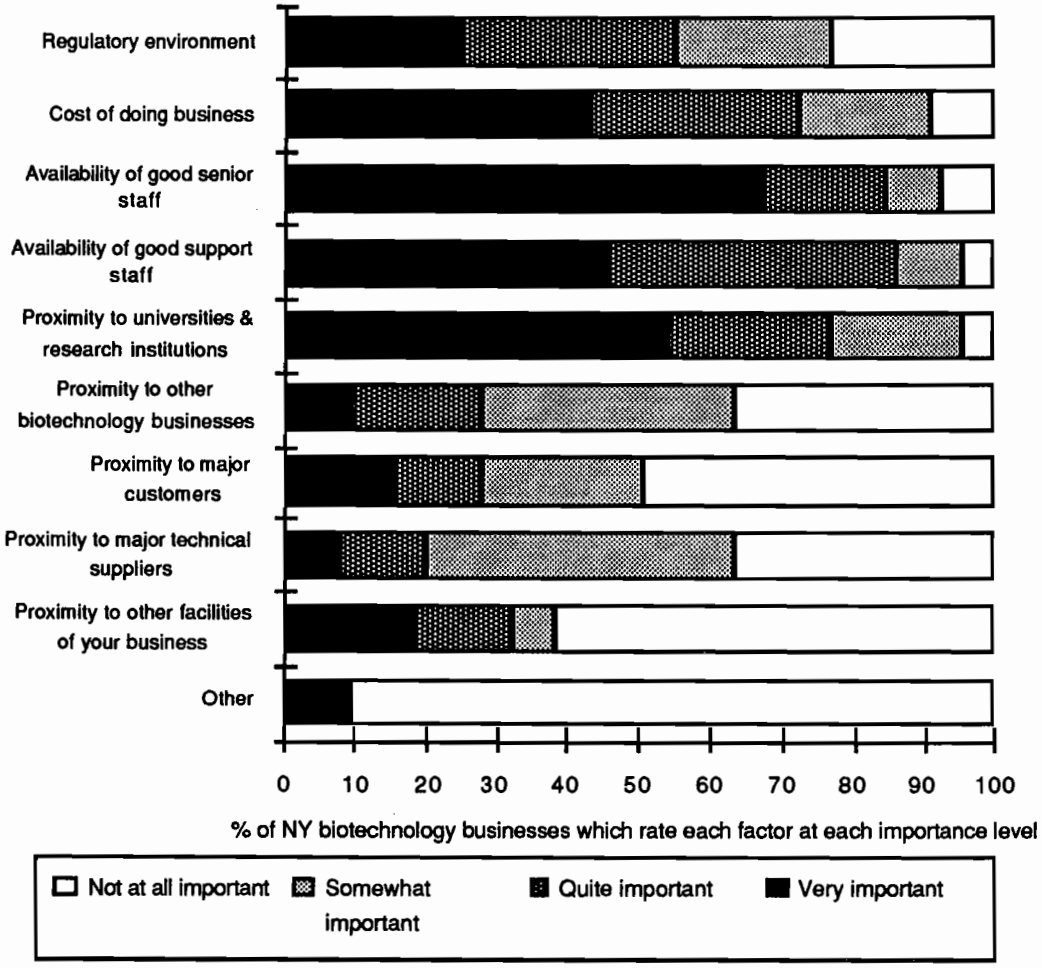


Figure 6.3

Advantageousness of Present Location for Manufacturing (by Various Factors) Compared with Potential Locations Outside New York, 1991

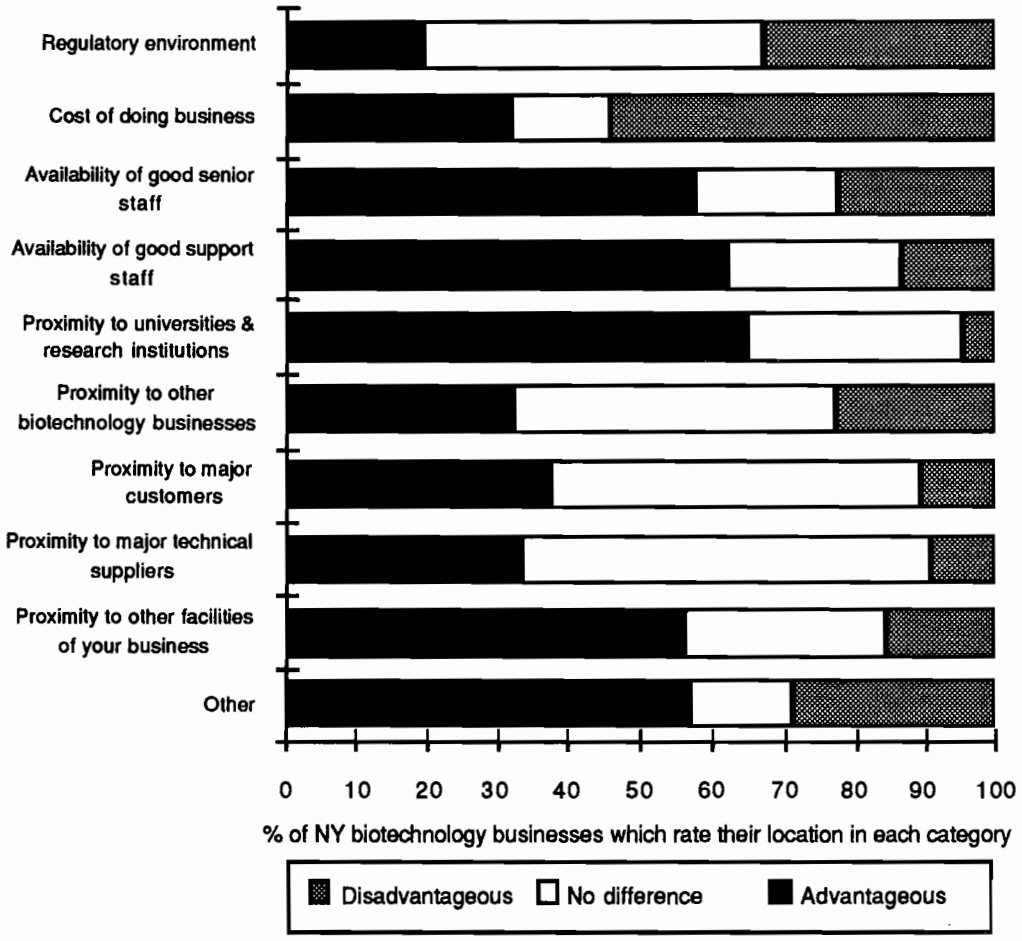
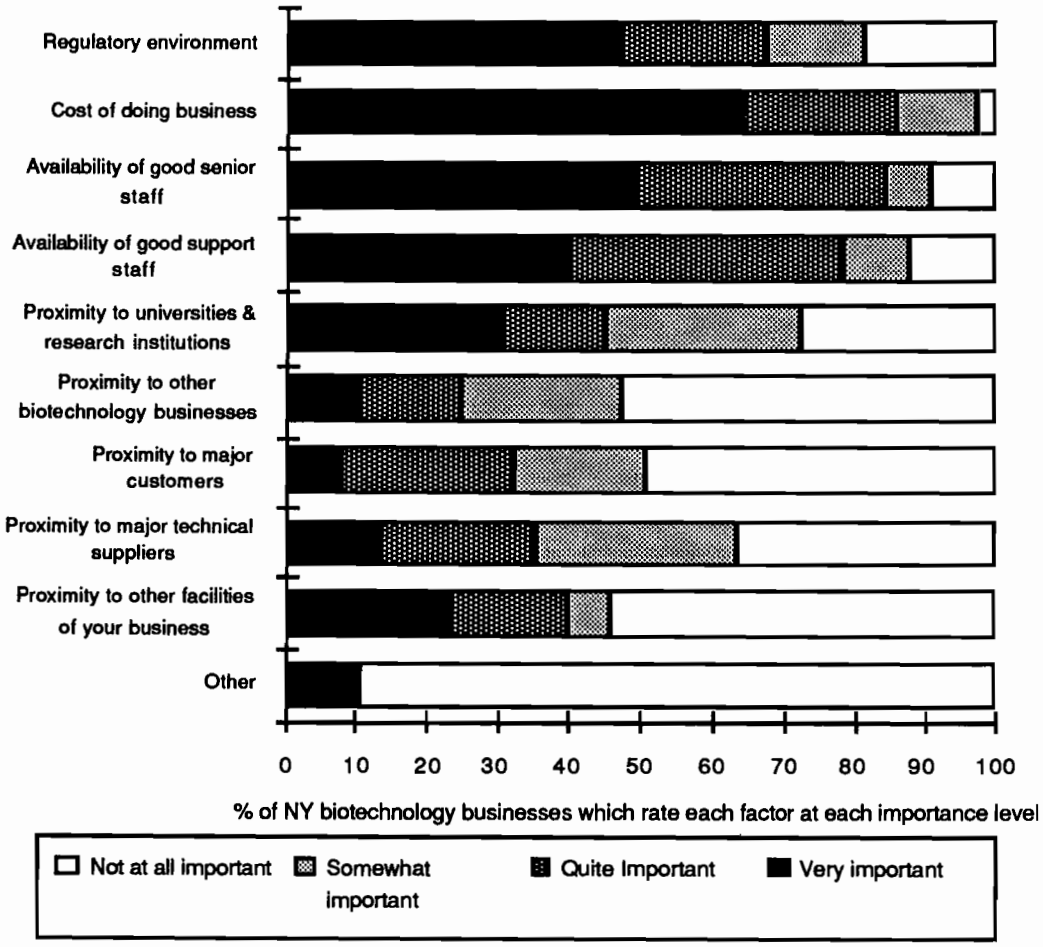


Figure 6.4

Determinants of the Attractiveness of a Location for Manufacturing, New York Biotechnology Businesses, 1991



Locational Advantage of New York for Research and Development in Biotechnology

Figure 6.1 plots the percentage of dedicated biotechnology businesses that consider their present primary location in New York to be either advantageous, disadvantageous, or of no difference compared to other potential locations outside New York for research and development, according to the following criteria: regulatory environment, cost of doing business (which includes all types of costs), availability of good senior staff, availability of good support staff, proximity to universities and research institutions, proximity to other biotechnology businesses, proximity to major customers, proximity to major technical suppliers, proximity to other facilities of the business, and "other" factors (e.g., general living environment, location of CEO/entrepreneur, et cetera).

Figure 6.1 shows that, for every factor except the cost of doing business, more businesses believe being located in New York to be an *advantage* than those which believe it to be a disadvantage. Even regarding the cost of doing business, however, less than half (47 percent) believe being located in New York to be disadvantageous; a slight majority (53 percent) believe that, taking all cost factors into account, New York is either *advantageous* (almost two-fifths believe it is a cheaper place to do business) or equivalent to other places.

While this last point may appear to be somewhat counter-intuitive, it should be recognized that costs are generated not only by paying taxes, wages, and rent, but also by the expenses involved in carrying out transactions. One of the advantages of a heavily populated area is that certain business services tend to be abundant, and that a high population of complementary organizations can reduce the transactions-costs of that location. Really talented people may be easier to employ in a "high-cost" region, because the risk factors for individuals in taking up employment with a given employer may be low due to the relative abundance of alternative employment opportunities (and therefore a company may be able to attain greater achievements for a given "wages dollar"). New York, it must also be remembered, covers a vast region, not all of which contains Manhattan-priced real-estate. Manhattan accounts for 0.05 percent of the state's land area, and New York City as a whole accounts for 0.64 percent of the total (New York State Statistical Yearbook, 1987-88, Table M-5).

The features of New York that stand out as big attractions for biotechnology research and development are what might be termed the "people and knowledge" factors. The single most attractive feature of New York appears to be the proximity of universities and research institutions, followed by the availability of personnel. Interestingly, more firms find the state to be advantageous because of the availability of good support staff (62 percent) than those who find it to be attractive because of the availability of good senior staff (53 percent).

The majority (71 percent) of businesses also cite some "other" factor as making their location in New York advantageous. In view of the evidence covered in Chapter Three, and informal insights gained while conducting the interviews, it appears that the main factor in "other" is that the primary

founder or founders of the business (and therefore probably the present CEO) were already located in New York.

Surprisingly, in view of the common image of New York, only 16 percent of the businesses consider the regulatory environment as making their location in New York disadvantageous for research and development.

Figure 6.2 graphs the responses of the businesses to questions about the relative importance of the ten factors covered by Figure 6.1. This information is required because the fact that most firms might consider New York to excel in "factor X" may be of little importance if "factor X" plays an insignificant role in influencing the behavior or attitudes of firms (i.e., the people within the firms).

Figure 6.2 reveals the factor which the survey respondents believe to be of the highest primary importance as a determinant of the attractiveness of a location, for research and development, is the availability of good senior staff. When primary and secondary importance are combined, the availability of good support staff is at least as important. These are followed by the importance of proximity to universities or research institutions (including the research facilities of hospitals). The other "proximity" variables do not rate very highly in the managers' thinking.

Cost factors *do* rate quite highly in the considerations of managers: 43 percent believe it to be very important, and 29 percent believe it to be quite important. In view of that fact that almost half of the businesses consider the cost of doing business in New York to make their location disadvantageous, we must conclude that the cost-related issues ought to be taken seriously. At the same time, it should be reiterated that almost two-fifths of the businesses actually find being located in New York to be *advantageous* for research and development from the point of view of cost.

The regulatory environment, according to Figure 6.2, also rates as a fairly important variable for managers, although only one-quarter believe it to be very important. When combined with the information from Figure 6.1, however, we are led to the conclusion that regulatory-related factors do not play as much of a significant role as locational factors for research and development despite popular impressions to the contrary, and despite the fact that managers may have to spend quite a bit of time dealing with regulations.

A minority (almost one-quarter) perceive some kind of disadvantage from being isolated from biotechnology businesses elsewhere (mainly California and Massachusetts), but this is not rated in Figure 6.2 as much of a significant determinant; in any case, slightly more businesses than not find New York to be advantageous for proximity to other biotechnology businesses.

The above considerations lead to the conclusion that most of the businesses believe that New York is an attractive location for research and development *vis-à-vis* the factors that most matter to them. The only significant disadvantage, when all is taken into account, is the cost of doing business. This problem appears to be more than counterbalanced, however, by the positive features of the state, and in any case not all firms find it to be a significant problem anyway.

Locational Advantage of New York for Biotechnology Manufacturing

Figure 6.3 plots the percentage of dedicated biotechnology businesses which consider their present primary location in New York to be either advantageous, disadvantageous, or of no difference compared with other potential locations outside New York, for manufacturing. It covers the same general criteria as Figures 6.1 and 6.2.

The most noticeable feature of Figure 6.3 is that the cost of doing business is more of a problem for manufacturing in biotechnology than it is for research and development. The majority (54 percent) find the cost of doing business in New York make it a disadvantageous location for biotechnology manufacturing. A similar situation exists with the regulatory environment, but this, while more of a problem for manufacturing than research and development, is still found by only one-third of the businesses to make their location in New York a disadvantage.

As shown by Figure 6.4, cost factors and regulatory factors actually rate as more significant determinants of locational attractiveness for manufacturing than they do for research and development. For biotechnology manufacturing, furthermore, cost is perceived as *the most important* locational factor, whereas for research and development the most important is the availability of good senior staff. The availability of good senior staff nevertheless still ranks as the second most important locational factor for manufacturing.

It appears, therefore, that the cost of doing business in New York is a definite obstacle to the local growth of the industry. At the same time, Figure 6.3 shows that other factors— the availability of good senior staff, the availability of good support staff, and the proximity of universities and research institutions —are believed by *the majority* to make New York an advantageous location for biotechnology *manufacturing*. Biotechnology manufacturing is not just a matter of routine and automated procedures, but requires good people and knowledge as well. These factors mitigate the problems created by high costs.

Figure 6.3 also indicates that the majority of the biotechnology businesses find their location to be attractive for manufacturing because of its proximity to other facilities of their business (generally their research and development facilities). This locational factor also rates more highly in Figure 6.4 (for manufacturing) than it does in Figure 6.2 (for research and development). Combining this factor with the other three majority-held positive-advantage factors, a picture emerges in which managers of New York's biotechnology businesses are faced with a dilemma: cost-related factors, and to a lesser extent regulatory factors, would lead them to prefer other locations, yet at the same time these factors are counterbalanced by several other factors (to do with knowledge, people, institutional resources, and inter-organizational proximity) that would lead them to prefer their present location.

Research and Development and Manufacturing in Tandem

Given the close links frequently existing in biotechnology between research and development and manufacturing, trade-offs almost certainly have to be made between the positive and negative

features of a given location for an organization's activities. It may even be that the cost problems, and perhaps also the regulatory problems, are intrinsic features of the places that have the requisite resources and milieu for successful commercial biotechnology.

The data considered so far in this chapter suggest that, on balance, most of New York's dedicated biotechnology businesses find the advantages of their location in the state to outweigh the disadvantages. In addition, the information presented in Chapter Three on the origins of New York's biotechnology industry suggests that the original location of the primary founder or founders is a more significant locational determinant than than the "locational variables" considered in Tables 6.1 and 6.2.

There is also at least some anecdotal evidence that the actual problems of cost in New York are not necessarily as severe as is normally thought. Even in Manhattan, as has been found by companies such as ImClone Systems Incorporated (located in lower Manhattan), suitable space for commercial biotechnology activities may sometimes still be found at quite reasonable prices (Waksal, 1991). Finally, the main competitors for New York in biotechnology— the San Francisco region and the Boston region —are also "high-cost" regions; and this is perhaps not surprising if the experiences and needs of the biotechnology businesses in those regions are anything like those from New York. Thus, reducing New York's high costs —even if this was possible— would not be an adequate response to the competitive pressure from California and Massachusetts.

The latest evidence on differentials in taxation costs between states in the New York region leads to the conclusion that, when all forms of taxation at the local, state, and federal levels are combined, there is not a great deal of difference between them; and a growing number of business relocation experts are admitting that taxation levels are not such an important determinant of business location decisions as has often been touted (Bartlett, 1991). The regions within the United States that do have significant taxation advantages over New York are not the regions which are serious competitors of the state in biotechnology, and may not have the other strengths making New York attractive to its biotechnology firms.

Effect of Locational Factors on Performance and Behavior of Businesses

To gain some sense of the variations between classes of biotechnology businesses in their perception of the overall advantage (or disadvantage) of being located in New York, two indices were constructed. An *Index of Locational Advantage of New York for Research and Development* (ILANYRD) was calculated for each business by aggregating its responses to each of the ten questions upon which Figure 6.1 is based. The index is designed so that the theoretical minimum is "-100" and the theoretical maximum is "100." At one extreme, a firm believing that it was advantageous to be located in New York from the point of all ten factors would receive a score of "100"; at the other extreme, a firm believing that it was disadvantageous to be located in New York from the point of all ten fac-

tors would receive a score of "-100." In the middle of the spectrum, a firm believing that there was no difference between New York and other potential locations for all ten factors would receive a score of "0." An *Index of Locational Advantage of New York for Manufacturing* (ILANYMF) was calculated on the same basis for each business by aggregating its responses to each of the ten questions upon which Figure 6.3 is based.

These indices may be used to explore relationships between perceptions of the locational advantages/ disadvantages of New York for biotechnology and other performance or behavioral variables.

Each dedicated biotechnology business in the survey was asked to indicate how likely it was to remain in New York State during the next five years. Eighty-one percent indicated that they would remain, 6 percent indicated that they did not intend to remain, and 13 percent were unsure. The mean Index of Locational Advantage of New York for Research and Development and the mean Index of Locational Advantage of New York for Manufacturing were calculated for each of these three groups. The results are presented in Figure 6.5.

Figure 6.5 shows that those businesses which exhibit a positive overall perception of New York as an advantageous location, from the point of view of the ten locational factors discussed above, are more likely to remain in New York than the rest. The group of businesses that indicated that they would remain in New York score a mean ILANYRD and a mean ILANYMF above those that indicated either that they were unsure or that they intended to leave the state. Those businesses intending to leave New York exhibit a score for both indices close to zero; this suggests not so much that they find their present location to be disadvantageous in general, but rather that there may be some other specific reason, such as a strategic alliance with a firm located elsewhere or an overwhelming advantage of some kind offered by an alternative location, which motivates them. The ambivalent businesses found New York attractive for manufacturing but unattractive for research and development.

These results suggest that the data on locational advantage factors analyzed above do serve as good indicators of the actual attitudes and likely behaviors of firms. In other words, they matter. To keep biotechnology businesses in New York, it is important to ensure that their managers perceive their location in the state to be advantageous.

Each business in the survey was also asked whether it is likely to commence or continue manufacturing during the next five years and, if so, whether it intends to do so within New York. Eighty-four percent answered "yes" to the first question, 10 percent answered "no," and 6 percent were unsure. Of the 84 percent which were already manufacturing or will be within five years, only 48 percent intended to locate their manufacturing activities within New York, 21 percent intended not to, and 31 percent were unsure where to locate their manufacturing. These responses suggest that despite the overall positive perceptions of New York held by most of its biotechnology businesses, the negative locational factors discussed above are probably significant enough to affect the future pattern of development in the industry.

Figure 6.5

Perception of Locational Advantage of New York and Likelihood of Biotechnology Business Remaining in New York

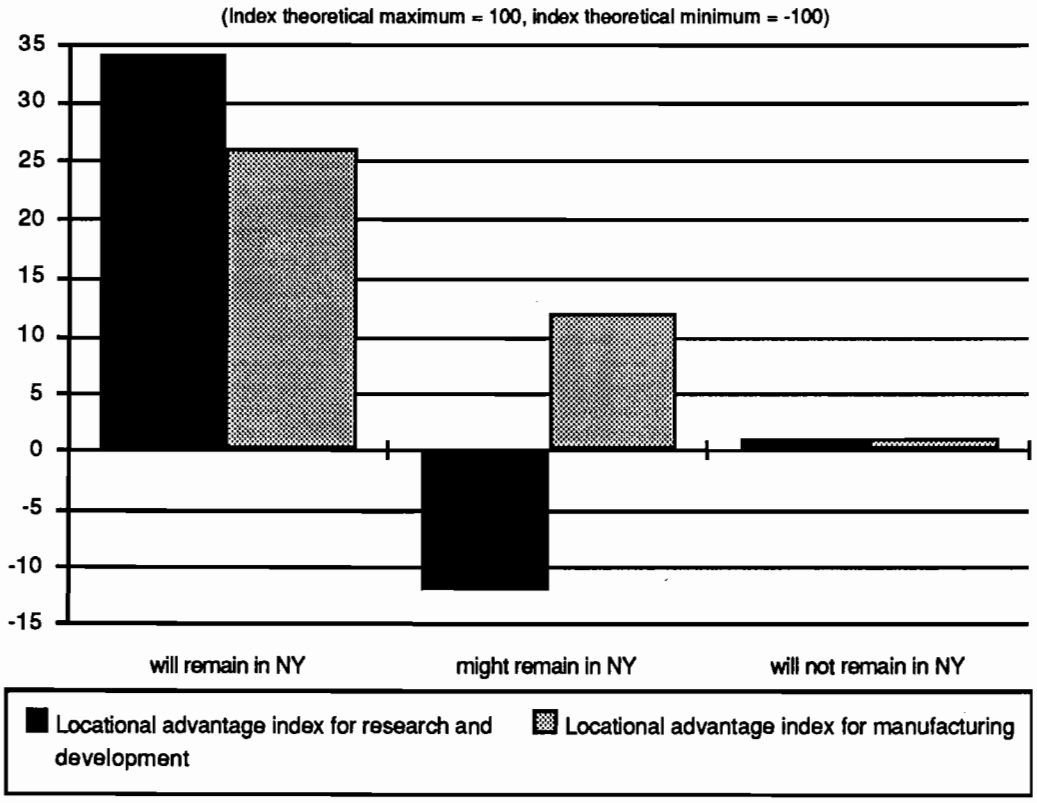


Figure 6.6 graphs the ILANYRD and the ILANYMF according to how likely businesses are to locate their manufacturing within New York. It shows a clear relationship between the scores for both ILANYRD and ILANYMF and the likelihood of the businesses manufacturing in New York. These results also reinforce the argument that managers' perceptions of the relative advantageousness of New York as a location for commercial biotechnology are likely to affect the future shape of the local industry, and therefore of its future competitiveness.

It should be stressed that all of the data reported above about locational factors reflect *perceptions* by managers of various factors associated with the primary location of their activities. The data are not objective measures of the actual practical circumstances under which firms operate, although they no doubt reflect something of those objective conditions. It is important to recognize this because it is highly likely that the more successfully a firm performs, the more positive an outlook its managers are likely to have towards their immediate environment, and the more the growth of the firm will provide a stimulus for it to draw upon the local region for support, resources, and other inputs. Managers who have a positive attitude towards the community surrounding their business are more likely to make effective use of local human, institutional, financial, and other resources —and therefore develop a positive assessment of the region. These attitudinal factors are no final substitute for realities in the actual location, but they can help frame and nurture the local milieu in which firms operate.

The issue of whether there might be self-reinforcing positive feedback between commercial performance and perceptions of locational advantage is explored in Figure 6.7

Figure 6.7 graphs the two indices, ILANYRD and ILANYMF, according to whether or not the biotechnology businesses have yet begun to generate revenue. It shows that the businesses which have begun to generate revenue score higher locational advantage indices for both research and development and manufacturing, although the pattern is stronger for research and development than it is for manufacturing. Without further analysis we cannot be sure which way, if any, the causality runs; but the graph confirms, as did the previous two, a correspondence between the perceptions of New York held by businesses and their behavior. It also points to the need for local communities wishing to develop a local biotechnology industry to stimulate the "virtuous circle" of positive perceptions, real locational advantage, and improved performance.

To summarize, this chapter has documented the perceptions of the managers of New York's biotechnology businesses about the factors which make their location in New York either advantageous or disadvantageous. The data presented gave some credence to the widely held view that firms in New York are encumbered by high costs and a difficult regulatory environment, although the regulatory environment seemed to be of less concern to managers than cost-related factors. We discovered, however, that many businesses actually find their location in New York to be advantageous *vis-à-vis* the very factors widely thought to make the state unattractive to businesses. The data also revealed that New York is perceived by the managers of its biotechnology businesses to possess a

Figure 6.6

Perception of Locational Advantage of New York and Plans for Future Biotechnology Manufacturing

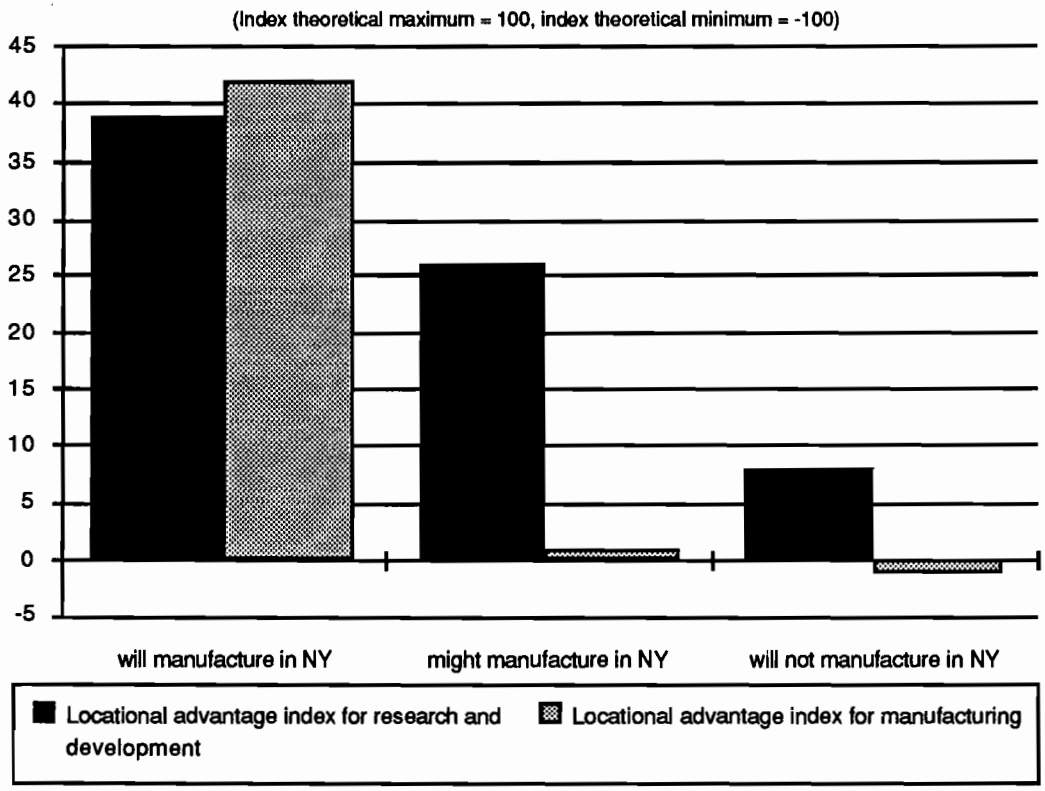
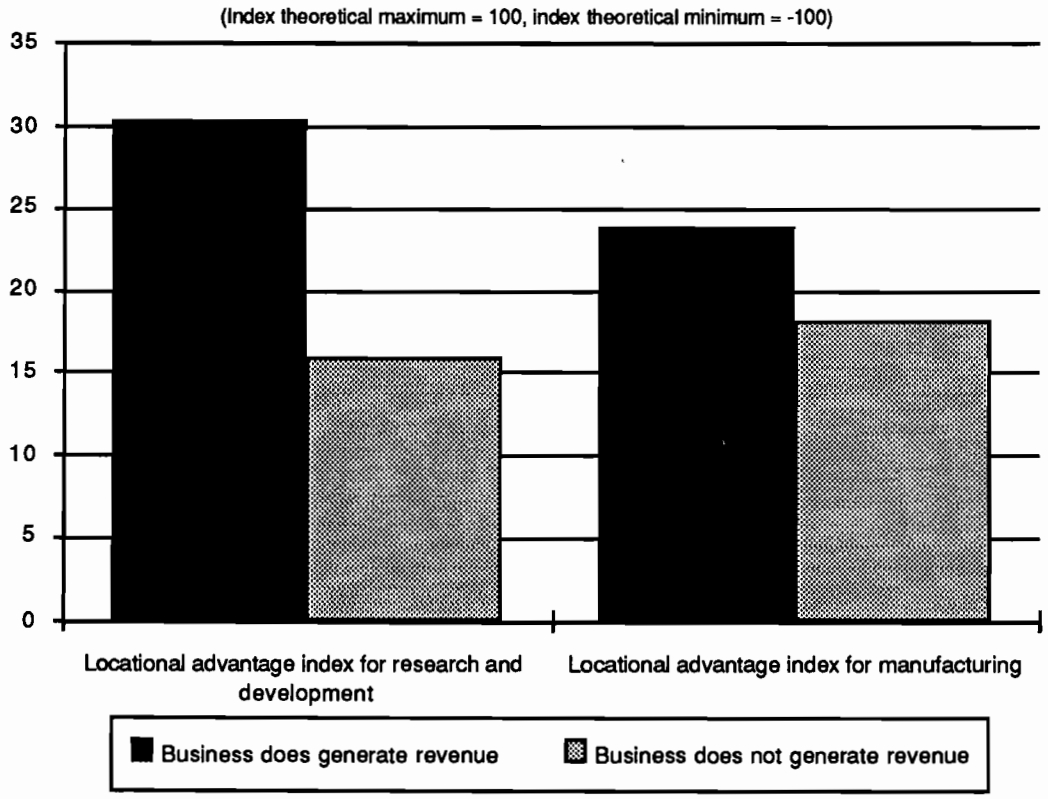


Figure 6.7

Perception of Locational Advantage of New York and Success in Generating Revenue



number of positive features —mainly to do with people, knowledge, and institutions— which counterbalance, and even outweigh, the problems which firms find in their location. In short, it appears that the sluggishness the New York biotechnology industry appears to exhibit, compared with its main competitors, cannot be explained simply by reference to supposedly inhospitable factors in the local environment. To the people who drive the industry, New York seems, without measuring up as outstanding by all factors, to be a good place to do biotechnology. The explanation for less-than-optimum competitiveness must involve factors not yet properly addressed in this study.

Before examining this issue further in the next chapter, we will look more closely at the second major problem of New York perceived by biotechnology managers— the regulatory environment. Regulations, more than the overall cost environment, can be *directly* addressed by public authorities, and therefore deserve more detailed analysis. It may also be argued that regulations indirectly cause increases in costs, so that while firms complain more about cost problems than regulatory problems, the latter may in fact be more significant from a policy perspective.

The Regulatory Environment

Most biotechnology businesses do complain about the prevalence of regulations with which they have to deal. In this study, an attempt has been made to determine not only whether businesses are bothered by the regulatory environment, but whether it significantly affects their behavior.

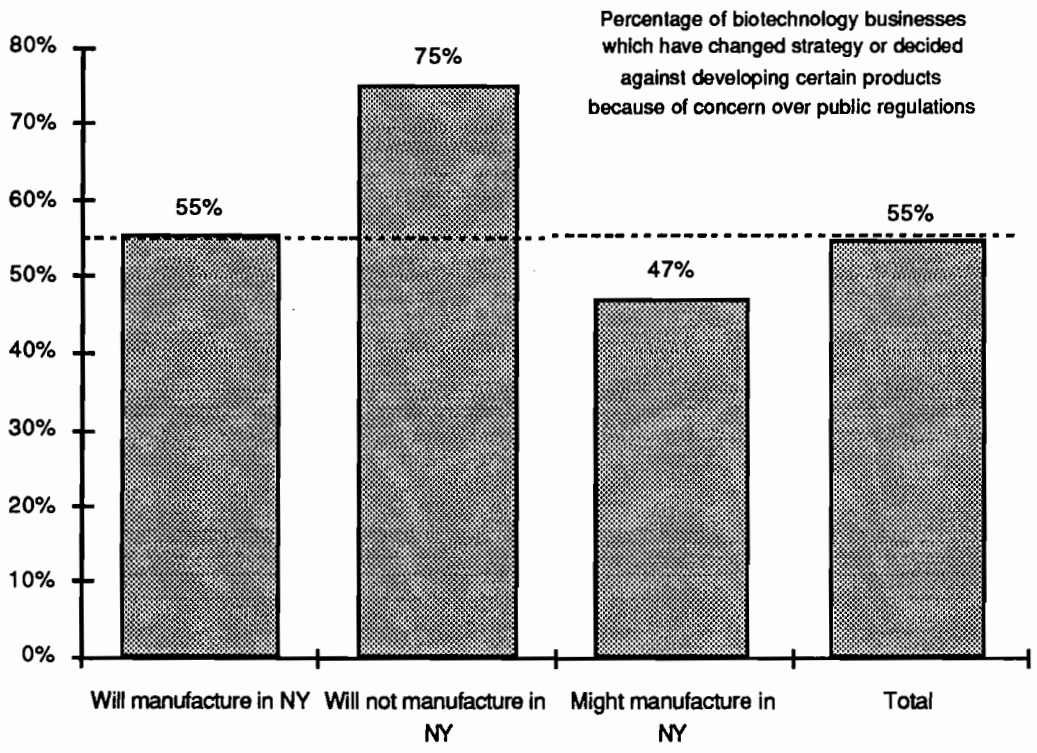
Each business was asked to indicate if it had ever changed its strategy or decided against developing certain products because of concerns over public regulations. Just over half (55 percent) indicated in the affirmative. The results were then graphed against the likelihood of each business locating its manufacturing facilities in New York (Figure 6.8).

Figure 6.8 shows that three-quarters of the businesses that have decided against locating their manufacturing within New York have had to change their strategy or decide against developing certain products because of concern over public regulations. Regulations, therefore, are an influence on the manufacturing propensity of firms. Public regulations are not, however, the dominant explanation for firms' manufacturing location decisions. Figure 6.8 also shows that over half (55 percent) of the firms which will manufacture in New York have encountered the same problems. Furthermore, the absolute number of biotechnology businesses that have encountered such regulatory problems and yet still intend to locate their manufacturing within the state (an estimated 36 businesses out of a population of 90) is much greater than the number that don't (an estimated 16 businesses out of a population of 90).

An attempt was also made in this study to differentiate between the effects of regulations at each of the several levels of government. In doing so, attention was placed upon the issue of the *implementation of regulations* rather than upon the existence or perceived legitimacy of the regulations as such. Each business was asked to indicate, for each level of government, whether it had ever experienced unreasonable delays in its activities due to inefficient or misdirected implementation of

Figure 6.8

Effect of Regulatory Environment on Propensity of Biotechnology Business to Conduct Manufacturing in New York During Next Five Years



regulations and procedures by public officials. For each case in which the answer was "yes," they were then asked to indicate how serious the impact had been. The results are portrayed in Table 6.3.

Table 6.3 reveals, first of all, that the most significant source of delays due to implementation of regulations is the federal government, with 43 percent of New York's dedicated biotechnology businesses having experienced such delays. Most of these delays, due to the FDA approval procedure and similar processes, are probably not affected significantly by the location of the firm. The impact of federal regulatory delays was serious ("very serious" and "quite serious" combined) on 64 percent of the businesses so affected (approximately 28 percent of the total population).

One-third of the businesses have experienced unreasonable delays due to inefficient or misdirected implementation of regulations and procedures by public officials of New York State. One-third of these found the impact of such delays to be very serious (approximately 11 percent of population); the proportion of those affected which found the impact to be serious ("very serious" and "quite serious" combined) was 63 percent (approximately 21 percent of the population). Thus, the State of New York can be considered to have led to serious negative impacts on about one-fifth of the state's biotechnology businesses due to perceived inefficient or misdirected implementation of regulations.

The regulatory impact of local government is not as serious as the impact of the state and federal levels. Only about 2 percent of the total population of New York's biotechnology businesses have experienced very serious negative impacts from implementation of regulations by officials of either city government or county government. Even if these categories are broadened to include those having experienced both quite serious impacts or very serious impacts, the proportion of the population for county government is 7 percent and the proportion for city government is 10 percent.

The regulatory environment, according to Table 6.3, is a problem for many firms and it has affected their behavior, but it is not likely to be a decisive influence on whether or not New York firms remain located within the state. In fact, in general, the state and local regulatory environment does not appear to have a serious negative influence on the strategies of the biotechnology businesses. Nevertheless, to improve New York's competitiveness in biotechnology it is necessary to pay attention not only to the regulations themselves but to the way in which they are managed and implemented.

To enable the analysis of variations in the experiences of the regulatory environment by biotechnology businesses in different parts of New York State, Table 6.4 cross-tabulates the primary data from Table 6.3 by region.

The first comment evoked by Table 6.4 is that the distribution of delays from the implementation of regulations by the Federal Government is quite uneven between regions. This suggests that experiences and perceptions of the regulatory situation are affected not only by the performance of public agencies but also by the nature of the activities of the businesses. As shown in Chapter Four, New York's biotechnology businesses vary a great deal in their technological specializations and mar

Table 6.3

Implementation of Regulations by Public Officials and Its Effect on Biotechnology Businesses

Percentage of New York biotechnology businesses which have experienced unreasonable delays in their activities due to inefficient or misdirected implementation of regulations or procedures by public officials

Level of Government	*Federal*	*New York State*	*Local County*	*Local City*
Encountered unreasonable delays	43%	33%	13%	19%
Impact very serious (% businesses)	38%	33%	13%	11%
Impact quite serious (% businesses)	26%	30%	38%	39%
Impact slightly serious (% businesses)	18%	15%	6%	11%
Impact not at all serious (% businesses)	18%	22%	44%	39%

Table 6.4

Implementation of Regulations by Public Officials and its Effect on Biotechnology Businesses (Variations by Region)

Percentage of New York biotechnology businesses which have experienced unreasonable delays in their activities due to inefficient or misdirected implementation of regulations or procedures by public officials

Region	*Local City*	*Local County*	*NY State*	*Federal*	*N*
New York City	9%	9%	18%	36%	11
Long Island	18%	14%	18%	32%	22
Lower Hudson	14%	0%	43%	29%	7
Upper Hudson	0%	0%	40%	60%	5
Capital	33%	50%	75%	50%	4
North	100%	100%	100%	100%	1
Mid West	50%	0%	50%	100%	2
Buffalo	50%	17%	33%	50%	6
Southern Tier	0%	0%	60%	60%	5
NY State	*19%*	*13%*	*33%*	*43%*	*63*

ket orientations (and therefore their regulatory regimes) between regions. There may also be some variations in the quality of services delivered by federal officials between regions — an interesting topic for further research — but it is probably of little significance in the light of other considerations.

The most striking result of Table 6.4 is that the biotechnology businesses located upstate experience the greatest problems with delays due to implementation of regulations *at all levels of government*. The proportion of businesses in Metropolitan New York that experienced unreasonable delays is much lower than that elsewhere in the state. New York City, in particular, registers a particularly low incidence of problems emanating from local government (the City of New York, and its boroughs); only 9 percent of its biotechnology businesses experienced unreasonable delays to implementation of regulations within the City. Businesses within New York City also have an unusually low incidence of problems generated by officials of the state and federal governments.

The experience of unreasonable delays due to the behavior of county and city governments by biotechnology businesses in Long Island, the region with the biggest population of firms, was similar to the state averages, but lower than upstate.

The main overall message presented by these data is that being located within metropolitan New York (New York City, Long Island, or Lower Hudson) in order to gain the advantages of access to people, knowledge, institutions, or other resources, does not necessarily have to be paid for by having more problems with implementation of regulations.

Although data collected as part of the formal questionnaire survey did not address this issue, a number of the New York City biotechnology businesses interviewed indicated informally that they did experience frustrations related to lack of coordination between different levels of government. For example, a firm in New York City may have to go through an approval process to gain permission for some of its activities for *both* the City of New York *and* the State of New York. Minor variations in the regulations or procedures of each may lead to inordinate costs, complications, or delays. In other words, the commercial biotechnology managers feel the need for more streamlining of the regulatory system between state and local government. Such improvements could increase the competitiveness of New York's biotechnology industry without reducing the fundamental role of public sector in monitoring and regulating the industry in the public interest.

Interstate Competitiveness and Locational Factors

To conclude this chapter, it will be interesting to refer to the results of a *technology assessment and marketing project* conducted by Arthur Anderson and Company for the Greater Philadelphia Economic Development Coalition (Anderson Consulting, 1990). The project aimed to describe the advanced technology resources of the greater Philadelphia area, to compare these with other significant regions across the United States, and to develop suitable data to aid marketing and public relations initiatives. The project found that Philadelphia has significant quantifiable strengths in the health-related and materials spheres of technology, with the health-related sphere including

biotechnology. One of the regions with which Philadelphia was compared was New York/New Jersey. The results are therefore useful to indicate something of the comparative position of New York/New Jersey as well as that of Philadelphia; and while New York is not treated separately, its perceived competitiveness is reflected in the combined New York/New Jersey results.

The project studied the following seven factors, which it used as indicators of the relative status of the health-related technology spheres of eleven regions: the presence of advanced research institutions; the presence of major medical schools and teaching hospitals; access to patient populations for clinical trials; presence of other health-related ("pharmaceutical and biotechnical") companies; access to venture capital; access to financial contacts and resources; and, finally, access to government institutions. The 11 regions were Atlanta; Boston; Chicago; greater Detroit; Los Angeles; Minneapolis; New York/New Jersey; greater Philadelphia; Pittsburgh; Research Triangle, N.C.; and greater Washington, D.C. (For some reason, presumably because it would have given too strong an emphasis in the study to California, the San Francisco Bay Area was not included.) For each of the regions, the project constructed a "relative quantitative ranking" based upon objective measures of the seven health-related factors, and a "perceptual attractiveness ranking" based upon a survey of executives in health-related companies across the eleven regions.

New York/New Jersey ranked first in the "relative quantitative ranking" for all the factors except access to government institutions (for which Washington, D.C., ranked first). According to the "perceptual attractiveness ranking," New York/New Jersey ranked first for access to patient populations for clinical trials; presence of other health-related ("pharmaceutical and biotechnical") companies; access to venture capital; and access to financial contacts and resources. It ranked second (behind Boston) for presence of advanced research institutions, and presence of major medical schools and teaching hospitals; and it ranked equal second with Philadelphia for access to government institutions.

Thus, according to the project, New York/New Jersey is the strongest region overall of the 11 regions in the health-related technology sphere. The project's results also revealed that New York/New Jersey does less well from the point of view of the *perceptions of executives* than it does according to various objective measures. This accords with the evidence surveyed earlier in this chapter that suggested that New York's biotechnology industry (the majority of which is oriented towards the health-related sphere) is not disadvantaged by being located in New York to the extent popularly thought. On the contrary, when a wide range of pertinent locational factors are taken into account, including factors other than those related to pure biological research, the region turns out to be quite attractive for commercial biotechnology.

Chapter Seven

The Dynamics of Biotechnology Competitiveness in New York

The previous chapter examined the various locational factors in New York that appear plausible as determinants of the state's competitiveness in commercial biotechnology. It was found that features of New York commonly touted as constraints on the growth of the biotechnology industry —such as the cost of doing business and the regulatory environment— are perceived as problems by many of the dedicated biotechnology businesses. It appeared unlikely, however, that these two factors are decisive influences on the industry. In other words, while they are important factors to be considered, they do not appear to be dynamic variables in the total process of biotechnology industry development. Accordingly, they should not be given too much prominence in the strategies of individual businesses or public economic-development agencies.

What Drives the Competitiveness of New York's Biotechnology Businesses?

If external locational factors are not key forces underlying the dynamics of the biotechnology industry, what then are? Drawing upon research about commercial biotechnology elsewhere (Willoughby & Blakely, 1990), and upon evidence identified earlier in this report, the following explanatory perspective is suggested.

If biotechnology businesses have emerged locally in New York, created from within existing local institutions by local people, and with roots in local institutions and local networks for communicating knowledge and expertise, then those institutions and networks may be seen as the essential foundation for the industry. The emergent biotechnology businesses therefore draw upon those local institutions and networks for knowledge, people, specialized facilities, business and scientific contacts, and other kinds of resources; and the local milieu that has acted as a seed-bed for the new enterprises must continue to provide a fertile soil with which to nurture them. In other words, the capacity of a local biotechnology industry to thrive depends upon how well it maintains the vitality of its relationships with the community of people and organizations from which it emerged in the first place.

One implication of this perspective is that if a biotechnology business is strongly embedded in the local biotechnology milieu, and if it has cultivated human and institutional links within that milieu that are both rich and deep, then it is likely also to have cultivated strong enough capabilities to enable it to transcend the constraints imposed by the "problems" of the region or locality.

For example, its communication with university research groups, its liaison with other biotechnology businesses, its ability to employ specialized instrumentation or software due to

association with local technical suppliers, or its links with customers such as pharmaceutical companies may give a business the capacity to innovate more rapidly than its competitors. This higher speed of innovation may be translated into a reduction of the total cost of developing a product (despite paying high wages or high rent), and an early positive revenue stream. In the same way, a business may be able to locate sources of investment capital on better terms and more rapidly than others. The total effect of these advantages may mean that strong "embeddedness" in the local biotechnology milieu can lead to enhanced performance and enhanced access to resources sufficient to ensure that locational problems (e.g., costs and regulations) may be treated as non-critical, even though they may be very real. Some firms manage to become competitive in the face of severe locational problems, and some do not.

The cardinal management skill, according to this perspective, is therefore not necessarily that of applying the "accountant's razor" to cut costs, but that of finding ways in which a business may cultivate competitive capabilities in the face of high resource costs and regulatory constraints. One way to mobilize such competitive capabilities is through facilitating better communication and collaboration within the local biotechnology milieu. This chapter explores evidence collected during this study that tests the fruitfulness of this approach.

Communication, Collaboration, and Performance

At the heart of this perspective — the "technological milieu" perspective— is the idea that the relative performance of biotechnology businesses is dependent primarily upon their patterns of inter-organizational communication and collaboration, rather than upon external locational factors such as the cost of doing business or the attractiveness of the regulatory environment.

In order to explore this idea in New York, it has been necessary to employ some kind of analytical construct to measure the performance of the state's biotechnology industry. A variety of indicators could be used for this purpose, including: the industry's prestige within the scientific community, the number of patents its members have produced, the number of scientific papers they have published, the level of formal qualifications of the industry's employees, the number of "scientific breakthroughs" reported in the news media, or the number of end-products that have successfully entered the market. All of these performance measures, as well as others, could be used legitimately to provide insights into the nature of the industry, to compare the relative performance of its members, or to make comparisons with local biotechnology industries elsewhere. However, because this study is concerned with the *economic* dimension of New York's biotechnology industry, primary attention has been placed upon documenting *commercial performance* as an aspect of overall performance.

The main construct used in this study as a measure of the commercial performance of individual businesses, for reasons of logical relevance, wide scope of applicability, and feasibility of data collection, has been the *annual rate of revenue growth* (Annrev). The figures used here for the

annual rate of revenue growth were produced from data collected directly from the businesses that were interviewed as part of the study. Because the data for many of the businesses were obtained under promises of confidentiality, and to ensure that information about individual organizations has not been revealed, only figures aggregated across groups of businesses have been presented here.

To explore the role of inter-organizational relationships as influences on the commercial performance of biotechnology businesses, each of New York's businesses interviewed in this study was asked a series of questions about both its *informal communication* and *formal collaboration* during the previous year with various types of organizations: other biotechnology businesses, universities and other research institutions, hospitals and other health care institutions, pharmaceutical corporations, specialized suppliers of instrumentation, equipment, software and technical services, and other types of organizations. Data in response to these questions were collected for organizations located in three geographical categories: the same local region within New York State as the business, elsewhere in the United States (including non-local parts of New York), and in foreign countries.

These data were then aggregated to construct eight indices of inter-organizational communication and collaboration:

- Index of Informal Communication (IIC)
- Index of Formal Collaboration (IFC)
- Index of Local Informal Communication (ILIC)
- Index of Local Formal Collaboration (ILFC)
- Index of National Informal Communication (INIC)
- Index of National Formal Collaboration (INFC)
- Index of International Informal Communication (IIIC)
- Index of International Formal Collaboration (IIFC)

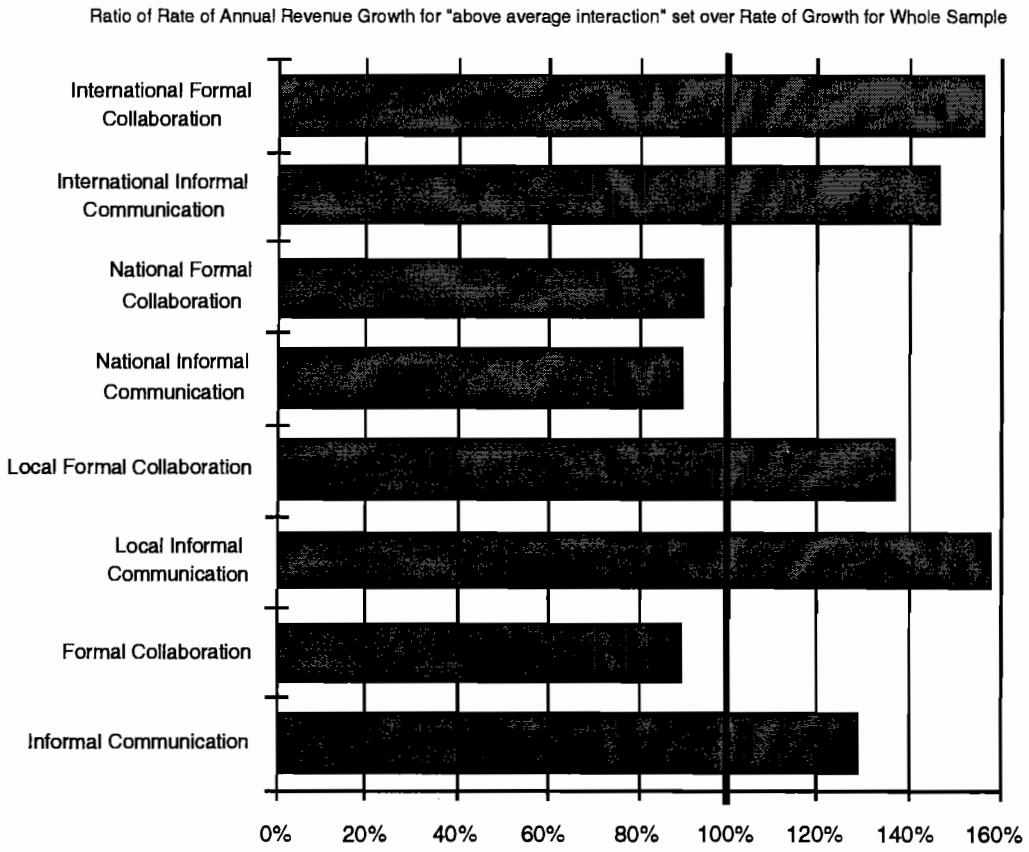
For each of the eight indices, the set of dedicated biotechnology businesses with an above-average score for the index was selected, and the mean annual rate of revenue growth for that set was calculated. This figure was then compared with the mean annual rate of revenue growth for the whole sample of businesses in the survey. These calculations allow exploration of the possible relationship between commercial performance and propensity for communication or collaboration. The results of this exercise are summarized in Figure 7.1.

Figure 7.1 reveals that businesses with above-average levels of informal communication with other organizations (of a variety of types) achieve above-average rates of revenue growth. It also reveals that higher performance levels are associated with higher levels of *informal communication* with other organizations more than with higher levels of *formal collaboration* with other organizations.

The figure also shows that the international and local arenas are more significant than the national arena in this respect. Those biotechnology businesses with above-average levels of *local* informal communication with other organizations (i.e., within the same sub-region of New York State)

Figure 7.1

Inter-organizational Relationships and Economic Performance



Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), 1991; © K.W. Willoughby 1991.

on average achieve the highest annual growth rates in their revenue. Likewise, those businesses with above-average levels of *local* formal collaboration achieve above-average revenue growth rates. A similar pattern exists for those businesses exhibiting above-average levels of both *international* informal communication and *international* formal collaboration with other organizations.

Figure 7.1 is therefore consistent with the insights presented earlier as part of the "technological milieu" perspective. The surprising result, however, is the concurrence of high levels of inter-organizational relationships (and associated strong performance) at the international and local levels, while those businesses emphasizing national linkages tend to exhibit lackluster performance. In other words, strong biotechnology businesses tend to be simultaneously *global* and *parochial* in their outlook. Local embeddedness and global connectedness do not need to be traded-off against each other as alternative strategic orientations of firms, but appear to be associated with each other.

The association between high revenue growth rates and high levels of inter-organizational relationships, which appear quite robust in Figure 7.1, were tested statistically to see whether a likely causal link between the latter and the former could be discerned. A series of regression equations were constructed to explore the likely causal relationship between Annrev (as the dependent variable) and the following communication and collaboration variables (as independent variables): Index of Local Informal Communication, Index of Local Formal Collaboration, Index of International Informal Communication, Index of International Formal Collaboration, Index of National Informal Communication, and Index of National Formal Collaboration.

The basic conclusion that can be drawn from these analyses is that there is a very strong case for claiming causal links between the independent variables and the dependent variable (for details see Willoughby, 1992). The statistical strength of the association varies between individual indices and according to how they are combined in the regression equations, but it is confirmed in all cases. The exceptions, of course (as expected from the evidence in Figure 7.1), are the indices of communication and collaboration in the national arena (INIC and INFC); for these variables, even with extremely high error levels, there is no statistically discernible causal relationship or association.

This general conclusion may be amplified with the following observations and comments.

The statistically discernible causal relationship may be observed for each of the four basic independent variables individually (ILFC at 5 percent error level, ILIC at 5 percent error level, IIIC at 10 percent error level, and IIFC at 10 percent error level), but the strength of the relationship increases when the variables are combined, especially when they are combined in such a way as to take into account possible interactions between the variables. Most of the regression equations that incorporate interactions between the variables achieve statistically significant results at the 1 percent error level (i.e., with a 99 percent confidence interval) or better.

When the variables are combined as interacting pairs, the most important independent paired-variable appears to be the combination of ILIC and ILFC. The results from a regression equa-

tion using only this combined variable ("ILIC*ILFC") as a predictor for Annrev are significant at the 1 percent error level. The equivalent equation using IIIC and IIFC achieves significant results only at the 5 percent error level. This suggests that, while both the local and international relationships are significant determinants of performance, the local relationships are of primary importance.

A more complex and comprehensive model — which incorporates interactions between informal and formal relationships in the local arena ("ILIC*ILFC"), informal relationships in the local and international arenas ("ILIC*IIIC"), formal relationships in the local and international arenas ("ILFC*IIFC"), informal and formal relationships in the international arena ("IIIC*IIFC"), and interactions between all four of the individual variables combined ("ILFC*IIFC*ILIC*IIIC")— achieves statistically significant results at much better than the 0.1 percent error level (i.e., with a confidence interval greater than 99.9 percent). This latter model also achieves a high correlation coefficient (almost 0.8) and a high coefficient of determination (almost 0.6). The details of this latter model and of the statistical tests are presented in Table 7.1. The results of the causal modeling exercise, in other words, mean that there is virtually no probability that the businesses in Figure 7.1 that exhibit high performance in revenue generation have not achieved this as a consequence of high levels of communication and collaboration with other organizations locally and internationally.

In conclusion, the main argument here may be extended with the observation that the measures used in this study as indicators of the inter-organizational relationships of New York's biotechnology businesses tend to be manifested in the form of a syndrome. That is, while each individual form of communication or collaboration tends to contribute positively to commercial performance, the strength of this contribution is increased markedly when more than one, and preferably all, of these four categories of communication and collaboration are present simultaneously— even though not all of them always make the same significant contribution under all circumstances. This suggests that biotechnology businesses wishing to improve their commercial performance will probably benefit from any effort to increase communication or collaboration locally or internationally —but that greatest improvements will be experienced when local, international, formal, and informal categories of inter-organizational relationships are pursued concurrently.

Communication, Collaboration, and Locational Factors

To investigate whether or not the locational factors covered in Chapter Six play a significant role alongside communication or collaboration factors in determining the relative performance of the biotechnology businesses, a similar exercise to the one just described was conducted for the two locational advantage indices discussed in the previous chapter.

The sets of dedicated biotechnology businesses with above-average scores for each of the eight communication or collaboration indices were selected. The mean Index of Locational Advantage of New York for Research and Development in biotechnology (ILANYRD) and the mean Index of

Table 7.1
Communication, Collaboration and Commercial Performance; Model of Determinants of Rate of Revenue Growth

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General Form of Regression Model:

$$Y = \beta_0 + \beta_1 X + \beta_2 Z + \beta_3 W + \beta_4 V + \beta_5 XZ + \beta_6 XW + \beta_7 ZV + \beta_8 VW + \beta_9 XZVW + e$$

N: 48 (18 CASES DELETED DUE TO MISSING DATA)
MULTIPLE R: 0.769
SQUARED MULTIPLE R: 0.591
ADJUSTED SQUARED MULTIPLE R: 0.494
STANDARD ERROR OF ESTIMATE: 116.80

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	749068.36	9	83229.82	6.10	0.00003
RESIDUAL	518389.55	38	13641.83		

Critical F(.001) = 3.87

Key to Variables

ANNREV = annual rate of revenue growth ("Y")
ILIC_C = index of local informal communication, centered ("X")
ILFC_C = index of local formal collaboration, centered ("Z")
IIIC_C = index of international informal communication, centered ("W")
IIFC_C = index of international formal collaboration, centered ("V")

Note: in this model the four indices of communication and collaboration were transformed into centered variables before being computed in the regression equation. The variables were centered by subtracting the average value of the non-transformed variable from each individual observation. Each transformed observation therefore became the deviation from the mean of the non-transformed variable. This procedure virtually eliminates multicollinearity between the product variables and the lower order single variables in the equation [Aiken and West, 1991].. The calculations were performed using the Systat Version 5 statistics package.

Locational Advantage of New York for Manufacturing in biotechnology (ILANYMF) were then calculated for each of the eight sets. These figures were then compared with the mean ILANYRD and ILANYMF for the whole sample of businesses in the survey. The results are set out in Table 7.2.

The results in Table 7.2 show that, in general, those businesses engaged in relatively high levels of communication and in collaboration with other organizations do not have a correspondingly high tendency to perceive New York as an advantageous location for either research and development or manufacturing (if anything, the opposite appears to be the case). In other words, the tendency to make a positive assessment of the location in which a business is located should not be seen simply as a reflection of a business's general propensity for "openness" or "interactiveness." This leads to the conclusion that the positive commercial performance associated with high levels of communication and collaboration is probably more than an indirect effect of objective external locational factors.

Those businesses with above-average levels of *local* inter-organizational relationships, however, do exhibit a more positive assessment of the attractiveness of New York as a location, as is also revealed by Table 7.2. This suggests that open inter-organizational relationships between biotechnology businesses *within* a city or sub-region make that place more attractive to those organizations than it otherwise would be. The fact that the pattern is stronger in the case of local formal collaboration than it is in the case of local informal communication suggests that the positive assessment managers of a business make about their location is probably determined more by the *actual presence* of other organizations with capabilities complementary to those of their own, than by the communicative propensity of the managers. The predisposition people in some businesses may have for interacting with people in other businesses may amplify their perceptions of the attractiveness of their location for doing business, but it is not the prime driver of that perceived attractiveness.

Thus, the intrinsic advantageousness of a place as a location for commercial biotechnology activities (i.e., the "objective" external conditions, such as regulations, costs, local availability of resources, et cetera), while obviously very important, does not appear to be a primary determinant of the commercial performance of biotechnology businesses. Rather, the propensity of businesses to interact with other organizations, both locally and internationally, appears to drive relative performance. In the case of local interactions, it also appears to enhance the perceived attractiveness of the place. This may be because high levels of local inter-organizational relationships actually form part of the "objective" conditions in which businesses operate.

In short, the locational advantage indices in Table 7.2 tend to affirm rather than undermine our main argument about inter-organizational relationships and commercial performance. To confirm this, multiple regression and analysis-of-variance were carried out on the relationship between ILANYMF (dependent variable) and the Index of Local Formal Collaboration (ILFC) and the Index of Local Informal Communication (ILIC) (independent variables) with ILFC and ILIC included sepa-

Table 7.2

Effect of Communication and Collaboration on Performance of Biotechnology Businesses, New York, 1991

Type of Index	*Ratio of variable for "sample with index score above mean" over variable for "whole survey sample"*					
	(1990-1991) Annual growth rate Revenue	(1990-1991) Annual growth rate Expenditure	(1990-1991) Annual growth rate Employment	(1986-1991) Annual growth rate Employment	ILANYRD	ILANYMF
Informal Communication	130%	124%	82%	55%	81%	100%
Formal Collaboration	90%	27%	94%	49%	85%	91%
Local Informal Communication	159%	61%	80%	98%	107%	122%
Local Formal Collaboration	137%	64%	67%	81%	122%	135%
National Informal Communication	90%	45%	86%	121%	81%	87%
National Formal Collaboration	94%	139%	98%	91%	74%	104%
International Informal Communication	147%	148%	110%	126%	59%	43%
International Formal Collaboration	157%	155%	84%	117%	33%	52%

"ILANYRD" = Index of Locational Advantage of New York for Research and Development (in Biotechnology)

"ILANYMF" = Index of Locational Advantage of New York for Manufacturing (in Biotechnology)

rately, together, and as interacting variables. This was repeated using ILANYRD as the dependent variable (for details see Willoughby, 1992).

In none of the cases was there a statistically discernible causal relationship between the variables; and in all cases both the correlation coefficient and the coefficient of determination were zero or near-zero. Even when the analysis sample was restricted to those businesses which recorded above-average levels of ILFC or ILIC, there was no statistically discernible relationship. Thus, the dynamic "competitive" variables (communication and collaboration) appear to be independent of the perceived locational advantage of a place. The apparent association at the local level is probably either coincidental or extremely indirect.

To further examine the legitimacy of the conclusions to be drawn from these relationships, similar statistical tests were conducted between annrev as the dependent variable and a number of other variables which reflect objective external locational factors (for details see Willoughby, 1992). These results will now be discussed.

In addition to the overall indices of locational advantage for New York (ILANYRD and ILANYMF), the following factors were tested as independent variables: REGSTRAT (an indicator of whether or not a business has ever changed its strategy or decided against developing certain products because of concerns over public regulations); REGERDB (an indicator of how advantageous or disadvantageous businesses view the regulatory environment of their location in New York for research and development); REGEMFB (an indicator of how advantageous or disadvantageous businesses view the regulatory environment of their location in New York for manufacturing); COSTRDB (an indicator of how advantageous or disadvantageous businesses view the cost of doing business in their location in New York for research and development); and COSTMFB (an indicator of how advantageous or disadvantageous businesses view the cost of doing business in their location in New York for manufacturing).

The analyses demonstrated, in summary, that the above indicators of locational conditions for commercial biotechnology activities are not significant determinants of the commercial performance of New York's biotechnology businesses (as measured by the rate of revenue growth). For all of the variables, the coefficients of determination were zero or miniscule; and, except for REGSTRAT and REGERDB, there was no statistically discernible evidence at all for causal links between the independent and dependent variables. In the case of REGSTRAT and REGERDB, evidence for determination between the independent and dependent variables appears only at the 25 percent error level. This suggests that the local regulatory environment *vis-à-vis* research and development might play some role in determining the overall performance of the biotechnology businesses; however, this is, at best, very weak, and probably not important. In any case, these latter two regulatory-related variables are clearly insignificant when compared to the variables indicating local and international relationships between organizations.

In summary, we may conclude that there is statistically significant evidence to support the argument that the relative commercial performance of New York's biotechnology businesses is determined primarily by the relative levels of informal communication and formal collaboration with other organizations both within New York State and internationally.

Communication, Collaboration, and Organizational Type

The factual information presented in this chapter so far was produced by aggregating data on the inter-organizational relationships of New York's biotechnology businesses across all of the following types of organizations: other biotechnology businesses, universities and other research institutions; hospitals and other health care institutions; pharmaceutical corporations; specialized suppliers of instrumentation, equipment, software and technical services; and other types of organizations. Table 7.3 sets out data on the percentage of biotechnology businesses which engaged in important interaction with each of the six organizational categories.

The most significant observation we may draw from Table 7.3 is that, in every organizational category, the geographical bias in the inter-organizational relationships of the whole sample of biotechnology businesses is the opposite of that exhibited by the set with above-average commercial performance (as illustrated in Figure 7.1). The biotechnology industry *as a whole* in New York emphasizes communication and collaboration with organizations elsewhere in the United States (other than the locality where the business is based), whereas the *high-performance businesses* emphasize local and international communication and collaboration.

The one area where this reverse pattern is not so marked is the interaction between biotechnology businesses and hospitals. The percentage of businesses engaged in important informal communication or important formal collaboration with *local* hospitals in New York is very similar to the percentage that did so with hospitals elsewhere in the United States. On the positive side, this reflects the size and strength of the health-care industry in New York; on the negative side, given the prominence of the state's hospital system, the fact that the level of local interactions between them and the biotechnology industry is not greater raises cause for concern.

The following proposition results from the foregoing analysis. *While some biotechnology businesses in New York thrive because they are embedded in the local biotechnology milieu, combined with a global orientation, the majority underplay these factors in their behavior, which reduces the composite performance of the industry below its potential. It follows that to improve its competitiveness with the biotechnology industry in other places, the New York biotechnology industry needs to enhance its inter-organizational relationships both within the local regions and internationally.*

Table 7.3 shows that the organizational group with which New York's dedicated biotechnology businesses tend to have the strongest interactions are the universities and research institutions,

Table 7.3

Communication and Collaboration between New York Biotechnology Businesses and Other Organizations, 1991

(Percentage of businesses which engaged in each category of inter-organizational relationship during the previous year)

Type of Relationship	Biotechnology Businesses	Universities & Research Inst.	Hospitals	Pharmaceutical Companies	Technical Suppliers	Other Organizations	*Index (0-100) All Org. Types*
Informal Communication (General)	82%	94%	57%	65%	66%	45%	*68*
Formal Collaboration (General)	63%	78%	37%	45%	45%	42%	*52*
Local Informal Communication	42%	72%	46%	29%	35%	23%	*41*
Local Formal Collaboration	22%	57%	34%	17%	18%	14%	*27*
National Informal Communication	75%	80%	48%	58%	57%	31%	*58*
National Formal Collaboration	55%	66%	32%	42%	40%	32%	*45*
International Informal Communication	30%	46%	26%	35%	22%	17%	*31*
International Formal Collaboration	31%	31%	12%	28%	11%	17%	*22*

Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), 1991.

followed by other biotechnology businesses. The importance placed upon biotechnology businesses over other institutions such as hospitals, pharmaceutical companies, and technical suppliers adds further weight to our emphasis in this study on local biotechnology industry clusters, rather than on simple notions of one-way technology transfer from universities and hospitals to commercial enterprises.

Table 7.4 shows how the effect of communication and collaboration on commercial performance varies between the different types of organizations with which biotechnology businesses interact. Each business was asked to indicate whether or not it had engaged in important interaction (formal collaboration and informal communication) with a range of organizations during the previous year. The mean annual rate of revenue growth for those which did against those which did not was then calculated for each organizational category. The results, shown in Table 7.4, demonstrate that the basic pattern observed in the aggregate (see Figure 7.1) also applies for all of the organizational categories. Businesses that engaged in inter-organizational communication or collaboration at the local level and the international level attained higher rates of revenue growth than those which did not interact with the following: other biotechnology businesses; universities and other research institutions; hospitals and other health care institutions; pharmaceutical corporations; and specialized suppliers of instrumentation, equipment, software, and technical services.

Communication, Collaboration, and the Development of the Industry

Having established the importance of inter-organizational communication and collaboration for the competitiveness of New York's biotechnology businesses, we should now briefly examine some of the implications of this for the development of the industry.

Table 7.5 lays out variations in the pattern of these relationships between size categories of the biotechnology businesses. It shows, first of all, that the large and top-tier businesses (which together account for 11 percent of the industry population) do not exhibit the general pattern apparent in the whole population; those firms with greater than 135 people do not increase their rate of revenue generation faster than the average.

The effect of communication and collaboration on the rate of revenue generation is greatest for the micro businesses (five or less people) and for businesses in the small to mid-size categories (26 to 135 people). In other words, it appears most important for start-up firms and for those making a transition from early-stage stability into major growth (such as is often found in firms that decide to become public companies). The importance of this for policy is that the "communication and collaboration" factor is most critical for a community that intends to strengthen the local biotechnology industry through a strategy of nurturing the growth of local firms than it is for one that aims to encourage mature firms to relocate. In Chapter Three it was shown that New York's biotechnology

Table 7.4

Communication, Collaboration and Rate of Revenue Growth; Variations between Organizational Categories, 1991

(Mean annual-rate-of-revenue-growth [ANNREV] by whether or not businesses engaged in each category of inter-organizational relationship during the previous year)

Mean ANNREV for sample = 70%

Organizational Category	Biotechnology Businesses		Universities & Research Inst.		Hospitals		Pharmaceutical Companies		Technical Suppliers	
Type of Relationship	engaged? yes	no	engaged? yes	no	engaged? yes	no	engaged? yes	no	engaged? yes	no
Informal Communication (General)	72%	55%	68%	86%	94%	38%	56%	90%	82%	47%
Formal Collaboration (General)	58%	96%	85%	29%	67%	71%	32%	104%	94%	43%
Local Informal Communication	110%	38%	79%	50%	112%	36%	119%	55%	139%	35%
Local Formal Collaboration	109%	56%	98%	38%	124%	43%	179%	48%	173%	39%
National Informal Communication	71%	62%	74%	57%	103%	41%	61%	80%	65%	77%
National Formal Collaboration	60%	86%	86%	43%	124%	45%	74%	67%	76%	64%
International Informal Communication	106%	43%	99%	42%	187%	35%	88%	61%	92%	61%
International Formal Collaboration	148%	62%	148%	37%	281%	39%	101%	59%	165%	56%

Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), 1991.

Table 7.5

Communication, Collaboration and Rate of Revenue Growth; Variations by Size of Business, New York, 1991

Ratio of annual-rate-of-revenue-growth [ANNREV] for "sample with index score above mean" within each size range over ANNREV for "whole survey sample"						
Type of Index	Micro (1-5)	Mini (6-25)	Small (26-50)	Mid-size (51-135)	Large (136-299)	Top-tier (>299)
Informal Communication (general)	143%	64%	330%	134%	24%	20%
Formal Collaboration (general)	121%	89%	10%	204%	24%	20%
Local Informal Communication	121%	79%	434%	214%	56%	20%
Local Formal Collaboration	90%	91%	266%	260%	44%	20%
National Informal Communication	121%	50%	291%	26%	44%	20%
National Formal Collaboration	143%	74%	330%	36%	44%	20%
International Informal Communication	193%	96%	254%	157%	54%	20%
International Formal Collaboration	100%	74%	254%	184%	100%	20%

industry has been built primarily upon the growth of locally generated (and generally small) businesses; this makes the "communication and collaboration factor" particularly pertinent to New York.

Table 7.6 provides data to explore the question of whether the "communication and collaboration factor" is important to the maturation of the industry. It shows that for all eight indices, those businesses which score higher than average are more likely to remain in New York than those which do not. The level of communication and collaboration appears to have no bearing on the intentions of those businesses which have definitely decided to leave New York, but appears significant for those which are undecided about whether they intend to remain in the state.

Thus, the strengthening of a culture of communication and collaboration— emphasizing the local and global arena —appears critical to the future development of the industry. It would enhance the performance of start-up and transitional firms, and increase their likelihood of remaining in New York once they reached maturity.

One final question that might be posed about the future growth of the industry is whether or not a trend towards New York's dedicated biotechnology businesses being bought by larger established companies (a national trend) might limit the propensity of the businesses to communicate or collaborate with other organizations, and thereby impede the overall growth and performance of the industry. To explore this, the indices of communication and collaboration were cross-tabulated against the corporate status of the businesses. The mean score for each index was calculated for both the discrete biotechnology businesses and the non-discrete biotechnology businesses (i.e., those which are part of another organization), and the results are summarized in Table 7.7.

Table 7.7 shows that the above fear is unfounded. Discrete biotechnology businesses actually exhibit lower levels of informal communication and formal collaboration with other organizations. Being part of a larger organization does not appear, in biotechnology, to dampen inter-organizational flows of information, and other forms of inter-organizational connection.

In conclusion, this chapter has shown that the propensity of New York's biotechnology businesses to engage in communication and collaboration with complementary organizations, and to pursue a strategy of simultaneous "local embeddedness" and "global connectedness," is likely to significantly influence relative commercial performance. The question the next chapter will address concerns the potential for local economic benefits to be captured within New York from the development of the state's commercial biotechnology sector.

Table 7.6

Communication, Collaboration and Likelihood of Remaining in New York

(Percentage of Dedicated Biotechnology Businesses Likely to Remain in New York)

Type of Index	Will remain in New York		Will not remain in New York		Might remain in New York	
	Index > mean? yes	no	Index > mean? yes	no	Index > mean? yes	no
Informal Communication (General)	92.9%	73.0%	7.1%	5.4%	0.0%	21.6%
Formal Collaboration (General)	85.7%	78.4%	7.1%	5.4%	7.2%	16.2%
Local Informal Communication	90.3%	73.5%	6.5%	5.9%	3.2%	20.6%
Local Formal Collaboration	93.8%	69.7%	3.1%	9.1%	3.1%	21.2%
National Informal Communication	86.1%	75.9%	8.3%	3.5%	5.6%	20.7%
National Formal Collaboration	88.2%	74.2%	5.9%	6.5%	5.9%	19.4%
International Informal Communication	90.6%	72.7%	6.3%	6.1%	3.1%	21.2%
International Formal Collaboration	90.9%	76.7%	4.6%	7.0%	4.5%	16.3%

Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), 1991.

Table 7.7

Communication, Collaboration and Corporate Status of Biotechnology Businesses

Type of Index	Mean Score for Index (theoretical min = 0; theoretical max = 100)	
	Discrete Biotechnology Businesses	Non-discrete Biotechnology Businesses
Informal Communication (General)	66	78
Formal Collaboration (General)	50	62
Local Informal Communication	39	53
Local Formal Collaboration	25	38
National Informal Communication	55	73
National Formal Collaboration	42	60
International Informal Communication	28	43
International Formal Collaboration	20	33
Locational Concern for Research & Development	42	55
Locational Concern for Manufacturing	41	51
Spatial Concentration of Business	89	82

Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), 1991.

Chapter Eight

Biotechnology Clusters and Complementary Industries

The previous chapter analyzed the role of communication and collaboration patterns in determining the competitiveness of dedicated biotechnology businesses. This chapter explores the implications of that analysis for biotechnology-based regional economic development in New York. Whereas the previous chapter was concerned with what an individual business may do to improve its competitiveness, this chapter is concerned with what a community (e.g., one in a city or in a particular geographical region) may do to improve it competitiveness *vis-à-vis* biotechnology.

The Economic Development Potential of Biotechnology

Biotechnology may produce both direct and indirect economic development impacts. The direct impacts consist of the employment and wealth created by dedicated biotechnology businesses themselves. The indirect impacts consist of the "multiplier" effects in other industries and in the wider economy that flow on from the activities of dedicated biotechnology businesses.

The indirect economic impacts are potentially much larger than the direct impacts. However, the dimensions of the indirect economic impacts of biotechnology are not uniform across the industry because the multiplier effects depend upon the nature of the relationships between the dedicated biotechnology businesses and organizations in complementary industries.

As well as being the basis for an industry in its own right, biotechnology is also an *enabling technology* for other industries such as health care, pharmaceuticals, chemicals, agriculture, environmental management, or food processing. Because the techniques produced by the biotechnology industry are so pervasive in the scope of their potential applications, the future competitiveness of these complementary industries in particular communities will be limited by the degree of their mastery of biotechnology. Access to the knowledge, products, and expertise of biotechnology businesses will be a key to the mastery of biotechnology by organizations in complementary industries. The richness of links between biotechnology businesses and organizations in other industries will therefore be a key factor limiting the scale of multiplier effects from biotechnology.

Inter-organizational links are important for biotechnology-based economic development in two directions. The better the links between organizations in complementary industries (such as pharmaceuticals) and biotechnology businesses, the greater the capacity the former have for developing novel commercial applications for the new techniques. At the same time, the stimulus for technological innovation experienced by biotechnology businesses will be enhanced through richer exposure to the commercial opportunities and problems of other industries amenable to biotechnology solutions.

In principle, a company in a "downstream" industry (such as the waste treatment, food processing, or horticulture industry) may gain access to biotechnology from anywhere in the world, and from any kind of organization involved in biotechnology, whether in the commercial or public sector. The transfer of technology is not as simple as this suggests, however, because technology cannot be completely encapsulated in a "blueprint," a patent, or in a set of operating codes — or even in a physical product. Technology involves a tacit dimension, which may be embodied in the routines, unspoken traditions, or maintenance procedures of an organization, or in the informal knowledge in the minds of the people who developed the technology. It may also require specialized resources, materials, equipment, or skills available to the company that developed the technology but not readily available to the licensee of the technology, and of which few people are consciously aware (e.g., the materials from which storage containers are made, a customized item of instrumentation, or a supply of specialty biological inputs).

The successful transfer of the "unarticulated" and informal aspects of biotechnology will probably require extensive human interaction and extensive organizational interaction. Such interaction is normally facilitated by close physical proximity. Thus, from the point of view of "downstream" economic development from biotechnology, it is important for complementary industries to have access to *local* biotechnology organizations. In addition, as suggested by the previous chapter, the capacity of a company to utilize information from international sources appears to be mediated by its capacity to participate in *local* networks for the exchange of information.

From the point of view of *local economic development* in biotechnology, what matters is that there is a strong *local* presence of both dedicated biotechnology businesses and businesses in complementary industries, and that these interact in a healthy way to transfer both technology and the stimulus for the development of new technology. Thus, the stronger the demand by local complementary industries for biotechnology innovations from local biotechnology businesses, the stronger those local biotechnology businesses are likely to be. The stronger the local biotechnology businesses become, the higher the chance will be that businesses in complementary industries will be able to make significant advances in their activities based upon the application of biotechnology.

Economic growth "in general" is not of much use to particular communities— such as Long Island, Buffalo, or New York City— unless there is a *local manifestation* of that growth. **The local development of self-sustaining economic capacity (linked to biotechnology) requires a local network of dedicated biotechnology businesses and complementary organizations, including technical suppliers, customers, and organizations providing specialized support services.** The stronger and more vigorous such networks become, the greater the *direct* local economic impacts of biotechnology are likely to be, and, consequently, the *indirect* local economic impacts of biotechnology are likely to be stronger. A healthy local biotechnology industry network nurtures a

virtuous circle of feedback between direct and indirect local economic benefits from local biotechnology activities.

The evidence from Chapters Six and Seven suggests that the development of such a network would empower local biotechnology businesses to gain access to greater resources, markets, knowledge, and expertise, sufficient to nullify or severely mitigate negative locational factors.

The chief policy implication of the perspective just outlined is that initiatives ought to be strengthened in New York to build up the quality and intensity of interactions among New York's dedicated biotechnology businesses themselves, and with complementary industries upstream (technical suppliers), downstream (customers), and laterally (support services). The balance of this chapter presents information about the existing pattern of some of these relationships, and the potential which may exist in each of the nine biotechnology industry regions in New York for improvement.

The Emergence of Local Biotechnology Industry Networks in New York

Each New York biotechnology business interviewed was asked to indicate whether it had engaged in significant informal communication or significant formal collaboration during the previous year with a variety of types of organizations within the *same local region* in New York in which it was located. The results, aggregated within each of the nine biotechnology industry regions, are set out in Table 8.1.

Three of the biotechnology industry clusters in New York— New York City, Capital, and North —exhibited above-average levels of informal communication with other biotechnology businesses. Given the small number in the survey sample for the two upstate clusters, the high levels of communication among New York City businesses is the most significant. Within the Long Island cluster, which has almost double the number of dedicated biotechnology businesses as New York City, only 38 percent of the businesses engaged in significant informal communication with other biotechnology businesses, whereas 64 percent of the businesses in the New York City cluster managed to do so. This shows that the level of communication between biotechnology businesses is not a simple function of the number of businesses located nearby (i.e., of the size of the cluster) but of other factors such as the proclivity of the businesses to share information or to seek knowledge from outside sources.

The data in Table 8.1 also show that high levels of informal communication do not necessarily translate into high levels of formal collaboration between businesses. Industry clusters appear to have an important role in facilitating learning and the sharing of information, apart from facilitating inter-organizational transactions.

The difference between the intra-industry communicative behavior of the Long Island cluster and the New York City cluster points to the likely importance of the *geographical density* of a biotechnology industry cluster for enriching communication networks. The businesses on Long Island are

Table 8.1

Local Communication and Collaboration Between Biotechnology Businesses and Other Organizations, New York, 1991 Disaggregated by Local Region Within New York York State

(Percentage of businesses which engaged in each category of inter-organizational relationship during the previous year)

Other Organizations	Type of Relationship	NYC	LI	LH	UH	CAP	NO	MW	BUF	ST	NY State
Biotechnology Businesses	Local Informal Communication	64%	36%	38%	20%	75%	100%	0%	43%	20%	42%
	Local Formal Collaboration	18%	18%	13%	0%	75%	100%	50%	14%	20%	22%
Universities & Research Inst.	Local Informal Communication	82%	64%	63%	60%	75%	100%	100%	86%	80%	72%
	Local Formal Collaboration	73%	55%	75%	20%	75%	0%	100%	43%	40%	57%
Hospitals & Health Care Inst.	Local Informal Communication	55%	55%	25%	20%	25%	0%	100%	71%	20%	46%
	Local Formal Collaboration	55%	27%	25%	20%	25%	0%	100%	57%	0%	34%
Pharmaceutical Corporations	Local Informal Communication	18%	32%	38%	0%	50%	0%	50%	29%	40%	29%
	Local Formal Collaboration	9%	18%	0%	0%	75%	0%	0%	29%	20%	17%
Technical Suppliers	Local Informal Communication	27%	36%	38%	0%	50%	100%	50%	57%	20%	35%
	Local Formal Collaboration	9%	18%	0%	0%	50%	100%	50%	14%	40%	18%
Other Organizations	Local Informal Communication	9%	14%	25%	20%	0%	100%	100%	14%	80%	23%
	Local Formal Collaboration	9%	5%	13%	0%	0%	100%	100%	0%	60%	14%

geographically more diffuse than those in New York City, and this may reinforce a sense of isolation and independence among the members of the cluster. In view of the high population of biotechnology businesses on Long Island, the data in Table 8.1 suggest that there is great scope for increased communication between biotechnology businesses in that cluster. If geographical dispersion is the primary reason for the relative paucity of inter-business communication, this might be mitigated through institutional mechanisms such as an expanded program of local industry meetings sponsored by an organization such as a local branch of the New York Biotechnology Industry Association, or through the establishment of a biotechnology park associated with a university or hospital.

The New York City cluster exhibits above-average levels of significant informal communication with local universities and research institutions. In addition, almost three-quarters have also engaged in significant formal collaboration with universities and research institutions. Long Island, in this category too, exhibits a below-average tendency for communication and collaboration; whether this is because of a conservative orientation towards communication, physical distance from relevant universities, or because of a lower density of researchers and laboratories in local universities, is not clear.

In general, New York's biotechnology businesses appear to associate more heavily with universities and other research institutions than with each other for information and significant transactions. Table 8.1 reveals that the state's universities and other research institutions have probably played a primary role in facilitating the growth of the biotechnology industry. The high levels of communication between these institutions and biotechnology businesses in the upstate clusters suggests that universities play an important role in compensating for the lower range of services, institutions, and networking opportunities found in non-metropolitan regions compared with metropolitan regions. The table also suggests that there is scope for enriching the network dimensions of the biotechnology industry clusters.

The hospitals and other health care institutions also play an important role in providing sources of information, services, expertise, and facilities for biotechnology businesses, with almost one-half of the state's biotechnology businesses having engaged in significant informal communication with them, and over one-third having engaged in significant formal collaboration with them. Interestingly, the highest use is made of hospitals and health care institutions by biotechnology businesses in the western region of the state (Buffalo and Mid-West), even though businesses in those clusters are less specialized towards health-care applications than those elsewhere.

The Long Island cluster exhibits a relatively low tendency to make formal use of the facilities and services of the hospitals on the Island. For most of the other clusters, there is reasonable parity between the tendency to communicate with people in the hospitals and the tendency to engage in formal collaboration with the hospitals. With the exception of the Long Island cluster (and ignoring the cluster in the Southern Tier, which appears to have little association at all with local hospitals), it appears that universities have a primary function as sources of information and ideas for the bio-

technology businesses, while hospitals play a relatively important role in the provision of services and facilities (presumably mostly for the conduct of clinical trials).

A fascinating insight which may be culled from Table 8.1 is that specialized technical suppliers to dedicated biotechnology businesses should not be seen just as purveyors of equipment and materials, but rather as sources of technical expertise — although the importance of this function seems to vary between the metropolitan and upstate clusters. In New York City, Long Island, Lower Hudson (and also Buffalo — a "mini" metropolitan region), informal communication far outweighs formal collaboration in the interactions of the businesses with technical suppliers. Presumably, biotechnology businesses in these clusters confront technical problems in their work, the solution of which involves input from people employed within the technical supplies firms. Most of the non-metropolitan biotechnology businesses, on the other hand (with the exception of those in Upper Hudson), appear to rely more heavily on joint ventures and various formalized transactions or alliances with technical suppliers rather than upon informal learning and assistance from them.

Finally, the relatively low percentage of businesses engaged in significant communication or collaboration with organizations in the "other" category indicates that the first five organizational categories cover most of the important areas of interaction. The potential for building up stronger biotechnology industry clusters in each of the nine regions, each one specialized in the character of the networks it forms with local complementary industries, will now be examined.

Biotechnology and the Health Care Industry in New York

A recent study produced for the Greater New York Hospital Foundation, Inc. (Aries, 1990: 99) observed that while New York City has a large biomedical complex, its success at generating private companies to further develop the new biomedical technologies and sciences is weak. The explanation offered by the report for this situation is interesting: "More than one company doing biotechnology work in New York finds it hard to do business in this city. The reasons given were not those of space or urban services, as initially suspected, but the somewhat distant relationships with the New York biomedical community" (Aries, 1990: 113-114).

The data in Table 8.1 show that biotechnology businesses in the New York City cluster actually exhibit above-average levels of interaction with local hospitals and health care institutions compared with those in other New York clusters (although this distinction is weaker in the case of universities). Compared with leading biotechnology industry clusters outside New York state, however, these levels appear to be relatively low. The Greater New York Hospital Foundation report, for example, concluded (Aries, 1990: 114-115):

> The working relationships of firms in Boston/Cambridge with their local university affiliated scientists appear to be much closer than similar relationships in New York. The concrete examples of this are the mutual scientific peer group meetings, and university assistance in providing small companies with space. In addition,

> though less tangible, a sense of cooperation, acceptance, and eagerness on the part of the private sector to be involved in the intellectual ferment of the local academy seemed to exist in Boston and Cambridge, but was not evident in the New York City interviews.

This conclusion accords with the conclusions of the previous two chapters in this report— greater communication and collaboration leads to greater competitiveness.

The majority (63 percent) of New York state's dedicated biotechnology businesses are oriented primarily towards the health care market, which means that enriching interactions with local institutions in the health care industry is likely to provide considerable scope for improving the vitality of local biotechnology industry clusters. Table 8.2 provides a range of data about the health services industry in New York, disaggregated by each of the nine biotechnology industry regions.

By the beginning of the 1990s, the health services industry in New York state directly employed over three-quarters of a million people, almost half of whom were employed in hospitals. Almost half a million health services employees were located within the three metropolitan biotechnology industry regions (New York City, Long Island, Lower Hudson), with New York City itself accounting for over 42 percent of the state total. The health services industry consisted of over 31,000 establishments (places of employment—labeled "units" in Table 8.2), over 300 of which were hospitals. Direct employment in the industry accounted for 10.3 percent of total employment (excluding public administration), with the total number being 64 percent greater than in 1975. To put it mildly, the health services industry in New York is big! It may also be viewed as an underutilized resource for the biotechnology industry.

The greatest proportion of dedicated biotechnology businesses that have engaged in significant informal communication with hospitals and health care institutions, according to Table 8.2, may be found in the Buffalo and Mid-West clusters. In absolute terms, however, the greatest activity may be found in New York City and Long Island, which together account for 57 percent of the biotechnology businesses which engaged in such communication during the previous year (these two regions combined contain about 55 percent of the state's human population and 59 percent of business employment, excluding public administration). They also account for about 57 percent of the biotechnology businesses which have built formal ties with hospitals and other health care institutions.

Biotechnology businesses in Long Island have a much lower tendency than those in New York City, Mid-West, and Buffalo to translate informal communication into formal collaboration with hospitals and other health care institutions. This may be because the links within the Long Island cluster are primarily to do with scientific communication and ideas rather than to conduct clinical trials and practical programs, but it might also reflect the possibility that hospitals on Long Island are not as attractive to biotechnology businesses as those located elsewhere, or simply that researchers in commercial biotechnology organizations in Long Island have strong associations with hospitals outside the region for long-term historical reasons.

Table 8.2

The Biotechnology Industry and the Health Care Industry in New York, 1991
Basic Data and Relationships Disaggregated by Local Regions within the State

Region	NYC	LI	LH	UH	CAP	NO	MW	BUF	ST	NY State
Total Population of Dedicated Biotechnology Businesses (1991)	16	28	12	5	6	4	4	8	7	90
Number of Biotechnology Businesses in Survey Sample (1991)	12	22	8	5	4	1	2	7	5	66
Estimated Local Employment in Biotechnology Businesses (1991)	527	826	981	281	99	432	318	544	73	4081
Biotechnology Industry Employment Density Index (1991)	0.29	1.47	3.73	1.69	0.54	1.25	1.02	2.00	0.49	1.00
Biotechnology Industry Firm Density Index (1991)	0.42	1.78	1.62	1.17	1.69	0.55	0.74	1.63	2.32	1.00
Biotechnology Businesses which Engaged in Informal (est. %)	55%	55%	25%	20%	25%	0%	100%	71%	20%	46%
Communication with Local Hospitals & Health Care Inst. (approx. #)	9	15	3	1	2	0	4	6	1	42
Biotechnology Businesses which Engaged in Formal (est. %)	55%	27%	25%	20%	25%	0%	100%	57%	0%	34%
Collaboration with Local Hospitals & Health Care Inst. (approx. #)	9	8	3	1	2	0	4	5	0	30
Number of Hospitals (1990)	89	36	31	24	19	40	38	29	32	338
Total Local Employment in Hospitals (1990)	164757	37681	22146	13245	17400	13566	23671	34115	21714	348295
Average Employment per Hospital (1990)	1851	1047	714	552	916	339	623	1176	679	1030
Total Number of Units in Health Services Industry (1990)	12066	6238	3029	1460	1288	2288	1873	1920	939	31101
Total Local Employment in Health Services Industry (1990)	329014	107970	58232	32598	38622	63978	56106	60196	29290	776020
Percentage of Health Services Units which are Hospitals (1990)	0.74%	0.58%	1.02%	1.64%	1.48%	1.75%	2.03%	1.51%	3.41%	1.09%
Percentage of Health Services Employment in Hospitals (1990)	50%	35%	38%	41%	45%	21%	42%	57%	74%	45%
Percentage Change in no. of Health Services Units (1975-1990)	17%	66%	46%	58%	38%	27%	26%	22%	8%	31%
Percentage Change in Health Services Employment (1975-1990)	57%	83%	72%	44%	78%	69%	69%	69%	53%	64%
Health Services Employment as % of Total Non-govt. empl. (1990)	9.7%	10.3%	11.9%	10.6%	11.4%	10.0%	9.7%	12.0%	10.6%	10.3%
Health Services Units as % of Total Non-government Units (1990)	6.1%	7.7%	8.0%	6.7%	7.1%	6.2%	6.7%	7.6%	6.1%	6.7%
Ratio of # Biotechnology Businesses over # Hospitals	18.0%	77.8%	38.7%	20.8%	31.6%	10.0%	10.5%	27.6%	21.9%	26.6%
Ratio of Biotechnology Employment over Hospital Employment	0.3%	2.2%	4.4%	2.1%	0.6%	3.2%	1.3%	1.6%	0.3%	1.2%

Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), 1991; assistance from Jim Panzer (Stony Brook, NY) for hospital data;
Primary data on health services industry provided by New York State Department of Labor, ES-202 Program, March 1991.

New York City has over twice the number of hospitals as Long Island, over four times the number of hospital employees, and over three times the total number of health services employees; a higher percentage of its health services units are hospitals. It is highly likely that hospitals provide a better resource for biotechnology activities than do non-hospital health services organizations, and that the usefulness of these resources is likely to rise as the size of the hospitals rises. The larger hospitals are more likely to develop specializations in medical research, and to develop a critical mass of researchers, facilities, and patients in each specialty, than would be the case for smaller hospitals. From this point of view, New York City presents the greatest potential resource for biotechnology businesses, with the largest number of hospitals, the largest population of hospital employees, and an average hospital size 180 percent of that across the whole state. Despite the slow growth in the population of New York City relative to other regions in the state during the last couple of decades, the number of health services employees in the City still grew by 57 percent over the 15 years to 1990.

The dominance of New York City in the hospital and health care sector may be one reason why biotechnology businesses on Long Island exhibit relatively low levels of collaboration with local hospitals: it is easier and more effective to make use of the large hospitals in the City than to cultivate collaborative arrangements with those in the suburbs. The same may be said of the Lower Hudson biotechnology industry cluster. There are communication and collaboration networks in biotechnology throughout the Greater New York metropolitan region which compensate somewhat for limitations in each of the local clusters. In the upstate clusters, however, the local networks appear to more important.

Interestingly, despite their upstate location, both of the Western New York regions (Buffalo and Mid-West) have sizeable health care industries in absolute terms (especially Buffalo, which is second only to New York City in its mean hospital size). Combined, they have about 35 percent the number of hospital employees of New York City, but 163 percent the biotechnology employment of New York City. Both of the Western New York biotechnology clusters (especially Buffalo) have significantly higher biotechnology industry density indices than New York City (see Appendix 4.1 for definitions of the indices), suggesting that those regions are better than New York City in *making use* of what resources are available in their local hospital sectors to fuel their emergent biotechnology industry clusters. In other words, the two Western New York regions are more efficient than New York City in generating biotechnology industry from the "soft infrastructure" available to them.

Table 8.2 suggests that there is considerable potential for Buffalo and the Mid-West to benefit economically in biotechnology by building on their hospital and health services sectors. The large average size of Buffalo's hospitals, the very high proportion of its health services workers employed in hospitals (57 percent), and the fact that it has the highest proportion of total employment in the health services sector of all the regions means that health care is a good complementary industry for biotechnology in that region. The very high levels of communication and collaboration with

hospitals and health care institutions exhibited by Buffalo's biotechnology businesses means that strong foundations for future growth have been established.

The Lower Hudson region has a very high proportion of its workforce in the health services sector and the largest single number of biotechnology personnel (not businesses) of all the regions; but its dedicated biotechnology businesses tend not to interact with local health services institutions very much.

To conclude, the health services industry in New York state is growing, with Long Island in particular showing a spectacular growth in employment of 83 percent over the 15 years to 1990. It is a great resource from which economic and technological stimulus for the biotechnology industry may be found —but the biotechnology clusters vary greatly in how well they take advantage of the resource. The New York City cluster has the greatest "health care resource base" upon which to draw, but the Buffalo biotechnology cluster makes the most efficient use of its local resource. Long Island is the location for the largest absolute number of local interactions with local hospitals, but its biotechnology cluster is less successful in translating communicative links into collaborations and alliances. The number of hospitals per biotechnology business on Long Island (1.28:1) is the lowest of all, however, compared with 3.76:1 for the whole state and 5.56:1 for New York City. Given the high growth rate in Long Island's population, and the high growth rate in health care and the biotechnology industry, however, the future for the industry in that cluster looks promising; nonetheless, it appears that more effective ties need to be formed between Long Island's health care institutions and biotechnology businesses.

Biotechnology and the Pharmaceuticals Industry in New York

The pharmaceuticals industry is presently a dominant outlet for biotechnology products, and despite the continual emergence of novel biotechnology applications outside health care, most commentators expect the pharmaceuticals market to remain dominant in commercial biotechnology for some time yet (Sterling, 1990: 7-9). One potential source of competitive advantage for the New York biotechnology industry is its geographical proximity to the hub of the U.S pharmaceuticals industry in the northeastern region of the country. Despite the fact that quite a few pharmaceuticals firms previously situated in New York City have relocated to other states in recent years, the industry in New York remains substantial, with over 120 businesses and almost 23,000 employees located in the state during 1990 (see Table 8.3). It therefore remains a potentially very important local complementary industry to biotechnology.

The total number of businesses in the pharmaceuticals preparations industry in New York declined by 15 percent over the previous one-and-a-half decades, from 144 units in 1975 to 122 units in 1990. The decline was most dramatic in New York City, which lost 55 percent of its pharmaceuticals businesses during that period. These disturbing figures should not necessarily lead to despair, however, because during the same period the number of employees (as opposed to busi-

Table 8.3

The Biotechnology Industry and the Pharmaceuticals Industry in New York, 1991
Basic Data and Relationships Disaggregated by Local Regions within the State

Region	NYC	LI	LH	UH	CAP	NO	MW	BUF	ST	NY State
Total Population of Dedicated Biotechnology Businesses (1991)	16	28	12	5	6	4	4	8	7	90
Number of Biotechnology Businesses in Survey Sample (1991)	12	22	8	5	4	1	2	7	5	66
Estimated Local Employment in Biotechnology Businesses (1991)	527	826	981	281	99	432	318	544	73	4081
Biotechnology Industry Employment Density Index (1991)	0.29	1.47	3.73	1.69	0.54	1.25	1.02	2.00	0.49	1.00
Biotechnology Industry Firm Density Index (1991)	0.42	1.78	1.62	1.17	1.69	0.55	0.74	1.63	2.32	1.00
Biotechnology Businesses which Engaged in Informal (est. %)	18%	32%	38%	0%	50%	0%	50%	29%	40%	29%
Communication with Local Local Pharmaceutical Corps. (approx. #)	3	9	5	0	3	0	2	2	3	26
Biotechnology Businesses which Engaged in Formal (est. %)	9%	18%	0%	0%	75%	0%	0%	29%	20%	17%
Collaboration with Local Pharmaceutical Corps. (approx. #)	1	5	0	0	5	0	0	2	1	15
Pharmaceutical Preparations Industry, Number of Units (1990)	23	50	18	5	3	10	4	5	4	122
Pharmaceutical Preparations Industry, Employment (1990)	5636	3336	7104	336	1024	2292	872	748	1464	22828
Pharmaceutical Preparations, Average Employment per Unit (1990)	245	67	395	67	341	229	218	150	366	187
% Change in # Pharmaceutical Preparations Units (1975-1990)	-55%	52%	-38%	67%	-25%	43%	0%	-38%	-20%	-15%
% Change in Pharmaceutical Preparations Employment (1975-1990)	3%	159%	9%	133%	-48%	-16%	71%	6%	-3%	9%
Pharmaceutical Preparations Industry, Firm Density Index (1990)	0.44	2.34	1.79	0.86	0.62	1.02	0.54	0.75	0.98	1.00
Pharmaceutical Preparations Industry, Ratio of 1990 FDI to 1975 FDI	62%	145%	63%	167%	77%	154%	109%	73%	91%	100%
Pharmaceutical Preparations Industry, Employment Density Index (1990)	0.55	1.06	4.83	0.36	1.00	1.18	0.50	0.49	1.76	1.00
Pharmaceutical Preparations Industry, Ratio of 1990 EDI to 1975 EDI	105%	194%	88%	184%	42%	68%	151%	104%	87%	100%
Ratio of # Biotech. Businesses over # Pharmaceutical Preparations Units	69.6%	56.0%	66.7%	100.0%	200.0%	40.0%	100.0%	160.0%	175.0%	73.8%
Ratio of Biotech. Employment over Pharmaceutical Prep. Employment	9.4%	24.8%	13.8%	83.6%	9.7%	18.8%	36.5%	72.7%	5.0%	17.9%

Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), 1991;
Primary data on pharmaceutical preparations industry provided by New York State Department of Labor, ES-202 Program, March 1991.

nesses) actually *increased* by 9 percent across the whole state, while the number of pharmaceutical preparations employees in New York City *increased* by 3 percent (to over 5,600 people).

An important story to cull from Table 8.3 is that there has been a change in the *structure* of the industry. There has been an increase in the mean size of the state's pharmaceuticals businesses from 145 people/unit in 1975 to 187 people/unit in 1990, suggesting some kind of maturation process rather than a decline. The changing structure is also reflected in regional variations in the industry over time. Long Island, for example, increased its number of pharmaceuticals businesses by 52 percent over the 15-year period to 1990, and increased its employment in the industry by a stunning 159 percent during the same period, while employment in the Capital region (around Albany) declined by almost half. Lower Hudson, the region presently home to the largest number of pharmaceutical preparations employees, experienced a decline in the number of businesses from 1975 to 1990, while Upper Hudson experienced a 67 percent increase in the number of its units and a 133 percent increase in the number of pharmaceuticals employees. These figures point to what might be labeled as the "suburbanization" of the pharmaceuticals industry in metropolitan New York. Long Island now has over double the number of pharmaceuticals businesses of New York City, while Long Island and Lower Hudson combined contain 56 percent of the industry's businesses statewide.

Long Island scored 2.34 for its 1990 pharmaceutical preparations FDI (firm density index), which means that it is by far the most competitive of all the nine regions in generating pharmaceuticals businesses; the only other regions to attain a positive FDI were Lower Hudson (1.79) and North (1.02). Scores of 1.0 or above for an industry density index indicate that a local region is "competitive" in that industry compared to the reference region (New York state). The increase in Long Island's pharmaceuticals FDI by 45 percent over the 15-year reference period, while that of Lower Hudson declined by 37 percent, indicates that Long Island's competitive position from the point of view of generating pharmaceuticals businesses has not only been high, but it has also been increasing.

Despite having only 60 percent of the pharmaceutical industry employment of New York City, Long Island's EDI (employment density index) is almost double that of the City, meaning that it is almost twice as competitive in generating pharmaceuticals employment. The ratio of the 1990 EDI for New York City over its 1975 EDI is 105 percent, meaning that New York City's competitive rank in pharmaceuticals employment within the state has not declined over the period, despite its relatively low productivity in generating new pharmaceuticals jobs. The equivalent ratio for Long Island is 194 percent reflecting the remarkable improvement in that region's competitive position *vis-à-vis* pharmaceuticals employment over the period.

The data in Table 8.3 also point to variations in the *character* of the pharmaceuticals industry between the regions. Long Island is dominated by a large number of small pharmaceuticals businesses, averaging 67 people/unit in size The average size of pharmaceutical businesses in most of the other regions lies roughly in the range between 200 and 400 people/unit. When this

information is combined with the growth data, a picture emerges of Long Island's pharmaceutical preparations industry consisting mostly of small entrepreneurial businesses, with many probably engaged primarily as manufacturers of generic and other products not subject to patents, or as contract manufacturers of patented products. This may well mean that there would be less scope on Long Island than in the other regions for sponsorship by local pharmaceuticals firms of scientific or technological work within the local dedicated biotechnology businesses.

The proportion of biotechnology businesses on Long Island that engage in communication or collaboration with *local* pharmaceutical firms, however, is slightly above the average for the state as a whole, as revealed in Table 3.8. Thirty-five percent of all the biotechnology businesses in New York which engaged in significant informal communication with local pharmaceutical corporations during the previous year are located on Long Island, and one-third of the state's cases of formal collaborations at the local level between biotechnology and pharmaceuticals businesses took place on Long Island.

The foregoing results suggest that — in contrast to popular opinion — pharmaceutical corporations do not need to be of the large established kind in order to offer significant prospects for collaboration or learning for local biotechnology businesses. In turn, this raises hope that a significant fillip may be given to the local biotechnology industry clusters in New York through efforts to build stronger networks with local clusters of the pharmaceutical preparations industry, whether or not they happen to be populated by prominent multi-national corporations with giant research laboratories. The prospects for success on a significant scale look greatest in the suburban region of greater metropolitan New York.

While the larger pharmaceutical corporations may be in a position to take advantage of collaborations with biotechnology businesses located outside New York, the smaller, entrepreneurial ones may find an entrance into the field of biotechnology easier through alliances with small, local biotechnology businesses. Greater interactions within the nine local regions of New York between local clusters of dedicated biotechnology businesses and local clusters of pharmaceutical firms will probably lead to an improvement in the competitiveness of both.

Biotechnology and "High-Technology" Manufacturing Industries in New York

Biotechnology is frequently viewed as the next wave of "high technology" following microelectronics, and is consequently looked upon by many communities as a source of hope for the reconstruction of their local industries. Biotechnology has therefore been heralded as the new economic "golden goose" by state governments, regional economic development agencies, and public-private business consortia. (Blakely & Nishikawa, 1989)

Some communities in the United States which have relied heavily upon defense subcontracting as a stimulus for the local economy have developed a dependence upon various

advanced-technology manufacturing industries for their local employment base. The technological foundations of these military-related industries generally revolve around electronics, communications, aerospace, software, and advanced materials. With recent changes in the global political-military balance affecting the United States, cutbacks in military spending may augur disastrous economic decline in these communities. As a result many, including those in New York, are seeking alternative growth industries to replace military sub-contracting. For a region such as Long Island, with its heavy dependence upon the aerospace industry, the search for viable alternatives is critical.

The problem with biotechnology as a complement or replacement for the electronics-related industries of the defense sector is that many of the basic scientific, technical, and practical foundations of the respective industries are quite different. People skilled in electronics, communications, or computerized control systems might not readily adapt to the milieu and specialized knowledge requirements of biology. Changes in the human resource base required for a switch from one industrial regime to another cannot be accomplished overnight.

For biotechnology to play a strong role in the reconstruction of local economies dependent upon defense sub-contracting, an important process of technological learning has to take place. This is not a matter of electronics engineers having to abandon their existing expertise to master a new profession — biological engineering — rather, it is a matter of identifying where the two technological arenas meet, and of cultivating a hybrid range of technological competence which draws upon both. Earlier research by the author of this study has indicated that firms in the Santa Clara region of California ("Silicon Valley") have managed to do just this. By 1988 about 80 percent of the dedicated biotechnology businesses in Santa Clara were specialized as technical suppliers to other biotechnology businesses, drawing upon the existing expertise of the region in electronics and software systems but utilizing this expertise in novel ways through interaction with the emerging biotechnology industry in the San Francisco Bay Area (Willoughby & Blakely, 1990).

The prospects for a hybrid technological arena bridging electronics and biology is not just stimulated by recent wishful thinking in the face problems with the defense sector. Almost a decade ago, two analysts of the emerging biotechnology industry, Lois Peters and Herbert Fusfield (1983: 20), recognized the importance for the development of industrial biotechnology of cultivating links between biotechnologists and practitioners of other fields of advanced technology:

> Reliable and cost effective production processes require a range of technologies that must operate in combination with the advances of the biological sciences. For example, pilot plant fermenters must be designed with specific biological organisms in mind. Continuous flow fermentation is only useful when an organism can excrete the desired product. The inherent variability of biological systems makes it necessary to monitor many parameters in order to ensure stable growth within a fermenter. This makes it necessary to develop specialized sensors to monitor pH, temperature, metabolites, and so on. Accurate knowledge and control of the cell's microenvironment are needed to optimize growth and conditions

> and product manufacture. Biological products must be tested and designed for stability. All of these developments require people trained in engineering, including computer sciences, with a knowledge of the biological processes involved. They call for advances in measurement and control. In the development of necessary instrumentation, software development becomes a critical factor.

The advances in technology called for by Peters and Fusfield require people who feel comfortable working across technological boundaries. In effect, this means that organizations involved in the new biology need to interact with organizations involved in the electronics and instrumentation fields, to name a couple of examples. For biotechnology to play an effective role in New York in the transition from defense-dependent high-technology industries to a more diversified economy with a more complex technological base, a process of interdisciplinary learning has to take place. This will only be achieved on a sufficient-enough scale to make an appreciable difference to the economy if there is significant communication and collaboration between organizations in each of the technological and scientific arenas. This will no doubt require overcoming institutional and professional-cultural barriers.

While the difficulties of cultivating hybrid technological expertise across biology and electronics are great, so are the potential benefits of doing so. Not only may the biotechnology industry benefit from exposure to other fields of "high" technology, but advanced-technology industries in the fields of electronics, instrumentation, software, and control systems, for example, may also benefit from association with biotechnology through stimulus for new product innovation and expanded sales. The challenge for New York is to identify nascent activities associated with each of the biotechnology industry clusters in the state that have reasonable potential for leading to strong local technological networks bridging biotechnology and other "high-tech" fields.

To assist with identifying these activities, Table 8.4 has been constructed to provide a profile of the existing high-technology manufacturing sector in New York, and the sub-regional propinquity of the biotechnology industry clusters to the high-technology industry clusters. Tables 8.5, 8.6, and 8.7 repeat this process for particular advanced technology industries in New York which appear to have strong potential for strengthening their role as specialized technical suppliers for biotechnology: the medical instruments and supplies industries, the measuring and controlling devices industry, and the research and testing services industry.

In constructing Table 8.4, a definition of "high-technology" manufacturing industry was employed based on the idea that an industry should be labeled as "high" in its technology when there is a higher than normal technical capacity in its workforce. The routine assembly of computer keyboards, for example, while it is part of the computer industry, should not thereby be considered to require high technical capacity. The data in Table 8.4 represent all manufacturing industries in New York (3-digit SIC classifications, excluding service industries) in which the technical capacity of the workforce is greater than the average for the manufacturing sector in the United States. For a detailed explanation of the definition see Appendix 8.1.

Table 8.4

The Biotechnology Industry and "High Technology" Manufacturing Industries in New York, 1991
Basic Data and Relationships Disaggregated by Local Regions within the State

Region	NYC	LI	LH	UH	CAP	NO	MW	BUF	ST	NY State
Total Population of Dedicated Biotechnology Businesses (1991)	16	28	12	5	6	4	4	8	7	90
Number of Biotechnology Businesses in Survey Sample (1991)	12	22	8	5	4	1	2	7	5	66
Estimated Local Employment in Biotechnology Businesses (1991)	527	826	981	281	99	432	318	544	73	4081
Biotechnology Industry Employment Density Index (1991)	0.29	1.47	3.73	1.69	0.54	1.25	1.02	2.00	0.49	1.00
Biotechnology Industry Firm Density Index (1991)	0.42	1.78	1.62	1.17	1.69	0.55	0.74	1.63	2.32	1.00
Index of Local Informal Communication (0-100) (Interaction of Biotechnology Businesses and All Other Organizations)	*42*	*39*	*38*	*20*	*46*	*67*	*67*	*50*	*43*	*41*
Index of Local Formal Collaboration (0-100) (Interaction of Biotechnology Businesses and All Other Organizations)	*29*	*23*	*25*	*7*	*50*	*50*	*67*	*26*	*30*	*27*
High Technology Manufacturing Industries, Number of Units (1990)	629	881	239	134	84	277	396	293	156	3089
High Technology Manufacturing Industries, Employment (1990)	18030	68600	22054	35604	13272	33710	82514	16550	31418	321760
High Technology Manufacturing, Average Employment per Unit (1990)	29	78	92	266	158	122	208	56	201	104
% Change in # High Technology Manufacturing Units (1975-1990)	-35%	15%	7%	21%	53%	40%	27%	34%	44%	4%
% Change in High Technology Manufacturing Employment (1975-1990)	-56%	4%	16%	18%	-45%	-13%	-18%	-40%	-8%	-16%
High Technology Manufacturing Industries, Firm Density Index (1990)	0.48	1.63	0.94	0.91	0.69	1.12	2.12	1.74	1.51	1.00
High Technology Manufact. Industries, Ratio of 1990 FDI to 1975 FDI	72%	89%	88%	98%	128%	122%	113%	128%	133%	100%
High Tech. Manufact. Industries, Employment Density Index (1990)	0.13	1.54	1.06	2.72	0.92	1.23	3.34	0.77	2.68	1.00
High Technology Manufacturing Industry, Ratio of 1990 EDI to 1975 EDI	58%	101%	122%	121%	58%	92%	94%	76%	107%	100%
Ratio of # Biotech. Businesses over # High Tech. Manufact. Units	2.5%	3.2%	5.0%	3.7%	7.1%	1.4%	1.0%	2.7%	4.5%	2.9%
Ratio of Biotech. Employment over High Tech. Manufact. Empl.	2.9%	1.2%	4.4%	0.8%	0.7%	1.3%	0.4%	3.3%	0.2%	1.3%

Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), 1991;
Primary data on high technology manufacturing industries provided by New York State Department of Labor, ES-202 Program, March 1991.

Table 8.5

The Biotechnology Industry and Technical Suppliers in New York, 1991: Medical Instruments and Supplies Industries
Basic Data and Relationships Disaggregated by Local Regions within the State

Region	NYC	LI	LH	UH	CAP	NO	MW	BUF	ST	NY State
Total Population of Dedicated Biotechnology Businesses (1991)	16	28	12	5	6	4	4	8	7	90
Number of Biotechnology Businesses in Survey Sample (1991)	12	22	8	5	4	1	2	7	5	66
Estimated Local Employment in Biotechnology Businesses (1991)	527	826	981	281	99	432	318	544	73	4081
Biotechnology Industry Employment Density Index (1991)	0.29	1.47	3.73	1.69	0.54	1.25	1.02	2.00	0.49	1.00
Biotechnology Industry Firm Density Index (1991)	0.42	1.78	1.62	1.17	1.69	0.55	0.74	1.63	2.32	1.00
Biotechnology Businesses which Engaged in Informal Communication with Local Technical Suppliers (est. %)	27%	36%	38%	0%	50%	100%	50%	57%	20%	35%
Biotechnology Businesses which Engaged in Informal Communication with Local Technical Suppliers (approx. #)	4	10	5	0	3	4	2	5	1	32
Biotechnology Businesses which Engaged in Formal Collaboration with Local Technical Suppliers (est. %)	9%	18%	0%	0%	50%	100%	50%	14%	40%	18%
Biotechnology Businesses which Engaged in Formal Collaboration with Local Technical Suppliers (approx. #)	1	5	0	0	3	4	2	1	3	17
Medical Instruments & Supplies Industry, Number of Units (1990)	60	71	29	7	8	29	12	27	8	251
Medical Instruments & Supplies Industry, Employment (1990)	1664	3256	2636	68	232	4972	604	1964	392	15808
Medical Instruments & Supplies, Average Employment per Unit (1990)	28	46	91	10	29	171	50	73	49	63
% Change in # Medical Instruments & Supplies Units (1975-1990)	-49%	42%	12%	17%	14%	53%	0%	17%	60%	-5%
% Change in Medical Instruments & Supplies Employment (1975-1990)	-45%	130%	52%	-70%	55%	130%	-70%	14%	-20%	22%
Medical Instruments & Supplies Industry, Firm Density Index (1990)	0.56	1.62	1.40	0.59	0.81	1.44	0.79	1.97	0.95	1.00
Medical Instruments & Supplies Industry, Ratio of 1990 FDI to 1975 FDI	63%	121%	102%	104%	105%	147%	98%	123%	162%	100%
Medical Instr. & Supplies Industry, Employment Density Index (1990)	0.24	1.49	2.59	0.11	0.33	3.71	0.50	1.87	0.68	1.00
Medical Instruments & Supplies Industry, Ratio of 1990 EDI to 1975 EDI	50%	154%	111%	21%	113%	168%	24%	100%	64%	100%
Ratio of # Biotech. Businesses over # Medical Instr. & Supplies Units	26.7%	39.4%	41.4%	71.4%	75.0%	13.8%	33.3%	29.6%	87.5%	35.9%
Ratio of Biotech. Employment over Medical Instr. & Supplies Empl.	31.7%	25.4%	37.2%	13.2%	42.7%	8.7%	52.6%	27.7%	18.6%	25.8%

Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), 1991;
Primary data on medical instruments and supplies industries provided by New York State Department of Labor, ES-202 Program, March 1991.

Table 8.6

The Biotechnology Industry and Technical Suppliers in New York, 1991: Measuring and Controlling Devices Industry Basic Data and Relationships Disaggregated by Local Regions within the State

Region	NYC	LI	LH	UH	CAP	NO	MW	BUF	ST	NY State
Total Population of Dedicated Biotechnology Businesses (1991)	16	28	12	5	6	4	4	8	7	90
Number of Biotechnology Businesses in Survey Sample (1991)	12	22	8	5	4	1	2	7	5	66
Estimated Local Employment in Biotechnology Businesses (1991)	527	826	981	281	99	432	318	544	73	4081
Biotechnology Industry Employment Density Index (1991)	0.29	1.47	3.73	1.69	0.54	1.25	1.02	2.00	0.49	1.00
Biotechnology Industry Firm Density Index (1991)	0.42	1.78	1.62	1.17	1.69	0.55	0.74	1.63	2.32	1.00
Biotechnology Businesses which Engaged in Informal Communication with Local Technical Suppliers (est. %)	27%	36%	38%	0%	50%	100%	50%	57%	20%	35%
Biotechnology Businesses which Engaged in Informal Communication with Local Technical Suppliers (approx. #)	4	10	5	0	3	4	2	5	1	32
Biotechnology Businesses which Engaged in Formal Collaboration with Local Technical Suppliers (est. %)	9%	18%	0%	0%	50%	100%	50%	14%	40%	18%
Biotechnology Businesses which Engaged in Formal Collaboration with Local Technical Suppliers (approx. #)	1	5	0	0	3	4	2	1	3	17
Measuring & Controlling Devices Industry, Number of Units (1990)	50	121	39	23	22	32	41	18	11	357
Measuring & Controlling Devices Industry, Employment (1990)	812	5872	1676	668	816	1068	3496	1420	468	16312
Measuring & Controlling Devices, Average Employment per Unit (1990)	16	49	43	29	37	33	85	79	43	46
% Change in # Measuring & Controlling Devices Units (1975-1990)	-21%	32%	26%	64%	175%	300%	37%	0%	83%	32%
% Change in Measuring & Controlling Devices Employment (1975-1990)	-48%	-7%	-40%	12%	206%	85%	31%	-10%	393%	-1%
Measuring & Controlling Devices Industry, Firm Density Index (1990)	0.33	1.94	1.33	1.36	1.56	1.12	1.90	0.93	0.92	1.00
Measuring & Controlling Devices Industry, Ratio of 1990 FDI to 1975 FDI	70%	81%	82%	105%	181%	276%	96%	75%	133%	100%
Measuring & Contr. Devices Industry, Employment Density Index (1990)	0.11	2.61	1.59	1.01	1.12	0.77	2.79	1.31	0.79	1.00
Measuring & Controlling Devices Industry, Ratio of 1990 EDI to 1975 EDI	59%	77%	54%	98%	275%	166%	127%	97%	487%	100%
Ratio of # Biotech. Businesses over # Measuring & Contr. Devices Units	32.0%	23.1%	30.8%	21.7%	27.3%	12.5%	9.8%	44.4%	63.6%	25.2%
Ratio of Biotech. Employment over Measuring & Contr. Devices Empl.	64.9%	14.1%	58.5%	42.1%	12.1%	40.4%	9.1%	38.3%	15.6%	25.0%

Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), 1991;
Primary data on measuring and controlling devices industry provided by New York State Department of Labor, ES-202 Program, March 1991.

Table 8.7

The Biotechnology Industry and Technical Suppliers in New York, 1991: Research and Testing Services Industry Basic Data and Relationships Disaggregated by Local Regions within the State

Region	NYC	LI	LH	UH	CAP	NO	MW	BUF	ST	NY State
Total Population of Dedicated Biotechnology Businesses (1991)	16	28	12	5	6	4	4	8	7	90
Number of Biotechnology Businesses in Survey Sample (1991)	12	22	8	5	4	1	2	7	5	66
Estimated Local Employment in Biotechnology Businesses (1991)	527	826	981	281	99	432	318	544	73	4081
Biotechnology Industry Employment Density Index (1991)	0.29	1.47	3.73	1.69	0.54	1.25	1.02	2.00	0.49	1.00
Biotechnology Industry Firm Density Index (1991)	0.42	1.78	1.62	1.17	1.69	0.55	0.74	1.63	2.32	1.00
Biotechnology Businesses which Engaged in Informal Communication with Local Technical Suppliers (est. %)	27%	36%	38%	0%	50%	100%	50%	57%	20%	35%
Biotechnology Businesses which Engaged in Informal Communication with Local Technical Suppliers (approx. #)	4	10	5	0	3	4	2	5	1	32
Biotechnology Businesses which Engaged in Formal Collaboration with Local Technical Suppliers (est. %)	9%	18%	0%	0%	50%	100%	50%	14%	40%	18%
Biotechnology Businesses which Engaged in Formal Collaboration with Local Technical Suppliers (approx. #)	1	5	0	0	3	4	2	1	3	17
Research & Testing Services Industry, Number of Units (1990)	905	227	167	63	96	137	92	98	48	1833
Research & Testing Services Industry, Employment (1990)	21248	9448	2476	1096	5912	3612	2488	4860	632	51796
Research & Testing Services, Average Employment per Unit (1990)	23	42	15	17	62	26	27	50	13	28
% Change in # Research & Testing Services Units (1975-1990)	18%	59%	92%	117%	60%	61%	100%	66%	129%	41%
% Change in Research & Testing Services Employment (1975-1990)	26%	17%	74%	474%	24%	121%	394%	42%	120%	39%
Research & Testing Services Industry, Firm Density Index (1990)	1.16	0.71	1.11	0.72	1.33	0.93	0.83	0.98	0.78	1.00
Research & Testing Services Industry, Ratio of 1990 FDI to 1975 FDI	97%	91%	117%	130%	99%	104%	131%	117%	155%	100%
Research & Test. Services Industry, Employment Density Index (1990)	0.92	1.32	0.74	0.52	2.56	0.82	0.63	1.41	0.34	1.00
Research & Testing Services Industry, Ratio of 1990 EDI to 1975 EDI	101%	69%	110%	356%	79%	141%	342%	110%	155%	100%
Ratio of # Biotech. Businesses over # Research & Test. Service Units	1.8%	12.3%	7.2%	7.9%	6.3%	2.9%	4.3%	8.2%	14.6%	4.9%
Ratio of Biotech. Employment over Research & Test. Service Empl.	2.5%	8.7%	39.6%	25.6%	1.7%	12.0%	12.8%	11.2%	11.6%	7.9%

Source: K.W. Willoughby, Center for Biotechnology (Stony Brook, NY), 1991;
Primary data on research and testing services industry provided by New York State Department of Labor, ES-202 Program, March 1991.

The first impression that may be drawn from Table 8.4 is that the need is great for New York to augment its traditional high-technology manufacturing industries with new advanced technology activity. While the number of employees in high-technology manufacturing industries in the state was almost one-third of a million people during 1990, this was almost 60,000 people less than during the mid-1970s (representing a drop in employment levels of 16 percent). In New York City there was a stunning decline of 56 percent in high-technology manufacturing employment from the mid-1970s to the end of the 1980s, and a 35 percent decline in the number of high-technology businesses. High-technology manufacturing industries have not been providing a panacea for the decline in traditional manufacturing employment.

Despite these disturbing figures for the state as a whole, some of the regions have nevertheless done very well. The most important message to be garnered from the data is not one of doom, but of recognition that there has been a change in the structure of the high-technology manufacturing sector and that this has implications for the regional distribution of emerging technology-based industry clusters.

Despite a net loss in high-technology manufacturing employment for the state, there was a net gain of 4 percent from 1975 to 1990 in the number of businesses in the sector. New York City, with its massive loss of 35 percent of these businesses, was actually the exception to the rule; all the other regions experienced a net gain in their number of high-technology manufacturing businesses. Against the general trend in the state, furthermore, there was an increase of over 11,000 people in the number of high-technology manufacturing employees in Long Island and the Hudson Valley. The suburban area of metropolitan New York has actually experienced significant high-technology growth during the period leading up to the 1990s. To an even greater extent than that which took place within the pharmaceutical preparations industry, there has been a suburbanization of high-technology manufacturing in New York during the last couple of decades.

The single largest high-technology manufacturing region, from the point of view of employment levels, is the Mid-West. It is also the region with the highest employment density index (EDI) and highest firm density index (FDI) for high-technology manufacturing. This means that, standardizing the data to account for the relative sizes of the economies in each of the regions, the local Mid-West region is the most productive of all in generating employment and enterprises in high-technology manufacturing. The outstanding performance of the region is determined largely by the contribution of Rochester.

The second largest high-technology manufacturing region is Long Island, with almost 69,000 employees in the sector. Long Island has the largest number of businesses in the high-technology manufacturing sector (almost 900 firms in 1990). Given the relatively small average size of these firms (78 employees, compared with a state average of 104,208 for the Mid-West and 266 for Upper Hudson), it appears that Long Island's high-technology manufacturing sector is probably constituted by a

relatively large proportion of entrepreneurial start-up firms. Long Island also scores moderately high industry density indices, making the region quite competitive in its capacity to generate jobs and firms in high technology. Although the Mid-West has a larger high-technology manufacturing sector than Long Island, its employment levels actually dropped by 18 percent and its employment density index declined by 6 percent from 1975 to 1990, while Long Island's high-technology manufacturing employment increased by 15 percent and its employment density index increased marginally.

During the same 15-year period, the firm density indices for high-technology manufacturing industries in the upstate regions all increased, while the reverse happened in the metropolitan regions. With the exception of the Southern Tier, all of the upstate regions experienced a decline in their high-technology manufacturing employment density indices. The same was true for New York City, which experienced a 62 percent decline in this index. The suburban regions around New York City, however, experienced an increase in their employment density indices during the period, with this trend most marked in Lower and Upper Hudson.

An interpretation that may be placed upon these figures is that there has been two major shifts in the structure of high-technology manufacturing in New York over the last couple of decades. First, there has been a shift in employment from New York City and upstate locations to the periphery of the greater metropolitan area. Second, there has been a shift from employment in large, established corporations towards small, new enterprises.

The establishment rate for new enterprises upstate has been greater than in the New York City suburbs, but the high employment growth of the latter indicates that suburban high-technology entrepreneurship is also generating growth over time within the firms. In other words, the economic development potential of high-technology manufacturing appears strongest in the metropolitan suburbs. The combination of high establishment rates for firms and high rates of job loss upstate suggests that the high-technology entrepreneurship in the upstate regions most likely stems from people previously employed by the larger corporations starting up local firms rather than being forced to leave the region or remain unemployed. There is probably also some "spillover effect" in the suburbs from firms closing down or down-sizing their operations in New York City.

Overall, if a statewide perspective is taken on high-technology manufacturing in New York —as opposed to just a New York City perspective — there are signs of hope for the future to be found in the widespread entrepreneurship that appears to be following the transformation of the previous high-technology regime. This means that the potential for inter-organizational learning to take place between dedicated biotechnology businesses and high-technology businesses is probably quite high. Despite its large absolute decline in high-technology manufacturing employment since 1975, however, New York City is still a major high-technology manufacturing region, accounting for over 600 firms and 18,000 employees in 1990. There are plenty of opportunities for interaction between biotechnology organizations and other advanced technology organizations.

Table 8.4 also shows that the propensity for New York's dedicated biotechnology businesses to interact with other organizations (whether formally or informally) is lower in the greater metropolitan area than it is in the North and Western parts of the state. In fact, overall, the communication and collaboration indices for biotechnology businesses are greatest in the Mid-West; when the strong overall high-technology position of this area is taken into account, it would appear that there is a good possibility of productive links being built locally there between biotechnology and other advanced technologies. Given the small absolute number of dedicated biotechnology businesses in the Mid-West, however, it would appear important for the state as a whole to find ways to encourage greater interaction between biotechnology businesses and other high-technology businesses in the greater metropolitan area.

The medical instruments and supplies industry (Table 8.5) and the measuring and controlling devices industry (Table 8.6) are two specific technology-based industries possessing skills and technical knowledge that are amenable to application in biotechnology. An example of a dedicated biotechnology business in New York that draws upon technical traditions (especially optical instrumentation) from these industries is the Olympus Corporation Biomedical Research Center in East Setauket, Long Island. These two industry groups combined (medical instruments and supplies, and measuring and controlling devices) included over 600 firms and over 32,000 employees in New York in 1990.

Long Island contains the largest concentration of both businesses (over 120 units) and employment (almost 5,900 people) in the measuring and controlling devices industry. The Mid-West has the second largest concentration, with over 40 businesses and about 3,500 people. The two regions also have the highest industry density indices. The fastest growth in the measuring and controlling devices industry has been taking place in the upstate regions, but the absolute numbers of firms are much greater in the greater metropolitan area.

The measuring and controlling devices industry is sufficiently well represented around the state that a biotechnology business located almost anywhere would probably be able to get fairly ready access to suitable firms to aid with the development of specialized instrumentation for their activities. Given the absolute size of both the biotechnology industry and the measuring and controlling devices industry in suburban New York (and Long Island in particular), however, the fact that only five cases of formal collaboration with local technical suppliers took place during the previous year (all on Long Island — excluding the upstate cases) strongly suggests that there is a great deal of opportunity for product innovation that has not yet been exploited.

The medical instruments and supplies industry has experienced a significant total growth in employment across the state over the 15 years to 1990, with the largest growth having taken place in Long Island and the North. The largest concentration of businesses in the industry lies on Long Island (over 70 units), and every region in the state except New York City and the Mid-West under-

went significant net growth in the number of firms in the industry during the 1970s and 1980s. As with the measuring and controlling devices industry, the medical instruments and supplies industry is an underutilized resource for the development of new technology and new technical capacity in New York's biotechnology industry. The distribution of the industries suggests that there is scope for specialized biotechnology/instrumentation industry clusters in more than one location in the state.

The largest concentration of firms and employment in the research and testing services industry is located within New York City (over 900 businesses and 21,000 people). Statewide, there are over 1,800 businesses and almost 52,000 people involved in the industry. Further investigations would be needed to make detailed recommendations about exactly how links might be built between biotechnology and this industry group. Nevertheless, when combined with the information from the measuring and controlling devices industry and the medical instruments and supplies industries, it is clear that there is a multiplicity of possibilities within each of the nine biotechnology industry regions in New York for inter-organizational interaction for the purpose of technology development in the area of technical supplies for biotechnology.

The above three industries incorporate a total of over 80,000 people in almost two-and-a-half thousand businesses which have some potential for complementing or augmenting the technical capacity of the state's biotechnology industry. Even if only a small proportion of the businesses proved to be technically pertinent for collaboration with biotechnology businesses, it could be an improvement over the present relatively low incidence (i.e., there were only approximately 17 cases of formal collaborations with technical suppliers last year).

Conclusions

This chapter has presented data on a range of industries which are complementary or potentially complementary to the biotechnology industry in New York. It has also made the argument that the scale of the economic impact from biotechnology will depend on the richness and depth of the linkages formed between the biotechnology businesses and the organizations in complementary industries in each geographical region within the state where biotechnology industry clusters may be found. The greatest long-term economic development potential from biotechnology will come when strong local industry networks are formed within New York based upon technological complementarities, the sharing of technical competence, or matching-up of other industrial needs. Despite recent troubles with the state's economy, New York has a sufficiently large and complex array of technologically relevant industries that the growth potential for biotechnology is very strong, if only the barriers to effective local communication and collaboration could be overcome.

Chapter Nine

Conclusion: Enzymes for Economic Development

What hope is there that New York's biotechnology industry will be able to build and sustain a competitive international position? This study has identified a number of current conditions encouraging confidence in the industry's future. Supporting evidence includes the following:

- New York's biotechnology industry is now a firmly established part of the state's economy. With 90 dedicated biotechnology businesses located in the state by 1991, and total assets estimated to be worth about $1.3 billion, the industry is three or four times larger than previously published reports have recognized.

- Fully 84 percent of New York's dedicated biotechnology businesses have either already commenced manufacturing or expect to be doing so during the first half of the 1990s.

- With one-third of its employees located out-of-state, New York's biotechnology industry has a growing national and international presence.

- New York's biotechnology industry is home-grown. Almost 90 percent of the founders of the state's biotechnology businesses were located in New York at the time they formed their business.

- The industry's technology is also home-grown; New York's biotechnology businesses spend about ten times more money on research and development than they spend on the purchase of licenses and access to technology developed elsewhere.

- There is considerable diversity in the pattern of ownership and corporate structure in the industry, but most of the businesses are locally controlled and managed. Thus, there is considerable scope for the future directions of the industry to be set by those who work within it.

- The industry is growing, and is comprised of both mature firms and young entrepreneurial start-ups. Three-quarters of New York's biotechnology businesses were formed during the last decade, and 30 percent were formed during the last four years. Despite economic difficulties in the state's economy, the biotechnology industry exhibits employment growth in all of the state's sub-regions. For example, in Long Island — the state's fastest growing industry region —commercial biotechnology employment increased by almost 80 percent during the year leading up to this study.

- Contrary to popular beliefs, the financial base of the New York biotechnology industry is not closely tied to the ebbs and flows of the public stock market. Less than one-fifth of the biotechnology businesses are public companies, and only 8 percent of the industry's finance during 1990/91 came from public equity. Revenue accounted for 44 percent of finance, and private equity accounted for two-and-a-half times the amount of finance raised from public sources.

- New York's track record in generating new businesses and jobs in biotechnology, in proportion to the size of the local economy, is greater than average for the United States as a whole. In this sense, the state's biotechnology industry is competitive.

- The majority of New York's biotechnology businesses find their location to be advantageous for R&D and manufacturing, compared with other potential locations outside New York. In spite of New York's purported problems with costs and regulations, the majority find that other features of the state — such as its human, knowledge, and institutional resources— outweigh these problems. Some biotechnology businesses actually find New York to be advantageous *vis-à-vis* costs and regulations.

- New York has a substantial base of industries complementary to biotechnology, which may serve as markets for biotechnology products and services, sources of material and technical supplies, stimuli for technological and product innovation, and as training grounds for skilled biotechnology personnel.

- The most dynamic biotechnology businesses in New York exhibit a capacity to perform strongly in the market despite obstacles such as regulations and costs. Revenue across the whole industry has recently been growing by an average rate of about 70 percent per year.

In summary, New York's biotechnology industry is substantial, growing, diverse, locally based, internationally oriented, and improving its revenue-generating performance. It has the basic requisites for being a key industry in the future economy of the state.

This study has shown that despite New York's strengths, despite it being home to a number of very successful companies, and despite being generally competitive at a national level, its main biotechnology competitors within the United States— California and Massachusetts— have stronger biotechnology industries by certain measures. New York's considerable accomplishments in biotechnology do not create grounds for complacency, because the relative competitiveness of the equivalent industries in the other two states could evolve into some kind of unsurmountable competitive advantage in the long term. Measures need to be taken to increase the relative performance of the state's commercial biotechnology sector.

This study has also shown that the negative locational factors that might be found in New York are not a primary reason for these differences in performance. Rather, the explanation for New York's competitive position being weaker than one would expect (other things being equal) almost certainly lies with lower than desirable levels of communication and collaboration within the biotechnology industry and between it and other industries. This evokes a double-sided message for policymakers. On one hand, because the causes for sub-optimum performance are largely intangible and beyond the direct control of public authorities or industry organizations, it is difficult to find a simple package of measures to alleviate the problems. On the other hand, for the same reason, the constraints to New York's biotechnology competitiveness ought not to be seen as immutable. In other words, the very factors which make it difficult for New York to be immediately pre-eminent in commercial biotechnology also provide grounds for hope that it is possible to build a maintainable internationally competitive position.

Because the constraints on improving the performance of New York's biotechnology businesses are largely intangible, future competitiveness of the industry can only be increased indirectly rather than directly.

This means, first of all, that short cuts to local industry development by trying to "import" ready-made firms from outside the region, with financial or other inducements, are unlikely to yield impressive results. The strategy of attracting firms to relocate from outside the region will generally only succeed if a strong local biotechnology industry has already been built through the local generation of new firms and new growth based upon local people, local knowledge, and local institutions. Put another way, there is no "instant gratification" in biotechnology, but rather long-term payoffs to sustained investment in the kind of environment in which biotechnology businesses thrive.

It also means, secondly, that it is generally not possible to build a competitive biotechnology industry through direct action aimed at particular firms or through particular methods or induce-

ments alone (such as tax breaks, isolated regulatory reforms, technology parks, research grants, or other kinds of subsidies). Rather, a whole range of measures need to be adopted to nurture the development of a strong local biotechnology milieu from which local biotechnology industry clusters emerge. Put another way, there is no magical "key" to turn that will guarantee success. It is not possible to just create the desired end product (a sustainable collection of competitive biotechnology firms); it is only possible to employ a range of techniques to create the conditions which may indirectly lead to the desired end product.

The principle of indirect rather than direct support for biotechnology industry development may be discussed using a biological allegory. The controlled production of biological materials may be manipulated through the use of enzymes as catalysts in fermentation processes. Similarly, various policy instruments and industrial support measures for biotechnology need to be viewed as "enzymes" in the biotechnology industry milieu "fermenter," rather than as direct means of producing local biotechnology firms. These ideas may be illustrated by a simple model portrayed in Figure 9.1 for interpreting the process of economic development in biotechnology.[1]

The primary feature of the model is that the regional industrial process associated with biotechnology involves three main dimensions: local biotechnology industry clusters, a regional biotechnology milieu, and regional development factors.

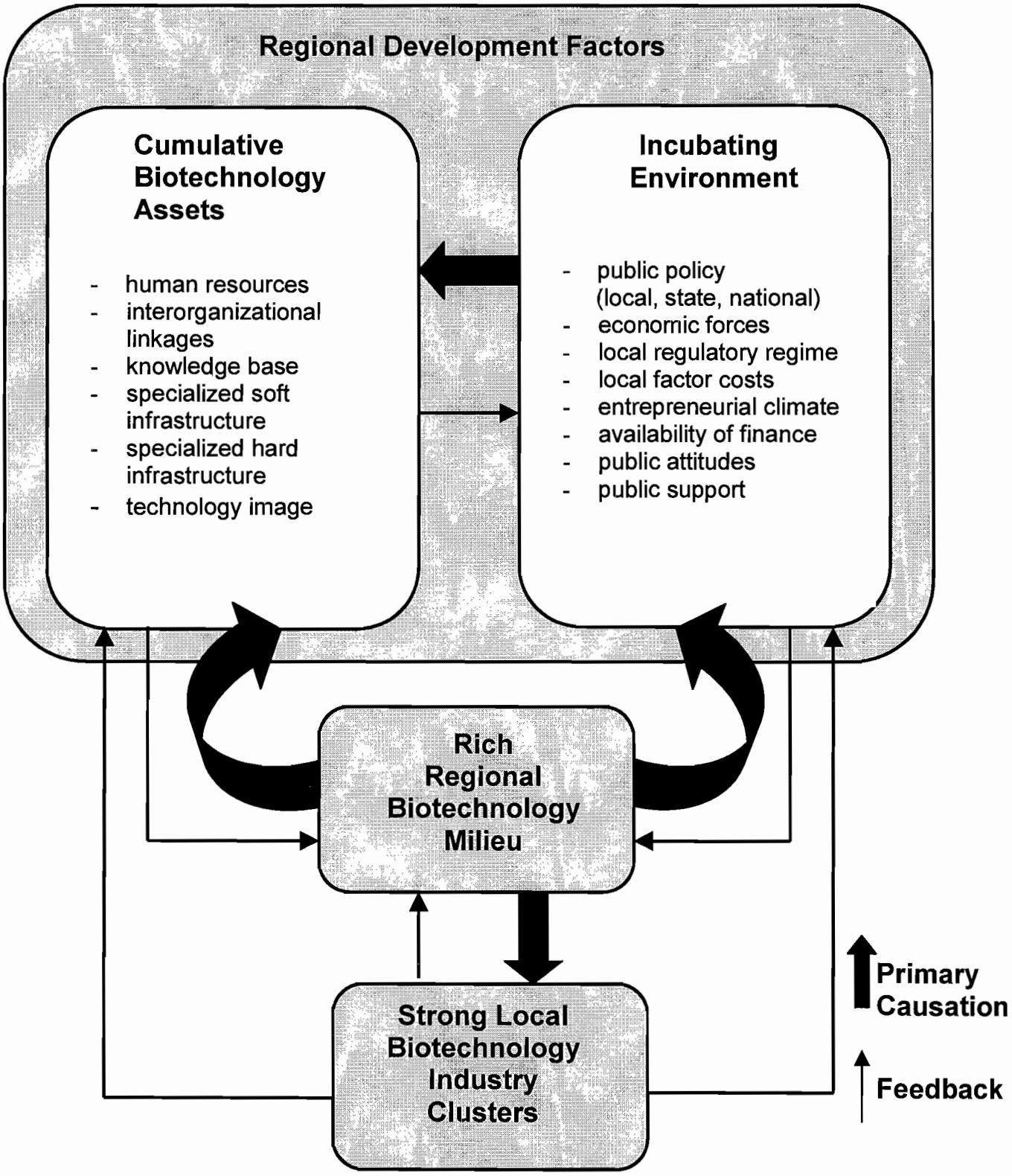
This way of construing the industry accords with the evidence assembled in this study that biotechnology businesses tend to emerge in local clusters which exhibit distinctive characteristics (e.g., market focus, locational preferences, pattern of inter-organizational linkages, human resource requirements, technological specialization). Locality is a fundamental aspect of the industry's dynamics, not just a convenient perspective from which geographers and planners may approach industry analysis. Economic development in biotechnology is a matter of *local economic development*, and not just of "development" in general.

The model also embodies the notion that local biotechnology industry clusters do not emerge in isolation, but rather within a regional biotechnology milieu. There are two levels at which the concept of "region" is relevant in this study: the *mega-region* (New York state) and the *local region* (represented by the nine "biotechnology regions" labeled herein as New York City, Long Island, Lower Hudson, Upper Hudson, Capital, North, Mid-West region, Buffalo, and Southern Tier). This study has suggested that while each of the biotechnology industry clusters is located within a local region and draws upon the peculiar features and assets of that region, the mega-region in which each of the local regions is located provides a context in which each of the biotechnology industry clusters has emerged. The concept of the biotechnology milieu applies to

[1]This model was developed by the author of this study during a recent study of the biotechnology industry in California. Figure 9.1 and part of the accompanying explanation are taken from the report of that study (see Willoughby and Blakely, 1990).

Figure 9.1

Model for Local Economic Development in Biotechnology



both of the regional levels. Local clusters of firms emerge within a local-region biotechnology milieu *and* a mega-region biotechnology milieu. This observation accords with other research carried out on the biotechnology industry, particularly in California (Willoughby & Blakely, 1990).

This use of the regional biotechnology milieu concept stresses that the growth of a strong local biotechnology industry cluster cannot generally be explained by the existence of any one particular locational factor. Rather, various locational factors contribute together to the growth of the milieu; there is no direct tight causal relationship between an individual locational factor and the emergence of a strong local biotechnology industry cluster.

In spite of indicating the milieu rather than individual locational factors as a source of biotechnology firm clusters, the model does specify "regional development factors" relevant to the formation of a regional milieu. Two main types of regional development factors may be specified: cumulative biotechnology assets (which are specialized resources in a *community* necessary for the emergence and flourishing of a biotechnology industry), and the incubating environment (which is necessary both to feed the assets and facilitate their mobilization for the purpose of nurturing a regional biotechnology milieu).

In principle there are probably forces acting between each one of the elements in the model and all of the others, and this could be represented by a complex web of two-way arrows linking each one of them. Figure 9.1, however, seeks to discriminate between those forces which are significant (both empirically and for the purposes of policy initiatives) and those which, while formally identifiable, are not of great interest. The most significant forces included in the model are symbolized by the thick arrows, and represent the processes which most directly lead to the development of local biotechnology industry clusters. The thin arrows represent the important feedback processes by which a rich regional biotechnology milieu and strong local biotechnology clusters, once established, may in turn nurture the regional development factors which were preconditions for their emergence.

The model presents public policy as only one element of the incubating environment necessary for the assembly and mobilization of a community's cumulative biotechnology assets, but it also presents the implications for the way in which public policy for economic development in biotechnology ought to be pursued if it is to be successful. Policies, taking on different forms at the various levels of government, should not aim directly at the establishment of biotechnology firms and clusters, but rather should have the following two objectives: (a) the promotion of cumulative biotechnology assets in regions where the development of a biotechnology industry is desired; and (b) the management and mobilization of those assets as a total system of resources for the nurturing of a regional biotechnology milieu. The milieu itself, combined with serendipitous and exogenous forces, will lead to the creation and strengthening of local biotechnology industry clusters. The clusters will produce feedback to nurture the regional development factors which undergird the

regional biotechnology milieu, but this is not something towards which policymakers necessarily need direct their attentions.

The model evokes the need for additional research to catalogue in detail the ways in which each of the different levels of public policymaking ought to function within this schema. For example, the maintenance of a substantial, quality knowledge base in a community (fed through such means as universities and public research institutions) may best be dealt with at a state or national level, while the promotion of specialized hard infrastructure (e.g., a supply of environmentally and scientifically appropriate physical plant and buildings) or combined specialized soft and hard infrastructure (such as a biotechnology research park, incorporating both professional services and physical facilities) might be more suitably handled at the local level.

Such analysis is beyond the scope of this report, but two important policy implications may be reiterated at this stage. First, public initiatives aimed at producing economic development from biotechnology should concentrate on the objectives of establishing and sustaining cumulative biotechnology assets in a region for the purpose of nurturing a regional biotechnology milieu. Second, such initiatives should recognize that industrialization in biotechnology tends to take on a locally specific character, reflecting characteristics of each incubation region, and therefore that policy initiatives ought to take into account the strengths, weaknesses, and distinctive features of the local regions.

This study has demonstrated that biotechnology, as exemplified by the New York biotechnology industry, is not an amorphous, homogeneous, spatially diffuse economic form. Rather, it is highly differentiated in its spatial pattern, character, strength, and relationship with the economic and geographic environment. The industry cannot be adequately understood unless it is analyzed from a regional point of view.

Communities within New York seeking economic development based upon biotechnology are faced with a number of critical *choices*. Most importantly, they need to choose between policies which reflect the unique resource base and environment of their region or those based upon seeking to emulate other regions. Choices also need to be made between placing attention directly on the needs of biotechnology firms as generators of local jobs and other economic benefits, or on the complexities of building up regionally specific cumulative biotechnology assets. The latter approach is not likely to produce fast results, but this study suggests that it is an essential, and probably the most important, element of durable technology-based regional economic development.

Can New York successfully compete in biotechnology? The evidence assembled in this report suggests "yes." Success, however, will not be automatic. It will depend upon building and maintaining a number of *local industry clusters* characterized by *strong biotechnology milieux* and nurtured by *rich networks for sharing knowledge* both locally and globally.

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Appendix 2.1

Copy of Sample Letter to Dedicated Biotechnology Businesses

Center for Biotechnology
130 Life Sciences Building
State University of New York at Stony Brook
Stony Brook, New York 11794-5208

516/532-8521
Fax 516/532-8577

Dr. Ima Yussie
President
Brilliant Biotechnology Corporation
100 Fortune Street
Very Long Island, NY 11563

Dear Dr. Yussie,

The Center for Biotechnology, in association with the New York Biotechnology Association, Inc., is presently conducting a project to identify ***strategies for the development of New York's biotechnology industry***. Ernst & Young has provided financial sponsorship for the project from its office in Long Island. The prupose of this letter is to inform you of this activity and to invite you to participate.

The project will produce:

- a published directory of biotechnology businesses in New York state;
- a report presenting a profile of the status of the New York biotechnology industry, accompanied by an analysis of how to achieve increased economic benefits from the state's biotechnology expertise;
- recommendations about policy and management issues relevant to firms, industry organizations (especially the New York Biotechnology Association), government, research institutions, and other support organizations;
- and, suggestions as to the most important kind of support needed from government.

The project is being led by Dr. Kelvin Willoughby, an expert in technology policy and economic planning, and an experienced analyst of the biotechnology industry, especially in California.

To enable us to produce the directory I would be grateful if you would take a few minutes to complete the information sheet enclosed, and then return it to the above address.

You will also be contacted soon by telephone with a request for an interview about various aspects of your business. We will not be seeking any private technical, scientific or legal details, but rather general information about your activities, and your experiences of the advantages and disadvantages of doing business in New York. Information you provide during the interview will be kept completely confidential. I would be most grateful if you would agree ot hte interview when contacted by Dr. Willoughby or one of the interviewers from the Center for Biotechnology.

Please feel free to contact either myself or Dr. Willoughby at the above telephone number if you would like to discuss the project in more detail.

Sincerely,

Dr. Richard K. Koehn
Director

Appendix 2.2

Name and primary location of organizations which constitute the population of Dedicated Biotechnology Businesses in New York, June, 1991

(Note: all locations are within New York State.)

1. Advance Biofactures Corporation, Lynbrook
2. Agway, Inc., Farm Systems and Applied Technology Division, Biotechnology Group, Syracuse
3. Alliance Pharmaceutical Corporation, New York Facility, Otisville
4. American Biogenetic Sciences, Inc., Copiague
5. American Bioresources, Jamaica
6. American Biorganics, Inc., Niagara Falls
7. Amur Research Corporation/Kerix Corporation, Valhalla
8. Analytab Products, Inc., Plainview
9. Anotec Separations, New York
10. Applied Genetics, Inc., Freeport
11. Applied Microbiology, Inc., Brooklyn
12. Arnel Products Co. Inc., Cherokee Station
13. Biocyte Corporation, New York
14. Bioindustrial Technologies, Inc., New York Division, Grafton
15. BioScreen, Inc., New York
16. Bioseparations, Inc., Ithaca
17. BioTechnology General Corporation, New York
18. Brain Research, Inc./Oncolab, Inc., New York
19. Bristol-Myers Squibb Company, Industrial Division, Biotechnology Group, Syracuse
20. Bristol-Myers Squibb Pharmaceutical Research Institute, Department of Investigative Toxicology, Syracuse
21. Bristol-Myers Squibb Pharmaceutical Research Institute, Molecular Biology Group, Buffalo (Westwood-Squibb Division), Buffalo
22. Cellular Products, Inc., Buffalo
23. Clinical Technologies Associates, Inc., Elmsford
24. Collaborative Laboratories, Inc., East Setauket
25. Culture Kits, Inc., Norwich
26. Curative Technologies, Inc., Setauket
27. Deltown Chemurgic Corporation, Fraser
28. Diagnostic Technology, Inc., Hauppauge
29. Direct Therapeutics, Yorktown Heights
30. DNA Plant Technology Corporation, Executive Office, Mount Kisco
31. Dynal, Inc., Great Neck
32. Encore Laboratories, Inc./Clark Laboratories, Inc., Jamestown
33. Enteric Products, Inc., Westbury
34. Enviro-Zyme, Inc., Stormville
35. Enzo Biochem, Inc., New York
36. Fairfax Biological Laboratory, Inc, Clinton Corners
37. Fibratek, Inc., Stony Brook
38. FTS Systems, Inc., Stone Ridge
39. GE Research and Development Center, Biological Sciences Laboratory, Schenectady
40. Gemini Science, Inc., New York Office, New York

41. Genencor International, Inc., Rochester
42. General Foods Corporation, Technical Center, Tarrytown
43. Genetix, Inc., Rye
44. Granular Specialties, Inc., Ronkonkoma
45. Hemazyme, Inc., New York
46. ImClone Systems, Inc., New York
47. Immco Diagnostic, Buffalo
48. Immunological Associates/Generic Immunologicals, Sayville
49. ImmunoSciences, Incorporated, Great Neck
50. Impath Laboratories, Inc., New York
51. Innovir Laboratories, Inc., New York
52. Intergen Company, Purchase
53. Lederle Laboratories, Medical Research Division, Pearl River
54. Life Technologies, Inc., Gibco Laboratories, Grand Island
55. Lifecodes Corporation, Valhalla
56. Litron Laboratories, Inc., Rochester
57. Liuzzi Microbiology Laboratories, Inc., Islip
58. MAP Pharmaceuticals, Inc., Stony Brook
59. Medtech Diagnostics, Inc., Bohemia
60. Melville Biologics, Division of New York Blood Center, Inc., Melville
61. Moltech Corporation, Stony Brook
62. Nanoprobes, Inc., Stony Brook
63. Narishige USA, Greenvale
64. New York BioLabs, Inc., Commack
65. Nutrimed Biotech, Ithaca
66. NYGene Corporation, Yonkers
67. Olympus Corporation, Biomedical Research Center, East Setauket
68. Oncogene Science, Inc., Manhasset
69. Orion Therapeutic Systems, Inc., Stony Brook
70. PDI, Inc. (Protein & DNA ImageWare Systems), Huntington Station
71. Pederson Biotech Resources, Inc., Ithaca
72. Phyton Catalytic, Inc., Ithaca
73. Praxis Biologics (Lederle-Praxis Biologicals, Division of American Cyanamid), Rochester
74. Pro-Cons Labs, Inc., Amhurst
75. Profile HF, Inc., New York
76. Progenics Pharmaceuticals, Inc., Tarrytown
77. Regeneron Pharmaceuticals, Inc., Tarrytown
78. StatChem, Inc., Bohemia
79. Sterling-Winthrop Research Institute, Rensselaer
80. T & B Bioclone, Inc., Buffalo
81. Taconic Farms, Inc., Germantown
82. Therion Corporation, Troy
83. United Biomedical, Inc., Lake Success
84. Upstate Biotechnology, Inc., Lake Placid
85. Vec-Tec, Inc., Schenectady
86. Viro Dynamics, New York
87. Virogenetics Corporation, Troy
88. Waste Stream Technology, Inc., Buffalo
89. Wessanin U.S.A., Inc., Research and Development Division, Biotechnology Group, Binghampton
90. York Biologicals International, Stony Brook

Appendix 2.3

Comparison of data base from 1991 survey of biotechnology businesses in New York by K. W. Willoughby (KWW data) with data on biotechnology businesses in New York extracted from Ernst and Young's *Biotech 91* study (E&Y data).

	E&Y data	KWW data
Number of businesses in sample	16	66
Average size of businesses (global)	77	70
Distribution of expenditure		
Cost of product sales	28.1%	27.0%
General, administrative, and marketing	30.2%	30.2%
Research & development	29.3%	37.4%
Other expenditure	12.4%	5.4%

Appendix 4.1

Industry Density Indices: Definition and Explanation

In this study, two measures of the "density" of an industry in a region have been employed: a *Firm Density Index (FDI)* and an *Employment Density Index (EDI)*. These are used as indicators of the relative capacity of regions to generate a particular kind of industry. Each index tells you something about the regional strength of an industry, standardizing the figures to take into account differences in the scale of the economies in the regions under consideration, the state of the industry in the whole state (or nation, as the case may be), and the current state of the whole economy throughout the state (or whatever reference region is used). That is, the indices take into account that, with all other things being equal, you would expect to find a large-scale industry (of a specified kind) in a large community, and a corresponding small-scale industry in a small community. For example, you would expect to find more restaurants in New York City than in Ithaca, but the fact that this was the case would not tell you if the restaurant industry was any more *dominant* or *strong* in NYC than in Ithaca. The indices enable "fair" comparisons between regions, standardizing for differences in the scale of the regional economies. In some academic disciplines, the measure labeled here as an "employment density index" is known as a "location quotient."

The industry density indices are designed so that they always compute to "1.0" for the reference region. A region with an industry density index of less than 1.0 is less "productive" than would be expected as "normal" for generating activity in that particular industry; whereas a region with a score of above 1.0 has above-average "productivity" in generating a local presence of the respective industry. Under certain assumptions, the indices may be used to suggest differences in the "competitiveness" of the regions under study. The formulas used here for the biotechnology industry are:

Biotech FDI for $region_n$ = {(biotech firms in $region_n$)/(biotech firms in reference region)}/{(all firms in $region_n$)/(all firms in reference region)}

Biotech EDI for $region_n$ = {(biotech employment in $region_n$)/(biotech employment in reference region)}/{(all non-government employment in $region_n$)/(all non-government employment in reference region)}

Likewise, identical formulae may be used for any industry, as follows:

$Industry_x$ FDI for $region_n$ = {($industry_x$ firms in $region_n$)/($industry_x$ firms in reference region)}/{(all firms in $region_n$)/(all firms in reference region)}

$Industry_x$ EDI for $region_n$ = {($industry_x$ employment in $region_n$)/($industry_x$ employment in reference region)}/{(all non-government employment in $region_n$)/(all non-government employment in reference region)}

The term "firm" used in these formulae has the same meaning as "business" in the report.

Appendix 8.1

Defining and Measuring High Technology Industries

The approach to defining "high-technology" industries employed in this study is founded on:

1. criteria which are constituted independently of popular images of "hitech"

2. criteria with indicators that can be measured objectively

3. criteria which relate to the content of what people do in technological practice, rather than to the style of technological end-products.

The approach has emphasized the *technical capacity of the workforce* in an industry as the most important factor determining its status vis-a-vis technology. Thus, an industry with a high technical capacity in its workforce is a "high-technology industry" (note: routine assembly of computer keyboards is not necessarily "high-technology" industry). Proxies for "high-technical capacity" can be derived from standard occupational data sources.

During the middle of the 1980s, a major study was conducted by Markusen, Hall, and Glasmeier, of the University of California at Berkeley, in which such a proxy measure was developed (see: A. Markusen, P. Hall, and A. Glasmeier, *High Tech America: The What, How, Where and Why of Sunrise Industries* [Boston: Allen and Unwin, 1986]). These scholars selected the following occupational categories as representative of "high-technology" work: engineers, engineering technicians, computer scientists, life scientists, and mathematicians. They then analyzed all manufacturing industries in the United States (at four-digit SIC Code level) to identify those with a higher proportion of their workforce in these "high-technology" occupations than the average for the manufacturing sector in the United States. They then worked out which three-digit SIC Codes categories could be used as a reliable approximation for the four-digit list. In this study, the resultant list has been the basis for data collection on "high technical capacity workforce" manufacturing industries in New York.

The SIC Codes which match the above criterion are: 281, 282, 283, 284, 285, 286, 287, 289, 348, 351, 353, 354, 356, 357, 361, 362, 365, 366, 367, 372, 374, 376, 381, 382, 384, 386. This list is based upon the current official SIC Code definitions (Executive Office of the President, Office of Management and Budget, *Standard Industrial Classification Manual, 1987* [Washington, D.C.: U.S. Government Printing Office, 1987]), adjusted to take into account changes in definitions adopted since the Markusen, Hall, and Glasmeier study.