Chapter 15

University Roles in Technological Innovation in California

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The public universities in the United States were established with goals of providing widespread, affordable access to higher education. Starting with agriculture and the mechanical arts well over a century ago, it has been recognized more and more that another important role of research universities, public and private, is in building the economy and improving societal conditions through innovation. This role has been well appreciated in California for the electronics, software, biotechnology, and communications industries, and in other areas such as health care and agriculture.

The purpose of this chapter is to indicate some of the ways in which universities, and the University of California in particular, have contributed to the development of California industries; to explore several recent organized structural and project efforts that are various forms of university, industry and/or government partnerships; to assess some of the most important factors for success and for meeting concerns about detrimental effects of such partnerships; and finally to assess reasons for the relative success of California. The state had no grand design for promoting technological innovation, but the wisdom of putting major state

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resources into public higher education has been a major spur to the large success that California has had in technological innovation.

Some Measures of Impact

The broadest contributions of California universities, or indeed universities anywhere, to the state are the educational development of the populace and the flow of graduates at all degree levels to positions in business, government, universities, and self-employment. Influences that are more specific to technological innovation are the education of holders of graduate and professional degrees, the flow to industry of inventions and relevant background information stemming from university research, and transitions of faculty and senior researchers to roles as entrepreneurs themselves. Some facts and figures pertaining to the biotechnology and wine industries provide more specific examples.

Biotechnology

Yarkin and Murray[2] have studied the flow of people from the University of California to the California biotechnology industry and the contributions that they have made to the development of that industry. In 2001, stemming from the original 1980 Cohen (Stanford University) and Boyer (University of California) patent on recombinant DNA technology[3] and subsequent research, over one-third of U.S. biotechnology companies were situated in California.

- These companies accounted for over 47 percent of research expenditures of the U.S. biotechnology industry and accounted for 53 percent of revenues.
- The California biotechnology industry provided 60,000 jobs at an average salary of $71,000, i.e., $4.3 billion of personal income.
- At least 35 percent of California biotechnology firms were founded by University of California faculty.
- At least 302 persons with University of California Ph.D.s were working in California biotechnology companies.
- Licenses to technology from the University of California were held by 82 biotechnology companies.

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[2] Cherisa Yarkin and Andrew Murray, "Assessing the Role of the University of California in the State's Biotechnology Economy: Heightened Impact Over Time," Working Paper No. 02–5, Industry-University Cooperative Research Program, University of California, March 2003, <http://ucdiscoverygrant.org/pdf/UC_Role_in_CA_Biotech_Economy_March 2003.pdf>.

[3] Maryann Feldman, "Commercializing Cohen-Boyer," <http://www.kauffman.org/pdf/tt/Feldman_Maryann.pdf>. See also <http://bancroft.berkeley.edu/Exhibits/Biotech/25.html>.

- Large clusters of biotechnology companies exist in the San Francisco Bay Area and San Diego, and 96 percent of California biotechnology companies are located within 35 miles of a University of California campus.

A less detailed companion study deals with the R&D-intensive communications industry.[4]

Wine and Viticulture

Historically, another very tangible contribution of University of California research has been to the development of the California wine industry.[5] Interestingly, the University of California programs in viticulture and enology originated through an act of the state legislature in 1880, sensing the economic potential of the industry and mandating that the state university take on the task of improving it. This research has largely been carried out at the University Farm at Davis, which became the Davis campus. During the period of prohibition of alcoholic beverages in the United States (1919–1933), research was carried out on viticulture, leading to the development of plant strains used now for over 95 percent of wine made in the United States and much of that made in other countries. Research in the 1930s focused upon the influence of climate on the growth of different varietals, leading to knowledge that underlies site locations for vineyards around the world. The Davis campus also developed malo-lactic fermentation, which allows the wine-making process to be chemically controlled to produce distinctive flavors and to exercise quality control. Maynard Amerine and associates at UC Davis developed a methodology of sensory evaluation that is in widespread use today. Nearly all wineries in the United States now have a UC Davis graduate as wine maker or manager. As well, students are sent to the UC Davis enology and viticulture programs from wine-making countries around the world. It is this long-term, sustained line of research that has made California wines excellent and highly competitive.

As of 2005,[6] the California wine industry

- contributed $51.8 billion to the California state economy and $125.3 billion to the United States economy;
- created 309,000 full-time-equivalent jobs in California, with $10.1 billion gross wages;

[4] Cherisa Yarkin, Andrew Murray, and Sam Chou, “The Role of University of California Scientists and Engineers in the State’s R&D-Intensive Communications Industry,” Working Paper No. 03–1, University-Industry Cooperative Research Program, University of California, April 2003, <http://ucdiscoverygrant.org/pdf/UC_Role_in_ CA_Commnications_Economy_April2003.pdf>.

[5] Lisa Lapin, “A Fine Blend,” *UC Davis Magazine* 19, no. 2, 2002, <http://ucdavismagazine.ucdavis.edu/issues/win02/feature_1.html>.

[6] MKF Research LLC, “Economic Impact of California Wine 2006,” MKF Research LLC, 2006. See also <http://www.wineinstitute.org/industry/statistics/2006/ca_wine_economic_impact.php>.

- sold 74 percent of its output in the other 49 U.S. states, creating 875,000 jobs in the U. S. as a whole;
- paid $3.2 billion in taxes and license fees to the state of California, and $1.8 billion in federal taxes to the U.S. government; and
- contributed over 95 percent of U.S. wine exports, which totaled $658 million.[7]

The developments of the biotechnology industry and the wine industry are but two examples of the contribution of university research and industry-university-government research projects to the economy of California. The role of university research in the development of California agriculture in general is another prime example. A recent consultant report explores the economic, health-related, and cultural contributions of the University of California more widely.[8]

Structural Organization and Support Initiatives

It is important to recognize that California achieved its status and reputation as a center for technological innovation and entrepreneurship without a grand design or substantial stimulation by the state government or other organized entities. The necessary ingredients were there, and the flower blossomed on its own. As one prominent example, the origins and reasons for the success of Silicon Valley are well analyzed in a classic work by Saxenian.[9] Silicon Valley worked so well because of cultural factors and modes of interaction that were peculiar to California. That Stanford University and the Berkeley campus of the University of California were close at hand was also important, as was the fact that the early, post-World War II development of what became Silicon Valley was favored and fostered by the Stanford provost, Frederick Terman.[10] Structured organizational and supporting initiatives have come later. I will explore six of these, in rough chronological order.

Industry-University Cooperative Research and MICRO Programs

Launched in 1981, the MICRO Program is designed "to support innovative research in microelectronics technology, its applications in computer and infor-

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[7] The Wine Institute, "California Wine Statistical Highlights," September 2006, <http://www.ineinstiture.org/industry/statistics/2004/ca_industry_highlights.php>.

[8] ICF Consulting, "California's Future: It Starts Here," report prepared for University of California, March 2003, <http://www.universityofcalifornia.edu/itstartshere/report/fullreport.pdf>.

[9] Anna-Lee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (Cambridge, Mass.: Harvard University Press, new ed., 1996).

[10] C. S. Gillmor, *Fred Terman at Stanford: Building a Discipline, a University, and Silicon Valley* (Stanford, Calif.: Stanford University Press, 2004).

mation sciences, and its necessary antecedents in other physical science disciplines."[11] The program involves industrial grants for research at the University of California, supplemented with matching state funds expressly designated for the program. The state and the university waive the usual university overhead for these projects. The program is overseen by a policy board with representatives from the state, industry, and the university. Peer review plays a strong role.

While the design of the program is not all that unusual, the size and success are. More than 500 companies have participated in the program over the years. In the year 2005–2006, 97 companies supplied $6.5 million for 104 projects, with another $3.8 million coming through the program from state funds, and yet another $3+ million corresponding to waived overhead.

In 1996, MICRO was augmented by creation of the Industry-University Cooperative Research Program (I/UCRP).[12] This program gives what are now known as discovery grants in a manner similar to MICRO, except that indirect costs are not waived. Five fields are covered—biotechnology, communications and networking, digital media, electronics manufacturing and new materials, and information technology for life sciences. As of 2008, since the 1996 inception of the program, 897 projects have been funded. On an annual basis, about $22 million of state and UC funds bring in about $36 million from industry. By any measure, these programs are a large success, serving to bring university researchers together with industrial scientists and engineers and contributing substantially through their outputs to the state economy. The programs fit the needs of both state industry and university research well.

UC CONNECT

In 1985, working with the San Diego business community, the San Diego campus of the University of California formed UC CONNECT,[13] an organization designed to facilitate the development of entrepreneurial businesses in the region. The organization is free-standing and connects entrepreneurs with technology, money, markets, management, partners, and support services. Approaches used include consultation regarding support resources for start-up ventures, networking events, educational opportunities, and recognition of outstanding accomplishments. In many respects, CONNECT is an organized effort aimed at replicating what occurred naturally in Silicon Valley. It recognized the need for these diverse services and networking in order for technological innovation to occur in as unimpeded a fashion as possible. CONNECT has been an important player in the establishment of the biotech and wireless communications industries in San Diego. It

[11] <http://www.ucop.edu/research/micro/>.

[12] <http://www.ucdiscoverygrant.org/AnnualReport.pdf>; <http://www.ucdiscoverygrant.org/>.

[13] <http://www.connect.org/>.

has since been replicated at the Davis campus of the University of California,[14] and in Scotland, Denmark, Norway, Sweden, and Taiwan.[15]

California Council for Science and Technology

Founded in 1988 as a not-for-profit corporation through enabling legislation from the state of California, the California Council on Science and Technology[16] emulates the roles that the National Research Council and the National Academies have on the federal level. The council consists of 30 members, supplemented by a much larger number of fellows, who are scientists, engineers, and technology leaders drawn from California's universities, corporations, and national laboratories. Council members are appointed for once-renewable three-year terms. Studies are undertaken at the request of branches of the state government, with the nature of the request often being developed jointly with CCST, at the initiative of either body. Project funding comes from state agencies and private foundations. An interrelated series of recent studies has dealt with the environment for science and technology in California, a critical-path analysis of the science and technology system within the state, and a critical-path analysis of the production of math and science teachers within California. Other example projects include a series of reviews of the state's $60 million per year Public Interest Energy Research Program and development of a recommended policy framework for intellectual property developed through state-funded research.

CCST studies generally get attention and action because they are requested from within the state government. Because of the lack of a state science advisor or office of science and technology function, CCST carries some of the roles that fall to the science advisor on the federal level. Examples are advising on recent landmark legislation for greenhouse-gas reduction and low-carbon fuel standards, analysis of the issues surrounding use of hydrogen as a fuel, and suggestions for components of a state science initiative.

California Technology, Trade, and Commerce Agency (TTCA)

TTCA was established in 1992 as an agency of the California state government. The missions of the agency were to promote business, employment, and trade, as well as economic competitiveness in general. The agency was also the primary state vehicle for projects associated with conversions of military bases to civilian uses. In addition, it had a $6 million program that gave matching grants of up to $200,000 for proposals to federal government agencies made by entities within the state for projects that held the potential of developing technology-based

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[14] <http://www.connect.ucdavis.edu/home.cfm?id=OVC,6>.
[15] <http://www.connect.org/programs/index.htm>.
[16] <http://www.ccst.us/>.

business in California. Reflecting political contention over the appropriateness of this role and a seeming consensus that the value added by the agency was not large, TTCA was discontinued in 2003 during a new administration.

California Institutes for Science and Innovation

Four major research institutes were launched in the year 2000, as a gubernatorial initiative to support the role of innovation in spurring the California economy. As originally defined, the initiative provided $100 million for each of three institutes, spread over four years, with a requirement that the institutes raise even greater funds as a 2:1 match. The institutes were to be on University of California campuses and would carry out research in fields believed to be promising for the economic growth of the state. They were envisioned as catalytic partnerships between university research and private industry that could expand the state economy into new industries and "speed the movement of innovation from the laboratory into people's daily lives" (Governor Gray Davis's Budget Summary, 2001–02).[17]

The university held an internal competition, encouraging multidisciplinary approaches and the involvement of multiple campuses. Topics for the institutes were not specified; instead the topics were a part of the competition. Final proposals were subjected to extensive peer review and were judged by a multidimensional, highly distinguished panel, external to the university. The use of a competition was essential to the quality of the proposals, as well as effective multidisciplinary and multicampus design. Because of the strength of the ultimate proposals, a fourth institute was funded by the state as well. The four institutes are:

- California Institute for Telecommunications and Information Technology [Cal-(IT)^2]— San Diego and Irvine campuses,
- California Institute for Quantitative Biomedical Research [QB3]—San Francisco, Berkeley, and Santa Cruz campuses,
- California Nanosystems Institute [CNSI]—Los Angeles and Santa Barbara campuses,
- Center for Information Technology Research in the Interest of Society [CITRIS]—Berkeley, Davis, Merced, and Santa Cruz campuses.

The needed aggregate match ($800 million) was a very large sum, yet it was raised and then some, with the total initial match being over $1 billion. The acquisition of these matching funds was facilitated by having the competition, since it was clear to donors that the match would be required to bring a particular institute into existence. The fact that the subject matters of the institutes were not specified before the competition provided yet another incentive for corporations to provide

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[17] Brenda Foust, "The California Institutes for Science and Innovation (Cal ISIs)," The Senate Source, University of California, January 2005, <http://www.universityofcalifornia.edu/senate/news/source/Calisi.pdf>. See also http://www.ucop.edu/california-institutes/>.

funding, since the institute in question would have to be selected in order for there to be an institute matching the particular interests of a corporation. The matching funds were raised primarily from industry for three of the institutes and primarily as federal government funds for the fourth (CNSI).

Because of the nature of the state budgetary situation at the time, the state funding was almost totally for capital expenditures. Thus the state funding has gone primarily into building the campus facilities that bring the researchers of an institute together. Core operating funds have been more of a problem, and have been provided so far from overhead[18] derived from incremental grants and other campus sources.

California Institute for Regenerative Medicine (CIRM)

CIRM is an organization that came to be in a very different way. California has a system of direct initiative ballot referenda that can be, and often are, used to enact laws directly by popular vote. In 2004, for the first time, this approach was used to establish a program of scientific research, through an initiative titled the California Stem Cell Research and Cures Act. It created the California Institute for Regenerative Medicine[19] to administer an "average of $295 million per year in bonds over a 10-year period to fund stem cell research and dedicated facilities for scientists at California's universities and other advanced medical research facilities throughout the state."[20] CIRM is overseen by an Independent Citizen's Oversight Committee (ICOC) with a specified composition appointed by designated officials and consisting of persons from specific, designated backgrounds. The initiative language is added to the state constitution, cannot be amended for three years, and requires 70 percent votes from both houses of the legislature along with approval by the governor in order to be amended (or negated) thereafter. Thus it is popularly described as "iron-clad."

This initiative did not arise from universities themselves institutionally. The prime mover was a group of advocates for medical cures and stem-cell research. The ballot proposition was promoted heavily, and indeed named, from the standpoint that stem-cell research would lead to therapy for incurable diseases such as diabetes, spinal-cord injury, and Alzheimer's disease.[21] The initiative was a very visible and tangible step placing California as a state in a forefront position within the United States in stem-cell research, as contrasted with federal policy which is currently quite restrictive.

[18] Overhead, also known as indirect costs, is typically supplied by government agencies and other funding bodies in the United States as a percentage of direct, identifiable cost. Overhead allows for the many noncosts associated with making research possible and effective that are not specific to the project, e.g., administration, buildings, maintenance, libraries, and computing support.

[19] <http://www.cirm.ca.gov/>.

[20] <http://www.cirm.ca.gov/prop71/pdf/prop71.pdf>.

[21] <http://www.signonsandiego.com/uniontrib/20041219/news_1n19stemcell.html>.

The ability of the state to sell the bonds was held up for about two years in a legal process initiated by those who oppose the use of embryonic stem cells for research. Meanwhile support of research commenced, drawing from a $150 million loan from state general funds authorized by the governor, supplemented by loans and gifts from private California foundations and individuals.

The initiative states that "the ICOC shall establish standards that require that all grants and loan awards be subject to intellectual property agreements that balance the opportunity of the state of California to benefit from the patents, royalties, and licenses that result from basic research, therapy development, and clinical trials with the need to assure that essential medical research is not unreasonably hindered by the intellectual property agreements." This language has muddied already unclear waters on ownership of intellectual property from state-funded research. This language and expectations of close-at-hand profitability stemming from the marketing of the initiative have led to considerable controversy surrounding ways in which the state of California can "recover" some of its investment in this and other research.

This venture, still ongoing, exhibits what can happen when the funding of research is tied so closely to the political process. Although, when all is said and done, much good may come of research sponsored through CIRM, the research itself and the research world in general will likely suffer from science becoming such an activist force in the political process and from the unrealistic expectations and constant public scrutiny thereby generated. It will also lead to other efforts to use the same process for restrictive new funding of research. A more detailed analysis of several of these issues has been given by Riordan.[22]

Indeed, there has already been another such initiative in 2006,[23] modeled in the earlier stem-cell initiative, which would have taxed producers of oil extracted in California to generate a fund of $4 billion over time, 27 percent of which would have been used for research on reduction of petroleum usage, renewable energy, energy efficiency, and alternative fuel technologies and products. It did not pass, reflecting in part after-the-fact voter dissatisfaction with the stem-cell initiative.

Project-Oriented Initiatives

In addition to the structures and mechanisms described above, there are four recent, major, California-based industry-university project initiatives that deserve consideration in connection with the theme of this chapter.[24]

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[22] D. G. Riordan, "Research Funding via Direct Democracy: Is It Good for Science?" *Issues in Science and Technology* 24, no. 4 (2008): 23–27.

[23] <http://www.voterguide.ss.ca.gov/props/prop87/prop87.html>.

[24] I should point out that I was not involved in the creation or review of any of these project partnerships in my administrative capacities at the University of California. Research agreements are executed by individual campuses of the University of California,

Novartis Agreement with UC Berkeley

In 1998 a controversial research agreement was made between the Berkeley campus of the University of California and Novartis, a large Swiss pharmaceutical and biotechnology company. This arrangement was one of many made between large biotechnology/pharmaceutical companies and major universities over the years, reflecting the very close relationship between academic research and commercial innovation within that field. However, it was unique in its design and in that it made such a sizeable arrangement between a commercial firm and a public university. A useful and insightful analysis of the drivers for the arrangement and the benefits and concerns has been made by Todd LaPorte.[25]

The agreement[26] followed a formal, two-year process in which the College of Natural Resources of the Berkeley campus solicited proposals from six major corporations, with four responding. By the terms of the agreement, Novartis contributed $5 million per year for five years, or $25 million total, for support of research in the Department of Plant and Microbial Biology. This was about 30 percent of the total extramurally funded research budget of the department. The portion of the funds devoted to overhead was 33 percent, covering renovations, support of the general graduate program, and general campus overhead.

Another very important component was access by Berkeley researchers on a confidential basis to the Novartis agricultural genomic database, coupled with $3 million for a Novartis facility near the campus with workstations through which that database could be accessed, and for advisory Novartis employees to help with access. The value of this aspect of the arrangement lay in the fact that a substantial amount of genomic data are confidential to large companies, thereby placing the academic sector in a situation where they carry out research without full access to the available knowledge base.

In return, Novartis received first rights to license a percentage of inventions from research in the department, whether or not supported with actual Novartis funds. That percentage was the ratio of the Novartis funding to the total departmental extramural research support, cited as a method of calculation recommended by National Institutes of Health guidelines for arrangements involving both NIH and private support. Novartis also received the conventional 30-day opportunity to review potential publications for patentable items, and an addi-

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not by the systemwide administration. The opinions expressed concerning them are solely my own as a hopefully objective observer.

[25] Todd LaPorte, "Diluting Public Patrimony or Inventive Response to Increasing Knowledge Asymmetries: Watershed for Land Grant Universities? Reflections on the University of California, Berkeley-Novartis Agreement," in *Commission on Physical Sciences, Mathematics and Applications, Research Teams and Partnerships: Trends in Chemical Sciences*, Report of a Workshop, 66–84, National Research Council, National Academy Press, Washington, D.C., 2000, <http://www.nap.edu/openbook/0309068274/html/66.html>.

[26] <http://www.berkeley.edu/news/media/releases/98legacy/11-23-98.html>.

tional 60 days if the decision was made to patent. Such a component of industry-university agreements is not unusual.

The project was overseen by a six-member advisory committee with three members from the campus (vice chancellor for research, dean, and a non-involved faculty member), and three members from Novartis. There was also a five-member research committee, three of whom were from the campus, to award actual grants.

There were a number of concerns expressed at the time and throughout the term of the agreement. These are summarized by LaPorte (*loc. cit.*). Many of the concerns dealt with academic freedom—the right of faculty to choose and pursue research as they see fit. Those concerns eventually formed the lead item for a story in the *Atlantic Monthly*.[27] As the controversy continued, there was an internal review commissioned, followed by an external review undertaken at the behest of the Academic Senate with the concurrence of the administration. That review,[28] since published as a book,[29] concluded that academic freedom and the academic conduct of the department had not been seriously compromised. The reviewers also made a number of recommendations, one of which was that the university should consider avoiding industry agreements that involve complete academic units or comparable large groups of researchers.

During the five-year period of the agreement, there was a major restructuring of Novartis that eliminated the unit that had made the agreement. Hence renewal of the agreement became moot.

In addition to the academic-freedom issue, which was probably well enough addressed with regard to the specifics of research, the essential issue surrounding this venture was the extent to which a public institution, and an entire department within that institution, can pair themselves with a private corporation. Can academic objectivity be maintained amid such a presence? And is it appropriate for a public institution that derives substantial taxpayer support, including corporation taxes, to match itself so visibly with one corporation? Conversely, it can be argued that a large amount of the total revenue of public universities (of order 77 percent for the University of California) comes from sources other than the state budget, and that corporations within the state do receive the benefit of

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[27] Eyal Press and Jennifer Washburn, "The Kept University: UC Berkeley's Recent Agreement with a Swiss Pharmaceutical Company Has Raised Concerns over Who Ultimately Directs Research," *Atlantic Monthly* 285, no. 3 (2000): 39–54. See also <http://www.aaas.org/spp/rd/ch26.pdf>.

[28] Lawrence Busch, R. Allison, C. Harris, A. Rudy, B. T. Shaw, T. Ten Eyck, D. Coppin, J. Konefal, and C. Oliver, "External Review of the Collaborative Research Agreement between Novartis Agricultural Discovery Institute, Inc. and The Regents of the University of California", Inst. For Food and Agricultural Standards, Michigan State University, July 13, 2004, <http://evcp.chance.berkeley.edu/documents/Reports/documents/NovartisBerkeleyFinaReport071204.pdf>.

[29] A. P. Rudy, D. Coppin, J. Konefal, B. T. Shaw, T. A. Ten Eyck, C. Harris, and L. Busch, *Universities in the Age of Corporate Science: The UC-Novartis Controversy*, (Philadelphia, Pa.: Temple University Press, 2007).

their taxes, even when such arrangements are made with single corporations. A final substantive issue is how confidential data can be used in publishable research while fulfilling simultaneously the requirements of the openness of science and the ability for others to seek to reproduce results.

The Artemisinin Project: Development of a Low-Cost Malaria Drug

A large and highly innovative partnership was put together in late 2004 to work towards making artemisinin, the precursor to a potent antimalaria drug, available to the undeveloped world at a cost that will enable widespread use. Malaria strikes up to 500 million people annually, killing about 1.5 million who are mostly from very poor areas of Africa and Asia. Derivatives of artemisinin, when mixed with other substances to form artemisinin combination therapies (ACTs) and used for only three days, are nearly 100 percent effective in preventing deaths from malaria. Artemisinin is currently derived from the wormwood tree, yet even at the current price of $2.40 per treatment is too expensive for widespread use in the poor countries that are most affected.

There are four participants in the five-year project[30]—the Bill and Melinda Gates Foundation, the Institute for OneWorld Health (IOWH), Amyris Biotechnologies, Inc., and the University of California, Berkeley. The aim is to use synthetic molecular biology to create artemisinic acid, a direct precursor of artemisinin, with the goal of reducing the cost of artemisinin by an order of magnitude. The Gates Foundation, with strong interests in health in underdeveloped countries, provides $42.6 million. Of that amount, $8 million goes to Professor Jay Keasling and his group at the Berkeley campus for pertinent research on the synthetic biology route to artemisinic acid, including engineering the microbe. Twelve million dollars goes to Amyris Biotechnologies, a for-profit company, for applied research on the pertinent processing techniques. The final $22.6 million goes to IOWH, a nonprofit pharmaceutical company, which will lead development of commercialization, marketing, and distribution, including meeting regulatory requirements for different countries and analysis and improvement of ACT manufacturing, supply chain, and distribution.

In contrast to most other pharmaceutical development, this partnership is designed to address the need for extremely low product cost. The Gates Foundation funds provide seed and start-up funding of a sort that would not be available from the venture-capital community. Similarly, the not-for-profit IOWH, with the Gates Foundation funding, can address the regulatory and distribution needs in ways that would not be viable in the for-profit sector. Finally, the intellectual property arrangements[31] are also unusual and are designed to promote low cost. The University of California has given royalty-free licenses to IOWH and to Amyris for the developing-world market, i.e., the market being addressed by

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[30] <http://www.artemisininproject.org/>.

[31] <http://www.tmgh.org/case-studies-treatment-for-malaria.php>.

IOWH. The license to Amyris is royalty-bearing for the developed world and for uses of artemisinin other that for malaria.

A key aspect of this project lies in the incentives that attract the various partners. The university benefits from having a very visible example of the utilization of university research for a great worldwide need, and as well can derive royalties from uses for malaria in the developed world and for other purposes. The nonprofit pharmaceutical company, IOWH, directly works toward its mission of making an effective malaria treatment available at a low enough cost in the underdeveloped world. The for-profit company, Amyris, can apply the processing technology that is developed in this project to other projects that rely upon the same platform technology; it develops a base of expertise and processing capability. The Gates Foundation has put together an effective team that can make a major contribution to world health, in the underdeveloped countries in particular, thereby addressing a primary mission of the foundation.

Climate and Energy Projects

The major world needs associated with greenhouse gases and sources and utilization of energy have led to two unusually large university-industry projects located in California. One is coordinated by Stanford University and the other by the University of California, Berkeley.

Stanford Global Climate and Energy Project

In 2002, Stanford University concluded an agreement with four corporations—ExxonMobil, General Electric, Toyota, and Schlumberger—for a Global Climate and Energy Project (G-CEP).[32] The sponsors pledged $225 million over 10 or more years to support a diverse program of precommercial research designed to lead to technological options for energy production and use with reduced greenhouse gas emissions. The project supports research teams at Stanford and elsewhere, and is not restricted to university research. Stanford administers the project. In an unusual step for such a consortium and a private university, the full wording of the founding agreement is available on the Internet.[33]

The project is governed by a management committee composed of single voting representatives of the four corporations, who rotate as chair, and the project director as a nonvoting member. Subject to general approval of topical areas by the management committee, the project director, who is a Stanford faculty member, and his staff oversee a peer review process whereby proposals are solicited, judged, and selected for funding. Thus, in essence, the four sponsoring corporations, acting in a consortium as a funding agency, have engaged Stanford

[32] <http://gcep.stanford.edu/>.
[33] <http://gcep.stanford.edu/pdfs/gcep_agreement.pdf>.

to administer a grant process to select projects, distribute funds, and monitor results.

Stanford holds legal title to inventions; however, the sponsoring corporations exercise guidance as to which inventions should be pursued for patent coverage. Sponsors also have exclusive rights to commercialize inventions for the first five years, royalty-free.

It is interesting to speculate regarding the motives for the industrial partners. First, it is important that the four corporations for the most part do not compete with one another; they are in complementary lines of business. Second, the sponsors engender a broad portfolio of underlying research, from which they may draw technologies that they may wish to develop, in most cases without competition from a direct competitor.

Funding agencies run by a university are relatively rare, but do exist in other forms. For example, the University of California administers three programs of state-funded research—breast cancer, AIDS, and tobacco-related disease—that are not restricted to University of California grantees.

BP Energy Biosciences Institute

In 2006, the multinational oil firm BP announced an intention to create an Energy Biosciences Institute, in conjunction with a major university. After preliminary explorations, BP invited five universities to form teams to submit proposals to join with BP in an Energy Biosciences Institute, which would be funded by $500 million spread over 10 years. This institute would bring BP researchers together with university researchers and would emphasize innovative means of creating and producing fuels from biological sources. In early 2007, the competition was won by a team headed by the University of California, Berkeley (UCB) and also including the Lawrence Berkeley National Laboratory (LBNL) and the University of Illinois at Urbana-Champaign (UIUC). BP spokespersons indicated that important factors in the selection of the Berkeley-led team were the large and diverse array of distinguished researchers, the tradition of technological innovation and entrepreneurship in the San Francisco Bay Area, and the history of successful, large, interdisciplinary science at LBNL. The recent attention given to the Artemisinin Project and Amyris Biotechnologies, for which the CEO was formerly president of U.S. Fuels Operations for BP, may have been helpful as well.

It is worth noting that LBNL is a laboratory of the U.S. Department of Energy, managed under contract by the University of California system. The inclusion of LBNL thereby brings the federal government into the arrangement. LBNL and the Department of Energy had earlier made major commitments to LBNL's new Helios project, which deals with renewable and solar energy.

The full proposal from the UCB-LBNL-UIUC team and other information on the Energy Biosciences Institute is available.[34] Elements of the arrangement and governance described in the proposal and mentioned elsewhere[35] include:

- construction of a 50,000 sq. ft., $120 million building on University of California land adjoining LBNL to house both the Energy Biosciences Institute and LBNL's Helios project, funded largely by state funds along with some private gifts;
- 35,000 sq. ft. of space in existing buildings on the Berkeley campus for three years before completion and occupancy of the new building;
- division of the institute into open and proprietary research portions, with 50 BP researchers who will do BP proprietary research accommodated in the building along with UC and LBNL scientists;
- up to 30 percent of the total funding being spent on the BP scientists;
- use of $100 million of the total funding at UIUC to fund research on crops for ethanol and other biofuels;
- a director who is both a UCB faculty member and a faculty senior scientist at LBNL, an associate director who is a BP employee, and a deputy director who is a UIUC faculty member;
- a governing board composed of eight senior persons from the various participating organizations (two from BP, one each from UCB, LBNL, and UIUC, and the director, associate director and deputy director of the Institute;
- 25 themed research teams, seven of which will be located at UIUC;
- payment of full institutional overhead to UCB and UIUC on all open research funded by BP, with 75 percent of these indirect costs returned by those institutions to the Energy Biosciences Institute for administrative purposes; and
- intellectual property to be owned by the participating institution that generates it, with BP having the right to license, royalty-free and nonexclusively, inventions made by researchers supported with BP money. Joint inventions will have joint ownership. BP as well has the right to take royalty-bearing exclusive licenses in a time-limited fashion.

An apparent motive for BP in setting up such an institute is close access to leading-edge research in an area that is seen as vital to the future of the corporation. By contrast to the Stanford G-CEP project, the company has placed a high premium on intimate day-to-day interactions of BP researchers with those from the other institutions.

There are a number of potential concerns to be dealt with in the relationship. One is how to handle proprietary research that is being carried out in close proximity with academic and national-laboratory researchers. The presence of proprietary corporate research on a university campus is not unprecedented, however. A second concern, familiar from the Novartis agreement described above, is the preferential position being given by a public university to a single private corpora-

[34] "Energy Biosciences Institute," <http://www.ebiweb.org>.

[35] Eli Kintisch, "BP Bets Big on UC Berkeley for Novel Biofuels Center," *Science* 315 (February 9, 2007): 746, 790.

tion with regard to the research of a large number of distinguished faculty members. A third concern is the need to ensure academic freedom in the choice and conduct of research. Recognizing such concerns, the Berkeley campus developed the proposal in close consultation with the leadership of the faculty Academic Senate.

Concerns about Industry-University Partnerships and How to Address Them

Several common concerns about industry-university partnerships have been mentioned already in connection with the preceding example. Concerns of this sort have been tallied, explored in a contemplative fashion and balanced against advantages by Bok,[36] Calhoun,[37] and Kirp,[38] among others. They have also been elaborated from a more uniformly negative point of view by Washburn.[39] For the most part, the concerns can be grouped into categories, as follows.

- Companies may unduly influence the research agenda; there will not be free inquiry.
- A conflict of interest occurs when a faculty member has industrial ties and related university research.
- Companies or faculty with ulterior motives may hold back damaging research results. This concern often occurs in connection with clinical trials.
- Public access to knowledge may be restricted. Knowledge that is inherently a public good may go into private hands because of exclusive licensing, publication delay, or not being published at all.
- Cross-fertilization of research may be impeded if universities accept confidentiality arrangements with corporations.
- A conflict of interest may arise if a faculty member determines whether an invention in which s/he has participated belongs to the university, a private entity, or both.
- Reliance upon private funding such as licensing revenue or corporate research support, or even upon government agency funding, may distort academic purposes and the academic agenda.
- Entrepreneurial faculty may be less engaged in classroom education.
- The humanities and social sciences will decline in attention and importance, because government and industrial funding is primarily directed towards the

[36] Derek Bok, *Universities in the Marketplace* (Princeton, N.J.: Princeton University Press, 2003).

[37] Craig Calhoun, “Is the University in Crisis?,” *Society* 43, no. 4 (2006): 8–18.

[38] D. L. Kirp, “Shakespeare, Einstein, and the Bottom Line” (Cambridge, Mass.: Harvard University Press, 2003).

[39] Jennifer Washburn, “University Inc.: The Corporate Corruption of Higher Education” (New York, N.Y.: Basic Books, 2005).

sciences and engineering. Put another way, the emphasis of the university will go to where the money is.

In the other direction, it must be recognized that academic research would become sterile if not cross-fertilized with industry. As well, the synergy gained by close linkages between universities and industry moves society and the economy forward much more efficaciously than would be the case if interactions did not occur frequently. Also, the nature of financing of public universities by state governments in the U.S. has changed because of budgetary stringencies and other commitments. Interactions between universities, industry, and the government should and must occur. The need is to manage them effectively so as to reap as many of the gains as is consistent with minimizing the concerns.

Universities have instituted, and continue to institute, numerous policies to deal with these concerns, in some cases working within federal or state guidelines. In addition to having policies, universities must have means of monitoring and enforcing them as well. The array of such policies and mechanisms for the University of California can be found at two web sites,[40] and a more general review has been given by Sugarman.[41] *Inter alia*, they cover such subjects as conflict of commitment, conflict of interest and disclosure of financial interests, consulting and other activities outside the university, disclosure of inventions, research misconduct, technology licensing, university-industry relations, use of university research facilities, publication policy, patent and copyright policies, research integrity, and reporting of improper activities.

Assessment of What Works Well

As is shown by the measures of success described earlier, the most universal contributions of universities to innovation are the flow of university graduates to both new and established technological companies, along with the flow of research-engaged faculty members themselves to these companies as both founders of start-up ventures and ongoing consultants.

Partnership initiatives of the sorts described above are clearly also very important. The partnerships work best when there are clear incentives for each of the parties to participate. Leveraging the resources of all parties can be attractive. Partnerships should be structured so as to minimize concerns regarding conflicts or improper influences and/or benefits. Potential points of concern should be addressed openly with understandable ways of meeting them.

Serious competition and selective choice of awardees are effective avenues toward high-quality projects and partnerships. Examples already cited where competition has clearly been a benefit are the California Institutes for Science and In-

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[40] <http://www.research.chance.berkeley.edu/main.cfm?id=9>; <http://www.ucop.edu/research/policies/welcome>.

[41] S. D. Sugarman, "Conflicts of Interest in the Roles of the University Professor," *Theoretical Inquiries in Law* 6, no. 1 (2005): 255–75.

novation, the Industry/University Cooperative Research Program, G-CEP and the BP Energy Biosciences Institute. Success breeds success, in the sense that a record of positive accomplishment is reassuring to investors.

Project design and/or active participation by government generally does not work well, because of political influences and contention. Government is best as a silent and enabling partner. This is a reason for the successes of UC CONNECT and the California Council for Science and Technology, as opposed to the short-lived California Technology, Trade and Commerce Agency.

From the viewpoint of industry, the Industry-University Cooperative research and MICRO programs afford ways to select and invest in research where industrial expenses are substantially leveraged with public funds. This is advantageous to both established and start-up companies. The California Institutes for Science and Innovation afforded another way to leverage funds, by assuring that an institute in an area of corporate interest would come into existence and by establishing liaisons with an institute. Neither of these structures advantaged single or few companies more than others.

In the case of the Artemisinin Project, the Gates Foundation has a different motive—to make a potent antimalarial drug available at very low cost worldwide. Profit or even recovery of investment are not issues, and that partnership has been constructed in ways and with licensing policies that will lead to the desired very-low-cost product.

University motives include (1) getting research results used in the marketplace and/or for public benefit (a mission of a public university), (2) enabling the conduct of well chosen research, and (3) gaining revenue from licensing, in what should be that order. The Artemisinin Partnership and UC CONNECT address the first goal. The Industry-University Cooperative Research Program, The California Institutes for Science and Innovation, and the Berkeley agreements with BP and Novartis addressed all three goals

For the state of California, the rationale is to foster the establishment of new industries and retention of existing industries, and thereby to build the economy and employment, as well as the standard of living of the state. Second, the state is interested in the overall health of its university system. The Industry-University Cooperative Research Program, the California Institutes for Science and Innovation, the California Council on Science and Technology, the California Institute for Regenerative Medicine, and the state investment in facilities for the BP Energy Biosciences Institute all address that goal, as did the California Technology, Trade and Commerce Agency. The California Institute for Regenerative Medicine has the feature of positioning the state to carry out research and attract scientists in an area currently discouraged by federal government policy. However, it has the drawbacks of lack of flexibility for the state in investing its resources (because of it being locked into the constitution) and attractiveness for political challenge because of both the way it came about and the nature of the research.

Why California?

California's success in launching new, technologically based industries and the close involvement of its universities in developing areas such as biotechnology stand in contrast to most other states in the U.S.[42] Why is it California that has flourished?

One key component is the strength of California's universities and the research output from them. Building the state's public-university systems has historically been a priority of the state government. A post-World War II economic boom provided the state with considerable resources during the 1950s and early 1960s to build its public universities and set a standard of strong budgetary support for them. The California Master Plan for higher education,[43] set in place in 1960, set a framework for the public university systems whereby the research mission and Ph.D. production were matched with the University of California, which was given a generous funding level commensurate with that mission.

Highly capable faculty were drawn to California and responded with high-quality research, as is evidenced, for example, by the considerable succession of Nobel Prizes awarded to California scientists in the postwar era. The universities produced excellent graduates, who were drawn by the salubrious climate and intellectual stimulation to want to stay in the state. Strong research universities and strong scientific talent drew science-based industries, which valued the proximity to and opportunities for interaction with such universities.

The University of California and the major private research universities in California have maintained their stature, allure, and research productivity by wise policies that base faculty advancement upon intensive peer review, continuing throughout a faculty member's career. As has been pointed out, California's strength in academic research has been built upon peer-reviewed competition and has thereby thrived. Both Stanford, through Terman, and later the University of California have made it a priority to spawn, assist, and work synergistically with California industry. California universities have also found ways to promote and reward multidisciplinary efforts, through buildings dedicated to multidisciplinary purposes, policies that promote multidisciplinarity, and close interaction with national laboratories (e.g., the Lawrence Berkeley National Laboratory and the Jet Propulsion Laboratory).

California was fertile ground for the development of Silicon Valley because of its strong scientific and technological base, an entrepreneurial spirit, and a tradition of easy, informal interactions. The various elements necessary to support entrepreneurship and start-ups were either present or readily developed. Once devel-

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[42] R. L. Geiger and Creso Sá, "Beyond Technology Transfer: U. S. State Policies to Harness University Research for Economic Development," *Minerva*, 43, no. 1 (2005): 1–21.

[43] J. A. Douglass, *The California Idea and American Higher Education, 1850 to the 1960 Master Plan* (Stanford, Calif.: Stanford University Press, 2000).

oped, they provided fertile ground for launching additional new technologically based industries. Again, success breeds success.

Strikingly, California developed as a hotbed of "high-tech" industries without an overall design, state-government structures incubating such industries, or even state-government policies that were particularly favorable to such industries. The contrast with efforts of other states over the past several decades is that California supported its state universities strongly at the time that set the stage for innovation, but did not until recently create innovation institutes or other state supporting structures. One early exception was the 1880 decision of the state legislature to foster a California wine industry, driven by the recognition that climatic conditions within regions of the state were favorable. The state has chosen to enable and occasionally to help co-fund technological initiatives, rather than create a plan, create state laboratories, or create incubators. The state has not had a science advisor, or even science committees within the legislature. But it has created and nurtured a body (the California Council on Science and Technology) to provide science advice when needed and useful, and both groups of companies in specific areas of industry and regions have provided structures such as UC CONNECT, Joint Venture: Silicon Valley,[44] the California Biomedical Research Association[45] and the California Healthcare Institute[46] to sustain and foster what has developed.

[44] <http://www.jointventure.org/>.
[45] <http://www.ca-biomed.org/>.
[46] <http://www.chi.org/>.