Future Directions for Federal Research Funding

Merrill Series on
The Research Mission of Public Universities

A compilation of papers originally presented at a conference
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Mabel L. Rice, Editor
Technical editor: Evelyn Haaheim

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Introduction

Mabel Rice

The Fred and Virginia Merrill Distinguished Professor of Advanced Studies and Director, Merrill Advanced Studies Center, The University of Kansas

The following papers each address an aspect of the subject of the eleventh annual research policy retreat hosted by the Merrill Center: *Future Directions for Federal Research Funding*. We are pleased to continue this program that brings together university administrators and researcher-scientists for informal discussions that lead to the identification of pressing issues, understanding of different perspectives, and the creation of plans of action to enhance research productivity within our institutions. This year's focus is the changing climate of research funding, the long timeline involved in developing university research resources (recruitment, high costs of start-up packages, construction of labs and high tech equipment, and other issues) and how to calibrate those investments with the likely sources of funding. Other issues include public advocacy for research, particularly with regard to stem cell research, and how best to guide research enterprises along the intersections of scientific advances, public needs, advocacy and political realities, and scientific resources in universities. The 2007 Merrill retreat provided an opportune time to consider the implications of these changes in public university funding and how the shift affects research infrastructure.

Benefactors Virginia and Fred Merrill make possible this series of retreats: *The Research Mission of Public Universities*. On behalf of the many participants over more than a decade, I express deep gratitude to the Merrills for their enlightened support. On behalf of the Merrill Advanced Studies Center, I extend my appreciation for the contribution of effort and time of the participants and in particular to the authors of this collection of papers who found time in their busy schedules for the preparation of the materials that follow.

Fifteen senior administrators and faculty from five institutions in Iowa, Kansas, Missouri, and Nebraska attended; they were joined by members of the Merrill Center board of directors; Jeremy Anderson, from the Kansas Governor's Office, and Keith Yehle, Director of Government Relations at KU. Keynote speaker James Battey, Director of the NIDCD at NIH, initiated the discussion by presenting his assessment of the status of stem cell research and the efforts of the NIH to foster development in that research. In addition to those presenters whose remarks are published here were participants who served as discussants. These include Kathleen McCluskey-Fawcett, who contributed a valuable perspective as a member of the Merrill Board and as Senior Vice Provost of Academic Affairs. Though not all discussants' remarks are individually documented, their participation was an essential ingredient in the general discussions that ensued and the preparation of the final papers. The list of all conference attendees is at the end of the publication.

The inaugural event in this series of conferences, in 1997, focused on pressures that hinder the research mission of higher education. In 1998, we turned our attention to competing for new resources and to ways to enhance individual and collective productivity. In 1999, we examined in more depth cross-university alliances. The focus of the 2000 retreat was on making research a part of the public agenda and championing the cause of research as a valuable state resource. In 2001, the topic was evaluating research productivity, with a focus on the very important National Research Council (NRC) study from 1995. In the wake of 9/11, the topic for 2002 was "Science at a Time of National Emergency"; participants discussed scientists coming to the aid of the country, such as in joint research on preventing and mitigating bioterrorism, while also recognizing the difficulties our universities face because of increased security measures. In 2003 we focused on graduate education and two keynote speakers addressed key issues about retention of students in the doctoral track, efficiency in time to degree, and making the rules of the game transparent. In 2004 we looked at the leadership challenge of a comprehensive public university to accommodate the fluid nature of scientific initiatives to the world of long-term planning for the teaching and service missions of the universities. In 2005 we discussed the interface of science and public policy with an eye toward how to move forward in a way that honors both public trust and scientific integrity. Finally, last year's retreat considered the privatization of public universities and the corresponding shift in research funding and infrastructure.

Once again, the texts of this year's Merrill white paper reveal various perspectives on only one of the many complex issues faced by research administrators and scientists every day. It is with pleasure that I encourage you to read the papers from the 2007 Merrill policy retreat on *Future Directions for Federal Research Funding*.

Executive summary

NIDCD and Stem Cells: Current Challenges and Future Promise

James Battey, Director, National Institute of Deafness and Other Communicative Disorders, NIH

- This paper provides an overview of stem cell research and roadblocks to progress in this area of science.
- When stem cells divide, they can either produce more copies of themselves (self-renewal) or they can produce daughter cells able to differentiate into one or more adult cell types.
- Scientists are using human embryonic stem cells (hESC cells) to explore the molecular mechanisms that determine how a pluripotent, self-renewing cell differentiates into a specialized cell type. Understanding these basic mechanisms of stem cells may enable us to someday mobilize and differentiate endogenous populations of pluripotent cells to replace a cell type ravaged by injury or degenerative diseases.
- Scientists require a more complete understanding of the molecular mechanisms that drive pluripotent cells into differentiated cells before they can attempt to use stem cell derivatives for clinical applications. Scientists will need to pilot experimental transplantation therapies in animal model systems to assess the safety and long-term stable functioning of transplanted cells.
- At present, there is no Federal law that limits research involving human embryos and embryonic stem cell research. However, limits have been placed on Federal funding for scientific research. Scientists may pursue research that may not be funded by the Federal government, so long as they procure non-Federal funds for such work.
- To help scientists identify stem cell lines eligible to receive Federal funding, the NIH created the Human Embryonic Stem Cell Registry (the Registry), which lists all human embryonic stem cell lines—at varying stages of development—that meet the President's eligibility criteria.
- Beginning in 1996 and every year thereafter, the Human Embryo Research Ban to the Department of Health and Human Services (DHHS) annual Appropriation Act prohibits the use of funds appropriated to DHHS to support the creation of a human embryo for research purposes or research in which a human embryo is destroyed, discarded, or subjected to risk of injury or death greater than that allowed under Federal requirements for fetuses in utero.
- hESC lines are extremely difficult to grow in culture. Since only a few laboratories in the United States are growing these cells, there is a shortage of people well-versed in the art and science of successful hESC culture.

- NIH offers training grants for institutions to provide hands-on training in the techniques needed to culture hESCs. In addition, the NIH is supporting training in many independent laboratories funded to perform investigator-initiated hESC research.
- NIH is supporting efforts at several different institutions to establish culture conditions using only well-defined components. The University of Wisconsin has reported progress towards eliminating the need for feeder cells either to establish or propagate hESC lines.
- NIH-supported Infrastructure Grant Awards have resulted in the generation of 21 human embryonic stem cell lines that are eligible for Federal funding and are ready to be shipped to investigators.
- NIH initiated a research and development contract to fund a National Stem Cell Bank (NSCB) at WiCell. It is the responsibility of the NSCB to consolidate as many of the 21 available lines as possible in one location, standardize quality control, and reduce the cost of the cells provided to researchers.
- While it is clear that transplantation-based therapies using hESCs are far from imminent, we can never know the full potential of these remarkable cells unless we embark on this important area of biomedical research.
- Research opportunities and advances, as well as links to other information about stem cell research can be found on the NIH Stem Cell Information Web site: stemcells.nih.gov.

Sustained and Balanced Investment in Research & Innovation Critical to U.S. Competitiveness

Prem Paul, Vice Chancellor for Research, University of Nebraska-Lincoln

- The United States' leadership in the global economy has been achieved through technological innovation resulting from significant investments in research and development (R&D). The majority of the R&D investment, especially for fundamental research, has been made through the federal agencies.
- The history of federal support of research and development over the past 30 years shows peaks and valleys in the level of federal R&D funding. These peaks and valleys represent periods of de-prioritization when other needs, such as social services, took larger shares of the federal budget, followed by an awakening to new challenges and a re-commitment to research and development.
- In more recent times, Congress and the President supported doubling of the National Institutes of Health (NIH) budget from 1998 to 2003, with increases of 15% per year. Unfortunately, the NIH budget has not increased since the doubling, but has flattened and actually decreased when adjusted for inflation.
- Although the doubling of NIH funding addressed the needs of medical research from 1998-2003, funding for the physical sciences and engineering suffered. This time, the stimulus for re-awakening the nation was the report "Rising Above the Gathering Storm: Energizing and employing America for a Brighter Economic Future" prepared by the National Academies of Science.
- The report suggested that we are not keeping up with other countries, that we must invest in developing our talent base in science, mathematics and engineering, and

that we must support fundamental research, which is the key to innovation. The report also stated that research and innovation talent, the availability of a qualified workforce, the quality of research universities, and federal support for research and development are all critical in attracting and retaining the multinational corporations that create jobs.

- This report has had enormous impact in awakening the U.S. to the need for additional investments in R&D. The American Competitive Initiative was launched by President Bush in 2006 with the promise of doubling funding for the NSF, DOE Office of Science, and the National Institute of Standards and Technology. Congress also has embraced the recommendations of the report.
- Still, the proposed NIH budget for FY08 is $28.8 billion. If enacted, this will be 7.4% below the 2004 highest level after adjusting for inflation. The NIH budget for the past five years has been flat and real purchasing power is 13% below that of 2003.
- Currently, distribution of total R&D as well as federal R&D obligations is disproportionate amongst states and between disciplines. Fortunately, Congress initiated the Experimental Program to Stimulate Competitive Research (EPSCoR) in 1978 to build capacity and infrastructure and better position under-funded states to compete for federal R&D.
- Currently, the IDeA program is now the largest such program, with more than $220 million in funding and has two primary programs – Centers of Biomedical Research The federal-wide EPSCoR/IdeA investment has been highly successful in building research infrastructure and has contributed to research capacity in 23 states.
- We as a nation need to continue to provide sustained investment for R&D to ensure long-term prosperity and global competitiveness. These investments need to be balanced across various disciplines and geographic regions to ensure that all of our available talent is engaged in the research and innovation necessary for us to compete successfully in the global economy.

The Importance of External Grant Support for a Public College of Arts and Science

Joseph Steinmetz, Dean, College of Liberal Arts & Sciences, University of Kansas

- External grant support of research provides a great deal of the funds that are necessary for members of the faculty to explore their research and scholarship. External grant support often provides the means for introducing undergraduate students to the world of research and scholarly pursuits.
- The undergraduate mission of Research I colleges of arts and sciences is to expose undergraduates to a wide variety of academic and provide exposure to a variety of research and creative activities that involve members of the faculty as well as postdoctoral scholars and graduate students.
- Faculty and students of colleges of arts and sciences in public institutions provide much of the research, scholarship and creative activity that form the bases of inquiry and the gathering and disseminating of knowledge.
- Given the large commitments to undergraduate and graduate teaching, faculty appointments in colleges of arts and sciences are quite different than in medical schools and research centers or institutes. Inevitably, there are conflicts that arise between teaching and research.

- The landscape of colleges of arts and sciences is in part driven by national priorities for research and teaching. Recently, there has been a trend that favors the formation of larger interdisciplinary and multidisciplinary teams of investigators. There has been a general building of the life sciences, in part because of the doubling of the NIH budget that has occurred over the past decade or so.
- Loss of external research support has some obvious negative consequences, including difficulty maintaining research programs, diversion of funds from under-funded areas of scholarship. Graduate and undergraduate participation in ongoing faculty and graduate student research would suffer, and the gap between funded researchers and unfunded might widen to a gulf. Important areas of study may disappear for lack of support as faculty are hired into areas thought to be of higher priority by external funding agencies.
- To ensure that research and scholarship continue to flourish in colleges of arts and sciences, we must encourage the establishment of interdisciplinary and multidisciplinary centers so as to make use of the full range of talent we have as effectively as possible. Departments and programs must keep up with current trends in their respective fields so they can take advantage of funding opportunities.
- Undergraduate and graduate students need to be prepared for careers with the skills necessary to help assess and identify future trends and directions. Faculty research for work in new areas should be supported, and faculty research bridge funding made available when funding levels are tight. University infrastructure that emphasizes group participation must be developed; this will require a shift in culture for many institutions.
- Federal funding policy makers should recognize that:
  1. Disciplines in the arts and sciences are important and worthy of continued study. The contributions of social and behavioral scientists, computationalists and humanists are great.
  2. More funding should be provided for career changes so that our brightest scholars are able to enter new research areas.
  3. Interdisciplinary and multidisciplinary approaches should be emphasized for training grants and other funding opportunities made available to graduate students and postdoctoral scholars.
- University administrators and those at external funding agencies must work more closely together to make sure that what is going on in the two spheres is maximally aligned and coordinated. There is a lot at stake here as our future rests largely with the students who currently occupy the seats in classrooms within our colleges of arts and sciences.

Update on the General Clinical Research Program and The Heartland Institute for Clinical and Translational Research

Richard Barohn, M.D., Professor and Director, Heartland Institute for Clinical and Translational Research, Kansas University Medical Center

Lauren S. Aaronson, Ph.D., R.N., Deputy Director, Heartland Institute for Clinical and Translational Research

- This presentation provides an update on both the General Clinical Research Center (GCRC) and the Heartland Institute for Clinical and Translational Research (HICTR).
- GENERAL CLINICAL RESEARCH CENTER (GCRC). A GCRC is an NIH-supported multidisciplinary research unit that facilitates investigator-initiated clinical studies and trials conducted by full-time faculty at an academic health center. We began the process of initiating a GCRC for the KUMC campus in 2002
- In January 2005 our GCRC became operational, and we began seeing subjects. In 2006, we applied for an NCRR/NIH grant, which was funded in April 2007 for $7.5 million over three years. As of August 2007, we have approved 82 protocols that use the GCRC resources.
- With the NIH funding, three new programs are also now available to young researchers: the Clinical Research Feasibility Funds (CReFF), Clinical Research Scholars Program (CRSP) and the Summer Clinical Research Program for Medical Students.
- In April 2007, Barbara Atkinson announced the formation of the Heartland Institute for Clinical and Translational Research. The HICTR is the infrastructure and vehicle for our CTSA application.
- In October 2005, the NIH released an RFA for institutional Clinical and Translational Science Awards (CTSA), "to transform the local, regional and national environment for clinical and translational science, thereby increasing the efficiency and speed of clinical and translational research…by creating an academic home…that integrates clinical and translational science across multiple departments, schools, clinical and research institutions".
- The HICTR extends beyond the walls of KUMC and the University of Kansas Hospital, bringing together several academic health centers and their affiliated hospitals and clinics. The HICTR is the academic home for clinical and translational research at KUMC and in the Kansas City region.
- Three resource centers were established to primarily support bench to bedside research, clinical research conducted within the walls of dedicated clinical research units, and community-based and bedside to practice research: the Novel Methods & Translational Technologies Resource Center (NM/TTRC), the Clinical Research Resource Center (CRRC), and the Population Health Research Resource Center (PHRRC).
- The HICTR also includes a dynamic Clinical and Translational Research Education Center (CTREC), which administers a pre-doctoral T32 program, a post doctoral K12 program, and numerous other educational and training programs including mentor training and support and a clinical research coordinator certificate training program.
- The NIH CTSA program is a major change in how the NIH is funding and supporting clinical and translational research. The ultimate goal of the CTSA program

is to see that the public's health is improved through more rapidly transferring results from increasing amounts of clinical research to actual health care practice.

The Natural History of a Federally Funded Researcher

Jordan Green, Associate Professor and Corwin Moore Chair in Communication Disorders, University of Nebraska-Lincoln

- The discipline of Communication Science & Disorder (CSD) provides a valuable window into current issues in the life of a behavioral scientist.
- Scientific discovery in the field of CSD is accumulating very slowly. The bases for most speech problems remain unknown and the diagnoses and prognoses of speech disorders are very subjective. Identifying objective criteria for classifying speech disorders has been an ongoing challenge and a major focus in the field.
- Progress in CSD research has been slowed by a leadership crisis, methodological limitations, and federal funding shortages. The field of CSD currently faces a shortage of Ph.D. students with the number of graduates falling short of the number needed to replace retiring faculty.
- The University of Nebraska-Lincoln (UNL) Undergraduate Creative Activities and Research Experience (UCARE) program provides undergraduates with funds to support a two-year research experience. More programs like UCARE are needed to raise students' awareness and interest in research careers.
- A number of initiatives have been implemented by ASHA, NIH, and UNL to encourage the development of new investigators. NIH's programs include the Small Grant Program (R03) and High Program Priority (HPP).
- Another significant challenge to training the next generation of researchers is the shrinking supply of available mentors. Several UNL initiatives are in place (the Grant Mentor and the Preparing Future Faculty Programs) to encourage the formation of mentored relationships between senior faculty, new faculty, and graduate students.
- More programs - like the NIH grant review training workshop sponsored by ASHA's Research and Scientific Affairs Committee - are needed to train the next generation of study section members and journal reviewers.
- Despite its obvious significance to quality of life, speech motor control is a topic that has been understudied. The dearth of scientific work is, in part, because speech is exceedingly difficult to measure. New technologies are needed for accelerating the rate at which researchers can acquire and analyze speech data. Fortunately, the NIH offers the Shared Instrumentation Grant (S10) that provides up to $500,000 annually for equipment related expenses needed by groups of NIH-funded investigators.
- Continuing education is also needed to make researchers aware of emerging technologies. To assist in educating the scientific community, NIH-NIDCD has sponsored several state-of-the-science workshops.
- The reduction in the relative number of grants awarded annually will have deleterious effects on research and education in this country. One necessary strategy to reduce the impact of the current funding crunch will be the formation of multicampus consortiums. Consortiums accelerate pace of discoveries by providing the most efficient means for scientist with diverse perspectives to achieve scientific consensus.

- The long-term goal of our research program is to advance the scientific understanding of speech production and its disorders. One necessary and particularly challenging aspect of our work has been the development of new tools for recording, measuring, and analyzing speech performance. To address this challenge, we have adapted 3D motion capture technology to obtain fine-grained measurements of face movements from infants and young children.
- ALS, which is another focus of our research program on speech production, is a progressive neurodegenerative disease that affects motor nerve cells in the brain and the spinal cord. The goals of our research on ALS are to identify sensitive, quantitative indicators of disease progression. To achieve these goals, we are using the technologies we have developed to study early speech motor development to quantify the natural history of disease progression in individuals with ALS - work which is currently funded by an initiative from the UNL Vice Chancellors of Research office to facilitate inter-campus consortiums.
- In summary, I have given the researcher's perspective on current challenges faced by my discipline and considered several measures to address these challenges which include s training the next generation of scientists, doing bigger, better science through consortiums, focusing funding efforts toward overcoming technological hurdles, and providing continuing education for scientists. A number of outstanding initiatives have already been put into place by the federal government, professional agencies, and universities to address many of these issues. These initiatives, although modest in size, suggest the research community is headed in the right direction.

Industry Funding of University Research: Can It Replace Federal Funding?

James A. Roberts, Vice Provost for Research, University of Kansas

- The latest funding information for U.S. universities shows that there was a decline in federal funds going to U.S. universities and colleges for research.
- While the percent of R&D funded by industry has been growing, the percent funded by the federal government has been declining, basically since the early 1960s, the post-Sputnik era.
- What fraction of university research funding comes from industry? The percentage has declined from a paltry 1.5% in the early 1990s to where it now hovers at about 1%.
- From the mid-1960s until about 2005 federal funding of university research grew exponentially. The approximate slope of the line indicates an annual growth rate of about 8.1%.
- Suppose that the total research funding level grows at the historic rate, as do state and other sources. Federal funding flattens, and industrial funding is computed to maintain the total. In order to do that, industrial funding of university research would suddenly have to begin growing at 40% annually, compared to an annual growth rate of 4.4% over the past 10 years. And in the end, by 2013, industrial funding would actually exceed federal funding. This simply isn't going to happen.
- What would be the unintended consequences if industry were in fact to make up for the reduced federal funding at universities? What would happen to funding levels

in specific fields of study? What would happen to the mix of basic versus applied research? Would the geographic distribution of research funding change?

- A shift in funding source from federal to industrial might result in a shift to engineering and pharmacy, with a corresponding reduction of funding in the social sciences, natural sciences, and education. In short, the fields with more opportunity for applied research might benefit disproportionately.
Industry tends to fund applied research and development, while the federal government funds basic research. In the scenario presented earlier, where industrial funding replaces flattened federal funding of research, if industry continued to spend only 5% of its budget on basic research there would be a drop of $19.4 billion by 2013 in basic research funding to universities.

- 85% of all U.S. research funding is conducted in the 'coastal' states. Both state and industrial funding have been growing more rapidly on the coasts than in the interior. The problem of unequal distribution of research funding is exacerbated by a shift from federal sources to industrial sources.

- To summarize: none of this is intended to say that industrial funding of research is not important. It absolutely is, and we in academia and the country in general need industrial collaborations. But if one asks the question "Can industry make up for a reduction in federal funding of research?" the answer is "Very unlikely." Not only that, there are some negative consequences if it were to happen.

- Basic research is crucial to the future of our society, and universities are where it is happening. To maintain our leadership as a nation, we must fund curiosity-based research that is not driven by agendas or intentional outcomes.

- In 1945, Vannevar Bush wrote: "Basic research is essentially non-commercial in nature. It will not receive the attention it requires if left to industry. …The simplest and most effective way in which the government can strengthen industrial research is to support basic research and to develop scientific talent."

Initiatives to Increase Faculty Competitiveness for Federal Research Funding

Beth A. Montelone, Associate Dean, College of Arts and Sciences, Kansas State University

- Extramural research funding is the lifeblood of research universities, and few faculty members are unaware that competition for Federal research dollars has become ever more intense in recent years.

- Kansas State University (K-State) has created or participates in a series of initiatives with primary or secondary goals of providing mentoring and/or resources to assist new faculty members in establishing the successful research programs necessary to achieve tenure. Several of these and their outcomes to date are described below.

- Center of Biomedical Research Excellence (COBRE) in Epithelial Health and Disease: The NIH-funded COBRE award to Dr. Daniel Marcus of the Department of Anatomy & Physiology in the College of Veterinary Medicine (CVM) began in 2002. It provides seed funding to the junior faculty and establishes a partnership with a mentor, with the goal of making the junior faculty competitive for independent NIH funding.

To date, six junior faculty members have successfully "graduated" out of the program and are now tenured.

- Kansas Idea Network of Biomedical Research Excellence (K-INBRE): K-State is a partner in this program, which is hosted at the University of Kansas Medical Center. It is funded through the National Institutes of Health Center for Research Resources for the purpose of strengthening biomedical research and training researchers in cell and developmental biology in the state of Kansas. The K-INBRE program has made Faculty Scholar Awards, Starter Grants, and Pilot and Bridging Awards to faculty members from K-State and other KS campuses
- Targeted Excellence: The K-State Targeted Excellence project is funded through the K-State Provost's Office from tuition monies. It was created in 2003 and is intended to enhance inter-disciplinary programs that show the most promise of elevating the university's stature. The program considers cross-departmental projects that involve multi-disciplinary themes or ideas, projects that may vary in length from short-term (one to two years) to long-term (up to five years), and requests from $50,000 to $2,000,000.
- The largest of these awards established new research centers and provide seed funding to stimulate innovative and collaborative research, and provide an important university resource for encouragement, support, and mentoring of junior faculty members. They are the *Ecological Genomics Institute* , the *Center for Genomic Studies on Arthropods Affecting Human, Animal, and Plant Health*, and the *Center for Bio-based Polymers by Design*.
- K-State Mentoring Program: The KSU Mentoring Program for Women and Minority Faculty in the Sciences and Engineering was created in 1993 with a grant from Sloan Foundation. It requires junior faculty members to identify a mentor in their discipline and provides small ($6000) awards that can be used for a variety of purposes. The most common requests include seed money for research supplies and assistants, professional travel, and attendance at short courses.
- K-State ADVANCE Institutional Transformation: K-State received a $3.5M Institutional Transformation Award from NSF in 2003. This five-year project, supported by the ADVANCE program, is intended to promote an equitable environment in which both male and female faculty members in science and engineering can thrive and succeed. Some of the ADVANCE programs are described below.
- The *ADVANCE Distinguished Lecture Series* is intended to help develop the professional network of junior women faculty and diffuse the effects of being isolated as the only woman in a department and geographic isolation in Manhattan. *Parallel Paths* is a peer group mentoring program in College of Veterinary Medicine. The *Career Advancement Program* addresses the transition from associate to full professor as well as providing opportunities for women interested in administration to gain experience in this area.
- The ADVANCE Project is in its fourth year. Early results show impressive increases in numbers of women faculty and increases in the ranks of tenured and full professor women in science and engineering.
- Collaborative for Outreach, Recruitment, and Engagement in STEM (Science, Technology, Engineering, and Mathematics) (CORES): Unlike the other programs described above, the CORES project does not provide direct mentoring or funding for

junior faculty members. Its goals are to synergistically enhance all of its constituent programs, facilitate recruiting and tracking of students, recruit students to K-State undergraduate and graduate programs, and to institutionalize and facilitate "broader impact" activities for K-State faculty preparing grant proposals.

- Kansas State University has recognized the need to cultivate junior faculty members by providing them financial resources and a supportive climate in order to enable them to become established extramurally funded researchers. Our programs, including the COBRE in Epithelial Health and Disease, Targeted Excellence, K-State Mentoring, ADVANCE, and CORES, are funded by a combination of extramural and internal sources. Return on investment data, where available, suggest that these are monies well spent.

The Time is Now: A 10-Year Vision and Strategy to Advance the Life Sciences

Barbara Atkinson, Executive Dean and Vice Chancellor for Clinical Affairs, KU School of Medicine

- The University of Kansas Medical Center has embarked on a 10-year journey to become a world-class life sciences research and teaching institution.
- The University of Kansas Medical Center's (KUMC) 10-year life sciences strategy is based on a regional collaboration among the region's many life sciences assets. This long-term strategy is further bolstered by the area's focus on entrepreneurial and collaborative life sciences research activities.
- As articulated by the Greater Kansas City Community Foundation's *Time to Get it Right* report, a successful life sciences strategy for the greater Kansas City region must include significant investments in its academic institutions. KUMC must be at the forefront to promote a united regional vision that transcends the state line to bring area assets together for a common purpose.
- At the same time, we remain steadfast in our education mission and recognize that quality researchers and clinicians often make the best teachers for our students.
- The 10-year journey requires transformation at many levels. A key component to this transformation will be a renewed focus on advancing the translational research capabilities of KUMC across many disciplines.
- The foundation for excellence in translational research already exists within KUMC. In October 2006, the NIH awarded KUMC, the Kansas City University of Medicine and Biosciences, and the Kansas City Veterans Administration Hospital – collaborators in the new Heartland Institute for Clinical and Translational Research (HICTR) – one of the new Clinical and Translational Science Award planning grants.
- In addition, KUMC just received another NIH grant totaling $7 million to support translational and clinical research in the Kansas City area. Together, these two grants position the HICTR to facilitate the translation of lab discoveries into lifesaving cures and to become a national model for excellence.
- Connected with the HICTR is the drug discovery initiative at both the Kansas City and Lawrence campuses. A key player in this process is the Office of Therapeutics, Discovery and Development (OTDD), which was developed and launched in January

2006 as a bi-campus initiative to streamline and improve the drug discovery and development process.

- The transformation of KUMC will require significant growth – and to that end, significant philanthropic and private investment. Over the next 10 years, KUMC will require an ongoing investment from the community to recruit 152 senior and 92 junior faculty and build and outfit more than 862,500 square feet of new research space.
- The 10-year costs for faculty and facilities are estimated at $798.6 million. While $798.6 million may seem extravagant, all economic indicators point to the potential for this investment to reap economic impact in the billions of dollars for years to come.
- A 10-year, $798.6 million investment supporting established, emerging, and translational research programs and shared resources at KU and KUMC will bring to our region new jobs, new scholars, and new discoveries. It will foster economic development while improving our ability to train health care professionals, and it will give those professionals better options for treating devastating diseases. The transformation is within our reach. Our dream has a plan...help us make it a reality.

Past as Prelude: Lessons for the Future Learned from 50 Years on the Edge

Steven F. Warren, Director, Schiefelbusch Institute for Life Span Studies, Director, Kansas Mental Retardation and Developmental Disabilities Research Center, Professor, Applied Behavioral Science

- How are we to maintain and even expand multi-disciplinary research centers in the current funding climate? What are the secrets to long-term success spanning a wide range of funding climates? The purpose of this paper is to briefly discuss some lessons or principles that I believe can make a real difference.
- Overview of the Life Span Institute (LSI): The mission of the LSI is to create solutions to problems of human and community development, disability, and aging. Currently it is both the oldest and largest research institute at KU with 12 research centers, over 90 PIs and 100 external grants, generating more than 20M in direct costs and 3.7M in indirect costs. The primary stakeholders are: NIH, HHS, USDE, State of Kansas, and various Foundations.
- Since 1960, LSI external funding has increased from $53,000 to over $20,000,000 annually. Over 49 years, $ have gone up 32 years and down 17 years (down 35% of the time). In first 30 years (1960-1990) award $ DECREASED 40% of the time (12 out of 30 years), while since 1990 it has decreased 31% of the time (6 out of 19 years). Also, <u>Multiple year</u> decreases have occurred 4 times.
- At the macro level, there are a lot of positive indicators that suggest the future for university based research centers should be bright in general. Bi-lateral support for science and research is good, and globalization has increased the appreciation for the value of science and research.
- There is an increased need for university research and states are getting into the game in a serious way. In addition, the death of corporate labs has increased the value and need for university research, foundations have more $$$ than ever, and donors will often support "big ideas" (e.g. curing autism, cancer, etc.).

- Caution signs in the macro environment include enormous pressure on the federal budget, rising cost of research infrastructure , and the fact that many universities and most medical research centers are HIGHLY leveraged.
- The Real Dangers: Treating research centers as cash cows, failure to bridge individual investigators during rough spots, cutting back support to centers during short term declines, simplistic forecasting methods, expecting unreasonable growth and "return-on-investment", and decoupling the research mission from the academic and service missions of the university
- Lessons from the Past for the Future: things go up more than they go down, keep a diversified portfolio, build from your strengths and stick to your mission, evolve or die, encourage competition at all levels, listen to the PIs, focus on the "impact" of the work, encourage, support, and reward collaboration at all levels, and persist, persist, persist.
- In summary, universities face very challenging conditions in terms of building the future of their research enterprises. This has mostly been the case in the past as well and so there is nothing really special about the current period. Securing our futures requires that we learn from the successes and failures of the past. Failure to attend to the lessons of the past could be the biggest source of risk in the present environment.

The Emerging Field of Ecological Genomics

Loretta Johnson, Associate Professor, Division of Biology, Kansas State University

- In 1995, the sequence of nucleotide bases (the genetic alphabet) comprising the DNA code for a free-living organism was determined for the first time. Since then hundreds of species have been sequenced, including the human genome in 2004.
- Genomics provides unprecedented opportunities to assess the health and integrity of ecological systems. An ecological system is the assemblage of living organisms interacting with each other and their physical environment. Just as genomics can characterize human responses to disease onset, so might it characterize the functions of ecological systems. Analogous to human medicine, it may be possible to use genomic methods to monitor ecological system responses to the challenges of global changes in environmental health.
- We all depend on ecological systems to sustain us – ecological applications of genomic technologies are therefore likely to be as important as medical uses. Just as we can use genomics in the pursuit of human health, we envision using these same methods to assess adaptive capacity, predict, and maintain the health of our environment.
- Ecological Genomics seeks to understand the genetic mechanisms underlying responses of organisms to their natural and changing environments. These responses include modifications of biochemical, physiological, morphological, or behavioral traits of adaptive significance. Ecological Genomics refers to the use of any genome-enabled approach to identify and characterize genes with ecological and evolutionary relevance.
- An Institute must have a firm foundation in an exciting science question. The overarching science question guiding the institute is: How are organisms adjusting to human-induced biotic and abiotic environmental changes at the genetic level?

- Our institute seeks to examine environmental effects on organisms at the level of genes and gene expression, and identify major genes and pathways directly involved in the organismal response to a changing environment.
- The KSU Ecological Genomics Institute is bringing the genomic revolution to the environment around us to better understand the health of the environment on which we all depend.
- The mission of the Ecological Genomics Institute is to advance the discipline of ecological genomics and to make EGI the center for ecological genomics locally, nationally, and internationally by providing a fertile intellectual environment as well as resources to enable integrated research approaches. The research is now supported through the KSU Provost's program in Targeted Excellence and that has enabled the Institute to expand and develop into the national and international leader in the new field of Ecological Genomics.
- Members of the KSU Ecological Genomics Institute have published 41 manuscripts, one book and two book chapters related to Ecological Genomics since the Institute's inception. Our seed grant program provides approximately 250K per year in funding for pilot studies to make researchers more competitive. Members currently hold 18 extramural grants ($5,468,790) relevant to Ecological Genomics, of which 10 ($2,344,160) were funded since the beginning of the TE project. Six intramural grants have been funded ($4,008,944). $1.15 million investment from TE in first 2 years has resulted in $2.3 million in extramural funds.
- The KSU Ecological Genomics Institute has implemented a number of programs that stimulate and provide support for research in this new field. Our annual ecological genomics symposium, now in its 5th year, attracts ~150 attendees from 45 different universities nationally and internationally. Technical workshops, visiting scholar programs, international student exchanges and other programs have successfully increased the visibility of ecological genomics at Kansas State University.
- Why is this institute so successful? First and foremost, the institute starts with cutting edge and big science questions as its foundation. Furthermore, we take advantage of unique skills and opportunities such as the research platform at Konza Prairie. We provide state of the art infrastructure to do cutting edge research and provide funding opportunities such as seed grants that promote competitiveness.
- Perhaps most importantly, inception of the ecological genomics institute began at the grass roots level, at the level of researchers who have a willingness to "think outside the box" and to "work outside their usual comfort zone". We posit that the next great discoveries in science will be at the intersection of diverse disciplines. Ecological genomics is a new model for such interdisciplinary research.

The Status of Research at Kansas University Medical Center

Paul Terranova, Director, Center for Reproductive Sciences, Kansas University Medical Center

- This paper summarizes KUMC's research progress in FY2006, in response to a request by Dr. Benno Schmidt and the Blue Ribbon Task Force. This Task Force was charged by the Greater Kansas City Community Foundation in early 2005 with evaluating the state of higher education in Kansas City.
- The task force completed its work on July 1, 2005. Their conclusions were subsequently published in the Time to Get it Right (www.gkccf.org), a report that identified two important elements to strengthen higher education in the Kansas City region: 1) a strong urban university and 2) enhanced research capacity.
KUMC reallocated internal funds to address specific issues within the report. The Blue Ribbon Task Force recommended that KUMC:
    - Develop a 10-year strategy to build research capacity
    - Add 100 high-quality researchers
    - Double enrollment in the Ph.D. program
    - Increase the number of postdoctoral fellows
    - Increase external research and development funding from $76M to $300M annually
    - Invest $645M in KUMC over 10 years
- KUMC developed a document entitled The Time is Now: a 10-year Vision & Strategy to Advance the Life Sciences, which was released in January 2007. This 48-page document summarizes KUMC's plan to build research (www.kumc.edu/evc/TheTimeIsNow.pdf).
- KUMC's 10-year vision plan estimates that 244 researchers are required in the established and emerging research programs in order to accomplish its goals. Specific recruits for research included 22 new basic science faculty and 6 clinical faculty from 2005 to 2006.
- Slow progress has been made in 2006 in terms of doubling the Ph.D. enrollment over 10 years as suggested by the Task Force, with a 3% increase in the number of predoctoral students over 2005. The total number of students enrolled for the fall of 2007 is 112 which represent an increase of 9.8% over 2006.
- A 24.6 % increase in the number of postdoctoral students was recorded in the KU School of Medicine from 2005 to 2006. This increase was largely due to increasing the number of faculty, increasing the amount of NIH funding, renewal of institutional NIH postdoctoral training grants, and garnering individual postdoctoral awards from NIH and other private foundations.
- Significant progress has been made regarding increasing external research and development funding from $76M to $300M over the next 10 years. The total dollars awarded in 2006 were $82.1M compared to $68.8M in 2005 (a 19.3% increase).
- Regarding investment of $645M in life sciences research over 10 years suggested by the Task Force, the KUMC 10-year strategy estimates that $798.6M is required. $380M is estimated for recruitment of 152 senior faculty, $73.6M for 92 junior faculty, $345M for additional facilities to house the expanding research faculty and programs.

- These estimates are detailed in 'The Time Is Now—A 10-Year Vision & Strategy to Advance Life Sciences' (www.kumc.edu/evc/TheTimeIsNow.pdf). KUMC and its partner institutions will seek opportunities with the State of Kansas including the Kansas Bioscience Authority, the Kansas City Area Life Sciences Institute, business leaders in the Kansas City region, Philanthropy, national resources including the NIH and other private foundations, Internal University Resources, and partnerships with area institutions that share our vision.

Keeping Our Bearings in Very Rough Seas

Brian Foster, Provost, University of Missouri/Columbia

- We have been presented with a daunting set of changes in the world of higher education-based research, and we can't just ignore them. In 1980, with passage of the Bayh-Dole Act, universities began to be able to profit from inventions of their faculty and staff coming out of federally funded research. Universities are now central to the national, state, and local economic development discussion as never before.
- Fundamental ethical issues about openness, publishing research results, and the like, challenge fundamental ethical premises of higher education. To be clear: these are not necessarily good or bad developments; they clearly are challenging and require fundamental rethinking of the basic premises of university research.
- Higher education has become politicized differently than at any time before. Any political figure can get broad interest in higher education issues, since they directly affect the lives of millions of constituents. In this sense, higher education is in a position much like health care was thirty years ago.
- All of the above has been exacerbated by the challenging state appropriations since the economic downturn in the early 21st century. Across the country, state appropriations were reduced or grew very slowly for the past five years or so, and for state universities, the proportion of total revenue that came from the state dropped dramatically.
- Another area that poses major concerns is the area of compliance, much of which is directly related to research—e.g., IRB, hazardous materials, radiation safety, and animal care. In a time of fiscal challenges, compliance costs have risen dramatically, and the consequences of noncompliance are enormous.
- A dramatic outcome of these changes is that there are growing disparities between the elite privates and the best publics in faculty compensation, in the socioeconomic status of students, in expenditures per student, and so on.
- There are fundamental, probably irreversible changes in the environment for higher education in the U.S. We have to adapt to these new circumstances. In fact, these dynamics rest on some very positive changes—at least from my point of view. The question is, how do we deal with these new dynamics?
- Develop other sources of funds. Some are obvious (e.g., philanthropic fundraising, tech transfer revenues), some challenge the culture of higher education (e.g., commercializing intellectual property). Corporate collaborations, community partnerships, regional cooperation - all could be key factors in achieving what no single

entity could do alone. It is critical that public universities position themselves effectively in their states.

- Effective enrollment management. If universities can shape their program inventory and their student body favorably, they may generate large amounts of new net revenue. This requires very business-like systems for understanding marginal costs, for shaping the student body to grow areas with sufficiently low marginal costs that significant profit centers can be created.
- Serious planning is a complex and demanding process. Good plans are layered in such a way that the mission statement and broad goals are very robust, essentially unchanged for decades, while tactical plans by which the broad goals are achieved are constantly adapting to the environment.
- Getting past our history. We usually think of the structure of higher education—especially curriculum and instruction—in ways that are very constraining, probably not cost-effective, and not the best ways to support student learning.
- Get serious about impact as the measure of success. Much of the stature of higher education institutions is based on characteristics such as restrictiveness of admissions, not the impact of the institutions on students. However, these are crude indicators of impact. In the research area, we tend to rely almost entirely on "poundage" (i.e., the volume of publications), sometimes on citations, and on research dollars generated to evaluate impact.
- We in higher education are in a new world. The environment has changed; the nature of higher education institutions has changed; public expectations have changed. It's challenging, but many of the changes are really triumphs. But business as usual will not work. We are at serious risk of losing all that we value if we don't adapt.

Rough Seas or Normal Swells?

Richard Lariviere, Provost and Executive Vice Chancellor, University of Kansas

- In the course of our discussions at this conference we have discussed many of the current challenges confronting research universities. Some of these matters are national/political issues and others are trends within the academy. I would like to try to place a couple of these issues in some kind of historical perspective.
- Perhaps the most compelling presentation of the conference has been that of Jim Battey on the current promise and challenges to stem cell research. The political storm around stem cell research is familiar to this group. It is important to note that the intervention of political causes in the realm of science is not a new problem. Like stem cell research, anti-communism was once the tool of the demagogue who knew little or nothing of the fundamental issues, but who rode the hobby-horse to electoral gains.
- Jim Battey's presentation is a source of encouragement. The scientists of the NIH clearly are not cowed by the current political interference with scientific inquiry. Such colleagues will rightly take a place of distinction in posterity's view of yet another peculiar moment in the history of science.

- Many of the presentations made by our colleagues here have had as their common theme money. Without adequate funding, the best minds and the most creative ideas will come to very little in the realm of research.
- When I listen to conversations in the academy on the question of society's support for higher education, I hear an understandable frustration verging on anger. This is understandable because most of our colleagues understand that the work that goes on in the academy has the potential to improve, shape, invigorate, and even save society. However, our audiences seldom share the same degree of understanding that we have. We sometimes fail to give them explanations that they can grasp. This is essential if they are to put our needs ahead of other voices in society.
- As Joe Steinmetz pointed out, public institutions are struggling to maintain their competitiveness. Whipsawed by diminishing legislative support and public resistance to tuition increases, staying competitive with the best of our private rivals is difficult.
- Brian Foster spoke of the entitlement status of higher education. He observed that a college degree has supplanted the high school degree as the base level of education that an American student should aspire to in order to achieve a good life. His point is that this shift has colored the conversations about access to higher education and has increased pressure to make accommodations for students who are under-prepared.
- I do not find this cause for alarm. What we do at major research institutions is dramatically different in purpose and effect than what takes place at community colleges and such places as the University of Phoenix. The challenge is in articulating how attending a research university differs from attending a community college.
- The challenge of describing the differences between community colleges and universities is more difficult than it may seem. The majority of American voters do not understand the difference. It is our obligation to be able to reasonably and clearly articulate the difference.
- If we look to history for a similar moment of dramatic shift of university attendance we can find it in the period just after World War II. The passage of the G.I. Bill changed America profoundly. At the time, there was vigorous opposition to this legislation by the higher education establishment. However, this "catastrophic imposition" on higher education resulted in the education of 14 Nobel Prize winners, three Supreme Court judges, three Presidents, 12 Senators, 24 Pulitzer Prize winners – not to mention millions of professionals in various fields.
- Dramatically heightened expectations for higher education is a good thing. But it *has* changed the playing field. We need to justify the huge investment that is being made in what we do. We need to explain what we do more often and more carefully than at any time in the past.
- The politicization of higher education to this degree is largely due to the fact that the stakes associated with what we do have never been greater. Higher education has to bear a greater share of basic research than has been the case at any time since World War II. The costs of higher education are growing at a rate that far outstrips increases in all other sectors except health care.
- Public higher education institutions such as ours are going to have to take more direct responsibility for our fiscal future. A billion dollar endowment for a research institution of 30,000 students is not adequate. Private endowments will be the leading

discriminator in determining which of our institutions will flourish and which will languish.

- There are large and serious challenges confronting higher education. Those challenges are not of any greater magnitude than those faced by previous generations of scholars and scientists in the academy. We have never had more money or greater numbers involved in our work than we have at the moment. It isn't enough money and there aren't enough scientists, teachers, and scholars in the pipeline to sustain what we will need in the future. But those challenges are likely to always be with us. That we have them is a reason for optimism rather than dismay.

Stem Cells: Current Challenges and Future Promise

James F. Battey, Jr., M.D., Ph. D.
Director, National Institute on Deafness and Other Communicative Disorders, NIH
Laura K. Cole, Ph.D.

When stem cells divide, they can either produce more copies of themselves (self-renewal) or they can produce daughter cells able to differentiate into one or more adult cell types. Human embryonic stem cells (hESCs) appear to have an unlimited capacity to self-renew in cell culture and can differentiate into hundreds of adult cell types. Scientists hope to use hESC lines to identify molecular mechanisms of cell fate determination, to culture human cells for use in new drug discovery and toxicity testing, and to generate differentiated cells for novel transplantation therapies. The National Institutes of Health (NIH) identified some roadblocks to progress in stem cell research and developed funding opportunities designed to overcome them. NIH recognizes the unparalleled promise offered by stem cell research, and has made investments in this field a priority for the foreseeable future.

What are stem cells?

Two characteristics distinguish stem cells: (1) they can divide to produce more copies of themselves (self-renewal) under appropriate *in vitro* or *in vivo* conditions, and (2) they are pluripotent, or able to differentiate into most, if not all, mature cell types. Stem cells derived from an early stage human blastocyst (an *in vitro* fertilized embryo after about five days in culture) have the capacity to renew indefinitely, and can theoretically provide an unlimited supply of cells. It is also possible to derive stem cells from non-embryonic tissues, including amniotic fluid, placenta, umbilical cord, brain, gut, bone marrow, and liver. These stem cells are sometimes called "adult" stem cells, and they are typically rare in the tissue of origin. Experts estimate that only one cell in 1,000 to 10,000 cells of an adult organ or tissue is actually a stem cell. Because so-called adult stem cells include cells from the placenta and other early stages of development, they are more correctly termed "non-embryonic stem cells." Non-embryonic stem cells are more limited in their capacity to self renew in the laboratory, making it more difficult to generate a large number of stem cells for a specific experimental or therapeutic application. Under normal conditions, non-embryonic stem cells serve as a repair pool for the body, so they typically differentiate only into the cell types found in the organ of origin. So far, there is little compelling evidence for trans-differentiation, whereby a stem cell from one organ differentiates into a mature cell type of a different organ. Many studies provide gene expression profiles or antigen staining rather than demonstrating the appropriate mature cell function. New discoveries may one day overcome any or all of these limitations of stem cells derived from non-embryonic sources. In fact, research directed towards this goal is currently underway in a number of laboratories. If we can learn to reverse the differentiation process to generate pluripotent cells from differentiated cells, the research community could study these remarkable cells without destroying human embryos.

What is the medical promise of stem cell research?

Scientists are leveraging the potentials of human pluripotent, self-renewing cell cultures to make a significant impact on biomedical research. These cells are enabling them to understand the molecular mechanisms that determine how a pluripotent, self-renewing cell differentiates into a specialized cell type (Figure 1). These mechanisms include epigenetic changes in the chromatin structure, developmental changes in gene expression, exposure to growth factors, and interactions between adjacent cells. Understanding these basic mechanisms of stem cells may enable us to someday mobilize and differentiate endogenous populations of pluripotent cells to replace a cell type ravaged by injury or one of many cellular degenerative diseases, including Type 1 diabetes mellitus, Parkinson's disease, myocardial infarction, and spinal cord injury, to name a few prominent examples. Alternatively, scientists may some day be able to coax human pluripotent cells grown in the laboratory to become a specific type of specialized cell, which physicians might be able to subsequently transplant into a patient to replace cells damaged by these same disease processes.

Scientists are gradually learning to direct the differentiation of pluripotent cell cultures into a specific type of cell, which can then be used as cellular models of human disease for drug discovery or toxicity studies. In the case of the fatal neurodegenerative disorder Huntington's disease (an autosomal dominant genetic disease), one could imagine that pluripotent cells differentiated into neurons in culture could be used to test drugs to delay or prevent degeneration. It is impossible to predict the many ways that a basic understanding of stem cell differentiation may lead to new approaches for treating patients with cellular degenerative diseases.

What are the sources of human pluripotent cell lines?

Currently, there are at least 6 sources that have already been used to establish human pluripotent stem cell lines. These include the "traditional" IVF-embryo method first reported by James Thomson in 1998, human primordial germ cells reported by John Gearhart, "naturally dead" embryos, chromosomally abnormal embryos, single cell embryo biopsy, and parthenogenesis. Scientists are actively pursuing alternative sources of pluripotent stem cells, some of which are being attempted using human tissue, and some which are only being done in animals at present.

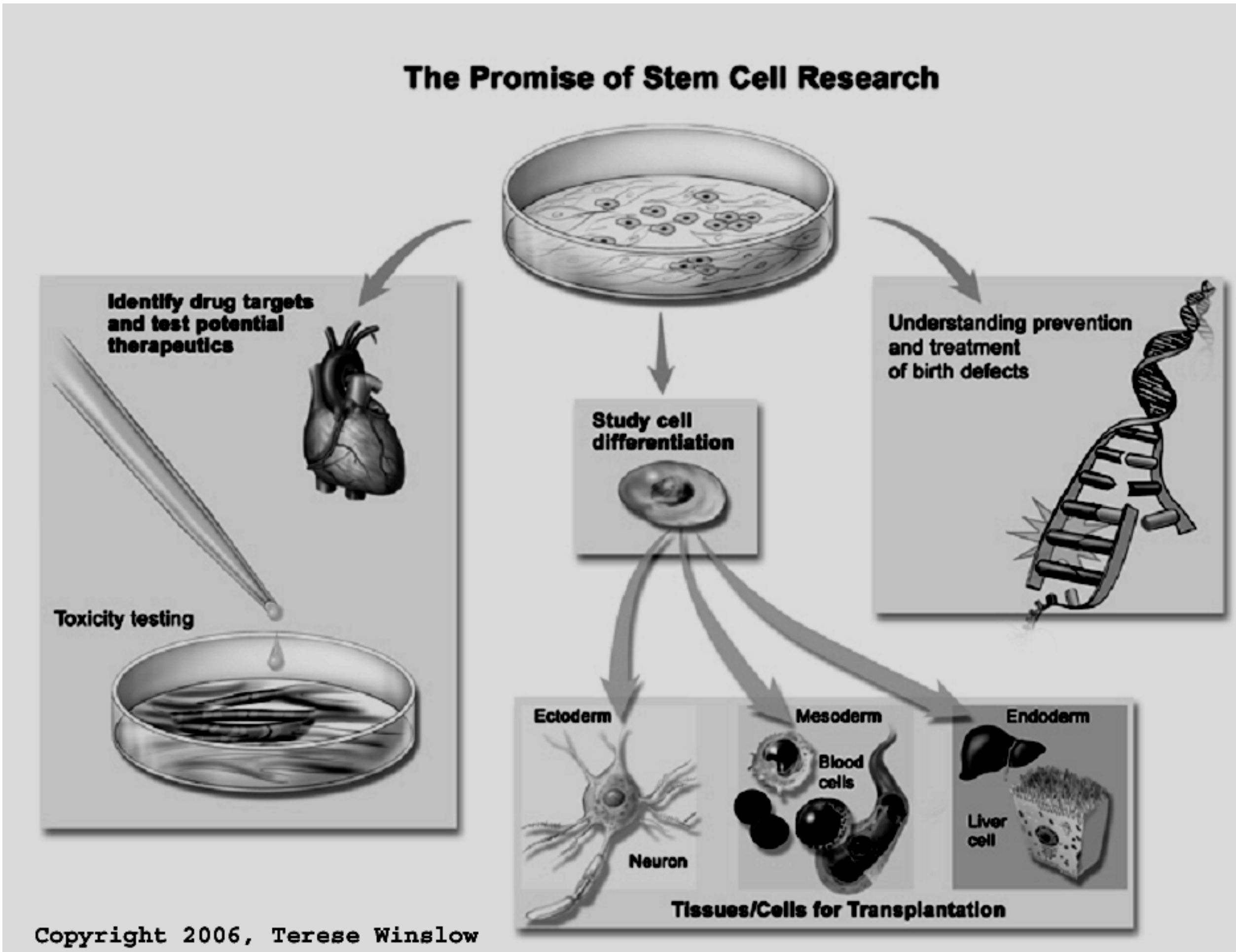


Figure 1. The Promise of Stem Cell Research
Stem cell research provides a useful tool for unraveling the molecular mechanisms that determine the differentiation fate of a pluripotent cell, and for understanding the gene expression properties and epigenetic modifications essential to maintain the pluripotent state. This knowledge may someday be used to generate cells for transplantation therapies, whereby a specific cell population compromised by disease is replaced with new, functional cells. Differentiated derivatives of human pluripotent cells may also prove to be useful as cellular disease models for understanding the biology of disease, and also for developing new drugs, particularly when there is no animal model for the disease being studied. These cells will also lead to improvements in human health in ways that we cannot predict.

Sources that have already been used to establish human pluripotent stem cell lines:

1) Traditional hESC Line Generation

In 1998, James Thomson, Ph.D., VMD at the University of Wisconsin was the first to succeed in generating human embryonic stem cell (hESC) lines[1]. His studies were built on approximately twenty years of cumulative scientific experience using mouse embryonic stem cells. The "traditional" IVF-embryo method for generating human embryonic stem cell lines uses embryos generated for in vitro fertilization (IVF) that are no longer needed for reproductive purposes. During IVF, medical professionals typically produce more embryos than a couple attempting to start a family may actually need. These extra, or spare, embryos are typically stored in a freezer for possible future attempts for additional children in the future. It is estimated that there are about 400,000 such spare embryos worldwide. If these embryos are never used by the couple, they will either remain in storage or be discarded as medical waste. Alternatively, these embryos could potentially be used to generate a hESC line.

To generate a hESC line, scientists begin with a donated blastocyst stage embryo, at about five days after it was fertilized in vitro (Figure 2A). The blastocyst consists of approximately 150-200 cells that form a hollow sphere of cells, the outer layer of which is called the trophectoderm. During normal development, the trophoblast would become the placenta and umbilical cord. At one pole of this hollow sphere, 30 to 50 cells form a cluster that is called the inner cell mass (ICM), which would give rise to the developing fetus. ICM cells are pluripotent, possessing the capacity to become any of the several hundred specialized cell types found in a developed human, with the exception of the placenta and umbilical cord.

Scientists remove the ICM from the donated blastocyst and place these cells into a specialized culture medium. In about one out of five attempts, a hESC line begins to grow. The conditions for culturing the cells are critical for maintenance of the self-renewing and pluripotent properties of these remarkable cells.

2) hESC Lines from Human Primordial Germ Cells

The laboratory of John Gearhart, Ph.D., at The Johns Hopkins Medical School, published a second method for generating human pluripotent stem cell lines in 1998[2]. They isolated specialized cells known as primordial germ cells (PGCs) from a 5-7 week old embryo and placed these cells into culture (Figure 2). PGCs are destined to become either oocytes or sperm cells, depending on the sex of the developing embryo. The resulting cell lines are called embryonic germ cell lines, and they share many of the same properties as embryonic stem cells. Scientists are actively working to define the similarities and differences between these two types of human pluripotent cells.

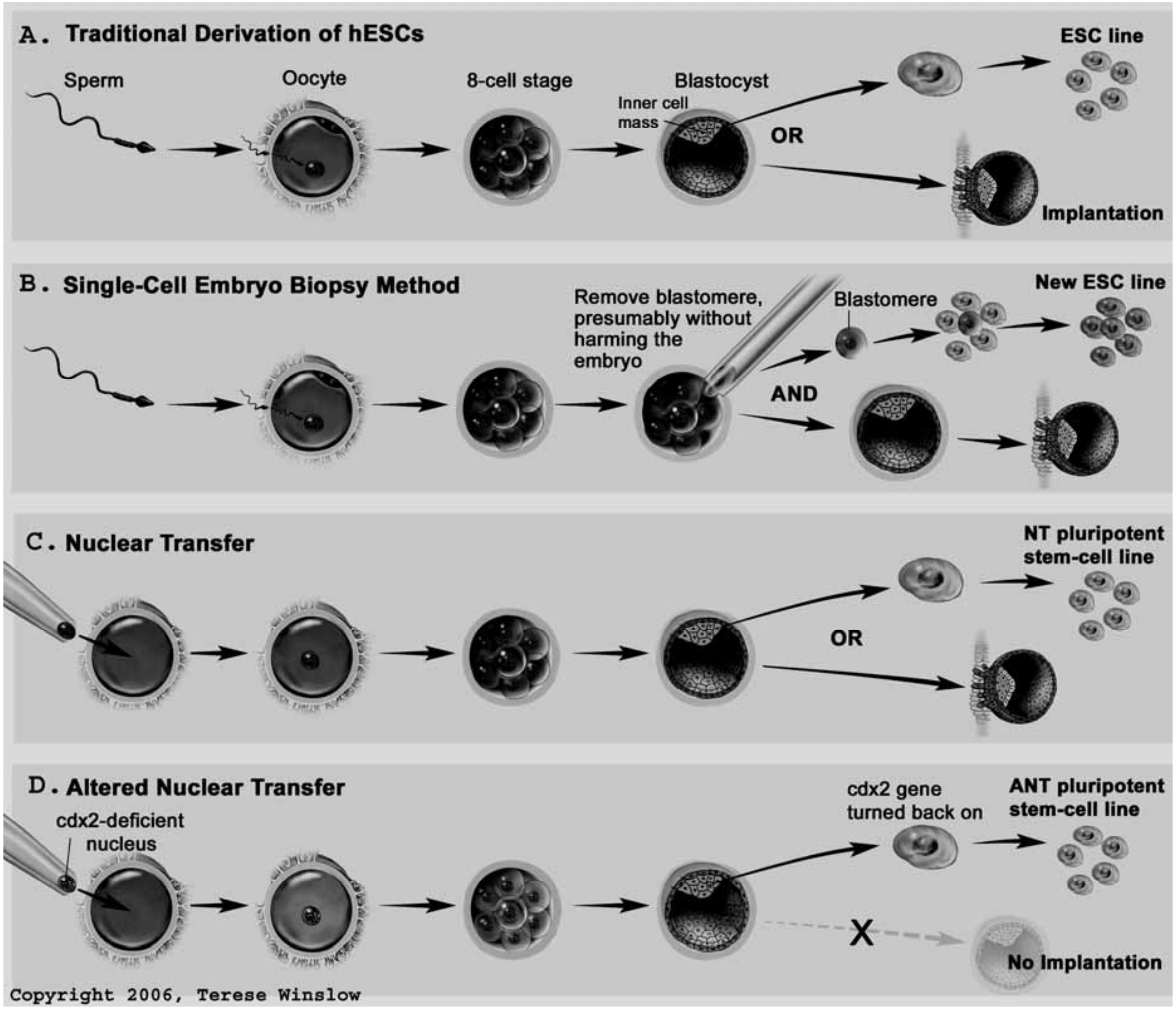


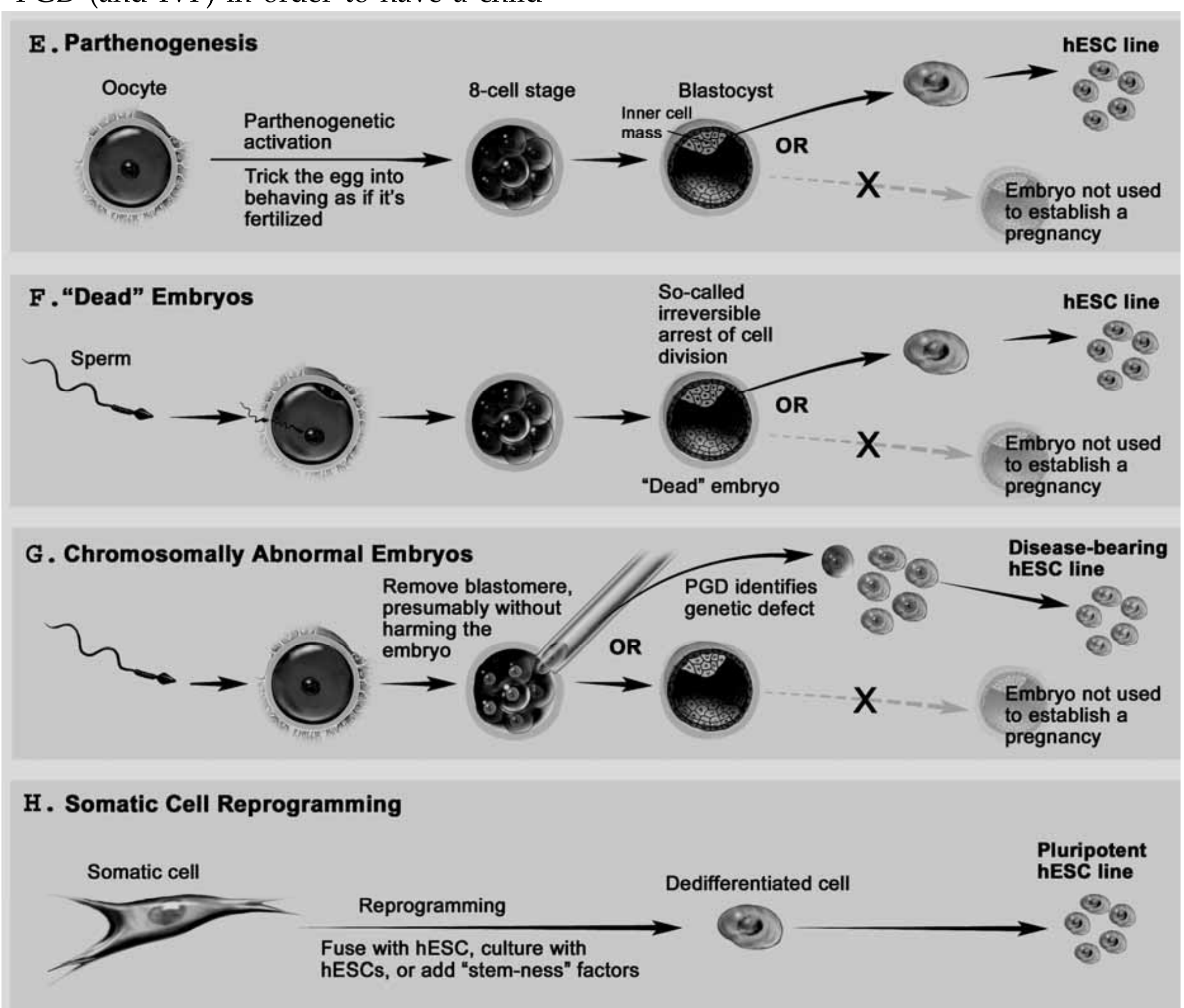
Figure 2. Alternative Methods to Create Pluripotent Stem Cells
Human pluripotent stem cells can be generated from embryos in IVF clinics, from the primordial germ cells found in a 5-7 week fetus, by somatic cell nuclear transfer (SCNT) into a donated human oocyte

3) hESC Lines from Dead Embryos

Embryos that stop dividing after being fertilized *in vitro* are not preferentially selected for implantation in a woman undergoing fertility treatment. These embryos are typically either frozen for future use, or discarded as medical waste. In 2007, scientists at the University of Newcastle, United Kingdom, generated hESC lines from IVF embryos that had stopped dividing[9]. These scientists used similar methods as described above under "Traditional hESC Line Generation", except that their source material was so-called "dead" IVF embryos (Figure 2F). The human stem cells created using this technique behaved like pluripotent stem cells, including making proteins critical for "stemness" and being able to produce cells from all three germ layers. Proponents of this technique suggest that when an IVF embryo dies naturally, the embryo could not develop into a human being, and thus could potentially be used to derive human embryonic stem cells without having to destroy a living embryo. However, ethical considerations make it uncertain whether scientists will equate this procedure of deriving hESC lines to organ donation. That is, scientists can remove live cells from dead embryos in the same way that they remove live organs from individuals who have donated them after death.

4) hESC Lines from Chromosomally Abnormal Embryos

Couples who have learned that they carry a genetic disorder sometimes use PGD (and IVF) in order to have a child that does not carry the disorder. PGD requires scientists to remove one cell from a very early IVF human embryo and test it for diseases known to be carried by the hopeful couple. Normally, embryos identified with genetic disorders would be discarded as medical waste. However, scientists at the Reproductive Genetics Institute in Chicago have capitalized on these embryos as a way to further our understanding of the diseases they carry (Figure 2G) -- they derived hESC lines from them[4]. The new stem cell lines can now be used to help scientists



understand how things go wrong in diseases such as thalessemia, Fanconi's anemia, muscular dystrophy, Huntington's disease, Marfan syndrome, adrenoleukodystrophy, and neuro-fibromatosis. Scientists plan to add to this list by deriving hESCs from embryos that carry additional genetic disorders.

5) hESC Lines from Single Cell Embryo Biopsy

In 2006, Dr. Robert Lanza and his colleagues at Advanced Cell Technologies (ACT) demonstrated that it was possible to remove a single cell from a pre-implantation mouse embryo and generate a mouse embryonic stem cell line[5]. Later that same year, Dr. Lanza's laboratory reported that they had successfully established hESC lines (Figure 2B) from single cells taken from pre-implantation human embryos[6]. The human stem cells created using this technique behaved like pluripotent stem cells, including making proteins critical for "stemness" and being able to produce cells from all three germ layers. Proponents of this technique suggest that since it requires only one cell from the embryo, the remaining cells may yet be implanted in the womb and develop into a human being. Thus scientists could potentially derive human embryonic stem cells without having to destroy an embryo. However, ethical considerations make it uncertain whether scientists will ever test if the cells remaining after removal of a single cell can develop into a human being, at least in embryos that are not at risk for carrying a genetic disorder. In addition, it is not clear whether or not the single cell used to generate a pluripotent stem cell line has the capacity to become a human being.

6) hESC Lines Created Via Parthenogenesis

Parthenogenesis is defined as an embryo created without fertilizing the egg with a sperm, thus omitting the sperm's genetic contributions. Instead, scientists "trick" the egg into believing it is fertilized, so that it will begin to divide and form a blastocyst (Figure 2E). In 2007, scientists at Lifeline Cell Technology in Walkersville, Maryland reported that they successfully used parthenogenesis to derive hESCs[13]. These stem cell lines retained the genetic information of the egg donor and demonstrated characteristics of pluripotency. They were also derived and grown on a human feeder cell layer. This technique may lead to the ability to generate tissue-matched cells for transplantation to treat women who are willing to provide their own egg cells. It could also offer an alternative method for deriving tissue-matched hESCs that do not require destruction of a fertilized embryo.

Human Stem Cell Lines Whose Potency is Still Being Determined:

The scientific literature also reports the isolation of human stem cells that have not yet been conclusively established as pluripotent. Two prominent examples of these putative pluripotent human stem cells include amniotic fluid stem cells and cell lines generated by somatic cell reprogramming.

1) Human Stem Cell Lines from Amniotic Fluid

Amniotic fluid surrounding the developing fetus contains cells shed by the fetus and is regularly collected from pregnant women during amniocentesis. Scientists have previously reported that some of these cells can differentiate into fat, muscle, bone, and nerve cells. Dr. Anthony Atala and his colleagues at the Wake Forest University have generated non-embryonic stem cell lines from cells found in both human and rat amniotic fluid[10]. They named the cells amniotic fluid-derived stem cells (AFS). Experiments demonstrate that AFS can produce cells that originate from each of the three embryonic germ layers. The cells are self-renewing and maintain the normal number of chromosomes after a long time in culture. However, undifferentiated AFS did not make all of the proteins expected in pluripotent cells, and they were not capable of forming a teratoma. The scientists developed *in vitro* conditions that enabled them to produce nerve cells, liver cells, and bone-forming cells from AFS. AFS-derived human nerve cells could make proteins typical of specialized nerve cells and were able to integrate into a mouse brain and survive for at least two months. Cultured AFS-derived human liver cells secreted urea and made proteins characteristic of normal human liver cells. Cultured AFS-derived human bone cells made proteins expected of human bone cells and formed bone in mice when seeded onto 3-D scaffolds and implanted under the mouse's skin. Although scientists do not yet know how many different cell types AFS can generate, AFS may one day allow scientists to establish a bank of cells for transplantation into human beings.

2) Human Cell Lines Generated by Somatic Cell Reprogramming – the Eggan Method

In 2005, Dr. Kevin Eggan and colleagues at Harvard University reported that they had fused cultured adult human skin cells with hESCs (Figure 2H)[3]. The resulting "hybrid" cells had many characteristics of hESCs—they grew and divided in a similar manner and manufactured proteins that are typically made in hESCs. Some as-yet unknown factor(s) within the hESCs enabled them to "reprogram" the adult skin cells to behave as hESCs. The cells still raise a significant technical barrier that must be overcome before they can be used to treat patients. Because fused cells are tetraploid (they contain four copies of the cellular DNA rather than the normal two copies), scientists must develop a method to remove the extra DNA without eliminating their hESC-like properties. If this hurdle can be overcome, this technique may one day allow scientists to create patient-specific stem cells without using human eggs. At present, this new approach to creating stem cells is a useful model system for studying how stem cells "reprogram" adult cells to have properties of pluripotent cells.

Pluripotent Stem Cell Lines Derived in animals

A third category of pluripotent stem cells includes those that have been isolated in animal models, but have not yet been generated from human tissues. Among these are pluripotent cells created by somatic cell nuclear transfer (SCNT), those derived by altered nuclear transfer, and those created by a form of reprogramming that drives cells to express genes characteristic of hESCs.

1) Stem Cell Lines from SCNT

SCNT (Figure 2C) is also referred to as therapeutic cloning, a term that causes confusion given the multiple uses of the word "cloning." Cloning refers to making an identical copy of anything—a molecule, cell, or, in this case, an animal. SCNT begins with the collection of human oocytes (eggs) from a female volunteer donor. The collection procedure carries some risks to the donor since she is asked to take drugs that stimulate the production of more than one oocyte during her menstrual cycle. Scientists then delicately remove the cell nucleus from the donated oocyte and replace it with the nucleus from a somatic cell -- an adult cell from elsewhere in the body,—hence the name somatic cell nuclear transfer. The oocyte with the newly transferred nucleus is stimulated to develop through a process called parthenogenesis—as defined previously. The oocyte may only develop if the transplanted nucleus—which came from a differentiated cell—is returned to the pluripotent state by factors found in the oocyte cytoplasm. This alteration in the state of the mature nucleus is called nuclear reprogramming. Understanding the molecular mechanisms that facilitate this process is another active area of research.

When parthenogenesis progresses to the blastocyst stage, the inner cell mass is removed and placed into culture in an attempt to establish a pluripotent stem cell line. Embryos generated by SCNT have successfully produced pluripotent cell lines in mice that appear to behave exactly the same as pluripotent cell lines generated from mouse blastocysts created by IVF. At this time, there are no published reports in which human embryos generated by SCNT have been used to generate a pluripotent cell line, although scientists worldwide are actively pursuing this area of research.

Why are scientists interested in using embryos generated by SCNT to create pluripotent cell lines? The nuclear genes of such a pluripotent cell line will be identical to the genes in the donor nucleus. If such a nucleus came from a cell that carries a gene mutation underlying a human genetic disease such as Huntington's disease, then all cells derived from the pluripotent cell line would carry this mutation. Cellular models of human genetic disease could be developed with this procedure, both to explore the underlying biology of disease and to develop drugs to slow or halt disease progression. Alternatively, if the cell providing the donor nucleus comes from a specific patient, all cells derived from the resulting pluripotent cell line would be a genetic match to the patient with respect to the nuclear genome. If these cells were used in transplantation therapy, the likelihood that the patient's immune system would recognize the transplanted cells as foreign and initiate tissue rejection would be reduced. However, because mitochondria also contain DNA, the donor oocyte will be the source of the mitochondrial genome, which is likely to carry mitochondrial gene differences from the patient which may still lead to tissue rejection.

A new technique reported in 2007 by Dr. Kevin Eggan and colleagues at Harvard University may expand scientists' options when trying to "reprogram" an adult cell's DNA[11]. Previously, successful SCNT relied upon the use of an unfertilized egg. Now, the Harvard scientists have demonstrated that by using a drug to stop cell division in a fertilized mouse egg (zygote) during mitosis, they can successfully reprogram an adult mouse skin cell by taking advantage of the "reprogramming factors" that are active in the zygote at mitosis. They removed the chromosomes from the single-celled zygote's nucleus and replaced them with the adult donor cell's chromosomes. The active reprogramming factors present in the zygote turned genes on and off in the adult donor chromosomes, to make them behave like the chromosomes of a normally fertilized zygote. After the zygote was stimulated to divide, the cloned mouse embryo developed to the blastocyst stage, and the scientists were able to harvest embryonic stem cells from the resulting blastocyst. When the scientists applied their new method to abnormal mouse zygotes, they succeeded at reprogramming adult mouse skin cells and harvesting stem cells. If this technique can be repeated with abnormal human zygotes created in excess after IVF procedures, scientists could use them for research instead of discarding them as medical waste. Human embryonic stem cells generated in this way would be an excellent match for the chromosome donor, helping to avoid the problem of transplant rejection. In addition, use of excess IVF zygotes for SCNT would eliminate the need for human egg donations. This technique may overcome some ethical objections to deriving stem cells from 5-day-old human embryos, since the abnormal zygotes that would be used for this technique are not believed capable of surviving until birth.

2) Stem Cell Lines Generated by Altered Nuclear Transfer (ANT)

Altered Nuclear Transfer (ANT) is a variation on standard SCNT that proposes to create patient-specific stem cells without destroying an embryo. In ANT, scientists turn off a gene needed for implantation in the uterus (*Cdx2*) in the patient cell nucleus before it is transferred into the donor egg (Figure 2D). The proponents of ANT attempt to address concerns about embryo destruction by suggesting that because the entity created is unable to implant in the uterus, it is not a true embryo. Early in 2006, Dr. Rudolph Jaenisch and colleagues at MIT reported proof of principle tests that ANT works in mice[7]. Mouse ANT entities whose *Cdx2* gene is switched off are unable to implant in the uterus and do not survive to birth. However, scientists used ANT to create viable stem cell lines capable of producing almost all cell types. The authors point out that this technique must still be tested with monkey and human embryos, and the manipulation needed to control *Cdx2* expression introduces another logistical hurdle that may complicate the use of ANT to derive embryonic stem cells.

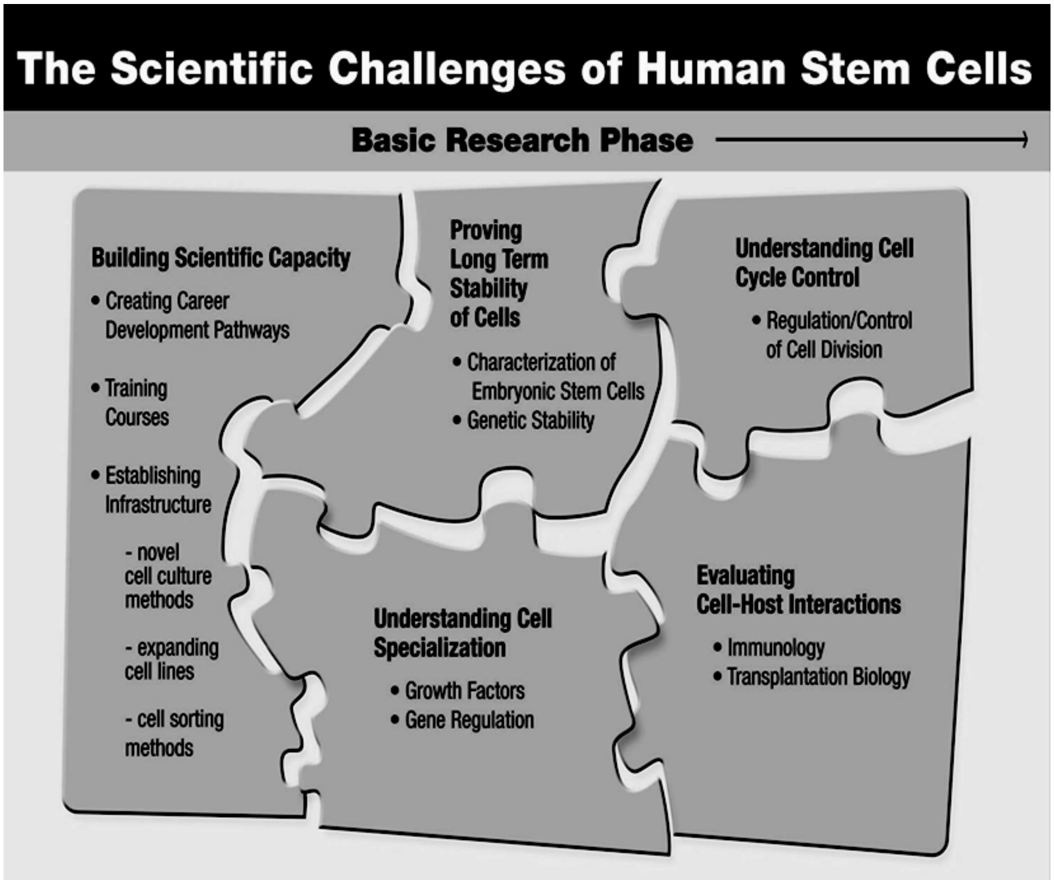


Figure 3. The Scientific Challenge of Human Stem Cells
The state of the science currently lies in the development of fundamental knowledge about the properties of human pluripotent cells. The scientific capacity needs to be built, an understanding of the molecular mechanisms that drive cell specialization needs to be advanced, the nature and regulation of interaction between host and transplanted cells needs to be explored and understood, cell division needs to be understood and regulated, and the long-term stability of the function in transplanted cells needs to be established.

3) Stem Cell Lines Generated by Reprogramming – the Yamanaka Method

In 2006, Dr. Shinya Yamanaka and colleagues at Kyoto University in Japan reported that they could use a virus to introduce four important stem cell factors into adult mouse cells and reprogram them to behave like embryonic stem (ES) cells (Figure 2H)[8]. They called the reprogrammed cells iPS, for induced pluripotent stem cells. However, iPS produced using the original technique could not do everything that ES cells can do. Notably, the original iPS cells do not make sperm and egg cells when injected into an early mouse blastocyst, and they do not make some changes to their DNA that help silence genes. Now the same scientists have modified their original technique, and they report that they can select for iPS that can make sperm and eggs[12]. Their 2007 report is accompanied by another from Dr. Rudolph Jaenisch and colleagues at MIT, which successfully reproduced the Japanese group's results[14]. In addition, the MIT scientists determined that iPS DNA is modified in a manner similar to ES cells, and important stem cell genes are expressed at similar levels. They also demonstrated that iPS injected into an early mouse blastocyst can produce all cell types within the developing embryo, and such embryos can complete gestation and are born alive. These research advances were made in mice, and scientists must still determine if the same techniques can reprogram cells of adult humans. If this can be accomplished, scientists should be able to develop stem cell lines from patients who suffer from genetic diseases, such as Huntington's Disease, spinal muscular atrophy, muscular dystrophy, and thalessemia. Such lines would be invaluable research tools for understanding specific diseases and testing potential drugs to treat them. A second use of reprogrammed cells would be to repair damaged tissues in the human body. The Japanese scientists noted that the virus used to introduce the stem cell factors sometimes caused cancers in the mice. This represents a significant obstacle that must be overcome before the technique can lead to useful treatments for humans. This work suggests an additional method for creating pluripotent stem cells that, together with studies of other types of pluripotent stem cells, will help scientists learn how to reprogram cells to repair damaged tissues in the human body.

What is the state of the science of human pluripotent cells?

The research community is currently in the stage of fundamental discovery, or the basic science phase of understanding the properties of human pluripotent cells. Researchers are gradually learning how to direct these cells to differentiate into specialized cell types of interest for research, and using these human cell types for attempts at drug discovery and transplantation therapy (Figure 3). Scientists require a more complete understanding of the molecular mechanisms that drive pluripotent cells into differentiated cells before they can attempt to use stem cell derivatives for clinical applications. Scientists will need to pilot experimental transplantation therapies in animal model systems to assess the safety and long-term stable functioning of transplanted cells. In particular, they must be certain that any transplanted cells do not continue to self-renew in an unregulated fashion after transplantation, which may result in a teratoma, or stem cell tumor. In addition, scientists will need to make sure that cells transplanted into a patient are not recognized as foreign by the patient’s immune system and rejected. At present, there are no clinical trials using cells generated by differentiating human embryonic stem cells, although scientists are hopeful that such trials will commence in the not-too-distant future. Human blood-forming (hematopoietic) stem cells from the umbilical cord and bone marrow are currently being used to treat patients with disorders that require replacement of cells made by the bone marrow, including Fanconi’s anemia and chemotherapy-induced bone marrow failure after cancer treatment.

What Federal laws and policies affect human embryonic stem cell research in the United States?

At present, there is no Federal law that limits research involving human embryos and embryonic stem cell research. For example, no Federal law prohibits attempts at cloning humans for reproductive purposes using SCNT—an activity that many individuals believe is morally repugnant since animal SCNT frequently produces abnormal fetuses and animals that are born dead or die soon thereafter. Several states have adopted laws that limit the scope of research within their borders, and a number of states have passed laws that provide state-based support for stem cell research.

However, limits have been placed on Federal funding for scientific research. On August 9, 2001, in his first televised nationally televised address, President Bush set forth his policy placing limits on the use of Federal funds for human embryonic stem cell research. The President announced that he would, for the first time, allow the use of Federal funds for study of embryonic stem cell line so long as prior to his announcement: (1) the derivation process (which commences with the removal of the inner cell mass from the blastocyst) had already been initiated; and (2) the embryo from which the stem cell line was derived no longer had the possibility of development as a human being. In addition, the President indicated that these additional conditions must be met: (1) the stem cells must have been derived from an embryo that was created for reproductive purposes; (2) the embryo was no longer needed for these purposes; (3) informed consent was obtained for the donation of the embryo; and (4) no financial inducements were provided for donation of the embryo. The President's policy does not pertain to human embryonic germ cell lines, whereby the pluripotent cells are derived from the primordial germ cells from a 5-7 week fetus rather than a human embryo. In addition, the President's policy does not pertain to the use of private or state funds for embryonic stem cells. Scientists may still pursue research that may not be funded by the Federal government, so long as they procure non-Federal funds for such work.

To help scientists identify stem cell lines eligible to receive Federal funding, the NIH created the Human Embryonic Stem Cell Registry (the Registry). The Registry lists all human embryonic stem cell lines—at varying stages of development—that meet the President's eligibility criteria. Seventy-eight such derivations were subsequently located at private institutions around the world, seven of which are duplicates located at Geron, a biotechnology company, and WiCell, a nonprofit research subsidiary of the Wisconsin Alumni Research Fund. Since all 78 derivations are owned by private entities, the owners are under no obligation to provide human embryonic stem cells to the research community and NIH has no authority to insist that this limited resource be shared. In addition, since some of the derivations are little more than a frozen inner cell mass, there is no guarantee that the cells

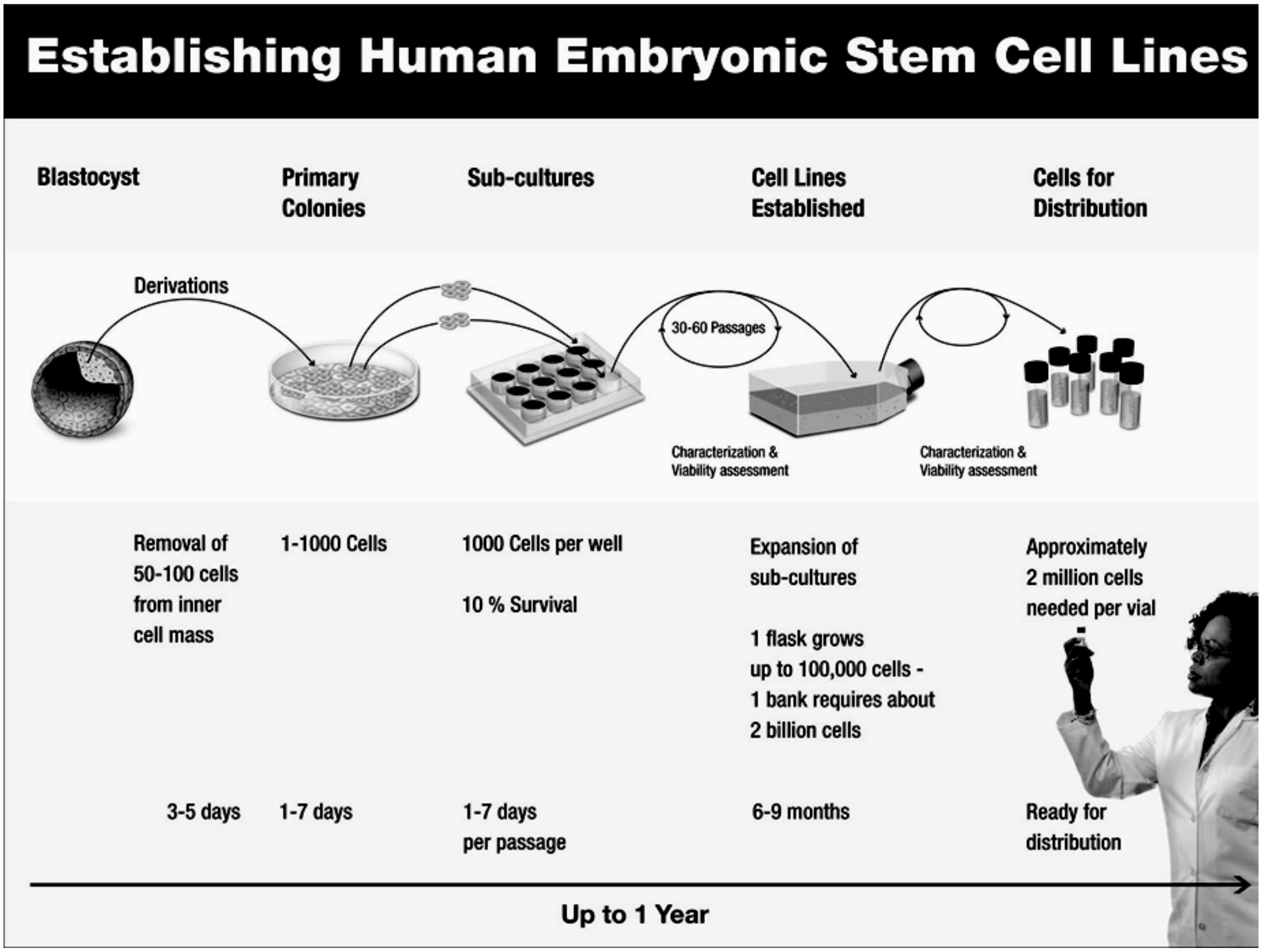


Figure 4. Establishing Human Embryonic Stem Cell Lines
The process of developing a human embryonic stem cell line is both time- and labor-consuming. It can take up to a year to progress from removal of the inner cell mass to achieving a well-characterized, scaled-up cell line ready to be distributed to the research community for study.

will propagate as a cell line when thawed.

The scale-up and characterization effort required to distribute cell lines is both time- and resource-intensive (Figure 4). In an effort to maximize the availability of cell lines eligible for Federal funding to the research community, NIH provided support through Infrastructure Grant Awards to allow private institutions with derivations on the Registry to prepare, expand, and characterize cell lines for responsible distribution to the community. Of the 15 private entities that own the 78 derivations eligible for Federal funding, nine have applied for and received NIH Infrastructure Awards with the intent of generating distribution-ready human embryonic stem cell lines from their derivations. These nine private entities control 40 of the 78 derivations eligible for Federal funding. Of these 40 derivations, 16 have failed to expand into pluripotent, self-renewing human embryonic stem cell lines, and one derivation was withdrawn by the donors. At the present time, 21 cell lines have been scaled up and characterized to the point at which they can be distributed to the research community for human embryonic stem cell research supported by Federal funding.

A second limitation was placed on the use of NIH budget authority by the Legislative Branch of the Federal Government for research that involves human embryos. Beginning in 1996 and every year thereafter, the Human Embryo Research Ban (also called the Dickey Amendment) to the Department of Health and Human Services (DHHS) annual Appropriation Act prohibits the use of funds appropriated to DHHS to support the creation of a human embryo for research purposes or research in which a human embryo is destroyed, discarded, or subjected to risk of injury or death greater than that allowed under Federal requirements for fetuses *in utero*. For the purposes of this prohibition, the definition of a human embryo is very broad including embryos generated by parthenogenesis. Since NIH budget authority falls under the DHHS appropriation, NIH funds cannot be used to create a new human embryonic stem cell line, because a human embryo created by either IVF or SCNT would be destroyed in the process.

Policies and laws in other countries are sometimes more permissive and other times more restrictive than in the United States, depending on the country in question. This complex issue is beyond the scope of this discussion, although it is fair to note that the United States is unique in having a policy that restricts activities funded by the Federal government but places no restrictions on research funded by other sources.

What factors are limiting progress in hESC research?

hESC lines are extremely difficult to grow in culture. The cells require highly specialized growth media, containing essential ingredients of variable quality. In addition, most hESC lines are grown in the presence of a feeder cell line, a layer of cells from a mouse or human source on which stem cells can grow and obtain nutrients but which has been treated so the feeder cells cannot divide. Proper preparation of the feeder cells is essential for successful culture conditions. hESC lines used to produce human cells for transplantation therapies may need to be propagated on a human feeder cell layer in order to reduce the risk of contamination by harmful mouse viruses or other proteins that may cause rejection.

Human embryonic stem cell cultures must be expanded using an exacting protocol, or the cells will either die or begin to differentiate spontaneously and lose their pluripotency and self-renewal properties. Since only a few laboratories in the United States are growing these cells, there is a shortage of people well-versed in the art and science of successful hESC culture. In order to expand this rate-limiting human resource, NIH offers training grants for institutions to provide hands-on training in the techniques needed to culture hESCs. In 2003, five such courses were established, and about 200 scientists were trained. In 2006, the number of courses was increased to seven, and NIH plans to continue to support this activity as long as the demand is evident. In addition, the NIH is supporting training in many independent laboratories funded to perform investigator-initiated hESC research.

Stem cell scientists frequently cite a compelling need for simplified, cost-effective and uniform cell culture conditions that will support the growth and pluripotency of most if not all hESC cultures. Optimally, these conditions would replace the feeder cell layer with purified stocks of necessary growth factors. Feeder cells add more steps to cell culture protocols, and may be problematic if an undesirable biological agent or molecule is unwittingly transmitted from the feeder layer to the cultured hESCs. This issue could result in additional safety concerns on the part of the U. S. Food and Drug Administration when they receive the first application proposing clinical trials involving transplantation of cells differentiated from hESCs. NIH is supporting efforts at several different institutions to establish culture conditions using only well-defined components. The University of Wisconsin has reported progress towards eliminating the need for feeder cells either to establish or propagate hESC lines. It will be essential to determine if the protocols for culture developed at Wisconsin can be simplified further or rendered less costly, since it requires the addition of purified growth factors that are very expensive. In addition, the cells must be monitored for genetic stability, sustained pluripotency, and continuous self-renewal over many passages in the new culture conditions.

Availability of hESC lines is another potential impediment to research progress. NIH-supported Infrastructure Grant Awards have resulted in the generation of 21 human embryonic stem cell lines that are eligible for Federal funding and are ready to be shipped to investigators. However, these cell lines are scattered among a variety of different providers, each specifying different requirements to be satisfied before shipment. In addition, a $5,000 licensing was required from all not-for-profit entities who requested a human embryonic stem cell line, since the intellectual property for derivation of human embryonic stem cell lines is currently held by WiCell, a biotechnology spin-off company started by the Wisconsin Alumni Research Fund. NIH conducted a competitive review of applications, and ultimately initiated a research and development contract to fund a National Stem Cell Bank (NSCB) at WiCell. It is the responsibility of the NSCB to consolidate as many of the 21 available lines as possible in one location, standardize quality control, and reduce the cost of the cells provided to researchers. The hope is that this step will simplify efforts on the part of the research community to obtain human embryonic stem cells for research, and reduce the cost to obtain the cells to $500.

In the short term, some of the challenges include the development of more robust culture conditions and protocols, understanding the molecular mechanisms that direct differentiation into specific cell types, and developing the human infrastructure to advance this exciting new scientific opportunity.

Once these challenges have been met, scientists will need to conduct transplantation studies in animal models (rodent and non-human primates) to demonstrate safety, effectiveness, and long-term benefit before stem cell therapies may enter into clinical trials. The risks and benefits of transplantation therapies will need to be very carefully considered, as these interventions represent a lifelong experiment with unknown consequences. While it is clear that transplantation-based therapies using hESCs are far from imminent, we can never know the full potential of these remarkable cells unless we embark on this important area of biomedical research.

Research opportunities and advances, as well as links to other information about stem cell research can be found on the NIH Stem Cell Information Web site: stemcells.nih.gov.

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Sustained and Balanced Investment in Research & Innovation is Critical to U.S. Competitiveness

Prem S. Paul, D.V.M., Ph.D.
Vice Chancellor for Research & Dean of Graduate Studies
University of Nebraska-Lincoln

The United States' leadership in the global economy since the 1950s has been the envy of the world. This leadership has been achieved through technological innovation resulting from significant investments in research and development (R&D). The majority of the R&D investment, especially for fundamental research, has been made through the federal agencies. These investments in fundamental research have paid big dividends and led to the development of innovative technologies and have been exploited to generate new and expanded commerce.

The new economy is just one example of the mega-benefits resulting from innovations in science and technology. People also are living longer and healthier lives as a result of discoveries in the medical sciences and the ample availability of high quality, safe food at affordable prices produced through advances in agriculture. Our success has led many other nations to adopt our model of supporting innovation. Recent indicators show that other countries have begun to invest higher shares of their gross domestic product in R&D. At the same time, U.S. investments have been reduced and, for many federal agencies, have not kept pace with inflation. If the U.S. is to continue to compete in the new economy, it is critical that we increase our investments in fundamental research. The recent report "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future" further makes this case.[1]

Increased and Sustained Investment in Research is Essential to our Future

Taking a look at the history of federal support of research and development over the past 30 years, one sees peaks and valleys in the level of federal R&D funding (see Figure 1). These peaks and valleys represent periods of de-prioritization when other needs, such as social services, took larger shares of the federal budget, followed by an awakening to new challenges and a re-commitment to research and development. Each time our nation has been challenged, we have responded and risen to the task. Leadership for those responses has come from multiple segments of the society – U.S. Presidents, federal agencies, and the U.S. Congress have provided key leadership. The scientific community, various constituent groups and business leaders have been critical for generating discussion and new ideas, as well as for building strong support for funding initiatives. The initiatives that have the support of these various groups have had the highest chance for success.

TABLE 1. GDP Share Invested toward R&D by Country/Economy for Selected Countries for Years 1998, 2001, 2002, and 2003.

Country/Economy	Share (%)
Israel (2003)	4.90
Sweden (2001)	4.27
Finland (2002)	3.46
Japan (2002)	3.12
Iceland (2002)	3.09
United States (2003)	2.67
South Korea (2003)	2.64
Switzerland (2000)	2.57
Denmark (2002)	2.52
Germany (2003)	2.50
Belgium (2003)	2.33
Taiwan (2002)	2.30
France (2002)	2.26
Singapore (2002)	2.15
Netherlands (2001)	1.88
Canada (2003)	1.87
United Kingdom (2002)	1.87
Norway (2002)	1.67
Australia (2000)	1.54
Russian Federation (2003)	1.28
China (2002)	1.22

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); OECD, Main Science and Technology Indicators (2004); Iberoamerican Network of Science and Technology Indicators, http://www.ricyt.edu.ar; and Science and Engineering Indicators 2006, http://www.nsf.gov.

TABLE 2. Total Federal and Nonfederal support of U.S. R&D as a share of GDP.

	R&D/GDP (%)		
Year	Total	Federal support	Nonfederal support
1981	2.31	1.08	1.23
1986	2.69	1.22	1.47
1991	2.68	1.01	1.67
1996	2.52	0.81	1.71
2001	2.74	0.72	2.02
2002	2.64	0.74	1.90
2003	2.63	0.76	1.87
2004	2.56	0.76	1.80
2005 preliminary	2.59	0.76	1.83
2006 preliminary	2.60	0.73	1.86

GDP=gross domestic product

R&D=research and development.

SOURCES: Department of Commerce, Bureau of Economic Analysis, special tabulations, 2004; Office of Management and Budget, special tabulations, 2004; and National Science Foundation, Division of Science Resources Statistics, special tabulations, 2007. Derived from Table 13, National Science Foundation Division of Science Resources Statistics, 2007.

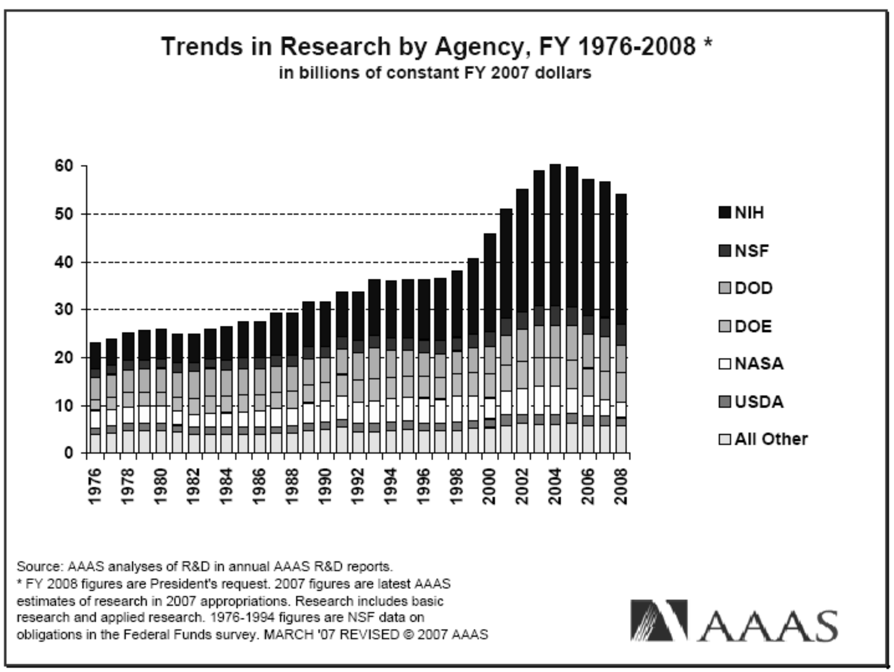

Figure 1. Trends in Research by Agency, FY 1976-2008 (Source: AAAS, 2007, see website http://www.aaas.org/spp/rd/trres08p.pdf**).**

Federal R&D Support History

Federal support for R&D can be grouped into four major eras:

- The Vannevar Bush Era, resulting in the establishment of the National Science Foundation
- The Post-Sputnik Space Race, resulting in the establishment of the National Aeronautics and Space Administration, the Defense Advanced Research Projects Agency and the National Defense Education Act in 1958
- The doubling of NIH Research funding from 1998-2003
- The Current Era: The American Competitiveness Initiative in 2006

Vennaver Bush Era

Following World War II, President Franklin Roosevelt gave a charge to the Honorable Vennaver Bush in a Nov. 14, 1944 letter[2] that is still appropriate and is an excellent example of presidential leadership. President Roosevelt said, "New frontiers of the mind are before us and if they are pioneered with the same vision, boldness and drive with which we waged this war we can create a fuller and more fruitful employment and fuller and more fruitful life." As a result of the presidential initiative, Vennaver Bush prepared a report[2] that had an enormous impact. He outlined the following five fundamentals in his report:

1. **"Stability of Support.** Whatever the extent of support may be, there must be stability of funds over a period of years, so that long range programs may be undertaken.
2. **Advisory Boards.** The agency to administer such funds should be composed of citizens selected only on the basis of their interest in and capacity to promote the work of the agency.
3. **External Grants.** The agency should promote research through grants and contracts to organizations outside the federal government. It should not operate laboratories on its own.
4. **Conduct of Basic Research by Universities without interference from Federal Government.** Support of basic research in the public and private colleges and universities must leave internal controls of policy, personnel, and method of scope of research to institutions themselves.
5. **Accountability of Research.** While assuring complete independence and freedom for the nature and scope and methodology of research carried on, the institution must be responsible to the President and Congress. "

As a result of Mr. Bush's report, the National Science Foundation (NSF) was established in 1950 and has been a great success story. The NSF has supported fundamental research leading to major discoveries and today is the largest source of funding for physical sciences, engineering, social sciences and environmental sciences research.

Post-Sputnik Era

The nation was challenged again with a loss in the space race when the Soviets launched Sputnik I on October 4, 1957 and Sputnik II on Nov. 7, 1957 (see reference 3 on Association of American Universities website for sputnik timeline). The U.S. responded on Nov. 21, 1957 with President Eisenhower's appointment of James Killian as the first Science Advisor to the President and the establishment of the President's Science Advisory Committee. The Defense Advanced Research Projects Agency was formed on February 7, 1958, and President Eisenhower signed the National Aeronautics Space Administration Act on July 29, 1958 to establish NASA. The President also signed the National Defense and Education Act supporting mathematics and science education that help prepare the U.S. workforce for the next fifty years.

These initiatives and the support of the Congress resulted in increased funding for fundamental research and R&D in general. Funding for the National Science Foundation increased from $34 million in 1958 to $500 million in 1968. Similarly, funding for NIH grew from $210 million in 1958 to $1.08 billion in 1968[3].

These investments and the vision of Vannevar Bush carried U.S. R&D through the late 1990s, but new vision and leadership were needed for the next decade. Representative Vernon Ehlers' 1998 editorial "The Future of Science Policy" captures this need well[4]. "Although the U.S. Science and Technology enterprise has achieved enormous success, it is essentially operating on autopilot. The policies that Vennaver Bush outlined in his 1945 report – Science – The Endless Frontier- still to a large extent guide the research enterprise. The context in which S&T presently operates has changed remarkably." He challenged the nation to set priorities for the science agenda and asked for input.

In more recent times, Congress and the President supported doubling of the National Institutes of Health (NIH) budget from 1998 to 2003, with increases of 15% per year. This was accomplished with the leadership and support of patient advocates, scientific and university associations, the U.S. Congress and the President. Unfortunately, the NIH budget has not increased since the doubling, but has flattened and actually decreased when adjusted for inflation.

Sustained and Balanced Support for R&D

Although the doubling of NIH funding addressed the needs of medical research from 1998-2003, funding for the physical sciences and engineering suffered. This time, the stimulus for re-awakening the nation was the report "Rising Above the Gathering Storm: Energizing and employing America for a Brighter Economic Future" prepared by the National Academies of Science[1]. This report was prepared at the urging of Sen. Lamar Alexander and Sen. Jeff Bingaman of the Committee on Energy and Natural Resources, with the support of Rep. Sherwood Boehlert and Rep. Bart Gordon of the House Committee on Science. They asked the National Academies to define "what top 10 actions policy makers should take to enhance the science and technology enterprise so the U.S. can successfully compete, prosper and be secure in the global community of the 21st century"[1].

This is an excellent example of leadership arising from multiple segments of society, including the business community, the U.S. Congress and the President. The report suggested that we are not keeping up with other countries, that we must invest in developing our talent base in science, mathematics and engineering, and that we must support fundamental research, which is the key to innovation. The report[1] also stated that four criteria are critical in attracting and retaining the multinational corporations that create jobs: research and innovation talent, the availability of a qualified workforce, the quality of research universities, and federal support for research and development.

The report stated: "Although the U.S. economy is doing well today, current trends in each of those criteria indicate that the United States may not fare as well in the future without government intervention. This nation must prepare with great urgency to preserve its strategic and economic security. Because other nations have, and probably will continue to have, the competitive advantage of a low wage structure, the United States must compete by optimizing its knowledge-based resources, particularly in science and technology, and by sustaining the most fertile environment for new and revitalized industries and the well-paying jobs they bring. We have already seen that capital, factories, and laboratories readily move wherever they are thought to have the greatest promise of return to investors."[1]

The four recommendations of "Rising Above the Gathering Storm"[1] were:

"1. Focus on actions in K-12 education (10,000 Teachers, 10 Million Minds). Increase America's talent pool by vastly improving K-12 science and mathematics education.
2. Research (Sowing the Seeds) Sustain and strengthen the nation's traditional commitment to long-term basic research that has the potential to be transformational, to maintain the flow of new ideas that fuel the economy, provide security, and enhance the quality of life.
3. Higher Education (Best and Brightest). Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit and retain the best and brightest students, scientists and engineers from within the United States and throughout the world.
4. Economic Policy (Incentives for Innovation). Ensure that the United States is the premier place in the world to innovate; invest in downstream activities such as manufacturing and marketing; and create high-paying jobs based on innovation by such actions as modernizing the patent system, realigning tax policies to encourage innovation, and ensuring affordable broadband access."

This report has been enthusiastically received and has had enormous impact in awakening the U.S. to the need for additional investments in R&D. The American Competitive Initiative was launched by President Bush in 2006 with the promise of doubling funding for the NSF, DOE Office of Science, and the National Institute of Standards and Technology. Congress also has embraced the recommendations of the report.

While it is exciting that there is long-overdue strong support for the physical sciences and engineering, funding for NIH has not kept up with inflation since the doubling was completed. The proposed NIH budget for FY08 is $28.8 billion. If enacted, this will be 7.4% below the 2004 highest level after adjusting for inflation, according to Koizumi, 2007[5]. Heinig et al.[6] report that the NIH budget for the past five years has been flat and real purchasing power is 13% below that of 2003, and argue that NIH be provided 3% to 4% increases after adjustment for inflation.

Department of Defense R&D funding also is not keeping up with DOD needs, according to a memo by John Young, Director of Defense Research and Engineering and Acting Undersecretary of Defense for Acquisition, Technology, and Logistics, who believes that the Defense S&T program should be expanded by $10 billion over five years to "keep pace with emerging threats"[7].

These suggested initiatives emphasize the need for increased investments in R&D in order for the U.S. to remain globally competitive.

A Balanced Portfolio

It is critical that the funding portfolio be balanced across various disciplines, between single investigators and multidisciplinary teams, between federal national laboratories and academic institutions, and across geographical regions of the United States. This helps ensure that solutions to global challenges are accomplished in a timely manner, are well accepted by society, and that talented people throughout the United States are engaged in addressing these issues.

Currently, support for various disciplines is uneven, and federal funding for the social sciences, humanities and arts is especially low (see Tables 3 & 4). Distribution of total R&D as well as federal R&D obligations is disproportionate amongst states. It is critical for our future that all states are actively engaged in R&D innovation and that young people throughout the U.S. have an opportunity to be benefit from these investments. Currently, more than 50% of total Federal R&D funding is obligated in six states (see Table 5). This disparity is not explained by population differences alone. The EPSCoR/IDeA states have about 20 % of the population, and 18 % of academic scientists and engineers who are engaged in research (Source: Data from NSF's Division of Science Resources Statistics, 2006, –Rolf Lehming). Fortunately, Congress initiated the Experimental Program to Stimulate Competitive Research (EPSCoR) in 1978 to build capacity and infrastructure and better position under-funded states to compete for federal R&D. The program has been so successful that congress expanded this program beyond the National Science Foundation to the Department of Energy, Department of Defense, and US Department of Agriculture, EPA, and NASA. A similar program also was initiated at the National Institutes of

Health and first funded in 1993 and is referred to as the Institutional Development Award program (IDeA). The IDeA program is now the largest such program, with more than $220 million in funding and has two primary programs – Centers of Biomedical Research Excellence (COBRE) and the Biomedical Research Infrastructure Network (BRIN), which has now been transformed into the Integrated Networks of Biomedical Research (INBRE). Information about the EPSCoR program can be found at: (http://www.nsf.gov/od/oia/programs/epscor/about.jsp). IDeA program information can be found at http://www.ncrr.nih.gov/research_infrastructure/institutional_development_award/. The federal-wide EPSCoR/IdeA investment has been highly successful in building research infrastructure and has contributed to research capacity in 23 states.

Table 3: R&D Expenditures in Science and Engineering Fields FY2005

Discipline	Total from all sources (Millions)	Federal R&D obligations (Millions)
Computer Sciences	1,406	1,023
Environmental Sciences	2,546	1,725
Life Sciences	27,603	17,691
Mathematical Sciences	495	346
Physical Sciences	3,704	2,674
Psychology	826	611
Social Sciences	1,675	691
Engineering	6,728	4,116

Source: National Science Foundation/Division of Science Resource Statistics. Survey of Research and Development Expenditures at Universities and Colleges, FY2005.

Table 4: R&D Expenditures in Nonscience Areas for the FY2005

Discipline	All Sources (Millions)	Federal Obligations (Millions)
Business & Management	1,750	764
Communications, Journalism & Libraries	75	26
Education	761	426
Humanities	194	58
Law	62	27
Social Work	87	26
Visual & Performing Arts	42	4
Others	309	145

Source: National Science Foundation/Division of Science Resource Statistics. Survey of Research and Development Expenditures at Universities and Colleges, FY2005.

Strong Universities as well as National Labs

While it is essential that federal investment in national laboratories remains strong, it is critical that funding between federal laboratories and universities is balanced. The relative percentage of obligations of federal funding between national laboratories and universities varies by agencies. At NSF, approximately 79% of the R&D budget goes to colleges and universities (8). At NIH, more than 80% of funding goes to universities (6). The Department of Energy Office of Science provides more than two-thirds of the funding to national laboratories. At the Department of Defense (9), basic and applied research is performed by DOD labs (32%), industry (40%), and universities and colleges (21%). DOD is the third largest federal sponsor of academic research, behind NIH and NSF.

In conclusion, we as a nation need to continue to provide sustained investment for R&D to ensure long-term prosperity and global competitiveness. These investments need to be balanced across various disciplines and geographic regions to ensure that all of our available talent is engaged in the research and innovation necessary for us to compete successfully in the global economy.

Disclaimer and Acknowledgements:

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The Importance of External Grant Support for a Public College of Arts and Science

Joseph E. Steinmetz, Dean
College of Liberal Arts and Sciences
University of Kansas

The punch line of this paper is easy to state at the very outset because it is obvious—external grant support is vital for the operation of a College of Arts and Sciences at a Research I level public institution of higher education like the University of Kansas. External grant support of research provides a great deal of the funds that are necessary for members of the faculty to explore their research and scholarship. External grant support provides funds for the training of graduate students, the next generation of scholars and researchers. And, external grant support often provides the means for introducing undergraduate students to the world of research and scholarly pursuits.

In many large, state-supported institutions of higher education, the College of Arts and Sciences is the largest unit, containing the most faculty and responsible for teaching the majority of credit hours at both the undergraduate and graduate levels. In many ways, the undergraduate missions of colleges of arts and sciences at large state institutions is the same as the institutional missions of smaller liberal arts colleges like Grinnell, DePauw, or Williams: To expose undergraduates to a wide variety of academic subjects that include the humanities, social sciences, and natural and mathematical sciences. In addition, to the goal liberal arts and science colleges at Research I institutions provide another important experience for undergraduates—exposure to a variety of research and creative activities that involve members of the faculty as well as postdoctoral scholars and graduate students. Generally, arts and science college students are exposed to a general education curriculum that builds problem solving skills and fosters creativity while preparing students for change. While majors and minors are earned, colleges of arts and sciences do not stress the development of discipline-specific skills, as is the case for professional schools on campus, but rather generalized academic skills that should enhance the students' chances for success after graduation.

Colleges of arts and sciences at large public institutions make a number of contributions to higher education. They teach many, many undergraduates in a wide variety of disciplines, students who make up the majority of society's future scientists, mathematicians, humanists, and social scientists. Colleges of arts and sciences at Research I institutions also offer a variety of graduate programs in many different departments. These graduate students contribute to the individual research programs of countless scholars while also making novel contributions to the scholarly literatures in their respective fields. They also actively participate in the teaching of undergraduates. Important for the present discussion, faculty and students of colleges of arts and sciences in public institutions provide much of the research, scholarship and creative activity that form the bases of inquiry and the gathering and disseminating knowledge.

Given the large commitments to undergraduate and graduate teaching, faculty appointments in colleges of arts and sciences are quite different than in medical schools and research centers or institutes. Generally, a 40-40-20 research-teaching-service model is applied where it is assumed that 40% of a faculty member's time is spent in research, 40% in teaching, and 20% in local and national service. How the 40% time in teaching is spent can vary greatly across units in a college, generally related to how research and scholarship is carried out. For example, in the bench sciences, such as biology or chemistry, teaching loads are typically 1-2 formal courses per year while in the humanities, such as history or philosophy, the teaching load is typically 4 per year. In general, 100% of the faculty member's salary is paid from public sources, although teaching reductions are sometimes awarded when salary is underwritten by external grant funds (which, for the most part, are only available for the sciences and social sciences). There have been some recent challenges to this model. Many areas of the social sciences conduct research in a manner that makes it difficult to determine if teaching loads should be closer to the sciences or to the humanities and the introduction of a number of new interdisciplinary fields (e.g., behavioral neuroscience) has made it more difficult to define teaching loads. Inevitably, there are conflicts that arise between teaching and research. For example, scientists from colleges of arts and sciences often compete for grant funding with scientists from medical schools where teaching loads are lighter and more time is thus available for research.

The landscape of colleges of arts and sciences is hardly static, in part driven by national priorities for research and teaching. Recently, there has been a trend that favors the formation of larger interdisciplinary and multidisciplinary teams of investigators who study problems that used to be studied by individual investigators in the social sciences and natural and mathematical sciences. This trend has not for the most part affected the humanities with exception of areas like ethics and perhaps language and cultural studies. Recently, there has been a general building of the life sciences, in part because of the doubling of the NIH budget that has occurred over the past decade or so. The general perception in many institutions is that funding for some of the traditional areas of the social and behavioral sciences is down (e.g., some basic areas of social psychology). However, it appears that there is an increasing number of social and behavioral scientists who are conducting research with life scientists in both clinical and basic science domains. The jury is still out as to whether this is a good trend or a bad trend. For example, many social and behavioral scientists are concerned about the futures of their fields and wonder if the future of the behavioral and social sciences is being driven by the short term availability of federal funds rather than by issues of curiosity, good scholarship, and long range planning considerations.

The opening premise of this paper was that external grant support is extremely important for the future of colleges of arts and sciences. One might ask: What would the consequences be if a down-turn in external support for faculty in arts and sciences colleges occurred or if federal research priorities shifted dramatically? Loss of external research support has some obvious consequences. First, many well-established researchers would have difficulty maintaining their research programs—their programs would become smaller and more focused and this would likely result in fewer advances and slower progress on many important issues. Second, to internally fund research programs, institutions may be forced to divert funds from important areas of scholarship that are already under-funded, such as the humanities, from undergraduate education, and from funds earmarked for building and maintaining necessary research infrastructure. Third, graduate training would suffer as fewer dollars would be available for research conducted by our next generation of scholars. Fourth, undergraduate education would suffer because at Research I institutions many undergraduates participate directly in ongoing faculty and graduate student research. Fifth, we might create an academy that is made up of individuals and institutions that represent the "haves" (with support) and the "have-nots" (without support) thus reducing the huge source of intellectual variation and diversity that exists between programs and institutions. There are also consequences for colleges of arts and sciences if research emphases and priorities abruptly change. Important areas of studies may disappear for lack of support as faculty are hired into areas thought to be of highest priority by external funding agencies. Indeed, almost all faculty in public colleges of arts and sciences are tenured or on tenure-track. Tenure, which is extremely important for maintaining academic freedom, makes quick changes in faculty composition nearly impossible to undertake. And, institutions made large investments to create existing faculties. These investments were made not only to establish research directions and priorities, but also to address the teaching necessary for delivering a comprehensive liberal arts and sciences education for the undergraduates.

Public institutions of higher education can take steps to ensure that research and scholarship flourish in colleges of arts and sciences. We should encourage the establishment of interdisciplinary and multidisciplinary centers, programs and departments that make use of the full range of talent we have as effectively as possible. We need to make sure that departments and programs keep up with current trends in their respective fields and disciplines so they are positioned well to take advantage of funding opportunities that present themselves in the future. We need to make sure that our undergraduate and graduate students are thoroughly prepared for careers that will inevitably change. We do not know for certain where the great research advancements will be in the future but we can provide our students with the skills necessary to help assess and identify the trends and directions. We need to find ways to seed faculty research for work in new areas and to bridge faculty research when funding levels are tight. Finally, we should design and build university infrastructure that emphasizes group participation in projects over individual laboratories and work-spaces; this will require a shift in culture for many institutions.

There are also things that federal funding agencies can do to ensure that research and scholarship continue to flourish. First, there seems to be a growing trend toward looking for all of the solutions to the world's problems in biology, chemistry and physics. Federal funding policy makers should recognize that not all problems in the world are best attacked from biological or physical science perspectives. That is, the potential contributions of social and behavioral scientists, computationalists and humanists are still great. Second, more funding should be provided for career changes so that our most productive and brightest scholars are "retooled" to enter new research areas. Third, emphasize interdisciplinary and multidisciplinary approaches for training grants and other funding opportunities that are made available to graduate students and postdoctoral scholars. Fourth, convince the skeptics in government that many disciplines in the arts and sciences are important and worthy of continued study. While it is easy to see why we should fund research on disease, weather patterns, or engineering, it is sometimes harder to see why studying history, social policy, ethics, or child behavior continues to be important. Finally, it is very important that university administrators and those at external funding agencies work more closely together to make sure that what is going on in the two spheres is maximally aligned and coordinated. There is a lot at stake here as our future rests largely with the students who currently occupy the seats in classrooms within our colleges of arts and sciences. It is very important that we are all on the same page.

The General Clinical Research Center (GCRC) and The Heartland Institute for Clinical and Translational Research (HICTR) at the University of Kansas Medical Center (KUMC)

Richard J. Barohn, M.D.
Director, Heartland Institute for Clinical and Translational Research
University of Kansas Medical Center

Lauren S. Aaronson, Ph.D., R.N.
Deputy Director, Heartland Institute for Clinical and Translational Research

At last year's Merrill Research Retreat, we informed you of two major projects that would provide infrastructure for clinical and translational research at the University of Kansas Medical Center (KUMC). These two efforts are the General Clinical Research Center (GCRC) and the Heartland Institute for Clinical and Translational Research (HICTR). At this year's retreat, we provide an update on both of these.

General Clinical Research Center (GCRC)

A GCRC is an NIH-supported multidisciplinary research unit that facilitates investigator-initiated clinical studies and trials conducted by full-time faculty at an academic health center. GCRCs provide clinical research infrastructure to investigators who receive funding from federal agencies, private foundations, and other peer-reviewed sources. The space, equipment, and personnel of the GCRC are provided at no cost for investigator-initiated clinical research studies. The GCRC program has existed for nearly 50 years and is funded through the National Center for Research Resources (NCRR) of the NIH. Further information can be found at their web site – www.ncrr.nih.gov.

We began the process of initiating a GCRC for the KUMC campus in 2002 and established four goals:

- Provide clinical investigators from the School of Medicine, School of Nursing and School of Allied health with a modern, state of the art facility in which clinical research could be conducted.
- Enhance multidisciplinary research across departments and the three schools.
- Enable and train junior faculty and trainees to become more involved in clinical research.
- Apply for federal funding to support the GCRC.

In January 2005 our GCRC became operational, and we began seeing subjects. In 2006, we applied for an NCRR/NIH grant, which was funded in April 2007 for $7.5 million over three years. As of August 2007, we have approved 82 protocols that use the GCRC resources.

At KUMC, the GCRC is currently a predominantly outpatient unit located in approximately 6,000 square feet of newly remodeled space on the ground floor of the Delp Pavilion. There are six patient examination rooms; a large infusion / procedure area; a specimen processing laboratory; a cognitive testing room; a patient lounge; an exercise physiology suite with a metabolic cart; a metabolic kitchen; a computer laboratory; a conference room for GCRC and clinical research-related meetings; and administrative rooms for the biostatistician, nursing and administrative personnel, the program director, and associate and assistant program directors. With the beginning of grant funding, we now also can accommodate overnight patients in the University of Kansas Hospital through a scatter-bed system.

Additionally, with the NIH funding, three exciting new programs are now available to young researchers:

Clinical Research Feasibility Funds (CReFF) provide $20,000 grants for pilot studies to young investigators (assistant professors or below). The proposed research project must use GCRC resources, and the applicants must first go through a protocol development process and meet with a senior investigative mentor, the research subject advocate, a biostatistician, and the GCRC administrative director. We fund five CReFF awards annually, and the first five awardees were selected in July 2007. These first five CReFF awards at KUMC are:

- Jeffrey Burns, MD, Department of Neurology, Intranasal Insulin and Memory in Early Alzheimer's Disease
- Rajib Bhattacharya, MD, Department of Internal Medicine – Division of Endocrinology, Metabolism and Genetics Hypovitaminosis D and an Inadequate PTH Response in Chronic Liver Disease Patients
- Patricia Kluding, PT, PhD, Department of Physical Therapy and Rehabilitation Sciences, Pilot Project of Health Promotion for People with Diabetes
- In-Young Choi, PhD, Department of Neurology – Hoglund Brain Imaging Center, Hyperglycemia and Oxidative Stress in the Human Brain with Diabetes
- Andrea Ely, MD, Department of Internal Medicine – Division of General Medicine, Kansas Primary Care Weighs In II

Clinical Research Scholars Program (CRSP). This program allows a medical student to take one year off between years two and three or three and four to engage in clinical research. Students, with their mentor's advice, submit a protocol for a clinical research project. During the course of the year they complete the project under their mentor's tutelage. They also take approximately 12 hours of course work in clinical research, including the Introduction to Clinical Research course initiated in 2006 by Dr. Richard J. Barohn. CRSP students receive a stipend of $25,000. Three students were selected and began the CRSP program in July 2007:

- Kelsie A. Kropp / Mentor – Kathryn A. Ellerbeck, MD, Department of Pediatrics, Sex Differences in Autism: Potential Role of Oxytocin Signaling
- David C. Harmon / Mentor – K. Allen Greiner, MD, Department of Family Practice, Tailored Touch Screen Computers for Colorectal Cancer Prevention in Safety-net Clinics
- George P. Thomas, Jr. / Mentor – Jeffrey Burns, MD, Department of Neurology, Intranasal Insulin and Memory in Early Alzheimer's Disease

Summer Clinical Research Program for Medical Students. This program allows up to five students to work in the GCRC for eight weeks in the summer between years one and two. They are assigned to a mentor and become involved in their mentor's project. They present results of their summer research experience at the KUMC Student Research Forum the following spring. Summer medical students receive a $1,400 stipend from the GCRC, which is partially matched by the medical school. The five students who participated in the GCRC Summer Clinical Program in June-July 2007 were:

- Janell Jones / Mentor – Patricia Kluding, PT, PhD, Department of Physical Therapy and Rehabilitation Sciences
- Jordan Roberts / Mentor – Patricia Kluding, PT, PhD, Department of Physical Therapy and Rehabilitation Sciences
- Willis Barrow / Mentor – Jeffrey Burns, MD, Department of Neurology
- Matthew Butler / Mentor – Richard Barohn, MD, and Yunxia Wang, MD, Department of Neurology
- Ryan Peck / Mentor – Jeffrey Burns, MD, Department of Neurology
- Anh Pham / Mentor – Richard Barohn, MD, and Mamatha Pasnoor, MD, Department of Neurology
- Luke Spencer-Gardner / Mentor Jeffrey Burns, MD, Department of Neurology

The Heartland Institute for Clinical and Translational Research (HICTR) and the Clinical and Translational Science Award (CTSA) Program

In October 2005, the NIH released a Request for Applications (RFA) announcement for institutional Clinical and Translational Science Awards (CTSA). Applications were due March 27, 2006. At that time, the NIH accepted two types of applications. The first was a one-time only planning grant application for $150,000 to allow academic health centers time, and some resources, to further develop a full CTSA application. The second type was the full CTSA application that could be as large as $6 million per year (if pediatric clinical research was involved and if the proposal included involving research in community settings; up to $4 million without these components). In addition to the $6 million per year, all existing NCRR funded K30 programs for clinical research curriculum, NIH Roadmap clinical research K12 and T32 programs, and the long standing NCRR funded GCRC grants are to be rolled into the CTSA application. By doing so, a full CTSA application could be awarded between $8 and $20 million annually for five years and become one of the largest institutional research grants that an academic health center could receive. The NIH plans to fund 60 full CTSA grants by 2012.

The stated purpose for the CTSA project was to forge a transformative and integrative academic home for clinical and translational science, "to transform the local, regional and national environment for clinical and translational science, thereby increasing the efficiency and speed of clinical and translational research…by creating an academic home…that integrates clinical and translational science across multiple departments, schools, clinical and research institutions". This new "home" in an academic health center must be a Center, Department, or Institute and must encompass all components of clinical research – including education, career development, and regulatory support components for clinical research infrastructure. These new clinical research units must promote multidisciplinary research teams, create an incubator for innovative research tools, and catalyze the application of new knowledge to clinical practice. Applicant organizations also must have degree-granting capabilities in clinical research that will lead a trainee to either a Masters or a Ph.D. degree in clinical research.

Shortly after the RFA was released, KUMC initiated a planning process to develop our response to this program. In March 2006, we submitted a planning grant which was funded in September 2006. With these funds we hired an operating manager and an administrative assistant. CTSA planning committees continued to meet, and a written plan was developed. In April 2007, Barbara Atkinson, MD, Executive Vice Chancellor and Dean of the School of Medicine, announced the formation of the Heartland Institute for Clinical and Translational Research with Richard J. Barohn, MD as Director and Lauren S. Aaronson, PhD, RN as Deputy Director. The HICTR is the infrastructure and vehicle for our CTSA application.

A Regional Approach to the HICTR

While the HICTR was established at KUMC, it extends beyond the walls of KUMC and the University of Kansas Hospital, bringing together several academic health centers and their affiliated hospitals and clinics (see Figure 1). This combined effort was created to nurture the next generation of clinical and translational investigators and to provide infrastructure support for innovative clinical and translational research in a way much greater than could be accomplished by its individual parts. Developing the HICTR in partnership with our colleague institutions on both sides of the state line also fits squarely within the broader vision of creating a major hub of Life Sciences research in the KC area.

With our partner institutions in the HICTR, we have developed a plan for training and supporting our next

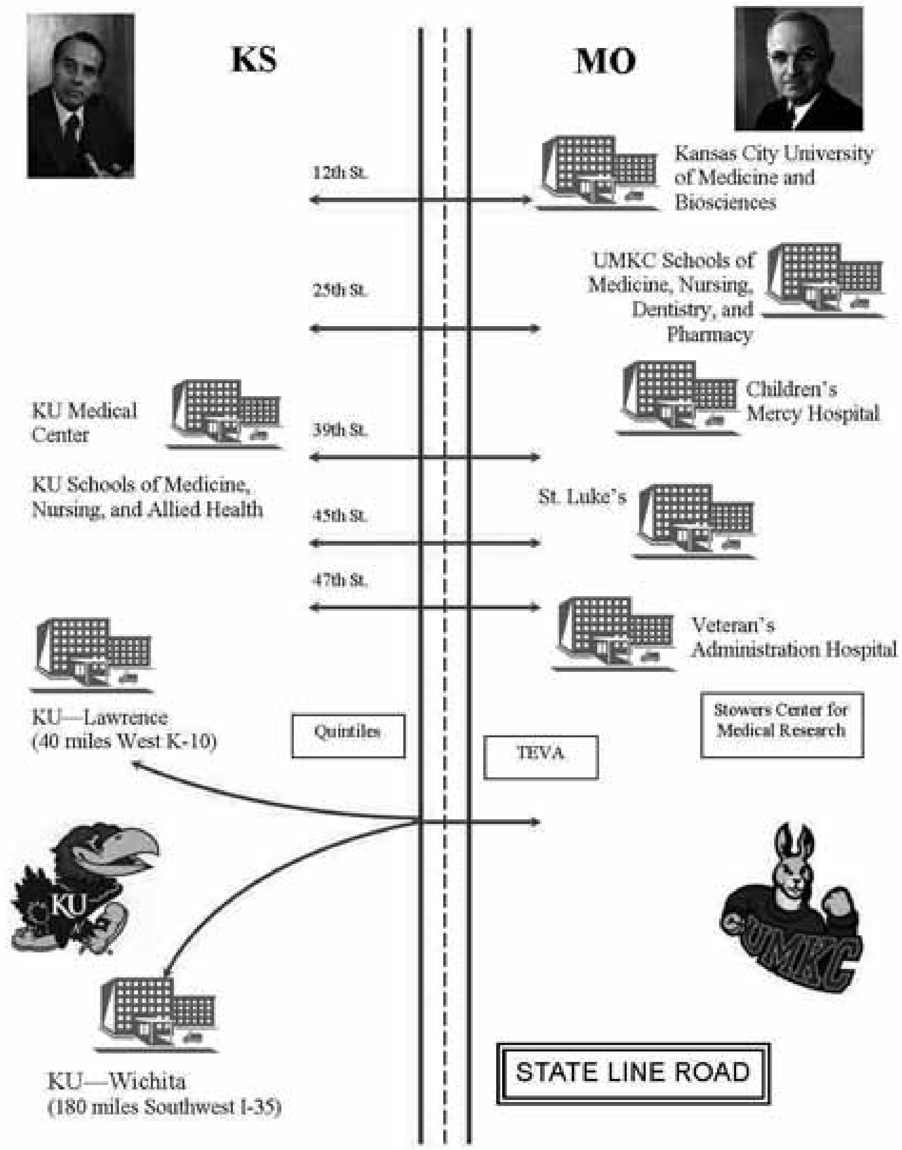

Figure 1. HICTR partnerships

generation of leaders in clinical and translational research and for providing health care scientists the tools to accomplish our unified goals through an infrastructure essential for moving clinical and translational research to new levels in our region. The HICTR is much more than an infrastructure vehicle for our CTSA application; it is a transformational, bridge-building entity that has quickly brought historically competitive academic and community health care systems together under one virtual and physical roof. Coming at an auspicious time for the KC region, the creation of the HICTR builds upon other recent and exciting developments—including the formation of the Kansas City Area Life Sciences Institute (KCALSI), the Kansas Bioscience Authority, the Stowers Institute for Medical Research in Kansas City, MO, and broad support of the governor, legislature, and public in Kansas for moving toward achieving a comprehensive cancer center at KUMC—backed by a $5 million annual commitment in each of the past two years. All of these efforts have stimulated new levels of philanthropic support from the community and from business sectors for accelerating biomedical research in Kansas and the KC region. Community leaders and organizations have appreciated the unprecedented relationships developing between our health care systems and they are active partners in this transformative process. For example, in 2000 the Kauffman Foundation awarded a five-year, $5 million grant to KUMC and Children's Mercy Hospital (where UMKC pediatric faculty and researchers are located) to stimulate collaboration across the state line by awarding pilot and full program grants that required co-investigators from both sites. More recently, the KCALSI sought and obtained community contributions to award the HICTR a $250,000 grant to launch our HICTR clinical research coordinator service. Private sector business enterprises, such as Quintiles, TEVA, Novartis, and Cerner, also have eagerly joined as HICTR partners and collaborators.

The new relationships we have forged are not only among the academic and affiliated health centers on both sides of the state line named in Figure 1, but also among a wide array of disciplines at each of our partnering institutions. Medicine, nursing, pharmacy, dentistry, allied health disciplines (such as physical therapy, hearing and speech, dietetics and nutrition), public health disciplines (such as health services, epidemiology, and health economics), biostatistics, bioinformatics, bioengineering, psychology and sociology are all needed to address today's major public health problems and all of these disciplines are active contributors to the HICTR. The multi- and inter- disciplinary collaborations currently active at KUMC and in the broader region will grow exponentially as we dramatically alter how we do clinical and translational research and open doors for wider collaboration. Through the HICTR, trainees from all campuses and from each of these disciplines will connect with each other, sharing educational and research experiences. And through the synergy created by the HICTR we envision enhanced opportunity to accomplish major advances in health and health care for all.

We believe the work done thus far to establish the HICTR at KUMC in partnership with our colleague institutions and the private sector in the Kansas City region position us to make unique and valuable contributions to the national CTSA consortium as set forth on the consortium webpage (http://www.ctsaweb.org/) with respect to:

- Encouraging the development of new methods and approaches to clinical and translational research
- Improving training and mentoring to ensure that new investigators can navigate the increasingly complex research system
- Designing new and improved clinical research informatics tools

- Assembling interdisciplinary teams that cover the complete spectrum of clinical and translational research
- Forging new partnerships with private and public health care organizations.

The HICTR vision, and penultimate goal, is to substantially add capacity for clinical and translational research in Kansas and the Kansas City region by revolutionizing such research through a dynamic partnership of university and academic health centers, major clinical facilities, community organizations, and private sector health industry entities in order to improve and enhance the health of all people. To do so, we set forth three central specific aims, which respond directly to the CTSA initiative:

- Dramatically increase the number of well-trained, multidisciplinary clinical and translational investigators in Kansas and the KC region through innovative and coordinated pre-doctoral, post-doctoral, and career-development educational programs in clinical and translational research;
- Dramatically increase the amount of cutting edge clinical and translational research in Kansas and the KC region through enhanced, creative, and coordinated infrastructure support from idea generation, proposal development and submission, through conduct, implementation, and dissemination of the research; and
- Dramatically alter the way clinical and translational research is conducted to be more responsive to community health needs and to more rapidly bring research findings to the point of care.

The HICTR is the academic home for clinical and translational research at KUMC and in the Kansas City region. A conceptual representation of the HICTR is in Figure 2. The HICTR will provide the structure, knowledge, and support needed for a wide array of clinical and translational investigations, allowing investigators to focus on their science.

The central support unit, or hub, of our HICTR home is the Clinical Research Development Office (CReDO). The CReDO is where investigators go to initiate contact with any HICTR services and core support. The CReDO houses a clinical research coordinator pool and a comprehensive research grant development program; provides the investigator-friendly interface with all other components of the HICTR, including all regulatory program requirements, and all services and resources available to HICTR investigators; and is the formal administrative site for our Pilot Studies and Scientific Review Program, our Regulatory Support Program, and our Ethics Program. As such, the CReDO is the major coordinating unit for the entire HICTR.

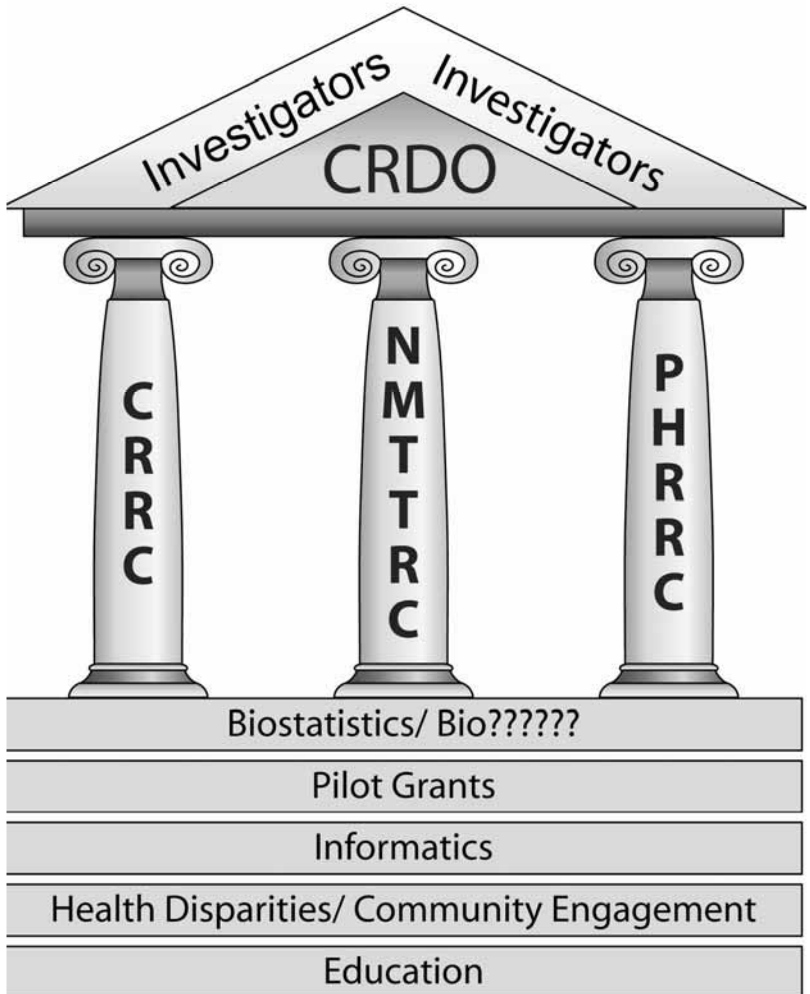

Figure 2. Schematic of HICTR. CReDO = Clinical Research Development Office; NMTTRC = Novel Methods/Translational Technologies Resource Center; CRRC = Clinical Research Resource Center; PHRRC = Population Health Research Resource Center.

The three vertical pillars in Figure 2 represent the Novel Methods & Translational Technologies Resource Center (NM/TTRC), the Clinical Research Resource Center (CRRC), and the Population Health Research Resource Center (PHRRC). These resource centers are established to primarily support T1 (bench to bedside) research, clinical research conducted within the walls of dedicated clinical research units, and community-based and T2 (bedside to practice) research, respectively. However, walls between these resource centers are permeable in order to support the considerable interaction that occurs as research moves from the bench through trials and other investigations with humans and on to implementation and dissemination in practice, and as ideas flow back again from all points along this continuum as experiences and discoveries give rise to new needs for investigation. Figure 3 depicts our conceptualization of this research process and the feedback loops.

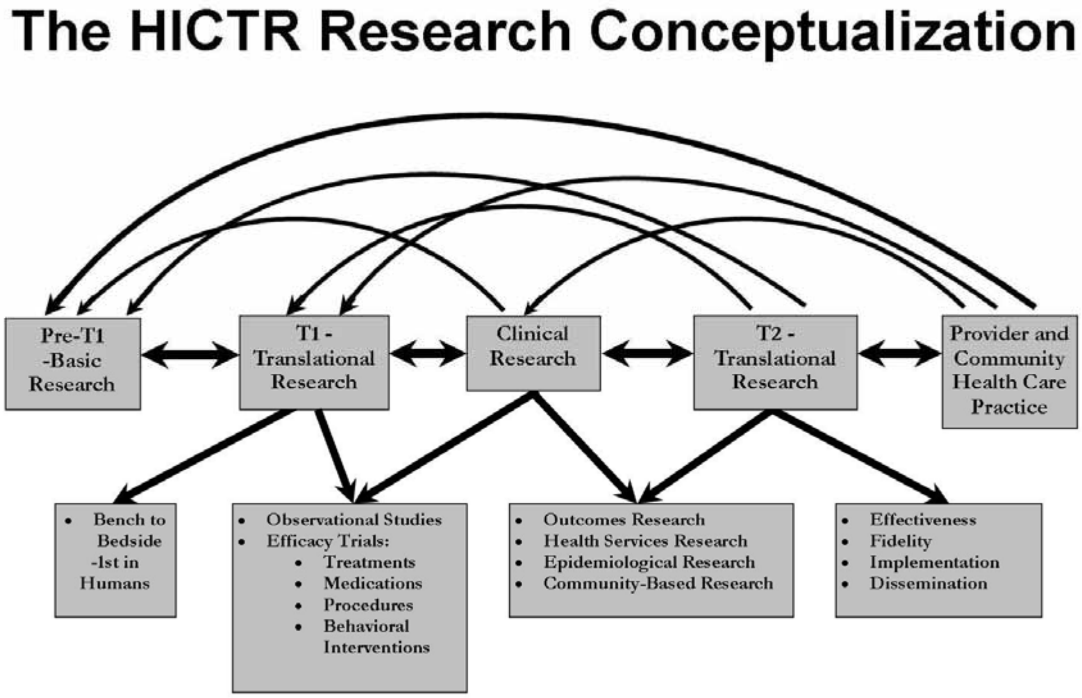

Figure 3. HICTR Research Conceptualization

As shown in Figure 3, not only is there feedback between adjacent boxes, but feedback from any location may go directly back to any other point along the continuum, depending on the idea underlying the feedback and the nature of the research needed to address the identified need. For example, in the process of implementing a new treatment, questions may arise that would stimulate new research needed at the bench, perhaps with respect to identification of new genetic markers. Or, community needs identified through the activities of our Community Engagement Program may generate research questions that must be addressed first at the bench level.

As shown in Figure 3, T1 research (defined in the CTSA RFA as "applying discoveries generated during research in the laboratory, and in preclinical studies, to the development of trials and studies in humans") involves studies characterized as first in human explorations drawing on evidence initially obtained at the bench. Clinical research includes observational studies as well as traditional clinical trials of treatments, medications, procedures and behavioral interventions. Depending on the nature of a particular study, outcomes research, health services research, epidemiological research and community-based research also may be characterized as clinical research (still in the discovery phase). When such research focuses on actual translation into practice, including issues of the cost-effectiveness of prevention and treatment strategies, it falls under the T2 research rubric (defined in the CTSA RFA as "research aimed at enhancing the adoption of best practices in the community"). Purely T2 research is best characterized as studies concerned with effectiveness, fidelity, implementation, and dissemination.

While the CReDO serves as the unifying and coordinating hub to ensure this dynamic interaction among all investigators and across all types of clinical and translational research, our three major resource centers have been established to each focus on discrete types of resources and the expertise needed to use these resources for T1 research, clinical research conducted within the walls of dedicated clinical research units, and community-based and T2 research. As such, the NM/TTRC includes cores for in vivo imaging, disease models and assessment, cell and tissue imaging, and biomarker and molecular interrogation.

The CRRC includes the GCRC at KUMC, the NIH funded Pediatric Pharmacology Resource Unit (PPRU) at Children's Mercy Hospital, the Clinical Trials Unit (CTU) at the Kansas City University of Medicine and Biosciences (KCUMB), the Clinical Research Institute (CRI) at the KU SOM in Wichita, and the clinical research facilities at Quintiles, a large private clinical research organization with which KUMC and the HICTR is partnering. The PHRRC provides a wide array of support services for clinical and translational research projects not provided through the NM/TTRC or the CRRC, including issues and activities related to accessing participants for research and working with communities and community providers, and houses the HICTR Community Engagement Program and Health Disparities Research Support Program. The PHRRC also will house and support use of large national research databases, such as the NHANES, and will maintain a repository of clinical research assessment tools, such as those recommended by the NIH Patient Reported Outcome Measurement Information System (PROMIS) collaborators.

To provide the full complement of resources needed to support the training and education of clinical and translational investigators and to support the generation of new clinical and translational research, the HICTR also includes a dynamic Clinical and Translational Research Education Center (CTREC), which administers a pre-doctoral T32 program, a post doctoral K12 program, and numerous other educational and training programs including mentor training and support and a clinical research coordinator certificate training program. And, the HICTR will support and provide biostatistics and informatics support and collaboration through the Center for Biostatistics and Advanced Informatics and through the Center for Healthcare Informatics.

Current Status of the National CTSA program:

In September 2006, when we were notified of the funding of our CTSA planning grant, the NIH also announced 51 other sites that had obtained planning grants and 12 sites that had been awarded full CTSA grants (Figure 4).

Figure 4

The initial 12 fully-funded CTSA sites are: Columbia University Health Sciences; Duke University; Mayo Clinic College of Medicine; Oregon Health and Science University; Rockefeller University; University of California, Davis; University of California, San Francisco; University of Pennsylvania; University of Pittsburgh; University of Rochester; University of Texas Health Science Center at Houston; and Yale University. The second round of CTSA applications went to the NIH in January 2007, and the NIH will soon be announcing another eight to 12 newly-funded sites. The next deadline for the CTSA application is November 7, 2007, and KUMC plans to submit at that time. The NIH recently announced two application dates for 2008 in June and October. As previously mentioned, the NIH plans to fund 60 CTSA grants by 2012.

The NIH CTSA program is a major change in how the NIH is funding and supporting clinical and translational research. It arose from recognition that such research was lagging, that fewer investigators were pursuing clinical research for a variety of reasons (including regulatory burdens, promotion and tenure concerns given the longer time periods necessary for clinical research, and other previous disincentives for engaging in clinical research), and that there are considerable delays in getting new treatments and other findings from clinical research into practice so that the public realizes benefits from these new discoveries. Recognition of the need to extend collaborations across many disciplines within and outside of medicine came from acknowledgement that today's health problems require the contributions of a wide range of disciplines, including bioengineering, epidemiology, nursing, public health, statistics, informatics technology, sociology, and many others.

The CTSA program already has stimulated major changes in how clinical and translational research is conducted at academic health centers competing for these coveted awards. Because of the importance of this relatively new initiative, the NIH CTSA program has been established under a cooperative agreement mechanism, and the NIH is actively involved with all funded CTSA programs, including with respect to a national evaluation effort and other activities involving collaborative efforts across funded CTSA sites. The ultimate goal of the CTSA program is to see that the public's health is improved through more rapidly transferring results from increasing amounts of clinical research to actual health care practice.

The Natural History of a Federally Funded Researcher

Jordan R. Green, Ph.D.
Associate Professor
Corwin Moore Chair in Communication Disorders
Department of Special Education and Communication Disorders
College of Education and Human Sciences
University of Nebraska-Lincoln

Over the past decade, many teaching universities have been aggressively growing their research programs. This swell of interest in academic research has occurred during a time when support from state funding sources for academic programs has declined. Consequently, the success of many universities as a whole has become highly dependent on the success of their research faculty. In this talk, I consider the growing scope of discipline of Communication Sciences and Disorders (CSD), current impediments to future progress in the field, and by way of example, the efforts of our federally-funded lab to address current research challenges. My perspective is that of an academic researcher whose career path has been supported continuously by grants from the National Institute on Deafness and Other Communication Disorders (NIDCD) starting from doctoral training to the obtainment of a large grant award. Also, highlighted are some examples of programs currently in place to promote research that have been implemented by NIH-NIDCD, the University of Nebraska-Lincoln (UNL), and the professional organization that supports my field, The American Speech-Language and Hearing Association (ASHA).

Introduction to Communication Science and Disorders

An estimated one in six individuals will suffer from a significant communication impairment in their lifetime. The ability to communicate is one of the most important human functions. Communication defines who we are – our personality, our relationships, and provides us access to the world. In some respects, my colleagues in the physical sciences are envious of the fact that I don't have to work very hard to convince others of the importance of research on human communication and its impairments. Also, that I don't have to search for interested funding agencies because NIH has an institute, NIDCD, that is dedicated primarily to funding research on communication disorders.

The profession of communication science and disorders (CSD) is a broad one, going beyond just speech and language, but also including audiology, cognition, swallowing, augmentative and alternative communication, professional voice, and even foreign accent reduction. The increasing scope of our profession poses a continual challenge with regard to training the next generation of practitioners and researchers. Speech science is a subdiscipline of CSD that encompasses the study of the anatomic, physiologic, neurologic basis of speech production and perception, and of the cognitive processes involved in communication. Speech science is supported by other subdisciplines including speech-language pathology and linguistics, anatomy and physiology, mechanical engineering, biomechanics, psychology, neuroscience, computer science, robotics, and genetics. The wide range of topics encompassed by CSD underscores the broad-level of expertise required to perform research on human communication and the necessity of interdisciplinary research.

In the United States, the field of CSD officially began in 1928. During that year, Sara Stinchfield was the first person in America to receive a Ph.D. degree in speech pathology and Raymond Stetson published an influential book called Motor Phonetics: A Study of Speech Movements in Action. Despite gradual progress, however, the pace of scientific discovery in the field of CSD is accumulating very slowly. The bases for most speech problems remain unknown and the diagnoses and prognoses of speech disorders are very subjective. Identifying objective criteria for classifying speech disorders has been an ongoing challenge and a major focus in the field.

Impediments to Future Progress in CSD

Progress in research has been slowed by a leadership crisis, methodological limitations, and federal funding shortages. Of course, many of these challenges are not unique to the discipline of CSD.

Leadership crisis: Perhaps our greatest challenge to preparing the next generation of leaders in CSD is in the recruitment of the next generation of scholars. The field of CSD currently faces a shortage of Ph.D. students with the number of graduates falling short of the number needed to replace retiring faculty. In 2001-2002, there were 333 unfilled slots for Ph.D. students according to a report (http://www.asha.org/students/academic/doctoral/phd_survey_sum.htm) prepared by the Joint Ad Hoc Committee on the Shortage of Ph.D. Students and Faculty in CSD. Recruitment should begin at the undergraduate level. Unfortunately, only a small number of undergraduate and graduate students in our field are exposed to research. One very successful program that engages undergraduates in research at UNL is the Undergraduate Creative Activities and Research Experience (UCARE) program. This program is funded by the Office of Undergraduate Studies and funded by the Pepsi Endowment and Program of Excellence funds. The UCARE program provides undergraduates with funds to support a two-year research experience. More programs like UCARE are needed to raise students' awareness and interest in research careers.

High priority should be given to programs that facilitate the development of beginning investigators. A number of initiatives have been implemented by ASHA, NIH, and UNL to encourage the development of new investigators. NIH's programs include the Small Grant Program (R03) and High Program Priority (HPP). Post doc training also should be strongly encouraged. Unfortunately, post doc training is rare in the field of CSD because many of our Ph.D. graduates are being hired upon completion of their degrees or even before graduating. Without solid academic skills and a strong publication record, these individuals may be placed in a compromising position when seeking tenure at R1 institutions.

Another significant challenge to training the next generation of researchers is the shrinking supply of available mentors, which is partially due to the large number of impending retirements in our departments across the country. The mentoring of junior faculty needs to be a high priority as it maximizes the likelihood of success and improves retention by imbuing a sense of institutional loyalty in faculty who are frequently courted by other institutions. A working definition of mentoring needs to be articulated that is specific and institutionally endorsed. Tangible incentives should be provided for mentors and mentoring should be considered as part of academic load. Several UNL initiatives are in place to encourage the formation of mentored relationships between senior faculty, new faculty, and graduate students. These initiatives are the Grant Mentor and the Preparing Future Faculty Programs.

The field is significantly shaped by decisions made by individuals serving as grant and manuscript reviewers. Poorly conceived reviews can be devastating for a new investigator. Yet, individuals who serve on these panels rarely undergo formal training and rarely receive feedback from peers or the institutions they serve. More programs - like the NIH grant review training workshop sponsored by ASHA's Research and Scientific Affairs Committee - are needed to train the next generation of study section members and journal reviewers. This workshop provides beginning reviewers the opportunity to co-review grants with more seasoned reviewers who have served on standing NIH review panels.

Methodological Limitations: Overcoming methodological limitations is central to any successful research enterprise. The study of speech is no exception. Despite its obvious significance to quality of life, speech motor control is a topic that has been understudied when compared to other aspects of motor control in humans1. The dearth of scientific work is, in part, because speech is exceedingly difficult to measure. Speech is the result of activity of approximately 70 muscles and many parts of the speech production system, such as the tongue, soft palate and pharynx, are inside the body and therefore difficult to observe directly. Speech movements are also very small and rapid; when speaking, we produce up to 12 sounds per second. Therefore, new technologies are needed for accelerating the rate at which researchers can acquire and analyze speech data. Recognizing the general need for continued technological advancement, NIH offers the Shared Instrumentation Grant (S10) that provides up to $500,000 annually for equipment related expenses needed by groups of NIH-funded investigators. These grants are important for providing researchers access to cutting edge technologies.

Continuing education is also needed to make researchers aware of emerging technologies. To assist in educating the scientific community, NIH-NIDCD has sponsored several state-of-the-science workshops. Another potential mechanism for continuing education includes the development of high quality E-learning on demand courses, particularly for continued education regarding robust and efficient experimental design and analysis techniques.

Federal funding shortages: Most of the speakers at this conference have commented on the challenges of maintaining and growing academic research programs given the current federal funding climate. Winning grants has become significantly more difficult for three primary reasons: (1) the growth rate of federal dollars for research has slowed, (2) the average grant size has grown, and (3) more researchers are competing for a smaller number of available grants. For example, in 1998 there were 24,000 NIH grant applications whereas in 2007, the number of applications were projected to be 49,000 (Giles & Wadman, 2006). This reduction in the relative number of grants awarded annually will have deleterious effects on research and education in this country. The underfunding of research will also considerably weaken research training programs with fewer students exposed to research and fewer departments awarding doctoral degrees.

One necessary strategy to reduce the impact of the current funding crunch will be the formation of multicampus consortiums. Such alliances have numerous advantages. Consortiums accelerate pace of discoveries by providing the most efficient means for scientist with diverse perspectives to achieve scientific consensus. They also allow for comprehensive, multilevel level description of a large number of subjects, which is needed to obtain statistically sound descriptions of disorders. They also minimize variability across studies due to heterogeneity among subjects and differences across labs in data collection techniques.

Efforts of one federally-funded lab to address challenges

The long-term goal of our research program is to advance the scientific understanding of speech production and its disorders. To achieve this goal, we are investigating three aspects of speech production: (1) typical oromotor development for speech and feeding, (2) physiologic basis of impaired speech, and (3) computer analysis of speech motor performance. The brief discussion below focuses on our established research program on speech motor development and our emerging research program on amyotrophic lateral sclerosis (ALS). One principle that guides our research is that basic knowledge about speech motor development and typical speech performance is essential for improved differential diagnosis and treatment of speech motor impairments. Because the number of physiologic studies on speech production is fairly limited, one necessary and particularly challenging aspect of our work has been the development of new tools for recording, measuring, and analyzing speech performance. Our research program is student focused, with students of all levels working on research. This work would not have been possible without continued support from NIH-NIDCD.

As alluded to previously, a major impediment to progress in our understanding of speech motor development has been the lack of viable experimental methods for recording articulatory behaviors from very young children. To address this challenge, we have adapted 3D motion capture technology to obtain fine-grained measurements of face movements from infants and young children. The data from these studies are being used to address long-standing theoretical and practical issues regarding early speech development. The large amount of data now afforded by this technology, however, has also led to new challenges associated with data reduction and analysis. To address this challenge we have developed a software program (SMASH) to improve the efficiency and reliability of physiologic data reduction. In SMASH, multiple data files are loaded into a graphic user interface, custom analysis routines are accessible from dropdown menus, most routines rely on algorithmic detection, and measures are automatically exported to a database.

ALS, which is another focus of our research program on speech production, is a progressive neurodegenerative disease that affects motor nerve cells in the brain and the spinal cord. The mechanisms that trigger motor neuron death are unknown and no definitive biomarker for ALS has been identified. Life expectancy is only 2-5 years after diagnosis. The diagnosis of the disease is provisional based on clinical observations and neurologic symptoms in the absence of other causes. Because the clinicopathologic markers of ALS are so poorly defined, diagnostic uncertainty is very high; patients are initially misdiagnosed up to 45% of the time and the diagnosis can take up to 12 months. Early detection is becoming increasingly important with the number of experimental treatments growing rapidly in recent years; the benefits of drug therapies will be maximized if they are administered early in the disease while motor neurons are still intact. The goals of our research on ALS are to identify sensitive, quantitative indicators of disease progression that can be used as outcome measures for determining the effectiveness of experimental drugs and for improving the detection of disease onset and the prediction accuracy of disease progression in bulbar ALS. To achieve these goals, we are using the technologies we have developed to study early speech motor development to quantify the natural history of disease progression in a relatively large number of individuals with ALS. The work is currently funded by an initiative from the Vice Chancellors of Research office to facilitate the development of inter-campus consortiums that engage members from a wide number of disciplines.

Summary

In summary, I have given the researcher's perspective on current challenges faced by my discipline and considered several measures to address these challenges which include (1) train the next generation of scientists, (2) do bigger, better science through consortiums, (3) focus funding efforts toward overcoming technological hurdles, and (4) provide continuing education for scientists. A number of outstanding initiatives have already been put into place by the federal government, professional agencies, and universities to address many of these issues. These initiatives, although modest in size, suggest the research community is headed in the right direction.

References

1. Giles, J. & Wadman, M. (2006). Grants fall victim to NIH success, Nature, 443, 894-895.

Footnote: One overly simplistic - but nonetheless revealing - demonstration of the paucity of studies on speech physiology is the results from a PubMed database search that was limited to the past five years of research. While the terms "grasp and hand" yielded 1882 publications, "speech and tongue" only yielded 285.

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Industry Funding of University Research: Can It Replace Federal Funding?

James A. Roberts

Vice Provost for Research, University of Kansas

The question addressed in this paper came about as a result of two events. One was the presentation and paper at last year's Merrill Conference by John Wiley, Chancellor of the University of Wisconsin-Madison. He, in good engineering form, applied some engineering principles to answering a question related to the privatization of universities.[1] Since I am also an engineer, I thought I could perhaps apply Chancellor Wiley's approach to a question related to the topic of this year's conference…the future of federal funding of research.

It was not long before the second event occurred. In May of this year, Dr. John Marburger, President Bush's Director of Science and Technology Policy, spoke at the Policy Forum of the American Association for the Advancement of Science (AAAS).[2] The appendix contains selected excerpts from his talk, in which he asserts that the federal government cannot continue to grow sponsored research at American universities at the rate it has been. In fact, he states that we can do all the R&D we need to do but he doesn't believe that we can accomplish it by simply appropriating more federal funds. He talked about the NIH increase, stating he couldn't see how such an expansion can continue, using the same business model that got us here. All universities are going to have to look to diversified sources of income, he said, working toward the notion of industrial funding of research. And then he gets into "economically relevant outcomes," comments we often hear on the local level.

There is no argument with the positive correlation between industrial research and economic productivity. And, yes, industrial research is good for the economy, and industrial sponsored research is good for universities. What Marburger is saying is that federal funding is not going to grow fast enough to keep up with the established pace, so state and private sector resources are going to have to replace federal funding.

Toward the end of his talk, Dr. Marburger said that even though we need industrial funding of research, the amount remains low relative to its potential. Dr. Michael Crow, President of Arizona State University, spoke in Kansas City this past week.[3] After his talk, I asked him about this issue and he agreed that industrial funding to replace federal funding couldn't be the entire answer. He added that the states need to step up and do things such as the establishment of an Arizona Science Foundation. But, as we shall see, state support of university research is low as well. So, let's just look at the numbers. Can industry-funded university research replace federally funded university research? If so, what might be the consequences?

Setting the Stage The words to the Kansas state song, "Home on the Range," state categorically, "… for never is heard a discouraging word…" I apologize for having to utter one in Kansas, but the discouraging word is a serious concern. The latest funding information for U.S. universities, compiled by the National Science Foundation, was just released. Fig. 1 is a graph of federal research and development (R&D) obligations to universities and colleges. The discouraging message is that for the first time since 1970, there was a decline in federal funds going to U.S. universities and colleges for research. I mentioned this in a speech I made recently following remarks given by Rep. Nancy Boyda, Congresswoman from the Second District of Kansas. She was alarmed and wanted to see this information. These are nominal dollars, not inflated. Obligations roughly approximate federal sponsored program

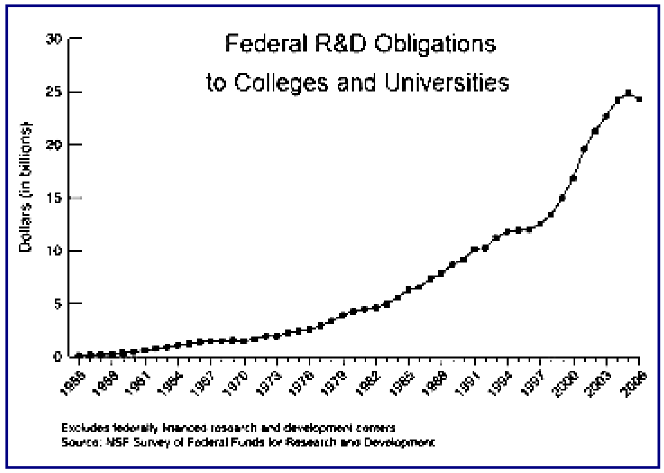

Figure 1

awards. Fig. 2 looks at U.S. total research and development as a percentage of the gross domestic product, going back to 1953 and projected for 2005 and 2006. There are some interesting observations. From an engineering perspective, the total U.S. R&D is a classic function, oscillating around and seemingly converging to 2.5%. Also, while the

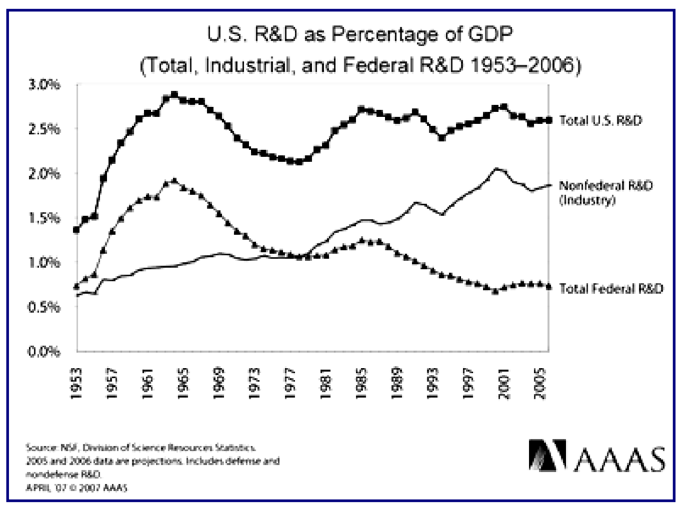

Figure 2

percent of R&D funded by industry has been growing the percent funded by the federal government has been declining, basically since the early 1960s, the post-Sputnik era. These data indicate that the

U.S. is maintaining its research output at a more or less constant percentage of the GDP (2.5%), and that industrial research

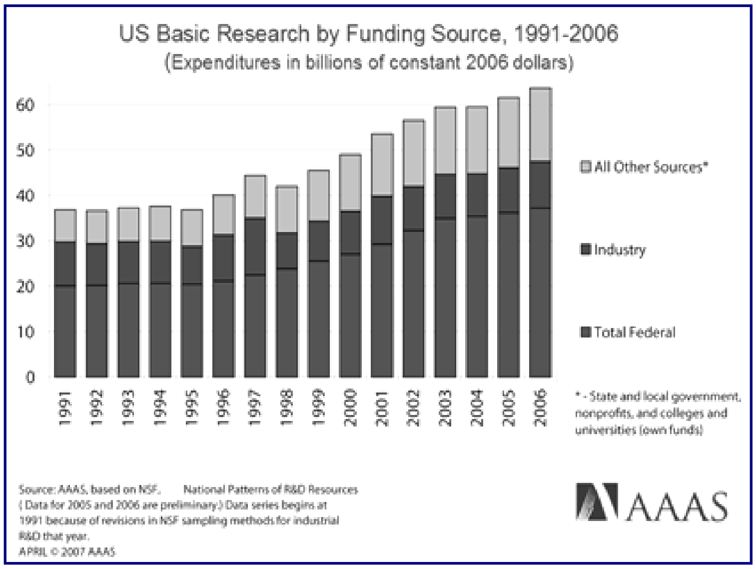

Figure 3

is indeed replacing federally financed research. But there are deeper implications with respect to basic versus applied research and funding of university-based research. Basic research funding is growing as well. Fig. 3 shows data from an AAAS chart that confirms this. But note that the industrial component has not changed much. Growth is coming from federal and other sources, not industry. Fig. 4 plots industrial sponsored R&D at colleges in universities in nominal dollars, going back to 1972. The good news is that it grew from something that wasn't very much at all to a substantial amount, and it grew fairly steadily until 2000. After the dot-com bust, though, it has stagnated. But let's look at this differently and ask what fraction of university research funding comes from industry. Fig. 5 plots this percentage, and now the picture is not as pretty. The percentage has in fact declined from a paltry 1.5% in the early 1990s to where it now hovers at about 1%. Plain and simple, industry is not, in general, a major source of funding for university research.

A Look at the Numbers

To analyze the question of industrial funding making up for a slowdown in federal funding of university research, assume that overall university research funding continues to

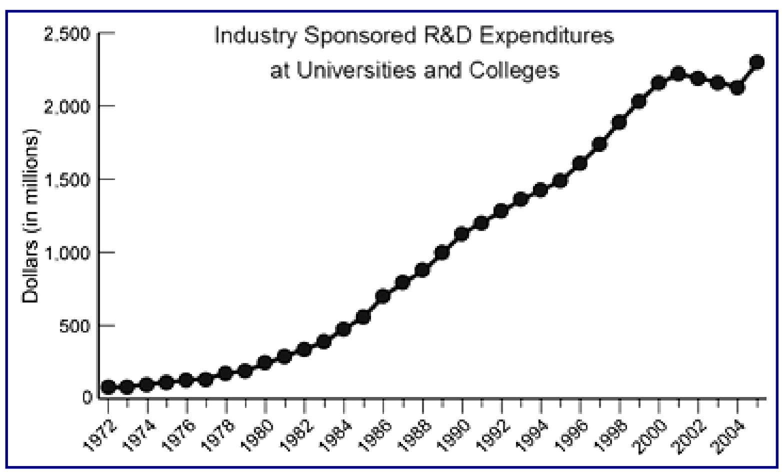

Figure 4

grow at its historic rate through 2013. In addition, assume that federal funding of research flattens, as it has recently, but allow state and other sources to grow at their historic rates. Then calculate the size of the industrial component needed to pick up the slack from the flattening of federal funding.

A useful device is to plot the historical data on a logarithmic scale. Fig. 6 shows such a plot for the data plotted on a linear scale in Fig. 1.

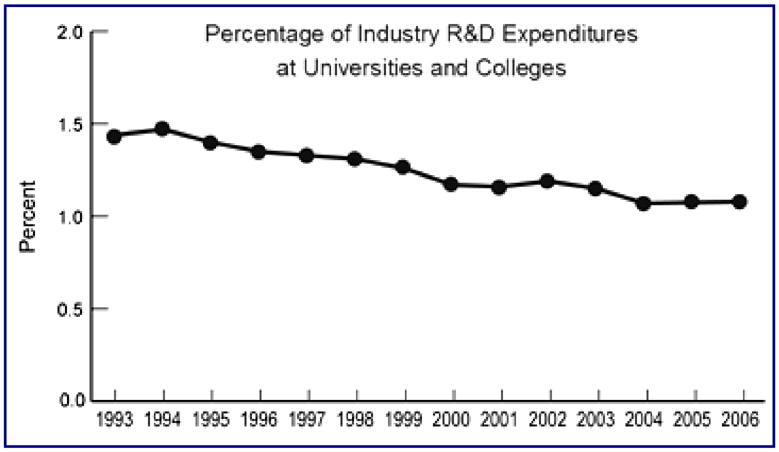

Figure 5

Exponential growth is a straight line on a logarithmic scale, and so we see that from the mid-1960s until about 2005 federal funding of university research grew exponentially. The approximate slope of the line indicates an annual growth rate of about 8.1%.

This is a measure of the 40-year commitment on the part of the federal government to fund university research.

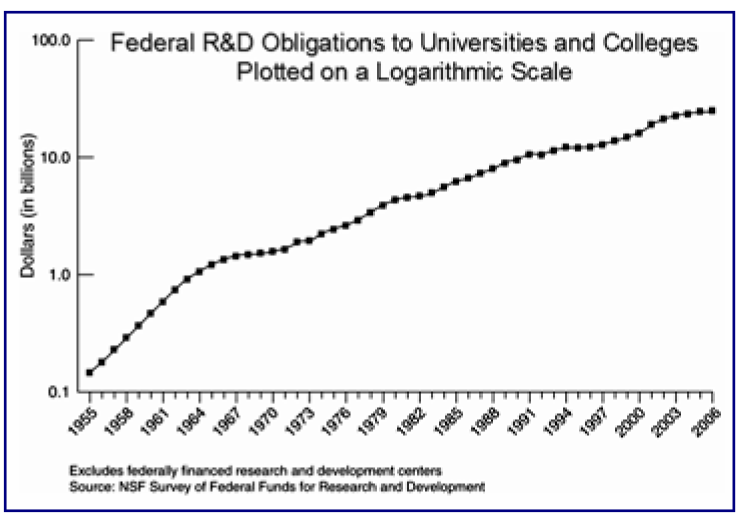

Figure 6

And the results, in terms of the strength of the U.S. economy and improvement in our standard of living, have been spectacular.

Fig. 7 shows the results of the analysis based on the assumed scenario. Again, the total research funding level grows at the historic rate, as do state and other sources. Federal funding flattens, and industrial funding is computed to maintain the total. In order to do that, industrial funding of university research would suddenly have to begin growing at 40% annually, compared to an annual growth rate of 4.4% over the past 10 years. And in the end, by 2013, industrial funding would actually exceed federal funding. This simply isn't going to happen. And why would industry do this anyway? They are not a charity out to replace funding for the collective national good just because the federal government has decided not to do it.

Unintended Consequences

For the sake of argument, let's go ahead and assume industry were in fact to make up for the reduced federal funding at universities. What are the unintended consequences of this "good" outcome? Three questions immediately come to mind:

- What happens to funding levels in specific

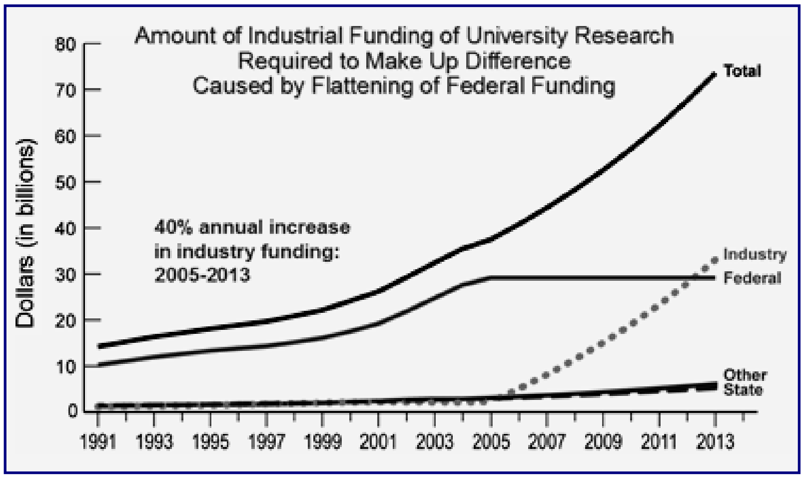

Figure 7

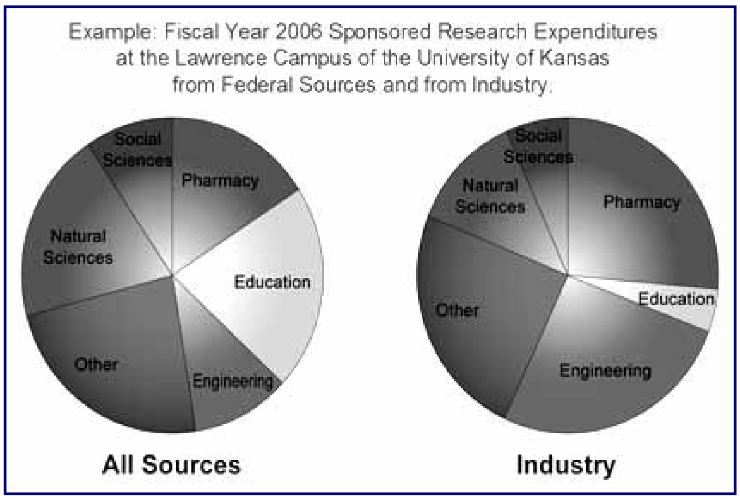

Figure 8

fields of study?

- What happens to the mix of basic versus applied research?
- Does the geographic distribution of research funding change?

The impact on the fields of study should be obvious. Fig. 8 shows the distribution of research funding on the Lawrence campus of the University of Kansas when broken down by federal funding (by far the largest source) and industrial funding. As you might expect, a shift in funding source from federal to industrial results in a shift to engineering and pharmacy, with a corresponding reduction in the social sciences, natural sciences, and education. In short, the fields with more opportunity for applied research benefit.

This raises the second of the unintended consequences relating to basic versus applied research in general. Fig. 9 graphs industrial R&D spending broken down into basic research, applied research, and development. First, note that the lion's share of industrial R&D is for "D." Further note that basic research constitutes only a small fraction (about 5%), and it grew by only 6% over the period of time shown.

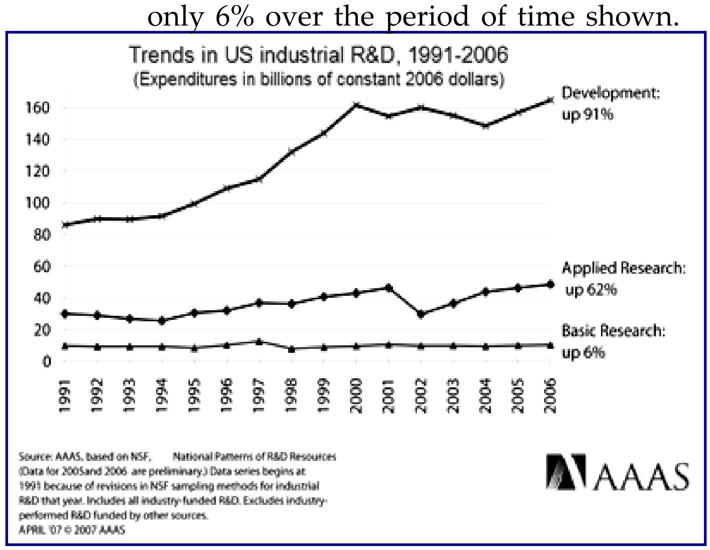

Figure 9

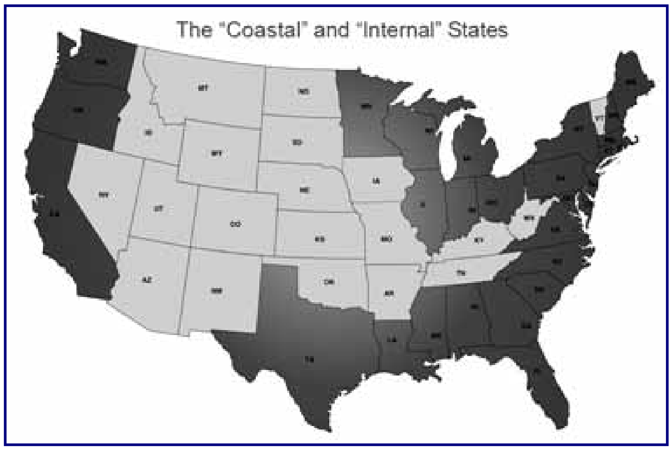

Figure 10

75% of federal funding is for basic research. To a first approximation, industry funds applied research and development, while the federal government funds basic research.

In the scenario presented earlier, where industrial funding replaces flattened federal funding of research, if industry continued to spend only 5% of its budget on basic research there would be a drop of $19.4 billion by 2013 in basic research funding to universities. This would have serious consequences for the future.

The third unintended consequence relates to geography. We in the Midwest are keenly aware that the "coastal states" garner proportionally more research dollars, federal laboratories, prestigious awards, etc. So to address this question with respect to the scenario about industrial funding replacing federal funding of university research, we arbitrarily sorted the states into a "coastal" group and an "internal" group. This was based simply on whether a state bordered the Atlantic or Pacific Oceans or the Great Lakes. Fig. 10 is a map of the states so divided. (Alaska and Hawaii aren't shown, but they are coastal in our definition.) 85% of all U.S. research funding is conducted in the coastal states.

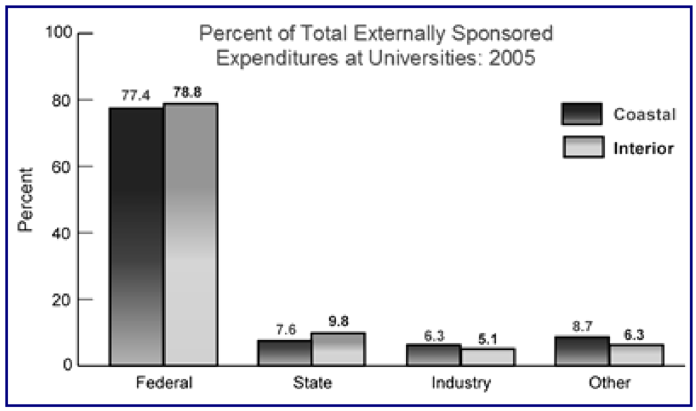

Figure 11

Fig. 11 shows the percentage of university research funding by source divided between the coastal states and the interior states. There are some small differences in the distribution of funds based on source between the coastal group and the interior group, but the interior states have a slightly

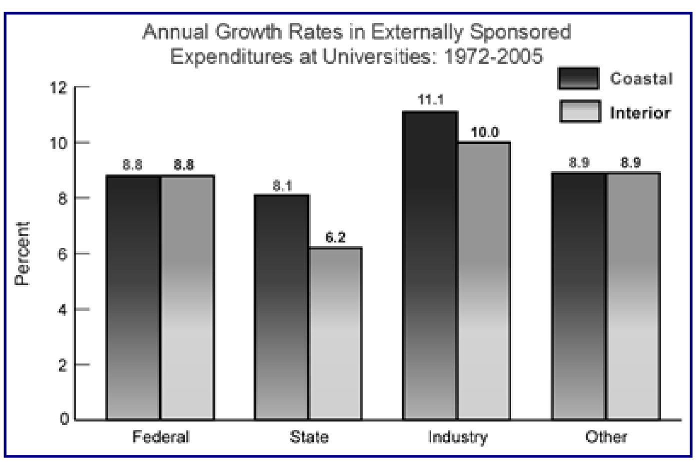

Figure 12

larger percentage of their funding coming from federal sources than do the coastal states.

Fig. 12 shows the growth rates broken down the same way. Both state and industrial funding have been growing more rapidly on the coasts than in the interior. So taking the growth rates and the distribution of funding by source, and using the same projection as before with industrial funding replacing flattened federal funding, we find that total R&D funding in the interior states falls from 15% of the total today to 13.6%. This is a 10% reduction and a potential loss of $1.2 billion to the interior states. So the problem of unequal distribution of research funding is exacerbated by a shift from federal sources to industrial sources. Universities in the coastal states pick up additional research funding at the expense of the interior states.

Summary

None of this is intended to say that industrial funding of research is not important. It absolutely is, and we in academia and the country in general need industrial collaborations. But if one asks the question "Can industry make up for a reduction in federal funding of research?" the answer is "Very unlikely." Not only is it very unlikely, there are some negative unintended consequences even if it were to happen.

The question we should be asking is not so much "could it" but "should it?" Basic research is crucial to the future of our society, and universities are where it is happening. To maintain our leadership as a nation, we must fund curiosity-based research that is not driven by agendas or intentional outcomes. This is the source of the great ideas and ultimately the great technological innovations that have given the U.S. the standard of living we all enjoy.

Going back to basics often works. In 1945, Vannevar Bush wrote: "Basic research is essentially non-commercial in nature. It will not receive the attention it requires if left to industry. …The simplest and most effective way in which the government can strengthen industrial research is to support basic research and to develop scientific talent."[4] Amen.

Appendix:

Excerpts of Remarks by Dr. John Marburger, Director, Office of Science and Technology Policy, Executive Office of the President

AAAS Policy Forum, May 2007, Washington D.C.

"I believe we can do all the R&D we *need* to do, and very much of what we *want* to do, but I do not believe we can accomplish this the way we would *like* to do it, namely by simply appropriating more federal funds."

"I cannot see how such an expansion [NIH budget doubling in 5 years] can be sustained by the same business model that led to its creation. New capacity can only be sustained by new revenue sources."

"The economics of university-based research are beginning to change to a new model with diversified sources of revenue. Federal science policy should encourage this change."

"Not only will it enable an expanded research enterprise, it will also promote development of capacity in areas likely to produce economically relevant outcomes."

"Moreover, economists have documented a positive correlation between industrial research investment and national economic productivity, and to the extent this correlation indicates a causal relationship, increased industrial research will be good for the economy."

"The message here is that federal funding for science will not grow fast enough in the foreseeable future to keep up with the geometrically expanding research capacity, and that state and private sector resources should be considered more systematically in formulating federal science policy."

"The level of industrially supported basic and applied research at universities remains low, however, relative to its potential."

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Initiatives to Increase Faculty Competitiveness for Federal Research Funding

Beth A. Montelone, Ph. D.
Associate Dean, College of Arts & Sciences, Kansas State University

Extramural research funding is the lifeblood of research universities, and few faculty members are unaware that competition for Federal research dollars has become ever more intense in recent years. While funding levels vary among and within agencies, the overall funding success rate for NSF was 25% in fiscal 2006[1], while for NIH it was 20%[2]. These compare with historical averages in the thirty-percent range during the 1990s[1, 2]. Figures 1 and 2 show that part of the reason for this drop is that the numbers of applications received by both agencies have increased substantially during the last ten years, while the number of awards made by each has stayed relatively flat. This is true despite the doubling of the NIH budget over the period 1998-2003.

The current budget situation does not suggest that the availability of grants will be changing soon; the President has proposed to increase some programs at NSF and DOE[3] but his science advisor has stated that scientists should not expect large influxes of money into other programs[4]. NIH director Elias Zerhouni also does not envision an improvement in the availability of traditional investigator-initiated awards, but points to a need to preserve future generations of scientists through programs to support new investigators via new grant programs and mentoring[5]. An example that NIH has already launched is the Pathway to Independence Award program, to which scientists still in postdoctoral positions can apply. If funded these individuals are eligible for two years of training support with a mentor and three years of funding in their first faculty position[6].

Kansas State University programs to develop new investigators

Kansas State University (K-State) has created or participates in a series of initiatives with primary or secondary goals of providing mentoring and/or resources to assist new faculty members in establishing the successful research programs necessary to achieve tenure. Collectively, these contribute to a nurturing atmosphere in the science and engineering departments at K-State. Several of these and their outcomes to date are described below.

Center of Biomedical Research Excellence (COBRE) in Epithelial Health and Disease

The NIH-funded COBRE award to Dr. Daniel Marcus of the Department of

Anatomy & Physiology in the College of Veterinary Medicine (CVM) began in 2002. This project was intended to enhance the careers of junior faculty members, both basic researchers and clinician-scientists, at K-State and other Kansas institutions. It provides seed funding to the junior faculty and establishes a partnership with a mentor, with the goal of making the junior faculty competitive for independent NIH funding. The theme of this COBRE is epithelial function in health and disease; its associated projects center on epithelial cell physiology or pathophysiology and provide a strong foundation for translational research.

The COBRE is comprised of seven teams of junior faculty members and mentors in the CVM and collaborating departments at K-State, the University of Kansas Lawrence campus, and the University of Kansas Medical Center. These individuals, along with the COBRE Director and advisory committee members, participate in a structured program of interdisciplinary interactions in video-conferenced seminars. The COBRE award also established three core facilities to support the research of participating faculty at K-State. These include a state-of-the-art confocal microscope facility; a molecular biology support facility; and an epithelial electrophysiology facility.

Outcomes of the COBRE: Over the last 5 years, COBRE participant progress resulted in 54 publications, and 218 presentations and abstracts related to COBRE activities[7]. Six junior faculty members have successfully "graduated" out of the program and are now tenured. A research community focusing on epithelial cells has emerged from the interactions promoted by the center. Extramural funding, particularly among investigators in the CVM Department of Clinical Sciences, has shown gratifying improvements in success rate and total dollars awarded since the start of the COBRE (see Table 1).

Kansas Idea Network of Biomedical Research Excellence (K-INBRE)

K-State is a partner in this program, which is hosted at the University of Kansas Medical Center. It is funded through the National Institutes of Health Center for Research Resources for the purpose of strengthening biomedical research and training researchers in cell and developmental biology in the state of Kansas. Its aims include building a research network, increasing the research base by providing support to junior faculty, postdoctoral fellows, and graduate students, encouraging undergraduate participation in research, and enhancing the research infrastructure in the bioinformatics area. The K-INBRE program has made Faculty Scholar Awards, Starter Grants, and Pilot and Bridging Awards to faculty members from K-State and other KS campuses.

Targeted Excellence

The K-State Targeted Excellence project is funded through the K-State Provost's Office from tuition monies. It was created in 2003 and is intended to "enhance those programs (primarily inter-disciplinary) with the most promise of elevating the university's stature."[8]

There have been four rounds of competition to date. The program considers cross-departmental projects that involve multi-disciplinary themes or ideas, projects that may vary in length from short-term (one to two years) to long-term (up to five years), and requests from $50,000 to $2,000,000. A total of 26 distinct projects have been funded in the first four competitions, some for relatively small amounts to initiate projects (ca. $100,000) and other large collaborative awards receiving $2M over multiple years. These major awards established new research centers and provide seed funding to stimulate innovative and collaborative research, and provide an important university resource for encouragement, support, and mentoring of junior faculty members. Some of these centers are described below.

The Ecological Genomics Institute brings together scientists using cellular and molecular biological approaches with those interested in ecological and evolutionary questions to create new cutting edge research and synergize interactions across colleges and departments. Part of their funding has been used as start-up for hiring two new faculty members and has supported initial research projects by other individuals and teams.

The Center for Genomic Studies on Arthropods Affecting Human, Animal, and Plant Health builds on expertise of faculty members in Agriculture, Arts & Sciences, and Veterinary Medicine who work on a variety of areas including insect developmental genetics, biochemistry, animal disease, and plant disease. It will build capacity in genomics and bioinformatics through personnel hires and equipment purchases. New faculty members are supported through a seed grant mechanism and the establishment of collaborative work groups.

The Center for Bio-based Polymers by Design fostered collaborations between new faculty and established researchers in the biomaterials area, including investigators from several engineering disciplines, biochemistry, chemistry, physics, and grain science. This group is in the process of submitting a proposal to NSF for a Materials Research Science and Engineering Center award, which would support graduate students, postdoctoral scientists, and junior investigators.

A recent summary of funding garnered by the projects supported by Targeted Excellence showed that $14.2M in extramural grants have been leveraged by the investigators associated with these projects (J. Guikema, personal communication). This compares favorably to a university investment of $15.5M for projects funded in the first three years. Since some of the projects included were underway less than a year when this accounting was done, it suggests that this investment will be profitable for the university over the long term.

K-State Mentoring Program

The KSU Mentoring Program for Women and Minority Faculty in the Sciences and Engineering was created in 1993 with a grant from Sloan Foundation. It requires junior faculty members to identify a mentor in their discipline and provides small ($6000) awards that can be used for a variety of purposes. Since 1999, funding has come from the office of the K-State Vice Provost for Research using grant indirect costs as the source. Eligibility is limited to tenure-track female and minority faculty in science and engineering who have not yet been principal investigator on a major extramural grant. The purpose is to provide junior faculty with mentors in their research areas who will help them achieve extramural funding, the first step necessary for tenure and success in science and engineering departments.

The program at its conception did not specify limitations on use of program funds and as it has evolved, broad guidelines have been developed that provide a great deal of flexibility to applicants. The most common requests include seed money for research supplies and assistants, professional travel, and attendance at short courses. Proposals that ask only for faculty or graduate assistant salary must be justified in terms of how they will professionally benefit the applicant. All proposals require a short description of activities in non-technical language, a detailed budget request, a listing of current and pending support, a description of the planned mentor-mentoree relationship with curricula vitae for each, and a letter of commitment from mentor.

Recipients of the mentoring fellowship are required to report to the Provost's Office on outcomes of the experience, including how the funding and mentoring relationship benefited them. A 2003 report on the program[9] included the information that the funding was used to obtain preliminary data, "jump-start" research projects, engage in professional travel to enhance research, and that the mentoring relationships so established continued following the award period. In some cases, mentoring relationships established as a result of the proposal submission went forward even if the proposal not funded.

To date, 57 individuals have received awards (11 women of color; 6 men of color); of these, 43 have received significant extramural funding to date. Of 32 faculty members who have become eligible, 25 have received tenure (78%), and 20 of these are still at K-State. Seven female recipients were promoted through the ranks to full professor since receiving their awards. An estimate for our 2003 paper showed that at that time, the extramural funding generated by the mentoring award recipients had provided over a one-hundred fold return on investment in the program. The tenure and retention data are higher than the overall average for science and engineering disciplines as well (unpublished data from K-State ADVANCE Project).

K-State ADVANCE Institutional Transformation

K-State received a $3.5M Institutional Transformation Award from NSF in 2003. This five-year project, supported by the ADVANCE program, is intended to effect changes in practices, policies, and procedures that promote an equitable environment in which both male and female faculty members in science and engineering can thrive and succeed. Some of the mentoring, networking, and professional development programs created by ADVANCE provide funding to support individual women faculty, while others are aimed at changing institutional practices[10]. The former can serve as models that are eventually adopted across the university. Some of these are described below.

The ADVANCE Distinguished Lecture Series is more than a seminar series, although that is the vehicle that was chosen. It was intended to help develop the professional network of junior women faculty and diffuse the effects of being isolated as the only woman in a department and geographic isolation in Manhattan. It provides $1200 awards to support seminar visits by national leaders in a junior woman's professional discipline. These awards are competitive and must be justified and approved by the project Steering Committee. This program has had excellent levels of participation and outcomes to date, some of which have been reported elsewhere[11]. Participants report that they have made substantive connections with prominent scientists and engineers from prestigious universities, government agencies, and private industry. The seminar hosts received valuable advice on grant proposals and publications, initiated collaborations, and have been invited for reciprocal visits to their guests' institutions. The ADVANCE leadership team is now working with the KSU Foundation to identify funding sources to institutionalize the program following the end of federal funding.

Parallel Paths is a peer group mentoring program in College of Veterinary Medicine. It was designed to foster the development of junior faculty members, sustain the productivity of established faculty members, and create an environment to help all participants succeed in their teaching, research, clinical, and service roles. Groups are open to both female and male faculty members. They hold monthly dinner meetings to discuss issues and concerns of junior faculty and have organized faculty development workshops. The dinner and workshop topics have included gender and other diversity issues; aspects of teaching and research, graduate student and resident training; work/life balance; and career advancement. Funds allocated to the program have been used to support faculty development. Outcomes over the last three years have been assessed by reports, surveys, and focus groups. Participants have reported benefits such as increased collegiality; enhanced cross-departmental dialogue; opportunities to learn about other faculty members' research interests; and an improved understanding of the promotion and tenure process[12].

Each participating college in the ADVANCE Project has created a program that supports the research programs of junior women faculty by providing seed money as well as funds for travel to conferences, funding agencies, etc. The project will be collecting information on whether seed funding has resulted in extramural grants, initiation of collaborations, and increased rates of tenure.

The Career Advancement Program is open to tenured women in all four colleges and addresses the transition from associate to full professor as well as providing opportunities for women interested in administration to gain experience in this area. Focus groups will be used in addition to quantitative outcomes to measure the success of this program.

The ADVANCE Project is in its fourth year. While it is difficult to identify metrics to measure institutional transformation, the early results show impressive increases in numbers of women faculty and increases in the ranks of tenured and full professor women in science and engineering[13].

Collaborative for Outreach, Recruitment, and Engagement in STEM (Science, Technology, Engineering, and Mathematics) (CORES)

The CORES project, which is funded by Targeted Excellence, unlike the other programs described above does not provide direct mentoring or funding for junior faculty members. Instead, it links science/engineering-based K-12 outreach and undergraduate research/ engagement programs, including those aimed at women and underrepresented minority students. Its goals are to synergistically enhance all of its constituent programs, facilitate recruiting and tracking of students, recruit students to K-State undergraduate and graduate programs, and to institutionalize and facilitate "broader impact" activities for K-State faculty preparing grant proposals.

The importance that Federal agencies are now placing on broader impact aspects of research proposals is illustrated by the recent call by NSF for chemistry multiuser instrumentation proposals[14]. This program, which is a vehicle for expanding the capabilities of investigators by providing expensive multi-user instrumentation to departments, now requires as part of the proposal, a statement of how acquisition or upgrade of the requested instrumentation will fit the departmental plan for broadening participation. The departmental plan itself must be submitted as a supplement to the proposal.

Summary

Kansas State University has recognized the need to cultivate junior faculty members by providing them financial resources and a supportive climate in order to enable them to become established extramurally funded researchers. Our programs, including the COBRE in Epithelial Health and Disease, Targeted Excellence, K-State Mentoring, ADVANCE, and CORES, are funded by a combination of extramural and internal sources. Return on investment data, where available, suggest that these are monies well spent. Future research at the level of the institution and the individual projects will continue to focus on the financial aspects and also will examine the impacts of such programs on tenure and retention of faculty.

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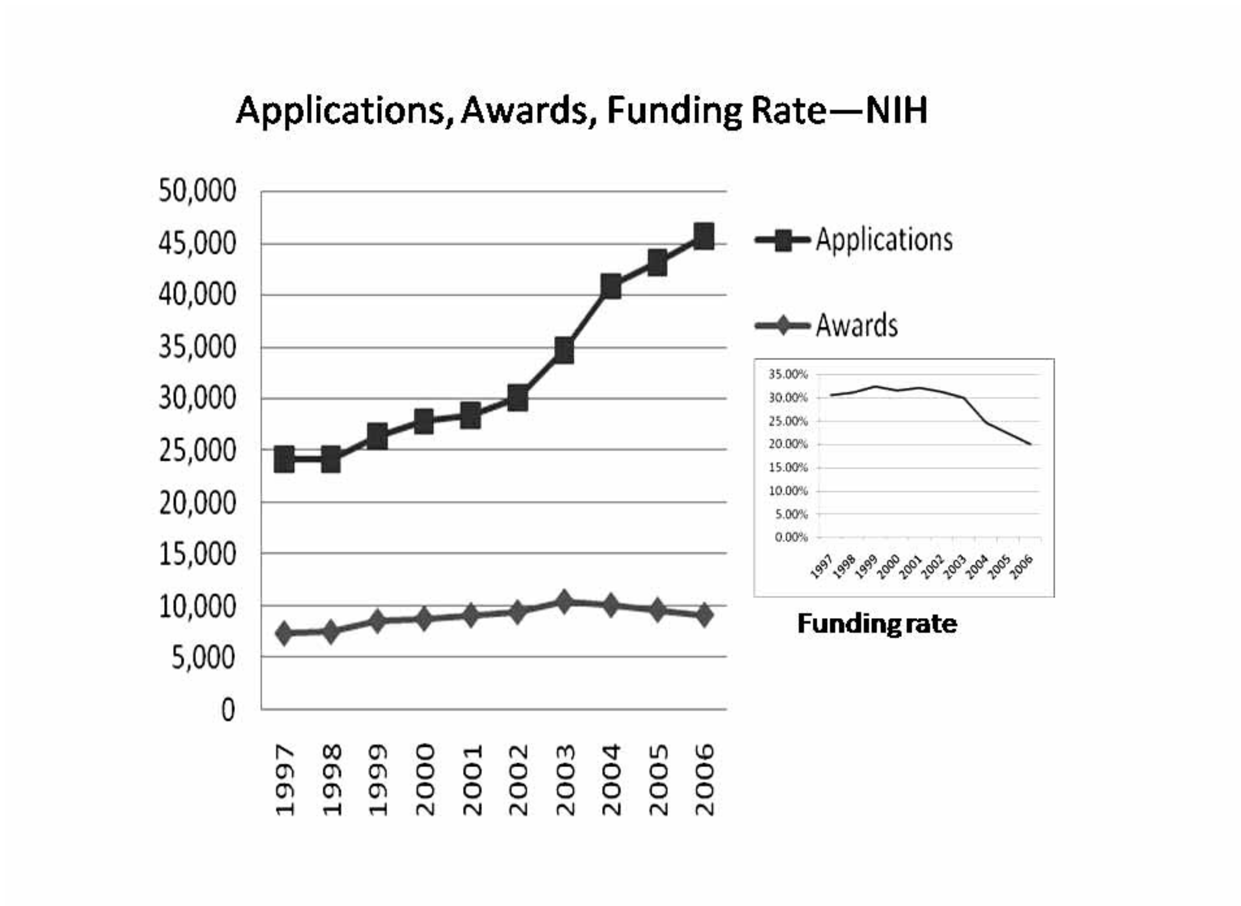

Figure 1. Applications for grants, awards made, and funding rate, all NIH institutes. Source –reference 2.

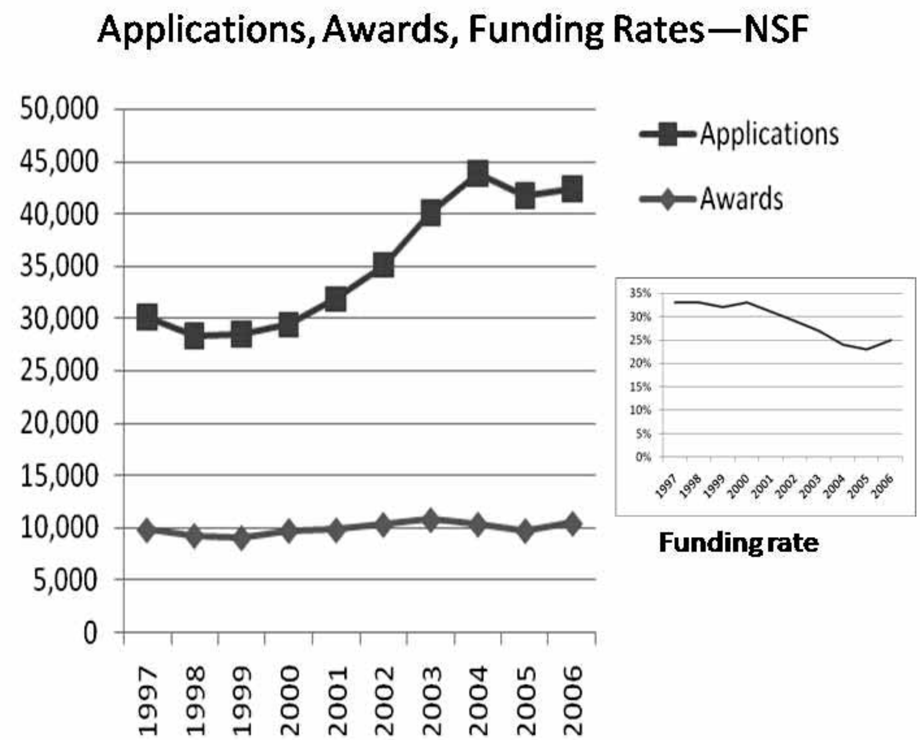

Figure 2. Applications for grants, awards made, and funding rate, all NSF programs. Source –reference 1.

Table 1. Funding success in K-State Department of Clinical Sciences

	FY04	*FY06*
# Proposals	30	32
$$ Proposals	$3,104,499	$3,202,946
# Awards	14	23
$$ Awards	$446,741	**$1,385,468**

Source: Dr. Lisa Freeman, Associate Dean of the College of Veterinary Medicine

The Time is Now: A 10-Year Vision and Strategy to Advance the Life Sciences

Barbara Atkinson, MD

Executive Vice Chancellor, University of Kansas Medical Center
Executive Dean, University of Kansas School of Medicine

The University of Kansas Medical Center has embarked on a 10-year journey to become a world-class life sciences research and teaching institution. Our goal is to effectively enhance and link basic and clinical research, and to provide the leadership to translate those achievements into improved health care and quality of life for the greater Kansas City region, the State of Kansas, and the nation. This journey represents the vision of not one organization, but many.

The University of Kansas Medical Center's (KUMC) 10-year life sciences strategy is based on a regional collaboration among the region's many life sciences assets, including the Stowers Institute for Medical Research, Midwest Research Institute, University of Missouri-Kansas City, University of Kansas-Lawrence, Kansas City University of Medicine and Biosciences, the Veterans Administration Hospitals, University of Kansas Hospital, Saint Luke's Health System, Children's Mercy Hospitals and Clinics, and Truman Medical Center. This long-term strategy is further bolstered by the area's focus on entrepreneurial and collaborative life sciences research activities supported by the Kansas City Area Life Sciences Institute, the Kansas Bioscience Authority, the area's clinical research organizations, and the strong regional philanthropic base.

Regional collaboration is paramount to reaching KUMC's vision of attaining world-class status and the greater Kansas City area's goal of becoming a top-20 life sciences region within 10 years. Other markets, such as Boston, Philadelphia, and San Diego, which are world-renowned for their achievement in the life sciences, have strong partnerships among their academic medical centers, public and private universities, multiple area hospitals, and private research institutions.

Similar collaborative strategies are being implemented in markets like Cleveland, Indianapolis, Los Angeles, and Phoenix, where the focus on a common research university is creating new opportunities for numerous institutions. Each of these markets share academic medical centers that stand out as the centerpiece of their respective life sciences communities. They provide synergies between public and private institutions, elevating life sciences research and entrepreneurialism.

As articulated by the Greater Kansas City Community Foundation's *Time to Get it Right* report[1], a successful life sciences strategy for the greater Kansas City region must include significant investments in its academic institutions. For KUMC, the report identified many opportunities for achieving world-class status, making it clear that KUMC must be at the forefront to promote a united regional vision that transcends the state line to bring area assets together for a common purpose.

Although this document is a road map to expand the research capabilities of the University and its Medical Center, it in no way diminishes our commitment to educating and training physicians and health care professionals for Kansas and the region. We remain steadfast in our education mission and recognize that quality researchers and clinicians often make the best teachers for our students. It is also important to note that this document is focused on research activities primarily housed on the Lawrence and Kansas City campuses. We recognize the stellar work that is conducted at the School of Medicine-Wichita campus and look forward to working with our colleagues and stakeholders in Wichita to outline their vision for the future.

The Transformation

The 10-year journey requires transformation at many levels.

KUMC's partnerships with life sciences organizations must be expanded and enhanced to support the region's and the University's long-term life sciences strategies. In addition, a similar transformation must occur within KUMC and across the related disciplines in the University of Kansas system. That internal transformation must fully integrate the Medical Center's biomedical research departments with complementary programs and efforts at the University of Kansas-Lawrence and the KU School of Medicine-Wichita. Doing so successfully will require a focus on three important areas: translational research, drug discovery, and the cultivation of research talent.

Translational Research

A key component to this transformation will be a renewed focus on advancing the translational research capabilities of KUMC across many disciplines. We will work to streamline the process of moving discoveries from the bench to the bedside, and we'll dedicate new resources to these efforts.

This focus on translational research is consistent with the National Institutes of Health's (NIH) recent launch of its Roadmap for Medical Research and, in particular, its priority for Re-engineering the Clinical Research Enterprise. The NIH Roadmap calls for a new emphasis on translational research designed to improve the movement of new discoveries from the bench to the bedside. Achieving excellence in translational research and drug discovery and development will allow KUMC and KU faculty to make more significant progress in disease prevention methods, diagnostics, and lifesaving treatments for patients.

The foundation for excellence in translational research already exists within KUMC. In October 2006, the NIH awarded KUMC, the Kansas City University of Medicine and Biosciences, and the Kansas City Veterans Administration Hospital – collaborators in the new Heartland Institute for Clinical and Translational Research (HICTR) – one of the new Clinical and Translational Science Award planning grants. Selection for this competitive award is a solid indicator that KUMC has what it takes to become a national leader in translational research.

In addition, there is more good news. KUMC just received another NIH grant totaling $7 million to support translational and clinical research in the Kansas City area. Together, these two grants position the HICTR to facilitate the translation of lab discoveries into lifesaving cures and to become a national model for excellence.

Drug Discovery

Connected with the HICTR is the drug discovery initiative at both the Kansas City and Lawrence campuses. A bi-campus team has come together to effectively articulate a 10-year drug discovery strategic plan focused on establishing the University of Kansas and its Medical Center as a premier institution in pharmaceutical research, pharmaceutical education, and commercialization of resulting intellectual property. A key player in this process is the Office of Therapeutics, Discovery and Development (OTDD), which was developed and launched in January 2006 as a bi-campus initiative to streamline and improve the drug discovery and development process. While the OTDD's first focus area is cancer, the university expects there will be many opportunities for other disease areas to benefit from the process developed for cancer.

Cultivating Researcher Talent

The 10-year life sciences vision demands that KU and its Medical Center not only break new ground in the translation of research, but also provide a thriving research enterprise and the growing cadre of leaders to support this growth. In keeping with the educational mission of an academic medical center and the recommendations of the Blue Ribbon Task Force, it will be important to expand the PhD program offerings and add post-doctoral personnel for specific research projects. PhD students and post-doctoral personnel are essential contributors to any research environment. Increased emphasis on attracting talented students and post-docs to both the Kansas City and Lawrence campuses will be critical.

Needed Investment

The transformation of KUMC will require significant growth – and to that end, significant philanthropic and private investment. Over the next 10 years, KUMC will require an ongoing investment from the community to recruit 152 senior and 92 junior faculty and build and outfit more than 862,500 square feet of new research space.

With the addition of 244 faculty as part of the 10-year plan, KUMC has set a goal of increasing extramural grant funding (National Institutes of Health and other external sources) from approximately $85 million per year to

$170 million per year by year five and $340 million per year by year 10.

The 10-year costs for faculty and facilities are estimated at $798.6 million.

Anticipated Return on Investment

While $798.6 million may seem extravagant to recruit new faculty researchers and build and outfit state-of-the-art facilities for their work, all economic indicators point to the potential for this investment to reap economic impact in the billions of dollars for years to come.

The amount of investment required is comparable to that of anew theme park or redevelopment of an entertainment district. The difference? In addition to fueling economic development, we will save lives.

Over the last five years, a number of studies have been conducted as part of the greater Kansas City life sciences initiative and the Kansas Economic Growth Act to indicate the potential return on research investments. The following highlights provide some illustration of the potential economic benefit of a substantial investment in the life sciences programs at KUMC and KU.

An economic impact analysis for Phase II of the Stowers Institute for Medical Research conducted by Andersen Consulting (2002)[2] projected that adding one million square feet of research space and 900 researchers would mean more than $1.4 billion to the regional economy over 10 years.

The Kansas Economic Growth Act's Bioscience Initiative (2004)[3] was the first in Kansas to demonstrate that investing in the life sciences could mean significant growth in jobs and research funding across the state. A study conducted by the Kansas Technology Enterprise Corporation and Ernst & Young LLP projected that a $500 million state investment over approximately 10 years in life sciences researchers, facilities, technology transfer, and commercialization would yield 23,000 new bioscience jobs, 20,000 indirect jobs, more than $1 billion in research funding, and more than 100 new start-up companies.

The Perryman Group Study (2005)[4], supported by the Kansas Technology Enterprise Corporation on behalf of the University of Kansas Cancer Center, demonstrates similar and even more far-reaching economic impacts associated with investment in the life sciences over 10 years. The Perryman Group specifically evaluated the impact of building a National Cancer Institute-designated Comprehensive Cancer Center at the University of Kansas. Based on extensive economic modeling, the study's authors projected a $1.3 billion economic impact in year 10 and every year thereafter, which includes $80 million in extramural research funding, 9,400 permanent direct and indirect jobs, and $584 million in related social gains due to reduced cancer mortality.

The investments required to pursue this vision are significant, but they promise returns of economic, health, and social gains that stand to transform our entire region.

KUMC Life Science Programs

Within the 10-year KU/KUMC life sciences strategy are a number of established and emerging disease and organ-based research programs, translational research programs, and shared resources that need additional investment to support the broader initiative. Each program requires the recruitment of senior and junior faculty as well as space to conduct research and access to shared resources.

Established Programs

The established disease and organ-based research programs currently enjoy strong extramural grant funding and a critical mass of faculty supporting the research and, in many cases, clinical goals. They are the most developed of KUMC programs and, in numerous instances, are already demonstrating significant leadership on a national scale in the form of research publications, clinical care, and patent filings. Key faculty appointments and additional consolidated research space will lead to further enhancement of these programs. The six established disease and organ-based programs are:

- Cancer
- Neuroscience/Brain Health
- Maternal/Fetal/Child Health
- Reproductive Sciences/Fertility
- Kidney
- Liver

Emerging Programs

The emerging disease and organ-based research programs are in development and have an initial core of faculty and research grants that warrant additional emphasis and funding. Along with the established programs, many of the emerging programs will play a significant role in the development of the Heartland Institute for Clinical and Translational Research and will benefit from the efforts to streamline the drug discovery and development process. These programs include:

- Bioengineering
- Bone
- Diabetes
- Heart
- Immunology/Virology
- Integrative Medicine
- Obesity
- Ophthalmology
- Personalized Medicine
- Public Health

Translational Research Programs

The translational research programs are interdisciplinary in nature and typically involve a number of disease and organ-based research programs as well as shared resources. The focus of these programs is to improve the translation of basic research into lifesaving cures for patients. KUMC's translational research programs have the potential to differentiate our community's broader life sciences strategy from the rest of the country. Two programs critical to achieving this potential are:

- Heartland Institute for Clinical and Translational Research (HICTR)
- Drug Discovery

Shared Resources

Shared resources are functions or services within the university that support a number of disease and organ-based research programs and are critical to processing and analyzing data, running tests, and conducting research. Growth in the disease and organ-based research programs cannot occur without parallel investments in shared resources. These shared resources are:

- Bioinformatics
- Biostatistics
- Compound Synthesis
- High Throughput Screening
- Mass Spectrometry/Proteomics

Conclusion

The Greater Kansas City Community Foundation's *Time to Get it Right* report could not have said it better – it truly is the time to get it right.

The time has come to commit to a focused long-term strategy that will transform the University of Kansas Medical Center into a high-performing institution driving new knowledge and lifesaving cures – one that will play an integral role in the cultivation of our regional life sciences opportunities. The benefits are clear – the greater Kansas City region and the State of Kansas will be players in the new, knowledge-based, global economy. And more importantly, we will improve the health of our citizens and prosper as a community.

The more than $2 billion investment in the Stowers Institute for Medical Research, the 10-year, $500 million investment in the biosciences by the State of Kansas, and the work to unite investment in the life sciences community, led by the Kansas City Area Life Sciences Institute, the Greater Kansas City Community Foundation and others, have created momentum towards excellence.

The foundation for KUMC's 10-year life sciences strategy has been in the works for many years, and progress to date has been considerable. The time is ripe to capitalize on this region's momentum and to reach for the next level – a level worthy of worldwide recognition.

Our goals are ambitious, and they will require the unified creativity and commitment of the entire region. Together we can recruit top talent, build and renovate world-class research laboratories, and attract external funding. We are poised to become a leading center of excellence in the life sciences.

The time is right...the time is *now*.

A 10-year, $798.6 million investment supporting established, emerging, and translational research programs and shared resources at KU and KUMC will bring to our region new jobs, new scholars, and new discoveries. It will foster economic development while improving our ability to train health care professionals, and it will give those professionals better options for treating devastating diseases. The transformation is within our reach.

Our dream has a plan...help us make it a reality.

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Past as Prelude: Lessons for the Future Acquired from 50 Years on the Edge

Steven F. Warren, Ph.D.
Director, Schiefelbusch Institute for Life Span Studies
University of Kansas

Starting a multi-disciplinary research center is a complex endeavor. Nevertheless, a large number of such centers have been created across this country and throughout the world in response to a range of scientific and technological advances and generous increases in public and private funding. Although the scientific advances have continued and even accelerated by many measures during this period, federal funding for research has leveled off and even decreased over the past several years. Consequently a question that faces many center directors as well as university leadership in general is how to maintain and even expand these initiatives in the current funding climate. What are the secrets to long-term success that span a wide range of funding climates?

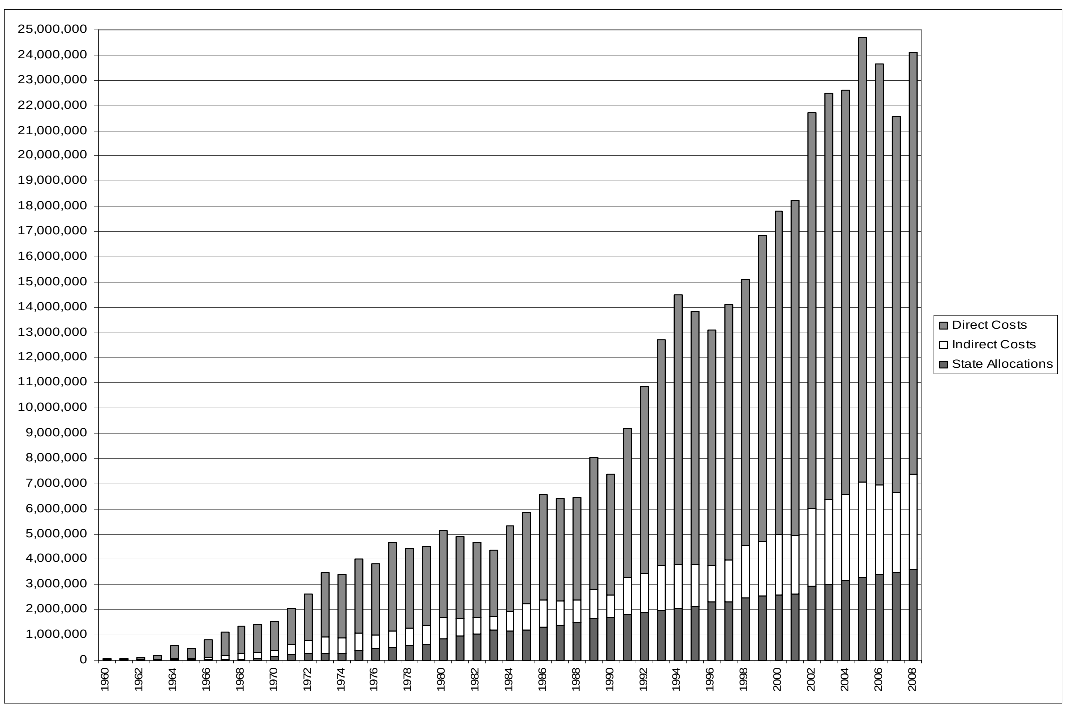
I am fortunate to direct a multi-disciplinary research institute with a relatively long history – well over 50 years in terms of its "modern era" and over 80 years since its initial inception. What lessons for research centers in general can be gleaned from our history? I believe that there are indeed some important lessons of direct relevance to the center directors and university leaders who face the challenges of sustaining both older and newer programs. The purpose of this paper is to briefly discuss some lessons or principles that I believe can make a real difference. I first provide a brief description of the Schiefelbusch Institute for Life Span Studies – the program I direct – because its history is the basis for most of the lessons I've learned. Then I suggest some general recommendations for university leaders and research administrators based on what I believe to be dangerous illusions that can harm research center programs in general. Finally, I conclude with a discussion of specific recommendations.

The Life Span Institute

The Schiefelbusch Institute for Life Span Studies (LSI) traces its roots to an act of the Kansas Legislature in 1921 (see Schiefelbusch and Schroeder, 2006, for a full history of this program). The visionary effort established a "bureau of child research" to be housed at the university. The seeds for the program in its present form were planted when Dick Schiefelbusch became the director in the mid-1950s. The program morphed into it present form in 1990 under the directorship of Steve Schroeder. The mission of the LSI is to create solutions to problems of human and community development, disability, and aging. At present it is both the oldest and largest research institute at KU with over 130 investigators from more than 20 academic discipline conducting at any one time between 100 and 110 externally funded research projects supported by more than 20 million dollars in direct costs and generating more than 3.5 million in indirect costs annually. These projects are located at the main campus in Lawrence, the medical center campus in Kansas City (KUMC), the Juniper Gardens Children's Project in Kansas City, and the Parsons Research Center in Parsons. The largest source of funding comes from the National Institutes of Health (principally NICHD and NIDCD) with the U.S. Department of Education providing the second largest amount.

The funding history of Life Span Institute since 1960 is represented in the figure below. There are three bar graphs represented – one for university support provided to fund core personal and infrastructure for the institute, one for external awards and one for indirect costs.

LSI Funding History: State Allocations and Grant Dollars - By Fiscal Year



Not surprisingly this graph shows an increase in all three types of funding over time. The university funding for the program (the bottom bar) shows a linear growth and a relatively modest trajectory. An analysis of this trend compared to the other trends shows that the "return on investment" of the LSI has changed dramatically since 1990. In 1990 the LSI generated approximately three external research dollars for every one dollar it received in university support. By early in the 2000s the return on investment had doubled to one dollar in university support for every six dollars in external award dollars generated.

A careful examination of this graph will reveal some other important information. Over the 49 year period represented external award dollars have increased 32 years and decreased 17 years. That is, awards have decreased roughly one-third of the time and increased roughly two-thirds of the time. Furthermore, multiple year decreases have occurred four times. Each of these decreases and increases occurred for various reasons – usually for several different reasons in fact. These explanations vary widely and reflect both national level issues (e.g. overall declines in research funding by some federal programs, or many federal programs as during the early Reagan administration years), and local conditions (e.g. a powerful new program was added to the institute, another program declined due to loss of key investigators, etc). The main point is that over this 49-year period, overall program funding has increased substantially, but in a pattern that might remind the reader of the stock market – a generally positive trajectory with lots of temporary declines.

The Present Macro Context

The performance of a research program should be evaluated in part on the basis of the macro context in which it exists (e.g. the amount of funding available nationally) and the micro context (i.e. the local situation). Both contexts are typically complex. At the macro level, there are a lot of positive indicators that suggest the future for university based research centers should be bright in general. These include:

- Bi-lateral support for science and research in the U.S. Congress
- A high level of support in general for research among the general populace
- The fact that research represents a very small slice of the overall federal budget, which undermines the argument that we are spending too much on it
- Globalization will continue to increase the value of science and research because these are viewed as indispensable necessities to compete effectively
- In recognition of the value of certain types of research (e.g. bioscience), states are getting into the business of supporting research using a variety of mechanisms.
- The death of corporate labs (e.g. the famous Bell Labs) has increased the need and value of university based research as a source of technological innovation capable of driving future business successes
- Private foundations have thrived in recent years and have far more resources to invest in research than they did previously
- Donors like to support "big ideas" (e.g. curing cancer or

autism) and are giving to universities for research related endeavors at record levels.

- And finally, we are faced with large daunting problems that require discovery and innovation (e.g. climate change, the autism epidemic, etc). In other words - there is a great need for university research.

There are also a number of caution signs in the macro environment that we certainly need to pay attention to. These include the following:

There is and will continue to be enormous pressures on state and federal budgets due to growing costs for entitlements, defense, and debt service that at the minimum may hold down the growth in research funding.

There are forces that wish to cut the amount of funding that goes for so called "indirect costs". Any successes in this effort could very seriously undermine the research enterprise.

While businesses and foundation are often interested in collaborating with universities and sometimes can be far more flexible and responsive than federal agencies, they can also be far more whimsical in their decision making. This can in turn make them poor partners for long term research support.

Research often requires new and specialized technologies to advance. The cost of these technologies continues to rapidly grow. Start-up, recruitment, and retention packages have soared as a result and there may be no end to this. It may result in the "haves" and "have nots" in terms of broadly competitive research universities. This dynamic could even ultimately decrease the breadth and depth of competition needed for rapid advancement.

Many universities and especially academic medical centers are highly leveraged at present. They have invested massive sums in research buildings and cutting edge technologies. In the kind of 'no growth' or even declining federal support environment that we are presently experiencing, the financial collapse of some research programs may be just around the corner.

Pressures on young investigators are unprecedented. They endure very long apprenticeships, then must get their own R01 or be denied tenure, and then continue to rake in external research dollars to support both their research and often their salary. As a result, the huge investment that goes into training a competitive research scientist can be washed out as people leave the academy for more stable careers.

The Real Dangers

These lists of positive indicators and caution signs reflect the present complexities of the macro environment. The positive indicators provide some assurance that our long term investments in research centers and infrastructure should pay off in a variety of ways – most importantly in making university research truly relevant to our national and global futures. But ignoring the caution signs would be foolish. What we need to do is view these as challenges to be overcome. Still there can be real dangers in how individual universities respond to these challenges.

What are some of these "real dangers"? They include the following:

Treating the overall research program of the university and/or individual research centers as "cash cows". This is one of the oldest games around. It happens when administrators view indirect costs generated by external grants as a means to fund other university priorities, including other research priorities. The excessive use of this approach can backfire by undermining the future of the very centers that produce these indirect costs. This in term may limit the long term impact and success of these programs or even lead to their competitive demise.

A variation on the cash cow syndrome is expecting unreasonable growth and return-on-investment from research programs in general and research centers in particular. This tendency was reinforced by the "go-go" (as in "grow-grow") atmosphere of the late 90's during which both the stock market and many university research programs grew at double digit levels for several years. This can and did lead to many high-risk "sure deal" ventures during this period that subsequently crashed.

Probably the biggest danger that can happen over time is the decoupling of the research mission of the university from the academic and service mission. This can happen slowly over time in insidious ways with various hidden dangers. It can create a chasm between schools and academic departments and faculty members that spills over into both graduate and undergraduate training. Then when the "research business" runs into rough seas, other sectors of the university may view the situation as "not their problem". Conversely, when the research mission is well integrated into the broader mission of the university it can clearly have a huge positive impact on both undergraduate and graduate training as well as the service mission.

Failing to provide bridge funding for junior and senior investigators when they go through a downturn in funding. With the current budget crunch at NIH, it can take two full years or more for a grant to be funded simply because of the massive number of outstanding proposals that may be ahead of it in line. At the LSI we have many investigators who eventually have received substantial NIH grants in the last three years, but who were required to submit their grant three times (an original submission, and two revisions). That is, they succeeded in a highly competitive world, but it took them a long time to do it. Our ability to bridge some of these successful investigators was in certain cases the key to keeping them successful and their research careers moving forward.

Cutting back core support from centers during short term declines. As the 49 year track record of the LSI demonstrates, overall funding goes down at times. Stable core funding support during these down periods is as much and possibly more important than during up periods. In a sense the message here is the same one given endlessly to investors in the stock market – DON'T invest at all unless you have the stomach to weather some down times. At the LSI we have benefited in general from a long term investment philosophy of our university. Of course this philosophy could change at any time. It's definitely not written in stone. So it needs to be reviewed and reconfirmed from time to time. This doesn't mean that core funding shouldn't be cut to centers. In fact, centers that under- perform by reasonable "context sensitive benchmarks" should be carefully evaluated and potentially reorganized or shut down.

Lessons from the Past for the Future

The beauty of a "mature" research program with a relatively long history like ours is that it has been through good times and bad times. Over this period certain strategies have been identified that seem to make a difference in the long haul. These strategies, coupled with wise practices by our university research administration, have clearly played a role in our success over the years. But it's important to point out that both are necessary and neither by itself is sufficient to guarantee success over the long term. So here is what we've learned over from our lengthy history of success.

Things go up and things go down. If they go up roughly twice and much as they go down, you are probably doing something right.

Diversify your portfolio. We have several different funding sources and at different times, each has been a larger or smaller contributor to our success. In 1969, our external grant budget came from only two federal sources, the NIH and the Department of Health and Human Resources and 80% came from NIH. In 1979, our external grant budget came from four sources (NIH, HHS, the US Department of Education, and the State of Kansas). By 1989 various foundations had been added to this mix and we now had five basic sources). In 1999 and 2008 we had 6 different sources. Over time our most constant source of external funding has been the NIH. Even so, as a percent of our total external funding they have varied from a high of 80% (1969) to a low of 32% (1999). They presently account for 48%. Like a good stock portfolio, diversification has helped us weather all sorts of bumps in the road over our long history.

Build from your strengths, stick to your mission, but don't forget that the rule of the jungle is that you evolve or die! We can't be world class in everything. But we can be world class in everything we choose to do. To do this, we must build and maintain strength areas and we have generally stuck to this approach over the past 50 years. The reason for this is Darwinian – we compete most successfully in our strength areas, and we recruit our best scientists in these areas, and so these have remained our strengths.

Compete, compete, and compete. Our strongest areas have generally been those in which we had to compete against highly talented scientists on a national level. Competition sharpens ideas and improves research, and thus leads to greater impact. Over time it winnows out the weaker ideas, the incomplete ideas, and the inadequate methods. It is fundamental to long term success.

Persist, persist, and persist. This is a long term game, a marathon of sorts. Failure is a necessary part of good science and is to be expected and even welcomed because it ultimately opens the path to success. The same is true in terms of succeeding in the highly competitive world of external research funding.

Encourage, support, and reward collaboration at all levels. Collaboration is anything but easy. But it often leads to better science and increasingly is necessary for scientific success in a wide array of domains.

Focus on the impact of the work. On one level scientists are deeply skeptical. The rules of science require them to be. But they are also romantics in a sense. Their work is about the creation of new knowledge, be it basic or applied knowledge. This is ultimately a noble pursuit that really can lead to improvements in the human condition and more. This is in fact the real work. Losing sight of this destroys the heart and soul of the scientific enterprise.

In summary, universities face very challenging conditions in terms of building the future of their research enterprises. This has mostly been the case in the past as well and so there is nothing really special about the current period. As usual, securing our futures requires that we learn from the successes and failures of the past. Fortunately there have been plenty of both. Failure to attend to the lessons of the past could be the biggest source of risk in the present environment.

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Ecological Genomics: Extending the genome revolution to the environment around us

Loretta Johnson, Michael Herman
Division of Biology, KSU and Co-Directors of the Ecological Genomics Institute
Steve Welch, Department of Agronomy, KSU

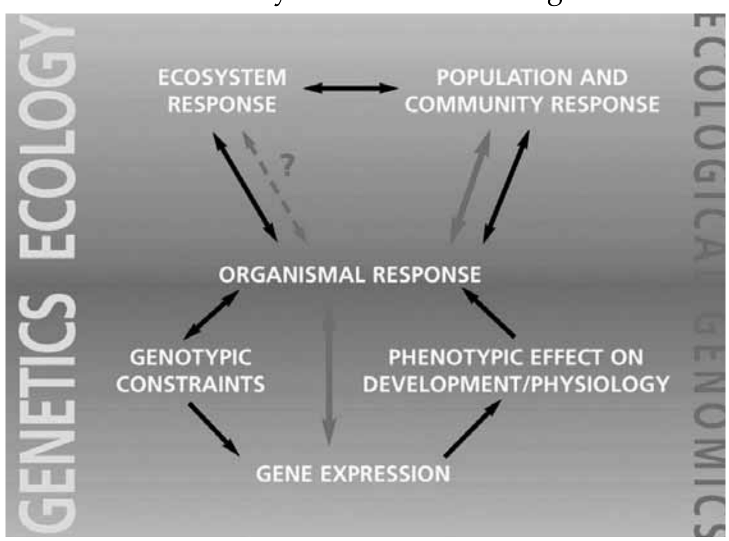
In 1995, the sequence of nucleotide bases (the genetic alphabet) comprising the DNA code for a free-living organism was determined for the first time. This sequence completely describes the protein building blocks of a small bacterium that causes ear and respiratory infections in children. Since then hundreds of species have been sequenced, including the human genome in 2004. Most of these genomes have applications to human health, agricultural improvement, and other important areas of biological research. Today the challenge is using our knowledge of billions of nucleotide bases to improve the human condition and better understand the living world around us. Currently, we are learning how to evaluate individuals' health (infectious disease states, tumors, drug and toxin responses, etc.) in terms of the activity of tens, hundreds, or thousands of genes. Already it is known, for example, that gene activity changes as some breast cancer patients become increasingly resistant to tamoxifen. In the future, gene activity levels may provide advance clues if a cancer patient is a good chemotherapy candidate or even reveal the earliest warning signs of impending disease. Ultimately, each individual may have his or her own genome sequenced in order to aid in disease diagnosis and therapy.

Similarly, genomics provides unprecedented opportunities to assess the health and integrity of ecological systems. An ecological system is the assemblage of living organisms interacting with each other and their physical environment. Just as genomics can characterize human responses to disease onset, so might it characterize the functions of ecological systems. Specifically, we may be able to use genomics to detect how ecological systems respond when challenged with human-dominated global change in the environment. Our Earth system is changing at an unprecedented pace due to carbon dioxide emission; temperature increases; excess fossil fuel emissions and fertilizers are causing an increase in nitrogen, which was once a limiting nutrient; and either excessive or, in other regions, insufficient rainfall. Synthetic chemicals and/or toxins such as heavy metals increasingly contaminate our water, soils, and air. The assemblage of plants, animals, and microbes that surrounds us is changing in response. Species are being threatened or, in other cases, expanding into regions they have not previously inhabited (sometimes with intentional or inadvertent human assistance). Analogous to human medicine, it may be possible to use genomic methods to monitor ecological system responses to the challenges of global changes in environmental health.

We all depend on ecological systems to sustain us – ecological applications of genomic technologies are therefore likely to be as important as medical uses. A fundamental question concerns organisms' genetic capacity to adapt to drastic environmental changes on short time and spatial scales. This capacity will undoubtedly vary across the spectrum of living organisms that beneficially or adversely contribute to human well-being. Just as we can use genomics in the pursuit of human health, we envision using these same methods to assess adaptive capacity, predict, and maintain the health of our environment. This, in the broadest sense, is the realm of the new field of ecological genomics described in more detail below.

The newly emerging field of ecological genomics

Ecological Genomics seeks to understand the genetic mechanisms underlying responses of organisms to their natural and changing environments. These responses include modifications of biochemical, physiological, morphological, or behavioral traits of adaptive significance. Previously, the complexity of these ecological interactions and organismal responses has made their genetic and mechanistic dissection difficult. However, recent advances in high-throughput genomic technologies and computational methods to handle the enormous amounts of data now make these complex questions tractable. Ecological Genomics refers to the use of any genome-enabled approach to identify and characterize genes with



ecological and evolutionary relevance. In other words, 'finding the genes that matter'.

By its very nature, ecological genomics is an interdisciplinary field, requiring a multidisciplinary approach that combines field studies with laboratory experiments with in ecologically relevant framework. Thus, while traditionally, ecological and laboratory-based genetic/genomic studies have occupied different areas of biological investigation (see Figure

1), Ecological Genomics seeks to integrate these disciplines by using genomic approaches in an ecological context. Furthermore, the rationale for such an integrated approach is compelling. Even though many organisms have had their genome sequenced, functions of the majority of the genes still remain unknown. Perhaps, the function of these genes will be revealed if the organism is placed in the evolutionary context and biotic and abiotic environment in which the organism has evolved. Recently, the importance of the ecological and evolutionary context for genomic studies was highlighted when parallel studies conducted in the growth chamber and under field conditions revealed a completely different set of genes expressed in these two experimental environments. Thus, the failure to conduct such studies under the field conditions can lead to misinformed research programs.

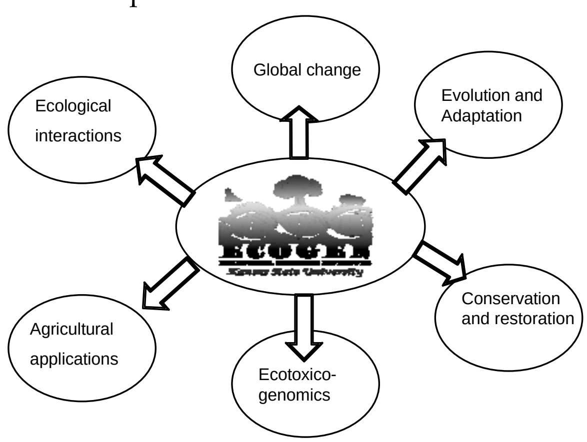
Building the Ecological Genomics Institute

"It is the science, stupid". Building an Institute must have firm foundation in an exciting science question. The overarching science question guiding the institute is: How are organisms adjusting to human-induced biotic and abiotic environmental changes at the genetic level? Today there is no more important ecological question than this in order to understand and predict the effects of human-induced changes to global abiotic and biotic environments. Prior studies of ecological phenomena in changing environments have focused primarily at the ecological system level. However, the ultimate controls of biological mechanisms are lodged in the genome. Thus, genetic and genomic studies of organismal responses to global environmental changes will provide the most complete understanding. For example, adaptive organismal responses to changes in the biotic environment, can be viewed as emerging from interactions between or among genomes. We can use genomics to get beyond phenomena to the genetic mechanisms.

Our institute seeks to examine environmental effects on organisms at the level of genes and gene expression, and identify major genes and pathways directly involved in the organismal response to a changing environment. Specific cross-cutting questions addressed in our institute include:

- What is the genetic basis for ecological responses to a changing environment?
- What are the regulatory and genetic pathways involved in organismal responses to their environment?
- What is the ecological context necessary to understand gene expression within organisms?

The Kansas State University Ecological Genomics Institute is positioned to lead this new field. Much of our research platform takes advantage of the long-term environmental experiments at Konza Prairie, that manipulate nutrients, water, and rainfall application. This focus is important because grasslands are the dominant native vegetation of North America, are relied upon heavily by humans, and provide the resource base for much of the global agricultural economy. In addition, grasslands supply us with clean water, recycle essential nutrients and preserve biodiversity. Some of our studies include the genomic responses of plants and soil animals to additions of nitrogen and changes in water availability. By taking advantage of the known genome sequences of laboratory or agricultural species, we are able to assess genomic responses of their native close relatives. For example, this research revealed that prairie grasses turn off genes involved in photosynthesis (carbon uptake needed to make plant biomass) in response to drought. Grasslands and global change is just one of several research foci (Fig 2) at the interface of ecology and genomics. The Kansas State University Ecological Genomics Institute is bringing the genomic revolution to the environment around us to better understand the health of the environment on which we all depend.



The goals and mission. The mission of the Ecological Genomics Institute is to advance the discipline of ecological genomics and to make EGI the center for ecological genomics locally, nationally, and internationally by providing a fertile intellectual environment as well as resources to enable integrated research approaches. Ecological Genomics originated as a novel scientific idea that was funded as the main state-wide research initiative by Kansas NSF-EPSCoR (Genomic Approaches to Study Organismal Response to Global Change (Co-PIs Johnson and Herman) in 2003-2006. Since then, the discipline has matured and grown in stature and reputation. The research is now supported through the KSU Provost's program in Targeted Excellence to build a research initiative into an institute and has enabled Ecological Genomics at Kansas State University to expand and develop into the national and international leader in the new field of Ecological Genomics.

The specific goals of the Kansas State University Ecological Genomics Institute are to:

- provide a fertile intellectual community of diverse participants (faculty, post-docs, students) from varied disciplines who are committed to advancing the field of ecological genomics. This requires promoting and enhancing the climate for interdisciplinary and collaborative research that transcends KSU departments and colleges, and universities, nationally and internationally.

- provide programs that support and promote collaborative ecological genomics research at the Institute as well as advance and guide the field at the national and international levels. Provide forums for dissemination of ecological genomics research within the university, nationally, and internationally.
- promote the use and development of the newest state of the art technology and tools to enable ecological genomics projects to prosper and to spawn new projects. Facilitate the development of research infrastructure.
- train the next generation of scientists in cutting-edge ecological genomics research by developing an interdisciplinary curriculum, while promoting ethnic and gender diversity, Provide training in relevant techniques, give them the skill set to enable them to be productive, contributing members of the ecological genomics community in science and education.
- provide visibility and recognition of EGI and the Ecological Genomics field by disseminating results and attracting extramural funds to allow us to conduct ecological genomics research. Solidify our role as a national and international leader and set the agenda for ecological genomics research. Use the ecological genomics program as a magnet to recruit top-notch faculty, post-docs, and students.
- promote diversity in science by providing research opportunities to members of under-represented groups (by partnering with the KSU SUROP and DSP programs). Disseminate knowledge to the general public by performing outreach activities that include educational opportunities for K-12 educators.
- develop applications for ecological genomics research using knowledge of genetic diversity and patterns of gene expression in tallgrass prairie communities.

Activities and Accomplishments

Scholarly Achievement. Science is the foundation of our institute. We have 3 new faculty hires in ecological genomics to advance the field. Furthermore, since the beginning of our TE institute up to and including June 2007, members of the KSU Ecological Genomics Institute have published 41 manuscripts, one book and two book chapters related to Ecological Genomics. As evidence of our leadership in this new field, we were invited to contribute an introduction and synthesis of the field for a recent issue of Heredity dedicated to evolutionary and ecological functional genomics (Ungerer, Johnson and Herman, 2007). Ecological genomics has also enhanced the research climate, making faculty more competitive for grants. Our seed grant program provides approx 250K per year in funding for pilot studies to make researchers more competitive. Members currently hold 18 extramural grants ($5,468,790) relevant to Ecological Genomics, of which 10 ($2,344,160) were funded since the beginning of the TE project. Six intramural grants have been funded ($4,008,944). $1.15 million investment from TE in first 2 years has resulted in $2.3 million in extramural funds .

Programs. The KSU Ecological Genomics Institute has implemented a number of programs that stimulate and provide support for research in this new field. Our annual ecological genomics symposium, now in its 5th year, attracts ~150 attendees from 45 different universities nationally and internationally. Others activities include technical workshops (AFLP, Bioinformatics and Genomics), visiting scholar programs, international student exchange with the ecogenomics program in NL, graduate student training program , and weekly journal club. Our institute has brought recognition to the new discipline and the university. Our website continues to be the top choice when one "Googles" Ecological Genomics. Statistics indicate a total of over 17,500 hits to date with international exposure. Through these activities, we have successfully increased the visibility of ecological genomics at Kansas State University.

A new paradigm for interdisciplinary research

Why is this institute so successful? First and foremost, the institute starts with cutting edge and big science questions as its foundation. The science questions are the basis for interdisciplinary collaboration that transcend departments and colleges. The science and intellectual exchange is the mortar that holds the foundation together. Furthermore, we take advantage of unique skills and opportunities such as the research platform at Konza Prairie. We provide state of the art infrastructure to do cutting edge research and provide funding opportunities such as seed grants that promote competitiveness. We demonstrate an effective management style such that tasks are delegated to committees to share the responsibility and to promote member buy-in, oversight is provided by a three-member external advisory board and five member steering committee and periodic independent program assessment and evaluation are provided by our KSU Office of education, innovation and evaluation. Perhaps, most importantly, inception of the ecological genomics institute began at the grass roots level, at the level of researchers who have a willingness to "think outside the box" and to "work outside their usual comfort zone". We posit that the next great discoveries in science will be at the intersection of diverse disciplines. Ecological genomics is a new model for such interdisciplinary research.

The Status of Research at KUMC: FY2005 vs. 2006 (The First Year of Progress in the KUMC 10-Year Vision)

Paul Terranova, Ph.D.
Vice Chancellor for Research
University of Kansas Medical Center

This report is a summary of KUMC's research progress in FY2006. Specifically, the summary is a response to a request by Dr. Benno Schmidt, the chair of the Blue Ribbon Task Force that was charged by the Greater Kansas City Community Foundation in early 2005 with evaluating the state of higher education in Kansas City. Dr. Benno Schmidt is a former president of Yale University and is current Chairman of the Board of Directors for Edison Schools, Inc. The Task Force consisted of notable higher education leaders, who collected information from several sources including two- and four-year college and university leadership, faculty, students, staff, civic leaders, clergy, superintendents, school board members, nonprofit leaders, government officials and citizens. The purpose of the study was to provide a framework for business, philanthropic, civic and government leaders to identify funding priorities and strengthen higher education in the Kansas City region. The task force completed its work on July 1, 2005.

Their conclusions were subsequently published in the Time to Get it Right report (www.gkccf.org), which identified two important elements to strengthen higher education in the Kansas City region: 1) a strong urban university and 2) enhanced research capacity. The report urged Kansas City to invest significant new resources in the University of Kansas Medical Center as a mechanism to enhance research capacity. Even though no community resources were provided during the first year after the report came out, KUMC took the report seriously and reallocated internal funds to address specific issues within the report. The following are details of the KUMC progress and fiscal years 2005 and 2006 are compared.

The Blue Ribbon Task Force recommended that KUMC develop a 10-year strategy to build research capacity, add 100 high-quality researchers, double enrollment in the Ph.D. program, increase the number of postdoctoral fellows, increase external research and development funding from $76 million to $300 million annually and invest $645 million in KUMC over 10 years. Each of these items will be addressed.

Regarding the 10-year strategy to build research capacity at KUMC, a document entitled The Time is Now: a 10-year Vision & Strategy to Advance the Life Sciences was released in January, 2007. This is a 48-page document that summarizes KUMC's plan to build research.

(www.kumc.edu/evc/TheTimeIsNow.pdf) This document provides statements regarding our vision from KU leadership, the transformation that is planned, and the needed investment and anticipated return on investment. Specific details regarding the established disease and organ-based research programs, emerging disease and organ-based research programs, translational research programs and shared resources are included.

Established programs include Cancer (University of Kansas Cancer Center, Neuroscience/Brain Health (Kansas Neuroscience & Brain Health Institute), Maternal/Fetal/Child Health (Institute of Maternal-Fetal Biology), Reproductive Sciences/Fertility (Center for Reproductive Sciences), Kidney (The Kidney Institute), and Liver (The Liver Center).

Emerging programs include Bioengineering (Bioengineering Research Center), Bone (Kansas City Osteosciences Institute), Diabetes (The Diabetes Institute), Heart (Cardiovascular Research Institute), Immunology/Virology, Integrative Medicine (Center of Excellence for Complementary and Alternative Medicine and Research), Obesity (Center for Physical Activity, Nutrition and Weight Management), Ophthalmology (department of Ophthalmology/Center for Ophthalmic Engineering/Clinical Eye Institute), Personalized Medicine (Center for Personalized Medicine) and Public Health (Institute of Public Health).

Translation research programs include the Heartland Institute for Clinical and Translational Research and Drug Discovery.

Shared Resources are Bio-informatics, Biostatistics (Center for Biostatistics and Advanced Informatics/ Department of Biostatistics), Compound Synthesis, High Throughput Screening, and Mass Spectrometry / Proteomics.

Regarding the addition of 100 high quality researchers over 10 years as suggested by the Blue Ribbon Task Force, KUMC's 10-year vision plan estimates that 244 researchers are required in the established and emerging research programs in order to accomplish its goals. Specific recruits for research included 22 new basic science faculty and 6 clinical faculty from 2005 to 2006.

In 2005, the research faculty in the School of Medicine at KUMC included 147 basic scientists and 43 clinical researchers for a total of 190. In 2006, 12 basic science and 6 clinical researchers were added for a total of 208 researchers representing a 9.5% increase in research faculty in 2006. Our 10-year vision includes addition of 244 researchers by 2015 which would more than double the research staff in the KUMC School of Medicine (from 190 to 434). More importantly, if the 244 researchers are largely clinical/ translational, then the clinical research workforce would increase more than 6-fold (from 43 to 287), which would complement the research infrastructure of the Heartland Institute for Clinical and Translational Research.

Planned estimates for the 244 senior and junior research recruits in the established, emerging and shared resource programs include 144 for established programs, 90 in emerging programs, and 10 in shared resource programs. In the established programs 85 additional research faculty are planned for Cancer, 24 in Neuroscience, 14 in Maternal-Fetal, 3 in Reproductive Sciences, 9 in Kidney, and 9 in Liver. For emerging programs, 90 additional senior and junior faculty researchers are planned with 19 in Bioengineering, 2 in Bone, 20 in Diabetes, 3 in Heart, 8 in Immunology, 8 in Integrative Medicine, 14 in Obesity, >10 in Ophthalmology, 3 in Personalized Medicine, and 3 in Public Health. These numbers are estimates and there may be considerable overlap between programs. For example, some of the cancer recruits may be in the area of public health or neuroscience.

In addition, several of the program recruits may partner with University of Kansas at Lawrence, University of Kansas School of Medicine at Wichita and the University of Kansas Hospital. The 10-year strategy is based on regional collaboration that includes additional partners such as Stowers Institute for Medical research, Midwest Research Institute, University of Missouri at Kansas City, Kansas City University of Medicine and Biosciences, the Veterans Administration Hospitals, Saint Luke's Health System, Children's Mercy Hospitals and Clinics and Truman Medical Center.

In terms of doubling the PhD enrollment over 10 years as suggested in the report, slow progress has been made in 2006 with a 3% increase in the number of predoctoral students over 2005. This increase represented the addition of 1 student in the combined MD/PhD program in 2006 for a total of 19 students. In the PhD only program 2 students were added for a total of 83 students in this program. In both programs in 2006, 102 students were enrolled whereas in 2005, 99 were enrolled. For the fall of 2007, five additional students have been added in to the MD/PhD program (total of 24) and five students have also been added in the PhD only program (total of 88).

The total number of students enrolled for the fall of 2007 is 112 which represents an increase of 9.8% over 2006. The addition of 12 students per year through 2015 in the PhD programs (combined MD/PhD and PhD only) would slightly more than double the number of PhD students enrolled in the KU School of Medicine.

65 postdoctoral students were recorded in the KU School of Medicine in 2005 and this increased to 81 in 2006 representing a 24.6% increase. This increase is largely due to a number of factors including 1) increasing the number of faculty, 2) increasing the amount of NIH funding (an ~17% increase in NIH funding was recorded between 2005 and 2006), 3) renewal of institutional NIH postdoctoral training grants that increased the number of positions, and 4) garnering individual postdoctoral awards from NIH and other private foundations.

In order to ensure continued growth in these areas, additional institutional postdoctoral training awards in established and emerging areas are needed.

Regarding increasing research and development funding from $76 million to $300 million over the next 10 years suggested by the Blue Ribbon Task Force, significant progress has been made. In FY 2006, the total dollars requested was $384.5 million compared to $362.9 million in 2005 representing a

6% increase. However, the amount of dollars award in 2006 was $82.1 million compared to $68.8 million in 2005 representing a 19.3% increase over 2005. NIH awards followed a similar trend with $45.4 million in 2006 compared to $38.9 million in 2005 representing 17% increase over 2005. The increase is likely due to the increased number of faculty researchers, applying for more and larger grants, and enhancing the synergy amongst the faculty by emphasizing programmatic centers and institutes.

As for the recommended investment of $645 million in life sciences research over 10 years as suggested by the task force, the KUMC 10-year strategy estimates that $798.6 million is required. $380 million is estimated for recruitment of 152 senior faculty, $73.6 million for 92 junior faculty for a total of $453.6 million in faculty costs over 10 years. Additional facilities will be needed at KUMC and KU-Lawrence to house the expanding research faculty and programs.

The estimated space requirements are 862,500 square feet of additional research space at an average cost of $400 per square foot for a total facilities cost over 10 years of $345 million. Thus, the total faculty and facilities cost over 10 years is $798.6 million. These estimates are detailed in 'The Time Is Now—A 10-Year Vision & Strategy to Advance Life Sciences' (www.kumc.edu/evc/TheTimeIsNow.pdf). How do we raise $800 million? KUMC and its partner institutions must seek opportunities with the State of Kansas including the Kansas Bioscience Authority, the Kansas City Area Life Sciences Institute, business leaders in the Kansas City region, Philanthropy, national resources including the NIH and other private foundations, Internal University Resources, and partnerships with area institutions that share our vision.

Keeping Our Bearings in Very Rough Seas

Brian L. Foster
Provost, University of Missouri – Columbia

We have heard some extremely interesting presentations today on important developments in higher education and in the world of research. They are interesting because they place us in a very changed world of higher education. Consider, for instance, stem cell dynamics—an issue for which I'm very sensitive given the recent events in Missouri related to funding for the University's biomedical research building. The important point is how closely stem cell issues are intertwined with political dynamics.

Prem Paul talked about the STEM (not "stem cell," but science, technology, engineering, and mathematics) pipeline. The issue is that the American science and engineering establishment simply is not sustainable with domestic student pipeline, but rather requires a very large international student pipeline.

Joe Steinmetz addressed an important change from individual investigator research toward a team approach—especially interdisciplinary teams of scholars. This is a very positive development, but it runs contrary to many strong "customs" in higher education, which are focused on departments and academic disciplines.

Steinmetz also talked about growing disparities between "haves" and "have not" higher education institutions—that those with a large resource base are growing their resources, while those with smaller resource base (including major public research universities like those represented at the Merrill Retreat) are increasingly challenged.

There was a good deal of talk about finding focus and achieving critical mass. The two presentations by Loretta Johnson and Steven Warren are wonderful examples of premier institutional centers of excellence, cutting across many disciplines, and defining new directions in research.

Clinical research also received a good deal of attention, especially with reference to the GCRC and CTSA initiatives from NIH, a reflection of the growing importance of clinical research in research universities.

Beth Montelone discussed programs to engage and enable junior faculty to become successful in the world of sponsored research—a key element of success for research universities… though there is a reality check in Jim Roberts' discussion of industrial funding for research, an entirely different model.

Jordan Green's presentation described a successful line of research that focuses on a technology-dependent program which, however, has not become a priority for federal research funding, and which therefore poses special issues for sustaining the program.

Jim Roberts discussed the prospects for industrial funding to replace federal research funding — a dubious proposition to be sure, although industrial funding is certain to become a major component of university research support.

John Brighton discussed the recent crisis in funding for federal earmarks, which has caused major disruption of some long-standing programs. The future of earmarks is uncertain, though there is general agreement that earmarks won't disappear.

Steve Warren gave a timely and appropriate warning that we don't want to panic — to over-react to the changes in the higher education environment. Fluctuations are normal. I agree. Nevertheless, we have been presented with a daunting set of changes—some positive, some negative—in the world of higher education-based research, and we can't just ignore the challenges. Moreover, it would be foolish to ignore the fact that changes in the research environment are accompanied by changes in the environment for educational and service programs, and the latter can't be separated from the research programs. Money is money, and competing demands on resources closely link the two main thrusts of research universities.

I said I was going to talk about keeping our bearings in rough waters. Maybe a more appropriate metaphor would have been to address keeping our canoe steady in the tsunami. What I'd like to do now is first to talk about the underlying dynamics for what is happening in higher education, then to take a forty-thousand foot view of what we might do to address these issues.

Background: The Underlying Dynamics

Entitlement status. So, what are the underlying dynamics? It seems to me that one of the most important is not directly related to research but has profound indirect impact. It is that higher education has effectively become an entitlement. It would be hard to overestimate the importance of the fact that the "access" rhetoric today commonly is based on the proposition that every American has a right to a college education. This proposition would have been unthinkable even twenty years ago, when post secondary education was still seen mainly as a way to get ahead, to "rise above one's roots." But now it's the base—the level to which everyone is entitled—not the way to get ahead, but the prerequisite for a good life. And, of course, this idea is supported by the wonderful fact that participation in higher education has grown greatly, and a majority of Americans now have at least some experience in post-secondary studies.

It would be difficult to argue that this is anything less than a triumph, even though many of our higher education institutions are wary of "lowering" admissions standards - restrictiveness being the currency of prestige in higher education. In any case, we are now presented with a student body unlike any that has been seen before: a very large proportion of first-generation (largely clueless) students, of minority students, of low-income students, and so on. They are very vulnerable, and frankly, we don't really know how to handle them and, often, we don't do a very good job of serving them. The fact is that there are stunning disparities in participation in higher education by socioeconomic status (SES). One recent study showed that in 142 selective institutions, 74% of the students were from the upper SES quartile, while 4% were from the lowest quartile!

A critical contributor to the entitlement status of higher education is the fact that post-secondary education has become highly sectored. That is, community colleges, public four-year institutions and private ones, the for-profit sector, and the university sectors are dramatically different in the populations that they serve and in the nature of the programs that they offer. Today, about 40% of post-secondary students are in community colleges—a sector that hardly existed forty years ago. And nearly 10% more are in the for-profit sector. This means that roughly half of the post-secondary students today are in traditional four-year institutions! The political implications of these facts are striking (I'll return to them later). The fact is, though, that research universities have tended to denigrate community colleges and regional four-year schools, to say nothing of the for-profit ones, and that has not served us well politically.

The point of all of this is that the university portion of higher education is dramatically re-positioned and is vulnerable insofar as it hasn't figured out how to deal with the new student body. Our success is questionable, and we are therefore vulnerable (given the entitlement status of higher education), all of which calls our credibility into question. This credibility problem is very important, given that for most people higher education is mainly about instructional programs.

Bayh-Dole Act. In 1980, with passage of the Bayh-Dole Act, congress repositioned higher education dramatically in the landscape of commercializing intellectual property and economic development. The critical change was that institutions of higher education could protect and commercialize intellectual property created on campus with federal support, and that repositioned them in a broad arena shared by major corporate players. Now, universities could profit from (on occasion at extraordinarily high levels) inventions of their faculty and staff coming out of federally funded research. They could partner with, license to, or compete with the corporate sector. And they could find themselves in conflict (especially in extremely costly litigation) with large corporations, both the university and corporation having a very large stake in the outcome.

It would be hard to overstate the importance of this development. In a world of global competitiveness, where the long-term economic vitality of the U.S. is under discussion…and is being challenged—in such a world, economic development issues are of great policy and political interest. Universities are drawn into this discussion in a new way following Bayh-Dole. We are, in fact, central to the national, state, and local economic development discussion as never before, especially as development of the knowledge economy" plays itself out. This is, of course, both a big asset and a big problem. We in higher education ARE central to the discussion, a politically advantageous position to be in. But we are also at risk in several ways, the most important perhaps being that unrealistic expectations of what we can do are widespread, in no small part due to our own unrealistic expectations and claims.

As regards university research, the problem is fundamental. The legal and regulatory environment is morphing constantly in higher education's technology transfer world—e.g., in such areas as conflict of interest. Even more difficult, fundamental ethical issues about openness, about publishing research results, about academic "credit" for, say, patents or startup firms in the hiring or promotion and tenure processes: these issues challenge fundamental ethical premises of higher education. To be clear: these are not necessarily good or bad developments; they clearly are challenging and require fundamental rethinking of the basic premises of university research.

Higher Education is Very Politicized

Perhaps the most important underlying dynamic follows directly from the first two: namely, that higher education has become politicized in a way very different than at any time before. That is to say, it is of great political interest in several ways. First, entitlements are always of compelling political interest, since they are of interest to a great number of political constituents. Any political figure can get broad interest in higher education issues (e.g., disparities in access or affordability), since they directly affect the lives of millions of constituents. In this sense, higher education is in a position much like health care was thirty years ago.

Second, and perhaps more important, higher education is now a VERY big enterprise. It touches the lives of tens of millions of people, and it is of great interest to large corporate interests. Consider the staggering amount of money in student loans. Or, think of the enormous investments (in the billions of dollars) in testing, in computers and other technologies, or in textbooks. The corporate constituents in these business arenas have a strong interest in shaping developments in higher education to enhance their businesses—a not unreasonable matter in itself. But the outcomes of such interests are not necessarily aligned with sound education policy, much as the military-industrial complex is not necessarily aligned with national economic or security interests. One can see the influence of such corporate interests in discussions of the Reauthorization of the Higher Education Act and of the Spellings Commission.

Third, our centrality in economic development discussions has also placed higher education in the center of key political discussions at the federal, state, and local levels. The economic development stakes are very high by any measure. Community viability, job prospects, almost all aspects of quality of life—all depend on the state of the economy. And they all depend on the state of the U.S. economy in a new, and sometimes frightening, global environment. The so-called "knowledge economy" has placed universities in an interesting, desirable, and in some ways vulnerable position in political process.

The point is that higher education has become a central interest in very high-stakes politics…not necessarily policy (though the policy issues are profound), but raw politics, at both the state and federal levels. This is a world in which we have played peripherally for a long time, but the centrality of our current position is new.

A couple of other matters. All of the above has been exacerbated by the challenging state appropriations since the economic downturn in the early 21st century. The effects have been felt at different levels in different states, but across the country the state appropriations were reduced or grew very slowly for the past five years or so, and for state universities, the proportion of total revenue that came from the state dropped dramatically. It is now unusual for state appropriation in major state universities to be much more than 20% of the total revenues—in a few cases now, under 10%. This changes the entire business model of the university. Research is central to the challenges of public research universities, since the fundamental resources (especially faculty, graduate students, and facilities) are heavily subsidized by the universities' "general operations" budgets.

Another area that poses major concerns, and that entails large costs is the area of compliance, much of which is directly related to research—e.g., IRB, hazardous materials, radiation safety, and animal care. In a time of fiscal challenges, compliance costs have risen dramatically, and the consequences of noncompliance are enormous. At the University of Missouri – Columbia, we recently determined that costs of compliance measures in research only—not FERPA, not fiscal matters, not SEVIS, not HIPAA—rose to more than seventeen million dollars (counting such matters as cost of time for members of IRB committees). These compliance issues are particularly serious in view of the potential for lapses to set off major political dynamics.

A final irony. Perhaps the most ironic observation in all of this is that with all of this change—especially the entitlement status of higher education and the political interest in access and affordability—is that the ultimate beneficiaries are the elite private institutions. When higher education was not an entitlement, when it was not the pre-condition for a good life, then higher education of just about any kind was a way to get a leg up on life. One could rise above one's roots—even middle class ones—with a generic higher education. But now that everyone is getting it, it's like secondary education fifty years ago, and the American dream of social mobility can best (i.e., most reliably) be done by going to the elite private institutions. And to be sure, their application numbers are soaring, their influence in core Washington discussions is growing, and in general, privilege reigns as it did decades ago. A dramatic outcome is that there are growing disparities between the elite privates and the best publics in faculty compensation, in the socioeconomic status of students, in expenditures per student, and so on.

Final thoughts on the fundamental dynamics of change. The point of all of these observations is not that the sky is falling. It is that there are fundamental, probably irreversible changes in the environment for higher education in the U.S. We do not have the option to pursue business as usual, but we have to adapt to these new circumstances. In fact, these dynamics rest on some very positive changes—at least from my point of view. Universal access to higher education is a thrilling development for those of us with passion for how higher education can enrich the lives of, say, first-generation students. Having a core role in economic development is exciting, well in keeping with the universities' commitment to creativity and innovation. Even reduced reliance on state funding has positive aspects in the politically charged world in which we now find ourselves. The question is, how do we deal with these new dynamics? How do we keep our bearings, and go where we need to go, in these very rough seas?

How Do We Navigate These Rough Seas?

No matter how positive a spin we put on the matter, the fact remains that we need new ways of operating. Positive change is still change. There are no magic bullets, but there are ways of thinking about our current environment that require careful consideration. The list below is not exhaustive, but it is a start.

Develop other sources of funds. In his compelling keynote address to the Merrill retreat last year, John Wiley argued that privatizing public universities lies somewhere between daunting and impossible…leaning strongly toward the latter. That said, there remain many possibilities for developing new net revenues. Some are obvious (e.g., philanthropic fundraising, tech transfer revenues), though we are often delusional in thinking about the magnitude of their potential. Some challenge the culture of higher education (e.g., commercializing intellectual property, and business-like enrollment management, the latter a problem primarily for public universities). But there is significant potential.

Development has long been a key activity at major privates. A small number of public universities have been seriously and effectively engaged for many years (University of Kansas and University of Nebraska – Lincoln among them), and some of those only recently committed have had major successes (e.g., the University of Missouri – Columbia is closing in on a successful billion dollar campaign). But realistically, while a billion dollar endowment is a significant accomplishment, and while the payout of roughly fifty million dollars a year is a very significant marginal enhancement of total revenues, it is not a replacement for the state appropriation at most public universities. Strong development successes require major investments and take years to bring to fruition, but they will be a key element in our future financial viability.

The volatile environment for federal research funding has given rise to discussions of how industrial funding can significantly replace federal grants. Corporate collaborations may provide another avenue to tapping funds from the private sector. There certainly is promise in these new kinds of relations, but there are also complexities in regard to traditional academic values about openness, publishing research results, and related matters. These issues converge in important ways with technology transfer initiatives by which intellectual property created at universities is commercialized—e.g., as the base of start-up companies, or by licensing to private firms. Again, tech transfer often gives rise to conflicts with traditional values, though it should be added that the issues are complex and there is by no means consensus in the academy. Moreover, universities take significant risks of many kinds, including the danger of ownership being challenged on any "big hits."

Community partnerships have become more important in several ways. The University of Kansas Medical Center, for instance, is developing a massive community partnership to develop the resource base and to pursue collaboration with local hospitals, UMKC, and the Stowers Institute. The University of Missouri – Columbia is working closely with the city of Columbia on co-developing the interface (an area of several square blocks) between campus and downtown. The University also works closely with the city in economic development activities. Working closely with local corporate partners in joint R&D and other areas is another example of community/university collaboration. Such initiatives have important potential to provide important marginal increments in resources.

Perhaps the most promising strategies revolve around effective enrollment management. If universities can shape their program inventory and their student body favorably, they may generate large amounts of new net revenue. This requires very business-like systems for understanding marginal costs, for shaping the student body to grow areas with sufficiently low marginal costs that significant profit centers can be created.

Finally, it is critical that public universities position themselves effectively in their states. State appropriations are a major part of total revenue at all state institutions even though they have dropped to less than 20% at most large public research universities. Making the most of state relationships is still either the largest or second largest revenue source (particularly unrestricted revenue) at most major public universities. Effective positioning may assure that the university receives more favorable appropriations than would otherwise occur.

Serious planning. Serious planning is a complex and demanding process that underlies disciplined and strategic use of financial resources, shaping of research and educational programs, careful development of physical infrastructure, effective recruitment and development of faculty and other human resources, and pursuit of many other key elements of a successful institution of higher education. Stature and recognition in higher education comes only after achievement for many years—a decade or two—after which informed observers come to expect high performance. Without such stature, success in research, recruiting high-level faculty, fundraising, and other areas is compromised. It is clear that the research proposals from, say, Michigan or Wisconsin are read very differently than those from regional universities. Similarly, major donors are attracted to high-profile institutions. And faculty and students clearly prefer institutions of high status, whose degrees have high cash value. Taken all together, stature and recognition are nearly everything in these areas.

Perhaps the most important means of achieving high stature are two seemingly contradictory capabilities: continuity and adaptability. Disciplined and strategic continuity of investment in facilities, faculty, students, and other elements of great schools is necessary to build critical mass and to achieve long-lasting performance that becomes recognized widely. Investments must cumulate, as must significant successes, and "thematic" continuity is a prerequisite for such cumulative success. But at the same time continuity of investment and purpose is being achieved, the institution's environment is in constant flux (e.g., federal funding, competitive environment, changes in the academic disciplines), and the institution must adapt constantly. Good plans are layered such that mission statement and broad goals are very robust, essentially unchanged for decades, while tactical plans by which the broad goals are achieved are constantly adapting to the environment. Any plan that lacks either long-term continuity or agility and adaptability will fail.

A budget is a financial plan. Any strategic plan that is not aligned with the budget is simply not a plan, though it may take the form of one. Any budget that is not aligned with the strategic plan is not really a budget (i.e., a financial plan). Achieving goals requires resources of many kinds, and short of simple luck, major success at achieving goals over a long period requires very disciplined use of resources.

Few universities are sufficiently resourced to compete head-to-head with the best institutions in those institutions' areas of strength. For example, The University of Missouri's Psychology Department has approximately 35 faculty, while that at Michigan has more than twice as many. Clearly, taking on Michigan broadly is at best a long shot. But if Missouri can identify the institution's unique assets that can position it uniquely in higher education, Missouri may lay claim to territory in which Michigan simply can't compete effectively. Strategic positioning, on the basis of unique assets, is a key part of planning to enhance competitiveness and ultimately stature. Such strategic assets can take many forms—e.g., unique facility, unique program mix, campus culture, strong corporate partners, or proximity to large government labs.

Regional cooperation. One way to extend the principle of strategic positioning is to look for regional strategic advantages—regional assets that can be exploited collaboratively in ways that the individual universities in the region could not achieve by themselves. Thus, for instance, a unique mix of program strengths across a region may allow collaborative successes, especially if there were other strengths that intersected the program mix—e.g., strong corporate partners or an unusual physical environment. Other regional strategies might be based on expensive facilities or instrumentation that no one institution or state could support, but that would be the foundation for making a special mix of programs achieve at a very high level. The political barriers (both within and outside the academy) to such collaboration are often extremely constraining, especially given the states' competitiveness in areas like economic development. But, in fact, regional academic cooperation can be a key ingredient to regional economic development, allowing states to achieve things together that no single state could achieve alone.

Getting past our history. Much of the institutional structure and process of higher education is a product of history, growing from an environment that is barely relevant to today's needs. The idea of graduating in four years (why not three and a half, or six?) is arbitrary at best. The time depends on the program of study and students' position in life. Dividing the curriculum into three-semester-hour segments (i.e., "courses") that meet three hours a week for fourteen weeks is arbitrary as well. (Often we have a course-bank rather than a curriculum; that's another problem, though perhaps related to the arbitrariness of the course structure.) One could argue that the idea of semesters, the three-hour course structure, and related institutions are logistically required, but I cannot believe we are so uncreative as to be unable to rethink this structure in a logistically viable way. Some higher education institutions have, of course, done interesting innovations—e.g., block courses at Colorado College, multiple formats in many MBA programs, and problem-based learning in some medical schools. But the point is that we usually think of the structure of higher education—especially curriculum and instruction—in ways that are very constraining, probably not cost-effective, and not the best ways to support student learning.

Get serious about impact as the measure of success. We often seem to focus less on the impact of our work than on trivial "indicators" of productivity like number of pages (or papers) published, grant funding received, or the number of credit hours generated. Much of the stature of higher education institutions is based on characteristics such as restrictiveness of admissions, not the impact of the institutions on students. These are at best crude indicators of impact, and at worst (and most likely) they are misleading, covering up our real impact or lack thereof. There are many areas in which one can find such inattention to impact; a few follow.

The area that probably receives the most attention these days is in looking at educational outcomes. Much of this discussion revolves around the tendency in higher education to assess students on the basis of subject matter knowledge in "courses" (i.e., grading), where the course objectives are primarily framed in terms of subject matter coverage. Mastery tends to be measured in terms of control of content, not ability to use it effectively, for instance. There is broad agreement today that more attention must be directed to defining learning outcomes and assessing students' proficiency, but we have a long way to go. More unsettling, perhaps, is the fact that as learning outcomes become "fashionable," we drift into a by-the-numbers approach to the issue that better serves the cause of easy assessment than of deep and effective learning.

In the research area, we tend to rely almost entirely on "poundage" (i.e., the volume of publications), sometimes on citations, and on research dollars generated. The exceptions are for those truly world-shaking research outcomes that are recognized by Nobel Prizes, Pulitzer Prizes, or election to the National Academies. I am not convinced by the argument that we need hard measures of productivity; in the end judgmental assessment is the only key to determining impact or potential impact. It is not too much of stretch to argue that the desirability of clear and objective measures would lead journals to accept or reject articles on the basis of an algorithm that counted the number of words in the average sentence, the number of complex versus simple sentences, and the number of words over eight letters—an obviously foolish idea, but I would argue not a great deal more foolish than the poundage criterion.

Tenure, an extremely valuable, even critical, part of our academic traditions, has taken directions that actually inhibit high impact research. The way we have implemented it provides incentives for junior faculty to avoid difficult and significant research (or teaching assignments, for that matter) in their pre-tenure years to assure the level of productivity (i.e., poundage) that assures tenure. They are often explicitly counseled to do safe projects that will assure several publications (minimal publishable units) that by definition are unlikely to have real impact. The worst part of this unfortunate practice is that junior faculty are socialized to a kind of risk aversion that virtually guarantees that we will see a great deal of research, the absence of which would have left the world no poorer. Again, judgmental assessment of the impact of the work is necessary. I tell tenure and promotion committees that I would much rather tenure and/or promote someone who took on a very difficult and significant problem, made a good effort, and failed than to tenure the risk-averse person who published twenty essentially meaningless minimal publishable units.

Conclusion

The point of this all is that we in higher education are in a new world. The environment has changed; the nature of higher education institutions has changed; public expectations have changed. It's challenging, but many of the changes, especially the broad participation and entitlement status, are really triumphs. But business as usual will not work. We are at serious risk of losing all that we value if we don't adapt.

Rough Seas or Normal Swells?

Richard Lariviere
Provost and Executive Vice Chancellor
University of Kansas

In the course of our discussions at this conference we have touched on many of the current challenges to the research enterprises confronting universities. Some of these matters are national/political issues and others are trends within the academy. I would like to try to place a couple of these issues in some kind of historical perspective in the hope that the scale of these problems might be better estimated.

Perhaps the most compelling presentation of the conference has been that of Jim Battey on the current promise and challenges to stem cell research. The political storm around stem cell research is familiar to this group. The slim margin of Missouri's decision to protect stem cell research, while a victory, was ultimately disheartening to those of us who had hoped for a more decisive statement by the voters. The consequences of this slim victory continue to reverberate. Opponents of stem cell research are encouraged and threaten to bring the matter back before the voters of Missouri yet again. The Stowers Institute has had trouble recruiting world-class scientists whose work involves stem cell lines not approved by the Bush Administration. The University of Missouri has had funds targeted to essential research infrastructure shifted to other purposes for fear that such infrastructure might one day be used for stem cell related research. This litany of continuing problems is discouraging and almost certainly bound to be a source of embarrassment in the judgment of history.

Lest we despair, however, it is important to note that the intervention of political causes in the realm of science is not a new problem. One needn't go back as far as Galileo to find similar serious impediments to science. In our own times we have seen moments when political matters could not only disrupt research agendas, but destroy careers. There was a time in the American academy when an accusation of communist sympathy could lead to termination and exile from the research and teaching that sustains every scientist. The parallels are worthy of note. Like the discourse around stem cell research, the hysteria associated with accusations of communist sympathy was not grounded in clear understanding of what such accusations or concerns involved. Like stem cell research, anti-communism was often the tool of the demagogue who knew little or nothing of the fundamental issues, but who rode the hobby-horse to electoral gains. In retrospect, those whom we most admire from that time are the members of the academy who steadfastly refused to be intimidated by the hysteria and continued in quiet resolve to speak what they knew to be the truth. Jim Battey's presentation is a source of encouragement. The scientists of the NIH clearly are not cowed (they may be inhibited but they are not silenced) by the current political interference with scientific inquiry. Such colleagues will rightly take a place of distinction in posterity's view of yet another peculiar moment in the history of science.

Many of the presentations made by our colleagues here have had as their common theme money. We should not shrink from the unvarnished assertion that it is money that is the prerequisite for our success. Without adequate funding, the best minds and the most creative ideas will come to very little in the realm of research. I often have the impression that we are much practiced in lamenting the absence of funding, but less good at articulating the reasons why we should be at the head of society's queue for its largesse. Beth Montelone did a good job of demonstrating how "situating" one's research in society's understanding of its own needs can enhance the chances for funding. .

When I listen to conversations in the academy on the question of society's support for higher education, I hear an understandable frustration verging on anger. I say that this is understandable because most of our colleagues understand in fundamental ways that the work that goes on in the academy is genuinely important and has the potential to improve, shape, invigorate, and even save society. What we do here is of the greatest importance for the future. We know this with a clarity that makes it frustrating when legislators, donors, and, yes, administrators don't act to support our work. But we have often skipped a step between our understanding and our frustration. Our audiences seldom share the same degree of understanding that we have. Legislators, alumni, donors all have an intuitive sense that what happens at KU or Missouri or Nebraska is genuinely important, often they have first-hand experience. But we sometimes fail to give them explanations that they can grasp. This is essential if they are to put our needs ahead of other voices in society.

As Joe Steinmetz pointed out, public institutions are struggling to maintain their competitiveness. Whipsawed by diminishing legislative support and public resistance to tuition increases, the challenges to keep our salaries, infrastructure support, and research investment competitive with the best of our private rivals is difficult. Still, it is useful to recognize that the $240 million/ year that the University of Kansas receives from the legislature, for example, is equivalent to the expendable yield on a $4.8 billion endowment. The difference lies in the future. Whereas a $4.8 billion dollar endowment, properly managed will continue to yield in perpetuity dividends that will be the equivalent of today's $240 million, we cannot be similarly optimistic about future levels of support from our legislatures.

Brian Foster discussed some of the special challenges that we face. He likens the current situation to paddling a canoe in a tsunami. While there are times when this metaphor seems about right, I do not see quite the same degree of turbulence in the currents we are navigating. Brian spoke of the entitlement status of higher education. This view is informed by his –quite accurate—observation that a college degree has supplanted the high school degree as the base level of education that an American student should aspire to in order to achieve a good life. His point is that this shift has colored the conversations about access to higher education and increased pressure –particularly in public institutions—to make accommodations for students who are under-prepared.

His analysis of this phenomenon focuses on the fact that the greater participation of Americans in post-secondary education has shifted in a very brief 20 year period--the concentration away from traditional four-year institutions to community colleges and for-profit institutions. The fact that 50% of students are now in the latter two types of institutions is, indeed, a new development. It is also the case that this shift alters the political dialogue around higher education. I do not, however, find this cause for alarm. What we do at major research institutions is so dramatically different in purpose and effect than what takes place at community colleges and such places as the University of Phoenix, that there is little in the way of comparison. The challenge is not that more students are in community colleges, the challenge is in articulating how attending a research university differs from attending a community college.

The challenge of describing the differences between community colleges and universities is more difficult than it may seem on the face of it. *We* know, because we are in the midst of the task. The majority of American voters, legislators, parents, and students do not know. It is our job—our obligation—to be able to reasonably and clearly articulate the difference between what happens at a research institution and what happens at a community college. The old stand-by of invoking the difference between being taught by someone who has read the book and someone who has written the book is not an adequate response to this challenge. Most of our audience in this discussion do not know what that succinct statement implies. In my opinion it is precisely this area of ignorance that lies behind the clamor for assessment of universities. There is a vague notion out there that somehow the vast array of higher education institutions is similar to the array of high schools: they all do the same thing, but some do it better than others. All we have to do is find the right metrics and we will be able to sort them all on to a scale of excellence and rank order them from 1 to 3200.

If we look to history for a similar moment of dramatic shift of university attendance we can find it in the period just after World War II. The passage of the G.I. Bill changed America more profoundly than most of us recognize.

This piece of legislation was initially proposed by Rep. Elliot Rankin of Mississippi, a man of few admirable political views. He was a proud racist, an aggressive anti-Semite, a vigorous member of the House Un-American Activities Committee and utterly uninterested in higher education except insofar as he viewed universities as the playgrounds of Jews and Communists. But he was an advocate of benefits for veterans. The result of his initial legislative proposal was the G.I. Bill of Rights which –among other things-- paid for four years of tuition (with a generous monthly stipend) at any institution of higher education in the United States. It is interesting, and perhaps instructive, that there was vigorous opposition to this legislation by the higher education establishment. James Conant, the President of Harvard was convinced that there would be a disastrous lowering of the quality of education in America because this legislation would fail to "distinguish between those who can profit most by advanced education and those who cannot." Even the progressive Robert Hutchins, President of the University of Chicago, predicted that the G.I. Bill would turn universities in "hobo jungles."[1] This "catastrophic imposition" on higher education resulted in the education of 14 Nobel Prize winners, three Supreme Court judges, three Presidents, 12 Senators, 24 Pulitzer Prize winners, 238,00 teachers, 91,000 scientists, 67,000 doctors, 450,000 engineers, 240,000 accountants, 17,000 journalists, 22,000 dentists and one million others who became lawyers, nurses, business people, artists, actors writers, and so on.

Dramatically heightened expectations for higher education is a good thing. But it *has* changed the playing field. It ratchets up the focus on us. We need to justify the huge investment that is being made in what we do. We need to explain what we do more often and more carefully than at any time in the past. We need to pay more attention to how our students are being prepared than we have ever had to do in the past. We are obliged to assert the value of what we deliver in venues and to a degree that has never before been required. Brian Foster is right when he says that the higher education has been politicized more than in recent memory maybe more than ever in history.

The politicization of higher education to this degree is largely due to the fact that the stakes associated with what we do have never been greater. Higher education has to bear a greater share of basic research than has been the case at any time since World War II. The costs of higher education are growing at a rate that far outstrips increases in all other sectors except health care. When there are large amounts of money at stake, the scrutiny and resentments grow, but it is better to be in the arena than on the sidelines.

Public higher education institutions such as ours are – of necessity – going to have to take more direct responsibility for our fiscal future. Our institutions—and by that I mean our colleagues, our alumni, our various publics—have not yet internalized the fact that private fund-raising on a scale and in a manner

[1] Edward Humes, *Over Here: How the G.I. Bill Transformed the American Dream*, Harcourt, 2006, p. 32.

that emulates those of the private institutions is unavoidable. The quicker we have leaders and administrators in place who understand this reality, the better off we will be. A billion dollar endowment for a research institution of 30,000 students is not adequate. It is a good beginning, but it is only a beginning. Private endowments will be the leading discriminator in determining which of our institutions will flourish and which will languish.

There are large and serious challenges confronting higher education. Those challenges are not of any greater magnitude than those faced by previous generations of scholars and scientists in the academy. However tempting it may be to place our particular moment at the pinnacle of history's complicated moments, it is the case that we have never had more money or greater numbers involved in our work than we have at the moment. It isn't enough money and there aren't enough scientists, teachers, and scholars in the pipeline to sustain what we will need in the future. But those challenges are likely to always be with us. That we have them is a reason for optimism rather than dismay.

CONFERENCE PARTICIPANTS 2007

Keynote Speaker

James F. Battey, Jr., M.D., Ph.D., Director, National Institute on Deafness and Other Communicative Disorders, NIH

Iowa State University

John Brighton, Ph.D., Vice Provost for Research

Kansas State University

Loretta Johnson, Ph.D., Associate Professor, Co-Director of Ecological Genomics Institute

Beth A. Montelone, Ph.D., Associate Dean, College of Arts & Sciences

The University of Kansas

Barbara Atkinson, M.D., Executive Dean and Vice Chancellor for Clinical Affairs, University of Kansas School of Medicine

Richard Barohn, M.D., Professor and Chair, Neurology Dept., KU Medical Center

Richard Lariviere, Ph.D., Provost and Executive Vice Chancellor

Kathleen McCluskey-Fawcett, Senior Vice Provost for Academic Affairs

Mabel L. Rice, Ph.D., The Fred & Virginia Merrill Distinguished Professor of Advanced Studies and Director of the Merrill Center

James A. Roberts, Ph.D., Vice Provost for Research and President, KU Center for Research

Richard Schiefelbusch, Ph.D., Director Emeritus of the Schiefelbusch Institute for Life Span Studies and the Merrill Center, and Merrill Board member

Joseph Steinmetz, Ph.D., Dean of the College of Liberal Arts and Sciences

Paul Terranova, Vice Chancellor for Research, University of Kansas Medical Center

Steven F. Warren, Ph.D., Director, Schiefelbusch Institute for Life Span Studies, and Merrill Board member

Keith Yehle, Director of Government Relations

University of Missouri

Brian Foster, Ph.D., Provost

University of Nebraska - Lincoln

Prem Paul, D.V.M., Ph.D., Vice Chancellor for Research

Jordan Green, Ph.D., Associate Professor and Corwin Moore Chair in Communication Disorders

Other Participants

Jeremy Anderson, Office of the Governor of Kansas