Accelerating Technology Transfer & Commercialization In The Life & Health Sciences

Final Report of the Panel of Advisors on the Life Sciences

Ewing Marion Kauffman Foundation
August 2003

KAUFFMAN
Foundation

Accelerating Technology Transfer & Commercialization In The Life & Health Sciences

Final Report of the Panel of Advisors on the Life Sciences

Ewing Marion Kauffman Foundation
August 2003

Solomon Snyder, M.D., Chair
The Johns Hopkins University
Baltimore, Maryland

Michael M.E. Johns, M.D.
Robert W. Woodruff Health Sciences Center
Emory University, Atlanta, Georgia

James J. Mongan, M.D.
Partners Healthcare System, Inc.
Boston, Massachusetts

James R. Utaski
Whitestone Capital, LLC
Princeton, New Jersey

CONTENTS

PREFACE

The Ewing Marion Kauffman Foundation convened a Panel of Advisors on the Life Sciences in the winter of 2003 to explore the role the Foundation might play in accelerating life sciences entrepreneurship.

The Panel used four key resources in its work:

- Review of the research literature.
- Interviews with experts and practitioners in life sciences technology transfer and commercialization, including Harvard Medical School's David Blumenthal, the Center for Disease Control Foundation's Charlie Stokes, Mark Rohrbaugh from the National Institute of Health's Office of Technology Transfer and, Christopher Colecchi from Partners Healthcare System.
- Regional meetings held in Boston and Atlanta on the challenges of local communities.
- Discussions with representatives of professional organizations, the venture capital community, and research groups regarding the development of data systems and the creation of stronger programs of professional development in the technology transfer field.

Based on its research, the Panel concluded that the Kauffman Foundation can make a tremendous impact in this new frontier of entrepreneurship in America.

In pursuing its work and completing this report, the Panel benefited from the substantial help, guidance, and research of Brian Biles and Eric Campbell.

The Panel's report includes key findings and recommendations for initiatives in which the Kauffman Foundation could make a major contribution to accelerating life sciences entrepreneurship. These initiatives, taken together, would:

- Address the most critical deficiencies in life sciences technology transfer and commercialization.
- Target work in areas lacking support and leadership from other foundations or public agencies.
- Leverage Kauffman funds by encouraging other private and public sector collaborations.
- Increase the number of entrepreneurs working in this area.

INTRODUCTION

The individuals and organizations that create and apply scientific knowledge hold a place of high esteem in American culture. Scientists and the institutions in which they work have enjoyed tangible benefits of this esteem in the form of elevated social status, generous public support for their work, public renown and increased personal and organizational wealth. In return, the American people expect, among other things, a continuous supply of new products and services that improve the human condition. The process by which these expectations are met is known as "technology transfer and commercialization."[1]

The Panel of Advisors on the Life Sciences was convened by the Ewing Marion Kauffman Foundation to explore the role the Foundation could play in accelerating life sciences entrepreneurship in a systematic and practical way. The Panel focused its work on current challenges and new opportunities to enhance technology transfer and commercialization.

This report addresses:

- The background and current status of the technology transfer process, including strengths, weaknesses, unmet needs and immanent challenges.
- Recommended actions to enhance the academic research community's ability to appropriately link new scientific knowledge, entrepreneurship and economic development.
- Practices and policies needed to guide future management and policy development in life sciences entrepreneurship.

The report concludes with a set of recommendations for initiatives the Foundation could pursue to accelerate life sciences entrepreneurship.

BACKGROUND

This section provides the key definitions and a discussion of the benefits of university technology transfer and commercialization.

Key Definitions

Technology Transfer and Commercialization – There is no universally accepted definition of technology transfer. Generally speaking, it is the application and sharing of scientific knowledge between researchers and research organizations. These may include:

- Federal laboratories
- Universities
- Industry
- Research institutes
- Local, state, and federal governments
- Third party intermediaries (e.g., venture capitalists and management companies)[2]

Technology transfer and commercialization is a process. Consider, for example, a university technology transfer program. Its purpose is to make the university's scientific innovations accessible to private industry, including start-up companies, venture capitalists, and state and local governments. Commercialization occurs when these discoveries are further developed into new products, processes, materials, or services that enhance the nation's health, reduce suffering, improve quality of life, or contribute to economic prosperity.

In the world of life and health sciences, technology transfer and commercialization is often referred to as going "from bench to bedside."[3]

Technology Transfer Definitions

The process of utilizing technology, expertise, know-how or facilities for a purpose not originally intended by the developing organization. Technology transfers can result in commercialization or product/process improvement.

-National Technology Transfer Center (NTTC)

The process by which existing knowledge, facilities, or capabilities developed under federal R&D funding are utilized to fulfill public and private needs.

-Federal Laboratory Consortium (FLC)

The formal transfer of new discoveries and innovations resulting from scientific research conducted at universities and nonprofit research institutions to the commercial sector for public benefit.

-Association of University Technology Managers (AUTM)

University-Industry Relationships – University-industry relationships (UIRs) are arrangements between for-profit corporations and universities or their faculty, staff and trainees, in which something of value is exchanged between key players.[4] In most instances, universities provide a service (e.g., research or training) or intellectual property (in the form of a patent, license, or advice) in return for financial considerations of various types (e.g., research support, honoraria, consulting fees, royalties or equity).[5]

UIRs are a primary mechanism to facilitate technology transfer and commercialization.[6,7] Indeed, it is virtually impossible to engage in successful technology transfer without forming some type of relationship between a university and a corporation.

Life and Health Sciences – The Association of University Technology Managers (AUTM) defines the life sciences as biology, medicine, basic chemistry, pharmacy, medical devices, and those involving human physiology and psychology, including discipline-related inventive subject matter, such as software and educational material. In contrast, the physical sciences, as defined by AUTM, are comprised of engineering, software, and business systems.

Benefits of University Technology Transfer and Commercialization

Health-Related Benefits. Medical research has generated remarkable progress in the prevention, diagnosis, and treatment of disease. Recent discoveries in the prevention of cardiovascular disease, the development of new antibiotics, and the treatment of premature infants, for example, have greatly reduced morbidity and mortality rates.

Many of these discoveries can be traced to university science departments. A leading economist estimated in the 1980s that 25 percent of new products and 29 percent of new processes commercialized by drug companies could not have been developed without substantial delay in the absence of recent academic research.[8] Similarly, an analysis of U.S. industry patent citations found that researchers in academic institutions authored 50 percent of all papers referenced on patents for drugs and medicines from 1993 to 1994.[9]

Several research fields hold great promise for further understanding diseases and the development of new products and services.[3] For example:

- Geneticists have identified the genes that play a role in breast cancer, ovarian cancer, juvenile diabetes, and certain types of lung disease.

- Proteomics researchers are advancing their understanding of the structure and function of proteins in health and disease.

- Neuroscientists and imaging specialists have gained unparalleled insight into the function of the human mind and nervous system.

Combined with advances in computer science, physics, and engineering, burgeoning knowledge in these fields promises to deliver new and improved diagnostic and therapeutic agents and processes for the 21st century.

Economic Benefits. The economic benefits from technology transfer and commercialization may largely be traced to collaboration between university researchers and industrial personnel.

As Cohen, Florida, and Goe showed in their 1994 study, such collaboration, among other types of interaction, is more effective in transferring information into the industrial sector than communication through traditional academic channels, such as publications and presentations.[10] Cohen and his colleagues further note the important role federal funding plays in creating and maintaining university-industry research centers (UIRCs) as potential mechanisms for technology transfer, as well as the likelihood for federal and industrial research to co-exist in close proximity to industrial settings. Their findings from a national survey of UIRC directors[11] indicate that:

- The overwhelming majority (70 percent) of UIRCs were created with government support and continued to derive about 86 percent of their research funds from government sources. On average, UIRCs received 46 percent of their funding from the federal government compared to only 31 percent from industry sources.

- Of the 211 patents generated by UIRCs in 1990, those predominantly funded by industry were the most productive, with the biotechnology field being the most prolific science field in generating new products from UIRCs.

- Twenty-two percent of UIRCs reported the creation of spin-off companies directly resulting from their work.

- Studies of “spill-over” effects provide further evidence of local benefits of industry-sponsored research on campuses.

One study found a positive association between university-based innovation and industrial innovation among companies operating in the same state, as measured by the number of patents issued to firms between 1972 and 1986.[12] In the drug industry, a one percent increase in university-based biomedical research was associated with a .28 percent increase in the number of patents issued to drug firms.

In a study of patent citing within newer patents,[13] Jaffe, Trajtenberg, and Henderson found that newer patents were significantly more likely to cite earlier patents that had originated in close geographical proximity than they were to cite patents from the same field and technological area that had resulted from work done in a different state, standard metropolitan statistical area, or county.

Technology transfer also has a perceptible economic impact on state and local economies in which universities are located. University researchers and their institutions have played leading roles in the establishment of high tech industries. Biotechnology and electronics companies such as Raytheon, Data General, Digital Equipment Corporation, Genetics Institute, Biogen, and Genentech were all founded and staffed by investigators at the Massachusetts Institute of Technology, Stanford University, the University of Minnesota, and the University of California.[14, 15, 16] In turn, the creation of these industries has strengthened local economies through the creation of high-paying technical and professional jobs, growth in tax revenues, and increased inflow of venture capital and other research-related services.

These companies may also become an additional source of revenue for the university research enterprise in the form of new research grants and contracts, licensing revenues, funds to train scientists, endowed chairs, and other philanthropic donations.

The Technology Partnership Practice of the Battelle Memorial Institute recently completed an indepth analysis of the State of Missouri's academic life sciences technology transfer potential.[17] They noted:

- For the year 1999, St. Louis University, Washington University and the University of Missouri system had combined research expenditures of $592 million, produced fine new start-up companies, and earned more than $9.75 in gross licensing income.

- Two nonprofit life science research institutions – the Donald Danforth Plant Science Center in St. Louis and The Stowers Institute for Medical Research in Kansas City – are expected to add 500 new research jobs and $100 million in life sciences revenues to the State of Missouri in the near future.

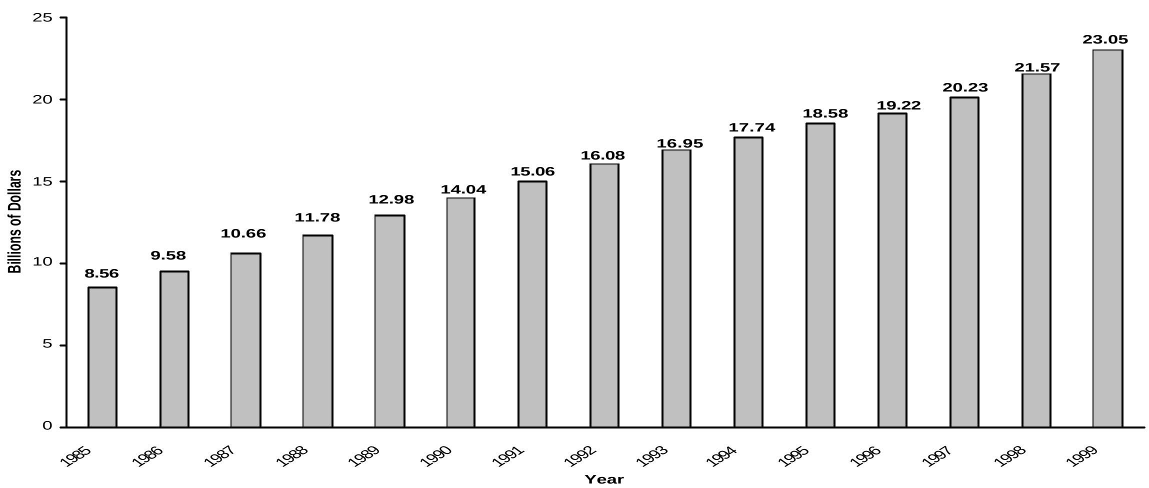
PANEL FINDINGS

National Investment in University Research

FINDING 1: The total national investment in university research has increased dramatically in the last 15 years.

As shown in Chart 1, total national investments in university research grew in all fields from 1985 to 1999, the most current year for which data are available. Over this period, total research and development expenditures in universities increased 170 percent, from $8.56 billion to $23.05 billion.

Chart 1: Academic R&D Expenditures in All Fields

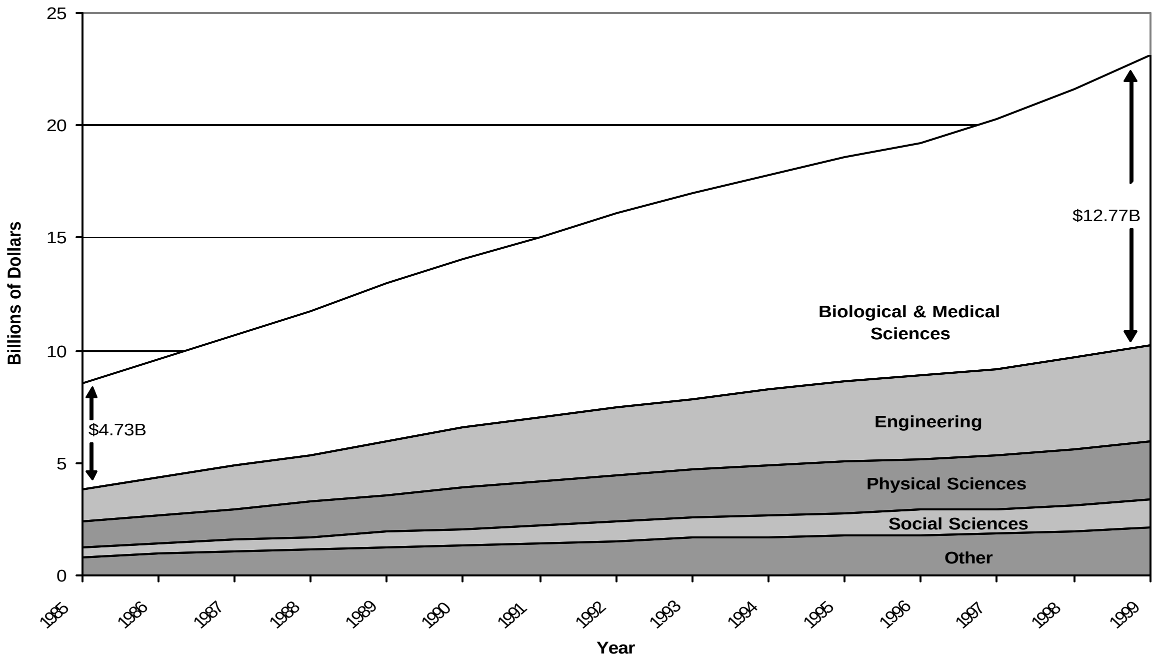


Source: *Science & Engineering Indicators -- 2002*, National Science Foundation, Figure 5-10.

FINDING 2: University research in the biological and medical sciences experienced the absolute largest increase in total funding over the last 15 years.

Chart 2 demonstrates that, from 1985 to 1999, expenditures in the biological and medical sciences nearly tripled from $4.73 billion to $12.77 billion. During this same period, expenditures in engineering fields increased from $1.4 billion to $4.26 billion, in the physical sciences from $1.5 billion to $2.6 billion, in the social sciences from $308 million to $1.2 billion, and in all other fields from $880 million to $2.16 billion.

Chart 2: Academic R&D Expenditures by Field, 1985-1999

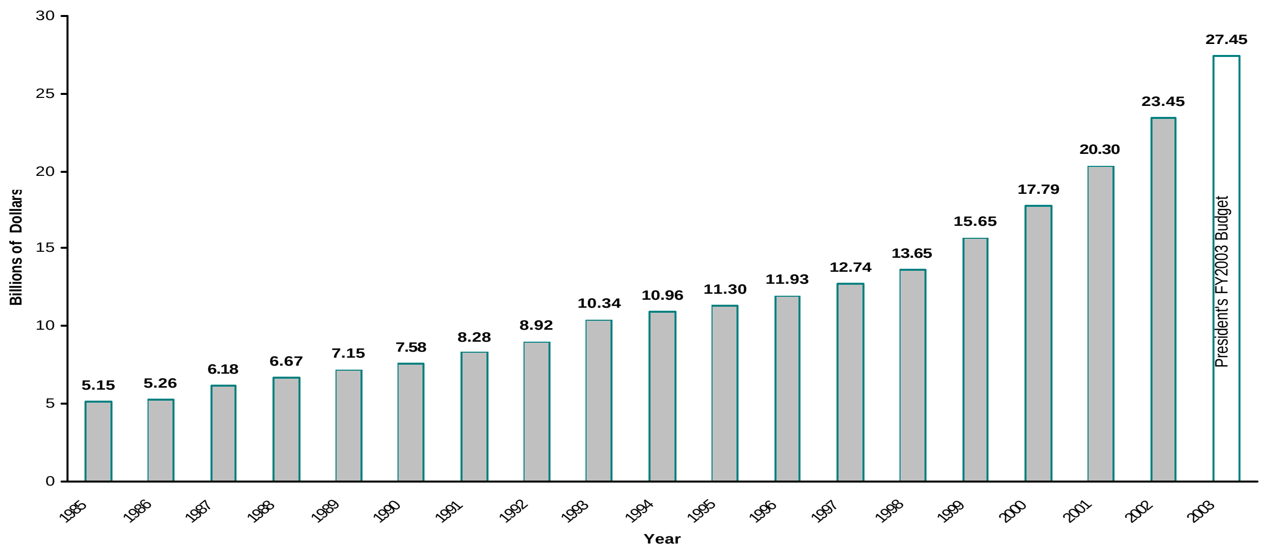


Source: *Science & Engineering Indicators -- 2002* , National Science Foundation, Figure 5-10.

FINDING 3: A significant portion of the increase in university research in the biological and medical sciences is attributable to the doubling of the NIH budget.

The federal government is the single largest supporter of academic research in the life and health sciences.[18] The majority of federal research funds in this field can be traced to the National Institute of Health (NIH), whose budget more than doubled over the last five years from $13.6 billion in 1998 to $27.2 billion in 2003.[19] This substantial budget growth resulted in a 19 percent increase in the number of research projects in academic settings (27,623 to 32,852) and a 21 percent increase in the number of scientists who are principal investigators, reaching 8,976 by 1999.[20]

Chart 3: Federal Appropriations to NIH, 1985-1999



Source for 2002-2003: *Budget of the United States Government, Fiscal Year 2003*, Office of Management and Budget, page 144. Calculated as sum of estimated total mandatory and discretionary appropriations. Source for 1895-2001: NIH Almanac, Appropriations, Section 1, page 257, available December 18, 2002, at http:/ www.nih.gov/about/almanac/appropriations/index.htm.

FINDING 4: University-industry relationships are common in the life and health sciences and account for 12 percent of all academic research funding.

Surveys of industry and faculty members conducted between 1994 and 1995[21] provide the most recent data on the prevalence and magnitude of university-industry relationships. Among key findings:

- More than 90 percent of surveyed senior life sciences company executives participated in some form of university-industry relationship,[22] the most prevalent being the retention of university faculty as consultants.

- Fifty-nine percent of surveyed firms sponsored campus-based research and 38 percent supported university-based training programs.

- Seven percent of the companies reported that faculty members were significant equity holders in their companies.

- Senior research executives report that their companies supported more than 1,500 university-based research projects at a cost of more than $350 million. Based on these reports, it was estimated that the life sciences industry as a whole supported more than 6,000 research projects and expended $1.5 billion for university-based research in the life sciences.

Another 1994-1995 survey of 2,052 research faculty members at the 50 most research-intensive U.S. universities (as characterized by research funding received by NIH) revealed that 28 percent of respondents received some research support from industrial sources.[23] Further, the prevalence of support was greater for clinical than non-clinical departments.

Relationships in industry research in the life sciences on university campuses tend to be small in size and short in duration. Industry respondents indicated that:

- Seventy-one percent of industry-funded research projects from 1994 to 1995 were funded at less than $100,000 a year.

- Only six percent of responding firms provided annual funding of $500,000 or more.

- Of the 84 percent of industry respondents whose firms had relationships with academia, the typical relationship lasted two years or less.

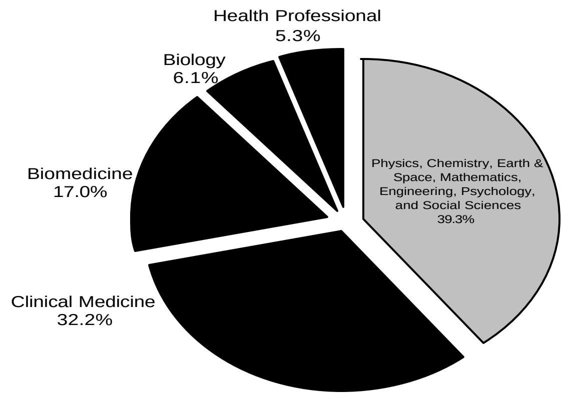
These findings suggest that – at least at the time of the survey – supported research tended to be targeted, that is, applied rather than fundamental.[4] Industry sources constituted a relatively small proportion (about 12 percent) of the total research funding given to universities in the mid-1990s.[6]

Products of the Academic Research Enterprise

FINDING 5: The number of published papers in the life and health sciences has increased dramatically in recent years.

Publications in the professional literature represent a major non-commercial product of university science departments. The number of articles published in peer-reviewed journals in clinical medicine, biomedical research, and the health sciences section of the Science Citation Index (SCI) grew by 17.5 percent from 1987 to 1999.[24] By 1999, the life and health sciences accounted for 60 percent of all scientific and engineering articles in the U.S. (see Chart 4).

Chart 4: Percent of Articles by Field

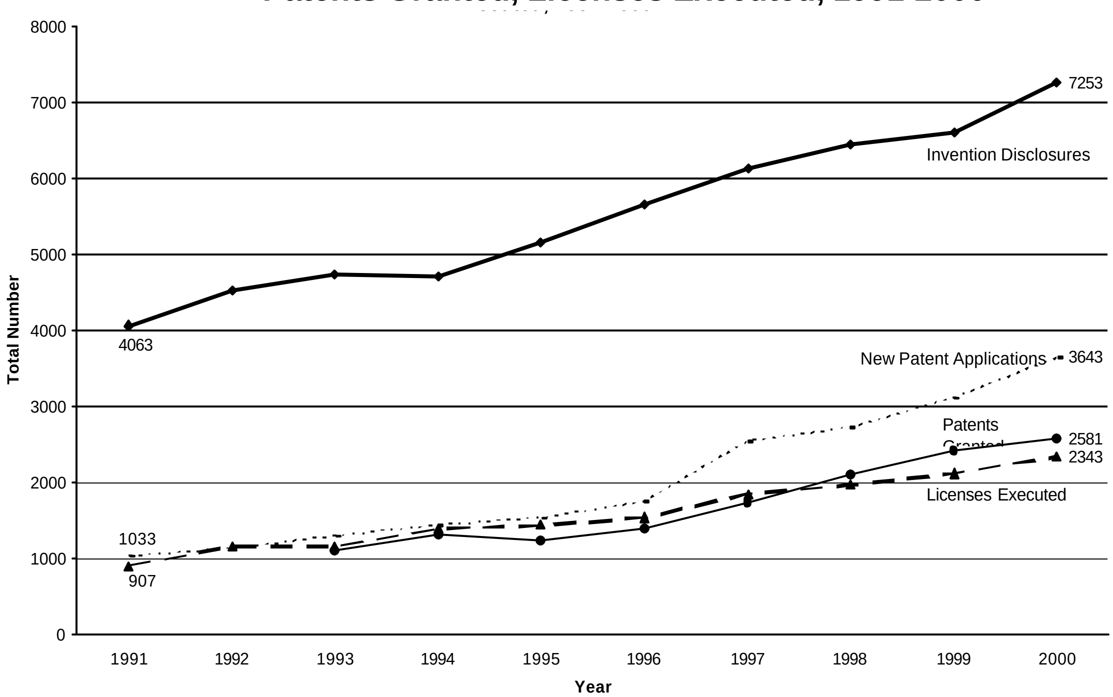


Source: Unpublished data from CHI.

FINDING 6: Overall, commercial products of universities have increased substantially in recent years.

Chart 5 depicts the substantial growth in the number of invention disclosures, patent applications, patents granted, and patents licensed from 1991 to 2000.[25] During nearly the same period, the number of start-up company formations increased nearly 90 percent, from 145 in 1994 to 278 in 2000. This may reflect a growing belief that the formation of a start-up company built around a new technology in the right circumstances may have greater potential for commercial success than licensing to an established company.

Chart 5: Invention Disclosures, New Patent Applications, Patents Granted, Licenses Executed, 1991-2000



Source: AUTM Technology Transfer Data for 10 Year Recurrent Respondents; patents granted unavailable for 1991 and 1992.

FINDING 7: Almost twice as many licenses are emerging in the life sciences disciplines as from the physical sciences.

The Association of University Technology Managers (AUTM) found that twice as many licenses (6,153) were granted in the life sciences as were granted in the physical sciences (3,153) in 1997, the most recent year that data relative to this comparison were collected.[45]

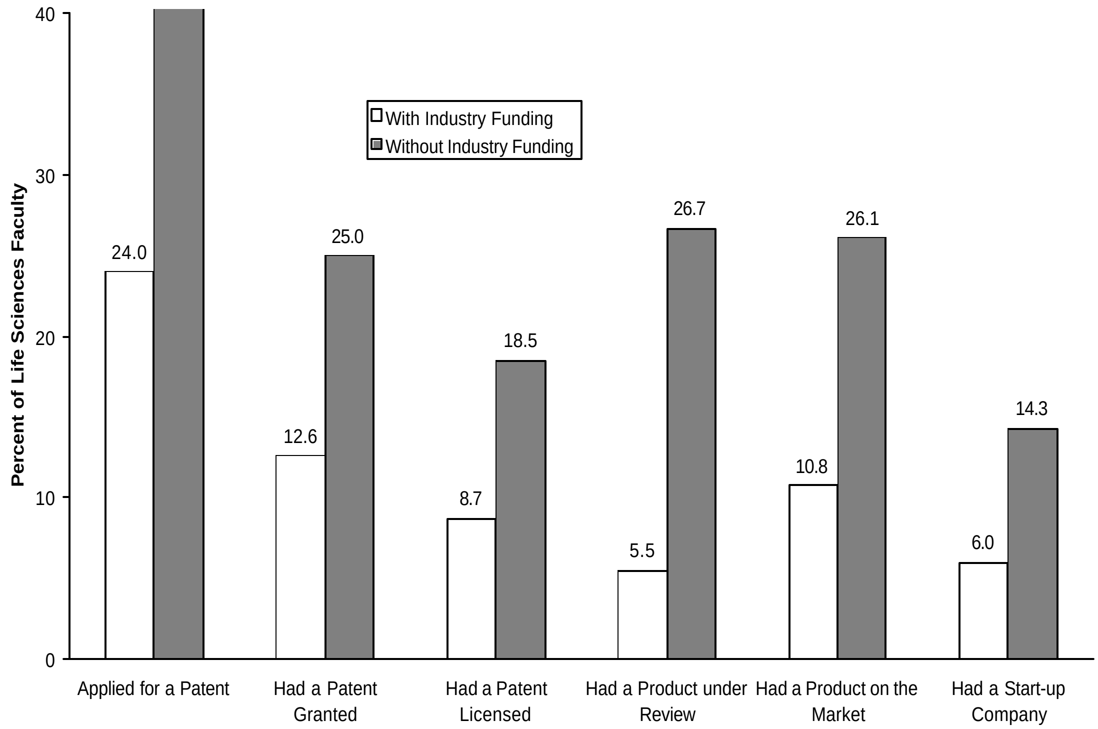
FINDING 8: Research funding from industry is associated with significantly greater research productivity on the part of faculty involved.

Receipt of industry funds is not associated with any detectable adverse effects on university-faculty productivity, as many had hypothesized. Indeed, if anything, industry funding is associated with enhanced productivity of involved university investigators.

A 1994-1995 survey of more than 2,000 life science faculty showed that those with funding from industry published significantly more articles in peer-reviewed journals in the previous three-year period than faculty without industry funding.[7] Faculty benefit from increased publications, as articles published in peer-reviewed journals represent one of the main criteria by which they earn promotions, tenure, prizes, research grants, positions in professional organizations and, ultimately, a possible place in the history of the scientific endeavor.[26] At the institutional level, more publications by faculty translate into greater prestige and potentially greater ability to attract top students, faculty, and future research funding.

Chart 6 shows that industry-sponsored research also is associated with an increased likelihood of commercial activity on the part of faculty and institutions. In 1996, Blumenthal and his colleagues found that, compared to faculty without industry funding, faculty with industry funding were significantly more likely to report having had applied for a patent, had a patent granted or licensed, had a product under review or on the market, or had started a company.[7]

Chart 6: Commercial Activities by Faculty with and without Academic Industry-Research Relationships



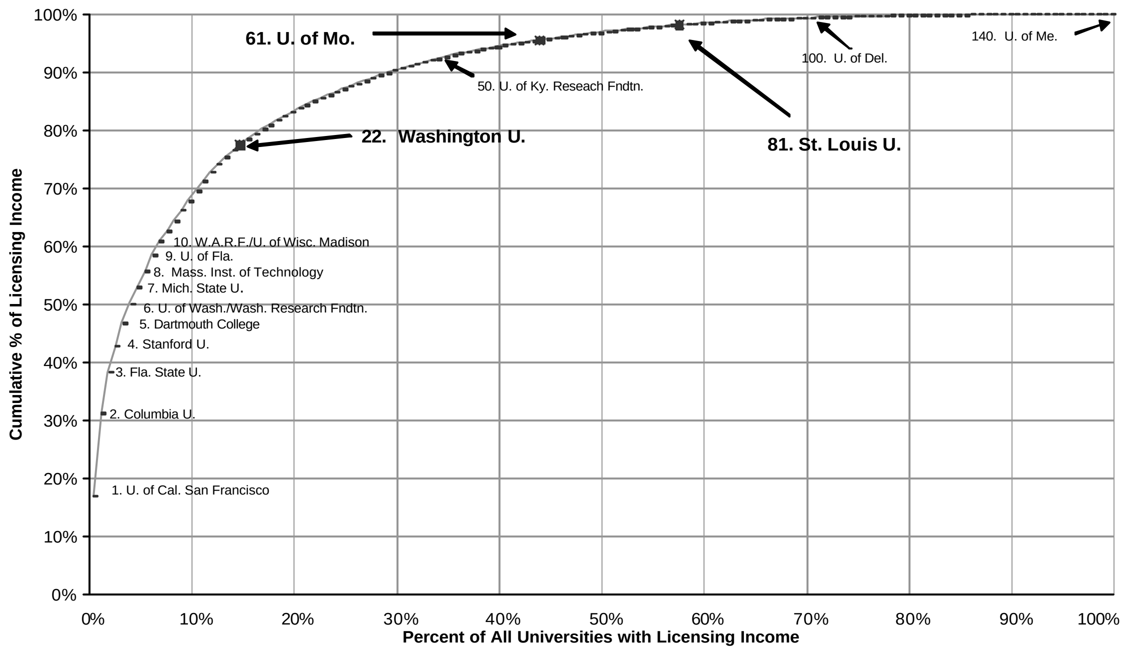
Source: Blumenthal et al., 1996.

Economic Benefits of Technology Transfer and Commercialization

FINDING 9: University income from technology transfer has increased in recent years.

From 1991 to 2000, income derived from gross licensing by a select group of universities increased 698 percent, from $121 million to $997 million.[27] However, the primary beneficiaries of licensing income were a very small group of universities (see Chart 7).

Chart 7: Cumulative Distribution of Licensing Income among Universities, 1999 and 2000.



Source: AUTM Technology Transfer Data for Two-Year Recurrent Respondents; N=140.

FINDING 10: Research-intensive universities and those with medical schools generate more income from technology transfer than less research-intensive universities and those without medical schools.

Table 1 shows the relationship between the existence of a medical school at a university and technology transfer activities. AUTM found that those universities with a medical school had, on average, more new patent applications, new licenses, and more income from licensing activities. Not surprisingly, similar patterns were identified when comparing R&D expenditures of high, medium, and low research intensity schools.

Table 1: Technology Transfer Activity by Selected Organizational Characteristics of Schools

	Average No. of New Patent Applications	N	Average No. of Licenses Executed	N	Average Gross Licensing Income ($ Million)	N
Medical Status:						
Medical School	133	39	90	42	$29.58	43
No Medical School	86	18	40	17	$14.81	17
Research Intensity (R&D Exp):						
High (>$400mil)	310	11	198	12	$60.87	12
Medium ($200-400 mil)	113	18	70	19	$24.77	20
Low (<$200 mil)	47	28	27	28	$10.64	28

* Data from AUTM 2000 Annual Survey—subset of 10 year respondents. (Analysis by Joshua Powers, Ph.D. at Indiana State University, 2003.)

Challenges to Technology Transfer and Commercialization in Universities

FINDING 11: University-industry relationships and technology transfer are associated with increased secrecy in academic science.

University-industry relationships have been shown to increase the risk of secrecy in science.[28,29] Life science faculty with industry research funding were 1.34 times more likely than those without such funding to report that they had delayed publication of their research results by more than six months to protect their scientific and commercial interests.

Researchers who had commercialized the results of their research (defined as having applied for a patent, had a patent granted, licensed a product, started a company, etc.) were 2.4 times more likely than commercially inactive faculty to report that they had denied another's academic request for information, data, or materials related to their research.

FINDING 12: Commercial activities and technology transfer may reduce the amount of basic research being conducted.

Another challenge to university-industry relationships and technology transfer is that these activities may lure faculty away from basic research – long the mainstay of academia – toward research that has more commercial application.

Unpublished research by Blumenthal and colleagues conducted in 1994 found that more than half of all life scientists felt that industry research funding pressured faculty to "spend too much time on commercial activities." Blumenthal also found that faculty members with industry funding were significantly more likely than those without to report that their choice of research topic had been influenced somewhat or greatly by the likelihood of the results having commercial application.[7]

FINDING 13: University-industry relationships and technology transfer may have a negative impact on the public image of universities and faculty.

The public's generous support of research, embodied in the large increases in appropriations to NIH and other public funding sources over the last decade, is founded on the belief that the results of research represent faculties' best efforts to detect the truth, untainted by commercial interests. Derek Bok, former president of Harvard University, wrote that university-industry relationships may "…undermine the university's reputation for objectivity."[30]

Recent research concerning the impact of university-industry relationships on the outcome of studies of the efficacy and safety of calcium channel antagonists in the treatment of cardiovascular disorders suggests there may be some cause for concern.[31] Between March 1995 and September 1996, more than 70 studies were published that were supportive, neutral or critical regarding the safety and efficacy of using calcium channel antagonists in a clinical setting. Stelfox and colleagues surveyed the authors of these studies about their relationships with the companies that produced the antagonists or with the companies that produced the products. They found that 96 percent of those authors whose research was supportive of the use of calcium channel antagonists had financial relationships with companies that produced the antagonists, compared with only 60 percent of those whose research was neutral or 37 percent of those whose findings were critical.

Stelfox and colleagues also found that professors were unlikely to reveal their relationships with industry funding sources in their writings. Of the 70 authors surveyed, only two disclosed their relationships with industry. Stelfox and colleagues question, "how the public would interpret the debate over calcium channel antagonists if it knew that most of the authors participating in the debate had undisclosed financial ties with pharmaceutical manufacturers."[31]

This study is not alone in concluding that industry funding may influence the outcome of academic research. A recent review of the literature published in the *Journal of the American Medical Association* noted that 11 published studies concluded that industry-sponsored research tends to yield industry-friendly conclusions.[32]

FINDING 14: Licensing of university technology has not kept pace with patenting practices.

The pace of new patent applications has accelerated in recent years (see FINDING 6, Chart 5). Some of this increase is an artifact of changes in patent procedures (i.e., an increasing need or interest in filing more than one patent on a single invention). The increase suggests, however, that over time universities may experience a growing portfolio of patented but unlicensed technologies, given the slower rate of growth in licenses executed.

Research has also shown a growing tendency by universities to patent less commercially attractive technologies, possibly as a function of new entrants to technology transfer practice with lower quality technologies[33], a myopic focus on revenue enhancement rather than industry incentives for licensing,[34,35] and/or continued informational and cultural barriers between universities and industry.[36]

FINDING 15: A very small group of universities are the primary beneficiaries of licensing income.

As noted in FINDING 9, the primary beneficiaries of licensing income are a very small group of universities. The 1999-2000 AUTM Licensing Survey revealed that, of the total $1.7 billion dollars in licensing revenues earned by 140 respondents, the top 10 income producers generated $1 billion or 60 percent of all licensing revenues (see Appendix 1). For comparative purposes, Appendix 2 provides institution-specific data on the top 25 institutions with 2002 NIH funding.

Furthermore, the majority of licensing from the top 10 institutions was generated from either one or two highly lucrative licenses. Examples include:

- Hepatitis B-Vaccine at the University of California
- Taxol at Florida State University
- Gatorade at the University of Florida
- Cisplantin at Michigan State University
- Vitamin D technologies at the University of Wisconsin

Recently, gains have come from the sale of equity taken in a start-up licensee firm that ultimately became successful (e.g., Medarex by Dartmouth College and Akamai Technologies by MIT). Other gains have been derived from successful settlements in patent infringement suits (e.g., Genetech and the University of California).

Technology Transfer in the Life Sciences in the U.S.

FINDING 16: There is a lack of reliable data regarding life sciences technology transfer activities in the U.S.

The U.S. has no systematic national data system on technology transfer and commercialization in the life sciences. AUTM, the federal government, and independent researchers collect technology transfer information. Still, none of these systems provides indepth data specific to life sciences activities. AUTM data on trends in the number of patents that emerge from universities, for example, cites patents in all scientific areas, including engineering, business, and agriculture. As a result, it is impossible to gauge institutional technology transfer in the life sciences apart from other scientific fields.

Moreover, AUTM data are not comprehensive because universities may choose not to participate. When evaluating AUTM data in comparison to National Science Foundation data, specific data points do not match nor do the data capture the broader economic impact of university technology transfer on the economy of local communities.

The lack of comprehensive data makes it difficult to evaluate the management of technology transfer activities and to develop best practices. It also poses challenges to economists and other researchers seeking to independently study the technology transfer enterprise.

FINDING 17: There is little understanding of best practices in the management of university technology transfer and commercialization activities.

Descriptions of practices followed by universities with the strongest track records in technology transfer and commercialization do not exist nor do experts agree on the most effective methods for universities to organize and operate in this area.

RAND, in the report they prepared for the President's Council of Advisors on Science and Technology, has reported a need for a "set of practices that facilitate technology transfer, derived from accumulated experience of universities, national laboratories, and corporation." Broad areas in which best practices could improve the management of technology transfer at individual universities include:

- Modeling of specific aspects of technology transfer processes.
- Defining measures of success for both processes and outcomes of technology transfer.
- Identifying different approaches to technology transfer that yield specific outcomes, such as the use of exclusive licensees.[37]

Specific unanswered questions regarding effective university practices include:

- How does a university develop a culture that simultaneously respects the norms and practices of academic science and fosters entrepreneurial activity with incentives for private revenues?
- How can faculty be encouraged to remain engaged after a licensing agreement since ongoing faculty-firm relations are critical to a technology's ultimate commercialization?
- How can universities leverage resources to finance the initial stage of product development that is often critical to enticing licensee firms and/or venture capitalists to become involved?

Prolonging lack of understanding of best practices is the absence of any broadly recognized source of technical assistance to university leaders and technology transfer managers. No organization in the U.S. has extensive experience and expertise in this area. Individual university leaders and managers who seek advice typically gather desired information by visiting or informally contacting individuals at well-known institutions. Due to a lack of robust data analysis, it is unknown whether recommendations from one university with a unique culture are transferable to another university.

FINDING 18: There is no comprehensive source of professional development and training for technology transfer and commercialization professionals.

Despite the increase in technology transfer activities, there is no comprehensive education system – similar to those in business in science – to educate new technology transfer professionals. In most instances, the education of new entrants in the field follows an apprenticeship model. Novices work on increasingly complex tasks under the tutelage of more experienced professionals. AUTM, the Licensing Executive Society, and the National Technology Transfer Center offer courses, seminars, and conferences, but their scope, number, and quality are limited. These deficiencies inhibit the dissemination of effective approaches to management.

FINDING 19: The technology transfer professional organization does not have a dedicated staff to assist in the development of the field.

AUTM, the primary professional association for university technology professionals, is a nonprofit association of more than 3,200 members representing more than 300 universities and organizations. It is managed by elected officers who serve on a voluntary basis. Staff assistance is obtained by contracting with a firm to provide administrative and management support.

This arrangement starkly contrasts with other major national associations that support research in the life sciences, such as the Association of Academic Medical Colleges and the American Association for the Advancement of Science. These organizations have large staffs, often consisting of experienced professionals who provide advice and services in data collection, professional education, and policy analysis and development.

Without such infrastructure, AUTM has limited ability to offer comparable services to university managers or the general scientific community.

FINDING 20: The potential of university-based high throughput screening facilities has not been adequately evaluated.

Among the primary outcomes of basic research in the life sciences are newly discovered biomaterials, such as molecules, enzymes, and proteins. These biomaterials are often referred to as “targets” upon which drugs act to fight disease. A pivotal step in the process of developing drugs is to learn which chemical and/or biological agents affect the performance of a newly discovered target.

Recent advances in computers, robotics and statistics have revolutionized the screening process by increasing its speed and accuracy. This process is known as high-throughput screening (HTS). At the simplest level, HTS uses robotics and computers to search through thousands and sometimes millions of known chemicals to identify those that have some impact on a biomaterial and, thus, demonstrate potential for drug development. This process is standard practice in industrial drug discovery and is becoming increasingly prevalent in universities.

HTS facilities can be found at an increasing number of universities and medical centers, including the Massachusetts General Hospital, Harvard University, Rutgers, the University of Kansas, and Rockefeller University. Among these facilities, there is great variation in the size, organization, management, and scope of work. Experts consider the HTS process critical in supporting appropriate decision making and allocation of resources to appropriate university innovations.

To date, there has been no systematic evaluation of the impact of these facilities on the academic technology transfer process or on the establishment of best practices in academic-based HTS. Given the cost of establishing HTS facilities and their tremendous potential to support the discovery of new drugs that bring revenue to the institution, a systematic study of these facilities is needed.

FINDING 21: NIH and other federal agencies do not actively encourage technology transfer and commercialization activities by life science institutions and researchers.

The Bayh-Dole Act of 1980 is the primary mechanism through which the federal government supports the transfer of technology developed with federal funds. The law states:

> It is the continuing responsibility of the federal government to ensure the full use of the results of the nation's federal investment in research and development.[38]

Nevertheless, NIH remains relatively passive in encouraging and monitoring technology transfer and commercialization by research institutions and scientists, who are expected to meet few standards. Reporting and monitoring of activities is minimal, and NIH provides only modest amounts of technical assistance and education to officials in this area.

Government's passive role in technology transfer contrasts starkly with its exceptionally active role in other areas of research. For example, NIH requires institutions in which clinical research is conducted to make proper preparations and provide adequate facilities to protect the persons involved in clinical research.[39] Similarly, research institutions must meet strict standards for the adequate housing and treatment of animals used in research. Federal policies provide that universities must have a financial accounting and reporting system to ensure that research funds are appropriately managed. In these areas, NIH has issued regulations, monitors institutional efforts, and provides active technical assistance and ongoing professional education.

FINDING 22: The benefit of national policies that support technology transfer and commercialization activities are now being questioned.

The Bayh-Dole Act gave universities and their scientists a financial motive to cooperate with industrial partners by enabling universities to claim ownership to intellectual property resulting from federally-sponsored research, and requiring that academic inventors receive a share of the gains from commercialization of these properties.

Recently, however, questions have been raised regarding the impact of these policies, particularly regarding high consumer prices for some prescription drugs.[40]

To date, no comprehensive analyses have been undertaken to assess the economic impact of Bayh-Dole or other major policies that affect the nation's technology transfer and commercialization practices. Most research in the area is narrow in scope, with implications and commentary often based on political views and economic interests. Most needed is a rigorous analysis of a cause-and-effect relationship between Bayh-Dole policies and the substantial acceleration in the patenting and licensing of university-developed technologies.

In the absence of analysis, opinions differ with respect to the benefits of Bayh-Dole. A recent article in the *Economist* referred to the Bayh-Dole Act as "the golden goose of innovation" in the U.S.[41] Some believe that patenting and exclusive licensing of even basic technologies is essential because the time for development is so long, thus making necessary incentives to develop these highly risky technologies.

Communication on the importance of technology transfer and commercialization to national leaders is also lacking. The biotech industry – mostly through its national association, the Biotechnology Industry Organization – provides information on specific issues, but there is no ongoing source of independent information for decision makers and the media.

In short, the lack of quality research and communication in this area has limited understanding of the potential for technology transfer to contribute to national economic growth while providing opportunities for those with negative views of these activities to attract a receptive audience.

GENERAL CONCLUSIONS

The Panel's findings suggest a set of conclusions that can guide recommendations for Kauffman Foundation initiatives:

Implicit Social Contract. The national investment of public funds in life sciences research represents an implicit social contract through which the public expects to receive new and better commercial products and services.

Increased Funding. National Institutes of Health funding for research in the life sciences has doubled in the last five years, increasing opportunities in technology transfer and commercialization in the life sciences.

Economic Development. The academic and commercial products of academic life science represent opportunities for technology transfer, institutional support and economic development at national, state, local and institutional levels.

Clustering of Resources. The majority of recent increases in university income from technology transfer and commercialization have clustered in ten universities associated with a very small number of commercial products/services.

Managing University-Industry Relationships. Increasingly common university-industry relationships in the life sciences must be managed in a way that encourages technology transfer and commercialization while protecting the non-commercial mission of research universities.

Challenges to University Technology Transfer and Commercialization. Challenges to university technology transfer and commercialization include: (1) increased secrecy in science, (2) a shift in the focus of academic science, (3) risk to academic institutions' reputations, (4) cultural differences between schools, and (5) a general lack of understanding of the potential economic benefits of technology transfer and commercialization.

Needed Activities. Activities needed to advance university technology transfer and commercialization include: (1) development of a data infrastructure, (2) creation and offering of pre-service and in-service professional education, (3) articulation and dissemination of best practices, (4) evaluation of university-based high throughput screening facilities, and (5) assessment of key aspects of national technology transfer policies.

RECOMMENDATIONS FOR KAUFFMAN FOUNDATION INITIATIVES

RECOMMENDATION 1: Provide support to strengthen data and benchmarking on life sciences technology transfer and commercialization activities.

Better data is critical to understanding the strengths, weaknesses, and outcomes of the nation's technology transfer and commercialization process. The Kauffman Foundation can make an important contribution in this area by supporting a major effort to improve valid technology transfer data collection and analysis.

This effort would respond to the President's Council of Advisors' recommendation to develop a set of metrics to better quantify technology transfer practices and their effectiveness. As the Council noted, "…identifying metrics to quantify program effectiveness is of increasing importance."[1?]

The development of a more detailed and current technology transfer and commercialization information system, as recommended by the Panel, would:

- Benefit university leaders, policymakers, researchers, and the technology transfer professions.
- Reduce the burden on university officials in providing data and facilitate the responsible storage, use, and dissemination of collected data.
- Assist efforts to document the most effective practices in technology transfer.

The new data system would provide information at individual institution and national levels regarding university activities, elements of the technology transfer process, and key outcomes of commercialization.

Specific data elements should include: (1) patenting and licensing, (2) cooperative activities between research organizations and the private sector, (3) consulting arrangements, (4) use of facilities, and (4) personnel exchange programs. Longitudinal analysis of performance and connections to the National Institutes of Health (NIH) and the National Science Foundation are also recommended.

The Association of University Technology Managers (AUTM), which has worked for years to manage and improve the nation's technology transfer data system and to promote widespread dissemination of its findings, should be an active participant in this data development effort. Others who should be involved include university officials, scientists, economists, biotech firm executives, investors, and technology transfer researchers, as well as representatives from academic associations, such as the Association of Academic Health Centers, the American Association of Medical Colleges, and the Association of American Universities.

The Panel also suggests providing support to strengthen AUTM's overall ability to serve as a national leader in technology transfer and commercialization. A strong organization with full-time staff would enhance the ability of leading professionals across the nation to participate in decisions made by public and private organizations. It would also improve their ability to work with the Kauffman Foundation, and in particular the National Institute for Technology Transfer in the Life Sciences.

RECOMMENDATION 2: Improve technology transfer at individual universities by establishing a National Institute for Technology Transfer in the Life Sciences.

The Panel recommends that the Kauffman Foundation establish a National Institute for Technology Transfer in the Life Sciences. The Institute would work directly with technology transfer professionals, senior research administrators, and biomedical scientists at universities and other research institutes to increase effective technology transfer in the life sciences.

Based in Kansas City, the Institute would be an independent nonprofit organization with expertise in the full range of technology transfer and commercialization activities. Institute staff would include experts in technology transfer management, commercialization and finance, business development, and law, as well as those with backgrounds in science, business, law, and possibly engineering. Consultants could provide complementary skills. The Institute would also draw on the expertise of individuals in life sciences companies, venture capital firms, and individual entrepreneurs.

> ***Recommendation 2A: The Institute should assist individual universities and their scientists to expand and improve the commercialization of products from life sciences research.***

Assistance should focus on documenting effective practices in the organization and management of technology transfer, and providing direct technical assistance regarding the operation of technology transfer and commercialization activities.

Documentation of effective practices would respond to the President's Council of Advisors on Science and Technology (PCAST) recommendation that such an effort be pursued. This work would include:

- Modeling of specific aspects of technology transfer processes.

- Defining measures of success for both processes and outcomes.

- Identifying variable approaches to technology transfer.

- Identifying relationships that indicate whether certain inputs and relationships yield specific outcomes.[42]

The Institute would focus on the central elements of successful technology transfer driven by research results, including:

- Organization and operation of a technology transfer office.

- Identification and assessment of intellectual property and decision on intellectual property.

- Incentives for researcher involvement in technology transfer.[43]

The Institute would provide models in areas such as:

- Intellectual property awareness and capture.
- Institutional incentives and culture.
- Methods for assessing the value of research.
- Project incubation and maturation.
- Licensing intellectual property.
- Marketing inventions.[44]

It would publish a series of user-friendly reports on its work. These reports would be widely disseminated to technology transfer offices and university research leaders, as well as consulting groups, biotech executives, and investors.

The Institute would also provide direct technical assistance, including onsite support, to universities regarding the operation of their technology transfer activities. This work would generally focus on specific processes that local officials seek to improve. It would also include evaluation of overall organization and effectiveness of the institution's technology transfer activities and provide recommendations for improvements. Over time, the Institute could develop capacity to provide delegated management of the technology transfer process to individual universities.

Recommendation 2B: The Institute should evaluate efforts by universities to add value to research inventions and reduce the risks of development of emerging technologies.

This should be an early focus of the Institute. The area between research and manufacturing is often referred to as "the valley of death," where research ideas at the proof-of-concept or prototype stage meet practical manufacturing considerations and economic realities. Many biotech industry leaders see this as the most challenging stage in the technology transfer and commercialization process in the life sciences.

Some universities are now supporting activities to address barriers that arise during this period. A review and analysis of these efforts would provide useful guidance to university and industry leaders on the most effective ways to overcome the barriers.

Recommendation 2C: Develop Institute capacity to provide delegated management of technology transfer processes for individual universities.

This work would include provision of all necessary activities, including:

- Strategic analysis of the scientific and commercial potential of discoveries.
- Identification and recruitment of potential partners.
- Location of venture capital funding.
- Provision of technical and legal assistance in negotiating licensing agreements or agreements for technology transfer.

The Institute could focus its work in this area by providing delegated management of specific technology transfer services. An example would be services in areas that raise issues of individual and institutional financial conflicts of interest. Licensees could be held and managed by the Institute, which would remove certain financial entanglements that exist when these relationships are managed with a single academic institution.

The Kauffman Foundation could initiate work in this area by contracting with a major consulting firm to conduct an extensive review of options for and feasibility of delegated management of all or selected technology transfer activities at universities and other research institutions.

Recommendation 2D: The Institute should evaluate the prospects of supporting the analysis of technology transfer and commercialization services in the Kansas City area in coordination with scientists at the Stowers Institute and other life sciences institutions in the metro area.

Recommendation 2E: The Kauffman Foundation should support targeted efforts, in coordination with the Institute, to improve university leaders' understanding of the importance of effective technology transfer programs.

This effort should be managed by associations of university and scientific community leaders, including the Association of American Universities, the Association of Academic Health Institute, the American Association of Medical Colleges, and the American Association for the Advancement of Science.

RECOMMENDATION 3: Enhance technology transfer efforts at the National Institutes of Health.

The Kauffman Foundation should enhance the role of the National Institutes of Health (NIH) by helping to identify and develop policies and practices that would strengthen technology transfer activities at NIH and its grantee research institutions.

NIH is the largest source of federal support for university-based scientific research. Its current $27 billion budget is more than twice the level of five years ago. The U.S. now invests more than four times as much as other G-7 countries combined in biomedical research. The new NIH director, Dr. Elias Zerhouni, was actively involved in technology transfer at Johns Hopkins University for many years and believes that NIH should strengthen its activities in this area.

The objective of the Foundation's work with NIH would be to increase emphasis on and success of technology transfer activities from intramural research at the Bethesda campus and extramural research supported by NIH at universities across the nation. A major focus would be to increase the impact of the NIH Office of Technology Transfer (OTT) and related offices at the individual Institutes. OTT, which provides guidance on technology transfer activities for grantee institutions, is the primary source of support for NIH administrators and scientists in this area.

Recommendation 3A: Support for this work should be provided to and managed by the Foundation of the National Institutes of Health (FNIH).

FNIH is an independent foundation that supports the mission of NIH by developing public-private partnerships to address needs unmet by public funding.

Activities that would be developed by FNIH with Kauffman Foundation support include:

- Working groups of NIH officials to identify current NIH policies and practices that inhibit technology transfer from supported research and to develop strategies to address these barriers.

- Focused meetings of NIH officials with leaders from the university, research, business and investment communities to discuss NIH policies that would improve support for technology transfer activities.

- Small conferences with senior NIH scientists and leaders from the university, scientific, biotech and investment communities to review current NIH priorities for research in key areas of the life sciences.

- Review of the possible NIH role in adding value to emerging technologies, including the development of high throughput screening centers similar to those supported by the National Institute of Neurological Disorders and Stroke.

Support should also be provided to a similar effort to conduct a study of technology transfer and commercialization processes at the Centers for Disease Control (CDC) through the CDC Foundation. Work with CDC would be coordinated with related activities at NIH.

> ***Recommendation 3B: The Kauffman Foundation should initiate work in this area by supporting an Institute of Medicine (IOM) blue ribbon panel to evaluate technology transfer policies at the NIH.***

IOM staff has extensive experience in assessing the effectiveness and efficiency of federal programs and key issues in the sciences. The IOM panel would draw on the expertise of members of the National Academies, who include the most senior national leaders in the life sciences, physical sciences, and engineering.

Their work would be conducted over a period of approximately 18 months in collaboration with senior leaders of the NIH and would be coordinated with initial work supported through the FNIH.

The IOM report would be disseminated to leaders and decision makers in NIH and the executive branch, as well as relevant Congressional committees, university leaders, the biotech and investment industries, and the national press.

RECOMMENDATION 4: Establish a National Commission on Technology Transfer in the Life Sciences.

The Kauffman Foundation should establish a National Commission on Technology Transfer in the Life Sciences to provide effective, highly visible national leadership on critical issues in this area. The Commission would review and report on major challenges facing technology transfer and commercialization in the U.S., and recommend future policies and steps necessary to protect and improve the nation's investment in the life sciences.

Specific objectives would include:

- Increase national awareness of the benefits of university-based federally funded research over the past 20 years.

- Serve as a resource to key government units, including NIH and Congressional committees.

- Review current policies and proposals and recommend national policies to enhance technology transfer in priority (i.e., revisions to Bayh-Dole, patent policy, research and development tax credits, and international patent harmonization).

- Communicate findings and recommendations to key individuals in the academic, private and government sectors, science organizations, and the press.

- Define a national research agenda to improve understanding of the benefits of technology transfer activities on the national economy.

The Commission would be comprised of approximately 18 national leaders, including biomedical scientists, university officials, technology transfer administrators, biotechnology and pharmaceutical firm executives, the investment community, former NIH and Food & Drug Administration (FDA) officials, lawyers, and researchers on science and the economy.

The Commission would meet over a period of three years and issue a series of reports. The Kauffman Foundation would publish the Commission's analyses and recommendations. They would be released with press briefings and sessions scheduled with senior public and private sector decision makers. Commission members and staff would also publish papers in major medical and research journals, make presentations at national meetings, and brief the media.

RECOMMENDATION 5: Support focused initiatives in communicating the importance of technology transfer and commercialization to national leaders.

The Kauffman Foundation should support a number of specific activities to elevate the issue of technology transfer and commercialization to national prominence. These could include:

- A seminar series to provide a forum for national science officials from various professional backgrounds to discuss critical technology transfer and commercialization issues. Participants would include staff from NIH, FDA, the National Science Foundation, the National Academy of Sciences, the U.S. Patent Office, and industry and academic trade associations.

- A briefing series for the national science and business media on current issues in technology transfer and commercialization, as well as new publications and findings of the National Commission on Technology Transfer in the Life Sciences and other Kauffman-supported projects.

- Annual meetings of life sciences technology transfer leaders to discuss current activities, modeled on the recent BIO/Gates Foundation meeting held in December 2002 on technology transfer issues on the development of treatments for the third world.

In future years, a BIO/Kauffman meeting could become a summit of leaders from all major sectors of the biotech world, featuring presentations by senior officials from NIH, FDA, Congress, the biotech and pharmacy industries and venture capital firms. Small break-out sessions would focus on timely issues of special interest to conference participants.

RECOMMENDATION 6: Support the education of the next generation of technology transfer leaders.

To provide the nation with well-trained technology transfer managers, the Kauffman Foundation should work to improve the education of the next generation of leaders.

Recommendation 6A: Work with key organizations to improve professional development programs.

The Kauffman Foundation should support work by AUTM and the Licensing Executives Society to improve professional development programs. This work could include the development of a sequence of courses necessary for junior and senior level staff, and senior seminar series on key issues for technology transfer leaders.

Analysis of the experience and educational background of those in the technology transfer and commercialization field is also recommended to gain insight into areas of strength and weakness.

Recommendation 6B: Work with selected business and health sciences schools to develop a targeted curriculum for future life science technology transfer managers.

Curriculum and courses developed with Kauffman Foundation support would encourage universities to expand their training in this area and would become part of future professional education programs developed by AUTM and other groups.

Universities selected for this effort would be drawn from those with a leading national business school and a top 20 research academic health center. These universities include the Michigan Institute of Technology, Columbia University, the University of Pennsylvania, Duke University, Washington University, Northwestern University, the University of Wisconsin, the University of Michigan, the University of California at Los Angeles, Stanford University, and the University of Washington.

Recommendation 6C: Establish a new fellowship program in life sciences technology transfer and commercialization.

This program would provide an intensive one-year educational experience in technology transfer management to 5-10 young professionals annually. Selected fellows – drawn from the fields of life sciences research, business, investment banking, and law – would have a demonstrated strong interest in technology transfer and commercialization.

Fellows would gain an indepth understanding of technology transfer practices and challenges in academic and industrial settings, thus enhancing their opportunities and contacts in the field. Fellows would also gain high quality, practical knowledge by working closely with a national expert in technology transfer at an institution known for excellence in the field (e.g. MIT, Stanford, Wisconsin, and Northwestern). Additional experiences might include special week-long seminars on key topics in technology transfer, site visits to institutions, meetings with individuals, and attendance at national conferences.

The program would draw on features of the post-doctoral program of the American Association for the Advancement of Science, as well as experience of the earlier Kauffman Fellows Program.

It should be noted that a fellowship program would be substantially more costly than support for the improvement of educational programs or the development of university programs.

RECOMMENDATION 7: Analyze the value of university-based screening centers to evaluate the effectiveness of new biomaterials.

The Kauffman Foundation should support the systematic evaluation of university-based high throughput screening (HTS) facilities, which are an important next step in moving discoveries through the development process. This evaluation would result in the development of best practices regarding the size, organization, management, costs, and results of these facilities.

The evaluation should be based at a major university or other institution with the necessary broad range of staff expertise. It should be performed by a team of individuals with direct experience in HTS in university and industry locations, university research management and program and financial evaluation. Study methodologies would include case studies based on site visits, financial analyses, and surveys.

Evaluation results would be communicated to university research leaders and managers of HTS facilities through reports, journal articles, and presentations at national conferences. The final report would outline effective practices for university-based HTS facilities and provide practical advice on implementation strategies. The results would also be made part of the ongoing work of the proposed National Institute for Technology Transfer in the Life Sciences.

RECOMMENDATION 8: Analyze the next steps in the development of the life sciences industry in Kansas City.

Building on the Battelle Memorial Institute's Technology Partnership Practice's recently completed analysis of the State of Missouri's academic life sciences technology transfer potential, the Kauffman Foundation should support additional analyses of current and potential capacity of life sciences in the Kansas City region.

APPENDIX 1

Distribution of Licensing Income Among Top 25 Universities

	Institution	Gross Licensing Income 1999&2000	% of All Licensing Income	Cumulative % of All Licensing Income	% of All Universities at or above this Level
1	University of California – San Francisco	$295,675,000	17.05%	17.05%	0.71%
2	Columbia University	$244,737,672	14.11%	31.16%	1.43%
3	Florida State University	$124,810,048	7.20%	38.35%	2.14%
4	Stanford University	$77,026,288	4.44%	42.79%	2.86%
5	Dartmouth College	$68,951,579	3.98%	46.77%	3.57%
6	Univ. of Washington/ Wash. Res. Fndtn.	$58,183,882	3.35%	50.12%	4.29%
7	Michigan State University	$49,432,874	2.85%	52.97%	5.00%
8	Massachusetts Inst. of Technology (MIT)	$48,548,982	2.80%	55.77%	5.71%
9	Univ. of Florida	$47,924,576	2.76%	58.54%	6.43%
10	W.A.R.F./Univ. of Wisconsin-Madison	$40,960,726	2.36%	60.90%	7.14%
11	Univ. of Pennsylvania	$30,855,972	1.78%	62.68%	7.86%
12	California Institute of Technology	$30,360,000	1.75%	64.43%	8.57%
13	SUNY Research Foundation	$30,088,439	1.73%	66.16%	9.29%
14	Harvard University	$30,066,753	1.73%	67.90%	10.00%
15	Univ. of Minnesota	$29,424,228	1.70%	69.59%	10.71%
16	Emory University	$28,780,467	1.66%	71.25%	11.43%
17	Georgetown University	$26,000,000	1.50%	72.75%	12.14%
18	Johns Hopkins University	$25,088,856	1.45%	74.20%	12.86%
19	Baylor College of Medicine	$22,224,799	1.28%	75.48%	13.57%
20	New York University	$19,184,044	1.11%	76.58%	14.29%
21	Univ. of Rochester	$16,393,918	0.95%	77.53%	15.00%
22	Washington University	$15,600,861	0.90%	78.43%	15.71%
23	Univ. of California Los Angeles	$14,891,000	0.86%	79.29%	16.43%
24	Tulane University	$14,508,919	0.84%	80.12%	17.14%
25	Univ. of Texas Southwestern Med. Ctr.	$13,489,493	0.78%	80.90%	17.86%

APPENDIX 2

Distribution of NIH Awards to Leading Academic Health Centers

Number	Institution	Per Hospital	Per AHC	% of all awards	Cum. %
1	Harvard University	$273,147,799	$1,002,120,511	7.23%	7.23%
	Massachusetts General Hospital	$243,612,895			
	Brigham and Women's Hospital	$205,122,985			
	Dana-Farber Cancer Institute	$98,907,652			
	Children's Hospital (Boston)	$68,537,119			
	Beth Israel Hospital (Boston)	$99,609,692			
	Massachusetts Eye and Ear Infirmary	$13,182,369			
2	University of Washington	$405,729,042	$572,496,433	4.13%	11.37%
	Fred Hutchinson Cancer Research Center	$166,767,391			
3	Johns Hopkins University	$510,005,326	$520,318,658	3.76%	15.12%
	Johns Hopkins Bayview Medical Center	$10,313,332			
4	University of Pennsylvania	$418,546,510	$481,742,386	3.48%	18.60%
	Children's Hospital of Philadelphia	$63,195,876			
5	University of California San Francisco	$365,365,909	$365,365,909	2.64%	21.24%
6	Washington University	$343,792,077	$362,856,749	2.62%	23.85%
	Barnes-Jewish Hospital	$19,064,672			
7	University of California Los Angeles	$317,017,181	$351,549,652	2.54%	26.39%
	Harbor-UCLA Research & Educ Inst	$17,636,764			
	Cedars-Sinai Medical Center	$16,895,707			
8	University of Pittsburgh	$308,144,862	$334,984,611	2.42%	28.81%
	Children's Hospital of Pittsburgh	$14,038,072			
	Magee-Women's Hospital	$12,801,677			
9	University of Michigan	$325,786,206	$325,786,206	2.35%	31.16%
10	Yale University	$289,899,944	$289,899,944	2.09%	33.25%
11	Duke University	$277,393,166	$277,393,166	2.00%	35.26%
12	Columbia University New York	$269,844,585	$269,844,585	1.95%	37.20%
13	University of North Carolina Chapel Hill	$264,263,425	$264,263,425	1.91%	39.11%
23	Baylor College of Medicine	$263,540,460	$263,540,460	1.90%	41.01%

14	Stanford University	$247,636,170	$247,636,170	1.79%	42.80%
15	University of California San Diego	$244,713,718	$244,713,718	1.77%	44.57%
16	University of Wisconsin Madison	$227,807,000	$227,807,000	1.64%	46.21%
17	University of Minnesota	$217,209,642	$217,209,642	1.57%	47.78%
18	University of Alabama At Birmingham	$211,672,387	$211,672,387	1.53%	49.31%
19	Case Western Reserve University MetroHealth Center	$203,883,400 $485,070	$204,368,470	1.48%	50.78%
20	University of Colorado Health Sciences Ctr Nt'l Jewish Center for Immun Children's Hospital (Denver)	$167,864,080 $27,938,188 $1,451,704	$197,253,972	1.42%	52.21%
21	Vanderbilt University	$195,248,691	$195,248,691	1.41%	53.62%
22	Cornell University North Shore University Hospital Hospital for Special Surgery Catholic Med Ctr Brooklyn Queens Nursing	$161,810,695 $12,354,989 $6,325,756	$180,491,440	1.30%	54.92%
23	Emory University	$178,520,037	$178,520,037	1.29%	56.21%
24	Boston University Boston Medical Center	$146,715,535 $27,529,948	$174,245,483	1.26%	57.47%
23	University of Southern California Children's Hospital of Los Angeles	$151,663,710 $16,796,261	$168,459,971	1.22%	58.68%
24	University of Texas SW Med Ctr/Dallas	$161,988,879	$161,988,879	1.17%	59.85%
25	University of Iowa	$158,018,371	$158,018,371	1.14%	60.99%

**data for 1996 since 2000 data unavailable

* The data for this table are for FY2002 and publicly available at http://grants1.nih.gov/grants/award/awardtr.htm#c. However, it is important to note that this data is intended represent the overall distribution of NIH funding among all AHCs not to predict the specific amount of funding at individual AHCs.

BIOGRAPHICAL SKETCHES

SOLOMON H. SNYDER, MD (Chair) is Director of the Department of Neuroscience and Distinguished Service Professor of Neuroscience, Pharmacology and Psychiatry at The Johns Hopkins University. Dr. Snyder received his undergraduate and medical training at Georgetown University and his psychiatric training at The Johns Hopkins University. In 1966 he joined the staff of the Department of Pharmacology at The Johns Hopkins University School of Medicine.

Dr. Snyder is the recipient of numerous professional honors, including the Albert Lasker Award for Basic Biomedical Research (1978), Honorary Doctor of Science degrees from Northwestern University (1981), Georgetown University (1986), Ben Gurion University (1990), Albany Medical College (1998), Technion University of Israel (2002), the Wolf Foundation Prize in Medicine (1983), the Dickson Prize of the University of Pittsburgh (1983), the Bower Award from the Franklin Institute (1991), the Bristol-Myers-Squibb Award for Distinguished Achievement in Neuroscience Research (1996) and the Gerard Prize of the Society for Neuroscience (2000). He is a member of the National Academy of Sciences, a Fellow of the American Academy of Arts and Sciences and the American Philosophical Society. He is the author of more than 1000 journal articles and several books including Uses of Marijuana (1971), Madness and the Brain (1974), The Troubled Mind (1976), Biological Aspects of Abnormal Behavior (1980), Drugs and the Brain (1986), and Brainstorming (1989).

Many advances in molecular neuroscience have stemmed from Dr. Snyder's identification of receptors for neurotransmitters and drugs and elucidations of the actions of psychotropic agents. The application of Dr. Snyder's techniques has enhanced the development of new agents in the pharmaceutical industry by enabling rapid screening of large numbers of candidate drugs. He founded Guilford Pharmaceuticals Inc. in 1993.

MICHAEL M.E. JOHNS, MD is Executive Vice President for Health Affairs of Emory University, Director of the Robert W. Woodruff Health Sciences Center, Chairman of Emory Healthcare, and Professor in the Department of Surgery, Emory University School of Medicine.

He began his career in the Medical Corp of the U.S. Army as assistant chief of the Otolaryngology Service at Walter Reed Army Medical Center, 1975 to 1977. He joined the Department of Otolaryngology and Maxillofacial Surgery at the University of Virginia Medical Center in 1977 and moved to Johns Hopkins University as professor and chair of Otolaryngology-Head and Neck Surgery in 1984. He served six years as Dean of the Johns Hopkins School of Medicine and Vice President for Medical Affairs at Johns Hopkins University. Dr. Johns is recognized for his work as a cancer surgeon of head and neck tumors and his studies of treatment outcomes.

He is the editor of the Archives of Otolaryngology and serves on the editorial board of the Journal of American Medical Association. He is fellow of the American Association for the Advancement of Science. He is a member of the Institute of Medicine and has served on its Council. He is Chairman of the Association of Academic Health Centers and is immediate past president of the American Board of Otolaryngology.

Dr. Johns obtained his M.D. with honors at the University of Michigan Medical School. During his career, he has been actively involved in the development of educational programs, and was instrumental in the revamping of the Johns Hopkins medical curriculum to meet changing health care needs. He has published and spoken widely on a board range of health policy issues.

JAMES J. MONGAN, MD is President and Chief Executive Officer of Partners HealthCare, a position he assumed on January 1, 2003. Partners is a non-profit integrated academic health care system founded in 1994 by Massachusetts General Hospital and Brigham and Women's Hospital. He is also Professor of Health Care Policy and Professor of Social Medicine at Harvard Medical School. From 1996-2002, Dr. Mongan served as President of Massachusetts General Hospital, the largest and oldest teaching affiliate of Harvard Medical School. MGH is consistently ranked among the top few hospitals in the nation and oversees the largest research program of any hospital or medical center in the United States.

Before his tenure at MGH, Dr. Mongan served 15 years as Executive Director of the Truman Medical Center in Kansas City and as Dean of the University of Missouri-Kansas City School of Medicine. Prior to that, he spent 11 years in Washington, DC. He served as a staff member of the United States Senate Committee on Finance for seven years, working on Medicare and Medicaid legislation, and he served in the Carter Administration as Deputy Assistant Secretary for Health and then at the White House as Associate Director of the Domestic Policy Staff.

Dr. Mongan is a member of the Institute of Medicine of the National Academy of Sciences. He chairs the Commonwealth Fund Health Care Reform Program Advisory Committee. He has served on the Board of Trustees of the American Hospital Association, the Kaiser Family Foundation and was a member of the Prospective Payment Assessment Commission of the US Congress.

A native of San Francisco, Dr. Mongan received his undergraduate education at the University of California, Berkeley and Stanford University, and his medical degree from Stanford University Medical School. He completed his internship at

Kaiser Foundation Hospital in San Francisco and served two years in the public health service.

JIM UTASKI is Founding Partner of Whitestone Capital, LLC, a venture capital firm located in Princeton, NJ. Whitestone Capital is engaged in funding seed and early stage companies who will benefit from senior level advice in their development stage.

Prior to founding Whitestone Capital, Jim held various national and international positions for over 25 years with Johnson & Johnson. Before retiring he held the post of Johnson & Johnson Corporate Officer and Vice President, Corporate Development, which included responsibility for mergers and acquisitions as well as heading Johnson & Johnson's venture capital group, the Johnson & Johnson Development Corporation. During his tenure several strategic acquisitions were made, including the following: Neutrogena (Consumer Products), Cordis, Joint Medical Products, DePuy (Medical Devices) and Centocor (Biotechnology).

He previously served as Chairman of the Board of FIRST (For Inspiration and Recognition of Science and Technology), a not-for-profit national high school robotics competition, and is currently Vice Chairman. He is a former member of the Board of Trustees of the Cancer Research Institute of New York City, and is past President of the Bucknell University Parents Board while also serving as a member of the University Board of Directors.

Mr. Utaski received a bachelor's degree from Northwestern University and an MBA from Harvard Business School in 1963. He and his wife, Nancy, are the parents of three children and have four grandchildren.

REFERENCES

[1] PCAST Subcommittee on Federal Investment in Science and Technology, 'Draft Summary Report: Technology Transfer of Federally Funded R&D." (Washington: President's Council of Advisors on Science and Technology, 2003).

[2] http://www.nttc.edu/products/guide/seca01.html

[3] The Commonwealth Fund Task Force on Academic Health Centers, *Bench to Bedside: The Current Status of Research at Academic Health Centers*. (New York: The Commonwealth Fund, 1998).

[4] Blumenthal D, Campbell EG, "Academic Industry Relationships in Biotechnology: Overview," in *The Encyclopedia of Ethical, Legal & Policy Issues in Biotechnology*, eds. MJ Mehlman and TH Murray (New York: John Wiley & Sons, Inc. 2000).

[5] Blumenthal D, "Academic-Industry Research Relationships in the Life Sciences: Extent, Consequences and Management," *Journal of the American Medical Association* 268, no.23 (1992): 3334-3339.

[6] Blumenthal D, Causino N, Campbell EG, Louis KS, "Relationships Between Academic Institutions and Industry in the Life Sciences—An Industry Survey," *N Engl J Med* 334, no. 6 (1996): 368-373.

[7] Blumenthal D, Campbell EG, Causino N, Louis KS, "Participation of Life Science Faculty in Research Relationships with Industry," *N Engl J Med* 335, no. 23 (1996): 1734-1739.

[8] Mansfield E, "Academic Research and Industrial Innovation," *Research Policy* 20, no. 1 (1991): 1-12.

[9] Narin F., Hamilton KS, Olivastro D, "The Increasing Linkage Between U.S. Technology and Public Science," *Research Policy* 26, no. 3 (1997): 317-330.

[10] Cohen WR, Florida R, Goe WR, *University-Industry Research Centers in the United State. (* Pittsburgh: Carnegie Mellon University, 1994).

[11] The survey had a response rate of 48%.

[12] Jaffe AB, "Real Effects of University Research," *The American Economic Review* 79, no. 5 (1989): 957-990.

[13] Jaffe AB, Trajtenberg R, Henderson R. “Geographic Localization of Knowledge Spillovers as Evidence in Patent Citations,” *Quarterly Journal of Economics* 108, no. 3 (1993): 557-598.

[14] Etzkowitz H. “The Making of an Entrepreneurial University: Traffic Among MIT, Industry and the Military, 1860-1960,” in *Science, Technology and the Military,* eds Mendelsohn E, Smith MR, and P. Weingart (Boston: Kluwer Academic Publishers 1988): 515-540.

[15] Etzkowitz H and L Peters. “Profiting from Knowledge: Organizational Innovations and the Evolution of Academic Norms,” *Minerva* Summer (1991): 133-166.

[16] Dorfman NS. “Route 128: The Development of a Regional High Technology Economy,” *Research Policy* 12, no. 6 (1983): 299-316.

[17] Technology Partnership Practice. *Life Sciences & Missouri’s Economic Future: An Opportunity to Build One Missouri*. (Cleveland, Ohio: Battelle Memorial Institute, 2003).

[18] The Commonwealth Fund Task Force on Academic Health Centers. *Bench to Bedside: The Current Status of Research at Academic Health Centers*. (New York: The Commonwealth Fund, 1998): page 11.

[19] Office of Management and Budget, *Budget of the United States Government, Fiscal Year 2003* (Washington: OMB, 2002), 144; and National Institutes of Health, “NIH Almanac, Appropriations, Section 1,” www.nih.gov/about/almanac/appropriations/index.html (18, December, 2002), 257.

[20] National Institutes of Health. “NIH Support for MDs and Ph.Ds,” www.grants.nih.gov/grants/award/trends/mdsphds7001.html

[21] Blumenthal D, Campbell EG, Causino N, Louis KS. “Participation of Life Science Faculty in Research Relationships with Industry,” *N Engl J Med* 335, no. 23 (1996): 1734-1739.

[22] Blumenthal D, Causino N, Campbell EG, Louis KS. 1996.

[23] National Institutes of Health. “NIH Support for MDs and Ph.Ds,” www.grants.nih.gov/grants/award/trends/mdsphds7001.html

[24] CHI Research. Unpublished data from analysis of the Science Citation Index, 2001. This includes articles published in the fields clinical medicine, biomedical research and the health science sections of the Science Citation Index.

[25] Unpublished analysis by Joshua Powers at Indiana State University in 2003. This is for a sample of academic institutions around the US from which continuous data exist (1991-2000).

[26] Fox MF. "Publication, Performance and Reward in Science and Scholarship," in *Higher Education: Handbook of Theory and Research,* ed. JC Smart (New York: Agathon Press, 1985): 255-282.

[27] Unpublished analysis of AUTM data from 1991-2000 by Joshua Powers at the Indiana State University, 2003.

[28] Blumenthal D, Campbell EG, Anderson MS, Causino N, Louis KS. "Withholding of Research Results in Academic Life Science: Evidence from a National Survey of Faculty," *JAMA* 277, no.15 (1997): 1224-1228.

[29] Campbell EG, Clarridge BR, Gokhale M, Birenbaum L, Hilgartner S, Holtzman NA, Blumenthal D. "Data-Withholding in Academic Genetics: Evidence from a National Survey," *JAMA* 287, no. 4 *(*2002): 473-481.

[30] Bowie N. *University-Business Partnerships: An Assessment,* (Lanham, Maryland: Rowan & Littlefield Publishers, Inc., 1994): 78-79.

[31] Stelfox HT, Chula G, O'Rourke K, and Detsky AS. "Conflict of Interest in the Debate over Calcium-Channel Antagonists," *N Engl J Med* 339, no. 2 (1998): 101-106.

[32] Bekelman JE, Li Y, Cross GP. "Scope and Impact of Financial Conflicts of Interest in Biomedical Research," JAMA, 389, no. 4 (2003): 454-459.

[33] Thursby JG and MC Thursby. "Who is Selling the Ivory Tower? Sources of Growth in University Licensing," *Management Science* 48, no. 1 (2002): 90-104.

[34] Colyvas J, Crow M, Gelijns A, Mazzoleni R, Nelson RR, Rosenberg N and Sampat BN. "How Do University Inventions Get into Practice?" *Management Science* 48, no. 1 (2002): 61-72.

[35] Bray MJ and JN Lee. "University Revenues for Technology Transfer: Licensing Fees vs. Equity Positions," *Journal of Business Venturing* 15, no. 5-6 (2000): 385-392.

[36] Siegel, DS, Waldman D, and Link A. "Assessing the Impact of Organizational Practices on the Relative Productivity of University Technology Transfer Offices: An Exploratory Study," *Research Policy* 32, no. 1 (2003): 27-48.

[371] PCAST Subcommittee on Federal Investment in Science and Technology, 'Draft Summary Report: Technology Transfer of Federally Funded R&D."

(Washington: President's Council of Advisors on Science and Technology, 2003): 58.

.
[38] Congressional Research Service. *Issue Brief for Congress: 2000*. (Washington: Congressional Research Service, 2000) www.ncseonline.org/NLE/CRSreports/Science/st-9.cfm?&CFID=9287911&CFTOKEN=21919030.

[39] Institute of Medicine. *Preserving Public Trust: Accreditation and Human Research Participant Protection Programs*. (Washington: National Academy Press 2001).

[40] Wyden, R. "Wyden Says NIH Failed to Secure Affordability, Fairness for Consumers on Taxpayer-Funded Cancer Drug." Press Release. http://wyden.senate.gov/media/2003/06062003_taxol.html.

[41] "Innovation's Golden Goose." *The Economist*, 12, December, 2002.

[42] PCAST Subcommittee on Federal Investment in Science and Technology, 'Draft Summary Report: Technology Transfer of Federally Funded R&D." p.58.

[43] PCAST Subcommittee on Federal Investment in Science and Technology, 'Draft Summary Report: Technology Transfer of Federally Funded R&D." p. 59-62.

[44] PCAST Subcommittee on Federal Investment in Science and Technology, 'Draft Summary Report: Technology Transfer of Federally Funded R&D." p. 63

[45]Association of University Technology Managers. "AUTM Licensing Survey, Fiscal Year 1997."