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**Reformulating the
Incubator Model:
Applications to
Commercial
Biotechnology**

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Abstract

State economic development agencies are engaged in a variety of efforts to increase the fertility of regional biotechnology milieus, indicating that the incubator model can take on a range of organizational forms and purposes. Traditionally, the incubator model of economic development has framed two hypotheses: (1) the propensity for new advanced technology firms to locate in central areas that afford external economies, and (2) the propensity for mature firms to relocate to lower-cost peripheral areas as their productive activities expand. Although the model provides one of the few theoretical frameworks that can account for patterns in the establishment and growth of new knowledge-intensive technology firms, it is not without shortcomings. In this paper, we argue that the case of biotechnology, particularly the widespread incidence of inter-firm alliances, cannot be explained by the basic incubator model and requires a reformulation of the hypotheses. The result is a modification of the concept to acknowledge the incipient workings of a social division of labor without physical relocation per se. Despite the need for theoretical adjustment, the incubator model still provides a working model for policymakers looking to promote indigenous growth of biotechnology firms.

Introduction

Over the past decade, regional economic development theorists have spent considerable energies addressing the following propositions: (1) a key element of economic competitiveness is **technology-based** development, that is, the ability to produce qualitatively differentiated and functionally improved goods and services; (2) technology-based growth is **spatially** determined by the conditions in a particular locational environment; (3) promoting the **indigenous** potential of regions to produce or to quickly adapt innovations is a desirable objective of economic development efforts; and (4) the private sector is the prime mover of economic development; however, the public sector has an important **auxiliary role**, for example, as "catalyst" and/or "facilitator." These propositions have influenced the economic development agendas of many state governments. Ewers and Wettman (1980), in their seminal discussion on innovation-oriented regional policy argued:

The regions which will win the fight for survival in a time of structural change will be those which are able to compensate for the loss of old markets either by developing new markets or through technological change of their production. (p. 165)

Such pronouncements, accompanied by attractive images of Silicon Valley and Boston's Route 128, have made their way into the language and metaphors of government leaders. It is a language that does not clearly differentiate between description and prescription. The language is embodied in success stories repeated through professional networks and popular media. And, like all good stories, there is action of heroic proportions and there are morals to be learned. Almost all of the major industrial states have begun a process of using the Silicon Valley metaphor of "growing your own" in a recent round of high-technology economic development. The lessons of successful semiconductor and microelectronic production districts provide a new conceptual framework for their economic policies.¹ This paper examines how states are applying an incubator or grow-your-own strategy in the high-risk, high-value biotechnology field.

The New Direction

The 1980s began with California and Massachusetts in advantageous positions for growth in biotechnology; however, their headstart was not seen as an insurmountable handicap by other regions. Thus, former Mayor Henry Cisneros assessed San Antonio's prospects for biotechnology in the following manner:

No...place has emerged as the runaway leader in this field. None of them has dominated to the extent that Silicon Valley has dominated in microelectronics. The truth is that there will never be a Silicon Valley equivalent in biotechnology because healthcare resources are more distributed. (quoted in Klausner and Van Brunt 1987: 135).

The early expectations of state and local officials were tied not to any existing configuration of industrial assets, but to the science driving the R&D-oriented industry; and the science has been booming. Martin Kenney documented the beginnings of commercial biotechnology, noting that it was "born in the laboratories of American research universities" (1986: 5). Others in the R&D fraternity, including medical centers and research institutes, are widely scattered throughout the U.S.

State investment in biotechnology is actually quite small compared to the expenditures of the Federal government and industry. For fiscal year 1987, state allocations specifically designated for biotechnology--excluding general university support--were estimated at \$147 million. In comparison, twelve Federal agencies spent roughly \$2.7 billion and the private sector invested another \$1.5 to \$2.0 billion (OTA 1988). Given the low amounts, states necessarily have to leverage their funds for maximum effect. Yet despite financial constraints, states display considerable energy, even a sense of urgency--as if some hypothetical "window of opportunity" might close at any time. The North Carolina Biotechnology Center, established in 1981, was the first major commitment of state resources to promoting biotechnology as a source of economic development. Just five years later, 33 states had economic development programs with some kind of explicit biotechnology element (OTA 1988). Part of the broad interest in biotechnology can be explained by the realization that competence in biotechnology goes beyond immediate job creation. Officials have alluded to the long-term and cumulative consequences of this new technological trajectory, as seen in the remarks of James Kenworthy, a program manager with the Michigan Strategic Fund:

The computer industry is concentrated on the coasts but 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 for being centers of the cutting edge science, but other areas will have to become expert at applying that science to their existing industries or risk migration of R&D and later new product production to these centers. State-funded economic development strategies need to crystallize this process of the intelligent decentralization of biotechnology capacities to the innovation needs of the basic medical and agricultural products of each region. (Montgomery County High Technology Council, Inc. 1987: 285)

To develop the type of technological capacity described by Kenworthy, state governments have had to hone their ability to translate ideas into marketable innovations. It is a *modus operandi* that Peter Eisinger of the University of Wisconsin-Madison calls "a pure example of state entrepreneurialism" where the goal is to create and expand markets

through targeted industries (1988: 267). For policymakers whose job is to make sense of, and respond to, new industries and changing markets, the theorists' propositional concepts often constitute a working model of how to proceed. This is the case with the incubator model. The incubating idea is frequently and casually mentioned in discussions of economic development; there is a taken-for-granted status of this metaphor. We will show that more careful explication of the incubator model can be useful for understanding state governments' involvement in commercial biotechnology, and for providing public policy guidance.

The first section of the paper contains a brief overview of the incubator concept in the economic development literature. Second, we will consider how the incubator concept relates to the needs of biotech firms themselves. The third section looks at specific examples of how states are implementing the incubator idea. We conclude by drawing the policy implications from our analysis.

The Life-Cycle of the Incubator Concept

Use of the incubator concept in a planning context is generally attributed to Edgar Hoover, Raymond Vernon, and others working on the New York Regional Plan Study in the late 1950s and early 1960s (Hoover and Vernon 1962). They observed that central urban areas are favorable for the birth and early development of manufacturing firms because of external economies, such as savings in travel times and close proximity to suppliers, sub-contractors, and markets.² In the early 1970s, citing the paucity of empirical evidence to support the incubator theory, Robert Leone, Raymond Struyk, and Franklin James formally articulated and conducted extensive tests of the "incubator hypothesis" (Struyk and James 1975, Leone and Struyk 1976, see also Fagg 1980). Little support was found for the "simple" hypothesis that central urban locations should experience

consistently disproportionate rates of firm births. Instead, there was stronger support for what the researchers called the "complex" hypothesis that, as firms mature and grow, they tend to become less dependent on the services afforded at incubation sites. Some relocation occurs within the core region; however, firms experiencing higher rates of growth are more likely to move to low-density outer areas.³ Although this research looked at intrametropolitan location patterns, we can draw a parallel to core versus peripheral regions, and their respective capacities for technological innovation and industrial growth. What is important here is a **geographical** unit of analysis--regions, rather than firms. The incubator hypothesis, as formulated by Struyk and his colleagues, is useful in linking the concepts of an "expected industrial form" and "locus of development." Of course, in applying this construct to biotechnology, we are not looking at new-firm activity across all manufacturing industries, but only within a limited range of technologies.

Table 1 summarizes the "simple" and "complex" hypotheses in relation to their primary industrial and spatial characteristics. The table also shows modifications of the hypotheses based on our study of the biotechnology industry. The "locus of development" in this case appears to be less dependent on agglomerations as generic phenomena than on the presence of a technological infrastructure, including, but not limited to, funded research, skilled scientific personnel, and modern laboratory facilities. We find ourselves in agreement with Edward Malecki's conclusions that, for concentrations of high-technology industries, "agglomeration economies may operate at a lower size threshold or in different ways than they traditionally have for manufacturing" (1984: 267). Thus, while the largest concentrations of biotechnology companies are located in major metropolitan areas, the beginnings of new clusters are also located in small cities and suburbs, such as Boulder, Colorado; Allentown and Malvern, Pennsylvania; and Madison, Wisconsin.

Table 1

The Incubator Hypotheses

<u>Concept: Incubator Model</u>	<u>Expectation: Industrial Form</u>	<u>Locus of Development</u>
Simple Hypothesis	New firm starts, exploiting new product development.	Urban areas with external economies
Complex Hypothesis	As firms mature, branch plants and production jobs relocate.	Peripheral areas with lower cost inputs
Reformulation	Both processes occur concurrently within separate, but allied, organizations. Focus on functional specialty in front-end of product cycle.	Magnet areas with assembled resources and expertise

The question of where biotechnology will emerge posits that "location" is a dependent variable. However, the relationship can also be inverted, with location as a determinant of potential biotechnology growth and the type of growth. Data on California biotechnology firms collected by the Biotechnology Industry Research Group (BIRG) reveal a dynamic relationship between the nature of regional biotechnology industry clusters and the nature of the place-specific assets in which they are located (Willoughby and Blakely 1989b). "Location" was found to be a strategic variable in differentiating the specialization of biotech firms within regions. The results are similar to Ewer and Wettman's finding that "regional differences in innovation performance exist, and that these cannot be fully explained in terms of sectoral or size structure" (1980: 167). Although further research is required to unbundle the "location" variable, both studies identify it as a residual factor inducing growth, a factor outside the industrial entities themselves.

In the "simple" hypothesis, the expected industrial form is limited to start-up firms; the "complex" hypothesis accounts for those same firms at a later, more mature stage.

Implicit in the latter is that, as the firm grows, it internalizes a greater number of functions and, therefore, is less dependent on inputs acquired in the market. Moreover, as the firm outgrows the entrepreneurial stage and becomes involved in full-scale manufacturing, the availability of lower-cost production labor becomes relatively more important in location selection. In the biotechnology case, firms are increasingly unlikely to obtain needed resources through either expansion or merger. Rather, the trend in biotechnology is toward strategic alliances with large, diversified corporations. These alliances join the distinct structures of small, dedicated biotechnology firms and oligopolistic, multi-branch corporations (Willoughby and Blakely 1989a).

With these hypotheses--simple, complex, and reformulated--one direction for research is to empirically test them. Our purpose here, however, is more limited. We are interested in examining the usefulness of the incubator as a policy model. In the next section we consider the suitability of the incubator model from the standpoint of industry trends, paying special attention to the growing significance of strategic alliances in biotechnology.

The Evolution of the Biotechnology Industry

The Office of Technology Assessment (OTA) defines biotechnology as "any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop micro-organisms for specific use" (1988: 3). Techniques subsumed under the umbrella term "biotechnology" include recombinant DNA techniques, cell fusion, protein engineering, and novel bioprocessing techniques. They are used in several industrial sectors that are commonly categorized as human therapeutics, human diagnostics, plant and animal agriculture, supplies (reagents) and instrumentation, specialty chemicals, and hazardous waste management. Another key distinction, as we

have mentioned already, is between the small, dedicated biotechnology firms (DBFs) and the large, diversified corporations (DCs). DBFs are entrepreneurial ventures started specifically to commercialize innovations in biotechnology.⁴ DCs, on the other hand, tend to be older and pursue multiple product lines, many unrelated to biotechnology.

Although biotechnology grew in the shadow of the computer and microelectronics industries, there are important differences between the two technical communities. Small computer firms are often started by engineers who previously worked for larger companies in closely related industries (Glasmeier 1988). We are beginning to see second-generation biotechnology firms; however, most DBFs are established by scientists associated with universities with no experience in production or in marketing products (Freeman and Barley 1989). The nature of R&D and the product life cycle also differ. The development phase of biotechnology products is relatively long. In particular, diagnostic and therapeutic products for humans and animals are subject to stringent regulatory procedures that have no parallel to the microelectronics market. The average time spent by companies getting their biotechnology products through clinical trials and regulatory review at the Food and Drug Administration is five years (OTA 1988). A "fast track" drug (such as AZT for AIDS treatment) can take half that amount. A very rough estimate of the cost to fund biotechnology products from early research to the market is \$100 million, with at least two-thirds of that spent on human trials and market introduction (Lunzer 1988: 18).

Microelectronics products are sold as components of more complex systems, whereas many biotech products are sold to end users or to the professionals who employ them. With microelectronics, there are many variations and incremental changes in style and performance characteristics; with biotechnology, every product starts from original science. In general, biotechnological innovation is not systemic in nature, compatibility

among different processes and products is not an issue and, therefore, there is no technological reason for firms to collaborate (Teece *et al.* 1987).

Borrus and Millstein (1983) juxtapose the role of Bell Labs as a national resource for semiconductor R&D, training, and personnel, against the absence of an equivalent institution in biotechnology. The Federal government has also been pivotal in providing resources for demonstration semiconductor projects and pilot plants, as well as a first market for prototypes. These are institutional gaps that have constrained biotechnology's progress. Although state governments cannot expect to fill all of them, the gaps provide clues to the types of institution-building state governments should consider.

Biotechnology gained national attention in 1980 after Genentech became the first DBF to go public, receiving record-breaking valuations from Wall Street. In the same year, a Supreme Court decision validated patenting rights to genetically altered micro-organisms. When analysts began looking at the industry, they were not surprised to find dynamic, state-of-the-art biotech companies in acknowledged high-technology hotbeds, such as the San Francisco Bay Area and Boston. Somewhat more surprising, however, were the other biotechnology companies found in outlying areas throughout U.S. As Stohr (1986) suggested, it appeared that the geography of incubators was indeed adjustable at this time and with this industry. In fact, the underlying capacity to start biotechnology firms existed in nearly all regions with strong university biosciences and agriculture departments.

Through the early and mid 1980s, industry watchers and public officials alike expected the biotechnology start-ups to follow the trajectory of their counterparts in microelectronics. Small R&D companies would grow into fully integrated multinationals and, in the process, generate a lot of high-paying jobs, taxes, and other economic benefits. However, there were also concerns that, as predicted by the "complex" incubator

hypothesis, firms would move their lower-skill production jobs once biotechnology products reached the manufacturing stage. These concerns are not unwarranted. Looking at the experience of pharmaceutical companies, one biotechnology executive commented on what it means to reach corporate maturity: "Full integration, as the major pharmaceutical firms understand the term, means spending hundreds of millions on R&D, having 5,000 salespeople, [and] building plants in Puerto Rico and around the world..." (Interview with Howard Greene in Burrill 1989: 145).

However, two events in the latter half of the 1980s changed the outlook for biotechnology's future enough to question the original incubator hypotheses. The first event was the stock market crash of October 1987 which drastically reduced the ability of biotech firms to obtain middle- to later-stage public financing in order to continue expensive R&D programs and to pay for the clinical trials necessary to obtain drug approval. The second event was the Swiss multinational Hoffman-LaRoche's 60 percent acquisition of Genentech stock in April 1989 at a cost of \$2.1 billion, of which \$492 million was initially available as new capital infusion. Genentech is widely considered the premier biotech company and its decision to affiliate with a stronger financial power, rather than to remain independent, marked a watershed in the industry's development.

In the wake of the Genentech-LaRoche deal, the sentiment pervading biotechnology circles was that "If Genentech couldn't make it, who could?" (San Francisco Chronicle 2/4/90).⁵ In actuality, this question probably overestimates the amount of independence even the largest DBFs have been able to maintain. Though short of outright acquisition, strategic alliances have been a feature of biotechnology almost from the beginning and remain prevalent. In a random sample of 200 relationships from their data base, Teece *et al.* (1987) found that the vast majority, 62 percent, were between DCs and DBFs, 10.5 percent were between DCs, and 5 percent were between DBFs (the remaining

arrangements involved universities, research institutions, and government agencies). A similar pattern was reported in Ernst & Young's survey of biotech firms, with over two-thirds of respondents involved in strategic alliances, ranging from 61 percent of small companies to 87 percent of large companies (Burrill 1989).

However, the objectives of strategic alliances have shifted over the years. In the early days, alliances were a means of technology transfer, allowing established corporations to learn about new technologies in an era when breakthroughs in traditional pharmaceuticals have become less common and many products are nearing the end of patent protection. Slow to start, DCs now invest considerable sums on in-house R&D of biotechnology. Still, research by McKinsey & Co. and Harvard University have found that pharmaceutical research productivity (as measured by biotechnology patent applications per \$10 million of R&D spending) is more than four times higher at small DBFs than at industry leaders (Ernst and Mackie 1988). Given this relative efficiency, smaller companies with their freewheeling and innovative lab atmosphere can bring an important chip to the strategic alliance bargaining table.

For DBFs, the primary motivation is straightforward; they want to build the capacity to market their bio-drugs or novel processes. But new DBFs whose products are still under development also derive value from the legitimacy of corporate affiliation. With biotech products closer to market today, the corporation offers not only financing, but also expertise in downstream phases (such as clinical testing, production capability, and a ready-made distribution system). Strategic alliances reflect the values placed on different resources. Barley and Freeman's (1990) research on strategic alliances finds a preponderance of agreements in phases beyond R&D, including manufacturing agreements, marketing agreements, and broader category of licensing agreements (any combination of the previous two) (see Table 2).

Table 2
Types of Strategic Alliances

<u>Type of Relationship</u>	<i>All Firms</i>		<i>U.S. DBFs</i>	
	<u>No.</u>	<u>%</u>	<u>No.</u>	<u>%</u>
Grant	83	3	67	4
Joint Venture	201	8	97	6
R&D Agreement	200	8	143	8
Development Agreement	463	17	303	18
Research Agreement	266	10	157	9
Supply Agreement	75	3	54	3
Manufacturing Agreement	140	5	103	6
Marketing Agreement	551	21	379	22
Licensing Agreement	478	18	315	18
Unspecified Agreement	192	7	103	6
Total	2649	100	1721	100

Source: Barley, Stephen and John Freeman. 1990. Technical Report: A Preliminary Analysis of Strategic Alliances in Commercial Biotechnology.

As economic developers, we are interested in the spatial implications of these interfirm alliances. Is proximity as significant a concern for alliance-building in biotechnology as it is in microelectronics? (See Saxinian 1989) Will dedicated biotechnology firms increasingly detach themselves from their university bases and relocate closer to their corporate sponsors? Table 3 shows a sample of strategic alliances that were formed between large and small firms in 1989. Because it is based on public information, there may be a bias against linkages between biotech firms and regional (rather than multinational) corporations. However, the effect of any bias is expected to be small because of the oligopolistic nature of the industries involved, and regional corporations are not likely to have the financial and market powers sought by DBFs. In any case, the clear absence of any discernible geographic pattern is striking. Unlike the high-technology assembly industries where proximity between partners is a key consideration, this does not

appear to be the case in biotechnology for a couple of reasons. First, biotechnology is knowledge intensive, so the data can be transmitted anywhere. Second, it is the scientist--not the science--that alliances are built upon at this stage. That is, large firms are reluctant to move scientists or to disturb their work while it is still in an embryonic stage.

Table 3
Selected Biotechnology Collaborations, 1988-89

<u>Smaller Company</u>	<u>City</u>	<u>State</u>	<u>State</u>	<u>City</u>	<u>Larger Company</u>
Agouron Pharm.	La Jolla	CA	IN	Indianapolis	Eli Lilly
Applied bioTech	Cambridge	MA	DE	Wilmington	DuPont
Athena Neurosci.	San Carlos	CA	IN	Indianapolis	Eli Lilly
Biotech Res Labs	Rockville	MD	Jpn	Tokyo	Ajinomoto
British Bio-tech	Oxford	U.K.	NY	New York	Pfizer
British Bio-tech	Oxford	U.K.	IL	Abbott Park	Abbott Labs
Cal. Biotech	Mountain View	CA	Jpn	Tokyo	Daiichi Seiyaku
Cal. Biotech	Mountain View	CA	NY	New York	Pfizer
Celltech	Slough	U.K.	NJ	Rahway	Merck
Cetus	Emeryville	CA	NJ	Nutley	Hoffman-LaRoche
Chiron	Emeryville	CA	NJ	Morris Plains	Warner-Lambert
Collagen	Palo Alto	CA	NY	New York	Bristol-Myers
Creative Biomol.	Hopkinton	MA	MO	Kansas City	Marion Labs
Genentech	So. S. F.	CA	Jpn	Tokyo	Mitsubishi Kasei
Genetics Inst.	Cambridge	MA	CA	Palo Alto	Syntex
ImClone Systems	New York	NY	NY	Pearl River	Lederle Labs
Immune Response	San Diego	CA	PA	Ft. Washington	Rorer Group
Immunex	Seattle	WA	NY	Rochester	Eastman Kodak
InGene	Santa Monica	CA	PA	Great Valley	Eastman Pharm.
InGene	Santa Monica	CA	Jpn	Osaka	Green Cross
Marrow-Tech	Albany	NY	NY	New York	Colgate-Palmolive
Nova Pharm.	Baltimore	MD	DE	Wilmington	DuPont
Nova Pharm.	Baltimore	MD	PA	Philadelphia	SmithKline Beckman
Procept	Cambridge	MA	MI	Kalamazoo	Upjohn
Synergen	Boulder	CO	NJ	Nutley	Hoffman-LaRoche
T Cell Sci.	Cambridge	MA	U.K.	London	Beecham
Xenova	Slough	U.K.	NJ	Nutley	Hoffman-LaRoche

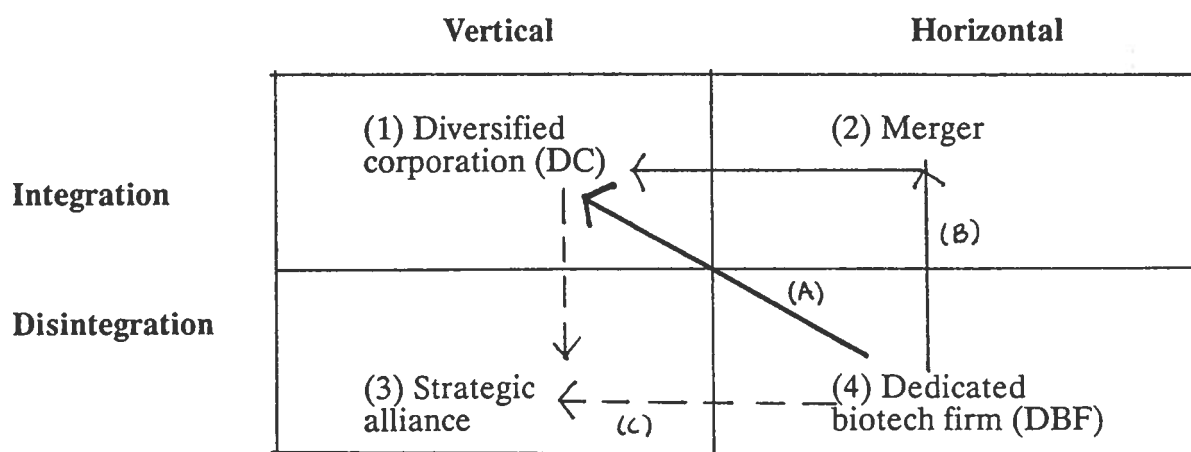
Source: Mark Ratner, 1989b. "Dealing with Large Companies" in Bio/Technology. 7 (Oct): 1013-1019.

With mutual advantages to strategic advantages, the co-existence of large and small firms may be an enduring feature of the industry's structure, rather than a transitory stage in biotechnology. Figure 1 shows the development of the biotechnology industry in a

schematic framework (modified from Cooke 1988). The vertical axis represents the level of corporate integration; the horizontal axis represents the alignment of functional relationships. The extreme cases are Box (1), **vertical-integration** epitomized by the large, diversified corporation in which all functions from R&D to production to distribution are conducted internally, and Box (4), **horizontal-disintegration** represented by the dedicated biotech firm whose limited resources are devoted primarily to R&D. The middle range organizational forms are Box (2), **horizontal-integration** or mergers, and Box (3), **vertical-disintegration** or strategic alliances. Also shown are three industrial development trajectories. The heavy line (A) shows original expectations that the entrepreneurial spinoff from university research would scale-up and become fully integrated. The thin solid line (B) represents predictions by industry analysts--yet unfilled--of merger waves, shake-outs, and market correction. The dotted line (C) shows a route to commercialization via strategic alliances. Under this scenario, the duality of DBFs and DCs is retained. A final note on the diagram. Although the horizontal and vertical dimensions are shown as dichotomous, in reality there are many intermediate gradations. And, importantly, where the arrow meets in the alliances box (3) is flexible: that point can lie closer to DCs (Box 1) or to DBFs (Box 4).

Figure 1

Alternative Development Trajectories in Biotechnology



As we proposed earlier, the incubator hypothesis can be reformulated as follows: The tendency for production and marketing jobs to "migrate" to peripheral areas will largely occur through the existing or expanded labor force of diversified corporations, rather than the branch plants of the biotech firms themselves. Strategic alliances simultaneously bifurcate and bridge the production system from R&D to manufacturing and distribution. What is indeterminate is allocation of functional responsibilities between the dedicated biotechnology firm and the diversified corporation. This is where a set of incubator policy tools could be productively utilized. In the sections below, we argue that, for many regions, the economic development potential of the biotech industry lies in the early stages of the product life-cycle--from the research side to the early development of pilot production in the R&D formula.

Rethinking the Incubator Metaphor for Policy Analysis

In a 1987 article, Allen Scott and Michael Storper critiqued the incubator hypothesis as "reasonable enough" from a "purely descriptive" standpoint, but "analytically sterile, a symptom of which is its readiness to fall headlong into biologicistic metaphor." (p. 219) With few exceptions, little attention has been given to the incubator model *per se*. However, it may be premature to dismiss the analytical potential of the model on the basis of its failure to yield a rigorous set of predictive relations.

We propose, instead, that the analytical strength of the incubator lies in the metaphor itself.⁶ Metaphors provide a way for inquiry to proceed by apprehending new relations through familiar categories and by helping us to see a common underlying form in things that superficially appear to be quite different or that exist in different contexts (Landau 1961). They reveal new attributes or cast old ones in a new light. With the

incubator metaphor, however, there has been a tendency to use it without clarifying the analogies that are being drawn and how it is used for policy design.

The original incubator metaphor proposed by the authors of the New York Regional Plan referred to the dense concentration of people, ideas, and commercial linkages to be found in major urban areas that would stimulate new business formation. "Incubation," in this context is a natural by-product of urban-ness. In contrast, when the incubator concept is used in a policy context, it refers to efforts to distill the essential elements for promoting entrepreneurship and simulating the rich, interconnectedness of the urban environment, within a circumscribed arena. Public authority is used to artificially re-create or alter the economic environment.

A look at everyday examples of incubators will help to illustrate the incubating environment. Common setting for incubators are the hothouse, the laboratory oven for cultures of microorganisms, the specially designed crib for infants at risk, and the poultry hatchery. In each of these cases, there is a protected, controlled environment to maintain optimal conditions. Besides regular monitoring, experts are on hand to intervene if any problem arises. Incubators usually regulate ambient conditions, such as light, temperature, and humidity. But they also assemble the nutrients, treatments, and stimulation necessary to promote and sustain development. It is important to note that not all individuals need the care of an incubating environment. Selection is involved in determining which firms are vulnerable and would benefit from incubation. The incubator is usually limited to the fledgling stage; it is not intended as a normal habitat. Indeed, the incubator metaphor begins to break down in an industry that is innovation-oriented; a portion of which is perpetually a fledgling. Thus even established biotechnology firms may find beneficial the incubating environment which spawned and nurtured their start-up.

The Incubator as a Working Model for State Policymakers

Policymakers face a difficult task in designing policies for industries like biotechnology that are evolving within an economic context that is itself fluid and unpredictable. The outcome has been a set of policy experiments by state governments that David Osborne describes as a "process [that] has little to do with ideology and everything to do with trial-and-error, seat-of-the-pants pragmatism." (Osborne 1988: 3).

The "experiments" have yielded considerable diversity in state-level biotechnology initiatives. In some cases, the lead has come from the Governor's Office, in other cases, the State Legislature or a multi-disciplinary Task Force. Universities are also central actors in biotechnology promotion, given the importance of research and training resources. Yet despite differences in organizational structure, legal authority, and financing capability, the incubating idea cuts across many of the states' efforts. There is widespread feeling that it is important to encourage home-grown development. In a survey of state economic development agencies conducted in this study, 75 percent of the respondents identified "encourage start-ups" as one of their top 3 economic development strategies.⁷ In fact, it was the most popular strategy, ahead of retaining or attracting biotech firms, supporting basic science, or promoting technology transfer (see Table 4).

Table 4

Ranking of State Biotechnology Strategies *

<u>Type of Strategy</u>	<i>Ranked Top 3</i>	
	<u>No. of States</u>	<u>%**</u>
Enhance the knowledge base of biotechnology research	20	63
Encourage the start-up of dedicated biotechnology businesses	28	88
Support the scaling-up of small biotechnology firms	17	53
Retain biotechnology firms already located in the state and encourage in-state expansion	21	66
Attract branch manufacturing plants of firms headquartered elsewhere	19	59
Attract complete firms presently headquartered elsewhere	10	31
Transfer new bioprocessing techniques to existing firms	17	53
Pursue general economic development (not specific to biotech)	15	47

* States were asked to rank the strategies listed with "1" being most important; strategies of equivalent importance could be given the same numeral ranking.

** 38 states responded, of which 6 states marked "no answer." Percentages, therefore, are based on n = 32.

Source: BIRG Survey of State Biotechnology Policies and Programs, 1989.

However, depending on the portfolio of programs a state actually adopts, implementation of the incubation concept may occur at varying levels of intensity or commitment. We distinguish three levels: incubation policies, incubation programs, and incubation places. The levels are cumulative so that states pursuing an pry

incubation-place strategy will also have a supporting network of policies and programs (Figure 2). Each level of incubation is described below and illustrated with state examples.

Figure 2

Matrix of Incubation Levels

<u>Level of Incubation:</u>	<i>Major differentiating characteristics</i>		
	Promote commercial <u>biotech</u>	Assemble regional <u>assets</u>	Maintain magnet <u>infrastructure</u>
Policy	X		
Programs	X	X	
Places	X	X	X

Table 5 fits selected states into this classification scheme. The assignments reflects our judgment based on responses to the BIRG survey, agency brochures, and information published in industry journals. (See also Appendix A.)

Table 5

Incubation Strategy of Selected States*

Incubation Policy		Incubation Programs		Incubation Places	
<u>States</u>	<u>DBFs</u>	<u>States</u>	<u>DBFs</u>	<u>States</u>	<u>DBFs</u>
California	111			Massachusetts	54
Connecticut	13			Maryland	38
Texas	13			New Jersey	24
				New York	20
Oregon	5	Wisconsin	16	Pennsylvania	9
Montana	2	Colorado	9	North Carolina	6
Arkansas	1	Florida	8	Ohio	5
Delaware	1	Minnesota	6	Michigan	4
Hawaii	1	Illinois	4		
New Mexico	1	Kansas	4		
Rhode Island	1	Indiana	3		
South Dakota	1	Georgia	2		
Idaho	0	Missouri	2		
Kentucky	0	Iowa	1		
Mississippi	0	Tennessee	1		
Average No. Firms (Lower Group)	.9		5.1		6.0

* The OTA Inventory identified a total of 402 dedicated biotechnology firms (DBFs) in 50 states. The 33 states listed above contain a total of 363 DBFs, i.e., accounting for over 90 percent of the total.

Source: U.S. Congress Office of Technology Assessment, 1988. New Developments in Biotechnology: U.S. Investment in Biotechnology, OTA-BA-360. (Washington, DC: Government Printing Office), Table 4-6, p. 68.

We now illustrate these different strategic formulations through state cases.

(1) Incubation Policy

An incubation policy is an official statement or policy position endorsing biotechnology as a desirable type of economic activity. In this sense, it is a species of industrial policy, where the intent of industrial policy is to express preferred patterns for the allocation of private resource allocation. According to Margaret Sharp, Sussex Policy Research Unit, industrial policy "reorients resources, provides bridging mechanisms for

industry to access the research base, and has a catalyzing effect on industry--making it willing to invest money more readily, to think about longer term strategic considerations." (Quoted in Ratner 1989c).

Although the incubation policy may be backed by considerable expenditure of public resources, the cost factor need not be large. The core element is a reliance on signals that spur market initiatives. Organizationally, the state usually provides for at least a minimal staff: a contact person or a small office within or attached to the commerce department or the high-tech agency, if there is one. Given a small staff, an energetic biotechnology promotional effort is unlikely. Rather, personnel time is likely to be channeled into rational coordination of the many programs that are administratively fragmented (Goldstein 1987) . Staff may also provide mediation between pro-industry interests and other government functions, such as regulation and education. The state which pursues the incubation-policy approach is more likely to depend on a trade association to coordinate the needs of its corporate members and to provide a more-or-less unified voice to which government offices can respond.

Texas provides an example of a state at the incubation-policy category. Promotion of biotechnology is the responsibility of the Office of Advanced Technology (OAT) within the Texas Department of Commerce. Official state interest in the biotechnology industry came relatively late, and its first project was a 1988 survey of firms involved in or related to biotechnology. Many of the firms are clustered in metropolitan areas, such as San Antonio and Houston. While the state has deemed it important to document the extent of biotechnology in Texas, there is expected to be limited follow-up. At the time of the survey, OAT Director Karen Ware noted that biotechnology groups within the state were forming their own network. It was hoped that the database being compiled from the state's survey could be turned over to the new industry organization. Because of limited

resources, the Office works best with groups that have "their own infrastructure" (Personal communication, 4/18/89).

The minimal intervention approach is also evident in the comments of Brian Levinson, Houston Economic Development Council: "There's already such a strong grass roots movement that we didn't see anything we could do in a formal plan that isn't already happening. The best we've been able to do is add our voice to tell anyone who will listen that it's time for Houston to be recognized as a serious research center." (quoted Gebhart 1989: 14).

California officials also take a hands-off approach in the business of biotechnology. Wes Irvin, California Department of Commerce Project Coordinator for biotechnology, estimates that his office is "probably aware of only 10 percent of what's going on" in negotiations involving California biotechnology firms (quoted in Ratner 1989a: 683). On the other hand, because biotech has a high profile in California, the governor has convened an Interagency Task Force for which Irvin provides staff support. Among its accomplishments, the Task Force has clarified and streamlined state regulations affecting biotechnology, and it has developed guidelines that local communities can adopt in formulating policies on environmental testing and zoning. Activities such as these are aimed at removing the obstacles that might impede biotech's expansion--still signals to industry, but of another sort.

In contrast to Texas and California, regions where development of biotechnology is neither self-evident nor spontaneous are more likely to develop a strategic plan. Plans fall into the incubation-policy category to the extent that the formality of the approach views government and industry in an arms-length relationship. The purpose of the plan is to rationalize dispersed resources (venture capital fund, R&D grants, management assistance

programs, training programs, etc.). The plan may also recommend expansion of, or marginal adjustments to, programs originally designed for all high-tech companies (or all small businesses) so they better address the specific needs of the biotech client.

An example of the plan-based policy is Oregon's "Enhancement and Diversification: Biotechnology in the Oregon Economy, 1988-2000" which was prepared in 1988 by the Biotechnology Industry Advisory Committee, Oregon Economic Development Department. The recommendations have not been implemented yet, but the report is indicative of the attempt to establish a clear path for biotechnology. The report calls for formulating and marketing biotechnology through a strategic plan: a "well thought-out plan is fundamental to orderly economic growth" (p. 25). Some have pointed to the unanticipated and haphazard growth of Oregon's Silicon Forest as an example to be avoided. The plan does not recommend the establishment of new economic development programs. Rather, it seeks to marshall existing resources and direct them toward biotechnology promotion by setting up a precise agenda and a list of objectives to be achieved.

(2) Incubation Programs

Incubation programs go beyond policy which is intended to influence private sector investment. As we have broadly defined them here, incubation programs also go beyond one-to-one counselling in the economic development office. Rather, the purposes of incubation programs are to cross-fertilize ideas and to bring together people and resources that can realize the commercial potential of innovations. If the intent of an incubation policy is to generate or adjust signals for private sector investment, then the intent of incubation programs is to involve the state directly in quickening the pace of innovation, sharpening the ability to bring new ideas to market, and increasing technological sophistication (Osborne 1988). These are programmatic elements that can be grouped

under rubric of moving products "from the laboratory to the marketplace." For this reason, incubator programs seek to assemble a soft infrastructure (Blakely *et al.* 1987): to facilitate information networks and exchanges, marry product innovations and business savvy, researchers and venture capitalists, start-ups and corporate sponsors. A prime example is the research grant which stipulates a requirement of matching funds or in-kind contributions from an industrial partner.

Eisinger (1988) reminds us that "interactions between universities and private industry are scarcely novel." But he goes on to point out that "most of [the] university-industry links were forged at the initiative of industry or individual researchers. What is novel about the current establishment of technology centers is that by and large they have been initiated by state governments in the name of economic development." (p. 284) Another way of looking at the novelty is to see states engaged in institutionalizing interactions that occur sporadically and disjointedly between the academic and industrial communities. Incubation-type programs that exploit university-industry linkages are usually established within the state university system, but often there is explicit encouragement of collaboration between two or more campuses, and with private universities in the state. A university-affiliated organization may change its legal status to encourage flexible interactions, such as more permissive stances toward investments, equity positions, or contract negotiations. University-industry arrangements may also take the form of partnership schemes that give member-contributors privileged access to certain academic resources. Finally, incubation programs may include a variety of structured communication channels, such as newsletters, symposia, and conferences.

Incubation programs have become increasingly popular in universities across a wide range of technologies, including biotechnology. Our example, Colorado, is a typical case. 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). It provides a single point-of-entry to broad-based biotechnology activities occurring throughout the state's higher education system. It is a vehicle for faculty researchers to discuss their individual needs, strengths, and research interests. A primary objective of CIRB is to promote interdisciplinary, multi-campus and industry-university collaborative research. By enhancing research capability, for example through a seed grant program, the state hopes to become more competitive in receiving large federal and foundation grants. By filtering the research proposals--delineating subareas of "research excellence" and directing (if implicitly) further research toward these areas--Colorado institutions are working to consolidate their expertise and develop prestige in specific fields.

(3) Incubation Places

Incubating policies and programs stress coherence and coordination. These approaches often amount to what Haider (1986) calls a kind of faddism where "similar to Noah's Ark, some states have 'one of everything' in the name of economic development" (p. 463). Incubation places cut across a variety of state functions. Instead of imposing a coordinative structure over existing programs, incubation places bring that coordination into a single agency.

As the name indicates, incubating places offer permanent physical facilities. Therefore, while conferences are important places for interpersonal exchange, they are not incubating places because they convene occasionally and in different places. Furthermore, what distinguishes incubating places as defined here is the mix of economic development and technical assistance programs. Thus, while some universities are incubating places,

others are limited to scientific interchange and lack the important quality of comprehensiveness. This strategy does imply a certain amount of duplicated services and costs. At the same time, many of these organizations are working toward becoming independent, self-funding organizations.

We identify three types of incubating places that meet the criteria--a physical structure populated by people and organizations involved in both scientific research and economic development. The first type includes the traditional incubator facility which is designed for start-up companies (Allen and Weinberg, 1989). Firms have private space for R&D and small-scale production, but they often share a common administration area, pool overhead services, and have access to experts for assistance with business development. These facilities can be valuable incubating places; however, we turn to two other types that are not usually recognized as incubation places. The "integrated biotechnology center" is described first, followed by the "entrepreneurial agency."

(a) Integrated Biotechnology Center

States with integrated biotechnology centers administer a wide range of programs and commit considerable resources to the promotion of biotechnology. The North Carolina Biotechnology Center is a "full-service" center devoted to biotechnology, housing a wide variety of services for start-up and growing companies. NCBC was created in 1981 as a division of the State Board of Science and Technology. In 1984, the Center was made a private, nonprofit corporation to increase its flexibility. The objectives of NCBC have been explained as follows:

[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." (Remarks by Gerry Hancock, chairman of the Board of Directors at a 1986 conference in Davis, California, p. 46.)

The Center carries out no scientific research of its own, although it awards grants and seed monies to scientific investigators and new companies conducting biotech R&D. NCBC sees as one of its key functions assistance to universities in putting together recruitment packages that will attract world-class scientists and promising young scientists. It has developed a biotechnology curriculum for the community college system and materials for high school teachers.

Another feature of the integrated center is the importance of physical facilities--a communications hub which regularly brings together researchers, entrepreneurs, and public officials to foster the formal and informal interchange of ideas. NCBC's information division maintains several databases and hosts conferences and workshops, as well as ongoing symposia. The spirit of the center is captured in Information Director Mark Dibner's report that "the Plant Molecular Biology Program meets at the center monthly to exchange ideas over pizza and soda and to hear a lecture... numerous university-industry collaborations have evolved from the meetings." (Dibner and Hafer 1989: 22).

Besides North Carolina, several states, including Pennsylvania, New York, New Jersey, and Maryland, have recently constructed or are planning to spend millions of dollars in brick-and-mortar projects dedicated to biotechnology. A major attraction of these biotechnology centers is the availability of sophisticated equipment which may be rented on a time-share basis, thereby allowing small firms to defray high fixed costs. This type of strategy has also been implemented at the Illinois Institute of Technology by the Federal government. Frank Young, director of the Food and Drug Administration, explains the rationale of magnet infrastructure as follows:

In the United States, we've done a very unusual thing, relative to other parts of the industrial world, by making our investment in fermentation pilot plants and scale-up plants before the product is actually ready for production. Typically, the product

arrives when the plant is a minimum of four years out of date, in some cases as much as eight. By making fermentation technology available to industry and university scientists through our consortium, on what amounts to a turn-key rental basis, we'll help companies delay their investment in state-of-the-art technology until their products have actually proved themselves in later-stage clinical trials. This should save enormous amounts of money.

Instrumentation in molecular biology becomes obsolete in something like two and a half years. If each of us--academia, industry, and government--buys state-of-the-art equipment and underutilizes it through its brief period of high performance, we're in effect lowering the productivity of capital in the nation. The FDA's initiative is a capital-sparing strategy." (From an interview in Burrill 1989: 154)

This type of structured place-making provides a new stimulus to the incubator model in an effort to enhance the "hatching" process.

(b) Entrepreneurial Agency

Some states have established institutions that participate directly in technology development and commercialization. Rather than simply promoting seedbed conditions that are favorable for start-ups, these entrepreneurial agencies are planting the seeds themselves. Industry analysts (either on staff or hired as consultants) scan the market to identify appropriate market niches, and in-house scientists conduct the requisite research to develop novel products. The agency may commercialize the product on its own or it can license the production and/or marketing rights or it can form a joint venture to perform these functions. Michigan and Ohio provide two examples of the entrepreneurial agency. While neither is self-supporting yet, their ultimate goals are to earn sufficient income to operate independently of state financing.

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. The Michigan Strategic Fund, Kellogg Foundation, and Dow Foundation provided initial capitalization of \$29 million for operations. A for-profit subsidiary, Michigan

Biotechnology Ventures was set up to provide economic return to the Institute and assure commercialization of Institute-developed 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-square foot building that contains a 20,000-square foot industrial-scale pilot plant which is designed to promote interaction of biologists and engineers. The pilot plant is also available to industry for a fee. 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.

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.

In Ohio, the Thomas Edison program was introduced in 1983 and, to date, the program has been capitalized to the sum of approximately \$33 million in state funds and \$80 million in non-state funds. There are nine research consortia of which two use genetic engineering technology. The Edison BioTechnology Center is in Cleveland and the Edison Animal Biotechnology Center (EABC) is in Athens. EABC, established in 1984, is the older of the two. Having started at a time when there were no private biotechnology companies in the state, EABC also has a more entrepreneurial orientation.

EABC is highly focused toward agricultural animal genetics because of long-standing animal transgenics research at Ohio University. Embryogen, Inc. is a for-profit animal biotechnology company spun off from EABC. Though autonomous from the Center, the two organizations remain tightly linked through Embryogen's exclusive right to license all Edison technology in return for continuing funding support and a royalty agreement. These cases illustrate state policies where the state wishes to catch up by fostering the incubator process, rather than waiting or hoping it will happen in their "nest."

Convergence of Industry Needs and Public Policy

In this section we trace the contours of complementarity between industry needs and public policy. The area of overlap suggests the parameters for an incubating environment. Earlier we reviewed the evolution of the biotechnology industry, noting the increasing importance of strategic alliances, but that the content of those alliances is subject to negotiation. Co-activities are one of the major avenues available to build value in the company. But the starting point for negotiations is inevitably biased against small companies biotechnology that operate under financial constraints and must give up some rights to production and/or markets. Yet it is important not to lose sight of the fact that the locus of manufacturing is a critical issue for the DBF's long-term viability. Stephen Duzan, CEO of Immunex, a Seattle biotechnology company emphasizes the

...importance of hanging on to some manufacturing as a means of developing facilities and people and expertise. Because we've done this, we've been able to invent some proprietary expression systems and a number of proprietary manufacturing technologies. These things may be as important as the creation of the molecules themselves because they make us cost-competitive. (Interview in Burrill 1989: 196)

According to the president of another biotechnology company observes that management is more and more inclined to wait it out until the potential value of a product

has been demonstrated in order to structure the best terms in a strategic alliance. "By waiting the potential value of the relationship--for the biotech company--can be significantly greater" (Interview with David Hale in Burrill 1989: 164). However, during the delay, say, until the Phase 2 clinical trials, the company continues to use up its own financial and human resources. An economizing business strategy, therefore, becomes ever more important.

One means of supplying resources to new biotech firms is through state economic development policies. Yet a slate of poorly-defined programs, all of which are nominally related to economic development, can be counterproductive and waste limited public resources. "Economic development has become everybody's business," writes Haider (1986). "As the domain and scope of the economic development field broadens, there is increased competition not only for resources but for roles among the many actors (p. 452). The incubator model can shape a plausible role for economic development. By looking closely at the stages of growth through which a biotech firm passes, the model helps to discriminate the types of interventions suitable for those stages. Direct forms of economic development assistance are limited to the early stages of a biotech firm's life cycle. Although a company may have significant capital needs (for example, to secure FDA approvals, build production facilities, and distribute its product), the large amounts and expertise required must be supplied by the private sector. As has traditionally been the case, state government can best intervene early in the product life cycle: in education and technology development, and in supporting commercialization and new firm starts.

Our research indicates that a successful incubating environment, therefore, is the ability of biotechnology firms to build up the value of its technology before it enters negotiations with a financing partner. The prototypical incubation place contains a fertile mix of technological stimuli, interpersonal exchanges, and contributions to fixed cost. For

the region, relative success may lie in a thriving population of R&D firms that never become manufacturing giants, but are likely to stay close to the sources of their original science, and contribute to the growth and advancement of the overall biosciences complex.

Policy Implications of the Incubator Approach

Although the workings of the market that we have outlined appear to coincide rather nicely with the workings of policy tools, this convergence was not in the policy picture when states embarked on their present courses. Strategic alliances have moved into the foreground only within the last few years, whereas most government initiatives are now five to ten years old. Were the states simply fortunate?-- that historical events seem to be validating the incubation-place strategy (which may very well be the outcome of local politics, bureaucratic dynamics, or other straightforward purposes). Or could it be that the incubation-place strategy contains something of inherent value--something that could be applied to the promotion of other innovation industries?

In a recent article, Florida and Kenney (1990) drew a distinction between industrial districts organized on the basis "simple flexibility" versus "structured flexibility." Silicon Valley and Route 128 are examples of simple flexibility which is characterized by dense networks of small entrepreneurial firms. The drawback, they note, is the high cost such districts in terms of high labor turnover and "chronic" entrepreneurship. In contrast, the authors cite Japanese manufacturing systems as examples of structured flexibility, where large corporations guide and govern a host of satellite supplier firms. In the biotechnology clusters we have observed, networks tend to be quite sparse. To the extent that incubator places serve as an institutional hub within a regional biotechnology complex, they resemble Florida and Kenney's structured flexibility. The important difference, of course, is that these institutions have hardly any powers of supervision and no sanctioning ability.

Nevertheless, if the expectations of state policymakers bear fruit, incubating places may yet stimulate the emergence of a third type of industrial district: one we could label "mediated flexibility."

It is true that some start-ups will emerge in unexpected places or flourish without any overt public assistance. The incubator metaphor does not claim otherwise. What interests us here are the more modest contributions to marginal growth. The argument for the incubator approach is that by pushing at the boundaries of economic viability, public policies can broaden the field in which new firms can take root. But casting the incubation concept as a yes-or-no policy issue can be misleading. Therefore we have proposed a typology that was arrayed against "degrees of incubation," i.e., levels of effort ranging from minimal tending to more energetic cultivation to extensive groundbreaking measures.

Notes

1. The search for promising high-technology industries usually occurred in the context of more comprehensive efforts to understand the workings of state economies, to identify sources of strengths and vulnerabilities, and to plan directions for the future. Examples include Pennsylvania's "Choices for Pennsylvanians," Michigan's "Path to Prosperity," and California's "Report of the Commission on Industrial Innovation."
2. In essence, the "simple" hypothesis combines three agglomeration factors described by Hoover (1937): scale economies, localization economies, and urban economies.
3. The "complex" hypothesis has been developed more fully by theorists looking at the geographical implications of Vernon's (1966) product-life-cycle model. See, for example, Stohr (1987) and Massey (1984).
4. Most of our references to DBFs include firms operating in all sectors. However, when discussing the industrial structure of biotechnology, our referent is the human diagnostics/therapeutics sector. This simplification is necessary as a practical matter to render the discussion more manageable. But it is also the case that the diagnostics/therapeutics sector is the largest within biotechnology (with approximately 50% of DBFs, OTA 1988: 10) and it is the most advanced, both in terms of the technology and commercialization efforts. There is also diversity among the diversified corporations, mainly those belonging to the oligopolistic industries of pharmaceuticals, chemicals, food processing, and agricultural supplies. Consistent with our focus on diagnostic/therapeutic DBFs, our main referent is their closest allies--the pharmaceutical companies. To the extent that DBFs and DCs share

common structural characteristics within their respective strata, our generalizations will be less distorted.

5. Outright equity acquisitions are the exception in biotech partnerings. Several reasons are given for the lack of greater merger and acquisition activity. For DCs, larger equity shares increase their risk of liability. Moreover, acquisition is no guarantee that DCs will get the scientific talent and creative R&D environment being sought. Managers and scientists of entrepreneurial biotech firms often resist the unavoidable bureaucracies of large houses. Many of the original key personnel at Hybritech, a company acquired by Eli Lilly in 1985, and at Genetic Systems, bought by Bristol Myers the same year, have since abandoned the ventures (Lunzer 1988). Large corporations are finding that they can selectively purchase access to technology through strategic alliances, and avoid having to put up a lot of capital upfront. Paradoxically, a DBF with a series of strategic alliances with different organizations, has in place a "poison pill" against takeovers, since technology could very well be tied up with one's competitors.
6. As used here, metaphor is similar to Kaplan's (1986) concept of informal narrative. He points out that this form of discourse is appropriate for resolving dilemmas when there are no clearly accepted external criteria. It allows policy analysts to think globally about who should do what, and how, when, and why they should do it. It would be a mistake to construe metaphors or narratives as "proof." Instead, these methods view policymaking as an interactive process, moving back and forth--between fact and a "conditioned idea."
7. The survey was conducted in 1988-89 by the authors through the Biotechnology Industry Research Group, University of California at Berkeley. Questionnaires were mailed to agencies in the 50 states that are charged with development of commercial biotechnology, or whose jurisdiction are 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-eight states returned usable questionnaires or participated through a telephone interview version, for a response rate 76 percent. Most states sent supplementary literature describing various programs, and this information was integrated into the analysis. In addition, follow-up telephone calls and/or in-person interviews took place in a limited number of cases. A more complete analysis of the survey data may be found in a working paper (Blakely and Nishikawa 1989).

Appendix A

Table A-1 matches selected states against the three levels of the incubator approach. Our evaluations were based on responses elicited through the BIRG survey, and supplemented by brochures, pamphlets, and reports published by the agencies themselves, or industry journals such as *Bio/Technology* and *Genetic Engineering News*. Two other sources were the proceedings of conferences sponsored by the Montgomery County (MD) High Technology Council (1988) and the University of California at Davis (1987). This preliminary attempt at classification allows us to see patterns in state biotechnology policies and helps to generate further questions for research.

Given the various motivations for states to stimulate biotechnology, it is perhaps not surprising that biotech policies and programs are more broadly distributed among states than the industry itself. The BIRG survey found official support for biotechnology not only in states that are well-known for high-tech activity, such as California, Massachusetts, and New York, but also in a variety of smaller states, such as Rhode Island, Arkansas, and South Dakota that each have only one biotechnology firm according to OTA's 1988 inventory. However, there is a correlation between states with fewer DBFs and those that are pursuing the incubation-policy approach, i.e., which requires the lowest level of resource commitment.

Another pattern that appears in the table is the polarity within categories (seen in our division upper and lower groups). The average number of DBFs in the lower group, increases from .9 for "incubation policy," to 5.1 for "incubation program," to 6.0 for "incubation places." Since we have noted that these strategies also represent progressively increasing levels of resource commitment, we would expect states to pursue a costly strategy if there is preliminary indications of success, such as the prior existence of biotech companies. On the other hand, given states like Ohio and Michigan which deliberately

took steps to create the industry, there is a possibility that catch-up strategies can have an effect on decreasing differentials among states. In either event, we are unable to draw conclusions about causal relationships from the matrix.

On the other side of the polarity, there are a few states with numbers of biotech firms that are much greater than the lower group average. States like California and Texas can take a less interventionist strategy because of natural economic dynamics. Indeed, some biotechnology advocates favor a hands-off approach, seeing it as what stimulated the industry's growth in the first place.

Table A-1
Incubation Strategy of Selected States*

Incubation Policy		Incubation Programs		Incubation Places	
<u>States</u>	<u>DBFs</u>	<u>States</u>	<u>DBFs</u>	<u>States</u>	<u>DBFs</u>
California	111			Massachusetts	54
Connecticut	13			Maryland	38
Texas	13			New Jersey	24
				New York	20
Oregon	5	Wisconsin	16	Pennsylvania	9
Montana	2	Colorado	9	North Carolina	6
Arkansas	1	Florida	8	Ohio	5
Delaware	1	Minnesota	6	Michigan	4
Hawaii	1	Illinois	4		
New Mexico	1	Kansas	4		
Rhode Island	1	Indiana	3		
South Dakota	1	Georgia	2		
Idaho	0	Missouri	2		
Kentucky	0	Iowa	1		
Mississippi	0	Tennessee	1		
Average No. Firms (Lower Group)	.9		5.1		6.0

* The OTA Inventory identified a total of 402 dedicated biotechnology firms (DBFs) in 50 states. The 33 states listed above contain a total of 363 DBFs, i.e., accounting for over 90 percent of the total.

Source: U.S. Congress Office of Technology Assessment, 1988. New Developments in Biotechnology: U.S. Investment in Biotechnology, OTA-BA-360. (Washington, DC: Government Printing Office), Table 4-6, p. 68.

Many states began their biotechnology programs before there was any "critical mass" of DBFs that would provide an incentive to develop support programs. We can ask, instead, whether states are reacting to the presence of an existing pharmaceutical industry that might supply the industrial infrastructure for biotechnology or be challenged by it. Table A-2 shows the numbers of pharmaceutical firms in each state (SIC 283). Again the general pattern seems to make intuitive sense. How state officials direct their biotechnology efforts is in resonance with existing industrial resources.

Table A-2
**Incubation Strategy of Selected States
and Drug Firms (SIC 283) in the State**

Incubation Policy		Incubation Programs		Incubation Places	
<u>States</u>	<u>Drug Firms</u>	<u>States</u>	<u>Drug Firms</u>	<u>States</u>	<u>Drug Firms</u>
California	128			Massachusetts	33
Connecticut	22			Maryland	28
Texas	56			New Jersey	143
				New York	144
Oregon	--	Wisconsin	15	Pennsylvania	58
Montana	--	Colorado	13	North Carolina	27
Arkansas	2	Florida	47	Ohio	41
Delaware	4	Minnesota	13	Michigan	35
Hawaii	--	Illinois	60		
New Mexico	--	Kansas	15		
Rhode Island	--	Indiana	30		
South Dakota	--	Georgia	28		
Idaho	--	Missouri	43		
Kentucky	--	Iowa	20		
Mississippi	6	Tennessee	19		

Source: U.S. Department of Commerce, Bureau of the Census. 1982. Census of Manufacturers, General Summary, Part 1, Table 2.

These matrices naturally lead us to ask whether different strategies have different impacts on start-up activity. Evaluations of this sort are complicated by the many tangled

strands that go into economic development. However, since some state programs are now reaching the ten-year point, there may be enough history at least to make worthwhile an in-depth investigation of how they operate. Another avenue of inquiry could focus on the strategy formulation stage: What kinds of planning decisions need to be made as government moves from incubation policy to programs to places? Place-specific actions involve an uneven distribution of state resources. How do states resolve actual or potential conflicts between benefits to "needy" peripheral areas versus concentration of resources in areas where research capability already exists?

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