Chapter 4
Biotechnology in the States

"We've got to do something to get this biotechnology applied in Illinois faster than it is in other countries. ”

Don Holt
Director, University of Illinois
Agricultural Experiment Station

“Biotechnology will change the world, giving us new tools in crop and livestock production and processing. For a $35 million investment, Iowa State University officials are confident we will attract over $120 million in research to Iowa over the next decade. ”

Governor Terry Branstad
Condition of the State Speech
January 12, 1987

“1 don’t think the people want the Biotechnology Center investing in the development of small businesses and their research without doing it very carefully. ”

Gerry Hancock
Former North Carolina State Senator

“Competitiveness may be a new issue to the Federal Government, but it’s old news to the States. While the precedents for forward-looking national strategies are few and far between, the 50 State governments have long been laboratories for policy experimentation. ”

Christopher M. Coburn
Executive Director
Ohio’s Thomas Edison Program

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Chapter 4

Biotechnology in the States

INTRODUCTION

In the past 20 years, State governments and local groups have increasingly used investment in high-technology industries as an economic development strategy. High-technology promises clean "sunrise" industries, an improved economy, new jobs, and a strengthened higher educational system. ' Recently, many of these initiatives have focused on biotechnology. States have different expectations about returns from biotechnology investment, which is reflected in how and where they spend their money. Some States, for example, spend money recruiting faculty at State universities to build a reputation that will then attract businesses into the area. Others direct most of their funds toward small firms, providing incentives and facilities for start-up. Most States pursue a combination of goals. How the States direct their biotechnology efforts depends on their existing industrial, educational, or natural resource base, and their philosophy on the role of State government in fostering small business development. Those States that are successful in nurturing the biotechnology industry rely on strong academic and research programs, a strong, local venture capital pool, and an unusually high level of interaction among researchers, manufacturers, and users.

This chapter examines State investment in biotechnology. In fall 1986, OTA surveyed all 50 States and the territories to determine the extent to which they are investing in new initiatives in biotechnology. OTA found a significant level of interest in biotechnology development at the State level; 33 States have allocated funds for biotechnology through centers of excellence, university initiatives, incubator facilities for new firms, or grants for basic and applied research in biotechnology. While most programs are too young to evaluate their success, their expectations are high.

[1]For the purposes of this discussion, OTA adopts the Department of Labor definition of "high- -technology " industries, as those industries with a ratio of R&D expenditures to net sales at least two times the average for all industries.

BIOTECHNOLOGY AND ECONOMIC DEVELOPMENT

Increasingly, State programs to foster economic growth and employment through the promotion of high-technology development surpass those found at the Federal level. As recently as 1980, only 10 States had programs promoting high-technology growth (15). Six years later, at least 43 States had high-technology programs, spending a total of $700 million in 1986 (5). OTA found that 33 of those programs include biotechnology.

In many ways, States are better able to leverage support, influence industry, and affect education than the Federal Government. State governments have traditionally performed key functions of importance to national economic development, such as basic infrastructure maintenance and improvement, basic and higher education, employment training and skills enhancement, financing for export stimulation, and promoting technological innovation. States are critically situated to promote university-industrial linkages that can facilitate the commercialization of research (14).

In most States, the Governor's executive offices for economic planning and development, department of commerce, or department of higher education have served as catalysts for promoting university-industry cooperation as a means for development. These initiatives are usually based on an analysis of the State's existing industrial base, and are undertaken in conjunction with more traditional economic development activities.

Economic development activities in the States seek to create jobs by offering inducements to companies. States compete with each other by tar-

geting attractive industries. What is new about these programs is their emphasis on expanding existing markets and creating new ones by accelerating innovation (8). State governments are attracted to high-technology industry because of the rapid expansion and its presumed potential to create jobs and revitalize distressed regions. States perceive biotechnology as a highly attractive set of industries because of its diversity of application, its dependence on a highly skilled, highly educated work force, its reliance on academe, and the short cycle from discovery to product. High-technology industries are also perceived to have fewer known environmental (and possibly occupational safety) problems than traditional manufacturing industries. This perception has changed, however, as communities face field testing of genetically engineered organisms and the prospect of gene therapy (13).

The rapid growth of State programs in biotechnology is an extension of previous State efforts to attract high-technology industries. For example, the growth of the microelectronics industry in California and Massachusetts (and the subsequent benefits accrued by those States) sent tempting messages to States dealing with declines in basic industries. Early successes with high-technology development (fostered by strong universities) positioned California and Massachusetts well for growth in biotechnology. Furthermore, previous experience may well have given them the lead they now enjoy in Statewide biotechnology development. Ironically, State government involvement in promoting biotechnology in these two States was minimal until 1985, most likely due to the lack of a need for additional catalysts.

Although California and Massachusetts house the largest percentages of dedicated biotechnology companies (27 and 13 percent of U.S. companies respectively), many other States have shown a keen interest in the development of biotechnology and have undertaken major initiatives to cultivate the industry.

Biotechnology Promotion at the Local Level

Some biotechnology efforts are developing or being initiated at the local level. The Biotechnology Park in Worcester, MA, was initiated and organized by the Worcester Chamber of Commerce, with funding assistance from local sources and the State. The concept of a Biotechnology Center affiliated with the University of California at San Francisco was discussed by the San Francisco Chamber of Commerce and endorsed by then Mayor Dianne Feinstein.

In Texas, the competition for State preeminence in biotechnology has generated local initiatives. The Dallas Biotechnology Task Force, established in 1984, raises money for the Dallas Biomedical Corporation, which will provide interim financing for research projects with commercial potential at the University of Texas Health Science Center in Dallas. Austin is competing with San Antonio to be the Texas center for biotechnology. San Antonio Mayor Henry Cisneros has been promoting biotechnology as a means to economic development and has proposed a 1,500-acre research park to attract biotechnology firms.

Table 4.1.—State Mechanisms for Promoting Biotechnology Development

Policy bodies:
- Governor's task forces, boards, councils, and commissions
- State mission agencies
  - —Commerce/economic development
  - —Higher education
  - —Science and technology offices

Appropriating and granting bodies:
- Legislature
- Nonprofit corporations
- Colleges and universities

Capital:
- Financial capital:
  - —Seed capital funds
  - —Venture capital partnerships
  - —Pension funds
  - —Grants
- Physical capital:
  - —Land use and zoning
  - —Research and science parks
  - —Incubator facilities
  - —Improvements in infrastructure
- Industrial revenue bonds

Management support:
- Business advocacy programs
- Government marketing programs
- Data retrieval and dissemination

Education:
- Kindergarten through grade 12
- Colleges and universities
- Worker training

SOURCE: Office of Technology Assessment, 1988.

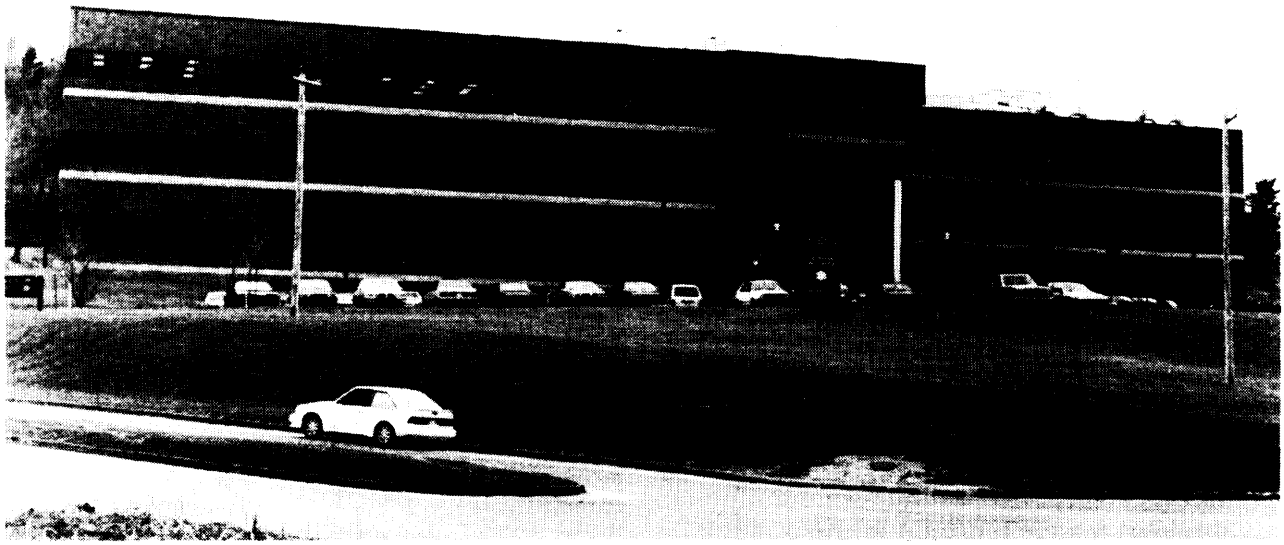

Photo credit: Thomas Morrisette, Worcester Area Chamber of Commerce

"One Biotech Park. " This 75,000-square-foot structure is the first building completed at the 1 million square foot Massachusetts Biotechnology Research Park located in Worcester, MA. As of March 1988, the building was fully leased.

In Maryland, Montgomery County has donated $9 million worth of facilities and additional millions in land to the Center for Advanced Research in Biotechnology, which is also funded by the University of Maryland and the National Bureau of Standards of the U.S. Department of Commerce. The county hopes to attract more biotechnology firms to its already thriving high-technology corridor. With a high percentage of scientists and engineers per capita and its close proximity to several Federal laboratories and research institutions, the county believes it is well positioned for development of a biotechnology-based industry.

In New York City, Columbia University has planned a $200 million biotechnology research park to be jointly funded by the city, the State, and the university. Four buildings to house academic and commercial research laboratories, office space, and retail outlets are planned. Officials hope that the research park will foster the biotechnology industry in New York City, revitalize a depressed neighborhood, and enhance the university's research capabilities.

Because dedicated biotechnology companies require less physical space than traditional manufacturing industries, cities and counties can offer land and low rent to companies. But cities and counties may be somewhat more limited than the States in what they can offer to attract these industries in a significant way. In contrast, at the State level, diversity of means can promote this industry. Many States can support biotechnology initiatives through appropriations from their legislatures or grants from nonprofit corporations. Support can take the form of financial or physical capital, management assistance, or education. Traditional methods for assisting small businesses, especially those in high-technology areas, are increasingly used to promote biotechnology development. Table 4-1 summarizes the mechanisms OTA found States using to promote commercialization of biotechnology.

OTA SURVEY OF STATE PROGRAMS IN BIOTECHNOLOGY

An OTA survey of State activities in biotechnology conducted in Fall 1986 found that 33 States and Guam directly support biotechnology activities, such as research, training, or development of facilities for research. An additional six States indicated they were conducting feasibility studies or were considering establishing a biotechnology initiative. The OTA survey revealed a wide range in the intensity level of these initiatives and diversity in their implementation. However, all of the States reporting intensified efforts on behalf of biotechnology report doing so in hope of economic development or promotion of academic excellence.

The States differ in their efforts in the following ways:

- the office, agency, or institution primarily responsible for the initiation of the program;
- the level of funding available annually for the support of research, facilities, or training;
- the mechanisms by which funds are raised;
- the base and method of operation for the program;
- the substantive concentration of the programs being funded; and
- the extent to which incentives are offered to attract biotechnology companies.

The types of initiatives States pursue depend, in part, on the influence of these factors. Therefore, the types of initiatives reported varied greatly. Some States are pursuing one path only, others a combination of approaches. The types of initiatives include:

- increased support for biotechnology research and development (R&D) in State universities and by biotechnology companies (33 States),
- programs or funds for biotechnology training at State colleges and universities (23 States),
- financial and technical assistance for biotechnology firms (27 States),
- discrete “Centers” mandated to facilitate communication between universities and industry to achieve technology transfer (28 States), and
- State-supported research parks and incubator facilities specific to biotechnology (6 States).

Table 4-2 displays the types of programs supported by States active in the promotion of biotechnology research and development within their borders.

Table 4.2.—State Activities in Biotechnology Research and Development

State	R&D Support	Training	Incentives for firms
Alabama	–	–	–
Alaska	–	–	–
Arizona	+		+
Arkansas	+	–	+
California	+	+	+
Colorado	+	+	+
Connecticut	+	+	+
Delaware	–		–
Florida	+	+	+
Georgia	+	+	+
Hawaii	–		–
Idaho	+	–	–
Illinois	+	+	+
Indiana	+	–	+
Iowa	+	+	+
Kansas	+	–	+
Kentucky	+	+	–
Louisiana	+	–	–
Maine	–	–	–
Maryland	+	+	+
Massachusetts	+	+	+
Michigan	+	+	+
Minnesota	+	+	+
Mississippi	–		–
Missouri “	+	–	–
Montana	–	–	+
Nebraska	–	–	–
Nevada	–		–
New Hampshire	+	+	–
New Jersey	+	+	+
New Mexico	–		–
New York	+	+	+
North Carolina .,	+	+	+
North Dakota	+	+	–
Ohio	+	+	+
Oklahoma	+		–
Oregon	+	+	–
Pennsylvania	+	+	+
Rhode Island	–		–
South Carolina	–	–	–
South Dakota	–		–
Tennessee	+	+	–
Texas	–		–
Utah	+	+	+
Vermont	+	–	+
Virginia .,	+		+
Washington	–		+
West Virginia	–		+
Wisconsin	+	+	+
Wyoming	–		–

SOURCE: Office of Technology Assessment, 1988.

Promotional and Implementation Base of State Biotechnology Programs

The 33 States reporting to OTA about their biotechnology programs represent a variety of approaches to the initiation and promotion of biotechnology. Although university systems play a major role in the design and implementation of biotechnology centers, the initiative for a biotechnology program in some States has come from the Executive Office of the Governor or the State legislature. The programs are often multi-faceted, and can involve direct funding of basic and applied research, allocations for university facilities or equipment, support of faculty salaries, or direct or indirect assistance to biotechnology companies.

Governor's Task Forces or governors with significant interest in high-technology promotion have been the catalysts for State actions in biotechnology in Illinois, Massachusetts, Michigan, New Jersey, New York, North Carolina, and Virginia. The oldest or largest biotechnology programs are. those promoted by the Governor's office, either through a special science and technology task force or commission, or through the executive mission agencies such as commerce or economic development.

One of the earliest efforts to promote biotechnology at the State level is in North Carolina. The North Carolina Biotechnology Center was founded in 1981 under the leadership of then Governor James B. Hunt to "stimulate multi-institutional and multi-disciplinary research and education programs in science areas related to biotechnology." Originally operated from the Governor's office, this agency is now a freestanding quasi-governmental organization funded by a legislative appropriation to the North Carolina Department of Commerce, with matching funds from industry.

The State of New Jersey has also initiated an ambitious biotechnology program, stemming from recommendations of the Governor's Commission on Science and Technology. The Commission studied the makeup of the New Jersey economy, examined the potential of high-technology industries, and eventually recommended the establishment and construction of a network of advanced technology centers at the State's public and private institutions.

More recently, Wisconsin's Governor established a special State council to accelerate economic development in biotechnology. Members of the Council will include the secretaries of the State Departments of Development, Natural Resources, and Agriculture, Trade, and Consumer Protection. The Council will be chaired by the chief executive officer of Universal Foods Corporation, a large food processing and production corporation.

Mission-oriented State agencies in the Governor's executive offices have served as catalysts for biotechnology programs in other States. Most typically, biotechnology promotion has arisen from the Governor's Office of Economic Affairs, Economic Development, or Department of Commerce. This is the case in Colorado, Iowa, Kansas, Massachusetts, Michigan, Minnesota, Nebraska, Oklahoma, Pennsylvania, Utah, and West Virginia. Most notable of these efforts are programs in Massachusetts and Pennsylvania. The Departments of Commerce in these two States have led the way in devising and implementing new State initiatives to stimulate technology research and education.

In Pennsylvania, the Ben Franklin Partnership Fund, established in 1982 with a $1 million Challenge Grant Program, established four advanced research centers. These funds provided the incentive for Pennsylvania State University to construct a building to house the Penn State Biotechnology Institute, which will receive Ben Franklin Funds. In addition, in 1987, Pennsylvania's Governor released $14 million in State funds for the Pittsburgh Biomedical Research Center at the University of Pittsburgh (expected by the Governor's office to be a major biotechnology research center). The Biotechnology Center will be built on the 48-acre site of a former steel company plant beside the Monongahela River. The Pittsburgh Technology Center, of which the Biotechnology Center is a part, is expected to create more than 1,600 jobs and attract $70 million in private investment. Planners calculate that more than $1.2 million in local tax revenue will be generated by the Center. This is an explicit example of the expectation that high-technology, biotechnology in

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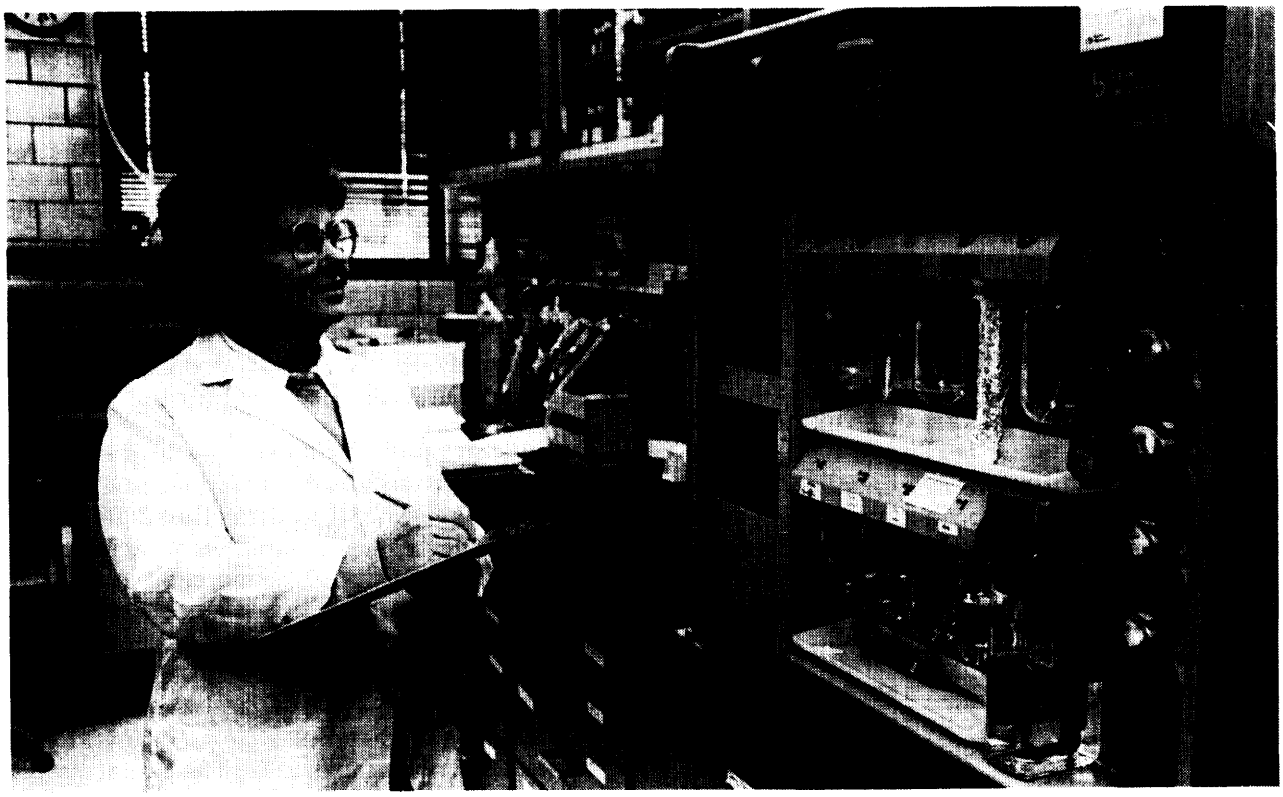

Photo credit: Biotechnology Center, University of Wisconsin-Madison

Research scientist records the progress of a protein sample on the Gas Phase Sequencer at the University of Wisconsin Biotechnology Center.

particular, will play a central role in revitalizing a region historically reliant on manufacturing.

Role of the University in State Biotechnology Programs

Universities are often important components in State economic development initiatives, particularly in high-technology, which requires a highly skilled work force. The availability of skilled labor is the most influential factor in the regional location of advanced technology firms (12). During the 1960s, U.S. universities responded to external and internal pressures to undertake additional research and problem-solving activities that related to the needs of the Federal Government and the cities. In the 1970s, universities sought to join with State governments to address a wide array of domestic issues. In the 1980s, universities are increasingly forging new partnerships with industry to accelerate the rate of scientific and technological innovation (2).

University service to the public is not new. Agriculture has long been the model of federally assisted public service by the university, through the Land Grant System (dating back to the Morrill Act of 1862). In 1962, NASA created the Sustaining University Program (SUP) to strengthen university research programs relevant to NASA missions. SUP was phased out in 1971 after being deemed a failure. NASA administrators felt that the universities had failed to respond to NASA goals, and observers felt that NASA's goals were unrealistic, "stemming from insufficient understanding of the nature of universities" (6).

In 1967, the National Science Foundation's (NSF) Intergovernmental Program was started to promote the use of scientific and technological re-

sources by State and local governments. In 1977, NSF implemented the Science, Engineering, and Technology (SSET) program to provide grants to governors and State legislatures for plans that would improve their use of science and technology. Implementation funds for these plans were insufficiently provided and the program was abandoned in 1981. Several of the programs the States now support grew out of strengths identified under the SSET program.

The intent of these Federal programs was to have university faculty take responsibility for the transmission, as well as the generation, of the knowledge they produce. Public universities have historically been entangled in multiple role expectations: ivory tower, service station, and frontier post (7). Philosophical differences regarding appropriate roles for educational institutions continue to influence discussions about the effects of public expectations on the quality of the research agenda and education.

In terms of biotechnology, the situation is no different. **Biotechnology owes much of its growth to academic science.** Not only has industry turned to the university as the source of cutting-edge research, but the States are also turning to their universities as the base of their biotechnology efforts. Many States recognize the value of a strong university system in attracting biotechnology companies. By creating expertise in the university system, States hope to attract and retain dedicated biotechnology companies as well as major pharmaceutical, chemical, and agricultural corporations. At the least, this form of educational investment policy infuses the universities with more resources for research and training, and at the most, attracts or creates a new technology base in the region.

Of the 33 States reporting State-supported biotechnology programs, 28 say they will rely primarily on their higher education institutions for the design and performance of biotechnology research and training. Early concerns about the influence of commercial biotechnology on universities seem not to be an issue in State-university initiatives (see also ch. 7). Public universities have traditionally cooperated with their State governments in programs to promote economic growth.

In 14 States, the university system has been the impetus for creating a biotechnology program, rather than being initiated by the State legislature or Governor's office. This is especially true in Texas, which has no Statewide biotechnology plan, and in California, where the university system has historically played a dominant role. Table 4-3 lists States where the university has been the promotional base for biotechnology rather than the Governor's office or the State legislature.

In many States, such as California, the department of higher education has led in promoting and implementing biotechnology programs, often independent of Executive action. In California, State-level promotion did not occur until 1985, well after California led in the number of biotechnology firms. The University of California (UC) System houses seven diverse biotechnology programs. San Diego State University and Stanford University also have centers. In addition, the University of California has established a multiyear effort to address the needs of biotechnology industries. This program, the Biotechnology Research and Education Program, is designed to facilitate the basic research underlying biotechnology and the training of future scientists at the nine campuses and three affiliated National Laboratories. Some would contend that the strength of the UC system has been the instrumental force in establishing a healthy biotechnology industry in California. The climate, a large venture capital pool, and expanding markets are additional inducements to industry.

In South Carolina, the push for economic development through high-technology has come largely from its universities. In 1986, the presidents of the State's three major universities announced plans for a 5-year joint research program totaling $600 million, of which a biotechnology

Table 4.3.—States Where the University Is the Promotional Base for Biotechnology

California	North Dakota
Florida	Ohio
Georgia	Oregon
Idaho	South Carolina
Louisiana	Tennessee
Maryland	Texas
New Hampshire	Wisconsin

SOURCE: Office of Technology Assessment, 1988.

center would be a small part. In Florida, Georgia, Idaho, Louisiana, Maryland, Oregon, and Wisconsin, biotechnology programs have also been developed primarily at the university level. Although biotechnology programs have not been promoted at the State level in Oregon, the Oregon Health Sciences University, the University of Oregon, and Oregon State University have spent considerable sums promoting biotechnology initiatives on their campuses.

The university-driven approach sometimes draws controversy. In 1987, the University of Georgia broke ground for a $32 million Biological Sciences Complex dedicated to research in recombinant DNA, molecular biology, and gene splicing. The Center is to be funded from the University's general instruction budget without any new or additional allocations from the university regents to cover the new positions created. As a result, other areas of the university are temporarily underfunded, drawing criticism from both faculty and students.

In Maryland, the University of Maryland has formed the Maryland Biotechnology Institute (MBI), comprised of five initiatives linked to the two campuses. As mentioned earlier, one center, the Center for Advanced Research in Biotechnology (CARB) has support from Montgomery County, MD ($9 million), and from the National Bureau of Standards (NBS) of the U.S. Department of Commerce. Although much of MBI's funds come from the State through the Department of Higher Education, the Governor's office provides no oversight. MBI plans an agenda in biotechnology R&Din the areas of agriculture, biomedicine, marine science, public policy, and protein engineering. All but the agricultural biotechnology centers were operational by 1987; it took several years to get the programs up and running. Critics of the late operational date charged that operating a biotechnology initiative under the guise of economic development may not be a manageable proposition for a university to undertake without State guidance.

Centers

Centers have become popular in the perception of the promise they hold for promoting economic development through biotechnology R&D. Usually based at universities, centers are multipurpose institutes created to foster interdisciplinary research, intercampus cooperation, and public-private collaboration. Centers can also provide technical and information assistance to university and industry scientists, and in some cases offer financial assistance to new firms. Table 4-4 lists discrete university-based biotechnology centers by State.

Centers differ in their evolution and structure. Some States with biotechnology initiatives do not have a center, but offer other incentives for R&D, such as grants and loans to both industry and academia. Altogether, 28 States have established centers or programs devoted specifically to research in areas directly related to biotechnology. In most cases, State funds were dispensed to one higher education facility for the creation of a research program. In some States-Colorado, Massachusetts, North Carolina, Pennsylvania, and Tennessee—the program is decentralized, with several State colleges and universities the beneficiaries of research and facility funds.

Not all centers that appear on paper are, as yet, operational. Many of the centers have been founded only within the past two years. The years indicated in table 4-4 represent year of founding, not year of operation. In some cases, funds have been authorized but not appropriated; in other cases, funds have been appropriated but not spent. Some centers are waiting for the construction of facilities and are operating ad hoc out of several departments within a university. In some States, the participation of several interests—State government, university administrators, and private donors—has created a complex bureaucratic network that has slowed action.

Table 4-4 also lists the substantive areas of concentration in the research programs of these centers. In most cases, several research areas in biotechnology are being pursued in a strategic manner. The university's existing departmental strengths, or the technological needs of the surrounding industrial base, provide the focus for development of specific capabilities. Newer, smaller programs, such as Connecticut's, have not yet targeted a specific area of research for funding, but will rely on newly recruited faculty to set a program agenda.

Table 4-4.—Biotechnology Centers Receiving Some State Support

Arizona
- Program for Excellence in Biotechnology (1986)
  University of Arizona, Tucson
  (biomedical)

Arkansas
- Biotechnology Institute (1985)
  Biomass Research Center
  University of Arkansas, Fayetteville
  (cell fusion, hybridoma, and monoclinal antibody technologies)

California
- Biotechnology Research and Education Program (1985)
- University of California
  Molecular Biology Institute, Los Angeles (1985)
  Biotechnology Program, Davis (1986)
  Center for Molecular Genetics, San Diego
  Center for Genome Biology, Riverside (1984)
  Plant Biotechnology Unit, Berkeley
  Gene Research and Biotechnology Program, Irvine (1983)
  Marine Biotechnology Center, Santa Barbara (1989)
- Molecular Biology Institute
  San Diego State University
- Center for Molecular and Genetic Medicine
  Stanford University

Colorado
- Colorado Institute for Research in Biotechnology (1986)
  University of Colorado,
  Colorado State University, and
  Health Sciences Center
  (reproductive physiology, fermentation, bioprocessing, agriculture, medicine, plant genetics)

Connecticut
- Biotechnology Center (1986)
  University of Connecticut, Storrs

Georgia
- Research Center for Biotechnology (1983)
  Georgia Institute of Technology
  (microbial, agriculture, biomedicine, bioreactors)
- Biological Sciences Complex (1987)
  University of Georgia
  (agriculture, medicine, energy)

Illinois
- Biotechnology Center (1986)
  University of Illinois, Urbana-Champaign
  (agriculture)
- Center for Plant Molecular Biology (1987)
  Northern Illinois University

Indiana
- Agrigenetics Research Center (1985)
  Purdue University
- Molecular and Cellular Biology Center (1985)
  Indiana University

Iowa
- Molecular Biology Program (1986)
  Iowa State University, Ames
  (agriculture, bioprocessing, food processing)

Kansas
- Center for Bioanalytical Research (1985)
  University of Kansas

Kentucky
- Biotechnology and Genetic Engineering Center (1987)
  University of Kentucky, Lexington

Louisiana
- Biotechnology Institute (1985)
  Louisiana State University

Maryland
- Maryland Biotechnology Institute (1984)
  University of Maryland
  (protein folding, crystallography, marine biotechnology, biomedicine, agriculture, policy)

Massachusetts
- Biotechnology Center of Excellence (1985)
  Massachusetts Biotechnology Research Institute
  Massachusetts State Colleges and Universities

Michigan
- Michigan Biotechnology Institute (1982)
  (fermentation, biomaterial products technology, waste treatment, industrial enzyme technology)

Minnesota
- Biotechnology Research Center (1983)
  Plant Molecular Genetics Institute
  Human Genetics Institute
  Institute for the Advanced Studies of Biological Process Technology
  University of Minnesota

Missouri
- Molecular Biology Program (1987)
  University of Missouri, Columbia
  (development and aging, disease resistance, energy, environmental applications)

New **Jersey**
- **Center** for Advanced Biotechnology and Medicine (1986)
  Rutgers University
  (biomedicine, protein science, structural biology)
- **Center for Agricultural Molecular Biology (1987)**
  Rutgers Cook College
- Lewis Thomas Laboratories (1985)
  Princeton University

New **York**
- Center for Medical Biotechnology (1983)
  SUNY Stony Brook
- Center for Biotechnology in Agriculture (1983)
  Cornell University

North Carolina
- North Carolina Biotechnology Center (1981)
  Duke University
  University of North Carolina
  North Carolina State University
  (bioelectronics, bioprocess engineering, marine, monoclinal lymphocyte technology)

Ohio
- Edison Animal Biotechnology Center (1984)
  Ohio University
  (livestock enhancement)
- Biotechnology Center (1986)
  Ohio State University
  (plant and microbial interactions, neurobiotechnology)

Oregon
- Center for Gene Research and Biotechnology (1983)
  Oregon State University, Corvallis
- Institute of Molecular Biology (1983)
  University of Oregon, Eugene

(continued on next page)

Table 4.4.—Biotechnology Centers Receiving Some State Support—Continued

Pennsylvania
- Biotechnology Institute (1987)
  University of Pittsburgh
- **Biotechnology institute (1984)**
  Pennsylvania State University
  (environmental microbiology, bioprocessing, plant and animal ceil culture, bimolecular structure and function)

Tennessee
- **Tennessee Center for Biotechnology (1988)**
  Tennessee State University System
  (plant cell tissue culture, hazardous waste management, environmental toxicology, drug delivery systems)

Texas
- Central Hybridoma Facility (NSF support 1985-1988)
  University of Texas, Austin
- Institute of Biosciences and Technology (1987)
  Texas A&M
- Institute of Biotechnology (1987)
  University of Texas Health Science Center, San Antonio

Utah
- Center of Excellence in Biotechnology (1985)
  Utah State University
  (plant and veterinary, biomedicine)

Virginia
- Center for Biotechnology (1985)
  Old Dominion University
- Institute of Biotechnology (1985)
  Medical College of Virginia of Virginia Commonwealth University
  (vaccines, biocatalysis, diagnostics)

Wisconsin
- Biotechnology Center (1984)
  University of Wisconsin, Madison
  (fermentation, biopulping, biocomputing, hybridoma, plant cell and tissue culture, sequencing and separation, enzyme improvement and production)

SOURCE: Office of Technology Assessment, 1986.

State Expenditures in Biotechnology

The States vary widely in the amount of funds they dedicate specifically to biotechnology. A multitude of problems arise if one tries to conduct an accurate comparison of State spending:

- Few States list biotechnology initiatives as a distinct line item in their budget. Those that do, such as New Jersey, North Carolina, and Massachusetts, provide an accurate figure for actual dollar support for biotechnology. In most States, however, the funds derive from several sources in the general funds and are directed to several recipients. Because of this, undercounting or overcounting can occur. In undercounting, for example, States that fund a Center of Excellence in Biotechnology might not count State support for biotechnology activities going on within the university system but outside the Center. For example, although the budget for the Massachusetts Biotechnology Center of Excellence only received an appropriation of $935,000 in 1987, this excludes $9 to $12 million of State appropriations for biotechnology activities at public universities and $26 million worth of biotechnology loan portfolios of State agencies. As an example of overcounting, States might report that a large portion of their health science budget is related to biotechnology without systematically verifying the claim.
- Most States provide the operating budget for a biotechnology program, but cannot easily segregate the amount of the budget derived solely from State coffers. Funds are categorized by type of expenditures rather than source of funds. Therefore, budgets often reflect funds derived from State appropriations, private donations, and Federal grants and contracts. With time and patience this information could be untangled. In the OTA survey, respondents were asked to report on the amount of investment by the State only. Calculated estimates were provided by many States in lieu of actual expenditures.
- Respondents often had the difficulty faced so frequently by those asked to account for biotechnology activities: that of definition. While some States define biotechnology narrowly, others consider spending in related areas to be relevant and include that in their figures. In all cases, respondents were asked to use the OTA definition of biotechnology for accounting purposes.
- Some States were unable to separate funds spent specifically on biotechnology. For

Table 4-5.—State Allocations for Biotechnology R&D, Training, and Facilities

State	FY 1986	FY 1987
Arizona	$1,170,000	$1,540,000
Arkansas	757,173	800,000
California	2,500,000	2,500,000
Colorado	500,000	500,000
Connecticut	665,000	1,100,000
Florida	5,050,000	7,050,000
Georgia	2,600,000	3,000,000
Idaho	438,800	450,000
Illinois	4,500,000	5,000,000
Indiana	4,000,000	1,029,904
Iowa	500,000	3,750,000
Kansas	162,000	172,000
Kentucky	908,500	896,600
Louisiana	670,000	NA
Maryland	2,600,000	3,900,000
Massachusetts	485,000	935,000
Michigan	6,000,000	4,000,000
Minnesota	1,032,000	1,100,000
Missouri	1,500,000	3,700,000
New Hampshire	150,000	450,000
New Jersey	10,000,000	35,690,000[a]
New York	34,300,000[a]	[a]
North Carolina	6,500,000	6,900,000
North Dakota	1,643,090	1,601,783
Ohio	2,194,787	50,000
Oklahoma	1,584,000	1,542,000
Oregon	350,000	360,000
Pennsylvania	2,848,824	18,035,494
Tennessee	NA	800,000
Utah	110,000	500,000
Vermont	NA	300,000
Virginia	1,500,000	1,750,000
Wisconsin	190,000	418,000

NA: Not available
[a]Indicates a multi-year appropriation

SOURCE: Office of Technology Assessment 1988

example, Illinois has allocated $3 million to 16 Technology Commercialization Centers that serve other high-technology interests as well as biotechnology. Therefore, its total reported budget for biotechnology can only be estimated and could be inflated or undercounted.

- Those States responding that they have no special programs in biotechnology could be subsidizing research through a research fund or through the usual support of their universities. For example, Texas reports no State-level program aimed at funding biotechnology, although biotechnology research is funded through general research funds available from the State. The University of Texas, Austin, supports biotechnology by housing the Central Hybridoma Facility, which was funded by the National Science Foundation at $120,000 a year until 1988 when the university had to absorb the cost. Texas A&M plans to spend $24 million to build an Institute of Biosciences and Technology to study and market developments in biotechnology. And Dallas billionaire H. Ross Perot has contributed to the construction of a research park in San Antonio that will be called the University of Texas Institute of Biotechnology.

Given these caveats, table 4-5 presents levels of direct support for biotechnology as reported by 49 States for fiscal years 1986 and 1987 (Alaska did not respond). Support includes funding of research, facilities, and training.

The range for reported spending varied from $110,OOO in Utah to a $34.3 million multi-year appropriation by New York in fiscal year 1986. Several States emerge as the frontrunners in terms of dollars spent. New York and New Jersey surpass all States in spending for fiscal year 1986; North Carolina, Michigan, and Florida followed, spending over $5 million each. Pennsylvania, which spent only $2.8 million in fiscal year 1986, has accelerated its biotechnology program dramatically in fiscal year 1987, allocating over $18 million, not including matching funds of $13,212,900 in fiscal year 1986 and $32,840,503 in fiscal year 1987. New Jersey increased its allocation more than threefold between fiscal year 1986 and fiscal year 1987, from $10 million to $35.6 million: the $35.6 million allocation was for a capital building program comprised of $8.6 million in New Jersey Science and Technology Commission funds and the balance provided by the two collaborating State institutions.

New York State reported that it committed $34.3 million specifically to biotechnology in fiscal year 1986 and an additional $80 million on health research that “may or may not involve biotechnology.” According to the Executive Director of the New York State Science and Technology Foundation, nearly 70 percent of those funds specific to biotechnology are spent on research; the remainder is spent on facilities and training. In fact, $32.5 million of the 1986 appropriation was for a build-

ing at Cornell University. The Center for Medical Biotechnology at the State University of New York (SUNY) at Stony Brook and the Center for Biotechnology in Agriculture at Cornell University each received $1 million for research funding. In addition to State funds, the Cornell center had three corporate sponsors that signed 6-year contracts totalling $2.5 million each. The SUNY center has 75 corporate sponsors, each involving specific research contracts. The New York Science and Technology Foundation awarded $250)000 in grants through its Research and Development Grants Program. Biotechnology training programs received $63,000 from the State in fiscal year 1986.

Maryland reported an allocation of $3.9 million in fiscal year 1987. This sum excludes a $9 million loan contribution from Montgomery County in the form of a building to house CARB, and the laboratory and personnel resources provided by a Partner in CARB, the National Bureau of Standards.

It is not clear whether the high funding levels currently appropriated by many States will be sustainable. These initially large investments might represent start-up or catch-up costs for facilities and equipment. Many States are depending on industry to assume a share of support after the initial State appropriations. Biotechnology initiatives are long-term investments and likely to be viewed as justifiable areas for cutback or elimination by State legislatures during times of fiscal stress. For example, in fiscal year 1985, Louisiana allocated $1.53 million to the Louisiana State University System Biotechnology Institute, That funding level dropped to $270)000 in fiscal year 1986 because of the State's fiscal problems. Funding in the future is uncertain.

Mechanisms for Raising Funds

Most programs are funded through general State revenues appropriated through a direct legislative action, or through higher education funds. Eight States have a discrete legislative appropriation dedicated to a Center program in biotechnology or to a nonprofit development corporation. As stated earlier, it is easier to obtain biotechnology spending figures from these States because the funds are centralized.

Several States have taken unique approaches to raising the necessary capital for developing high-technology programs. In Iowa, a London-based chemical company withheld $8 million in capital investment in Iowa until the State agreed to provide $5 million a year for related biotechnology research at Iowa State University. In response, the Iowa legislature agreed to allocate $3.5 million from the State's lottery revenues.

In Missouri, fiscal year 1987 new State lottery revenues were devoted to education—including $3.7 million for biotechnology research. Facilities at the University of Missouri-Columbia were funded as part of a Statewide $600 million General Obligation Bond issue.

Perhaps the most impressive bond issue was a $90 million Jobs, Science, and Technology Bond Issue approved by the voters of New Jersey in 1984. Of the $90 million, $35 million is targeted for biotechnology. The bill establishes the Advanced Technology Center in Biotechnology and requires joint governance by Rutgers University and the University of Medicine and Dentistry of New Jersey. The New Jersey Commission on Science and Technology is now faced with raising new revenues.

In addition to floating public bonds, some States have relied on proceeds from natural resource revenues to fund research in biotechnology and other technologically based fields. In Michigan, dedicated oil and gas revenues flow to the Michigan Strategic Fund, which provides support for the Michigan Biotechnology Institute. Other support comes from the State's General Fund, which supports the universities. Montana funds the Montana Science and Technology Alliance through funds appropriated from coal severance tax proceeds.

Many States, such as Pennsylvania, Massachusetts, New York, and Ohio, require an industry match to supplement State appropriations, Programs funded through the Pennsylvania Ben Franklin Partnership are supported via a capital fund appropriation requiring a one to one match from the recipient (the actual match has been running four to one). The funds designated for the University of Pittsburgh Biotechnology Center, for example, are derived from the capital budget—

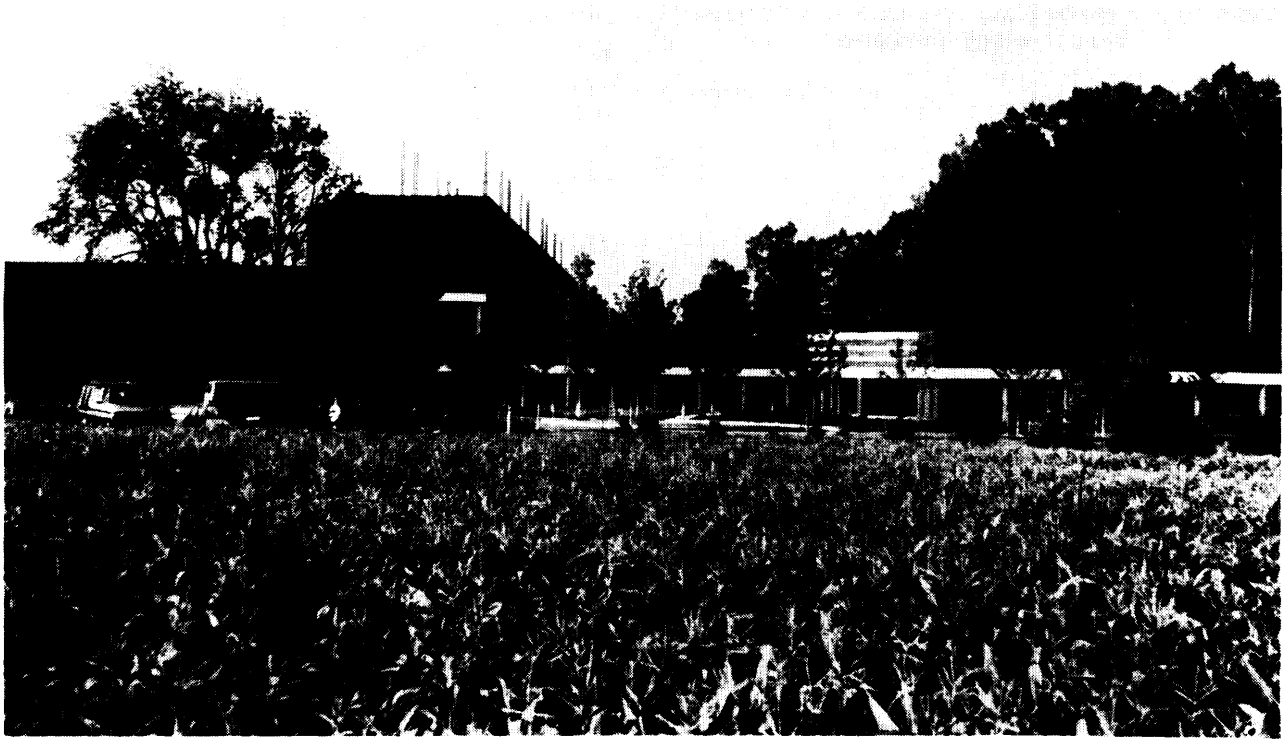

Photo credit: Michigan Biotechnology Institute

The Michigan Biotechnology Institute, a 120,000-square-foot business and research center funded by an industrial revenue bond issue, a low-interest State loan, and Institute funds.

the money in this case came from the State share of real estate transfer taxes. The matching funds are provided by a variety of organizations, most prominently private sector firms, but universities provide substantial in-kind support (11). A similar matching system exists in the Thomas Edison Program in Ohio. Matching private sector contributions can include cash, state-of-the-art equipment, and essential personnel, and in the case of small companies, use of facilities and equipment.

Special Incentives for Biotechnology Companies

Support of small business development and growth is a traditional State function. As a nation, the United States provides more direct support to small business development than does any other industrialized country (9). State departments of commerce and economic development have long-standing programs designed to assist small businesses. In some cases, support is offered through technical and management assistance; in other cases the support is financial or in the form of incentives.

Few States have special incentives or means of support specifically for biotechnology companies. Rather, biotechnology firms are eligible for the same benefits as those available to other small businesses or other high-technology firms. Most States recognize the need to do more than just attract firms from other States. Instead, they've come to understand the importance of aiding existing entrepreneurial companies. Small companies may receive direct assistance for expansion or R&D, or indirect assistance in the form of facilities, tax incentives, customized job training, or technical or management support. And, as many firms plan manufacturing facilities, States may find their business climate more or less hospitable than that offered for R&D.

A few States already have a significant lead in attracting biotechnology firms, with 50 percent

Table 4-6.—State-by-State Distribution of Dedicated Biotechnology Companies

State	No. firms	Percent
California	111	27
Massachusetts	54	13
Maryland	38	9
New Jersey	24	6
New York	20	5
Wisconsin	16	4
Connecticut	13	3
Texas	13	3
Washington	13	3
Colorado	9	2
Pennsylvania	9	2
Florida	8	2
Minnesota	6	1
North Carolina	6	1
Ohio	5	1
Maine	5	1
Oregon	5	1
Virginia	5	1
Illinois	4	<1
Kansas	4	<1
Michigan	4	<1
Indiana	3	<1
Louisiana	3	<1
Utah	3	<1
Arizona	2	<1
Georgia	2	<1
Missouri	2	<1
Montana	2	<1
Nebraska	2	<1
Alabama	1	<1
Arkansas	1	<1
Delaware	1	<1
District of Columbia	1	<1
Hawaii	1	<1
Iowa	1	<1
New Hampshire	1	<1
New Mexico	1	<1
Rhode Island	1	<1
South Carolina	1	<1
Tennessee	1	<1
West Virginia	1	<1
Total	403	100

SOURCE: Office of Technology Assessment, 1988.

of dedicated biotechnology companies located in just five States. California remains the leader in number of firms, with 111 companies, or 27 percent of the U.S. industry. Massachusetts is second with 54 (13 percent), followed by Maryland with 38 (9 percent), New Jersey with 24 (6 percent), and New York with 20 (5 percent). Table 4-6 shows the geographical distribution of dedicated biotechnology companies by State.

State programs are challenging the traditional notion of the Federal Government as the major benefactor of the research community. For State governments, support of R&D is a relatively new function, although the motivation is historic—economic development. Many States now offer competitive grants programs in R&D for which anyone can apply.

Direct Financial Assistance

Direct financing of research is but one method of direct financial assistance for biotechnology companies. Direct financial assistance for expansion, a traditional method of small business assistance, is widely available through State economic development programs. Tax-exempt financing in the form of industrial revenue bonds can lower the cost to borrowers. Direct loans and loan guarantee programs are available to any business. Perceiving a need for unique financial assistance programs for high-technology companies, many States recently established programs targeted to high-technology firms. These programs maybe quasi-public corporations that provide venture capital in the form of seed money. Arkansas, Arizona, California, Connecticut, Florida, Louisiana, Massachusetts, Michigan, New York, Ohio, Pennsylvania, and Wisconsin all have funds for new high-technology ventures.

Development Corporations.--Numerous States have established nonprofit development corporations or authorities to serve as forums for and overseers of State policies affecting high-technology development. These bodies may identify, develop) and apply advanced technologies for economic growth. In some States, such as Arkansas, the Science and Technology Authority can issue bonds) own patents, and enter production contracts and agreements. Development corporations award funds to both industry and universities.

Biotechnology often benefits from these science and technology corporations:

- In Indiana, the Corporation for Science and Technology awarded $4.5 million to Purdue University to conduct biotechnology research on new and improved crop strains, to improve biotechnology training methods for students, and to create a science base attractive to the biotechnology industry. Indiana University's Institute for Molecular and Cellular Biology received $1.2 million from the corporation

to establish two research centers for monoclonal antibody production and for gene sequencing.

- Michigan has established the Michigan Strategic Fund which funds up to 75 percent of the costs incurred in developing products and processes important to creating jobs in the State. Genetic engineering is one of the four targeted areas of this program.
- The Massachusetts Technology Development Corporation, a quasi-public corporation founded in 1979, provides seed capital with other private investors and has succeeded in boosting private investment nearly 10 times the original amount (1). More specific to biotechnology, the Massachusetts Centers of Excellence Corporation, operated from the Governor's Office of Economic Affairs, funds research and development activities in five applied fields, of which biotechnology is one. The Massachusetts Industrial Finance Agency authorized a $1.5 million industrial revenue bond for continued expansion of the Biotechnology Research Park.
- The Center for Innovative Technology in Virginia is a nonprofit corporation targeting research in four broad areas perceived to be important to Virginia's economic future. Biotechnology is one of these four areas.
- The Innovation Partnership in Biotechnology Program in New Jersey provides nearly $500,000 to five academic research institutions. The funds are matched by industry funds and in-kind services.

In many States, university-industry collaboration is a condition for qualifying for research funds. Arkansas, Connecticut, Massachusetts, Pennsylvania, Tennessee, and Virginia all have programs requiring that proposals be submitted as a joint venture between a university and a firm. Often, awards are made on the basis of scientific and technical merit, followed by potential economic benefit to the State. University-industry relationships in biotechnology are discussed further in chapter 7.

Indirect Financial Assistance

States can help small businesses through a variety of in-kind mechanisms, such as site selection assistance, customized job training, legislation to assist in capital formation, technical assistance programs, property tax abatement, and income tax credits.

Incubator Facilities.—Research incubators provide low-cost office and laboratory space for entrepreneurs and struggling firms. Arkansas, Colorado, Illinois, Maryland, Massachusetts, and New York have constructed or are planning to construct incubator facilities specifically for biotechnology companies.

The Biomass Research Center at the University of Arkansas, Fayetteville, operates a biotechnology business incubator. Funds for the incubator were awarded by the Arkansas Science and Technology Authority. The Catalyst Bio Technology Industrial Incubator Project in Louisville, CO, is a public-private venture involving a consortium of corporate research facilities and staff of the University of Colorado at Boulder, Colorado State University in Fort Collins, and the Colorado School of Mines.

The College of Agriculture at the University of Illinois plans to build a business incubator at its research farm where scientists from industry can use university research to develop and market new farm products. Businesses will be selected for participation on the basis of their potential for developing a marketable product (within 2 to 3 years) that could be manufactured in the State and be used to help Illinois agriculture. An 11-member committee of farmers, agribusiness representatives, and university faculty will review proposals to select companies. The Illinois Department of Commerce and Community Affairs has awarded a $200,000 grant to the incubator. The university will contribute an additional $400,000.

Tax Incentives.—Taxes are important to small, expanding high-technology companies because cash flow is critical. State and local taxes take cash from a company when they need it most, at the outset of business when little or no revenues are being generated. Recognizing this, most States offer some type of tax incentive for business expansion. Efforts to provide incentives for high-technology companies have increased recently.

In 1981, California eliminated taxes on capital gains for investments in eligible "small business stock" held for 3 or more years, a novel approach

that encouraged additional venture capital investments in startups and other small businesses. The State of Indiana allows a tax credit of 30 percent on individual investments in a venture capital pool administered by the Indiana Corporation for Innovation Development (15). Minnesota encourages technology development and spin-offs by offering a tax credit of 30 percent of the value of the technology transfer that occurs when a small business is spun off from a parent firm.

Arkansas offers State R&D tax credits, and Iowa offers property tax abatement and State income tax credits for high-technology firms.

Information and Technical Assistance.—Ac - cording to a 1983 survey by the Council of State Governments, 48 States offer general business information or related technical assistance (10). This assistance may include site location, permits, labor force availability, or accessibility to databases,

Increasingly, States are designing technical assistance programs to match innovators with investors. A venture capital network created in New Hampshire consists of databases of entrepreneurs and their ideas and individuals wanting to make investments. The Wisconsin Innovation Center helps inventors evaluate the commercial feasibility of their ideas and inventions. Only one State has designed a program specifically for biotechnology companies: the North Carolina Biotechnology Center has compiled a compendium of North Carolina scientists conducting biotechnology research and a list of North Carolina biotechnology companies and their activities.

Arizona, Kansas, and New York have programs to assist companies applying for Federal Small Business Innovation Research (SBIR) dollars. In Arizona, the Arizona Innovation Network and Arizona State University have formed a consortium that is expected to help small technology companies reap the benefits of the SBIR program. New York State sponsors the SBIR Promotion Program. Chapter 3 describes the extent to which SBIR funds have been used to assist biotechnology firms.

THE NATIONAL SCIENCE FOUNDATION EXPERIMENTAL PROGRAM TO STIMULATE COMPETITIVE RESEARCH

For a few States, Federal assistance has provided a new opportunity for developing biotechnology. In 1978, the National Science Board of the National Science Foundation (NSF) responded to concern over the geographical distribution of awards by initiating the Experimental Program to Stimulate Competitive Research (EPSCoR). This program aims to improve the quality of the science and engineering research environment in States that are least successful in competing for Federal R&D awards.

The EPSCoR program is conducted in two phases: a planning Phase A and an implementation Phase B. In Phase A, States are given nine months and a $125)000 planning grant to assess their science and technology base and to develop a 5-year research improvement plan. Phase B awardees receive additional funds to enhance their scientific and technical base. Awards are based on scientific merit and local commitment to improving science and engineering. In the first round—1985—NSF awarded 5-year Phase B grants ranging from $2.4 million to $2.9 million each to Arkansas, Maine, Montana, South Carolina, and West Virginia.

In 1986, the National Science Board awarded Phase B grants totaling $23.5 million to another set of jurisdictions—Alabama, Kentucky, Nevada, North Dakota, Oklahoma, Puerto Rico, Vermont, and Wyoming. In turn, the States and Puerto Rico pledged a total of $67.9 million to help implement their EPSCoR programs.

At least five States plan to use the EPSCoR funds to build on their expertise in biotechnology:

- Vermont will use the funds to create faculty positions in recombinant DNA and molecular biology at the University of Vermont (4). The State plans to match the EPSCoR funds with $300,000 to fund research projects in areas relevant to biotechnology.
- In North Dakota, the EPSCoR funds are contributing to a $250,000 program in Cellular

and Molecular Biology at North Dakota State University (3).

- The Montana Science and Technology Alliance has targeted biotechnology as one of eight technology areas under consideration for funding.
- The University of Kentucky has designated biotechnology as one of the Centers of Excellence in its 5-year plan and the EPSCoR plan. EPSCoR funds are dedicated to a Membrane Sciences Research Program in a newly formed Biotechnology and Genetic Engineering Working Group.
- In Oklahoma, $303)000 and $323,000 of the EPSCoR funds were spent on biotechnology in fiscal year 1986 and fiscal year 1987 respectively.

While it is too early to assess the extent to which EPSCoR funds will help certain States gain a foothold in biotechnology it is clear that biotechnology is a field some States had in mind when developing their strategic plan for Phase A of the EPSCoR program.

SUMMARY AND CONCLUSIONS

Thirty-three States reported to OTA that they are actively engaged in some form of promotion of biotechnology research and development, as a means of academic excellence in their colleges and universities, and as a path to economic development. Six additional States are studying the feasibility of a special initiative within their borders. Clearly there is room for many players, and the Nation will benefit from the role that States can play in funding basic and generic applied research in biotechnology. Whether these programs will yield returns within an acceptable policy cycle will depend on the patience and commitment of State policy makers and their public. It is inevitable that States will compete with each other in the race for excellence in biotechnology. Many factors contribute to a firm's decision to locate within a State. New State programs to attract firms and faculty can only address some of those factors. At best, this interstate competition will create the net effect of a positive business environment in most States and localities. Furthermore, as biotechnology firms establish separate manufacturing facilities, a new set of criteria could influence site selection than was used in siting R&D facilities.

The early influx of Federal dollars into defense and aerospace research in regions such as Research Triangle Park, Route 128, and Silicon Valley played a major role in establishing a successful high-technology economy for North Carolina, Massachusetts, and California, respectively. These three well known regions of high-technology development owe their early growth and success, in large measure, to Federal spending for R&D. In the future, no one region or State maybe able to dominate Federal funds in the manner these States have in the past. Federal research dollars are now more widely disseminated. However, those States with universities that receive a large share of Federal biological and biomedical research funding will retain an advantage over those that are still struggling to establish a strong research capability.

It is too early to tell who the winners will be. The only available measures of strategic position to date are the age of the program, the size of its budget, and the number of biotechnology companies already established within a State's borders. The oldest biotechnology program–in North Carolina-is only in its seventh year. And although it is the oldest program, it is not funded at the highest level.

The problem of inadequate and differing performance measures will remain. Some States will consider their programs a success if they achieve research excellence in their universities. others will measure success by the growth of the biotechnology industry within their borders. Ultimately, the success of a State initiative must be judged from the State or local perspective. Officials with a long-term view and the patience to wait will realize that the benefits of investment

in biotechnology may be far in the future. Biotechnology is not a big employer. Small biotechnology companies do not require large physical plants. Biotechnology is a research-intensive field with a longer lead time to the marketplace than other fields, particularly in view of the need for regulatory review of many of its products. In this sense, biotechnology differs greatly from other high-technology areas, such as microelectronics, where the time between invention and sales can be relatively short. The real payoff to investment in biotechnology probably will be technologically based. That is, strategic investment in biotechnology may yield applications (e.g., new crops, pesticides, or health care) that might genuinely effect change in the State's economic or industrial base. Thus, it will be more the application of the technology that transforms the economy, not a new work force or a taxable physical plant.

The mode and philosophy of economic development varies greatly from State to State. Those States with the earliest and most ambitious programs, such as North Carolina, Massachusetts, and New Jersey, have all had strong leadership from the Governor's office. In each of these States, the Governor assumed the role of chief economic development officer, making a profound impression by his personal involvement in the economic development process. State biotechnology programs with strong support from their governor could fare better than those trying to muster resources haphazardly without an explicit executive endorsement.

Initiatives need to be keyed to each State's existing economic and academic base, The development of high-technology industry results from close cooperation with academic centers of excellence, the availability of highly skilled labor and sufficient risk capital, aggressive venture capitalists, and proximity to Federal research dollars and facilities.

Long-term research programs run counter to the tradition of quick turn-around on State investments. But States could lead all levels of government in the design of applied research programs and could succeed in areas where the Federal Government will not. For those States able to sustain their investment for a prolonged period of time, biotechnology could serve them and the Nation well. States facing fiscal stress, educational insufficiencies, and severe unemployment could find such long-term investment a difficult prospect.

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