# Analyzing an Innovative Environment: San Diego as a Bioscience Beachhead

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## Abstract:

This article examines dynamics underlying the growth of a flourishing bioscience cluster in San Diego, California, to illustrate the construction of an innovative environment and the matching of place characteristics with a specific economic activity. Extensive interviews explore the formation of synergistic connections promoting the political, economic, and social networks of entrepreneurial individuals at the metropolitan scale. Spatial proximity is shaped by real estate considerations within and between local clusters in a volatile industry affected strongly by shifting access to financial and human capital. Five key factors underlying regional success are found to be access to an outstanding research university, advocacy leadership, risk financing, an entrepreneurial culture, and appropriate real estate, knit by an intensive information exchange network.

## Article:

The clustering of innovative business sectors in particular metropolitan areas continues to generate interest among academics searching for underlying explanations and planners seeking to bring success to their cities. Numerous studies speculate on reasons for the rise of these "technopoles" in particular places (Castells & Hall, 1994; Scott, 1990; Scott & Storper,1992), while calling for further study of their developmental dynamics (Cooke, Uranga, & Etxebarria, 1998; Scott, 1990). In response, the following consideration of San Diego's success in growing a bioscience-oriented life science cluster underlines the importance of human and structural factors, integrating individual-oriented network theory with region-based milieu explanations.

As commonly used in the industry, "life science" firms by Standard Industrial Classification (SIC) codes include those focusing on biotechnology (SIC 2833-6, using genes to make products), pharmaceuticals (SIC 2830, including manufacturing, sales, and distribution), surgical and medical devices (SIC 3841, mechanical assistance), associated research and development (SIC 8730, research and development), and testing specialties (e.g., SIC 8071, research centers, labs). The term *bioscience* used in this research emphasizes the biopharmaceutical and medical device components of the life science cluster in San Diego (see Table 1). Two major bioagriculture firms arrived in 1999, but they are an exception in the disease-oriented mix of companies (CONNECT, personal communication, 1997).

Special needs of a bioscience cluster, as a type of research-dependent innovative industry, are highlighted. Five factors are crucial for the development of a bioscience cluster: an outstanding research university with a relevant specialty, a local entrepreneurial culture, strong advocacy leadership, available risk financing, and appropriate real estate. The first factor reflects the bioscience industry's need to remain tightly tied to a research university due to the competitive nature of being first to commercialize a discovery by bringing it to market as a trademarked product. Good science is not necessarily good business. Effective technology-transfer arrangements require balancing the university's desire to capture the resources arising from the research of its faculty against the high income and patent revenues that private industry would offer that same faculty involved in commercial areas of applied research (Powell & Owen, 1998). San Diego pioneered effective technology-transfer arrangements in bioscience.

**TABLE 1**
**San Diego Bioscience Industry by Firm Type and Employees**

| *SIC Code* | *Business* | *Firms 1993* | *Firms 1996* | *Employees 1993* | *Employees 1996* |
|---|---|---|---|---|---|
| 2830 | Drugs | 39 | 48 | 3,318 | 3,030 |
| 3841 | Surgical and medical instruments | 41 | 48 | 3,167 | 3,165 |
| 8071 | Medical laboratories | 109 | 100 | 1,923 | 1,891 |
| 8730 | Research and testing services | 339 | 236 | 12,447 | 8,225 |
| Total | | 528 | 432 | 20,855 | 16,311 |

SOURCE: U.S. Department of Commerce, Bureau of the Census (1994, 1997).

The second indispensable and embedded attribute lies in a local culture supportive of experimentation, failure, and recovery. Every drug attaining final Federal Drug Administration (FDA) approval reflects the testing of 5,000 to 10,000 compounds. This enormous investment of time and money over a lengthy process threatens the life span of small, innovative companies (Morrison & Giovannetti, 2000). Entrepreneurship is more likely to occur if the local culture supports such risk-taking and provides features decreasing some of the risks, such as the next item: advocacy. Leadership actively promoting industry needs and networking constitutes the third crucial component. Beyond structural milieu considerations, the human element of leadership imparts a critical competitive edge to dynamic locations.

Risk financing, the fourth element, must be sufficient to carry a company through the long time needed to develop a product from an idea through testing stages to market acceptance. Venture capitalists are much more willing to loan to companies they can easily visit or to individual entrepreneurs they already know. Regions such as California and Massachusetts, where a prior high-technology industry prospered (primarily computers), are disproportionately endowed with such financiers (Prevezer, 1998). Liberal local financial institutions or well-received stock offerings (referred to as initial public offerings, or IPOs) are required for long-term survival.

The final factor consists of a supply of real estate available for the three corporate growth stages of start-up, initial self-supporting quarters, and full-fledged operations. Bioscience work involves “messy” media, such as blood and tissues, so companies need specially configured laboratories that are less interchangeable than general office space or even “cleaner” high-tech companies dealing principally with wires and computers. Developers must be willing to build such facilities on a speculative basis, given the high failure rate of fledgling enterprises. They are more willing to do so if a critical mass of such companies creates a steady demand for these units.

The second section of this study outlines innovative milieu and network theory, focusing on the role of regional attributes as a geographic attraction factor for nurturing high technology-intensive businesses. San Diego presents an intriguing case study of an unlikely innovative milieu due to both its location *outside* the usual high-tech regions of San Francisco and Boston and its proximity to much larger metro area rivals slightly to the north. San Diego shares its mid-size rank with many other cities dreaming of benefiting from such a dynamic industry cluster (Blakely & Nishikawa, 1992; Markusen, Lee, & DiGiovanna, 1999; Walcott, 1999).

The third section applies this model to the California case study by examining how San Diego became Bioscience Beach. The rise and demise of local hero Hybritech (the first bioscience firm to generate substantial profits for those involved) and its associated corporate progeny are chronicled, along with lessons learned. The crucial role key individuals played in transforming San Diego from another Sun Belt site to a “Bioscience Best Practice” model is detailed based on a series of targeted interviews. These first three elements are analyzed as subsections in the third part. The fourth section analyzes locations of bioscience clusters within the San Diego metropolitan region, offering examples for the fourth and fifth factors of financial and physical capital. The conclusion highlights examples of the proposed five elements, emphasizing the importance of linked support and advocacy networks within a consciously constructed network. These connections resuscitated a region from one dependent on a downsizing economic base to one profiting from a laboratory-led growth engine.

## BUILDING AN INNOVATIVE MILIEU ON A BIOSCIENCE BASE: THEORETICAL AND METHODOLOGICAL ISSUES

Particular industries cluster in particular places (Krugman,1991; Porter, 1990). The benefits of proximity are apparent on a geographically local scale (Cooke et al., 1998; Malecki, 1991, 1997; Simmie, 1998). Key characteristics of innovative milieus include a local atmosphere supporting innovation from discovery through production, entrepreneurs, close interaction among firms, and externalities such as expanding capital and labor markets (Camagni, 1995; Haug & Ness, 1993). This study of San Diego's bioscience base extends current theory on the workings of these clusters (Aydalot & Keeble, 1988; P. Hall, 1990; Malmberg, 1997; Malmberg, Solvell, & Zander, 1996).

In particular, controversy based on a variety of surveys and interviews in different places concerns the appropriate prioritizing of factors critical to a successful innovative milieu. Saxenian (1994) argues that the key distinguishing characteristic is the ease and frequency of communication. Contrasting case studies of regions possessing high-tech company clusters reveal the impact of different local cultural attitudes, such as Salt Lake City, Utah's entrepreneurial Mormonism and entities in the Raleigh-Durham area of North Carolina enticed by university research that drew labor and other companies (Goldstein & Luger, 1993). Others hold that competition between firms, rather than the local culture, promotes knowledge spillovers (Porter, 1990). Some studies claimed that a concentration of similar companies is sufficient to induce useful interaction (Glaeser, Kallal, Scheinkman, & Shleifer,1992; Griliches,1992). Goetz and Morgan (1995) used statistical tests to determine that the amount of research and development (R&D) spending and the number of scientists in the specific sector most strongly influenced bioscience firm location. San Diego's example tests the notion that network-promoting structures, as well as individuals, are required for innovative activity (Audretsch, 1998; Saxenian, 1994).

The power of individuals to effect change clarifies the role of various agglomeration theories, from transaction cost to flexible specialization. Generating scientific discoveries and corporations depends on particular people. The location of these individuals is integral to explaining why a city such as San Diego successfully produced a cluster, whereas equally ambitious neighbors such as Orange County and Los Angeles have not. Regional attributes alone overlook the networks individuals construct through their associations with institutions or by virtue of personal leadership (Barnes, 1989; Sternberg, 1996). The energetic entrepreneur spans and connects the laboratory and business worlds (Kenney, 1986). The success of the University of California at San Diego (UCSD) in spawning and sustaining a biotech cluster provides an important case study for understanding how innovation occurs in particular locations.

Sources of information used in this research include interviews, trade publications, and studies and surveys done by local government and industry groups, as well as commercial and government data. The most insightful information was obtained through 31 interviews, largely conducted during two visits to the San Diego area, as well as through several extended telephone conversations. Interviews provide unique and indispensable value by supplementing available numeric data (Cresswell, 1998; Schoenberger, 1991).

Companies were selected for interviews based on the proportion of firms in the same field in that location and by prior recommendation. Half of the interviews (15) were conducted in Torrey Pines, the most expensive and desirable area bordering the UCSD campus. Of those interviewed, 14 were from biopharmaceutical companies, 4 were medical device manufacturers, 5 were affiliated with a research institute, and 8 were economic developers. The spread of interviewees reflects different locations, sectors, and perspectives. An initial list of subjects was selected based on recommendations by CONNECT, UCSD's "Program in Technology and Entrepreneurship" and the major local organization promoting high technology companies. Subsequent interviews provided a more representative coverage of life science industry components.

## HOW SAN DIEGO BECAME BIOSCIENCE BEACH: INSTITUTIONAL AND HUMAN NETWORKS

In an industry with many more but less easily tracked private firms, major clusters of public biotechnology companies occur in the San Francisco Bay area, New England (primarily Boston), San Diego, New Jersey, and

Los Angeles-Orange County (see Figure 1). San Diego is the least examined area, with the smallest population but a proportionately well-funded industry base (see Figure 2). With the exception of the year 2000, San Diego kept pace with its much larger municipal neighbor to the north, competing with Los Angeles–Orange County for funds, companies, and technical labor. One city's strength is the other city's weakness, from commute times to airport connections and environmental cleanliness. In 1997, San Diego outpaced San Francisco in per capita National Institutes of Health grant dollars, at 10 times the national average (California Healthcare Institute & KPMG, 1998). By 2001, San Diego ranked first in attracting biopharmaceutical venture capital (41%) and fifth in total national venture capital (PricewaterhouseCoopers, 2001). Involvement of foreign pharmaceutical companies is difficult to trace due to lack of U.S. government reporting requirements (Welles,1990). Anecdotal evidence indicates deals with but not domination by Japanese and European pharmaceutical concerns on specific product development cases. The major sector of employment expansion in San Diego's life science cluster is in biopharmaceutical companies. Bioscience is the second fastest-growing cluster in the San Diego region, with an employment increase of 97% from 1990 to 1996. It commands the third-highest employment (23,000), topping the chart if medical services are included. San Diego's bioscience industry maintained a steady core of companies and employees from 1994 to 1997 (San Diego Association of Governments, 1997).

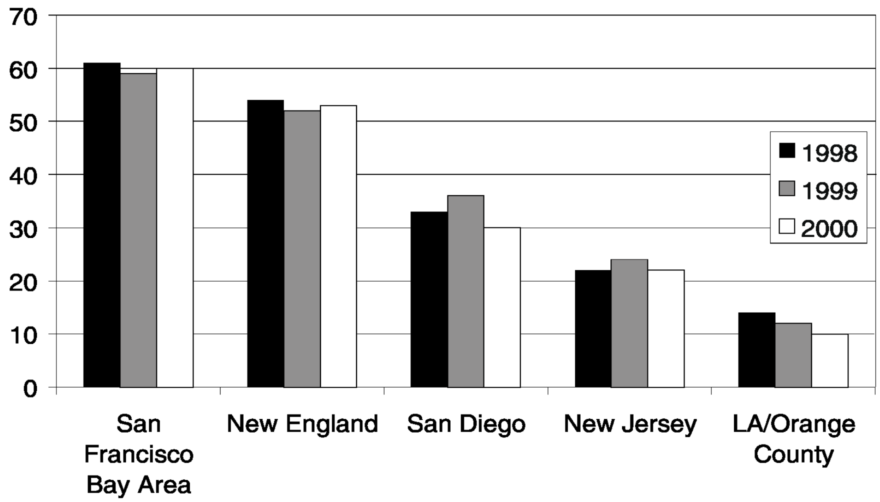


**Figure 1: Number of Public Biotechnology Companies**
SOURCE: Morrison & Giovannetti (1999, 2000).
NOTE: San Diego clearly leads the nation in its concentration of biotechnology firms per metropolitan area, as computed by a leading industry accounting firm.

### *The University Connection*

The story of Hybritech, the most prolific biotech company in San Diego, illustrates some of the challenges to getting established, major pitfalls, and potential dynamism of both the life science industry and the region (Bowie, 1994; CONNECT, personal communication, April 23, 1998; personal communications, April 1998, October 1998). By 1976, pharmaceutical giant Eli Lilly and Company was deeply concerned with the decreasing ability of the pig pancreas supply to meet a growing demand for insulin, its major product. Lilly's research investments spurred a race between rival labs at Harvard and the University of California at San Francisco (UCSF) to create insulin. The outcome was the first commercial application of bioscience in the health industry, birthing biotech firms Genentech at UCSF in 1976, Hybritech at UCSD in 1977, and Biogen at Harvard in 1978. Each company was affiliated with a key scientist and university (S. Hall, 1987; Prevezer, 1998). The West Coast's prominence in bioscience sprang from factors associated with its earlier computer industry roots: a risk-supportive environment, venture capital networks, mobile trained labor, and a regional culture of open communication.

Hybritech began as a technology transfer from UCSD, illustrating the importance of the first hypothesized factor for a bioscience base. Firm cofounders Tim Wollaenger and Ted Green knew each other from previous employment with Chicago's Baxter Travenol Pharmaceutical. They met again in the course of a routine sales call. Green had an idea he was discussing with various venture capitalists, one of whom knew of a scientist named Ivor Royston working on a similar idea at UCSD. The San Diego location of Hybritech, which became the basis of that region's bioscience cluster, thus flowed from a fortuitous connection of venture capital, footloose entrepreneurs, and a researcher with a marketable breakthrough idea. Human networks made the connection possible. The innovative idea (cloning monoclonal antibodies in large batches to avoid tricky calibration and quality-control issues) that became the basis of Hybritech proved to be the most productive source of other firms in metro San Diego (see Figure 3).

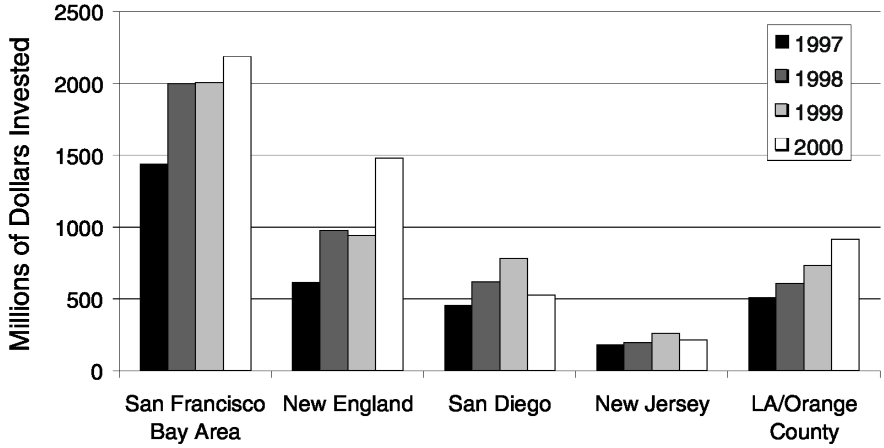


**Figure 2: Research and Development Funds**
SOURCE: Morrison & Giovannetti (1999, 2000).
NOTE: With the exception of one year, San Diego's ability to attract research and development funds keeps pace with much larger areas.

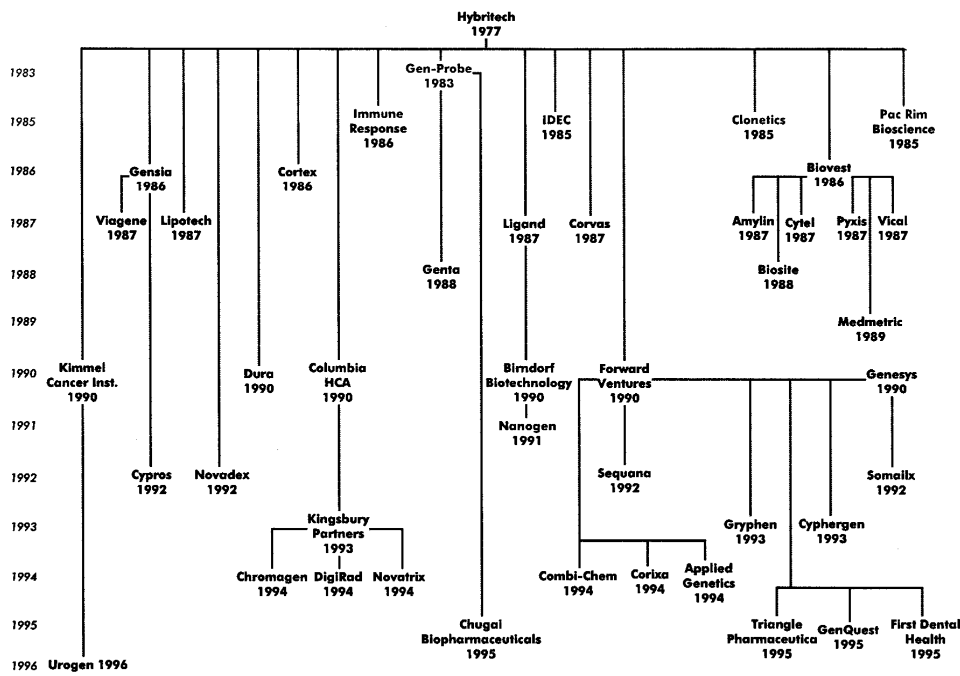


**Figure 3: Hybritech Corporate Offshoots: Companies Formed by Former Employees**
SOURCE: UCSD CONNECT (1997).

The arrangements under which Royston continued to work at UCSD while developing products for an outside corporate entity led the way for a new relationship negotiated with the UC system. Because the company on whose board he served as founding scientist gave him a number of grants, the "Royston Amendments" were drafted to define the rights of all interested parties, such as the university and corporation, and their obligations to publish or patent. The Bayh-Dole University and Small Business Patent Procedures Act of 1980 permitted the passing on of ownership rights for federally funded technology to not-for-profit universities, which then engaged in transactions with companies. These transfer arrangements were the critical *modus vivendi* permitting scientists to keep their tenured jobs at universities and work on research while securing outside federal and corporate funds. The annual Association of University Technology Transfer Managers survey demonstrates the growth of research funds from all sources and the increasing prominence of corporate largess. The arrangement in this case involved a swap for company stock in lieu of royalties for the university, as practiced by the Stanford-UC Berkeley Center for Biotechnology Research, which was set up in 1981. Other universities around the country followed, evolving from the founding of land grant universities by the Morrill Act in 1862 (Rosenberg & Nelson, 1994). The center received 30% equity in a promising company in exchange for the option to license university patents, using the standard agreement researchers sign when employed by the university (California Department of Commerce, 1988; P. Hall, Bornstein, Grier, & Webber, 1988). Such arrangements enable "star scientists" to maintain associations with both the university system and local businesses. As "founding scientists" or members of corporate scientific advisory boards, their contributions during the critical IPO stage were crucial to biotech's development and San Diego's success (Zucker, Darby, & Brewer, 1998).

### *Local Entrepreneurial Culture*

Hybritech located as close as possible to the UCSD campus so that former university employees and company scientists could drive to work in the same direction as their previous jobs without alerting their neighbors that they had "gone corporate" (CONNECT and personal communication with company founder, 1998). Salaries from corporate success eventually dispelled the taint, as more companies made the leap from the laboratory to the business world with commodified innovations. The initial corporate site on Torreyana Street is now part of a primarily biotech science park, as is the Roselle Street location of many other early firms on a nearby mesa top.

The convergence between pharmaceuticals and biotechnology promotes collaboration (Mowery & Rosenberg, 1989). It also opens up new avenues for biotech companies to secure funding to stoke their notoriously high cash "burn rate" in pursuit of a marketable product and feeds new innovations into pharmaceutical product pipelines (Grabowski & Vernon, 1994). The need for large amounts of start-up funds to carry companies through the lengthy years of testing and ultimate FDA sanctioning often leads to the firms' acquisition by experienced pharmaceutical giants (Pisano, Shan, & Teese, 1988). Hybritech's use of recombinant DNA technology and their product's potential application to colon cancer treatment attracted Eli Lilly and Company. Lilly purchased Hybritech in the late 1980s to capitalize on its experimental colon cancer drug. Hybritech's founders made enormous profits, according to personal interviews, and the price Lilly paid for Hybritech attracted attention to biotech's possibilities for generating money (Crabtree, 1998; CONNECT and personal communication with founder, 1998). Six years and a score of drug development projects later, Lilly decided the application it was interested in would not work, so a large diagnostics firm acquired Hybritech. Thus ended a classic corporate move to get into a new technology. The number of newly wealthy, creative employees who subsequently separated from Hybritech created a core of local venture capitalist "angels" eager to increase their profits and stay in an attractive area, both geographically and professionally, by assisting start-ups. The notoriously footloose "bubbles of biotech ... who could go anywhere to work and want exciting places to live" (personal communication, 1998) found other local enterprises to work in or start up to stay in San Diego.

Innovative milieu elements fall into the realms of personal, corporate, and regional cultures. The large number of biotech firms founded in San Diego by Hybritech's former employees speaks to the culture clash between bureaucratic pharmaceutical companies and experimental, driven biotech entrepreneurs. The "organization man" culture of large companies prioritizes compliance to company norms and teamwork above individual brilliance (Collins & Moore, 1970). Entrepreneurs need to be free to act on the possibilities of an idea, bringing it quickly through the stages of development, test-market, improvement, and final production. The sheer number of successful Hybritech spinoffs (see Figure 3), traced in the chart by the university and high-tech business organization CONNECT, attests to the strength of the local milieu that sustains innovative companies.

### *Advocacy Leadership Promoting Networks*

San Diego's experience demonstrates the impact of specific individuals on the development of a region through propinquity-enhanced networks, highlighting advocacy as the third critical factor in cluster success. San Diego's outstanding development as a biotechnology center rests in part on its good fortune in attracting dynamic, forward-looking individuals who plan and advocate links between university research and companies within the industry, and between the industry and outside organizations, whether government agencies, financial institutions, or flower shops. One interview subject who worked in San Diego but is now located in another region of the country put it succinctly: “The Number 1 reason for San Diego’s success is *people*. Success breeds success.” He cited Ivor Royston, the scientist-founder of Hybritech, as an example of “extremely driven scientist-entrepreneurs who like to build up companies, then use an ‘exit strategy’ [sell off to larger company] to do it again” (personal communication, August 18, 1998). San Diego supports several “serial entrepreneurs,” such as Royston, Tim Wollaenger, and Howard Birndorf, illustrated by the proliferating interconnected companies in Figure 3.

**TABLE 2**
**Interview Responses**

| *Questions* | % |
|---|---|
| 1. Major location considerations for being in San Diego[a] | |
| a. Research institutions | 100 |
| b. Cluster of firms | 90 |
| 2. Role of university connections | |
| a. Access to research ideas | 93 |
| b. Access to labor pool (founder scientists, students, etc.) | 67 |
| 3. Role of advocacy organizations | |
| a. Raise profile in larger community | 32 |
| b. Facilitate networking, ties within bio community | 81 |
| 4. Role of venture capital | |
| a. Invest funds from local technology profits | 20 |
| b. Nurture local biotech start-ups | 10 |
| 5. Relations with other firms/up and downstream | |
| a. Local suppliers of materials | 0 |
| b. Share local labor pool | 39 |
| 6. Role of locational propinquity | |
| a. Sublease from other firm | 16 |
| b. Attractive place for bio firms | 52 |
| 7. Number of spin-offs/role of spin-offs | |
| a. Entrepreneurial atmosphere | 67 |
| b. Mintain location ties | 32 |

SOURCE: Author.
a. Respondents citing this factor ($N = 31$).

Interview question categories and responses are outlined in Table 2. As reflected by respondents, UCSD’s prominence in biotechnology-related research areas constitutes the core research institution requirement for cluster development, along with the presence of the Scripps Institute of Oceanography and the Salk Institute (Organization for Economic Co-Operation and Development, 1987; personal communications). Local military facilities, from the Naval Ocean Systems Center to U.S. Marine and Navy bases, supplement a critical labor base of engineering and technical talent. Employment at military facilities dropped from a 1990 peak of 44,000 to 14,600 seven years later (Markoff, 1997). Locally sufficient labor pools—or the ability to attract them—crucially affect cluster creation (Glaeser,1998). The greatest economic development impact of public sector investment in human resource training, physical capital, and research and development comes from place-concentrated synergies of government, corporate, and university efforts (Malecki, 1985).

Clustering is itself an attraction element, as evidenced by its being ranked as the third most influential among interview subjects (see Table 2). The Scripps Institute of Oceanography, the Scripps Research Institute (the world’s largest private biomedical research institute), the Salk Institute (a large, highly respected private biological research center), UCSD and area research hospitals such as the Scripps Clinic supply cutting edge ideas, innovations, and trained labor (Stutz, 1992). Scripps, Salk, and UCSD professors coordinate lectures and advertise them on the Internet, examples of the cross-fertilization prevalent in this cooperative setting. Knowledge spillovers come directly from university lectures and laboratories rather than from migrating employees bearing company practices, as in other regions (Saxenian, 1994; personal communications, April 22-24,1998). Companies prioritize clustering close to research centers, expanding to new facilities in the same area, and continuing cluster affiliation (San Diego Association of Governments [SANDAG], 1998).

Hopeful economic developers are attracted by the potential link between research at a major university and highly profitable companies with well-paid employees generating other companies, jobs, and economic multipliers. Rather than forcing developers to rely on enticing large, established companies from other areas, a place can grow its own locally embedded enterprises. The spillover effect of physical proximity between innovative companies and research institutions is clearly established, particularly in regard to benefits for smaller, start-up firms at the city level of spatial interaction (Audretsch, 1998). However, an outstanding university with a biological specialty is not sufficient in itself to create a cluster. Feldman's (1994) study illustrates how Johns Hopkins University failed, despite its deliberate attempts and numerous grants from the close-by Washington, D.C.–based National Institutes of Health, to parlay its well-known medical research facility into a dynamic cluster for Baltimore. If the city is not attractive to prospective inhabitants and fails to build a critical mass of interacting companies along established networks, sustainable clusters will not develop.

Advocacy organizations receive high marks for cluster creation, according to interview respondents. Investment in constructing local advice and social networks can be understood as a risk-minimizing behavior in the face of steep odds (Gordon & McCann, 2000). The ability of individuals to transform their regional political economy through social networks has been illustrated through case studies of medical clusters in other cities outside California (Llobrera, Meyer, & Nammacher, 1999). Technology transfer from a dynamic research university, or regional concentration of institutions of higher education with a similar specialty, is a *sine qua non* for development of an innovative industry cluster (Audretsch, 1998; Rosenberg, 1982). Stanford University successfully applied the Massachusetts Institute of Technology's model of technology transfer, based on frequent communication between participants (Saxenian, 1994), to create Silicon Valley. This in turn inspired Richard Atkinson, chancellor of the University of California, to follow the success of Stanford's Frederick Terman by building a biotech base through university technology transfers in San Diego in the 1980s (Markoff, 1997). After selling his high-tech business because he was diagnosed with cancer, retired entrepreneur Bill Otterson acquired an interest in health issues along with a new lease on life. UCSD hired him to head CONNECT, the first major network organization linking San Diego's life science industry companies, chief executive officers (CEOs), and products to each other and the larger community. Assisted by San Diego's Regional Economic Development Council (SDREDC, BIOCOM & PriceWaterhouse,1998), CONNECT was founded by UCSD in 1985 as an "incubator without walls" for nurturing high technology companies. Otterson became a "hands-on, in-your-face bulldog for the technology industry" (CONNECT board member, personal communication, March 18,1998), introducing entrepreneurs to financiers, and politicians to technology issues. Local political bodies recognized the general benefit to their constituents in assisting the economically important industry with votes favoring specific programs benefiting bioscience concerns.

The urge to organize San Diego's life science companies came from one local scientist-entrepreneur who attended a meeting in San Francisco about facilitating biotechs and came back greatly impressed with the attempt to project industry concerns across a wide range of issues (Parks, personal communication, April 22,1998). The Biomedical Industry Council (BIC) primarily represented industry CEOs. Founded in 1991, the San Diego Biocommerce Association (BIOCOM) widened the industry's impact by including representatives of other groups affected by biotech's success, from law and accounting firms to hospitality and real estate representatives. Both BIOCOM and CONNECT actively lobby government bodies at every level on issues of concern to the industry. BIOCOM/*san diego* grew out of BIC and BIOCOM. The systemic integration of these organizations with SANDAG and San Diego's EDC enhanced the impact of key corporate investors and innovators.

Individuals who work in the same industry, serve on joint advocacy and study committees, and meet together frequently forge powerful organization networks to raise bioscience's profile in both the community and state. Several examples illustrate this point. Efforts to recruit highly competitive research and managerial talent include showcasing cliffs cascading with colorful poppies and lunch breaks taken up with windsurfing. More challenging are substandard schools, traffic gridlock, and immigration problems. The campaign to neutralize negatives is in high gear, from industry's advocating K-12 public school board candidates to stiffening high school requirements to end "social promotions." Individuals involved in this industry employ both human and institutional networks to build a better social base for their economic endeavors. As in other states nurturing a bioscience cluster, integration of university, industry, and social networks constitutes a key feature (Haug, 1995; Walcott, 1999).

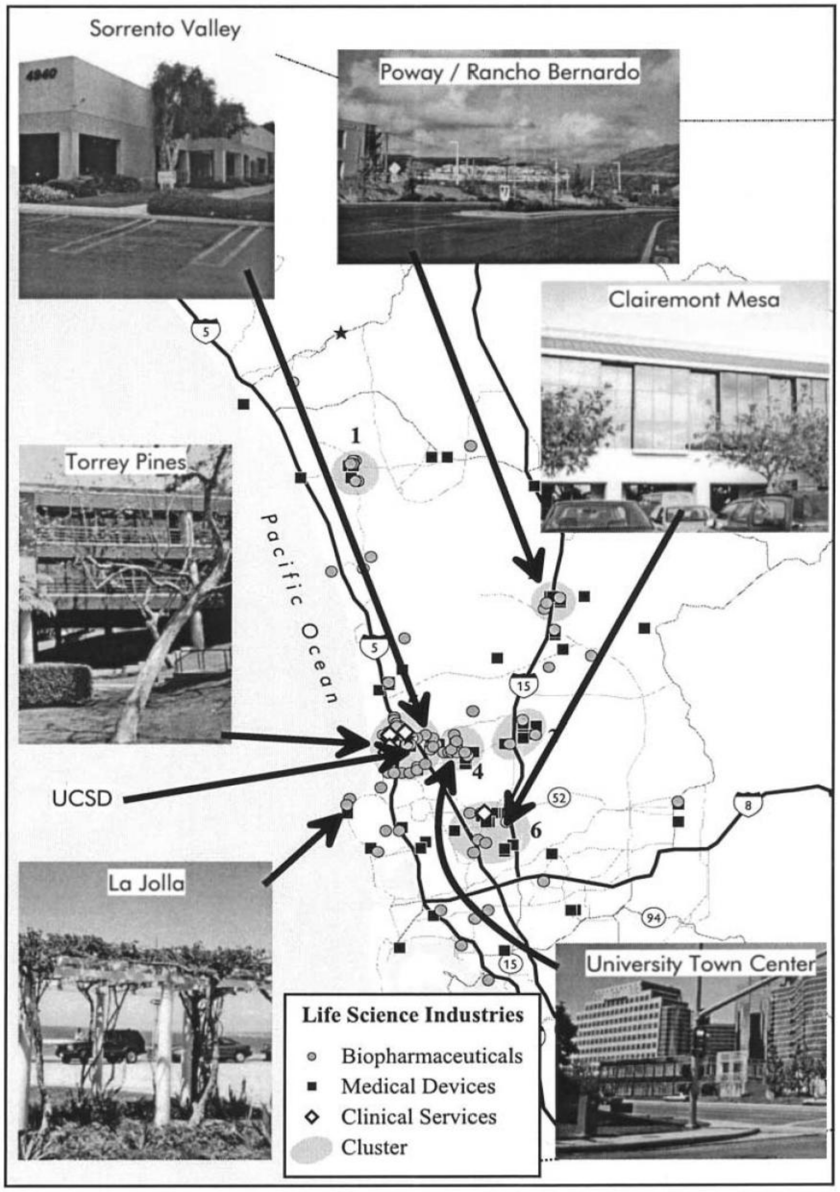


**Figure 4: Bioscience Corporate Clusters**
SOURCE: University of California, San Diego (UCSD), CONNECT, personal communication, 1998.
NOTE: Cluster settings vary widely by cost, setting, and architecture.

## BIOSCIENCE LOCATIONS WITHIN METROPOLITAN SAN DIEGO

The roles of risk financing and real estate location, the financial and physical capital, constitute the fourth and fifth proposed factors in cluster creation. San Diego's size and the concentration of most of its bioscience components on the north side helped forge a cohesive cluster. SANDAG divides the region into major statistical areas (MSA) for data purposes. The North City MSA, which includes part of the city of San Diego as well as Del Mar, Poway, and unincorporated La Jolla, is home to UCSD and most of the biotech companies. It also features the San Diego region's highest amount of retail shopping space, the largest population and number of housing units of all the regional MSAs (one quarter of the total in both categories), the fastest growth, and the highest median household income (SANDAG, 1998).

The centrality of the university-scientist connection to bioscience businesses (Audretsch & Stephan, 2000; Zucker et al., 1998) accentuates the competitive edge for real estate in close geographic proximity to the innovation source. A study of biotechnology IPOs showed that San Diego companies listed the highest percentage of scientists from local research institutions on the science advisory boards of new biotechs (Stephan, Hawkins, & Audretsch, 2000). A map of life science companies in San Diego relative to the campus of UCSD illustrates this geographic attraction for business clusters (see Figure 4).

Locating close to the university serves several purposes. Given the expense of biotech research and development facilities, the ability to use university infrastructure represents a considerable cost savings. Because a tenured faculty scientist-inventor often supervises the innovative development, company management feels a strong need for frequent access to the laboratory benefiting from corporate grants. Venture capitalists prefer visiting their portfolio investments in the minimum number of stops. Clustering clearly works to the advantage of the financier with a portfolio of local firms (personal communications). The opportunity to lunch, linger, and listen with other capitalist entrepreneurs in nearby restaurants is another cluster plus often cited. One interviewee stated that San Diego now has more technology than it can manage and plenty of venture capitalists who understand how to form successful clusters and commercialize inventions to successful products (personal communication). Geographic proximity demonstrably promotes knowledge spillovers from a flow of ideas that fuel economic growth (Audretsch,1998; Glaeser et al., 1992). Along with proximity to major research centers, a colocation strategy is based primarily on real estate considerations, given the shortage of affordable and suitably modifiable spaces in primary locations. Several interviewees indicated reasons for the demise of the “virtual company” include the “high tech–high touch” desire to see the product, the grant-funded laboratory, and the scientist. Venture capitalists invest in building relational networks, requiring proximity in this contact sport (Fried & Hisrich, 1995).

The centralizing factor for each cluster, aside from UCSD, is real estate development marketed for either prestige or affordability, depending on the company’s life cycle stage. An apparent location contradiction in this high-cost-high-risk industry is the concentration of facilities on extremely expensive land despite the fact that most executives in a recent poll indicated that their primary site consideration was affordability (SANDAG,1998). For the loan-providing institution, however, the primary consideration is its lease turnover time. The weak financing outlook of prospective tenants hampers provision of biotech facilities. The facility must be re-let quickly to other tenants without loss to the owner and must not be rapidly rendered technologically obsolete. Ideally, the facility is built as a generic lab cell with the ability to expand easily. The facility must be market-specific for present and future users.

An address-matched map of bioscience firms, along with their local cluster affiliation, is provided in Figure 4. Predominant facility type indicates the stage of the firm in the development cycle. Funding dominates the life cycle of bioscience firms. The generative idea often comes from the laboratory discovery of a key scientist. The second stage requires seed capital from personal funds or venture capital for incubator exploration of product potential. The third “early” stage often involves national programs such as Small Business Innovation Research–type funding through the FDA testing period. Traditional venture capital usually assists at the later stages of precommercialization. Sustained FDA approval procedures can require “mezzanine” capital.[1] Following FDA approval, the IPO can provide funds to manufacture a key product. The final stage results in a self-sustaining income flow and independent quarters (Arthur Anderson, 2000). At any stage, the incipient biotech company can merge with or be acquired by another firm, often a large pharmaceutical company with a compatible product line, deep funding, and experience in the manufacture and distribution process. San Diego’s shortage of water looms as a potential deterrent to mature-stage development of manufacturing facilities. The shortage of affordable land for manufacturing also conspires to keep companies quiet concerning their combination of production with R&D facilities.

The most intense concentration of firms is clearly around UCSD, along adjacent Torrey Pines Road and surrounding mesas. Medical laboratories indicate the presence of several hospitals along the ring road around the university and its medical school. The next university-hugging cluster is the University Town Center, located on flatter land at the base of the university rise and adjacent to an upscale mall of the same name, reflecting the comfortable incomes of those who live and work nearby. Rents in this modern glass tower office complex are high. Bioscience businesses not able to afford the area closest to the university seek industrial or science park spots along major transportation arteries, where they can reach universities and research centers in less than 30 minutes (personal communications, April 22-24, 1998; October 30, 1998).

The Sorrento Valley structure to the northeast of UCSD illustrates two very common and important real estate strategies. Several bioscience companies occupy customized renovated warehouse space within a tech-park cluster, in buildings linked by a parking lot and subleased from one dominant tenant. These start-ups need affordable, limited space characterized by several industry architects as one small reception area in front, a conference room, space for doctorate-level research, technicians, and a laboratory in the back. Much warehouse space is built on speculation and quickly reconfigured by adding plumbing, ductwork, filters, and refrigeration.

Bioscience businesses cluster in local office and industrial parks along a major road connecting busy highway routes 5 and 15. Strip malls and apartments line the direct road frontage, with industrial parks stretching less obtrusively behind, as predicted in a study of metropolitan land-use restructuring (U.S. Congress Office of Technology Assessment, 1995). The Miramar cluster directly to the north of Miramar Naval Air Station occupies affordable land in an industrial park. The Clairemont Mesa cluster to the south of the air station lies on another highway connecting road. Zoning requirements limit the height of buildings close to the Pacific Ocean to three stories in Torrey Pines and La Jolla. The firm photographed (Sibia) occupies the original site of the Scripps Institute of Oceanography.

A general typology of bioscience firm life cycle location can be constructed based on interview evidence and direct observation of every life science cluster in metropolitan San Diego. Location of facilities proceeds from a university research laboratory to a low-cost site in a subdivided warehouse near other biomedical firms, then to a larger area in a more prestigious place closer (and pricier) to the university of its birth. Employees of growing high-tech firms, for example, reported that their time of joining a company was measured by its square footage at that stage. The final step is product manufacturing, which takes place in a separate facility at a greater distance from the city. Owners seeking to start a business in the more affordable eastern county area are precluded from doing so unless it involves manufacturing. This situation often results in splitting a firm into headquarters in the UCSD vicinity and a production facility to the south or east of the administrative office (personal communications, 1998).

## CONCLUSION: GROWING BIOSCIENCE IN A NURTURING CULTURE

Sustaining a thriving base of bioscience companies in a particular place requires certain features that are more specialized than general innovative milieu needs. This case study discussed five specific categories. Presence of an outstanding research university in a specialized field constitutes the first critical component of an innovative milieu. Bioscience companies, more than computer or other technology-related businesses, need to remain in close physical contact with university labs. San Diego is well supplied with bioscience research institutions, from UCSD to the Scripps and Salk institutes.

A regional culture that supports failure, as long as lessons are learned and applied in the next attempt, constitutes the second factor assisting growth of an innovative milieu. Biotechnology represents a particularly high-risk-high-reward innovative sector. The disjunction between a scientific innovation and a commercial success in medicine further complicates the chances for a firm’s longevity. This makes it even more desirable for a region to contain a number of such companies, given the high employee turnover rate. San Diego embodies the West Coast culture of open communication.

The next major requirement consists of dynamic individuals, from Terman at Stanford to Otterson and a handful of entrepreneurs in San Diego, who exercise leadership by constructing and energizing advocacy organizations, such as CONNECT and BIOCOM. They also utilize these organizations to promote information exchange networks. Bioscience centers demand a free flow of ideas between laboratory scientists, entrepreneurs, and doctors. San Diego’s leadership sprang from both business and university sectors, creating organizations and raising bioscience’s profile to politicians and others who have benefited throughout the metro area and state.

The fourth crucial component of innovative milieus is the availability of adequate nontraditional risk financing. Due to the high risk and long time needed for testing that involves human subjects, the amount of funding needed is particularly large for biotech companies. The interest of deep-pocket large pharmaceutical companies in securing new products for development is another factor. Again, San Diego was fortunate to combine a supply of venture capitalists in nearby Northern California with Eli Lilly's interest in one company's product application potential.

The last major comparative component lies in the need for a three-tier real estate market, providing space for companies from incubation to start-up and through established market-seasoned success. Given the inherent messiness of biotech businesses, the need for specially configured laboratories, and the high turnover rate, the real estate market must support both subletting and a bedrock of amenities for employees. San Diego has been willing to invest in all of these. Demand for clustering drove original sites up the price escalator, with occupancy maintained by bank preference for lucrative, easy-to-fill offices. The combination of these factors created a physical, fiscal, institutional, and human network supportive of a particular high-technology sector with clear needs and rewards for its city and citizens. Success came from indigenous seeds and efforts of individuals absent in other places, leaving San Diego an innovative biotech beachhead.

**APPENDIX**
**San Diego Bioscience Industry Interviews**

| *Name* | *Company—Industry* | *Location* |
|---|---|---|
| 1. Elliot Parks | Myelos—pharmaceutical | Mira Mesa |
| 2. Bill Comer | Sibia—pharmaceutical | La Jolla |
| 3. Duane Roth | Alliance—pharmaceutical | Torrey Pines |
| 4. Employee | Alliance—pharmaceutical | Torrey Pines |
| 5. Kirby Black | Advanced Tissue Science—pharmaceutical | Torrey Pines |
| 6. Janet Wall | Advanced Tissue Science—pharmaceutical | Torrey Pines |
| 7. Patricia Lowenstam | Isis—pharmaceutical | Carlsbad |
| 8. Don Grim | Hybritech—pharmaceutical | Torrey Pines |
| 9. Employee | IDEC—pharmaceutical/manufacturing | Torrey Pines |
| 10. Phil Schneider | IDEC—pharmaceutical/manufacturing | Torrey Pines |
| 11. David Robinson | Ligand—pharmaceutical | UTC |
| 12. Howard Birndorf | Nanogen—pharmaceutical | Mira Mesa |
| 13. Employee | Aguoron—pharmaceutical | Torrey Pines |
| 14. Richard Piazza | Hepatix—medical devices | Torrey Pines |
| 15. Marcia Neumann | Sunrise Medical—medical devices | Carlsbad |
| 16. Doug Obenshain | Ernst & Young—accounting | San Diego |
| 17. Tim Wollaenger | Venture capitalist | UTC |
| 18. Carole Ekstrom | Director, CONNECT | UCSD |
| 19. Marcelle Vogel | BIOCOM | Mira Mesa |
| 20. Head of staff | State assemblywoman | San Diego, Sacramento |
| 21. Alan Pau | Director, UCSD tech transfer | UCSD |
| 22. Fred Stutz | Geographer, San Diego State University | San Diego |
| 23. Julie Meyer Wright | President, EDC | San Diego |
| 24. Steve Weathers | Biosciences, EDC | San Diego |

NOTE: IDEC = IDEC Pharmaceuticals, Corporation; UTC = University Town Center; UCSD = University of California, San Diego; BIOCOM = San Diego Biocommerce Association; EDC = Economic Development Council.

## NOTE

1. Capital needed for the prolonged stage of testing the product after it gets off the "ground floor" of discovery and initial development. This capital can be harder to raise than that at the venture stage because returns are reduced in proportion to risk reduction.

## REFERENCES

Arthur Anderson. LLP and Indiana Chamber of Commerce. (2000). *Indiana venture capital study*. Indianapolis, IN: Indiana Chamber of Commerce. Available from www.indianachamber.com/Venture_Summary.pdf
Audretsch, D. (1998). Agglomeration and the location of innovative activity. *Oxford Review of Economic Policy*, *14*,18-29. Audretsch, D., & Stephan, P. (2000). Company-scientist locational links: The case of biotechnology. *The American Economic Review*, *86*, 641-652.

Aydalot, P., & Keeble, D. (1988). *High technology industry and innovative environments: The European experience*. London: Routledge.
Barnes, T. (1989). Structure and agency in economic geography and theories of economic value. In A. Kobayashi & S. Mackenzie (Eds.), *Remaking human geography* (pp. 134-148). London: Unwin Hyman.
Blakely, E., & Nishikawa, N. (1992). Incubating high technology firms: State economic development strategies for biotechnology. *Economic Development Quarterly*, *6*, 241-254.
Bowie, N. (1994). *University-business partnerships: An assessment*. Lanham, MD: Rowman & Littlefield.
California Department of Commerce, Office of Economic Research. (1988, May). *Technology transfer: The California experience*. Sacramento: State of California Press.
California Healthcare Institute and KPMG. (1998). *The biomedical frontier: 1998 report on California's biomedical R&D industry*. La Jolla, CA: KPMG.
Camagni, R. (1995). The concept of innovative milieu and its relevance for public policies in European lagging regions. *Papers in Regional Science: The Journal of the Regional Science Association*, *74*, 317-340.
Castells, M., & Hall, P. (1994). *Technopoles of the world: The making of 21st century industrial complexes*. London: Routledge.
Collins, O., & Moore, D. (1970). *The organization makers: A behavioral study of independent entrepreneurs*. New York: Appleton-Century-Crofts.
Cooke, P., Uranga, M., & Etxebarria, G. (1998). Regional systems of innovation: An evolutionary perspective. *Environment and Planning A*, *30*,1563-1584.
Crabtree, P. (1998, February 17). Venture capital finds home here. *San Diego Union-Tribune*, pp. C1, C3.
Cresswell, J. (1998). *Qualitative inquiry and research design: Choosing among five traditions*. Thousand Oaks, CA: Sage. Feldman, M. P. (1994). The university and economic development: The case of Johns Hopkins University and Baltimore.
*Economic Development Quarterly*, *8*, 67-76.
Fried, V., & Hisrich, R. (1995). The venture capitalist: A relationship investor. *California Management Review*, *37*, 101-113.
Glaeser, E. (1998). Are cities dying? *Journal of Economic Perspectives*, *12*, 139-160.
Glaeser, E., Kallal, H., Scheinkman, J., & Shleifer, A. (1992). Growth in cities. *Journal of Political Economy*, *100*, 1126-1152.
Goetz, S., & Morgan, R. (1995). State-level locational determinants of biotechnology firms. *Economic Development Quarterly*, *9*, 174-185.
Goldstein, H., & Luger, M. (1993). Theory and practice in high-tech economic development. In R. Bingham & R. Mier (Eds.), *Theories of local economic development: Perspectives from the disciplines* (pp.147-171). Newbury Park, CA: Sage.
Gordon, I., & McCann, P. (2000). Industrial clusteers: Complexes, agglomeration and/or social networks? *Urban Studies*, *37*, 513-532.
Grabowski, H., & Vernon, J. (1994). Innovation and structural change in pharmaceuticals and biotechnology. *Industrial and Corporate Change*, *4*, 435-449.
Griliches, Z. (1992). The search for R&D spillovers. In *National Bureau of Economic Research* (Working Paper#3768). Hall, P. (1990). *The generation of innovative milieu: An essay in theoretical synthesis* (Working Paper #505). Berkeley: University of California, Institute of Urban and Regional Development.
Hall, P., Bornstein, L., Grier, R., & Webber, M. (1988). *Biotechnology: The next industrial frontier*. Berkeley: University of California Press.
Hall, S. (1987). *Invisible frontiers: The race to synthesize a human gene*. London: Sidgwick & Jackson.
Haug, P. (1995). Formation of biotechnology firms in the Greater Seattle region: An empirical investigation of entrepreneurial, financial, and educational perspectives. *Environment and Planning A*, *27*, 249-267.
Haug, P., & Ness, P. (1993). Industrial location decisions of biotechnology organizations. *Economic Development Quarterly*, *7*, 390-402.
Kenney, M. (1986). *Biotechnology: The university-industry complex*. New Haven, CT: Yale University Press.
Krugman, P. (1991). Increasing returns and economic geography. *Journal of Political Economy*, *99*,483-499.
Llobrera, J., Meyer, D., & Nammacher, G. (1999). Trajectories of industrial districts: Impact of strategic intervention in

medical districts. *Economic Geography*, *76*(1), 68-98.
Malecki, E. (1985). Public sector research and development and regional economic performance in the United States. In A. Thwaites & R. Oakey (Eds.), *The regional economic impact of technological change* (pp. 115-131). New York: St. Martin’s.
Malecki, E. (1991). *Technology and economic development: The dynamics of local, regional, and national change*. New York: Longman Scientific & Technical.
Malecki, E. (1997). *Technology and economic development: The dynamics of local, regional, and national competitiveness*. London: Addison Wesley Longman.
Malmberg, A. (1997). Industrial geography: Agglomeration and local milieu. *Progress in Human Geography*, *20*,3 92-403. Malmberg, A., Solvell, O., & Zander, I. (1996). Spatial clustering, local accumulation of knowledge and firm competitiveness. *Geografiska Annaler*, *78 B*, 85-97.
Markoff, J. (1997, March 24). San Diego—the wireless valley: An information revolution revives its economy. *The New York Times*, pp. C1, C6.
Markusen, A., Lee, Y., & DiGiovanna, S. (Eds.). (1999). *Second tier cities: Rapid growth beyond the metropolis*. Minneapolis: University of Minnesota.
Morrison, S., & Giovannetti, G. (1999). *New directions 98*. Palo Alto, CA: Ernst & Young.
Morrison, S., & Giovannetti, G. (2000). *Convergence: The biotechnology industry report*. Palo Alto, CA: Ernst & Young. Mowery, D., & Rosenberg, N. (1989). *Technology and the pursuit of economic growth*. Cambridge, UK: Cambridge University Press.
Organization for Economic Co-Operation and Development. (1987). *Science parks and technology complexes in relation to regional development*. Paris: OECD.
Pisano, G., Shan, W., & Teese, D. (1988). Joint ventures and collaboration in the biotechnology industry. In D. Mowery (Ed.), *International collaborative ventures in U.S. manufacturing* (pp. 183-222). Cambridge, MA: Ballinger.
Porter, M. 1990. *The competitive advantage of nations*. New York: Free Press.
Powell, W., & Owen, J. (1998). Universities and the market for intellectual property in the life sciences. *Journal of Policy Analysis and Management*, *17*, 253-277.
Prevezer, M. (1998). Clustering in biotechnology in the USA. In G. Swann, M. Prevezer, & D. Stout (Eds.), *The dynamics of industrial clustering: International comparisons in computing and biotechnology* (pp. 124-193). Oxford, UK: Oxford University Press.
PricewaterhouseCoopers. (2001). *Insights and solutions: MoneyTree survey report*. Available from http://www.pwcmoneytree.com/region
Rosenberg, N. (1982). *Inside the black box: Technology and economics*. Cambridge, UK: Cambridge University Press. Rosenberg, N., & Nelson, R. (1994). American universities and technical advance in industry. *Research Policy*, *23*, 323-348.
San Diego Association of Governments. (1998, May/June). San Diego regional employment clusters: Engines of the modern economy. *Info*, pp. 2-31.
San Diego Regional Economic Development Corporation, BIOCOM, & Price Waterhouse LLP. (1998). *Barometer on the future of San Diego’s biomedical industry*. San Diego: Regional Economic Development Corporation.
Saxenian, A. (1994). *Regional advantage: Culture and competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.
Schoenberger, E. (1991). The corporate interview as a research method in economic geography. *Professional Geographer*, *43*,180-189.
Scott, A. (1990). The technopoles of Southern California. *Environment and Planning A*, *22*, 1575-1605. Scott, A., & Storper, M. (1992). *Pathways to industrialization and regional development*. London: Routledge.
Simmie, J. (1998). Reasons for the development of “Island of Innovation”: Evidence from Hertfordshire. *Urban Studies*, *35*,1261-1289.
Stephan, P., Hawkins, R., & Audretsch, D. (2000). The knowledge production function: Lessons from biotechnology. *International Journal of Technology Management*, *19*, 165-178.
Sternberg, R. (1996). Regional growth theories and high-tech regions. *International Journal of Urban and Regional Research*, *20*, 518-538.

Stutz, F. (1992). Working the cities: The regional economic base. In P. Pryde (Ed.), *San Diego: An introduction to the region* (pp. 155-164). Dubuque, IA: Kendall.
U.S. Congress Office of Technology Assessment. (1995). *The technological reshaping of metropolitan America*, *OTA-ETI-643*. Washington, DC: U.S. Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. (1994). *County business patterns: California*. Washington, DC: U.S. Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. (1997). *County business patterns: California*. Washington, DC: U.S. Government Printing Office.
Walcott, S. (1999). High tech in the Deep South: Biomedical firm clusters in metropolitan Atlanta. *Growth and Change*, *30*, 48-74.
Welles, E. (1990, February 1). The Tokyo connection. *Inc*. Available from http://www.inc.com/articles/details/printable/ 0,3535,CID5030_PAG2/REG6,00.html
Zucker, L., Darby, M., & Brewer, M. (1998). Intellectual human capital and the birth of U.S. biotechnology enterprises. *American Economic Review*, *88*, 290-306.