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The Search for a New Golden Goose:
State Strategies for the Biotechnology Industry

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The Search for a New Golden Goose: State Strategies for the Biotechnology Industry

Abstract

Many state policymakers see biotechnology as a new "golden economic goose" that will provide technological leadership and industrial wealth. This paper discusses the results of a survey on state biotechnology policies and programs. The authors conclude that many state governments are employing lessons learned from earlier experiments with industrial policy and science and technology policy and putting together a wide variety of strategies to enhance their competitiveness. It is important not only to ask what types of programs states have adopted, but also how they are being implemented; in particular, how new institutional arrangements are emerging among key actors involved in commercial biotechnology. Five models are proposed to differentiate and elaborate these institutional arrangements. The authors also relate the experiences of other states to the California context and suggest policy directions that could allow greater state benefits to be captured from biotechnology development.

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I. Introduction

The Competitors

State policymakers throughout the nation have engaged in a new competition for high-technology leadership. Texas, California, Massachusetts, and North Carolina are well known for their aggressive economic development policies focusing on high technology. In fact, it has been the leadership of these states that has stimulated a fierce competition among the rest of the nation's states to enter the high-stakes, high-risk area of developing a high-technology economic base. The competition between states has become intense, and, at times, bitter.

Many state policymakers see the emerging field of biotechnology as the new "golden economic goose" that will provide them with the technological capacity to compete with California and the other leading states for technology leadership and industrial wealth. Unlike the microelectronics industry, where California was almost alone, the state now faces stiff competition from dozens of other states in biotechnology. The competitive states recognize California's headstart, but they are more than encouraged by the recent successes of competing states, like North Carolina and Texas, as they enter the competition to develop or pluck one or two of California's most recent golden eggs.

The Biotech Goose

Biotechnology is one of the fastest growing and most significant industries in the nation. Its significance is in part measured by the number of firms and communities seeking to become the leaders in the field. There is little doubt that the industry has tremendous potential. Whether biotechnology

has the same economic and/or employment potentials of the earlier computer revolution is the subject of considerable speculation. There are estimates that the biotech industry is already a \$3.2 billion industry in its infancy as a medical technology. By the turn of the century, it is forecast to be worth as much as \$100 billion, encompassing a wide range of activities from health, to agriculture, to bioelectronics.

It is clear that the biotech industry is emerging in the same locations that spawned the earlier microelectronic revolution. As a result, these states are positioning themselves to attract biotech firms in the same manner they lured electronic and communications firms. However, biotechnology is not like the computer industry, in which the first entrepreneurs started out in their garage. The regulatory and capital requirements for this new industry create new openings for state government intervention. One problem for state policymakers is the paucity of information with respect to the types of inducements, incentives, or infrastructure required to meet the particular needs of the biotech industry.

The State Experience

State policymakers are taking advantage of lessons from the microelectronics experience and recent attempts to revitalize their economies in the face of global competition. But unlike traditional economic development strategies and even early high-technology promotion efforts, states appear to be adopting a targeted, rather than a shotgun, approach in the case of biotechnology. In the early rush to capture one of the "golden biotech eggs," development specialists often returned to well-worn lists of favorable location attributes and re-mixed the ingredients for a new variant of development. However, preoccupation with the studies of business climate and state rankings

has abated as policymakers find the concept too undependable; and further, that it makes little sense to compare states without regard for differences in their industrial base (Erickson, 1987).

Increasingly, state governments are paying special attention both to the needs of existing technology-based enterprises and to their own competitive advantage vis-a-vis the basic stages of technological innovation and commercialization. As a result, states are formulating more balanced strategies to recruit, retain, and incubate firms, depending on their economies, historical assets, the future directions they have chosen, and the role of advanced technologies within those strategies.

Public officials are employing a wider and more creative array of tools. The Office of Technology Assessment's 1984 census of state initiatives for high-technology development required 40 functional codes for the different types of programs. Sternberg (1987) constructed a more elaborate taxonomy in which policy instruments were categorized according to the type of government power exerted. Six government prerogatives affecting business were classified against nine business functions, resulting in a 54-cell matrix to help policymakers choose the right tools from an expanding toolkit. These tools, even skillfully applied, may have little impact on forming a high-technology economic development strategy. Therefore, in this paper we examine a particular set of policy devices that states are using in biotech to tease out some new principles of high-tech industrial attraction.

Policymakers are also addressing the charge that economic development programs lack explicit objectives, not to mention an accounting of costs and benefits. While most biotechnology programs are too young for analyses of cost-effectiveness, program designers have built in evaluation criteria, such as scientific peer review, evidence of jobs created or saved, formulas for

external matching funds, and marketing plans for new commercial products. The types of benefits sought reflect states' expectations about returns from investment in biotechnology. All of this has meant a rising risk calculus for biotechnology promotion at the state level. A review of state biotechnology development incentives prepared by the California Senate Office of Research in 1985 concluded:

The strategies that states are applying in the pursuit of biotechnology are a good deal more sophisticated and better funded than past economic development strategies, which have been, more often than not, marketing efforts designed to encourage firms to locate new production facilities in their states. (Griffing, 1985: 33)

High Technology as Industrial Policy

State biotechnology policies, of course, are influenced by the needs of the industry. However, the conceptualization of what that policy should entail has also been influenced by two related trends, identified in the literature as state industrial policy and science and technology policy.

State economic development approaches in the 1970s and 1980s are linked to the failure of macroeconomic conditions to ensure regional economic health and the inability of the federal government to craft an industrial policy that would counter deteriorating economic conditions. Though state industrial policy was originally seen as a second-best solution, it is now widely recognized as an appropriate scale for public economic intervention. Goldstein points out that "the subnational regions vary enormously in the sectors they would choose as targets for industrial policy, in the amount of power held by various groups that have stakes in industrial policy (e.g., organized labor, big business, small business, community groups) and in the cost and benefits the region expects of an industrial policy" (1987: 1).

In a subsequent study, Bergman and Goldstein (1988) distinguished three views of industrial policy, reflecting three different institutional arrangements and variations in policy content. These views were categorized as follows:

1. mainstream--calling for a reduction in contradictory policy objectives and more rational policy tools to coordinate all societal resources
2. de facto--embodying the notion that government intervention is tolerable only so long as it does not restrict market efficiency, and
3. progressive--centering on the breakdown between labor and capital and concerned with the issue of equitable participation in the policymaking process.

Using the three views as a framework, Bergman and Goldstein analyzed fourteen industrial policy initiatives and found that despite individual differences, the larger policy picture showed the clear emergence of regional and local industrial policies in the hands of a few unelected representatives of business and major institutions. The movements they identified are consistent with a corporatist mode of policymaking. Schmitter defines corporatism as:

a system of interest representation in which the constituent units are organized into a limited number of singular, compulsory, noncompetitive, hierarchically ordered and functionally differentiated categories, recognized or licensed (if not created) by the state and granted a deliberate representational monopoly within their respective categories in exchange for observing certain controls on their selection of leaders and articulation of demands and supports.
(Schmitter, 1979: 13)

At its best, corporatism is seen as an efficient means of gaining the consensus and support of key players who are expected to have dominant roles in implementing the strategy. On the downside, corporatism conveys a sense of deal-making at the expense of those who are not organized. The latter case

appears to have brought about the downfall of the much publicized Rhode Island Greenhouse Compact. The Greenhouse Compact was engineered by Ira Magaziner, a prominent advocate of neo-liberal industrial policy. It was a comprehensive economic development package whose key characteristics included the need to focus and identify areas in which Rhode Island had a competitive advantage (Silver and Burton, 1987). The Compact's most visible component was a series of greenhouses that would nurture new products and new technologies; however, other measures provided for mature industries, as well as infrastructure development and quality-of-life issues in general.

The Rhode Island plan was carefully phased over seven years so that the entire program would become self-financing, but initial capitalization hinged on a bond issue referendum. According to Silver and Burton, the Greenhouse Compact was presented to the electorate as an "all-or-nothing package"--a tactical decision by its architects. The position articulated in the Greenhouse Compact report was that public endorsement of the policy would send a loud signal to the business community that Rhode Island was serious about economic development in a way that would outstrip activities conducted by other states. Failure of the bond vote is largely attributed to the absence of popular legitimacy. "The Greenhouse Compact was so 'strategic' that the voters saw it as a boondoggle" (Silver and Burton, 1987: 146).

The latest extension of the state industrial policy literature is seen in the work of Osborne (1987, 1988) and an edited volume by Fosler (1988). These works not only focus on the particulars of new programs, but also on new institutional arrangements--new relationships between the public and private sectors. As Osborne states: "[T]he most important lessons that emerge from the states... concern how government should proceed, not what it should do. The specific programs chosen are far less important than the way in which each

program is carried out: how it fits into an overall strategy, what principles underlie that strategy, and how the different pieces fit together" (1988: 259, emphases in original). A similar view is expressed by Fosler: "The organizational challenge has been to strengthen the capacity of individual organizations to perform economically important tasks, while simultaneously accounting for links among organizations that form parts of broader systems whose overall performance is important to the economy" (1988: 321).

Science and Technology Policy

In contrast to economic development policies whose benefits are largely confined to the jurisdiction creating them, the benefits of science and technology policy--the production of technical knowledge--are extremely mobile. Bradley and Rees thus conclude that "science and technology policy is not an autonomous dimension of state politics," but the handmaiden of other policies to which the knowledge can be applied, such as economic development or agriculture (1987: 8). Schmandt and Wilson looked at state science and technology policies and found that many of the policy functions fall within the purview of traditional state roles. The unique feature crossing all policies, however, was the use of resources and programs to target the particular needs of the high-technology sector:

The R&D policy cluster may not be different in kind from the agricultural research and extension activities of state governments, but they are occurring in industrial sectors not heretofore targeted, and they are being implemented in new institutional formats, such as the university-industry research center. The policy cluster dealing with entrepreneurship and new-firm generation consists of programs similar to traditional business assistance programs but are distinctive in terms of sectoral targeting and institutional format; the public supported industrial incubators are a novel departure. (1988: 133)

Thus, while state industrial policy has emphasized the need to replace zero-sum games of smokestack-chasing with a more positive and comprehensive vision of economic generation, science and technology policy has focused on the technologies that provide the new industrial opportunities. Utah economist Robson points out that "with advancing technology... there is a general but strong belief that new opportunities are emerging 'every day' and broad and new economic development programs are needed to identify and implement the new business opportunities for wealth and jobs" (1986: 117).

The Literature on State Biotechnology Policy

The literature on biotechnology is growing rapidly; however, discussion of state-level policy is spotty. To date, the most thorough analysis has been conducted by the Office of Technology Assessment (1988). OTA surveyed state programs and compared state initiatives by functional categories, such as university programs, centers, direct and indirect financial assistance, and information and technical assistance. OTA also compared levels of state expenditures and mechanisms for fund-raising. The study concluded that it is still too early to determine who the winners will be in current efforts to capture biotechnology development. For states hoping to attract firms, siting criteria for manufacturing facilities may turn out to differ from siting criteria for R&D firms. For states seeking to grow a biotechnology industry within their borders, the results may take longer than is acceptable for policymakers and the public, given what OTA notes is a tradition of quick turn-around on state investments. The application of technology, OTA concluded, may be more important than a new work force or taxable physical plants.

Klausner and Van Brunt (1987) provide a brief, journalistic comparison of biotechnology programs in North Carolina, San Antonio (Texas), and the

Baltimore-Washington Corridor. Also, from time to time, biotechnology periodicals, notably Bio/Technology and Genetic Engineering News, have contained profiles of individual state policies usually written by state officials; for example, California (Rinehart, 1988), Massachusetts (Watson and Quezada, 1987), and North Carolina (Diamond, 1986). State governments often conduct their own background investigations of other state programs, usually in preparation for a major policy initiative. Such a study was prepared by the California Senate Office of Research (Griffing, 1985); however, these documents tend to be circulated among a small professional community and are not readily accessible to the general public. A national conference on Collaborative Initiatives in Biotechnology, organized by the Montgomery County (Maryland) High Technology Council and held on November 1-3, 1987, produced conference proceedings which contain a good collection of descriptive material on state policies. Fortunately, this document is being distributed by the National Technical Information Service, which may enlarge its readership.

Other writers have looked analytically at selective pieces of the state policy environment. Dibner (1988b), of the North Carolina Biotechnology Center, has analyzed state-sponsored biotechnology centers based on an in-house database. Kenney's (1986) detailed study of the university-industry relationship addresses state policy somewhat indirectly, in terms of higher education systems which are creatures of state government.

Biotech Strategies: The Race for Image, Wealth, and Jobs

This study contributes to the literature on state biotechnology policies in two ways. First, we present survey data collected by the Biotechnology Industry Research Group in the winter of 1988-89. State officials were asked to state their expectations of biotechnology development, what they see as the

locational strengths and weaknesses of their state, and what programs are being devised and implemented to achieve their development objectives.

Not surprisingly, we found most states work with a dynamic model of the technological innovation and commercialization process and are developing programs to alleviate bottlenecks in that process. Increasingly, our research indicates a movement away from a cafeteria-style, industrial-attraction mechanism within states to more integrated approaches with specific industrial targets. That is, states are engaged in more long-term economic development and capacity-buildup using technology-based industrialization strategies.

We analyze our findings in terms of the theoretical literature on state industrial policy and science and technology policy. We find that biotechnology promotion efforts at the state level can be distinguished by the type of organizational arrangement pursued. A framework of high-technology corporatism--based on a triad of government, industry, and universities--is clearly developing as the institutional capacity for achieving state government technology policy strategies. We use this triad model to examine the variations among state approaches.

Finally, this study offers policy implications for California. Our intent is to provide California policymakers with an update of initiatives and emerging trends in other states. But we do not simply urge Californians to look over their shoulder. Ultimately, the success of any state initiative must be judged on its own terms--how it works in a particular context. California's loose, university-led, biotechnology strategy has been shaped in response to external factors, such as the needs of research-oriented start-ups, and internal factors, such as the current ideology about the ideal role for government vis-a-vis private industry. We have seen from other BIRG studies of biotech's economic geography that the biotech industry in California is

evolving. Moreover, the competitiveness picture across the U.S. is also changing. The question, then, is whether existing state policies are still adequate in a dynamic policy context. In this regard, the diversity of other state experiences provides lessons that may be appropriate for California policymakers.

Structure of the Report

Section II reports the largely quantitative findings of the BIRG state survey to develop a cross-sectional view of state biotechnology policies and programs. In Section III, we go back to take another cut at the data from an institutional or organizational perspective. In Section IV, we piece together California's policy structure in greater detail, followed, in Section V, by lessons that can be drawn for the future of the state's biotechnology strategy.

II. BIRG Survey of State Biotechnology Policies and Programs

In late 1988, we mailed questionnaires nationwide to state agencies charged with the development of commercial biotechnology, or whose jurisdiction related most closely to this field. The respondents were directors of biotechnology centers, high-technology agencies, or general economic development departments of state government. Thirty-seven states returned usable questionnaires, for a response rate of 74 percent. In addition, most states sent supplementary literature describing various programs, and this information was integrated into our analysis.

Table 1 shows the states that responded. States are categorized into three groups according to the size of their biotechnology industry. To standardize the classification, we used two data sources: the U.S. Congress Office of Technology Assessment (OTA) and BioScan, a commercial directory of biotechnology firms. We refer to these groupings to determine whether there

are patterns among states in which the presence of commercial biotechnology is major, moderate, or minor. As shown in Figure 1, "major" states constitute 21.6 percent of our sample, but account for 80.4 percent of the biotechnology firms, using the OTA data. "Moderate" states make up 29.7 percent of the sample and have 15.2 percent of the biotechnology firms. Almost half the states in our sample (48.6 percent) are considered "minor" states but, together, have only 4.3 percent of the biotechnology firms in the nation.

TABLE 1

States Participating in the Survey

<u>Minor</u>	<u>Moderate</u>	<u>Major</u>
Alaska	Colorado	California
Arkansas	Florida	Connecticut
Delaware	Georgia	Illinois
Hawaii	Indiana	Maryland
Idaho	Iowa	Massachusetts
Kentucky	Kansas	New Jersey
Louisiana	Michigan	North Carolina
Mississippi	Minnesota	Pennsylvania
Montana	Missouri	
Nevada	Ohio	
New Hampshire	Oregon	
New Mexico		
North Dakota		
Rhode Island		
South Carolina		
South Dakota		
Tennessee		
West Virginia		
Mean Number of Firms		
BioScan, 1987 ^a	0.4	4.3
OTA, 1988 ^b	0.8	4.4
		20.7
		32.3

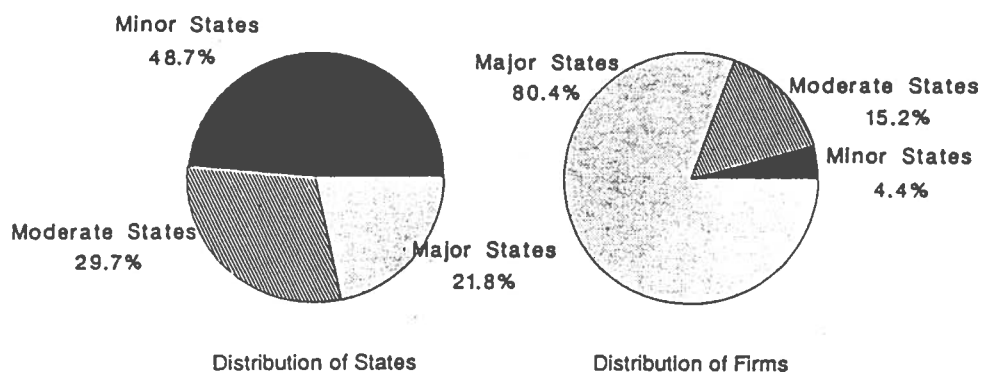
Sources:

^a BioScan is a database produced by the Cetus Corporation and updated five times a year. These data are from mid-1987.

^b Table 4.6 in U.S. Congress Office of Technology Assessment, 1988. New Developments in Biotechnology: U.S. Investment in Biotechnology (Part 4), Special Report OTA-BA-360 (Washington, DC: Government Printing Office).

FIGURE 1

Profile of Survey Respondents



Overall Policies

Four out of five states (81 percent) report that they have an economic development policy which targets high-technology industries. However, the percentage of responding states that target biotechnology specifically drops to 51 percent. Nevertheless, 79 percent of the states feel that biotechnology is "very important" or "somewhat important" for economic development. And virtually all of the states (95 percent) report that biotechnology is "very important" or "somewhat important" for their science and technology policy. This result is unexpected because economic development benefits, such as jobs and taxes, usually accrue to the state, while the benefits of science and technology policy, such as increases in the store of knowledge, behave more like public goods which are not easily confined by state boundaries. Nonetheless, states see biotechnology as a strategic technology base. This probably reflects the "imageability" of biotech as a lead industry for other forms of development.

Of the different types of biotechnologies, human diagnostics was identified as a major sector by the largest number of states--twenty states or 59 percent. Second in frequency was plant agriculture, reported by 18 states or 53 percent. Human therapeutics and industrial equipment or instrumentation were considered major sectors by fifteen states each, followed by animal/veterinary with fourteen states. Ten states indicated that industrial chemicals and process engineering were major sectors in their state. Of course, designation as a major sector must be qualified by the overall size of the biotechnology industry in each state--that is, whether a state has 10 firms or 100 firms. Nevertheless, it provides a picture of spatial distribution across the various sectors. In other words, diagnostics firms tend to be spread across the country, while firms engaged in industrial chemicals or

process engineering tend to be spatially concentrated. We note, too, that these responses reflect the perceptions of state policymakers. Given the paucity of hard industry data, we suspect that perceptions are influenced by anecdotal information and the national media but that these informal sources of information, in turn, help to shape state policies.

We hypothesized further that policymakers would target the particular bio-industries that already have a significant presence in their state. The survey results, however, show that the majority of states do not distinguish among sectors when it comes to promoting biotechnology. Of the states that do target, plant agriculture was seen as most attractive (35 percent). Industrial chemicals was seen as least attractive (13 percent). The latter provides an interesting contrast to Japan and Western Europe, where specialty chemicals based on new bio-processing techniques are strongly promoted by governments, partly as a way of revitalizing the mature chemical industries.

There is a more subtle form of targeting, however, through state grants and seed moneys for R&D projects and joint university-industry product development projects. Requests for proposals often specify preferential project areas that coincide with and reinforce faculty expertise in state institutions.

Changes in Biotech Firms and Employment

Modest growth in the numbers of both firms and jobs appears to be the norm for biotechnology firms in the past five years: 56 percent of all states said that the number of firms "increased slightly," while 48 percent said the number of jobs "increased slightly." Several states reported significant increases in jobs (39 percent) and firms (29 percent). An interesting pattern emerges when we disaggregate the responses: significant firm growth tended to

occur in major states, but significant job growth was reported most often by moderate states.

TABLE 2

Policymakers' Perceptions of Changes in the Number of Biotech Firms and Jobs

	<u>Minor</u>	<u>Moderate</u>	<u>Major</u>
<u>No. of firms (last 5 years)</u>			
Increased significantly	7%	36%	63%
Increased slightly	60%	64%	37%
No change	33%	0%	0%
<u>No. of jobs (last 5 years)</u>			
Increased significantly	13%	70%	50%
Increased slightly	60%	30%	50%
No change	27%	0%	0%
n	18	11	8

Source: BIRG State Survey

R&D versus Manufacturing

According to respondents, a greater proportion of firms in their state are engaged in R&D (77 percent) than any other type of activity. Manufacturing is the second most prominent activity (65 percent), followed by marketing and distribution (52 percent). Curiously, only 7 respondents said that clinical trials and regulatory approval processing are major activities in their respective states. This is unexpected, since clinical testing is a precondition for the production of many biotechnology materials.

When asked about the importance of university-based R&D, 94 percent of the respondents rated this as "very important" or "somewhat important"; only 6 percent said it was "not very important." In contrast, responses were more lukewarm with regard to the importance of manufacturing. While three out of

four states said that manufacturing is "very important" or "somewhat important," almost a quarter of the states claim that biotech manufacturing is "not very important" or "not important at all." This seems to be a contradictory finding in light of the fact that "increasing the number of skilled jobs" is a declared objective of so many states.

Economic Development Strategies

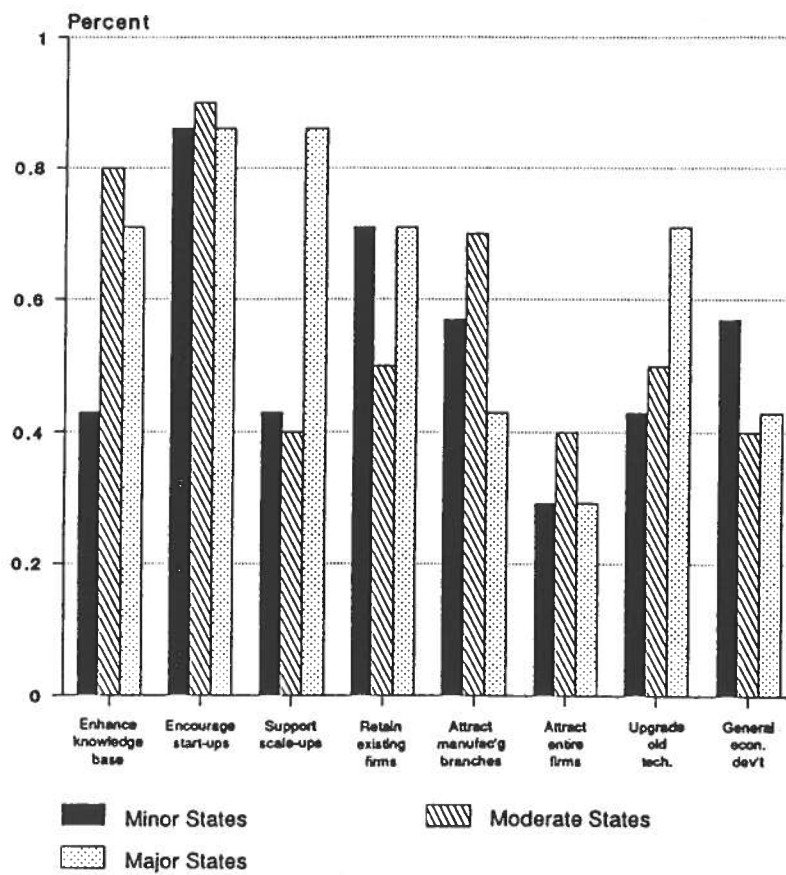
Figure 2 shows how states ranked various strategies for promoting biotechnology. "Encouraging start-ups" was the preferred strategy for states in all three categories. This result is consistent with other industrial policy studies that have shown states shifting toward "grow-your-own" policies. There is a greater tendency for states in the moderate category to pursue a catch-up strategy of attracting manufacturing plants or entire firms from elsewhere. At the same time, though, these states also feel that it is important to invest in their knowledge base. Major states, meanwhile, are concentrating on the scale-up of young firms whose products are reaching the market and the transfer of biotechniques to traditional industries. This pattern is similar to Western Europe. Minor states want to ensure that existing firms remain in the state. In addition, these states, more than the others, have a strong interest in pursuing economic development in general.

Economic Development Programs

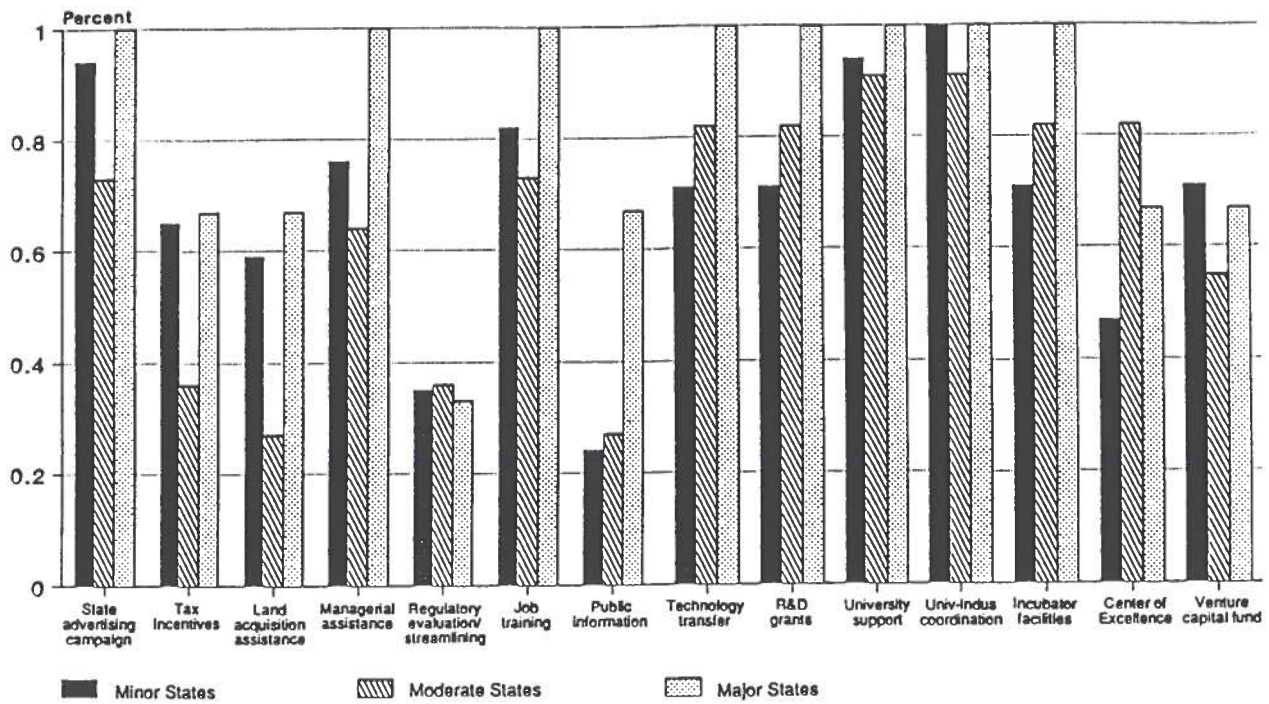
The bar graphs in Figure 3 indicate the relative prevalence of various types of promotional programs. Not surprisingly for an industry based on advanced technology, there is a strong emphasis on university-related inducements. Tax incentives and land acquisition assistance, at one time the mainstays of economic development policies, are active components in only half of the states today. We see some evidence that states use public resources to

FIGURE 2

State Strategies for Economic Development



State Economic Development Programs



make up for a lack of competitive advantage. For example, 71 percent of the minor states said they have a venture capital fund, compared to 67 percent of the major states and 55 percent of the moderate states. Barely one-third of all states have addressed regulations explicitly, although this is a major concern on the part of the biotech firms themselves. It may be that states do not see regulation as primarily a state issue, but rather as an area for national government initiative. Public information is the least popular program. What appears to be a serious policy oversight probably will change as more firms enter the advanced stages of product development and require an informed environment for public decision-making. It should be noted that two-thirds of the major states already have a public information program. These states see the hazards of promoting an industry that can engender so much public fear.

Policy Objectives

As expected, "skilled jobs" tops the list of public expectations associated with biotech development: 43 percent of the states mentioned it as their foremost objective; 89 percent ranked it within their top three objectives. "Better scientific knowledge base" and "expansion of indirect jobs and taxes or economic diversification" are other key objectives.

Top Three Objectives

o Increase the no. of skilled jobs	89%
o Improve scientific knowledge base	82%
o Expand indirect jobs and taxes	71%
o Improve state image	46%
o Improve education system	39%
o Raise quality of life through applications of biotechnology	39%
o Expand real property tax base	36%
o Balanced regional development	25%

Evaluation

The survey contained an open-ended question on evaluation criteria.

Responses that appeared repeatedly included the following:

- o Scientific, peer evaluation of R&D projects
- o Attraction of private industry and federal investments, to support R&D projects and small business start-ups in terms of a leverage ratio
- o Number of businesses helped
- o Number of jobs created or saved
- o Number of new firms or dollar amount of business investment
- o New products or patents
- o Number of new faculty recruited, chairs established, and graduates

An example of performance targets is seen in the following projections made by administrators of the Colorado Institute for Research in Biotechnology (CIRB) for a seed grant program:

- o \$20 of external funds raised for every \$1 of public investment
- o \$15 million in new business growth over 5 years (based on Colorado Advanced Technology Institute experience with Advanced Materials)

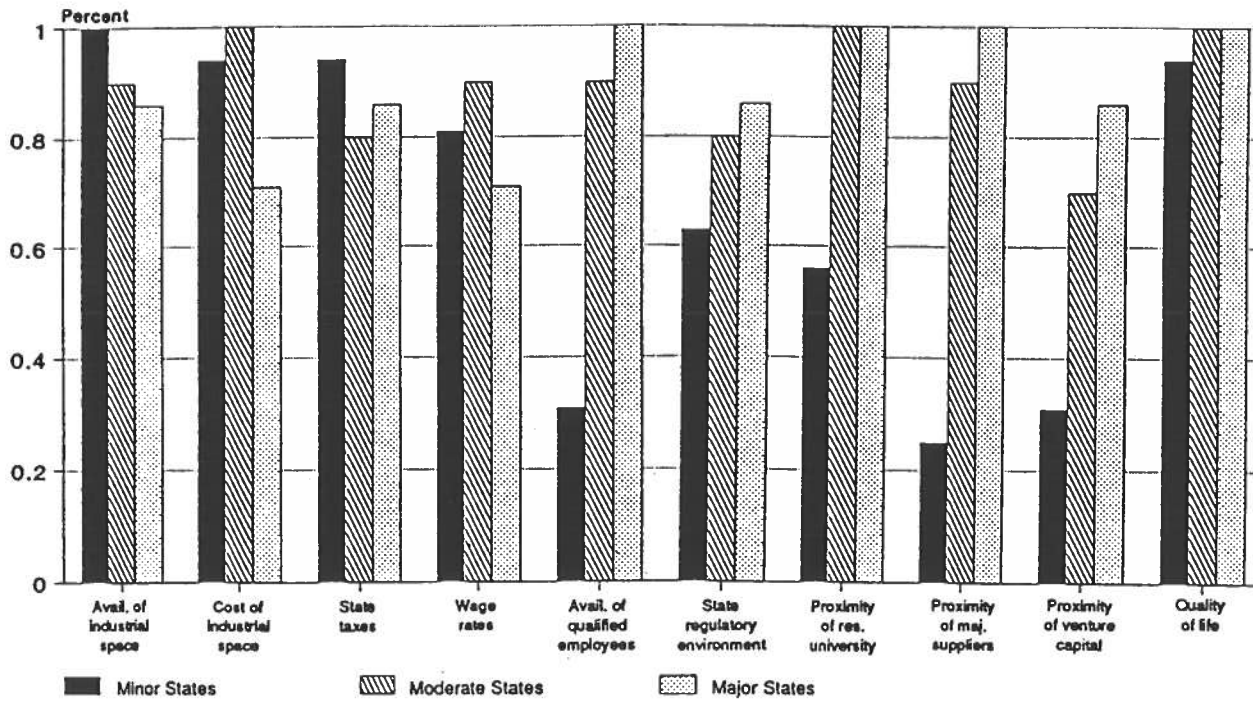
For a proposed bioprocessing center, the 5-year forecast included:

- o 500 jobs in new or expanded firms
- o 8 new start-ups
- o 25 products or processes
- o 35 trained industrial personnel
- o \$1.5 million in industrial matching funds
- o \$10 million in federal matching funds
- o 20 additional M.S./Ph.D. in bioprocessing and retention of superior faculty

Locational Advantages

Figure 4 compares locational advantages across the three categories of states. Almost all of the states claim an advantage in the quality of life. Other advantages mentioned frequently are availability of industrial space (94 percent) and the cost of industrial space and state taxes (both 75 percent). Moderate states indicate a competitive advantage in the cost of industrial space and wage rates. As a group, minor states are particularly deficient in

Policymakers' Perceptions of State Locational Advantages



the availability of qualified workers and proximity to major suppliers and venture capital. In fact, proximity to venture capital was mentioned least frequently overall--by only 36 percent of the states. It is a particularly critical indicator because many public economic development programs are, in effect, substitutes for a venture capital market that can raise funds and provide technical and managerial expertise.

Competition in Biotechnology

We see two competitive patterns taking shape across the country. The first is regional: for example, Nevada identified California, Oregon, Utah, and Arizona as potential competitors--contiguous states forming a region. Michigan and Iowa, both moderate states, mentioned each other--both members of a regional agro-economy. The second pattern involves an upper tier of national competitors. In this case, front-runner California was always mentioned along with Massachusetts, as well as various combinations of major states, such as New Jersey, Maryland, and North Carolina.

III. Biotechnology Development Strategies: An Institutional Approach

In addition to the survey data, we requested brochures, annual reports, and other descriptive material about state biotechnology initiatives. Biotechnology policies reflect state-specific expectations about returns from biotechnology investment. How state officials direct their biotechnology efforts depend on the existing industrial, educational, and natural resource base, as well as their philosophy about the role of state government. This policy context affects how and where states spend their money.

Allowing for these individual differences, however, an argument could also be made for a limited number of state models that are viable within current business and production parameters. Notably, none of the states in our

sample are engaged simply in "gene chasing" or attempting to generate the next Silicon Valley via transplantation. In one form or another, the states are working from the ground up to change the environment in which public and private decisions are being made.

Typologies of institutional formats are not new. Osborne (1988) identified four models for stimulating interaction between businesses and university researchers whose ultimate goal is to develop new products:

- o matching grant model
- o research institute model
- o academic department model
- o university research park model

In addition, five models were used by him to categorize schemes for industrial extension or technology transfer:

- o turn-around model (including loans and hands-on management assistance for firms in mature industries)
- o challenge grant model
- o applied research institute model
- o industrial extension agent model
- o academic referral model (affiliation with university or community college)

Fosler (1988) grouped governmental coordinating devices as follows:

- o core economic development program in a single agency
- o interagency coordination, e.g., through cabinet council or staff office on economic affairs attached to the governor's office
- o public-private task force
- o civic institutions
- o private group, either sectoral trade association type or general business roundtable

Biotech State Promotion Models

Our classification scheme consists of five models based on the high-technology corporatist framework of state government, private industry, and academia. These five probably capture the range of institutional arrangements that have the maximum probability of supporting the biotechnology industry.

Linkages in the Models

Government-Industry Link. The role of government policy in fostering high-tech industrial growth has been the subject of considerable debate. Roger Vaughan and Robert Pollard (1986) note that state government has played only a minor and passive role in the growth of the most successful high-technology regions. It is unlikely, they feel, that initiatives will be successful unless research-oriented institutions are already present and of high quality. Therefore, states need to pursue a strategy to overcome barriers to innovation and entrepreneurship, and to establish "critical mass" and "critical quality" to attract private support. Edward Blakely and his colleagues (1987) agree that governments should focus on creating the appropriate conditions for technology-based development, rather than forcing firms into the environment. But instead of a defensive strategy, they urge a pro-active role for government, starting with in-depth assessment of the region and the development of support systems suitable for targeted industries. AnnaLee Saxenian's study (1987) of Cambridge, England, concluded that even assembling the "right" set of locational ingredients does not guarantee innovative regions. Cambridge has many of the same advantages attributed to the success of Silicon Valley, but lacks the social networks and economic linkages that underlie the latter's dynamism.

Government-University Link. Though state universities have maintained quasi-independent governing structures, they clearly have a special relationship with state government in synchronizing policies to further the interests of residents and taxpayers. Because biotechnology in the early stages has owed more to "scientific push" than to "market pull," the university has been a primary source of cutting-edge research and expertise and the means by which states have hoped to spawn, retain, and attract biotechnology firms.

Besides generating technology, universities are expected to transmit the knowledge they produce (as typified by the agricultural extension system) and to produce a skilled workforce.

Industry-University Link. The industry-university partnership has been explored in depth by Martin Kenney (1986). He notes that the recent wave of cooperation actually precedes biotechnology, beginning in the early 1970s with establishment of new criteria for certain National Science Foundation funds. University administrators across the country began to seek opportunities that would link their institutions and faculty members with the private sector. State legislators also allocated special monies to encourage university-industry collaborations (Kenney, 1986).

Statistics from recent studies document the extent of the two-way relationship between industry and the universities. As many as ninety percent of universities with biotechnology programs report getting funds from industry. For most firms, university R&D accounts for less than 10 percent of their R&D budget, but this type of collaboration is significant for some firms (OTA, 1988). A survey of 1,200 faculty at 40 universities by David Blumenthal and his colleagues (1986b) revealed that biotechnology researchers with industry support publish at higher rates, patent more frequently, participate in more administrative and professional activities, and earn more than colleagues without such support. On the industry side, university research is generating four times as many patent applications as other company research (recognizing, of course, that applications are not perfectly correlated with commercial potential), and 41 percent of companies investing in university research have derived trade secrets from that work (Blumenthal et al., 1986a). The proportion of industry-sponsored biotechnology research is 16-24 percent, but industry-sponsored campus research across disciplines is 4-5 percent.

Models of Development

Our analysis of the survey data, combined with state descriptive materials and interviews with state officials of the leading states, provided us with a framework for developing some archetypical approaches or models. These are discussed hereafter.

The first three models, (1) industry-led, (2) university-led, and (3) plan-based, are distinguished by their focus on certain linkages. The fourth model, the integrated center, features stronger coordination of all three legs. The fifth model, the entrepreneurial agency, features a larger government role which subsumes most of the functions of the other approaches into a single framework. The models are constructed as ideal types for the sake of comparison. In actuality, state strategies are not rigid. The state examples following the model description also need to be qualified as selective, albeit central, aspects of state policies. Their purpose is to illustrate features of the model, rather than to serve as complete case studies. (Program descriptions are drawn from source material listed in the references by state.)

1. Industry-Led Model, featuring liaison or partnership with a trade association

In this model, state government provides minimal staffing for the promotion of biotechnology, often through a small office or a single contact person. Thus, it depends on the industry to develop its own articulated network: for example, through a trade association. The trade association coordinates the needs of its corporate members and provides a more-or-less unified voice to which the state office can respond.

Massachusetts: The Biotechnology Center of Excellence (BCE) is one of five centers under the Massachusetts Centers of Scientific Excellence. The BCE is a research and dissemination organization. A trade association,

Massachusetts Biotechnology Council (MBC), was established in 1985 almost coincident with the establishment of BCE, and the two organizations continue to work closely together. The MBC is a lobbying and trade development organization that is interested in promoting Massachusetts as a natural leader in biotech. Because of limited funds, BCE seeks to accomplish its objectives through partnerships with private and non-profit (university) sectors. "We're essentially a grant-making agency," according to Fernando Quezada, who heads BCE. The original focus of the grants was applied R&D projects; however, projects in public information and business enterprises have also been funded.

Among its programmatic accomplishments, BCE has been involved in the development of a series of biotech facilities within a park of some 100 acres located across from the state's medical center in Worcester. Facilities are designed specifically for biotech firms--for example, with abundant wet lab space, etc. As of mid-1988, One Biotech Park was constructed and fully leased to biotechnology and closely related firms. A second Biotech Park was in construction and being leased. Construction and leasing had also begun on a third Biotech Park. Plans were being prepared for a commercial incubator facility that would have services oriented to start-up firms.

The biotech incubator facilities are run by a consortium of private investors and universities. State seed money of \$1 million raised over \$25 million from the private sector. According to Quezada, the consortium came together at about the same time as BCE in order to package proposals and to take advantage of state funds that were anticipated with BCE's establishment. It is possible that the Massachusetts Biotechnology Council and the Biotech Park Consortium might not have coalesced in the absence of a catalyst such as BCE.

Texas: Promotion of biotechnology is the responsibility of the Office of Advanced Technology within the Texas Department of Commerce, a department formed a year ago. Texas has no coordinated biotechnology policy, but the Office does work with biotech groups. Director Karen Ware noted that because her office is small, it works best with groups that have "their own infrastructure," such as trade associations. At present, the office is conducting a survey of biotechnology firms in Texas. Over 175 firms are being contacted for the survey. Ware notes that biotech groups within the state are currently in the process of meeting to see whether a network or association can be formed. In the event such an organization comes into existence, the database being compiled from the state's survey may be turned over to the new biotech industrial organization.

2. University-Led Model

The university-led network coordinates academic resources, often across disciplines and across campuses. It provides a single point of entry to broad-based biotechnology activities occurring throughout the state's education and research system. In some cases, the university-based organization is set up as an independent research institute to increase the state government's flexibility (for example, to make certain kinds of investment, to take equity positions, or to negotiate certain types of contracts). Its main functions are to filter and enhance research capabilities within the state and to become more competitive in receiving large federal grants. Another key responsibility is to foster university-industry collaboration, sometimes using entrepreneurial methods, such as soliciting corporate membership in partnership schemes that give members privileged access to certain academic resources.

Colorado: In 1984, the Governor's Cabinet Council on High Technology initiated a strategic planning program that focused on all of Colorado's high-technology industries. Early in the process, biotechnology was recognized as a major "homegrown" industry with relationships that could be traced to university research.

At the heart of Colorado's biotechnology initiative lies the Colorado Institute for Research in Biotechnology (CIRB). Through this consortium, faculty at the major Colorado universities and biotech companies discuss their individual needs, strengths, and research interests. A primary objective of CIRB is to promote interdisciplinary, multi-campus, and industry-university collaborative research. The seed grant program is expected to lead to full R&D proposals to federal agencies, industry, and other sources.

Florida: The Florida High Technology and Industry Council has worked to coordinate the biotechnology efforts at the University of Florida (UF), a public institution, and the University of Miami, a private institution. The Council has a biotechnology committee under whose auspices a biotechnology research network has been developed. At UF, the Interdisciplinary Center for Biotechnology Research coordinates semi-autonomous academic units that have separate budgetary powers. A related organization is the Biotechnology Institute for Research and Development, which works through Florida Research Foundation, Inc. a private, non-profit corporation that can hold equity interest in businesses, own patents, and receive license and royalty fees. The Institute has a system of Industrial Members, Associates, and Affiliates for technology transfer.

Maryland: Maryland Biotechnology Institute (MBI) was established by the Legislature of the State of Maryland in 1986 as a component of the University of Maryland, with funding phased over a three-year period. At present a total

of 72 tenurable fully-funded staff lines are available to MBI with a total budget (salaries plus operating funds) of \$4.95 million. MBI provides cohesion for biotechnology projects dispersed in different departments and laboratories. The Task Force Report recommending establishment of MBI stated: "All campuses of the University, by encouraging collaboration among investigators, will make the sum greater than the constituent parts in productivity and creativity."

MBI is the administrative component of an institute which consists of four technical centers and one program for public policy issues and information dissemination. The mission of MBI is not to develop any specific product of commercial interest, although it is expected that important inventions will emerge as a matter of course. Rather, MBI's mission is to carry out basic research in the area of biotechnology; provide training in biotechnology to graduate students and other scientists; and provide a core of expertise and facilities that will further economic and scientific development in biotechnology throughout the state.

The centers in agriculture, medicine, and marine biotechnology are scattered throughout the State's higher education system. A fourth center, the Center for Advanced Research in Biotechnology (CARB), was established in 1986 on the Shady Grove campus as a joint effort of three levels of government: the University of Maryland, the National Bureau of Standards, and Montgomery County, Maryland.

MBI exemplifies a case in which biotechnology has been thoroughly institutionalized within the university system. It is not classified as an integrated center (Model 4), because most of the economic development programs are housed in a separate University of Maryland unit, the Engineering Research Center (ERC).

3. Plan-Based Model, coordinating general-purpose government programs

In plan-based state strategies, a high-technology agenda is laid out in a plan which may include a specific mandate to promote biotechnology. The plan is laid over an existing system of economic development programs serving a broad clientele which is not limited to high technology or biotechnology. To be effective, the plan must coordinate dispersed resources that are administered by different functional agencies (venture capital fund, R&D grants, incubators, management assistance programs, training programs, etc.)

Minnesota: For two years, Minnesota pursued a biotechnology policy through the Minnesota Council on Biotechnology, which was established in 1985. However, because of political and other reasons, the Legislature stopped funding the Council during the 1987 session. Minnesota has no current active biotechnology policy, but its four-year plan exemplifies the model.

The Biotechnology Plan served as an umbrella, recommending policy changes throughout the state government. Within the university system, it endorsed increased funding for existing biotech research units and recommended establishment of a new biomedical engineering center. The plan further supported an apparatus for industry-university interaction, including a privately-funded innovation center for scale-up and support services for product commercialization. Beyond the state's higher education system, the plan recommended comprehensive integration of biotechnology into the high school curriculum. It also identified areas for possible changes in state policies to encourage growth, including favorable insurance laws and regulations for animal experimentation. Structural changes were proposed in the state bureaucracy and legislature to pin institutional responsibility for biotechnology concerns.

Oregon: "Enhancement and Diversification: Biotechnology in the Oregon Economy, 1988-2000" was published in October 1988. This report to the Governor of Oregon was prepared by the Biotechnology Industry Advisory Committee and commissioned by the Oregon Economic Development Department. The recommendations have not been implemented yet, but the report's approach is indicative of a plan-based strategy.

The report calls for the formulation and marketing of a strategic plan. Advocates stress that a "well thought-out plan is fundamental to orderly economic growth" and point to Silicon Forest as a contrary case of unanticipated and haphazard growth. The plan does not recommend the establishment of new economic development programs. Rather, it seeks to marshall existing resources and direct them toward biotech promotion by setting up precise goals:

- o identify industry patterns and niches
- o inventory the state's strengths (e.g., researchers and resources)
- o develop a marketing plan to differentiate Oregon biotechnology
- o obtain concurrence in the role of higher education to development of Oregon's biotechnology industry
- o establish key goals in terms of the intended size of the industry (in 5 years), intended size of the academic base to support industry, targets for recruitment (research facilities, corporations), and dissemination of jobs.

Some states, such as Arkansas and Tennessee, reported below, have comprehensive organizations to promote high-technology industries. They have also developed proposals which, if implemented, would centralize and increase the magnitude of their biotechnology effort (relative to other high technologies), thereby shifting the states from Model 3 to Model 4.

Tennessee: The Tennessee Technology Foundation developed plans in 1983 for a Tennessee Center for Biotechnology, which would be an independent technology-transfer corporation. The plan called for the center's funding to be supplemented by research contracts from industry, royalties, and property

income from an industrial park for biotechnology firms. "From the Tennessee Technology Foundation's point of view, the Tennessee Center for Biotechnology is just the sort of major complex needed to bring a significant wave of private sector industry to the Technology Corridor," read an article in the foundation's newsletter. The center, a not-for-profit corporation, would contain several research institutes for basic and applied research. It would be closely associated with either a subsidiary corporation or by contractual agreement with a for-profit Technology Development Corporation that would promote commercial application of ideas. Both corporations would be housed in a new 100,000-sq.-ft. building with space for 30-35 scientists and new spin-off businesses. This building, plus ancillary facilities, including greenhouses and field plots, would be sited in the Biotechnology Industrial Park, where buildings and land would be available for lease to biotechnology companies.

Arkansas: The Arkansas Science and Technology Authority currently sponsors basic and applied research grant programs, a business incubator program, and a seed capital investment program in a variety of high technologies. ASTA has sought to boost its biotechnology effort by proposing a National Biotechnology Cooperative to be located in existing space partially occupied by FDA's National Center for Toxicological Research in Jefferson, Arkansas. The demonstration project is billed as the SEMATECH of biotechnology. Located between Little Rock and Pine Bluff, the facility was constructed in the early 1950s for containment of bioweapons and designed for high-level containment of microorganisms. The entire facility was demilitarized in 1970-71. The state's biotechnology proposal includes a 10,000-sq.-ft. central area to house common equipment to be made available through lease arrangement. Separate lab and offices around the common work area would allow proprietary research and product development. According to

ASTA's brochure, the "key element of this proposal is the co-location on site of representatives of the regulatory agencies responsible for approving biotechnology products--EPA, FDA, and USDA. The agencies would review scientific plans prospectively to assure that the necessary types of research will be conducted with the aim of producing an approvable application in the shortest time possible."

4. Integrated Biotechnology Center Model

Biotechnology centers have proliferated in the last few years. Dibner (1988b) reported centers in 20 states by 1985. The definition of biotechnology center used here is narrower than most and refers to an integrated, multi-purpose organization. States with integrated biotechnology centers, according to our classification, both administer a wide range of programs and commit considerable resources to the promotion of biotechnology. In some states, such as New Jersey, it may be a high-tech organization (with a biotechnology arm) which has access to its own programs supplying venture capital, R&D grants, and technical and managerial assistance. In other states, such as North Carolina, it may be a "full-service" center devoted to biotechnology. A distinction between Model 3 and Model 4 is that the former assumes a "U-form" organization divided by functions, while the latter is the public-sector equivalent of an "M-form" organization with services grouped under the technology area (Chandler, 1962). Another distinctive feature of the integrated center is the importance of physical facilities--a hub which brings together researchers, entrepreneurs, and public officials to foster the formal and informal interchange of ideas. Attractions to the center may vary, including the availability of sophisticated equipment or specialized seminars and conferences. States pursuing this strategy have

recently constructed or are planning to invest millions of dollars in brick-and-mortar projects.

New Jersey: The New Jersey Commission on Science and Technology was established in 1982 as a partnership between industry, government, and academia to foster the growth of businesses in advanced technological fields. A \$90 million "Jobs, Science and Technology Bond Act" was passed in 1984, and program operating support now approaches \$20 million per year. The Commission became a permanent state agency in 1985. Biotechnology is one of four "thrust areas," along with telematics, advanced materials, and environmental protection technologies. Nine university-based Advanced Technology Centers expand the research base and also determine how new discoveries may be applied to traditional and emerging industries. A series of Commission-founded Technology Extension Centers facilitate transfer of new information and new technologies.

Based on strength of New Jersey's pharmaceuticals and related industries, the Commission has targeted biotechnology as the number one priority. The flagship is the Center for Advanced Biotechnology and Medicine (CABM), which is under joint sponsorship of Rutgers and the University of Medicine and Dentistry of New Jersey at Piscataway. The multi-site arrangement includes a core facility located between the two university campuses, a cell fermentation and separation unit at the Waksman Institute of Microbiology at Rutgers, and a clinical research unit at Robert Wood Johnson Medical School. The core facility will be housed in a 100,000-sq.-ft. structure costing \$33 million and to be operational by 1990.

Other biotechnology centers are the Center for Advanced Food Technology (CAFT) and the Center for Agricultural Molecular Biology (AgBIOTECH) at the Cook College campus of Rutgers University in New Brunswick. Both centers have plans to construct new facilities. The Networks Laboratories program allows

academic and industrial researchers to obtain access to a broad range of instrumentation expertise at six New Jersey locations on a fee-for-service basis.

North Carolina: The North Carolina Biotechnology Center (NCBC), the nation's first such center, was created in 1981 as a division of the State Board of Science and Technology. For the first two and a half years, its role was largely exploratory and developmental. NCBC worked with the universities to coordinate the biotechnology activities already underway and to attract new biotech industries.

Based on a study committee report, a comprehensive long-range program was begun and NCBC was reorganized as an independent non-profit corporation in late 1984. Funds appropriated to NCBC are channeled through the Department of Commerce and are governed by a contract between the Department and NCBC.

In remarks to a 1986 conference in Davis, California, Gerry Hancock, chairman of the Board of Directors, stated that NCBC "demonstrates that North Carolina still believes in the technique of stimulating economic growth in high-tech fields by creating an independent institution outside of government, but funded largely by government, to act as a coordinator and catalyst for the overall development of a given field" (p. 46). NCBC is seen as an appropriate instrument to help develop a coordinated program in the state's public and private universities without challenging academic freedom or stifling basic research. One of its key functions is to assist universities in putting together recruitment packages that will attract world-class scientists and promising young scientists. NCBC grants seed money to scientific investigators and funds new companies conducting R&D. It has developed a biotechnology curriculum for the community college system and materials for high school

teachers. In addition, the information division has hosted conferences and workshops and maintains several databases.

5. Entrepreneurial Agency Model

Where biotechnology centers are principally clearinghouses for funds and technology rights, some states have established institutions that are directly involved in technology development and commercialization. Rather than simply promoting conditions that are propitious for new firms--seedbed conditions--these entrepreneurial agencies are planting the seeds themselves. Staff industry analysts (or consultants) scan the market to identify appropriate market niches; then in-house scientists work on quite-specific projects with the intent of turning research into commercial products. While none of the centers in this group (5) are self-supporting, their ultimate intentions are to earn sufficient income to become independent.

Michigan: The Michigan Biotechnology Institute (MBI) was founded in 1981 as part of a statewide strategy to revitalize and diversify the economy. It is located in Lansing, close to Michigan State University. MBI was chartered as an independent, non-profit corporation. Initial capitalization of \$29 million for operations was provided by the Michigan Strategic Fund, Kellogg Foundation, and Dow Foundation. MBI's goal is to achieve self-sufficiency in the mid-1990s by obtaining funds for sponsorship of research projects from services performed for clients and revenues from commercialization of its technology.

MBI's research agenda is set by combining information on markets and industry trends with analysis of technological feasibility, and to assure development of technology with high commercial potential. The Institute is located in a new 120,000-sq.-ft. building that contains a 20,000-sq.-ft. industrial-scale pilot plant and is designed to promote interaction of

biologists and engineers. Research projects are started at an earlier stage than industry, but carried farther toward commercialization than universities. Commercialization is achieved via licensing, formation of joint ventures, or creation of spin-off companies. Projects are divided into three categories: (1) product and process R&D which have a goal of commercialization within 4-5 years, (2) targeted exploratory research, and (3) exploratory research.

Besides carrying out its own research and development, MBI has programs to help focus university research on commercially important problems, assist entrepreneurs in developing marketable technology, and perform contract research for industry. If a company funds research at MBI, scientists can work alongside MBI staff during the course of the project. The pilot plant is also available to industry for a fee.

Ohio: The Thomas Edison program was introduced in 1983 as the centerpiece high-technology initiative of Governor Richard Celeste's "competitiveness strategy" for renewing the technological, economic, and human resources of the State of Ohio. To date, the program has been capitalized to the sum of approximately \$33 million in state funds and \$80 million in non-state funds. Emphasizing home-grown effort, the program contains three components: seed capital grants, technology incubators, and eight research consortia--each of which involves a business-driven partnership between industry and academia. All funds granted by the state must be matched by the industrial partner on at least a 1:1 basis.

The Edison Animal Biotechnology Center is Ohio's biotechnology consortium. The structure of the Center reflects the fact that Ohio had no functioning biotechnology industry at the outset--only the commitment of the Department of Development to "build" totally new industries. The Center is

highly focused toward agricultural animal genetics because of prior animal transgenics research at Ohio University.

In addition to being highly focused, the Edison Center is directly and actively involved in all of the research and development programs supported with its funds. It employs 38 persons (including 34 scientists or technicians) and maintains a large three-story laboratory complex separate from its supported university-based academic laboratories. The overall collaborative effort which the Edison Center drives has three components: university-based research funded by the Center, the Center's bridge institute, and the joint industry research efforts. This three-part structure provides the entire continuum from concept generation to product development.

Because the biotechnology industry was virtually non-existent in Ohio in 1984 when the Edison Center was established, an animal biotechnology company, Embryogen, Inc., was set up in conjunction with the Edison Center. Though autonomous from the Edison Center, this for-profit corporation is tightly linked to the Center. The linkage takes the form of an exclusive right to license all Edison technology granted to Embryogen by the Center in return for continuing funding support to the Center from Embryogen and a royalty agreement. The business success of Embryogen, Inc., is shared by the collaborating university partners, since some equity in this corporation was granted to university partners where appropriate. Embryogen also has the option of sub-licensing to a larger corporation.

IV. Biotech Promotion in California

California's policies on biotechnology have developed incrementally with initiatives from the universities, industry, and state administration. If there is a unifying strategy, it is one based on the

underlying view that governmental authority in the economic development sphere should be exercised against potential barriers to further industrial growth. Governor George Deukmejian's approach has emphasized a concern for the "basics" (education and physical infrastructure), and a good business climate--factors that attract business to the state. Although the State of California spends as much as \$30 million on a variety of direct economic development programs through the Department of Commerce, this budget pales in comparison to an estimated \$3 billion for overall transportation support, \$150 million for water resources program, over \$16 billion for K-12 education programs, and \$5 billion for higher education (Perry, 1988).

Before Deukmejian assumed the governorship, his predecessor, Governor Jerry Brown, appointed the California Commission on Industrial Innovation to develop a new industrial strategy for the state. In many ways, this commission, composed of leaders from industry, academia, labor, and the financial community, was California's first explicit attempt to define an economic development strategy (Henton and Waldhorn, 1988). The Commission sponsored the first state studies of biotechnology (Feldman, 1982). It promoted the view that government should play a positive role in creating a business climate that would foster innovation and entrepreneurship. The Commission, however, delivered its recommendations at the end of the Brown administration, and much of its impact was lost when Brown left office in 1982.

After coming into office, Deukmejian sponsored another comprehensive economic development study, called "Job Creation for California in the Decade of the Eighties." The report, issued in 1983, targeted 15 growth industries. Although biotechnology was not mentioned specifically, listed were fields in which biotechnologies are commonly applied: bioengineering, medical instruments, agricultural technology, and aquaculture. Staff from the

Department of Commerce was assigned to specialize in these areas. The policy emphasis on economic development continued until 1984, when public furor over outdoor testing of the genetically engineered ice-minus bacteria diverted attention to regulatory issues.

On the legislative front, the University of California, in 1984, approached Assemblyman Sam Farr, Chair of the Assembly Committee of Economic Development and New Technologies, urging the legislature to focus on biotechnology as "something coming up on the horizon." "It's going to be bigger than computers and the legislature really needs to get involved" (remarks by Josh Newman, Davis Conference).

The Committee on Economic Development and New Technologies took control of a bill which had been introduced into the legislature requiring biotechnology products to comply with the California Environmental Quality Act. Instead of pursuing regulation, however, the bill was turned into a study vehicle. A 40-person advisory group was assembled, including industry representatives, academics, and members of the environmental community. The result was passage of Assembly Concurrent Resolution 170 (ACR 170) in August 1984. The measure, authored by Assemblyman Farr, formally recognized the importance of biotechnology to the State of California and called for two investigative studies: the first, a study of all existing, pending, and elapsed federal and state regulations affecting the California biotechnology industry; and the second, a study of incentives offered by other states and countries to promote the development of biotechnology in those jurisdictions.

These studies directed public attention to two challenges facing California's biotechnology industry: (1) the need for increased public awareness and acceptance, and (2) elimination of unnecessary delays in getting new biotechnology products to market.

Among the recommendations of the regulations study were the following:

- o State agencies should rely as much as possible on existing regulatory authorities but ensure clear responsibilities and demarcations of authorities. Furthermore, they should defer, wherever possible, to the federal government on the development of new regulations for the industry.
- o Each involved state agency should develop a clear policy statement on its role in regulating biotechnology and its products. Policy statements should also contain assurance for protection of proprietary information, so that California will remain a hospitable climate for biotechnology development.
- o An Interagency Task Force on Biotechnology should be formed to rationalize the regulatory scheme among various agencies.
- o A Biotechnology Science Board with scientific, financial, and legal expertise should be established to advise the state administration.

In what was perhaps the most sweeping proposal, the report called on California's lawmaking body to pass an organic or omnibus bill to set state policy and clarify jurisdiction of existing regulatory authorities administered by state agencies, if the executive branch failed to act.

On the basis of this report, Governor Deukmejian established an Interagency Task Force on Biotechnology in November 1985 to find overlaps between the state and federal systems in order to simplify the regulations. Equally important was the need to identify gaps between the two systems. The Task Force's deliberations and findings on regulations and risk assessment were important in framing concepts that still affect biotech policymaking. The discussions confirmed the adequacy of the existing permit structure, which covers all known product types. The special concerns of genetic engineering, it was felt, could be addressed through additional items in the standard permit application. In the product-based approval system, four agencies have regulatory prerogative. An alternative permitting structure would have lumped together approvals based on biotechnological processes. By rejecting the

alternative, state administrators avoided the creation of a new regulatory body (since the individual agencies would still need to conduct regulatory operations). Biotech companies, individually and through the California Industrial Biotechnology Association, also tended to favor the existing structure, although it has unravelled the concept of a unique, more-or-less cohesive biotechnology industry. Among policymakers, "biotechnology" has been seen as a double-edged sword to be used with caution: it is accompanied by semantic baggage, some of which is pejorative, and, therefore, not necessarily advantageous for promoting legislation.

After their comprehensive review, the Task Force issued a handbook on biotechnology permits and regulations, including flowcharts clarifying the governmental review process (Rinehart, 1988). According to a state official, the handbook has become quite an effective marketing tool, demonstrating that the state is on top of the regulatory issue.

The Interagency Task Force, created by Executive Order, is the only state body on biotechnology with official standing. Its responsibilities have extended to:

- o Serving as the principal liaison between the State of California and federal agencies, including the President's Cabinet Counsel on Biotechnology, on matters affecting the biotechnology industry.
- o Development of educational programs on biotechnology for the benefit of the general public, resulting in an information booklet on the release of recombinant DNA organisms into the environment.
- o Dissemination of information to new California biotechnology firms about compliance with California statutory and regulatory requirements.

Meanwhile, the second legislative report, evaluating alternative economic development policies for California, received less-concrete follow-up. There has been a reluctance to create public bureaucracy in pursuit of industrial

biotech policy. John Griffing, author of the report, notes that even a simple matching-grant program would require someone to determine eligibility, someone to determine categories for proposals, someone to select or approve projects, and administrative and monitoring personnel. Discussions about establishing a biotechnology center met with mixed reaction from the public and private sectors, and the idea never took hold. In 1988, the legislature approved a food-safety research center at UC-Davis, but this measure was vetoed by the Governor.

More visible policy steps have occurred in educational institutions, where the state has found familiar and comfortable footing. In the education policy area, there has been a differentiation of education needs among: (1) the general public, (2) opinion leaders and the media, and (3) formal education of students and teachers. In 1985, University of California President Gardner formed the Biotechnology Task Force to assess challenges and needs at nine campuses and three affiliated national laboratories. On the recommendation of this group, the system-wide Biotechnology Research and Education Program was established and has since become a clearinghouse on educational matters. The program's annual budget of \$1.5 million is the only designated biotech money from state funds. The money is distributed in grants that address the needs of all three groups mentioned above.

The UC program is under the overall authority of the Director and Executive Committee, which is composed of one faculty representative from each of the nine, plus the three DOE labs, and the Agricultural Experiment Station. It is assisted by an Advisory Committee, the members of which are selected by the University President and who include representatives of the California biotech industry, state agencies, and environmental organizations. They help

to define emerging or expected areas of research or personnel needs so that the program is attuned to the long-range requirements of the state and the nation.

The California State University system followed with the Program for Education and Research in Biotechnology. Although the CSU program has the Chancellor's approval, it must still compete with other initiatives for a budget allocation.

An additional source of research funds is administered by the Office of Competitive Technology under the Department of Commerce. Eligible projects are not limited to biotechnology. Of 29 projects funded in fiscal year 1989, the first year of operations, seven projects were related to biotechnology; and they garnered \$1,033,200 or 15 percent of the total \$6.6 million. The objective of the grants program is to transfer new discoveries to the marketplace with matching contributions from the private sector.

One of the latest state initiatives is the formulation of regulatory guidelines for local governments by the Interagency Task Force. The intent is to provide a platform for local discussions; to avoid "knee-jerk" reactions as companies reach more advanced stages of testing and manufacturing. An incident like the ice-minus case can have far-reaching negative consequences. Monterey County has not received a single permit application since then, and there is evidence of firms going outside the state to conduct tests.

V. Conclusions

A Florida biotechnologist summed up prevailing views about development strategy when he said, "there's no reason large corporations would locate here when they can choose from the Californias--we have no choice but to develop de novo." Indeed, many states are taking ideas from industrial policy and science and technology policy and putting together a variety of strategies that are

designed to increase competitiveness with respect to commercial biotechnology. However, as with microelectronics earlier, California has not needed either a catch-up strategy or a greenhouse strategy. The state's leadership in industrial biotechnology has forced the state to be a policy leader. Like a pioneer exploring unfamiliar terrain, the policymaking trail is marked by the obstacles met and overcome. Thus far, California officials have responded quickly and effectively to remove the obstacles and neutralize potential policy crises. Other states, meanwhile, are sending scouts to blaze trails that might not be traveled for some time, and to construct permanent structures along the way to fortify the territory.

California policymakers have had to respond to an industry that grew quickly. From the outset, biotech firms--a primary policy constituency--indicated that what they needed was minimal government interference (Feldman, 1982; Pfund, 1983). Equally important, the private sector appeared to provide the necessary supports for industrial growth.

However, the policy environment in 1989 is different from that of the Commission on Industrial Innovation studies in 1982 or the ACR 170 studies in 1985. Below, we integrate some of the biotech promotion experiences of other states and the theoretical literature on economic development. Our conclusions may have a different ring in the policy climate of California today.

1. Grounding the benefits of state investment in biotechnology:

technology transfer

The state's head start in biotechnology was based on technological breakthroughs, and there continues to be an emphasis on scientific virtuosity. In a sense, the intellectual talent in California's academic and research serves as a national resource base. Equally important, though, is the ability

to extract the full potential of the higher education system as a state resource. In particular, the state government can take up the slack in supporting applied research and technology transfer. In biotechnology, unlike semiconductors, the federal government is not providing substantial funds for process engineering and the development of pilot and production facilities (OTA, 1984, Appendix C). State initiatives, such as Maryland's Center for Advanced Biotechnology, New Jersey's Network Laboratories, and the Michigan Biotechnology Institute, are reaching out to industry by addressing these concerns and underwriting specialty facilities and equipment that can be "rented" by smaller firms.

James Kenworthy, manager of the Michigan Strategic Fund, notes that the computer industry is concentrated on the coasts, but that no region of the country can afford to be behind in applying the capability of computing to its existing business. Similarly, only a few areas of the country can expect to have the infrastructure necessary to be centers of cutting-edge bioscience, but other areas will still have to become expert at applying that science to their existing industries or risk migration of R&D and, later, new production to the more aggressive centers (Kenworthy, 1988). Indeed, state-funded economic development strategies should galvanize the process of systematic decentralization of biotechnology capacities to the needs of healthcare, agriculture, food processing, and waste management--all the potential footholds for innovation.

Some of the greatest potential for biotechnology in California lies in the interior, natural-resource-dependent regions. States as diverse as Michigan, Oregon, Colorado, and New Mexico are approaching biotechnology from the resources angle. Biotechnology is expected to have direct effects on the primary industries--agriculture, fisheries, forestry, and mining. But we can

also expect spillover effects on related service and manufacturing industries. These linkages require further study. Early innovators can frequently reap the benefits of improved competitiveness, and these opportunities should be identified. At the same time, policymakers also need to anticipate adverse or unintended effects (Erickson and Maitland, 1982; Dewar, 1988).

2. Creating biotechnology product niches

Given the current state-of-the-art in biotechnology, industrialists report that competition is heating up over limited product niches, especially in human healthcare. With other new technologies, such as semiconductors, governmental agencies created important first markets.

States can be more influential in their role as consumers of biotechnology, i.e., through the use of procurement powers for health services, waste disposal, and environmental quality control and improvement. For example, Proposition 65 in California has generated demand for new products, such as immunoassays, that can detect hazardous chemicals in the environment. In Massachusetts, the Biotechnology Center of Excellence has sought to inform other state agencies about biotechnological innovations that might help them to do their jobs better. Biotech firms themselves have not aggressively pursued organizations like the State Public Health Department as a market. With limited marketing staff, the dedicated biotech firms usually work through large pharmaceutical firms who, in turn, go through the federal government (e.g., Medicaid/Medicare policy on minimum requirements and reimbursables). The Massachusetts Center tries to short-circuit the cycle by approaching state agencies directly and informing them about what is available so that the agencies can make their own demands on federal administrators.

3. Second thoughts on the need for additional industry support

One argument supporting California's status quo is that the biotechnology industry itself does not favor additional government programs. After an initial flurry of governmental studies and legislation, the industry is coming to the state for help less frequently. In part, earlier problems have been resolved or, where they have not been resolved, the state is seen as unable (or unwilling) to provide certain types of assistance.

Financing is an ever-looming problem for many medium-sized firms that require considerable R&D funds and are also beginning to capitalize manufacturing activities. Yet many of them are neither receiving product revenues nor ready for an initial public offering. The industry has responded by spawning strategic alliances between smaller firms and established corporations. However, as more states succeed in developing start-ups, there is the possibility of competition over corporate sponsorship. Would California-based start-ups be at a disadvantage vis-a-vis those in New York or New Jersey or Illinois--areas where large corporations tend to be based?

4. Decentralizing state government policy

Some of the most promising state programs are comprehensive, but decentralized in terms of R&D centers and extension services. The intent of these programs is to become the core of a local network, one that is close to the client companies as well as the market for quick and detailed feedback. Decentralization of biotechnology programs is desirable if regions are qualitatively different, as they appear to be in California's case. A biotechnology center, such as one proposed for Richmond, may be a good pilot case and should proceed expeditiously.

5. Building on California's university-based biotech strategy

With so many states developing from within, the strongest competition goes back to the source of ideas: top-notch faculty who have the ability to move whole labs and a coterie of graduate students from one institution to another, from one state to another. The North Carolina Biotechnology Center, for example, has put together more than two dozen faculty recruitment packages in biotech. This is the real bottleneck. Capital can be raised in relatively short order, but quality personnel--the soft infrastructure--takes time (Blakely et al., 1987).

The OTA (1988) has raised another red flag in its prediction that the distribution of federal R&D funds will not be as concentrated as it has been in the past. Such an allocation policy would be unfavorable for California.

6. Strategic policymaking--building an institutional base

Perhaps the greatest deficiency of California's biotechnology promotion strategy is limited institution-building within the state government. At present, the main policymaking body consists of the Governor's Interagency Task Force and part-time staff. Given few resources, we note and commend the efforts of state policymakers to engage in a process that encourages discussion and strengthens popular legitimacy for their chosen course. However, the current arrangement is vulnerable to changes in top leadership--as will occur in 1990. To some extent, a change in regime inevitably results in a rethinking of policies--but the State of California cannot afford to start from scratch at this point in the game. The prospect of gubernatorial change notwithstanding, the state can adopt a strategic posture. By this, we mean an institutional format that allows state officials to routinely gather, monitor, and analyze information about biotechnology. It should operate in collaboration with, but

separate from, industry to provide a public-sector view of investment opportunities and costs, to anticipate changes in the industrial climate, and to link biotech's potential with government activities in other areas.

Despite periodic concerns about its imminent demise, such as after the stock market crash on October 19, 1987, the golden goose is a larger, healthier creature than ever before. The industry globally will continue to change as it encounters new challenges and tests its wings. The more successful state incubation programs undoubtedly will expand the population of new biotechnology firms. These opportunities for increased competition and cooperation can be beneficial for all concerned. But the State of California must keep a vigilant eye on the roost.

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