Global Research Collaborations

Merrill Series on
The Research Mission of Public Universities

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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 twelfth annual research policy retreat hosted by the Merrill Center: *Global Research Collaborations*. 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 on international collaboration in research: what the benefits may be, how collaborative relationships are developed in an academic setting, and the means of addressing issues such as intellectual property, differing funding models, and data sharing over international borders. The 2008 Merrill retreat provided an opportune time to consider the implications of the increase in international research collaborations, and how these collaborations are managed and fostered.

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.

Ten senior administrators and faculty from four institutions in Kansas, Missouri, and Nebraska attended; they were joined by members of the Merrill Center board of directors and Kate Wolff, from the Kansas Governor's Office. This year's retreat featured two Keynote speakers. David Lightfoot, Assistant Director of the NSF, Directorate for Social, Behavioral, and Economic Sciences, discussed how cyber-infrastructure has influenced the development of international research collaboration in Social Science research. Marion Müller, Director of the North America Office of the German Research Foundation (DFG), described how her foundation is actively supporting international research collaboration through several different funding vehicles. In addition to those presenters whose remarks are published here, Joseph Steinmetz served as moderator and contributed a valuable perspective as a member of the Merrill Board and as Dean of the College of Liberal Arts and Sciences at the University of Kansas.

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. Our retreat in 2006 considered the privatization of public universities and the corresponding shift in research funding and infrastructure. Finally, last year's retreat focused on the changing climate of research funding, the development of University research resources, and how to calibrate those resources with likely sources of funding.

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 2008 Merrill policy retreat on *Global Research Collaborations*.

Executive summary

International Collaboration in the Social and Behavioral Sciences

David Lightfoot, Assistant Director, National Science Foundation
Directorate for Social, Behavioral, and Economic Sciences

- Many kinds of collaboration are routine and involve no special mechanisms. A few years ago, NSF worked on recommendations about how we might internationalize work in the social sciences more effectively.

- The world has changed and made collaboration easier, mostly through easier travel and more effective telecommunications. Also science has changed and there is greater emphasis on interdisciplinary work.

- One of the major tools is what the US terms cyberinfrastructure and what Europeans term e-science. Now for the first time in the history of science all scientists use cyberinfrastructure for many purposes; new computational facilities have become part of the infrastructure of all the sciences.

- All of the initiatives discussed in this article have cyberinfrastructure at their core and that has been a major focus at NSF over the last few years, with the establishment of the Office of Cyberinfrastructure within the Office of the Director three years ago.

- Virtual organizations, drawing scientists together outside the bounds of geography, constitute a major tool for new international collaborations and we need to understand their possibilities as well as we can.

- Our experience is that joint proposals with parallel funding and parallel review processes are successful, because each funding body is getting more net research for their partial support of the overall project.

- The NSF is interested in cultivating international collaboration at the level of principal investigators from different countries who seek to undertake common research. Agencies from different countries can collaborate to develop the international infrastructure that is so needed by our sciences.

International Research Collaboration: Just Nice to Have or Necessary?

Marion Müller, Director, North America Office, German Research Foundation

- The DFG is the central research funding organization that promotes research at universities and other publicly financed research institutions in Germany. Its foremost goals are promotion of collaboration between scientists and academics and cooperation with the respective national research funding organizations. Almost all of the DFG's funding schemes offer international components.

- Germany “pushes” students and young scientists to spend an extensive time period of their academic career outside of Germany, and also offers various sources to fund these times abroad. The US is the leading destination of choice for DFG-funded

postdocs as well as for conference and lecture trips. There are currently about 350 DFG-funded postdocs in the US.

- However, in the US, postdoctoral studies abroad are often considered as removing talented young scientists from the scientific mainstream and making it harder for them to compete on a difficult US job market after returning. Faculty members, academic advisers and graduate students across all disciplines seem to share the perception that tenure-track ambitions are incompatible with doing a foreign postdoc.

- The support for international collaboration is an integral part of the DFG's mission. The DFG has not only opened all its funding schemes to foreign nationals willing to do science in Germany, but it supports collaboration between German scientists and international partners in all of its funding programs and with a multitude of instruments.

- The DFG's Research Training Groups combine innovative top-level research and structured promotion of excellent young researchers in an international setting. A key objective of Research Training Groups is to enable the speedy research-related qualification of doctoral researchers. Doctoral researchers are enabled and expected to conduct independent research early on. Research Training Groups aim to accelerate doctoral training and lower the age at which scientists and academics finish their doctorate.

- Intensive large scale and medium-term collaborations need careful preparation and long-term planning. Preparatory trips or collaboration visits to the partner's institute or department can be supported through the DFG's international cooperation funds. Likewise, funding for bilateral events is provided to facilitate cooperation between scientists and academics with the aim of developing scientific contacts.

- One of the largest obstacles in international research collaboration is so-called double jeopardy, the dependence on separate funding decisions by each of the funding agencies in the USA and Germany. As long as international research collaboration is exposed to double jeopardy, one cannot blame researchers if they opt out for the safe way; namely to design a research project where the international collaborative component is nice to have but not necessary and comes into the picture only once national funding has been secured at both national fronts.

- International research collaborations are nice to have, of course, but more than that they are increasingly and vitally necessary to tackle important challenges and to keep science successful and competitive. However, the different stakeholders, not least the funding agencies, university managers and policymakers, must create a habitat where international collaboration can truly thrive and bear fruit.

Lessons Learned from International Research Partnerships

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

- International research partnerships have played a critical role in increasing food availability in many developing countries. Two of UNL's current international programs are collaborative partnerships; we highlight lessons learned from these two efforts to inform the creation and foster the success of other international partnerships.

- The goal of the UNL- University of Zambia (UNZA) partnership is to build capacity to better confront infectious disease, especially HIV/AIDS and AIDS-associated diseases. The Nebraska-based Fogarty training program's ultimate aim is to help biomedical personnel in Zambia slow or halt HIV transmission and minimize the negative health effects of HIV/AIDS-related malignancies and diseases. Zambia's Ministry of Health is so pleased with the program's successes that it uses the Nebraska Program as a model of U.S.-Zambian collaboration.

- UNL has a number of collaborations with various Chinese research and education institutions. Research and training collaborations have been set up with Nankai University, which is among the top 10 universities in China. The Nebraska Fogarty Training Program has provided training for 13 Chinese fellows. So far every fellow who has completed the training program has resumed their former post and actively engaged in HIV/AIDS and AIDS-associated disease research.

- INTSORMIL is a USAID program established to provide research and training support to developing countries. Among the global strategies of the INTSORMIL program are: Sustainable crop production systems, sustainable plant protection systems, germplasm enhancement, crop utilization, technology commercialization, and building national agricultural systems. UNL has led the INTSORMIL in West Africa since its inception and successfully won the 2006 renewal competition. The majority of the INTSORMIL-trained workforce has returned home with new skills, enhancing in-country capacity through research and administration.

- Recently, funding from USAID has been significantly reduced, but several important CRSPs like the INTSORMIL have continued to receive support. More recently, NIH's Fogarty International Research and Training program has provided funding for infectious disease research in West Africa.

- Mutual trust and common goals lead to mutually beneficial relationships; these are among the most critical factors when forming successful partnerships. Retention of the talent pool in partner countries is critical. Individuals that emerge from these programs are frequently highly sought after because there is enormous competition for well-trained workers in developing nations. Program sustainability is important – without it, the impact on in-country capacity is minimized. Programs that help provide new skills to local citizens can help create new businesses and improve local economies are often successful.

Facilitating Faculty-Driven International Initiatives

James Guikema, Associate Vice President for Research, Kansas State University

- A major, research extensive university must recognize the global scope of effective scholarship and strive to instill a global perspective in the classroom, in research and scholarly activities.

- This concept of free and open inquiry is at the core of the higher educational mission of a vibrant university. The goal is for the university to achieve a curriculum that remains sensitive to a global perspective and seeks to optimize international linkages. Achieving such a goal requires the active participation of the faculty of the institution. Universities must be proactive to reach the goal of globalization. Kansas State University's Office of Research and Sponsored Programs (OSRP) has identified four challenges that the research administration can address to make globalization and international collaborations a reality.

- Faculty is the key in international collaboration, and distance is an activation energy threshold that needs to be overcome for such collaborations to flourish. One strategy is to present funding opportunities to the KSU faculty in both a timely and a frequent basis. A database specialist is available to assist every faculty member, and especially those in the first several years of their appointments, in obtaining information on funding sources beyond those like NSF and NIH that are well known.

- Graduate education is a global enterprise. Over a half million foreign students studied in the United States in 2005, and our nation is not unique in hosting international students. We should be using these students to cement research linkages abroad. International doctoral students often return to their home countries and join the scientific workforce at home. US faculty members, therefore, have a ready source of collaborators by relying on their own graduates. As these collaborations mature, the internationalization of graduate education could potentially be institutionalized by the establishment of joint degree programs.

- There are legal and ethical challenges when faculty members initiate projects that will be managed overseas. Universities will be expected to be in compliance with the laws and regulations at home, made difficult when the funds are spent overseas.

- A modern university has the obligation to its faculty, students, and stakeholders to ensure the global nature of its research enterprise. The offices that provide the research administration for the university must have that mindset as well. At KSU, the Office of Research and Sponsored Programs strives to provide this for our stakeholders.

Think Globally, Organize Systemically

Jack Schultz, Director, Christopher S. Bond Life Sciences Center, University of Missouri

- US research universities are not currently structured so as to enhance the success of international collaborations. Integrating systems science into the administrative architecture is a key solution.

- There is considerable difficulty in discerning what is actually feasible in an international research collaboration, what complications will occur, and in foreseeing unintended consequences. Many factors that come into play include importation issues, fiscal issues, and socio-cultural issues. Investigators need constant and frequent updates on changing regulations and sociopolitical circumstances. However, this kind of resource is nearly nonexistent. Most US universities are addressing globalization at the level of undergraduate education.

- A very important trait of interactions in complex systems is that the outcomes, products, eventual states, of a system are not evident from merely examining the participants. Complex systems have 'emergent properties', or behaviors not predictable by examining individual elements. It takes multiple perspectives and approaches to unravel complex interactions.

- There is only one sort of organization where the disparate disciplines needed to unravel the emergent properties of complex systems commonly co-occur: the research university. The problem of integrating the disparate interests for international collaboration is truly daunting. Institutional culture leaves it to the individual researcher to solve these problems, but this engenders a real opportunity cost.

- All research programs are increasingly international research programs, whether the researcher goes abroad or not. Yet training, at least in the sciences, continues to focus on what happens in one's field, on one's campus, in one's lab or office. Researchers who do go abroad are challenged to decipher unexpected factors ranging from minor annoyances to major interference.

- Research universities should be able to provide information about the factors that will influence the work abroad to researchers. An officer or entire staff whose job it is to help researchers become aware of global issues when developing research projects would contribute greatly to the university's mission.

- Because academics are trained to focus narrowly and develop their research in a domestic setting, they would benefit from an agency whose role is to suggest or even outline the complexity of the system in which their research will be carried out. Universities should consider systems analysis a critical element in the academic administration system, since the benefits range from enhancing their own effectiveness to their global impact.

Biodiversity Prospecting and Conservation Programs: Models for International Collaboration

Barbara Timmermann, University Distinguished Professor and Chair, Dept. of Medicinal Chemistry, University of Kansas

- An International Cooperative Biodiversity Groups (ICBG) Program was awarded in 1993 for research into drug discovery from medicinal plants, biodiversity conservation and economic development in Latin America. This ICBG program, entitled "Bioactive Agents from Dryland Biodiversity of Latin America", serves as a model for the implementation of the ICBG principles, which are, ultimately, the principles of the United Nations Convention of Biological Diversity (UNCBD). Based on this model, bioprospecting research continues at KU.

- The drug discovery and development goal of this ICBG is to identify biologically active molecules from plants as chemotherapeutic candidates for tuberculosis, cancer and other diseases of concern to developed and developing countries.

- One of the project's central goals was to address and promote biodiversity conservation and sustainable economic activity, including minimizing negative environmental impacts while ensuring that equitable economic and social benefits from discoveries accrue to the country, community, and organization which facilitated the discovery of the natural product.

- The successful collaboration of the members of this ICBG required detailed agreements among the various participants, which defined work and funding commitments, ownership of materials, licensing rights and distribution of future financial benefits, if any. Each two-way agreement defined the scope of work obligations of the University and of the collaborator.

- The real benefits from these types of collaborations are in the collaborative interactions established among the participating countries, the databases developed as a result of the project, the technology transfer and the training of students and faculty through active exchange programs.

- From our direct participation in the ICBG efforts in search for biologically active agents from terrestrial plants, we can conclude that such an endeavor is a very complex process that requires the involvement of not only scientific expertise, but also expertise in a variety of human activities including diplomacy, international laws and legal understandings, social sciences, politics, anthropology, sociology and knowledge of local language and culture.

- In the long term, this project has built institutional and international relationships between the U.S. and developing countries that will continue to grow beyond the life of the project and will serve as an effective model for others who seek to develop similar relationships.

Partnering In China: A Case History

Barbara Couture, Senior Vice Chancellor for Academic Affairs, University of Nebraska-Lincoln

- China is the most rapidly changing economy in the world—a fact that no institution, private or governmental, can ignore. The social, political, industrial, and ecological impacts of China's rise are world-wide and affecting us nationally

- Beyond China's importance to our economy and its reliance on our research universities to fuel innovation, China poses tremendous potential as a source of new university students. China, at present, has fewer than 1000 universities and 9.5 million potential freshmen. Only 2.7 million have hopes to enroll.

- International programs require a solid, open, and well-articulated partnership between the cooperating institutions. All personnel associated with partnership need to first and foremost understand their roles in securing the partnership; these individuals' commitment to those roles will assure that the partnership is institutionally grounded.

- In pointing to our case study partnership with XJTU, we focus here on seven strategies that can lead to a partnership with a foreign institution that succeeds:

    - Assure institutional compatibility
    - Build on existing relationships
    - Recruit institutional brokers
    - Make and honor agreements
    - Create a physical presence
    - Develop a shared story
    - Practice patience

- Partnering with China can be rewarding and beneficial for research universities here and in China. The benefits to UNL have been visible and immediate. When all our partnership degree plans with XJTU CC are fully realized, we will add 500 new Chinese undergraduate students to UNL each year. Because we are under capacity in our undergraduate operations, this means a substantial increase in tuition revenue as well as an economic boost to Lincoln.

The Tribolium Genome Project: An International Collaboration

Susan Brown, Professor of Biology, Kansas State University

- The large data sets produced by genome sequencing projects have spurred the formation of global collaborations that are highly interdisciplinary. The Tribolium Genome sequencing consortium is an example of such a collaboration.

- In today's research world, it takes an international consortia of scientists to organize their efforts: first to justify a genome sequencing project, and then to coordinate the annotation efforts once the sequence is in hand. Interactions between consortium members have lead to several federally and internationally supported projects, some

of which continue today, past the formal conclusion of the genome sequencing project.

- We proposed sequencing the genome of the red flour beetle *Tribolium castaneum,* a world-wide pest of stored grains. The red flour beetle is now the third best invertebrate model organism for genetic studies of development, physiology and toxicology after Drosophila and the free-living nematode, *C. elegans*. Sequencing the Tribolium genome provides our first insight into a Coleopteran genome, and there are more species in this order than in any other.

- Several research groups, predominantly in the US and Europe, use Tribolium as a model system in which to study the genetic regulation of development; Evo-Devo studies. Analysis of the Tribolium genome was expected to provide insight into developmental studies in both fruit flies and vertebrates. Genome sequencing projects require funding from multiple sources. Academic, industrial and federal agencies contributed to the Tribolium Genome project.

- Computational analysis of the genome revealed more than 16,000 gene models. A subset of these needed to be manually evaluated to determine the quality of the genome sequence and the value of the computer generated gene models. More than 100 scientists from 67 institutions world-wide provided the initial analysis of the Tribolium genome.

- **The future of genome sequencing projects.** The first wave of genome projects was federally funded and their progress was followed in detail by the entire research community, as befitting a new research paradigm. The second wave of projects was also justified by white papers. With the advent of new sequencing technology, genome sequencing projects are now in the realm of individual research grants. Soon a genome sequence may be considered preliminary data for a research project grant. Even when it reaches this stage, sequencing the average eukaryotic genome will be an international collaboration, uniting researchers world-wide, through their interest in the next genome.

An International Initiative in Biomedical Research Training

Salvatore Enna, Associate Dean for Research and Graduate Education, University of Kansas Medical Center

- One stimulus for internationally coordinated educational programs is the need to preserve fundamental research technologies that might otherwise be lost.

- Paleo drug discovery was a linear process, with all experiments conducted in humans, and the only endpoints being efficacy and safety. Modern drug discovery began in the 19th century as a result of advances in chemistry and physiology. By the mid-20th century it was clear that drugs exert their effects by interacting with biochemical pathways, and that the physiological and clinical responses to these agents result from effects at the cellular level.

- Towards the end of the 20th century, advances in molecular biology opened new avenues for drug discovery. The Molecular Period which began in the 1980's and extends to the present, is characterized by a shift in the initial objective of drug discovery from first identifying agents that display efficacy and safety, and therefore likely clinical activity, to first identifying agents on the basis of their target selectivity, which may or may not ultimately prove to be of any clinical benefit.

- As federal support for physiological research waned in comparison to molecular studies, investigators and academic departments abandoned work in the former to concentrate on the latter. Besides slowing advances in the physiology sciences, over time this change of priorities reduced the number of faculty with interests and expertise in this area, thereby diminished training opportunities in the field.

- The decline in IOSP training has led to manpower shortages in the field in the pharmaceutical industry and government regulatory agencies. It is speculated this lack of expertise and the steady erosion in the population of those capable of teaching IOSP are responsible, at least in part, for the decline in the number of novel drugs reaching the market.

- In 2004 the United States National Institutes of Health (NIH) began funding short courses in integrative and organ system pharmacology. Currently, the NIH supports summer IOSP short courses at four institutions. The International Union of Basic and Clinical Pharmacology (IUPHAR) assembled a task force to assess the global need for IOSP training and to design programs to meet the demand for such instruction at strategic locations around the world.

- As the IUPHAR program involves collaboration among academic institutions around the world, it is a prime example of a global research and training initiative. This undertaking exemplifies how academia, industry, and federal governments can work together in pursuing a common goal.

International Medical Research Infrastructure: KUMC and Beyond

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

- The advent of the internet has enabled researchers to communicate without geographic bounds and thus research is no longer geographically restricted. US universities must have a global presence in order to remain competitive.

- There are several benefits of developing an international research network. The expertise provided by the various partners will allow broadening of the research goals and technologies utilized in the research. Additional benefits include enhancing the institution's competitiveness for grant opportunities, engaging new students, staff, and faculty with outstanding credentials. For clinical trials, the patient base may be increased.

- International collaborations can enhance discovery and strengthen research programs by integrating basic and clinical research where feasible, to encourage translational research. In establishing international collaborations, a solid vision is required including short and long term goals.

- India is launching an open source drug discovery initiative to accelerate development of new drugs to treat infectious diseases of worldwide importance. It is establishing a web-enabled interactive open source platform that will list the current design challenges for developing drugs to treat drug resistant tuberculosis, malaria and HIV.

- Why use open source? First, the goal is to help resolve key scientific and drug discovery problems with multiple inputs thus accelerating drug development/discovery in specific disease areas. One driving force for using open source is that many of the drug discovery problems are complex requiring many labs for insights. However, the timing of disclosure, protection of the discovering scientist(s), and subsequent product patent filing limitations may all be formidable issues.

- The KU School of Pharmacy has a high national ranking as evidenced by their continued success with NIH funding, training of students, and the quality of their faculty. Major strengths are in the areas of Chemical Methodologies Library Design and Drug, Discovery, Development and Delivery. Whether an open source discovery program would facilitate the movement of drugs through the pipeline is uncertain at this time. However, enhancement of collaborations at the local, national and international levels is critical for future success.

The Global Land Grant University: What Does That Mean at Mizzou?

Brian Foster, Provost, University of Missouri

- MU's international activities are extensive. They involve research, graduate and undergraduate instruction, Extension, and economic development. They are diffuse and deeply embedded across all colleges. Nevertheless, international programs are often marginal to the institution. They lack continuity, organizational support, centrality and a compelling narrative to build adequate political support. In short, they are interesting, challenging, productive—but they are not a key priority by consensus! We are global—but under the radar.

- MU has a long history of international involvement. Consider the following.
    - 1500 international students in 2007-08—about 5% of total enrollment
    - 1,000 international visiting scholars traveling on J-1 visas
    - More than 1,100 students earned academic credit abroad in 2007-08
    - MU has active agreements with over 160 international universities and government agencies.

- **FAPRI in Ireland and the UK:** MU's Food and Agricultural Policy Research Institute's (FAPRI's) made an analysis of agricultural policy in the United States.

Upon the invitation of the Prime Minister, FAPRI began a long-term project that addressed the implications for Ireland of a series of agricultural policy reforms that the EU was considering.

- **Pasture-based Dairying in Missouri**: A new kind of dairy farm is emerging in Missouri, modeled on a pasture-based system of dairy production, much of which was developed in New Zealand. Since 2004, these pasture-based dairies have produced more than $12 million in annual milk sales, with more than $37 million in total economic impact, and 330 new jobs. The New Zealand connection, facilitated by MU Extension, has opened a new kind of dairy production that has had significant impacts on the Missouri economy, on local communities, and in general, on the quality of life in Missouri.

- **MU Programs in East Africa**: MU's current project, the Southern Sudan Revitalization Project, will manage about $4 million per year in facilitating activities of USAID in the area. Among other activities, MU will conduct a census that is necessary for the upcoming election. In addition, there will be work on such issues as land title laws and on creating viable government agencies. The MU project in Southern Sudan is seen as a possible model for addressing issues in Darfur.

- **University of Missouri and University of Western Cape:** A large majority of South Africans receive treatment from traditional healers, using traditional therapies developed over centuries, treating conditions ranging from the common cold to HIV AIDS. The effectiveness and safety of these therapies have not been scientifically addressed. The TICIPS program (The International Center for Indigenous Phytotherapy Studies), under direction of PI William Folk (MU Professor of biochemistry), is pursuing such studies, with the goal of incorporating these traditional therapies into conventional health care systems.

- It is clear that this international commitment shows a strong land-grant mind set. There is much more at MU than the land-grant mind set and mission—basic research, liberal arts education, and professional education, for instance. But the land-grant mind set has enriched all aspects of the complex MU mission.

International Collaboration in the Social and Behavioral Sciences

David Lightfoot
Assistant Director, NSF. Directorate for Social, Behavioral, and Economic Sciences

International collaboration has been a constant at the National Science Foundation, US scientists do a lot of it and increasingly. International activities are built into very many grant proposals and they are quite simply part of normal science. It is sometimes said that international collaboration is expensive and difficult but many kinds of collaboration are routine and involve no special mechanisms. Sometimes special mechanisms and efforts are indeed needed. Over recent years, after the September 11th attacks, there have been difficulties stemming from the issuance of visas but those difficulties have now evaporated in large part, as new procedures have begun to run smoothly.

In addition, NSF has conducted special workshops and run joint solicitations with funding agencies from other countries. A few years ago, to take an example of something of general interest for this meeting, we worked with the UK Economic and Social Science Research Council (ESRC) to fund the Social Science Research Council (SSRC) to make recommendations about how we might internationalize work in the social sciences more effectively.
Recommendations were made and four have been acted upon: establishing the International Forum for Funding Agencies (IFFA), an International Data Forum (IDF), annual conferences on international cyberinfrastructure or e-social science, and collaborative work with international development agencies.

Alongside international collaboration, we should recognize that there is international competition and countries, including the US, are concerned about how well they compete in the science and engineering enterprise. This may work against collaboration in some instances.

In any case, international collaboration needs to be viewed alongside interdisciplinary and interinstitutional work and the move toward big science, tackling big questions with interdisciplinary teams of scientists, often with social and behavioral scientists working with scientists from other domains. This reflects the fact that the world has changed and made collaboration easier, mostly through easier travel and more effective telecommunications. Also science has changed and there is greater emphasis on interdisciplinary work as

we tackle bigger problems and cultivate more innovative science, which often stems from new connections. In this paper I will concentrate on new initiatives that encourage science tackling big questions that involve large-scale operations; such initiatives offer the richest possibilities for new international collaborations in the human sciences.

One of the major tools of this big science is what in the US we call cyberinfrastructure and what Europeans call e-science. Cyberinfrastructure has become the common tool and this represents a remarkable development in the history of science. Different sciences have always had their own tools: Astronomers have had their telescopes, physicists their colliders, biologists their sequencers, sociologists their surveys. But now for the first time in the history of science all scientists use a common tool, cyberinfrastructure; new computational facilities have become part of the infrastructure of all the sciences. To be sure, astronomers and sociologists use cyberinfrastructure differently but there are common issues, mostly relating to the establishment and curation of massive data archives, along with the accompanying issues of privacy and confidentiality, and virtual organizations are now re-shaping the way that science is conducted in almost all areas.

The development of cyberinfrastructure is of great interest to the human sciences, which study human behavior in many domains, including the behavior of scientists, and have much to contribute to developing the infrastructure associated with new computational capacities. Certainly cyberinfrastructure has enabled the advancement of social and behavioral sciences; the fields that I work in, language variation, acquisition and change, have been transformed over the last generation and papers look very different from what was published a generation ago, mostly in terms of reliance on massive data archives and the associated analytical techniques. In addition, the social, behavioral and economic (SBE) sciences inform the design of effective cyberinfrastructure and they assess the impacts of cyberinfrastructure and ways for it to benefit society; for these sciences, cyberinfrastructure is itself an object of study.

The contributions of the social and behavioral sciences are significant and many, are covered in detail in 2005 report from joint CISE-SBE Airlie House conference, and have been incorporated into NSF's *CI Vision for 21st Century Discovery* (NSF, 2007). Here I will use cyberinfrastructure as a lens on emerging areas of interdisciplinary, potentially transformative science, where there are opportunities for scientists from different disciplines, institutions and countries to collaborate. I will discuss the social and behavioral science contributions to cyberinfrastructure with respect to five key NSF investment areas:

- Adaptive Systems Technology
- Environment
- Science of Science & Innovation Policy
- Complex Systems
- Cyberinfrastructure

Adaptive Systems Technology

Much has been learned about how the brain functions in the past generation through various imaging tools. These tools and technologies include:

- More powerful computationally based imaging devices
- Tools for gathering coordinated, simultaneous data from different monitoring devices (SBE/CISE/OCI Next-Generation Cybertools award to U. Chicago)
- High performance computers capable of storing and analyzing massive data sets

However, brain science is still in its infancy and present machines measure what they measure and have severe limitations – new tools and technologies are necessary to help us better understand the anatomy, development, and physiology of the brain. New tools will come from collaborations between people working on brain function, on the one hand, and chemists, physicists and nanotechnologists, on the other. AST aims to promote the collaborations that could develop new technologies mimicking the brain processes we understand and new technologies that will enable new understanding of how human brains work. These collaborations cross disciplines and international borders.

Environment

NSF established its first ever inter-directorate standing program two years ago. The Dynamics of Coupled Natural & Human Systems is supported by the Biological Sciences, GEO and SBE and focuses on human factors in environmental change, both human causes and consequences for humans. This is viewed as a vehicle for future investments in environmental matters, including work on climate change. Any modern work on environmental matters is based on new possibilities provided by Geographical Information Systems (GIS), which combine geospatial data with data gathered by social and behavioral scientists, allowing sophisticated research on environmental change, resource inequality, business networks, criminal justice, health and disease. There is a focus on disasters and that, too, integrates climate, environment and social science data to enable better prevention, preparation and mitigation. Environmental work also involves simulations of societies; current simulations are too simplistic to capture social processes in even small groups, so substantial high-speed computing resources are required. And new kinds of observatories enable fine-grained multidimensional recording of natural and human-built assets over time.

Science of Science & Innovation Policy

The new program in the Science of Science & Innovation Policy (SciSIP) aims to develop the data, tools and knowledge needed to establish a new social science of science and innovation policy. It promotes the study of the returns that public and private sectors receive from R&D investments in science and engineering; gathering data to improve and expand science metrics, indicators of research investments and returns on such investments; production of usable knowledge from data to understand innovation and returns to investments in the US and overseas; and developing new kinds of data extraction

and virtual collaboratories bringing social and behavioral scientists together with scientists from specific domain to examine and understand what it means to make progress in that domain. This work needs international collaboration for the purposes of comparison.

This work requires developing new indicators, both redesigns and new surveys. For example,

Redesign of the Industrial R&D Survey

Costs associated with a firm's R&D – U.S. and abroad
R&D workforce in industry
Conduct of R&D by industry
Intellectual Property and licensing – innovation related data

S&E workforce – Postdocs

Need statistical information on all postdocs in all sectors
Address data void on foreign degreed postdocs

S&E Workforce – National Survey of College Graduates

Decennial census – long form eliminated: problems and opportunities
New approach to include S&E immigrants and will provide more timely, comprehensive, & current data

These new indicators are critical to meet the challenge to develop a new social science of science policy, for a better understanding of the competitiveness element of the American Competitiveness Initiative, to fulfill NSF's legislative mandate to be a clearinghouse on the S&E enterprise, to improve the biennial Science & Engineering Indicators, and for the development of the SciSIP program. Improved workforce indicators are also critical for NSF's Congressional mandate to report on women, minorities, and persons with disabilities in science and for the agency's efforts to broaden participation in the S&E workforce.

This is an area ripe for international collaboration. Every government that runs any kind of science program is interested in this kind of work. Also different countries have different models of science funding and there is much to be learned from international comparative work.

Complex Systems

Complex systems have many interacting elements (neurons, individuals, societies), often with stochastic and intricate interactions. Behavior of the systems cannot be understood by examining the individual constituents only. They have "emergent" properties: complex, system-level behavior emerges from simple rules governing interacting elements. Systems require analysis from many viewpoints and at many levels and that kind of work is facilitated now by new computational capacities. A vehicle for supporting this kind of work at NSF is the new Cyber-Enabled Discovery & Innovation (CDI) initiative (http://www.nsf.gov/crssprgm/cdi). One theme of the CDI solicitation is Understanding Complexity in Natural, Built and Social Systems. CDI supports multidisciplinary, transformative research and not business as usual and seeks to promote innovation in, or innovative use of, computational thinking. It is a substantial five-year initiative with $52M in FY08, projected to rise to $250M in FY12.

A particular focus of work on complexity is on how complex systems change, sometimes dramatically,

comprehensively and quickly; such "catastrophic" changes constitute the "tipping points" of Malcolm Gladwell and others and such phenomena pervade the human sciences in the emergence of new properties at individual, group or system levels; examples are the collapse of economic markets, stampeding behavior on crowds, and catastrophic language change in developing children and across generations. Dynamic interrelationships between social, behavioral, biological and physical factors often lead to or reflect dramatic change in the environment. Complex networks of interrelationships across multiple scales raise intriguing questions in their dynamic properties and that has been a focus of our Human Social Dynamics (HSD) initiative, which we will now be embedding in our core programs.

Cyberinfrastructure

All of the initiatives I have discussed have cyberinfrastructure at their core and that has been a major focus at NSF over the last few years, with the establishment of the Office of Cyberinfrastructure within the Office of the Director three years ago. New cyberinfrastructure has brought progress within the human sciences as in the other sciences and engineering. But the human sciences are also concerned with cyberinfrastructure as an object of study. Social and behavioral scientists are interested in human behavior, including human behavior within the context of science.

One feature of this general interest is a concern for virtual organizations, how they work and how they might work better. Virtual organizations, drawing scientists together outside the bounds of geography, constitute a major tool for new international collaborations and we need to understand their possibilities as well as possible. A new solicitation invites work on this topic, dealing with social and technical issues. Virtual Organizations as Sociotechnical Systems (VOSS) supports scientific research directed at advancing the understanding of what constitutes effective virtual organizations and under what conditions virtual organizations can enable and enhance scientific, engineering, and education production and innovation.

VOSS funded research must be grounded in theory and rooted in empirical methods. It must produce broadly applicable and transferable results.

Basic science and parallel funding

It is worth pointing out that NSF is a basic science agency. We support work on basic science and generally not on policy. We are acutely aware of the needs of policy makers and seek to support science of interest to policy makers. The emphasis on basic science makes NSF different from some funding agencies for the social sciences in other countries where policy concerns have more direct consequences for the scientific agenda. International collaborators need to bear in mind NSF's goals in supporting the Social, Behavioral & Economic Sciences:

1. Increase fundamental understanding of human behavior and society by supporting basic research, infrastructure, and education in the SBE sciences.
2. Provide societal relevance by providing information on

critical national problems such as terrorism, business failures, global workforce, America's educational system, and the implication of large-scale trans-formational changes for ethnic and cultural diversity and equality.

Within those limits, we are always open for international collaboration on the basis of what our Director sometimes calls the "byob principle:" bring your own budget! This means parallel review and parallel funding:

The U.S. collaborator submits a description of the work and a budget for the U.S. activities to the NSF, while

The partner submits a parallel or even identical proposal to his/her funding agency along with a budget for the collaborative activities.

The NSF proposal undergoes the usual review process as does the non-NSF proposal.

Our experience is that joint proposals of this type review well, because each funder is getting more net research for their partial support of the overall project. A notice of this approach to joint funding is on the SBE website.

The Directorate is interested in supporting not only work that falls within the standard disciplines but also interdisciplinary work. We have disciplinary programs:

- Linguistics
- Physical Anthropology
- Cultural Anthropology
- Archaeology
- Social Psychology
- Economics
- Sociology
- Political Science
- And interdisciplinary programs:
- Cognitive Neuroscience
- Developmental & Learning Sciences
- Documenting Endangered Languages
- Perception, Action & Cognition
- HOMINID
- Geography & Regional Science
- Environmental, Social & Behavioral Science
- Decision, Risk & Management Sciences
- Science of Science & Innovation Policy
- Innovation & Organizational Sciences
- Methodology, Measurement & Statistics
- Science & Society
- Law & Social Sciences

Interdisciplinary programs reflect mature interdisciplinarity, where there is a community of reviewers and panel members. But we also do a lot of co-funding on an ad hoc basis, where a proposal submitted to one program may be of interest to other programs within the Directorate and in other directorates or even other agencies. This is worth bearing in mind particularly for topics that are themselves inherently of international interest, such as Migration, Comparative Science Policy, and the Science of Poverty Alleviation.

Infrastructure

When social and behavioral scientists think about international collaboration, there are aspects that are different from the other sciences and I

believe that we need to be thinking more, much more, about an international infrastructure. There are no Japanese or Italian data in physics or chemistry. Cannonballs fall from the Tower of Pisa as they fall from similar towers in Japan. But social and behavioral scientists are interested in the different social and political contexts of different countries and need data on education, health, security, etc in different countries. In our fields there are Japanese and Italian data that are different. Comparative work requires comparable data from different countries so that we are comparing apples with apples and not with oranges. This is of central concern to our sciences and much, much more needs to be done.

Our Human & Social Dynamics initiative has developed interesting international infrastructure that can be a model for other enterprises. The Integrated Public Use Microdata Series (IPUMS) has been developed by Principal Investigator Steven Ruggles of the University of Minnesota. The goal is to preserve and harmonize census microdata from around the world and make them freely accessible to researchers.

In much of the world, census microdata are either unavailable or difficult to obtain. In the few countries where census microdata are readily available to researchers, they have become an indispensable part of social science infrastructure. In the journal Demography, the leading U.S. journal of population, census microdata are used three times as often as any other source for studies of the U.S. or Canada. No alternate source offers comparable sample sizes, chronological depth, or widespread availability across countries.

We began funding IPUMS in 1994 and the scope has extended progressively.

1999-2004: International Integrated Microdata Access System (NSF Social Science Infrastructure Project), $3.5 million; 28 censuses from 7 countries

2004-2009: International Integrated Public Use Microdata Series (NSF HSD Project), $5 million; 128 censuses from 37 countries

1999-2009 Additional funding from 3 NIH grants to assist with Latin American and European components of the project

IPUMS-International is now the largest public-use population database in the world, with extensive microdata from 26 countries, 80 censuses and data on 202 million individuals. But this is just the beginning: there are now agreements for 200 censuses from 70 countries, over 3 billion person records, and negotiations are in progress for another 100 censuses.

The work of IPUMS represents a considerable technical achievement. Investigators have gathered data from the last 50 years, compiled without modern computers and facilities, and stored under conditions that sometimes leave much to be desired. These data have now been translated into English and stored in a form where they can be used by current machines and have the right interoperability properties to be usable in the foreseeable future. The data are already the subject matter of thousands of articles and books and this will explode as the scale of the data is

increased significantly over the next few years. The impact is transformational and affects many disciplines. The data are good for:

- The study of large-scale trans-formational changes such as economic development, urbanization, fertility transition, large-scale migration, population aging, mass education.
- Relationships of social and economic change to variations in climate, geography, and environment.
- Human consequences of social, economic, and demographic trans-formations in such diverse areas as family structure, economic inequality, cultural diversity, and assimilation.

Conclusion

I have looked at international collaboration in the human sciences, focusing on scientific opportunities, dealing with big scientific questions and large-scale projects, where international collaboration would be particularly beneficial to our sciences. I have not focused on mechanisms and procedures and they should follow scientific needs. We have done much collaborative work with the Deutsche Forschungsgemeinschaft (DFG), the UK Research Councils for the Arts and Humanities (AHRC) and the Economic and Social Sciences (ESRC), the Agence Nationale de Recherches (ANR) in Paris, the National Natural Science Foundation of China (NNSF-C), and others. We have participated in several EUROCORES programs over the last few years. Let me be clear that NSF is interested quite generally in cultivating international collaboration at the level of principal investigators from different countries who want to undertake common research and at a broader institutional level where agencies from different countries can develop the international infrastructure that is so needed by our sciences.

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International Research Collaboration: Just Nice to Have or Necessary?

Marion Müller
Director, North America Office, German Research Foundation (Deutsche Forschungsgemeinschaft, DFG)

Internationalization certainly is one of the most used buzz words of our time. Almost everything can and does get internationalized these days from marketing methods over Iphones, to efforts against combating kleptocracy. Internationalization has been the subject of much discourse and has profound effects on today's political, economic and cultural life. This wide-ranging process also has a major impact on colleges, universities, national laboratories and funding agencies; internationalization has become a challenge for higher education experts and science managers. And yet if we are to believe Goethe, who wrote "Science and the arts belong to the whole world. The barriers of nationality vanish before them", then science is per se international and international research collaborations are not just nice or necessary but intrinsically natural.

In fact, the internationalization of science is often taken for granted. The laws of nature transcend political, national and linguistic boundaries, and the international flow of knowledge rendered science global long before the world was declared flat and "globalization" became a fashionable commonplace for the growing interconnectedness of markets and the pervasiveness of new information technologies. Indeed, the virtual form of internationalization through the worldwide web assumes a natural and integral part of today's scientific processes and exchanges.

Nonetheless, an analysis of recent developments shows that the topic of internationalization of higher education and research ranks high on the agenda of policymakers, higher education management and faculty. The German government not long ago published an internationalization strategy[1] and the US National Science Board recently released a study on *International Science and Engineering Partnerships: A Priority for US Foreign Policy and Our Nation's Innovation Enterprise*.[2] At the same time, German and American universities and funding organizations are also developing or re-thinking their international activities and strategies. Internationality is, it seems, on the one hand a matter of fact characteristic of science, and yet, on the other hand, a prerequisite for its success, which can be actively shaped and influenced and hence plays a vital role in the national styles of organizing and funding science. Science and research

are international in scope and activity but when it comes to science education, organization and funding national social, cultural and political values and strategies enter into the picture and determine and shape international collaborations.

This paper aims to give some attention to an activity which is often assumed to be self-sufficient, and at the same time attempts to examine the role of international research collaborations with a special focus on research links between Germany and the United States. It claims that while international research collaborations are at the heart and core of any successful national internationalization strategy and are vital to give science the competitive edge which it needs to progress, they are not yet used to their full potential. It argues that in order to bring transatlantic research collaborations from an ad-hoc, random and self-sustaining mode to a new, more systemic dimension, it requires an understanding of the specifics of the two research (funding) systems, a seizing of opportunities as well as strategic thought. Transformation and new impulses are needed to optimize transatlantic research networks.

The paper has three parts. By way of introduction it presents a few facts and figures about the Deutsche Forschungsgemeinschaft (German Research Foundation, DFG) that are essential to understanding its international activities. In a second step, it looks at the aforementioned opportunities by discussing the need for internationalization in general, and by taking a comparative view on "internationalization made in Germany" and "internationalization made in the US"; thirdly it examines the role of a national funding agency in enhancing international research collaboration.

The DFG is the central research funding organization that promotes research at universities and other publicly financed research institutions in Germany. Its current budget is approximately 2 billion Euros, roughly 58 percent of which comes from the federal government and round about 42 percent from the state authorities.

It is very important to note that the DFG is not a government agency – it is a self-governing association under private law. DFG membership is made up of German universities, non-university research institutions, scientific associations as well as the Academies of Science and Humanities. The members also elect the DFG president.

Unlike partner organizations in the UK, the US or Canada, the DFG serves all branches of science and the humanities. Its activities focus on funding research projects carried out by scientists and academics working at universities or research institutes and on selecting the best projects in a process of fair and transparent competition.

The DFG has a special focus on the advancement and education of young scientists and academics and encourages their early independence. The DFG advises parliaments and public authorities on questions relating to science and research; it fosters links between science and industry, and last but not least and of particular

importance for this paper, promotes international research collaboration.

The DFG sets strategic foci in selected countries by maintaining representations there. The foremost goals of the Sino-German Center for Research Promotion in Beijing and of the liaison offices in Washington, New York, Moscow and New Delhi (and as of 2009 Tokyo) relate to the promotion of collaboration between scientists and academics and cooperation with the respective national research funding organizations.

Our North America offices in Washington, DC and New York aim:

- to maintain and extend contacts with current and former DFG award holders and alumni in the United States and Canada,
- to inform US and Canadian universities and research institutions about Germany as a location of science and research and about opportunities for research collaboration,
- to support and expand cooperation with partner organizations in the USA and Canada in order to create or improve framework conditions that allow for international research collaboration,
- to follow and assess science and research policy developments in the United States and Canada in fields relevant to the DFG with respect to basic research.

Almost all of the DFG's funding schemes offer international components. In general, it is possible to apply for the funds needed for cooperation in addition to project funding itself.

Let us return to the initial question, whether international research collaboration is a luxury or a necessity. Vijayalakshmi Pandit, the first woman to be elected President of the UN General Assembly, claimed that the creation and advancement of knowledge has to be a collaborative international activity. "No nation," she said, "has a monopoly of knowledge, it has become the common heritage of civilized man, but its fruits are available to us only through cooperation." And Norman Augustine in his recent essay titled "Is America Falling off the Flat Earth" comes to a similar and even more poignant conclusion: sustainable competitiveness requires proactive engagement with what is going on around us. Contextualizing the US economic competitiveness he states: "Leadership is not an American birthright. … Simply being an American does not guarantee a high-wage job anymore".[3] And I would claim the same holds true for the American science and research sector and, of course, equally applies to Germany and many other nations as well.

Several factors drive the growing need for the internationalization of science:

- the globalization of the world economy,
- increasingly international communication networks, career opportunities and choices, and interpersonal interactions and collaborations,
- a growing need for international recruitment of students, faculty, skilled workforce,
- the speed of knowledge creation,

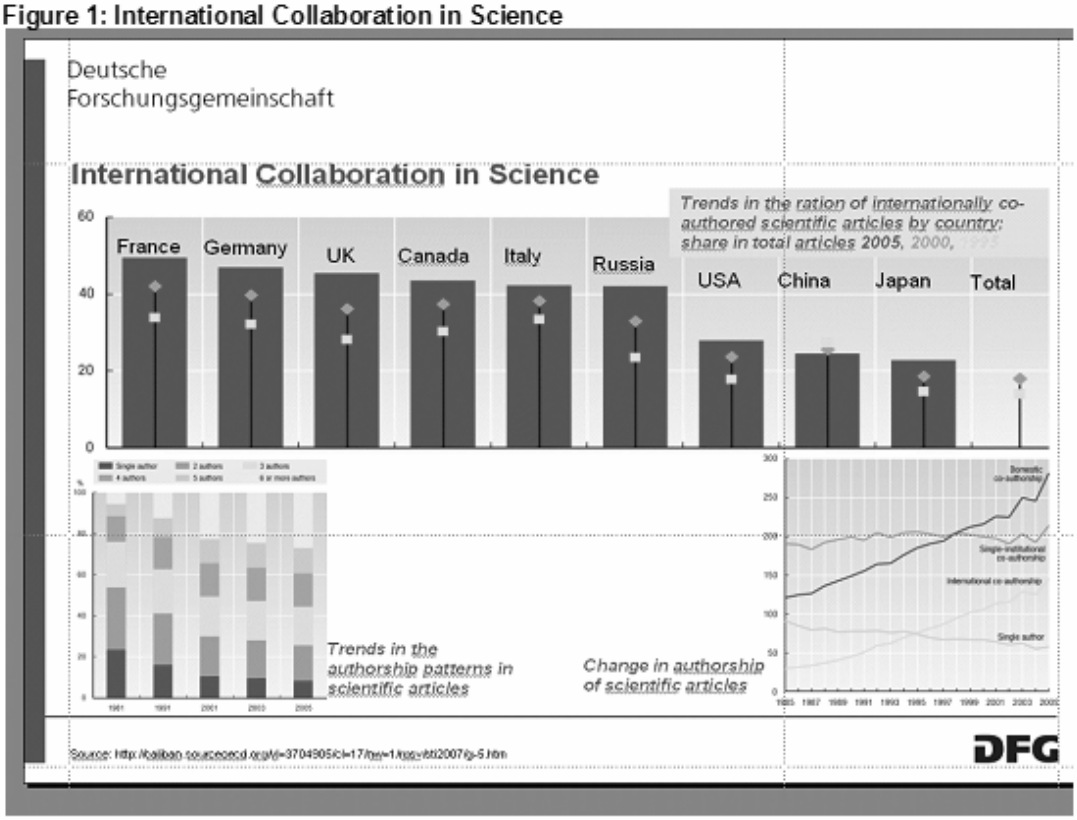
- the complexity of research questions,
- challenges that know no borders: SARS, AIDS, forest fires, energy issues, pollution, global warming, species extinction, terrorism, health care, and hunger need partnerships and collaborative efforts.

Answers to these and other global research questions will most likely be found in international science networks rather than in national science contexts. To mention just a few examples, think of the human genome project or the particle physics research at CERN.

Science can best advance when it draws on and utilizes all the best sources of knowledge, the best brains and the best infrastructure, wherever they may be located. An examination of the OECD statistics for international collaboration as manifested in co-authorship shows that the volume of international co-authorship has increased considerably over the years (Figure 1).

A report by Jonathan Adams et al.[4] published in 2007 likewise shows that the volume of international collaboration has gone up significantly between 1996-2000 and 2001-2005. This trend can be noticed across all countries and across all the main disciplines. Adams et al. demonstrate that for the US collaboration as a proportion of output increased by 5.3 percent, in absolute terms approximately 89,800 papers. The corresponding figures for Germany

Figure 1: International Collaboration in Science



Source: Analysis was conducted based on Science Citation Index on CD-ROM [1985-2005]; provided by Thomson Scientific; analyzed by National Institution of Science and Technology Policy in Japan.
http://caliban.sourceoecd.org/vl=3704905/cl=17/nw=1/rpsv/sti2007/g-5.htm

demonstrate an increase in collaboration by about 40,000 papers or 8.6 percent.[5] Moreover, Adams' data and tables show that Germany, the UK and the US dominate world research links as the largest and highest quality research economies. 30 percent of Germany's collaboration is with the US but only 13.1 percent of US collaboration is with Germany.[6]

The international pooling of talents, ideas and techniques in pursuit of solving global research problems yields extra value that would not have been achieved otherwise. Looking at the citation performance of papers in *Nature* between 1994 and 2003, Gareth Roberts showed that co-authored papers were cited two or three times more frequently than the average nationally authored papers in the same journal.[7]

From the drivers of internationalization of science outlined above and the international co-publications we can see that communication and collaboration among scientists promote scientific progress. No one national group has a monopoly on good ideas. International collaboration and interaction is hence necessary and beneficial. And yet, it can be argued, that international collaboration is not used strategically and systematically enough to truly internationalize institutions of higher education and laboratories. Neither universities nor funding agencies in Germany and the US have fully embraced international collaboration as the key concept to research excellence, which in turn empowers a country's innovative capacity and safeguards its economic competitiveness.

It should be a strategic goal to build on, foster and enhance existing research networks and to endeavor to develop and sharpen new transatlantic collaborations. Increased interaction is mutually beneficial to US and German science and research. While the internet revolution and the aforementioned modern communication facilities have greatly reduced hurdles of geographical distance, the stumbling blocks still to be overcome are pride, prejudices, misconceptions and clichés that undoubtedly exist about each other's science and research systems.

Internationality needs people who collaborate, programs that encourage them to do so and institutional policies and framework conditions that make collaboration work. However, notions and mechanisms of internationalization function quite differently in Germany and the US. Core elements of internationalization policies are still curiously national.

Knowledge is mostly transferred through people. But what exactly do we mean when we talk of internationality with regard to people? The concepts differ greatly on both sides of the Atlantic. Internationality in science needs both mobile people and open doors. And it is in the areas of mobility and open doors that a fundamental difference between "internationalization made in Germany" and "internationalization made in the United States" manifests itself.

In the case of Germany, one can speak of a "push" or export/ re-import-based internationalization strategy. Germany "pushes" students and young scientists to spend an extensive time

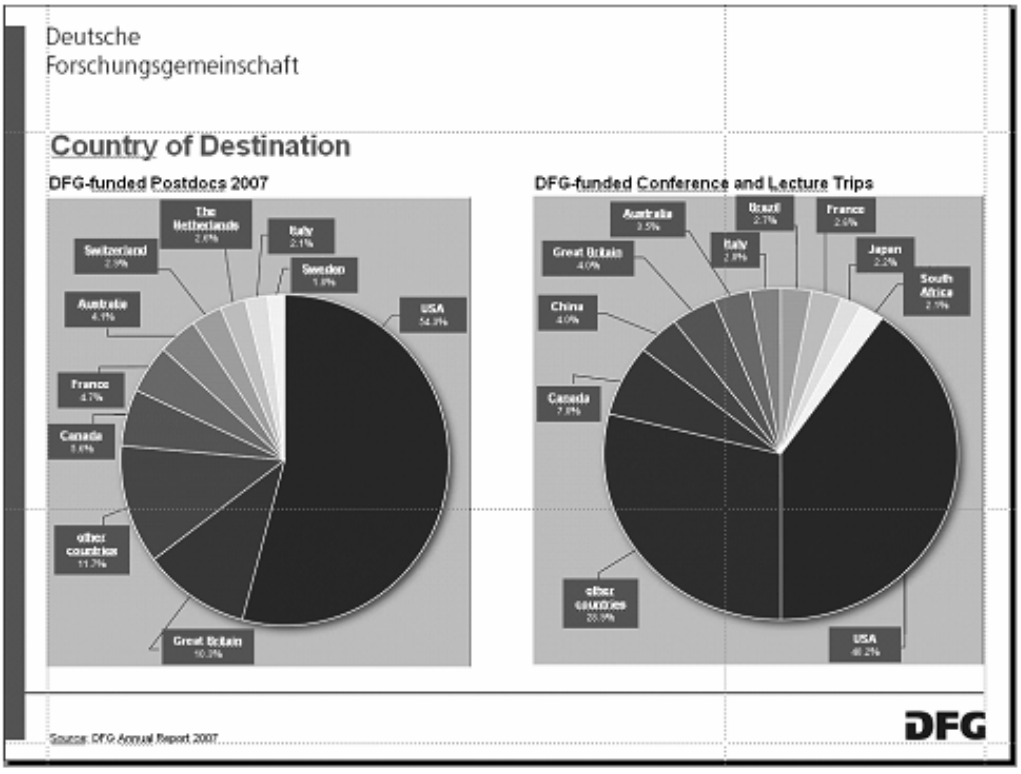
period of their academic career outside of Germany, it encourages them to become immersed in laboratories, universities and research institutions abroad, and also offers various sources to fund these times abroad.

With regard to the openness of the national higher education and research system, Germany's universities have come a long way. Germany now ranks third among host countries for international students. However, more endeavors are needed to increase the proportion of international graduates and postdocs.

German students are on average more mobile than many of their international peers. The target for the years to come is to raise the number of students with significant international academic experience from one in three to two in three. Internationality thus requires mobility. The rationale behind it is that international modules within academic vitae are on the one hand regarded as essential for the successful career of the individual researchers, and that on the other hand internationally trained or experienced young scientists also enrich the national system and their immediate work environment when they return home. Moreover, many German researchers continue the US research links and contacts they established during their postdoc time, which often lead to an exchange of students or visiting professorships.

The DFG statistics clearly show the direction of this mobility: the US is the leading destination of choice for DFG-funded postdocs as well as for conference and lecture trips (Figure 2).

Figure 2: Country of Destination



Source: DFG Annual Report 2007

There are currently about 350 DFG-funded postdocs in the US. The most popular host institutions include the country's top research schools, Yale, Princeton, Rockefeller University, the National Institutes of Health, Johns Hopkins University, and MIT to name but a few.

To sum up: mobility is a chorus for German policymakers, faculty and postdocs. A postdoc period abroad constitutes an essential building block in the careers of young researchers, tests and sharpens their skills, helps to build a sustainable network of colleagues and friends, deepens their understanding of the science system of the host country and is generally considered advantageous for their academic CV.

Americans, on the other hand, seem to fear that going abroad means at worst going into a "scientific" desert or at best taking a little detour in one's career. Postdoctoral studies abroad are often considered as removing talented young scientists from the scientific mainstream and making it harder for them to compete on a difficult US job market after returning. Faculty members, academic advisers and graduate students across all disciplines seem to share the perception that tenure-track ambitions are incompatible with doing a foreign postdoc. And yet, despite this obvious reluctance to embrace an extensive research stay abroad as a worthwhile or even beneficial undertaking, the American research scene can rightly be classified as very international.

In the case of the US, one could speak of a "pull" or "import" internationalization strategy. Internationalization happens mainly and automatically within its borders, internationalization happens through opening doors.

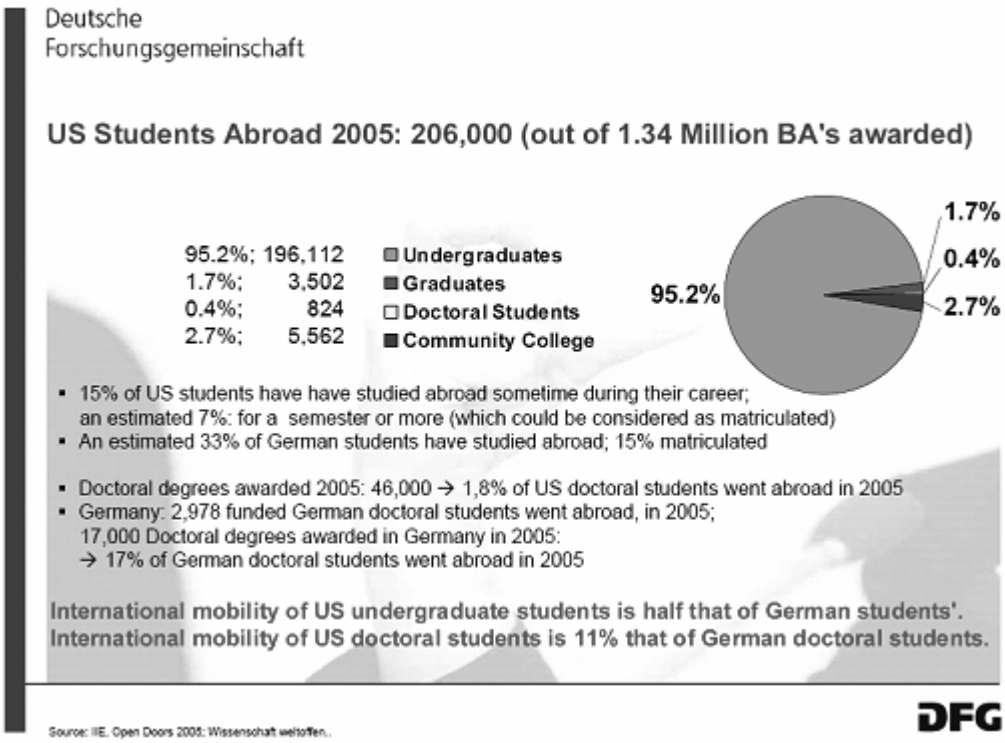
Figures show that the United States pull foreign talent to their labs, universities and research institutions and offer incentives to attract the best minds. It is the presence of these students that makes the campuses international. If one looks at the internationalization strategies of US institutions of higher education, one of the prime targets is to further internationalize their student body. It is an internationalization of the domestic research environment through the import of foreign talent. International students constitute an important element for doctoral studies in the United States. Almost half of all international students are studying at the graduate level, with a majority in doctoral programs. International students account for 13 percent of all graduate students, significantly higher than the approximately 3.5 percent of all undergraduate students that are international students. There has been a significant rise of foreign-born doctoral/post-doctoral scientists in the US. With a growth rate of 10.9 percent in the period 2002-2006 the increase in S&E doctorates awarded to non US-citizens was almost three times as high than that to US citizens (3.7 percent).[8] In the social/behavioral sciences, the physical sciences, and engineering, the representation of foreign PhD recipients is particularly striking; among doctorate recipients in 2005, those from outside the US accounted for approx. 20 percent in social/ behavioral sciences, 38 percent of degrees in the physical sciences and almost 67 percent in engineering.[9]

Although the vast majority of US students still graduate without any study abroad experience, it is true that there is an increasing tendency on the part of American universities to nudge their students towards international experience; but often this is being done in the form of study abroad programs based on exported US courses taught from American textbooks and by American staff and awarding American credit points. Some American universities establish campuses abroad where mostly undergraduates enjoy American education in a European setting. Some even say that an American student's time abroad is more of a chaperoned field trip than an immersion into a foreign academic culture.

The statistics published by Open Doors[10] show that out of approximately 206,000 young US academics going abroad only about 0.4 percent are at the doctoral level and only 0.2 percent spend a full calendar year abroad (Figure 3).

Among the most cited reasons and most prominent goals to be pursued through an international experience are language study, cultural learning or public diplomacy. It is very seldom that university programs or political rhetoric highlight an excellent research environment abroad as a reason to seek international research experience. On the whole, the international mobility of US undergraduate and graduate students is half of that of their German peers. A glance at the countries that graduates, postdocs and established researchers prefer going to shows that for German scientists the US is the most common

Figure 3



destination for research experience whereas Germany ranks between second and fourth among the destination of choice for American scientists and researchers.

A recent analysis from the Center for International Initiatives at the American Council on Education (ACE) states that internationalization is not a high priority on most US college campuses. The survey found that "many institutions do not see internationalization as integral to their identity or strategy. Less than 40 percent of institutions made specific reference to international or global education in their mission statements. The percentage of colleges and universities that require a course with an international or global focus as part of the general education curriculum dipped from 41 percent in 2001 to 37 percent in 2006. Fewer than one in five had a foreign-language requirement for all undergraduates. The majority of institutions do not have a full-time person to oversee or coordinate internationalization. Although the proportion of institutions offering education abroad opportunities has grown sharply to 91 percent in 2006 compared with 65 percent in 2001 student participation has remained low. 27 percent of institutions reported that no students graduating in 2005 studied abroad."[11] "Overall, internationalization doesn't permeate the fabric of most institutions," said Madeleine F. Green, vice president of ACE's Center for International Initiatives and co-author of the survey. "It is not sufficiently deep, nor as widespread as it should be to prepare students to meet the challenges they will face once they graduate."[12]

And this, it can be argued, is partly the case because going abroad is not deeply enough entrenched in science proper.

As generalizing as the short analysis of "internationalization made in Germany" and "internationalization made in the US" may sound, it yields lessons to be learned on both sides.

Germany can no longer afford to simply market on demand, but most choose a more systematic approach. It needs to understand how important it is to step up to the plate and show its wares, which is to say to market its strong science reputation and raise awareness within the United States of the strength of German research.

In the face of the gathering storm and a weakening economy, the US on the other hand might also have to refocus and see internationalization more from an active outward-looking perspective.

The following section proposes to examine the role that a national funding agency plays in facilitating international research collaboration by looking at what the DFG does.

The support for international collaboration is an integral part of the DFG's mission. The DFG promotes international project collaboration, international mobility of scientists and researchers and the internationalization of German universities by internationalizing research activities, showing presence in foreign countries, and by cooperating with European as well as international partners. The DFG is also represented as an institution in various scientific and science policy organizations and bodies at an

international and a European level. However, research collaboration functions primarily through people in a bottom-up mode, not through institutions. The promotion of international research collaboration is not and can never be an end in itself, but is meant to create added value for science and research in Germany.

The DFG's concept of added value can be described as encompassing several aspects:

- Collaboration and strategic alliances with the best in the world: International research collaboration enables researchers to participate in networks of cutting-edge and innovative activity. For scientists and researchers, collaboration provides opportunities to move further and faster by working with other leading people in their field. It is, therefore, unsurprising and we have seen it when looking at internationally co-authored publications that collaborative research is also identified as contributing to some of the highest impact activity.
- Quality assurance and enhancement through competition: Excellent research needs self-critical competition in order to safeguard continuous quality assurance and enhancement. Given the global dimension of research questions the respective national funding systems cannot be the sole frame of reference for this. Germany's top scientists and researchers have to match with the best in the world.
- Promotion of young scientists and researchers: The innovative and self-renewing forces of a science system depend upon the continuous supply of excellent, well trained and highly-motivated young people. It is crucial that young German scientists acquire substantial research experience abroad and that the German science system be enriched through young international scientists and researchers.
- Access to infrastructure, people, research facilities and other resources: In addition to human resources, German science needs access to international large scale facilities and infrastructure (libraries; research "objects" like tropical forests, oceans, plateaus, accelerators).
- Increasing awareness of the strength of the national system: International collaboration affords the opportunity to market and promote the strengths of the national system abroad.
- Global responsibility: As one of the leading, politically independent research funding agencies, the DFG has the responsibility to engage itself internationally in causes that further the welfare of mankind and nature.
- Exchange of experience: Funding agencies need the continuous and open exposure to international reference systems in order to constantly improve and enhance their own program portfolio. A number of challenges that funding agencies face are not national but can be found in the international arena: difficulties in the supply of scientists and engineers, questions of how to

handle interdisciplinary projects, how to organize international peer review, and standards of good scientific practice. These are issues that concern funding agencies around the globe.

The following section addresses two of the DFG's international activities, namely the internationalization of research activities and cooperation with international partner organizations.

The DFG has not only opened all its funding schemes to foreign nationals willing to do science in Germany, but it supports collaboration between German scientists and international partners in all of its funding programs and with a multitude of instruments. In general, it is possible to apply for the funds needed for cooperation, in addition to the project funding itself, regardless of the specific type of project funding involved.

Cooperative projects with foreign partners are generally supported on the principle of reciprocal responsibility or matching funds mechanism: The researchers working in Germany interact with the DFG, while their collaborative partners working abroad liaise with the funding bodies in their own country.

Between 2004 and 2006 11.8 percent of foreign collaboration partners that German academics, funded in the DFG's Individual Grants Program, worked with were from the US. Within the DFG's Collaborative Research Center Program, international collaboration can take two different forms: either as a center (German national) to center (US national) collaboration, or through the integration of an international project into a "German national" Collaborative Research Center. 35 Collaborative Research Centers and seven Transregional Research Centers reported official international collaboration in the form of individual projects; of these 14 and 2 were respectively with US partners.

While many links revolve around leading researchers, it is essential that the young generation of up-and-coming researchers becomes more involved in collaborative networks and international activities. The DFG's Research Training Groups[13] combine innovative top-level research and structured promotion of excellent young researchers in an international setting. They center on the qualification of doctoral researchers within the framework of a focused research program and a structured training concept that prepares doctoral researchers for the complexities of the job market that face scientists and academics. A key objective of Research Training Groups is to enable the speedy research-related qualification of doctoral researchers. As they focus on their respective core research topics, doctoral researchers also gain an overview that goes beyond their specialties by working within the larger context of a Research Training Group. Doctoral researchers are enabled and expected to conduct independent research early on. Research Training Groups aim to accelerate doctoral training and lower the age at which scientists and academics finish their doctorate. In this way, the participation of young researchers in Research Training Groups helps qualify them to compete in the international job market. An indicator of the attractiveness of this kind of PhD program is the proportion of

international participants, 30 percent international PhD students and 40 percent international postdocs.

A special variant of the program are the International Research Training Groups, in which German universities cooperate with research institutions in other countries to offer structured doctoral programs. Their purpose is to encourage and deepen bilateral cooperation in the training of young academics between German universities and universities or research institutions in other countries. They promote systematic research cooperation through joint research and qualification programs, cooperative, cross-border supervision of doctoral researchers of both partner groups, and long-term research stays for doctoral researchers at the respective partner institutions.

The DFG currently has 55 of these International Research Training Groups with a wide array of European and non-European countries. Seven research training groups have US-American counterparts. One such example is the Center for Metropolitan Studies, a joint venture between Berlin's three universities on the German side and Columbia, NYU and Fordham University on the American side. PhD students and post-doctoral students from across nine disciplines and six countries work together to research the problems of the modern metropolis. As part of the program, the Berlin-based students spend at least three months studying in New York during their studies, and PhD students from Columbia and NYU come to work in Berlin. In addition, they profit greatly from having co-advisors for their theses from co-taught courses as well as from a rich program of guest lectures, workshops and colloquia.

Intensive large scale and medium-term collaborations like these do not fall from the sky but need careful preparation and long-term planning.

Hence, in addition to providing general research funding for specific international projects, the DFG also provides funding for preparatory measures that facilitate personal contact. Preparatory trips or collaboration visits to the partner's institute or department can be supported through the DFG's international cooperation funds, as long as the visit is not in connection with general cooperation between the institutes involved, but is associated with a specifically planned cooperation project or a specific joint research project.

Likewise, funding for bilateral events is provided to facilitate cooperation between scientists and academics with the aim of developing scientific contacts. As of next year, all these instruments will be merged into one and can be applied for in a “pick and choose” combination style as needed to initiate an international collaborative project.

Another program, which serves as a nucleus for the development of sustainable research collaborations, is the DFG's Mercator Visiting Professorship Program.[14] It enables Germany's research universities to invite highly qualified scientists and academics working abroad to complete a DFG-funded stay at their institutes. The visit should focus on joint cooperative projects by the guest and host. By assuming teaching duties, visiting

professors contribute to providing a clear international dimension to the research-oriented training of young researchers in the host departments.

To ensure that the special knowledge and skills of international researchers participating in this program of excellence become accessible to a wider audience in Germany, the DFG provides travel allowances for the visiting professor to visit other interested research institutes in Germany. The application process is very simple for the visiting professor. In fact, it is the German host who submits the application. He or she suggests to his or her university to invite the respective researcher as a Mercator Visiting Professor. The university then submits an application to the DFG to obtain funding for the professorship as well as for travels within Germany. If approved, the German university can invite the researcher and a fruitful transatlantic collaboration may begin.

Many letters, which the DFG has recently obtained from US-Mercator-alumni, bespeak the value of the program not only for the individual researcher but also for the young academics they work with, their field of science and last but not least for society as a whole. In addition to the personal enrichment, lasting memories, friendships and contacts the US scientists experienced in Germany, they name as additional positive results of their research stay: co-authored publications, the development of groundbreaking knowledge, sustainable collaborations as well lively students, doctoral students and professorial exchanges, joint lecture series and media attention.

Let us now discuss the relevance that links between funding agencies have for international research collaboration. Clearly, effective cooperation among funding agencies will stimulate research contacts. One of the largest obstacles in international research collaboration is so called double jeopardy, the dependence on separate funding decisions by each of the funding agencies in the USA and Germany. Double jeopardy deters principle investigators from research collaborations that begin with a joint planning phase continue with writing one joint proposal and flow into jointly working on the common project. As long as international research collaboration is exposed to double jeopardy, one cannot blame researchers if they opt out for the safe way; namely to design a research project where the international collaborative component is nice to have but not necessary and comes into the picture only once national funding has been secured at both national fronts.

The DFG values the benefits of partnerships with its US counterparts and views them as an essential vehicle to create framework conditions that are attractive for research collaboration from scratch. Building on already existing bonds, the DFG seeks to strengthen its ties with its American partners – NSF, NIH, NEH, DoE, to name but a few – in order to stimulate and enhance transatlantic research contacts.

Unlike on the European stage, where scientific collaborations across national boundaries are made relatively easy through a number of programs and funding schemes, German-US

partnerships in research funding are on the whole less institutionalized and managed more on an ad hoc basis. On the European level, the "Money follows researcher" scheme allows PIs to transfer their grants to another country when they start a new position there. And most recently, the DFG, the Austrian Science Fund (FWF) and the Swiss National Science Foundation (SNF). have introduced the so-called "lead agency principle" which will make transnational collaboration considerably easier. In the case of transnational projects, the three countries accept the peer review decisions reached by the "lead agency", which is the agency which handles the major part of the projects.

Although German - US science funding cooperation is less institutionalized, there are, of course, effective inter-agency agreements in place designed to promote research collaboration. For example, the NSF and the DFG have cooperative activities in chemistry. Under the joint chemistry solicitation, applicants can submit one proposal which is evaluated jointly by a set of reviewers who then reach a joint funding decision. Preference is given to proposals where the involvement on the US and German sides is balanced and complementary. The use of cyberinfrastructure to facilitate data sharing and communication, as well as the exchange of students and junior investigators are strongly encouraged. There is also close collaboration in the field of material sciences and last but not least, the annual DFG-NSF Research Conferences, which identify new directions in a specific field of science and technology, bring together scientists from both countries and foster future scientific collaborations between them. These jointly planned and organized conferences support interaction between groups already communicating on an informal basis and help initiate new collaborations between scientists currently working independently. The long-term goal is to help scientists establish strong collaborative ties that will, on a more formal basis, bring "value-added" content to proposals submitted to both the DFG and the NSF in their existing programs. Ties will begin to be formed by the conference participants but then, hopefully, spread to the German and American scientific community in general.

Increasing international collaboration will also make peer review more international. The following figures offer a picture of the composition of the international reviewers the DFG consulted between 2005 and 2007: The proportion of scientists and academics working abroad and who participated in the written review process during the study period was 17.7 percent (or 4,930 scientists and researchers). This is a significant increase in comparison to previous report periods, 8 percent from 1999 to 2001 and 13 percent from 2002 to 2004.

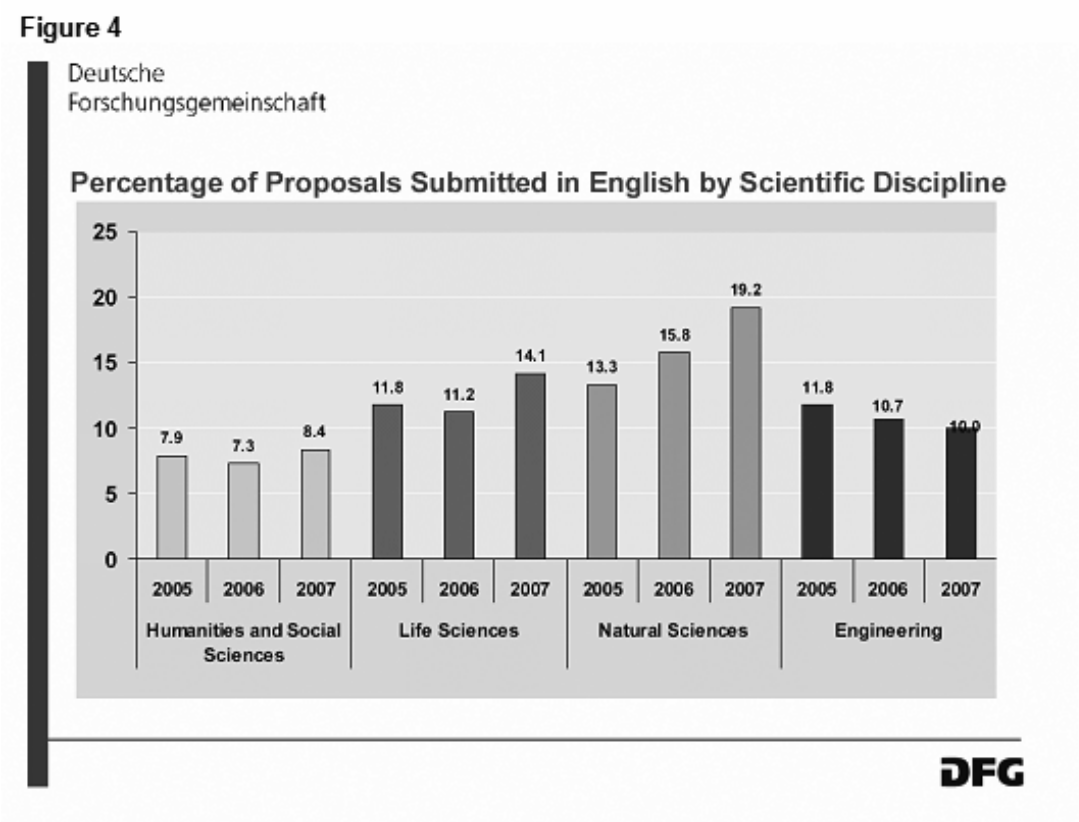
From 2005 to 2007, the overall participation of peers from North America in the DFG peer review process across all disciplines amounts to 3.4 percent. 19 percent of all international reviews come from North America. This, of course, requires that applications be submitted in the lingua franca of science, English.

Figure 4 shows the percentage of proposals submitted to the DFG in English.

In the German federal government's recent Excellence Initiative, a nationwide competition for extra research money, the percentage of international reviewers was over 80 percent. American researchers participating in the Excellence Initiative's peer review process have become multipliers for the exciting things happening at German universities. American universities have expressed a keen interest in collaborating with the universities that were successful in obtaining funding and have thus become internationally visible landmarks of scientific excellence. While the Excellence Initiative no doubt actually initiates competition by attracting the best brains and creating the best possible research environment, at the same time, it opens up new opportunities for international research cooperation, for the training of doctoral students, for common use of large scale equipment, for exploratory workshops as well as for the development of grass root international projects.

In conclusion, let us return one more time to the opening question. International research collaborations are nice to have, of course, but more than that they are increasingly and vitally necessary to tackle important challenges and to keep science successful and competitive. However, in order to render them as natural as they used to be, e.g. in the early modern period, the different stakeholders, not least the funding agencies, university managers and policymakers, must create a habitat

Figure 4



where international collaboration can truly thrive and bear fruit.

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14. http://www.dfg.de/en/research_funding/scientific_contacts/mercator/index.html

Lessons Learned from International Research Partnerships

Prem S. Paul, Vice Chancellor for Research & Economic Development
Charles Wood, Director of the Nebraska Center for Virology
John Yohe, Director of the International Sorghum and Millet Program
University of Nebraska-Lincoln

International research partnerships have played a critical role in increasing food availability in many developing countries. Among the most successful examples of such partnerships is the Green Revolution, which had significant impact upon developing nations like Mexico and India. During the early 1940s, Mexico imported half of its wheat; India experienced widespread famine during 1963. But as a result of the Green Revolution, Mexico became self-sufficient in terms of crop production by 1956 and was exporting half a million tons of wheat by 1964. Similarly, India became self-sufficient with the assistance of the international research community and funding from the Rockefeller and Ford Foundations. Today, India annually exports 4.5 million tons of rice. Irrigation, fertilizer, and seed technologies were keys to these international successes.

The University of Nebraska-Lincoln (UNL) – like many of America's land grant institutions – has a long tradition of forming highly successful international partnerships to help train scientists and build in-country educational and research capacity. One example of UNL's successful partnerships led to the establishment of a new university in Turkey. Mustafa Kemal Ataturk, Turkey's founding father, had aspirations for the creation of a strong university to educate Turkish citizens; UNL helped start this new university during 1957. A large number of UNL faculty traveled to Turkey to help develop Ataturk's academic programs, train faculty, and educate students. Many Turkish faculty members came to Nebraska and received their training at UNL before joining Ataturk's faculty ranks. Today, Ataturk University is a thriving higher education institution with 17 faculties (colleges), 2,446 faculty staff, and 42,000 students. One of us (Prem Paul) represented UNL at Ataturk's 50th anniversary celebration during the summer of 2007. During this celebration, UNL and its faculty were hailed as key to the start and success of Ataturk University.

In this paper, we summarize two of UNL's current international programs: collaborative partnerships focused on infectious disease in Zambia and China and the INTSORMIL program in Africa. We highlight lessons learned from these two efforts to inform the creation and foster the success of other international partnerships.

Research Partnerships on HIV Research in Zambia

For more than a decade, UNL has enjoyed productive research and training collaborations with Zambian

partners. Charles Wood, director of the Nebraska Center for Virology, works with University of Zambia colleagues to conduct HIV/AIDS research. Dr. Wood has built strong ties with the University of Zambia's College of Medicine, the University Teaching Hospital (UTH), and the Zambian Ministry of Health. As a background, Zambia is one of the most urbanized countries in Africa, and it has one of the lowest population-to-land ratios on that continent. The country is approximately half the size of Europe and home to almost 11 million people. Lusaka, the capital of Zambia and home to the University of Zambia (UNZA), has an estimated population of more than 2 million individuals. Zambia has mining and agriculture as its major industries. The goal of the UNL-UNZA partnership is to build capacity to better confront infectious disease, especially HIV/AIDS and AIDS-associated diseases. Dr. Wood and his partners train in-country health care providers and researchers, enhance the Zambian research and training infrastructure, and develop additional collaborative research and educational projects.

Dr. Wood's collaborations with Zambia started 12 years ago when he was on faculty at the University of Miami and helped train the late Dr. Gonapati Bhat (1996) and Dr. Chipepo Kankasa (1997) through the NIH-supported Fogarty AIDS International Training and Research Program. When Dr. Bhat returned to Zambia, he became Head of Pediatrics at UTH and initiated a collaborative research project with Dr. Wood on Kaposi's sarcoma and human herpesvirus-8. The collaboration was successful and led to a number of subsequent collaborations. It provided funds for Dr. Kankasa (who had since returned to Zambia) to study perinatal transmission of HIV and a human herpesvirus known as HHV-8, which is linked to an AIDS associated cancer: Kaposi's sarcoma.

This collaboration has led to a number of research grants from NIH (e.g., the National Cancer Institute, the National Institute of Allergy and Infectious Diseases, the National Institute for Mental Health, and the Fogarty AIDS International Training and Research Program). UNL's grant is one of only 25 Fogarty International Training and Research Programs on HIV/AIDS in the U.S. A total of 33 individuals have been trained at UNL with this grant since its initiation during 2000 (two are currently in the program and 30 of them have returned to Zambia). The training program's ultimate aim is to help biomedical personnel in Zambia slow or halt HIV transmission and minimize the negative health effects of HIV/AIDS-related malignancies and diseases. To date, the program has focused on training personnel, developing healthcare capacity and infrastructure, and leveraging grant funds to build in-country training and treatment programs focused on HIV/AIDS and other associated diseases, including the monitoring of anti-retroviral treatment (ART) resistant viruses. Important collaborations with other HIV/AIDS programs have developed under the leadership of former Fogarty fellows (e.g., Drs. Bhat, Kankasa, and Tendai M'soka). Zambia's Ministry of Health is so pleased with the program's successes

that it uses the Nebraska Program as a model of U.S.-Zambian collaboration.

The infrastructure built through the Nebraska-based Fogarty training program has expanded from supporting training on opportunistic infections and cancer to the pressing need to monitor the development of HIV drug resistance upon the recent roll-out of large-scale ART programs. This expansion facilitated *and* resulted from successful integration with other in-country initiatives. For example, President Bush's Emergency Plan for AIDS Relief (PEPFAR) partnered with Dr. Kankasa and the UTH Department of Pediatrics to provide support for a Pediatric Center of Excellence (PCOE), which is dedicated to ART and follow-up care of HIV infected children.

The UTH infrastructure was built from scratch 12 years ago (before initiation of the Fogarty training program). At that time, there was no office space, telephone line, computer, internet access, laboratory, or dedicated study clinic. Now there is a centralized and dedicated training laboratory and clinic, satellite and FTP site linkages, and wireless internet, all supporting a number of projects and training efforts. A state-of-the-art 3,000 sq ft molecular virology laboratory was completed in 2005 in response to the need for laboratory support for projects and training efforts related to the scale-up of Zambia's ART program. The laboratory was made possible with support from the Nebraska Center for Virology and through different ongoing projects conducted by Drs. Kankasa and M'soka.

Current Collaborative Research in China

UNL has a number of collaborations with various Chinese research and education institutions, including Xian Jiaotong University in Shanghai, Zhejiang University in HangZhou, and Nankai University in Tainjin. Research and training collaborations have been set up with Nankai University, a public university under the jurisdiction of the Chinese Ministry of Education. Nankai is a comprehensive university with a curriculum that includes the humanities, natural sciences, technology, life sciences, medical sciences, and the arts. Nankai has 18 colleges and schools and offers 71 bachelor's degree programs, 206 master's degree programs, and 117 Ph.D. programs. Total enrollment stands at approximately 12,000 undergraduate students and 9,000 graduate students. Nankai is among the top 10 universities in China.

Dr. Wood has a history of training and research collaboration with Nankai dating back 22 years. Among his former trainees include Professor Yunqi Geng, who has served as the Vice President of Nankai and who is currently the In-Country Coordinator for Nebraska's Fogarty Training Program in China. Nankai made a commitment to strengthen biomedical research in its School of Medicine by developing a stronger partnership with the institution's College of Life Sciences. Because Nankai was interested in 1) building on the ongoing basic virology research conducted in its College of Life Sciences to develop an HIV/AIDS research agenda and 2) establishing the Nankai AIDS Institute, a partnership between UNL and Nankai seemed natural. Even though the Chinese

component of the Nebraska Fogarty Training Program did not start until 2003, the program already has provided training for 13 Chinese fellows (10 of them have returned to China and three are currently being trained in Nebraska). So far every fellow who has completed the training program has returned home, resumed their former post, and actively engaged in HIV/AIDS and AIDS-associated disease research. Our returning Chinese fellows are not only actively publishing, but they also have received a number of competitive research grants, including the Global Health Research Initiative Program award and several prestigious Sino National Science Foundation research grants.

Our collaborations with Zhejiang University and University of Xian-Jiaotong are developing and are addressed in another presentation.

International Sorghum and Millet Collaborative Research Support Program (INTSORMIL)

INTSORMIL is a U.S. Agency for International Development (USAID) program established in 1979 to provide research and training support to developing countries. The global INTSORMIL program involves 17 U.S. scientists at six universities and the USDA and 23 host country national research programs in 18 countries throughout East Africa, West Africa, Southern Africa, and Central America. Global strategies of the INTSORMIL program are:

- Sustainable crop production systems
- Sustainable plant protection systems
- Germplasm enhancement
- Market-focus
- Crop utilization
- Technology commercialization
- Building national agricultural systems

UNL has led the INTSORMIL since its inception and successfully won the 2006 renewal competition. Other partners in the current Collaborative Research Support Program (CRSP) are Kansas State University, Ohio State University, Purdue University, Texas A&M University, West Texas A&M University, and USDA-Agricultural Service, Tifton, GA. Like UNL, Kansas State University, Purdue University, and Texas A&M University have been partners throughout the program's existence. Other universities have participated based on program needs and focus and the interests and relative strengths of those universities in the areas of selected focus. The focus of the current agreement is sorghum, millet, and other grains (e.g., tef, fonio and finger millet). Multiple disciplines are represented among the collaborative team, including: production-marketing specialists, food processing scientists, animal nutritionists, biochemists, entomologists, plant pathologists, weed scientists, and technology transfer specialists.

The focus of INTSORMIL is on increasing food security and promoting market development of sorghum, millet, and other grains through targeted basic and applied research, education, short term training, and technology transfer to promote adoption and economic impact. The approach is to conduct research

relevant to the local problems of host countries and in collaboration with host institutions and involves regional, interdisciplinary and multi-organizational teams. The program has been well received by the participating countries. It has supported 873 foreign graduate students and 211 postdoctoral fellows and visiting scientists. The majority of the trained workforce has returned home with new skills, enhancing in-country capacity through research and administration. Some of the accomplishments include:

- Increase in yield and grain quality
- Enhancing utilization and value of sorghum
- Development of broad variety of sorghum and millet-based food products
- Utilization of sorghum and millet forage and grain in feed applications

Battelle recently conducted an independent assessment of the INTSORMIL program in West Africa (where the program has been active for 29 years). What was observed in West Africa was, in effect, revolutionary: the structuring of a new integrated economic development system to achieve meaningful change in rural, urban, and national living standards. The Battelle report concludes with the statement that "INTSORMIL is generating powerful impacts through projects at the village level and these should be extended to national and regional scales. INTSORMIL technologies are readily capable of more than doubling sorghum and millet output in the developing world." This is good news in light of the current food crisis.

Funding Opportunities

In the past, funding for international research partnerships was plentiful; the major funding source was USAID. Private foundations, such as the Rockefeller and Ford Foundations, also provided critical funding for international projects. However, funding from USAID has been significantly reduced, but several important CRSPs like the INTSORMIL have continued to receive support. More recently, NIH's Fogarty International Research and Training program has provided funding for infectious disease research. The U.S. Department of State also sponsors several programs that support international collaborations; similarly, the USDA Foreign Agricultural Service provides funding for international scientist and student exchanges. The National Science Foundation's Office of International Science & Engineering provides funding for a wide range of projects that have an international scope. Competitive Fulbright fellowships support scholar exchanges as well as graduate fellowships – important resources to foster collaborations in the arts and humanities.

The New Africa Initiative

The National Association of State Universities and Land Grant Colleges (NASULGC) has launched an initiative to foster collaborations between U.S. and African universities to help African universities build capacity. NASULGC has obtained $1 million from USAID to provide planning money to catalyze these U.S.-African partnerships. The rationale for the Africa-U.S. Higher

Education Initiative is that with the leadership of NASULGC, additional funding will be identified to support partnerships created by USAID's initial investment.

Lessons Learned

*Personal Relationships***.** Reviewing the best practices of successful long-standing partnerships and based on personal experience, we believe the most important factor in developing international partnerships is development of effective personal relationships. Mutual trust and common goals lead to mutually beneficial relationships; these are among the most critical factors when forming successful partnerships. This is especially essential because some Western organizations have a history of taking advantage of partnerships with developing countries to competitively compete for large grants. Then, when the grant funds run out, there is no organization, structure, or trained workforce to continue the programs – much to the chagrin of the international "partners."

Retention of talent. Retention of talent pool in partner countries is critical. International programs can have a significant impact when they focus on long-term partnerships to build in-country human resource capacity. Expanding the talent pool and building sustainable infrastructure in-country so that talent is retained is a hallmark of the most successful international collaborative partnerships. UNL's relationships with UNZA and its INTSORMIL partners are successful because of significant investment in training local talent and creating opportunities for in-country retention of that talent.

Sustainability. A major challenge facing global partnerships is development of strategies to retain in-country talent subsequent to training or technical assistance efforts. Individuals that emerge from these programs are frequently highly sought after because there is enormous competition for well-trained workers in developing nations. Program sustainability is important – without it, the impact on in-country capacity is minimized. Programs that help provide new skills to local citizens can help create new businesses and improve local economies are often successful. Such efforts help sustain the programs long after seed funding is gone. Education of and buy in by local governments and stakeholders help international partnerships ultimately take ownership of such programs, which is essential to sustainability.

Leadership. Successful programs have devoted leaders who have experience working in the international arena. They also have characteristics that nurture personal relationships and follow-through with regard to the commitments they have made.

Acknowledgments

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Facilitating Faculty-Driven International Initiatives

James Guikema
Associate Vice President for Research
Kansas State University

A major, research extensive university must recognize the global scope of effective scholarship and strive to instill a global perspective in the classroom, in research and scholarly activities, and in the graduate educational arena. In the shadow of 9/11, the National Science Board published *Toward a More Effective Role for the US Government in International Science and Engineering*, which made this point very effectively. They stated:

> "In a contentious world, bilateral and multilateral cooperation in science and engineering help create a universal language and culture, based on commonly accepted values of objectivity, open-mindedness, tolerance sharing, integrity, and free inquiry."

This concept of free and open inquiry, made richer by exchanges between diverse cultural perspectives and the knowledge that national borders are artificial constraints on scholarship, is core to the higher educational mission of a vibrant university. As Anton Chekhov once stated, "There is no national science, just as there is no national multiplication table."

The goal, therefore, is for the university to achieve a curriculum and an overarching research mission that remains sensitive to a global perspective and seeks to optimize international linkages. Putting such a goal in practice does much in establishing an international reputation for the institution. Similarly, achieving such a goal requires the active participation of the faculty of the institution, with the benefit of enhancing the international reputations of the faculty participants. Faculty members craft the curricula of an institution, and are the hands-on creators of its scholarship. They are busy individuals and abstract benefits such as an enhanced international reputation are not sufficient motivators to drive international collaborations. The distance between Manhattan, KS, and Lincoln, NE, is a barrier to collaborations, and the distance to Munich is much, much greater.

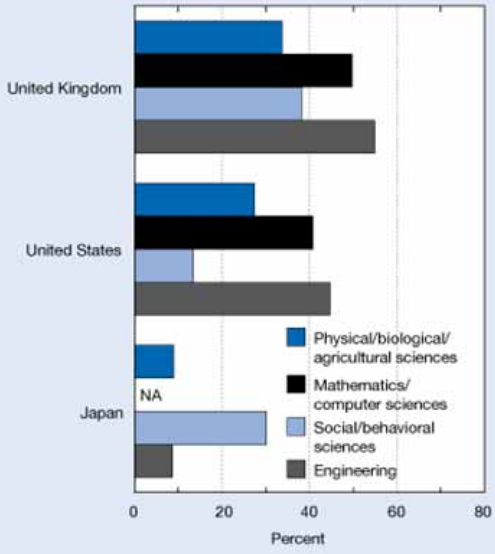
Universities must be proactive to reach the goal of globalization, and the research office can help lead the charge. Kansas State University's Office of Research and Sponsored Programs (OSRP) has identified four challenges that the research administration can address to make globalization and international collaborations a reality.

Challenge #1: Getting Faculty Members to Think Globally

As indicated above, the faculty is the key in international collaboration, and distance is an activation energy threshold that needs to be overcome for such collaborations to flourish.

Certainly, communication technology and the development of collaboration software environments have taken us a long way in mitigating distance as a factor, yet the synergistic value of face-to-face interactions, even if intermittently, can not be overstated.

Figure 2-39
S&E foreign graduate student enrollment, by selected industrialized country and field: 2005



NA = not available

NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Japanese data include mathematics in natural sciences and computer sciences in engineering. Foreign graduate enrollment in U.S. data includes temporary residents only; United Kingdom and Japanese data include permanent and temporary residents.

SOURCES: United States—National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov; United Kingdom—Higher Education Statistics Agency, special tabulations (2007); Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, special tabulations (2007). See appendix tables 2-22, 2-45, and 2-46.

Science and Engineering Indicators 2008

One strategy taken by ORSP is to present the funding opportunities to the KSU faculty in both a timely and a frequent manner. We publish a weekly *Funding Bulletin* that highlights extramural opportunities from federal, state, and private sources. These opportunities span the range of scholarship at KSU, and are not limited to the STEM disciplines. In addition, we have a section clearly devoted to international and multicultural opportunities.

OSRP has obtained access to several funding databases, including *Community of Science*. A database specialist is available to assist every faculty member, and especially those in the first several years of their appointments, in obtaining information on funding sources beyond those like NSF and NIH that are well known.

For some faculty members, however, these opportunities do not exist and the strategy of ORSP is to create them. Using internal funding, OSRP maintains two grant programs. The first, a Faculty Development Award program, provides funds for international travel – most often linked to presentations at international conferences. The second, University Small Research Grants program, provides limited funds faculty members in those disciplines where other internal KSU opportunities do not exist and where the opportunities for extramural funding are extremely rare. During the past six years, these two programs have provided over 380 opportunities for international travel and/or research for KSU faculty members.

Challenge #2: Build on your Strengths

During the past 5 years, KSU has implemented a process to prioritize and to fund interdisciplinary research as a way to promote collaborative research in a strategic manner. This process, called "Targeted Excellence", integrates research teams in areas that

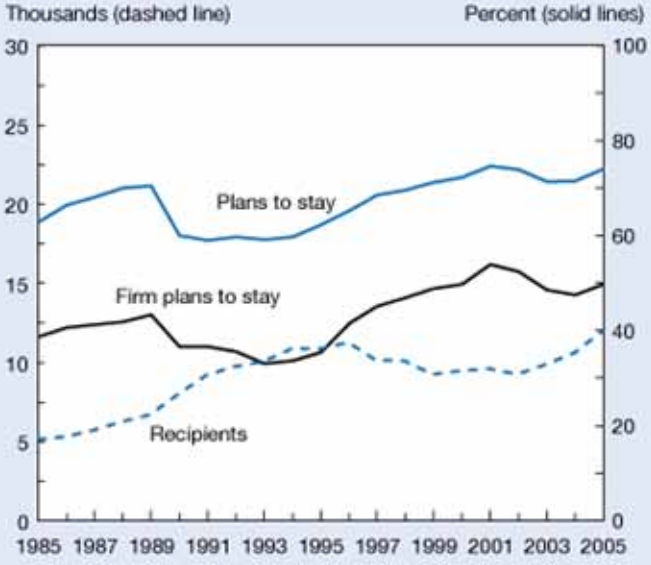
our faculty members are already individually successful, with an eye toward large opportunities such as federal center grants like the NSF National Environment Observatory Network program. Often, the collaborative teams that are successful have an international linkage in place.

Two programs that were jump-started by the TE process merit special mention. The first, Ecological Genomics, is a new interdisciplinary program that is fast becoming a recognized discipline within its own right. The interrelationship between the genome of a species, both at the individual and at the community levels, and its response to the environment is especially relevant during times of environmental change. This team has built a strong collaboration with colleagues in The Netherlands, and is working to implement faculty and graduate student exchange programs.

Second, the African Area Studies program was enhanced by TE funding. This program is multifaceted. It provides research funding on issues of African politics and economics. It enhances the undergraduate curriculum by providing resources for teaching of African languages. It encourages linkages that have developed in the sciences as well, and has fostered existing linkages with Senegal, Botswana, and South Africa.

We have learned to build on our strengths apart from the TE process as well. OSRP supports extramurally-funded programs that have international recognition that predates the TE process. One example is the focus on the grasslands of the tallgrass prairie, a program supported by an NSF Long-Term Ecological Research (LTER) grant for the past three decades. An extension of this has been funded by the International LTER to compare the grasslands of KSU's Konza Prairie Biological Station with the savannahs of Sub-Saharan Africa.

Figure 2-29
Plans of foreign recipients of U.S. S&E doctorates to stay in United States: 1985–2005



NOTES: Degree recipients include permanent and temporary residents. See appendix table 2-33 for plans to stay by place of origin and field of study in 4-year increments.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2007).

Science and Engineering Indicators 2008

A second example of a major international initiative born outside of the TE process is the successful completion of a genome project. The usefulness of the red flour beetle as a model of embryonic development has

been established by two decades of research. Because of this, KSU faculty members led an international consortium in constructing a white paper which provided a compelling rationale for the sequencing of this genome. USDA, NIH, and other organizations agreed, and the project has just been published in *Nature*. An article in this issue, authored by Dr. Susan Brown, details this project.

Challenge #3: Effectively use Graduate Education to Globalize Research

Graduate education is a global enterprise. Over a half million foreign students studied in the United States in 2005, and that our nation is not unique in hosting international students. A large number of these are graduate students and, as shown in Figure 2-39, they are studying all areas of the STEM disciplines. Often, these students come to the US grounded in a science background and rarely are they encouraged to discuss their research in their home countries. Rather, we should be using these students to cement research linkages abroad. Instead of blanket recruiting, targeted practices could select students who have shared interests with international colleagues, from the international colleague's home country, perhaps with employment opportunities with those colleagues after graduation.

International doctoral students often return to their home countries, as shown in Figure 2-26, and join the scientific workforce at home. US faculty members, therefore, have a ready source of collaborators by relying on their own graduates.

As these collaborations mature, the internationalization of graduate education could potentially be institutionalized by the establishment of joint degree programs. Within public institutions, this is difficult because of differing oversight organizations established by each state. Vibrant collaborations would be possible if these oversight boards were to grant institutions the jurisdictional authority to establish ad hoc joint degrees when strong opportunities arise.

Challenge #4: Provide Mechanisms of Effective Financial and Administrative Oversight to Projects Overseas

There are legal and ethical challenges when faculty members initiate projects that will be managed overseas. Universities will be expected to be in compliance with the laws and regulations at home, made difficult when the funds are spent overseas. If humans are the focus of the research, for example if the project involves screening for HIV, do the processes and procedures conform to the Institutional Review Board and are the investigators aware of the laws of the host country? If the project requires special equipment that the researchers bring with them, can the researcher bring that equipment along without violating the US Export Control regulations? Does the collaborating institution have an effective grants management administration or the ability for fiscal accountability that US granting agencies expect?

KSU has a grant with the World Bank to help rebuild the College of Engineering

within Kabul University, and we face these challenges and more.

Summation

A modern university has the obligation to its faculty, students, and stakeholders to ensure the global nature of its research enterprise. The offices that provide the research administration for the university must have that mindset as well. At KSU, the Office of Research and Sponsored Programs strives to provide this for our stakeholders.

Think Globally, Organize Systemically

Jack Schultz
Director, Christopher S. Bond Life Sciences Center
University of Missouri

Whether or not one agrees that the world is flat,[1] it is certainly getting flatter all the time. Increasing flatness is revealed in the swiftness with which everything from information to disease sweeps around the globe, changing habitats, health, economies and cultures. Combined with the increasing requirement for collaboration to address complex issues, this situation has transformed international research collaboration from a luxury to a necessity. Evidence of that necessity is seen in conferences like this one and in the structures of US funding agencies and institutions of higher learning.

The nature of modern research, and the remaining social, cultural and economic diversity around the world combine to make international research collaborations considerably more complex than strictly domestic programs. Moreover globalization in many arenas means that almost any research activity must be considered in the light of a rapidly growing web of interactions which vastly multiplies the number of possible intended and unintended consequences. In this essay I suggest that US research universities are not structured so as to enhance the success of international collaborations, and that integrating systems science into the administrative architecture is a key solution.

Minor complexities and annoyances

In the sciences, it would be difficult to find a researcher at a major research university who does not have one or more interactions outside the US. Such arrangements range from almost daily information exchange, through student exchanges and active physical collaborations. Federal funding agencies in the US and abroad have entire divisions devoted to supporting such collaborations, and a constant flow of funding opportunities for work abroad crosses the computer desktop of most researchers. Indeed, a successful researcher is often in the position of making difficult decisions about which opportunity to pursue based on what can be accomplished, the difficulties and complications to be encountered, and availability of willing collaborators.

It is not difficult to find potential international collaborators, and a feature of the flattened (electronic) world is that it is not difficult to ask about willingness. What has not been eased is the difficulty in discerning what is actually doable and what complications will occur, and the unintended

consequences that could arise from what seems like a straightforward project. Researchers working in different fiscal, social and cultural environments may not have similar values or views of what constitutes satisfactory progress and what difficulties are tolerable. For example, I once used window-screen cages in a study of insects on plants in rural Argentina. Little did I realize that window screen was a precious commodity in the nearby community, and my project was made impossible because of repeated theft of my cages. On the other hand, daily life in town became considerably more comfortable, a fact that clearly outweighed my desire for a PhD in the minds of local residents.

Minor complications like window screen theft arise from local socioeconomic circumstances, and might not be predictable even to local residents. But many factors that come into play while carrying out research abroad are predictable and well known to experienced travelers and their agents. Examples include importation issues (e.g., need for legal assistance at customs), fiscal issues (e.g., monetary exchanges, existence of cooperative banks), and socio-cultural issues (e.g., bribes). These are all topics about which the average researcher learns entirely from experience, sometimes at some risk. If research institutions agree that international collaborations are important, it would seem wise to establish resources for these programs to ensure their success. This kind of resource is nearly nonexistent.

When these kinds of travel complexities arise for undergraduates studying abroad, most universities and colleges have individuals or agencies on campus and abroad capable of addressing them (although with variable success). It is quite unusual to find an International Programs office that has a research support mandate; most US universities are addressing globalization at the level of undergraduate education. Researchers planning to work abroad must depend on more experienced colleagues or their international contacts for information about the vagaries of working at a particular locale. Foreign study students have access to substantial detail about their target countries, mainly because they and their parents have demanded it. No such support for research abroad exists at most US universities. In my own example, my French foreign study-experienced daughter is by far my best (only) source of advice about working in France. And while she can warn me about the lengthy vacation periods during which I might not have access to a laboratory she really can't help with more detailed research-based issues.

A survey of the positions of international programs in the organizational hierarchies of US universities and colleges indicates that the international program office is usually led by someone at the Vice Provost or Vice President level and is usually devoted to undergraduate education. Even when international program offices include research support staff, it is unlikely that they offer a very comprehensive understanding of the issues involved in doing research around the globe. On the other hand, international program staff and their contacts abroad make an effort to

provide similarly detailed information to undergraduates going abroad.

Major complexities, orange peels and biofuels

Learning national, regional and local idiosyncrasies is possible, if painful, for the individual researcher or research team. While having access to information about these minor complexities would make program development and research outcomes smoother, in most cases these issues do not make or break a research collaboration and they usually do not have global consequences.

However, there are levels of complexity at which the researcher's focus on his/her project can influence success or failure and have unforeseen consequences at a larger scale unless the work is placed in a global context. There is increasing awareness of the relationship between globalization and research, as seen in federal regulation of the movement of endangered or pathogenic organisms. Federal oversight and warnings issued to researchers have both increased dramatically in response to the demonstrated ease with which such organisms can be transported among countries and continents. Regulatory responses are typically driven by unfortunate experiences or fiscal issues rather than by foresight. As a consequence, investigators need constant and frequent updates on changing regulations and sociopolitical circumstances. Even funding agencies are frequently behind the curve as new regulations (e.g., collection permit requirements) go into effect, so that grants may be awarded in violation of international or even US policies and laws.

The singular focus investigators bring to their research is important to its success. However, that focus can blind the investigator to the broader context in which the research's findings will be important. As a consequence, results of a "successful" project may turn out to me incorrect or inconsequential or even have a negative impact when considered in the broader context of a flattened earth. For example, Daniel Janzen (University of Pennsylvania) developed a project to reclaim pasture dominated by imported African grasses in northwest Costa Rica to return it to dry tropical forest.[2] This was part of a decades-long project to restore a large portion of seasonally dry Costa Rica to its original state and expand preserved land there as part of national parks.[3] It may be the oldest, largest and most successful habitat restoration project in the world. Janzen's research indicated that mulch with citrus peels suppressed the alien grasses and together with fire suppression permitted the forest to re-establish itself.[2] Janzen entered into agreements with local citrus processing plants for routine shipments and spreading of peel mulch. This effort was justified on the basis of the argument that natural ecosystems provide 'goods and services' (clean water, forest products, etc.) that can be valued monetarily.[4] The negotiated agreement with the citrus company valued a range of ecosystem services in specific monetary terms, and a value of mulch was set as "payment" for these services.[2] This arrangement was in force by 1999, and continued into the 21st century.

I visited Dr. Janzen in April of 2008 and asked how the citrus peel project was going. His answer: "it is over". When I asked why, the following story emerged. Three changes unforeseen by Janzen had occurred to doom the project. Cheap fuel and air fares during the 1990s had made development of resorts, vacation homes and second residences in the area accessible to so many North Americans (a new airport made northwest Costa Rica an affordable 3 hour flight from major US cities) that property values began to exceed the value set on them in the Janzen-citrus processor agreement. In fact, property values increased 10-fold in many cases, making the land more valuable for development than for "ecosystem services".

Then an expanding middle class in developing countries dramatically increased demand for fuel and the price of oil rose rapidly. While air fares followed, air lines suppressed increases and air travel continued. A global response was to invest in production of biofuels, especially ethanol from corn and sugar cane. Brazil has been a world leader in ethanol production since the 1970s and it began expanding ethanol production in response to demand, at the expense of food and fiber plantations.[5]

Finally, a series of hurricanes in 2005-2008 dramatically reduced the production of citrus in the US.[6] Besides destroying matures trees, these storms carried foreign diseases that directly or indirectly (through hygiene programs) destroyed millions of trees. It will take as many as 10 years for US citrus production to recover to pre-hurricane levels. Because the US is a major consumer of citrus products, especially environmentally "green" citrus oil cleaners, other nations are in the position of compensating for this loss. In previous citrus downturns (e.g., resulting from frost damage) Brazil was a major contributor to the US citrus supply.[7] However, the global demand for biofuels has led Brazil to reduce citrus production in favor of ethanol production, reducing its ability to help.[5]

Costa Rican citrus growers saw the US shortfall as an opportunity. The rising land values and the expanding demand for citrus products made it clear to them that the original contract to exchange land value for peel mulch now undervalued land, which was better devoted to expanding groves. Moreover, environmentally "green" cleaners are extracted from citrus peels, and comprise the chemistry that Janzen found suppressed African grasses. Taken together, global trends towards cheaper, greener fuels and cleansers made Costa Rican citrus producers want to keep their peel mulch, extract cleansing agents, and sell the extracted mulch to ranchers anxious to retain the alien African grass pastures Janzen was trying to eliminate. The citrus companies became competitors for land, could afford to pay more than restoration advocates, and hence limited the expansion of national parks and restoration efforts.

Throughout, the binding contract Janzen negotiated with the Costa Rican government and citrus producers to supply citrus mulch to the national park restoration effort remained in effect.[2] How could the citrus producers escape

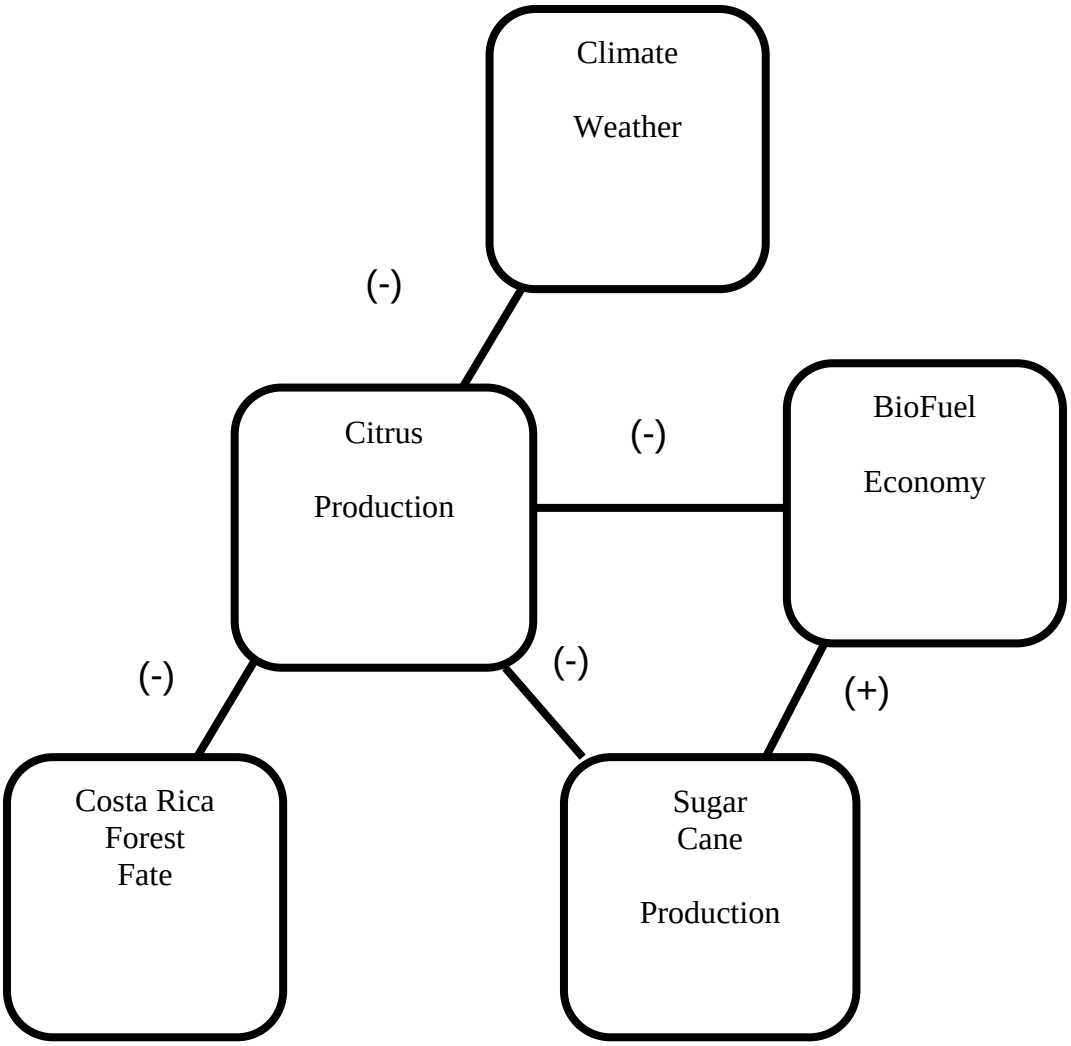
this and maximize profits while the US felt the shortfall of citrus products? The citrus producers lobbied the Costa Rican legislature, which produced a bill outlawing dumping biological materials, including agricultural 'waste' on federal lands. The contract was nullified and the citrus producers were free to use castoff rind from juice production as they wished.

Janzen's project was an international collaboration which included scientists of several types from several countries, the citrus industry in Costa Rica, federal environmental agencies and international environmental groups. As such, it had a much broader base than most science collaborations, but then its goals included significant changes in land use and economics. In fact, Janzen's efforts helped convince Costa Rican government to set aside in natural preserves a greater proportion of its land area than has any other country, including the US. Over the past few decades, the economy of Costa Rica has shifted from agronomic to ecotourism as dominant features. Ecotourism is second only to electronic components produced by INTEL in bringing in foreign currency, and it earns more foreign exchange than the nation's former export staples, bananas and coffee, combined.[8] Janzen's efforts in support of this move have gained him every significant award he could possibly win, and Costa Rica has become a model of transition to environment-friendly economies.[3]

The complexity of this situation is nothing short of astounding. What started as a promising application of a basic research discovery – the impact of orange rind (citrus chemistry) on plant growth and its use in habitat restoration – was sideswiped by global economic, climatic, and ecological factors no field biologist was likely to consider in planning an international research project. Janzen has long been well-connected with the Costa Rican government. He even established a federal biodiversity agency in Costa Rica. But the impact of weather on North American crops, the global demand for biofuels, and the profitability of environmentally-sound products never entered into his research plans. In the end, Janzen remarked, what he really lacked was good lawyers to deal with industry and legislative maneuvering.

A systems perspective

The citrus peel/ecology/economics story can be represented as a box-and-arrow model. Such a picture would depict the major factors and their interactions. Climate influences weather (hurricanes), which influences citrus production and crop value; middle class growth in India and China plus dwindling reserves and political unrest influence fuel prices, which influence biofuel production, etc. The resulting picture, a complex set of lines connecting boxes, is easy to imagine. A group of events, forces or elements that can be connected by interactions in this way is what we call a system. An ultrasimplified version of the Janzen problem would be:



Box-and-line network models are common depictions of all sorts of systems ranging from electronic grids to ecological communities to human social systems. An entire science, systems science, has developed to the point that there are entire departments focused on quantifying and understanding how different sorts of connections relate to each other.[9] A very important trait of interactions in complex systems is that the outcomes, products, eventual states, of a system are not evident from merely examining the participants. Complex systems have 'emergent properties', or behaviors not predictable by examining individual elements.[9, 10] Ecologists have long appreciated that the natural world is a complex system comprised of many complex systems, and the concept of emergent properties has guided ecosystem science for many years. In fact, Daniel Janzen's scientific career has produced one spectacular example after another of complex interactions among species. Many of his, and similar discoveries by others, have come about by collaborating across disciplines; it takes multiple perspectives and approaches to unravel complex interactions.[10]

With the flattening of the earth, our perspectives on systems are changing. Since virtually no place on the earth can be said to be uninfluenced by humans, human activities are increasingly seen as part of ecological systems.[11] The impact of humans on complex ecological systems can now span the globe in a very short period of time. Species are transported around the world and introduced to new systems at will, or more typically by accident, transforming the systems receiving them. We can now alter species in ways and to an extent never seen before, with largely unknown consequences on complex interactions we really don't understand yet. [11]

With humans in the mix, concatenated systems outside nature enter into the picture. As we see in the orange peel example, humans added complex economic and social systems to the factors influencing the future of the tropical ecosystem Janzen is trying to restore. Entire disciplines exist to understand those human systems. Add global weather patterns (hurricane impacts), a notoriously complex and difficult system to decipher, and their socioeconomic impacts, and it is clear that Janzen would need a vastly expanded corps of collaborators from disciplines that usually don't interact (climatology, economics, law), working with international - global - systems to ensure that he could predict the outcome of his efforts and the future of the northwest Costa Rican forest.

The research university's role

There is only one sort of organization where the disparate disciplines needed to unravel the emergent properties of complex systems commonly co-occur: the research university. But despite considerable rhetoric and a mandate to integrate (particularly for land grant universities), universities and their administrations have not been very successful in making the most of this opportunity.[12] Individual researchers are still rewarded primarily for individual, not team, efforts. Highly visible, successful faculty are not encouraged to develop interactions with and skills in junior colleagues. Collaborative opportunities are missed more than made because of a lack of communication and intellectual isolation, especially on larger campuses.

Given the difficulty in developing interdisciplinary collaborations within a campus, the problem of integrating the disparate interests and far-flung connections needed for international collaborations is truly daunting. Institutional culture leaves it to the individual researcher to solve these problems, but this engenders a real opportunity cost. The typical successful researcher has an eye for funding opportunities. Justifications for funding particular kinds of research come and go, and sometimes researchers are tempted to see a new trend as a way to fund a new or even existing line of research. Of course, that research must in some way serve the needs of the funding agency, but some ongoing work can often be rolled into such a body of work, even if it's not quite on the same target. For example, current interest in biofuel development is generating a funding stream that attracts the attention of university researchers in many fields. As the orange peel story illustrates and many have documented, the net value of investing in biofuels remains uncertain,

and depends strongly on global economies of two types: monetary and carbon. If time, money and careers are to be well spent on such projects, a global systems perspective is absolutely essential. A productive scientific career can be wasted by hitching one's funding to a post whose reliability and utility can be influenced dramatically by such diverse and distant factors as climate change, economic trends, a focus on 'green' technology, etc. Those factors reach around the globe to influence the utility and future success of individual research projects, and the successful investigator must realize that, even when the research focus seems local and narrow. Nothing is local or narrow any more.

All research programs are increasingly international research programs, whether the researcher goes abroad or not. Yet training, at least in the sciences, continues to focus on what happens in one's field, on one's campus, in one's lab or office. Researchers who do go abroad are challenged to decipher unexpected factors ranging from minor annoyances to major interference. Researchers accustomed to controlled experimentation eventually learn that nothing is totally controlled. The best way to deal with this is to imbed one's research in the systems context appropriate to it and work with collaborators whose expertise is in the other elements of the larger system. As Janzen learned, a habitat restoration project based on a narrow biological finding can be influenced – even halted – by global factors ranging from weather to politics. What is needed for a project like that is a collaborative team with economists and lawyers who are as qualified as the biologists.

Universities trying to internationalize their student bodies provide resources that inform students about the factors that will influence them abroad. Research universities should be able to provide similar information to researchers to handle the minor annoyance part of the system in which they will work. But what about the major factors that produce unforeseen outcomes? Universities cannot characterize the particular global systems in which each researcher might work. However, it is possible to learn about and call attention to larger trends and issues likely to influence international research outcomes. For example, plant scientists in the Bond Life Science Center at the University of Missouri are interested in developing biofuels from corn and soybeans. As part of their closest administrative relationship, the Center Director asks hard questions about the global impacts of and impacts on their research. Will this research have a salutary impact on the global carbon budget? Do economic trends indicate that there is a future to what they wish to develop? If they are going to work in international teams, are there cultural, social or legal factors that may negate their progress (e.g., an unwillingness to deal with genetically modified organisms)? The exercise of asking questions at the system level forces the investigator to consider specifics, and can be useful even if the systems analyst is not intimate with the research.

The ability to keep abreast of global, international developments and ask

researchers questions that may steer or focus their decisions could be done by administrators who can stay in contact with such information. On most campuses, administration of international programs is done at a level quite removed from these issues, by people who are not or maybe never were engaged in international problem-solving. Frankly, my experience with some foreign-study offices suggests that they might not have much experience with foreign study. An officer or entire staff whose job it is to help researchers become aware of global issues when developing research projects would be invaluable, and could contribute greatly to the "global land grant" university's mission.[12,(Foster, this volume)] This goal could also be accomplished by generating broader collaborations, for example among faculty in science units and those in relevant liberal arts units with international, global interests. I suspect that it may be easier to devise a staff devoted to placing research ideas in a global context, perhaps as part of the grant proposal preparation process.

Paying attention to complex systems and developing quantitative models predicting their behavior is now a well established academic discipline. Systems scientists are interested in all sorts of systems; it's system organization, not the identity of the elements that form the underlying focus of study.[9] We need to promote the application of this discipline to the formation of interdisciplinary, international collaborations and coalitions. For that matter, universities would certainly benefit from systems analysis of themselves.[13] A university agency staffed by "applied systems scientists" whose job it is to place research projects in the larger context to which they belong would be an invaluable resource and could be necessary for many institutions to achieve their goals. The concept of an "Office of International Programs" needs dramatic expansion in concept and application.

Conclusions

Forming international research programs is one example of a larger problem in university-based research: a failure to appreciate the complex contexts in which projects are imbedded. The complexity arises from natural, social, economic and other causes, and includes elements that range from minor annoyances to major roadblocks. Globalization is a reality at many levels, so that almost no research project is truly isolated from complex systems that may span the globe. Because academics are trained to focus narrowly and develop their research in a domestic setting, they would benefit from an agency whose role is to suggest or even outline the complexity of the system in which their research will be carried out. Because systems science is "taxon-free" (the identities of the elements are not as important as their relationships) a system scientist can make a significant contribution to individual projects without be expert in the research proposed. Universities should consider systems analysis a critical element in the academic administration system, since the benefits range from enhancing their own effectiveness to their global impact.

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Biodiversity Prospecting and Conservation Programs: Models for International Collaborations

Barbara N. Timmermann
University Distinguished Professor
Chair, Department of Medicinal Chemistry
University of Kansas

An International Cooperative Biodiversity Groups (ICBG) Program was awarded in 1993 for research into drug discovery from medicinal plants, biodiversity conservation and economic development in Latin America. While biodiversity from arid lands is well known to produce a vast array of natural products as defensive agents and poisons, they have received much less attention than plants from the tropical rainforests as potential sources of drugs for human health. This project, funded by the U.S. government, has been undertaken in cooperation with universities and research institutions from the U.S.A., Argentina, Chile and Mexico, and U.S. pharmaceutical and agrochemical corporations. This ICBG program is unique in its emphasis on the United Nations Convention on Biological Diversity regarding the implementation of policies on conservation of natural resources, intellectual property rights and other issues of concern to host countries.

INTRODUCTION

Medicines from plants with biological/pharmacological activity have a long history of use in both traditional and modern societies as phytomedicines, herbal remedies, purified compounds approved by the Food and Drug Administration (FDA) and as starting materials for further chemistry or biocatalysis modifications (Jones et al., 2006; Butler, 2004; Balunas and Kinghorn, 2005; Koehn and Carter, 2005). Drug discovery from plants still provides important new drug leads against diverse diseases such as cancer, malaria, HIV/AIDS and tuberculosis (Butler, 2004; Newman et al., 2005). However, drug discovery from plants faces many challenges, including legal and logistical difficulties involved in the collection of plant materials (Rosenthal, 2002; Soejarto et al., 2004), the lengthy and costly process of bioassay-guided fractionation, isolation and chemical characterization (Balunas and Kinghorn, 2005) and the elimination or reduction of natural product research programs at pharmaceutical corporations and U.S. federal agencies (Butler, 2004; Koehn and Carter, 2005).

A majority of new medicines derived from plants have been applied toward the treatment or prevention of cancer (Newman et al., 2003). Progress

has been made in cancer chemotherapy, a considerable portion of which can be attributed to plant-derived drugs. Anticancer agents from plants currently in clinical use include four main compound classes and their synthetic and/or semi-synthetic derivatives: Vinca (or Catharanthus) indole alkaloids from Catharanthus roseus (L.) G. DON (Apocynaceae; formerly Vinca rosea L.), epipodophyllotoxins from Podophyllum peltatum L. (Berberidaceae), taxanes from Taxus brevifolia NUTT. (Taxaceae), and camptothecins from Camptotheca acuminata DECNE (Nyssaceae). Two other classes of compounds from plants are showing promising results in advanced clinical trials, namely, the combretastatins and their derivatives from Combretum caffrum KUNTZE (Combretaceae) and the homoharringtonine alkaloids from Cephalotaxus harringtonia C. KOCH (Cephalotaxaceae) [Newman et al., 2003]. Despite the major advances in caner prevention and treatment, new drugs are still needed, since some cancers have become resistant to currently available treatments and certain types of cancer lack appropriate drug treatments.

Beginning in 1993, the International Cooperative Biodiversity Groups (ICBG), a program administered by the Fogarty International Center (FIC), National Institutes of Health (NIH), and supported through funds through NIH, National Science Foundation (NSF) and U.S. Department of Agriculture (USDA) Foreign Agricultural Service (FAS), started operation in an effort to integrate the following goals: improvement of human health through drug discovery, incentives for conservation of biodiversity, and development of new models of sustainable economic activity that focus on the environment, health, equity and democracy. The implementation of this program is based on the belief that the discovery and development of pharmaceutical and other useful agents from the world's biodiversity can, under appropriate circumstances, promote scientific capacity development and economic incentives to conserve the biological resources from which these products are derived (Fogarty International Center, 2004). The drug discovery effort is focused on diverse target organisms, comprising five (Eubacteria, Protoctista, Plantae, Fungi, Animalia) of the six kingdoms of overall biodiversity.

The ICBG entitled "Bioactive Agents from Dryland Biodiversity of Latin America" serves as a model for the implementation of the ICBG principles, which are, ultimately, the principles of the United Nations Convention of Biological Diversity (UNCBD). In the two phases of operation (1993-1998 and 1998-2005), and until the author moved to Kansas from Arizona, this ICBG consortium consisted of a US-based academic institution (University of Arizona), four Latin American academic and research institutions (Pontificia Universidad Catolica de Chile, Santiago, Chile; Instituto de Recursos Biologicos, Buenos Aires, Universidad Nacional de la Patagonia, and the Centro Nacional Patagonico, Chubut, Argentina; and Universidad Nacional Autonoma de Mexico), one US research institution (Institute of Tuberculosis Research, Chicago) and two US industrial partners

(Wyeth Research-Pearl River, New York and Fort Dodge Animal Health-New Jersey). Based on this model, bioprospecting research continues at KU with new host country collaborations (e.g., Panama) under new institutional agreements.

This project has involved plant collection, extract and fraction preparation, screening of extracts and fractions in cytotoxicity and mechanism-based in vitro bioassays, dereplication of active plant species, activity-guided fractionation, compound isolation and structure elucidation, in vivo testing in animal models, lead optimization, and compound development. Although extensive data have been collected through the course of this project, this paper describes the different projects within the program in regard to plant procurement, drug lead discovery, conservation activities as well as intellectual property rights and issues of concern to host countries.

The drug discovery and development goal of this ICBG is to identify biologically active molecules from plants of arid and semi-arid ecosystems in Argentina, Chile, and Mexico as chemotherapeutic candidates for tuberculosis, cancer and other diseases of concern to developed and developing countries. In addition to scientific study, the work promotes economic growth in areas where the plants are collected, involves local populations wherever possible, collects indigenous knowledge about the plants and their uses, and works to conserve biological resources through educational programs.

BOTANICAL COLLECTIONS AND INVENTORY

Many xerophytic plants are known for their medicinal properties and for the complex arrays of natural products they manufacture as apparent adaptations to extreme conditions of heat, desiccation, ultraviolet radiation, and herbivory to which they are exposed. Arid-adapted plants are noteworthy by providing host plant defenses against infectious disease, parasitism or predation (Timmermann and Hoffmann, 1985; Hoffmann et al., 1993; Maatooq et al., 1996).

The ICBG program focused on plants from different regions in Latin America and allowed for the systematic screening of medicinal, endemic and local plants with a battery of high throughput biological assays. The feasibility of a plant-screening program depends on effective procurement strategies using a combination of random, taxonomic, ecological and ethnobotanical strategies.

In order to incorporate national priorities into the site selection process, regions of high interest for conservation as well as community development were considered as recommended by governmental and non-governmental conservation organizations in each host country. Plants collections were undertaken in diverse ecosystems such as the cold deserts and steppes of Patagonia and Tierra del Fuego, as well as the phytogeographical provinces of the Monte and the Chaco in Argentina; the hyper-arid desert of Atacama and the semi-arid and arid central Chile, and the drylands of central and western Mexico.

This program was designed so that plant collections, inventories, and other activities were in agreement with the appropriate domestic and international laws, such as laws on endangered species (CITES) and plant conservation. When working in the natural areas of origin of the plants, permission was always sought at the national and local levels. In some cases, agreements were made with local non-governmental organizations and provincial governments in the source countries. A formal, written plant collection agreement was undertaken with source countries prior to all plant collections.

Voucher specimens for taxonomic identification and future reference were collected and deposited at all institutions in host countries and in various herbaria in the US. For most species, numerous anatomical parts (including leaves, twigs, flowers, fruits, roots, bark, and other parts, or combination of parts) were collected (called samples). Dried specimens were shipped to the US for chemistry research.

When available, local collaborators in the collection areas were contacted and interviewed about plant remedies from the local flora. This knowledge was gathered primarily to help insure preservation of this cultural knowledge, to increase the chance of drug discovery leads, to develop local phytomedicines and to maximize the potential of rewarding the local community with financial benefits.

Extensive ecological data, including edaphic, altitudinal, and climatic factors, were recorded during plant collections in order to build a database that allowed us to correlate the ecological conditions with biological activity. Further understanding of the relationships between plant profiles and biological activity lead us to more direct and informative plant collection endeavors currently underway. The relational database used in this research was NAPIS (NAtural Products Information System).

EXTRACTION AND SCREENING ACTIVITIES

Once a plant species was located in the wild, a necessary amount of above-ground biomass was collected to yield approximately 1 kg of dry weight of material to generate organic extracts according to established protocols. To date, more than 10,000 extracts were formatted into microtiter plates and tested for biological activity in a wide variety of sensitive, selective assay systems in a variety of therapeutic areas. About 45 different screens have been employed for the initial assays and for follow up studies. In order to maximize efficiency and avoid potential conflicts of interests, a wide assortment of mechanism-based, whole organism and enzyme-induction assays were employed in the primary screening program to detect lead extracts with interesting and desired mechanistic properties. All plant samples were subjected to a battery of biomedical bioassays using several automated, high throughput enzyme assays developed and performed at Wyeth (Pearl River, New York) and the Institute for Tuberculosis Research (Chicago) while the agrichemical and veterinary tests were performed at Fort Dodge Animal Health (Monmouth Junction, New Jersey). Therapeutic areas of potential

target applications in human health included oncology, anti-infective, central nervous system, metabolic and inflammatory disease and women's health. An extensive battery of organisms resistant to a wide variety of clinically used antimicrobial agents were employed for secondary testing of active leads.

BIOASSAY-GUIDED ISOLATION

When biological activity was detected and confirmed for a sample in at least one screen it was considered a positive lead. Bulk plant collections in the order of one-to-three kilograms of dry biomass were obtained for these positive samples or hits following the initial screens. Active extracts were evaluated in a panel of secondary screens and by chemical dereplication for prioritization. Bioassay-guided fractionation of active extracts was conducted for isolation and identification of the active compound(s). Chemical novelty, activity in secondary functional assays, and in vivo results were used in the prioritization of active compounds. New active lead molecules were selected for structural modification to generate new analogs with enhanced activity and reduced toxicity.

High-performance liquid chromatography/mass spectrometry (HPLC/MS) dereplication involved off-line fractionation/LC/MS analyses. Those compound classes found to be most active can be considered during dereplication processes in future drug-discovery efforts from plants.

Active extracts were fractionated into 96-well plates by HPLC. Fractions were tested for biological activity and active fractions were analyzed using MS to detect inferred molecular weight (s) of active compounds. These molecular weights were then compared to those of known bioactive agents from within the same taxonomic genus or family using natural products databases (e.g., Natural Products ALERT (NAPRALERT), Beilstein, SciFinder Scholar, and the Dictionary of Natural Products). Extracts containing bioactive compounds not previously isolated or reported were prioritized for further fractionation.

Large-scale bioassay-guided fractionation was conducted to isolate and identify active compounds. Fractionation was conducted using open, low pressure, and vacuum column chromatography (e.g., normal-phase and reversed-phase silica gel, alumina, and Sephadex LH-20). HPLC and TLC were also utilized as necessary. Active fractions underwent continued fractionation to isolate compound (s) responsible for activity.

Compounds were identified by various spectroscopic techniques including UV, IR, and proton and carbon nuclear magnetic resonance (NMR) spectroscopy, and low- and high-resolutions mass spectrometry (MS). Additional 1D- and 2D-NMR experiments were performed as necessary to determine structures unambiguously. When necessary X-ray crystallography and circular dichroism (CD) were also utilized to determine absolute configuration.

Although the largest part of our drug discovery research remains confidential, we have been able to publish chemistry results in peer reviewed journals following the filing of a provisional patent application. To date,

about 500 compounds were isolated and elucidated of which 60 are novel compounds (Waechter et al., 1998, 1999 a, b, c, 2001 a,b; Valcic et al., 1998, 1999, 2002; Flagg et al., 1999, 2000; Timmermann et al., 1999; Caldwell et al., 2000; Munoz et al., 2001 a,b; Mata et al., 2001, 2002, 2003; Gutierrez-Lugo et al., 2002; Rojas et al., 2003; Woldemichael et al., 2003 a, b, c, d; Gu et al., 2006; Khera et al., 2003, 2007). The chemical classes found include simple aromatics, benzopyrans, benzofurans, unusual flavonoids, mono-, sesqui-, di- and triterpenoids, steroids, monomeric, di-, and trimeric phenylpropanoids and alkaloids. Information regarding the relationship between compound classes and class diversity may be further utilized to support the continued search for bioactive compounds from plants.

The structural diversity of active compounds isolated during the course of this research also points towards the importance of continued exploration of plant secondary metabolites in the drug discovery process, since the structural diversity and compound characteristics of natural products are not readily accessible through synthetic or combinatorial chemistry

INFORMATION AND DISSEMINATION

The goal of the information management and dissemination component has been to support the research, conservation, and economic growth efforts of the overall project by building information handling capabilities at all project sites and by promoting the exchange of information between the cooperating institutions. Based on a survey of all project participants in each country at the beginning of the project, specific objectives identified were to: 1) develop general project-related communications products; 2) build a plant database catalog integrated with bibliographic and geographic information systems (GIS) functions; and 3) provide technology transfer and training in the use of these information systems. Throughout the course of the project, these objectives have remained largely the same, although specific activities have changed and evolved according to newly identified needs and interests. A web site was designed to provide a complete historical record of the project in English as well as in Spanish and included lists of publications and presentations resulting from the project, the full-text of selected documents, slide shows of conservation activities and special features such as links to web-versions of several databases.

One of the project's central goals was to address and promote biodiversity conservation and sustainable economic activity, including development of strategies for minimizing negative environmental impacts while ensuring that equitable economic and social benefits from discoveries accrue to the country, community, and organization which facilitated the discovery of the natural product. Several workshops were held to insure that biodiversity, intellectual property rights, and cultural issues were considered in the process of prospecting for plant resources (Timmermann and Montenegro, 1997; Suarez et al., 1999).

Conservation and development goals were closely linked to this ICBG's

academic research process. The plants collected for drug discovery purposes formed only a part of the information gathering process. Research to support biodiversity management was integrated into independent research projects such as the study of adaptations of native plants to the local environment; facilitating plant regeneration following harvesting for medicinal purposes; as well as growth dynamics, interactions with pollinators, defensive mechanisms against predation, and other relevant fields.

INFRASTRUCTURE BUILDING

A considerable effort in this ICBG was directed towards infrastructure-building and professional training in the source countries to develop long-term collaborative and sustainable relationships between the institutions involved. Benefits associated in this project have been apparent from the start as evidenced by the support received by the affiliated academic institutions in the host countries. It was recognized that the advancement on basic knowledge on plant biodiversity and conservation was important to the academic programs of all institutions. Certain infrastructure improvements have been added such as laboratory and conservation equipment, vehicles, germplasm and herbarium facilities. University students (US and foreign) have been trained and were being given the opportunity to use the equipment and data for their academic theses and dissertations.

COLLABORATION AGREEMENTS

The successful collaboration of the members of this ICBG required detailed agreements among the various participants, which defined work and funding commitments, ownership of materials, licensing rights and distribution of future financial benefits, if any. This design of the agreements resembles a wheel in which the University serves as the hub of the wheel and each of the collaborators as a spoke (Rosenthal, 1997). Seven agreements had to be negotiated on an individual basis. The challenge of this construction was the necessity to assure that all agreements were consistent with the others. The advantage of the separate agreements was our ability to address specific concerns on an individual collaborator basis.

Each two-way agreement defined the scope of work obligations of the University and of the collaborator, responsibility for permits and for obtaining informed consent, the collection and preservation of data, ownership of inventions, confidentiality, funding support, bioassay screening, reports, responsibility to establish a sustainable agricultural source of the bioactive plant in the region of its collection, and collection and distribution of royalties to the participating parties.

Royalties, should there be any, will be divided into a “collector’s share”, an “inventor’s share” and a “conservation share”. The employing institutions of all named inventors of a patent will equally divide the “inventors share” (45% of all royalties). Further distribution by the institutions to the inventors will be dictated by existing policies. Since collectors are not generally recognized as inventors, the collector will receive a separate “collector’s share” (5%) and the

remaining (the largest) share (50%) will be distributed to a conservation fund in the area of the collection of the country of collection.

It is important to realize that the probability that this or any other ICGB project will discover and develop a commercially viable drug is quite small. For example, it is estimated that it may require the evaluation of 50,000-100,000 compounds in order to obtain a single marketable drug (Kuhlmann, 1997). Not all leads will produce a drug; nearly all (49 or 50) of the compounds that show promise at an early stage in the development process will fail when evaluated in a more advanced animal model. Therefore, the real benefits from this type of collaborations are in the collaborative interactions established among the participating countries, the databases developed as a result of the project, the technology transfer and the training of students and faculty through active exchange programs.

COMMUNITY DEVELOPMENT AND BENEFIT SHARING

An important objective of this ICBG program was to promote local responsibility for the conservation of biological diversity. In particular, we were interested in deriving products from ecologically healthy, diverse habitats that will enhance the well being of the local people, as well as benefiting humanity generally. If an industrialized product is developed from plant material, the community from which the plant sample originated will have priority in producing raw material from in situ populations, if management allows a sustainable production. Cultivation of commercial crops in the priority community will be necessary if the natural population cannot sustainably produce sufficient material, as is very likely. Hence, the local community will benefit economically by additional jobs and tax revenue as well as by conserving the natural habitat.

This ICBG was actively involved in community work at the request of source country schools, local communities, agricultural extension stations, and non-governmental organizations. Regular training workshops were provided on conservation of native plants to elementary and high school teachers and students as well as farmers and medicinal plant collectors and processors.

Many local communities became involved in the use of, and in the production of, herbal remedies. The Mexican and Chilean Health Departments (Ministerios de Salud), for example, are continuing the process of enforcing national regulations requiring the registry of these products. Such registration includes a monographic study of the botany, ethnobotany, chemistry, pharmacology and toxicology of each plant ingredient. The first effort in this direction was published in three monographs by our project and others are to follow (Pena et al., 1998; Montenegro et al., 1999, 2001).

Environmental trust funds have been established in each host country in order to administer any royalty that could be generated by products derived from this project. In addition, we continue collaborating with advisors of the Argentinean, Chilean and Mexican Senate's commissions that are drafting legislation on access and benefit sharing of biological resources.

CONCLUSIONS

This summary used the Latin American ICBG program to illustrate a particular framework developed for research into drug discovery from natural products derived from medicinal plants of mostly xeric environments, biodiversity cataloging and conservation as well as economic development. As such, this ICBG has been specifically designed for the existing scientific, technological, cultural, geographical, legal and technological situations in Argentina, Chile and Mexico.

From our direct participation in the ICBG efforts in search for biologically active agents from terrestrial plants, we can conclude that such an endeavor is a very complex process that requires the involvement of not only scientific expertise, but also expertise in a variety of human activities including diplomacy, international laws and legal understandings, social sciences, politics, anthropology, sociology and knowledge of local language and culture.

In the long term, this project has built institutional and international relationships between the U.S. and developing countries that will continue to grow beyond the life of the project and will serve as an effective model for others who seek to develop similar relationships.

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Partnering in China: A Case History

Barbara Couture

Senior Vice Chancellor for Academic Affairs, University of Nebraska-Lincoln

Partnering with China to meet academic objectives is almost a given, although less than a decade ago it is unlikely that most American research universities would have made this claim. In this brief report, we outline reasons why it is crucial for them to do so, and cite particular reasons that lead the University of Nebraska—Lincoln to pursue academic partnerships with Chinese institutions, focusing on elements that have lead to our success, in particular, with Xi'an Jiaotong University.

Why China?

China is the most rapidly changing economy in the world—a fact that no institution, private or governmental, can ignore. The social, political, industrial, and ecological impacts of China's rise are world-wide and affecting us nationally. In the summer of 2008, at the G-8 economic summit alone, news commentators who have generally focused on U.S. economic leadership were bubbling with claims that the summit simply was ineffective without China at the table. And, of course, expectations for China's leadership have heightened following Beijing's highly visible—and some would say unsurpassable—success with the summer Olympics.

In addition to national worries about China's dominance, in the U.S. each of our states has also taken notice of China's rise and, in some cases, this has led to economic growth for industries stoking China's economic engine. Nebraska is no exception; not only is China a trade partner, but it also is one of the fastest growing importers of Nebraska products. Though our exports are small comparatively, they increased from $51M in goods to China in 2000 to $187M in 2007, making China the 4th largest importer of Nebraska goods after Canada, Mexico, and Japan. Of interest to us at the university, Nebraska's top exports are in the areas of Processed Foods, Machinery Manufacture, Crop Production equipment, and Transportation Equipment—all industries which parallel expertise at the University of Nebraska in agriculture, biosciences, and engineering.

But beyond China's importance to our economy and its reliance on our research universities to fuel innovation, China poses tremendous potential as a source of new university students. With 1.3 billion residents, and 20% of the world's population, China's post-secondary education system cannot meet the growing demand for services; services that can be provided, in part, by American

universities. Chinese universities are now at full-capacity, and the demand for college education is woefully unsatisfied.

Just 28% of qualified Chinese high school graduates can enroll in Chinese universities/colleges—there simply are not places for the rest. China, at present, has fewer than 1000 universities and 9.5 million potential freshmen. Only 2.7 million have hopes to enroll. Although universities are rapidly expanding on the mainland, the gap in demand and supply at this time poses a potentially huge opportunity for American higher education, especially for those universities in states where population is dwindling and concerns about future university enrollment dominate.

And why not?

Yet with such seemingly boundless opportunity can also come great risk. Higher education today is rife with examples of failure in China. In 2006, *The Chronicle of Higher Education* reported that more than 700 foreign academic programs were operating in China. Kermit Hall, interviewed for an article on the topic and who was, at the time, president of SUNY Albany, said prophetically about this boom in academic programming: "China is clearly the Klondike of higher education at the moment." *The Chronicle* reported then that both the demand for education and the potential for profit in China were enormous. Successful programs cited then included the University of Nottingham, the University of Maryland and UT-Arlington.

Two years later, *The Chronicle* presented a more sobering picture, reporting a near scandalous review of the Missouri State University partnership with Niaoning Normal University. MSU was unable to recruit professors from Missouri to teach in the branch campus they established, students who attended classes there were ill-prepared, especially in the English language, and cheating among students was rampant. In addition, the facilities at the institution were poor, and students reported typical classes of about 100 students with little interaction, many taught by distance education, with only a facilitator on site.

Much of the criticism of American academic programs in China was linked to inadequate investment. Faculty members hired to teach in the MSU program at Niaoning earned about $13,680. By contrast, the U. of Nottingham's program in Ningbo paid professors $40,000 a year, plus a housing allowance, a salary comparable to those we might expect for lecturers and some assistant professors in the United States. But aside from a lack of adequate investment, the MSU failure also illustrated a lack of articulation of the value, meaning, and purpose of the academic partnership, an articulation that we will argue here is crucial to success of programs established.

What does it take to "partner"?

Certainly adequate investment is important for any quality enterprise, but in the case of partnership programs equally important is a solid, open, and well-articulated partnership between the cooperating institutions. To illustrate this point, we focus here on two of UNL's marquee partnership programs with Xi'an Jiaotong University (XJTU):

- The UNL Confucius Institute offers Chinese language and cultural education to Nebraskans

and serves as a cultural bridge for business and industry.

- Our partnership degree program with XJTU City College (an affiliate of XJTU) invites qualified selected students at XJTUCC to take 2 years at their home institution (XJTUCC), including English taught by a UNL faculty member and then transfer to UNL as 3rd year students, where they will complete their coursework and earn a UNL degree.

The success of both of these programs was born of our attention to the core meaning of "institutional partnership." For us at UNL it boils down to this principal: Collaborators work together; partners build together. Partnerships require complete trust and faith in the future success of both institutions through forwarding the partnership. Like happy marriages, good institutional partnerships require not only upfront work to ensure a happy union, but also attention paid to how partners are working together on a regular basis. Institutional partnerships also require deep "family" connections on many levels, from president or chancellor to chief academic officers; to research officers, faculty and support staff; and to public relations personnel, student affairs officers, and events staff. All personnel associated with partnership need to first and foremost understand their roles in securing the partnership; these individuals' commitment to those roles will assure that the partnership is institutionally grounded. And, like all happy partners, they also will feel committed to celebrating its success.

In pointing to our case study partnership with XJTU, we focus here on seven strategies that can lead to a partnership with a foreign institution that succeeds:

- Assure institutional compatibility
- Build on existing relationships
- Recruit institutional brokers
- Make and honor agreements
- Create a physical presence
- Develop a shared story
- Practice patience

1. Assure institutional compatibility

Both UNL and XJTU are similar, though obviously different. We house about the same number of students and we both are located in the middle of our nations. We share similar values: Love of farmland and agriculture—typical "midwestern" values for straightforward talk and hard work. Both institutions also share distance from the nation's capital. We were amused by a remark of XJTU's president, who, on a visit to UNL, remarked on our similar relationships to our nation's capitols—just as we feel some freedom from Washington's dominance being in the middle of America, they also enjoy a bit more relaxed atmosphere because they are far enough from Beijing! UNL and XJTU are both strong comprehensive research universities; they are national universities with strong regional presence and sensibilities. Also, similarly, both institutions have a research ambition to "catch up" to east coast universities (Harvard for us, Beijing U for them). Noting these similarities has helped forge a common bond across institutional officers.

2. Build on existing relationships

Xi'an Jiaotong University was not a stranger to UNL. Individual faculty members had established research relationships with the university which had grown, in some instances, to study abroad programs for our students. Prior to establishing the Confucius Institute and our partnership degree programs we had sent students to study at XJTU in the summer, accompanied by professors in business and engineering, and several professors of engineering, business and math had on-going research relationships with colleagues at XJTU. In fact, it is these pre-relationships that have strengthened the partnership as we established new programs. Faculty and staff who travel to China often "hook up" with friends and colleagues of those who have made previous trips to the institution, widening the circle of those engaged in keeping the relationship strong.

3. Recruit institutional brokers

We cannot emphasize enough the importance of having colleagues aboard who have a personal commitment to securing the partnership and doing all things—big and small—to maintain connections between institutions. We established a "special assignment" post as Director of Chinese Initiatives for Dr. David Lou, a professor of Mechanical Engineering at UNL. Professor Lou was born in China, is now a U.S. Citizen, has resided in the U.S. for decades, and has a long and successful history as a professor and administrator at UNL. His passion for the projects, his knowledge of Chinese and Chinese culture, and his dogged enthusiasm has kept us on track. He served as an institutional advocate who understood how best to work with our partners and also how to make UNL's existing systems work with China. Furthermore, he apprised us of numerous important steps to establishing the relationship, including work with the Chinese embassy in America, contacts with specific administrative offices at XJTU and other Chinese universities, and protocol for visitations. When we established the Confucius Institute at UNL, Dr. Lou was our natural choice to direct the program.

Our chief partner institutions, XJTU, also has assigned superb "institutional brokers" who provide the same services to UNL. Susan Song, Associate Director of International Programs, and Zhenping Feng, Director of International Programs, and their colleagues at XJTU are our partners' "go to" folks for all matters of concern from drafting international agreements, to assuring that UNL colleagues and students visiting XJTU are safe, happy, and well-fed.

4. Make and honor agreements

Gone is the time when a simple Memorandum of Understanding was all we needed to be off and running in arranging faculty and student exchanges, filing away the fancy document signed with a flourish by chancellors and presidents. Although the traditional MOU that establishes a friendly relationship certainly plays an important part, increasingly agreements must cover much more if academic and research partnerships are to succeed. All agreements must be in writing and they must be thoroughly understood. But equally important, the agreements must point to mutual benefit of both partners.

At UNL, we are now "rethinking" the way we handle international agreements, placing them into two categories: those which involve standard MOUs and often a limited relationship between a faculty member or a department and a researcher or a program at another institution, and those that are more complex, leading to—perhaps—joint degrees, technology transfer, or economic development. We are revamping our procedures for reviewing international agreements, expanding required reviews to include, in some cases, our business office, our technology transfer office, legal counsel, and others. And we have established an International Programs Advisory Committee which is charged to advise us on general criteria for establishing such complex relationships. For instance, we want deep partnerships to advance our core values, to increase academic quality, and to increase our visibility as an international university. In the case of academic programs, we want them to increase and enhance student enrollment; our research programs should advance research quality and opportunity for economic investment.

For both the Confucius Institute and the Partnership Degree program we drafted multiple agreements, first outlining a vision for the programs and later going into finer detail. These agreements were reviewed by our international programs office, our deans, vice chancellors, student affairs officers, and other officers as appropriate. At XJTU they were reviewed by their international programs office, by their academic officers and president, and, in the case of the Confucius Institute, by Hanban, the Chinese government educational agency promoting Chinese language and culture, and the Chinese embassy.

The agreements had to address mutual expectations on some fairly fundamental issues, such as budget and who pays for what services, timelines for delivery of students or programs, and ways to "exit" the agreement, if necessary. At UNL always the expectation was for deep connection of the partner institutions with academic programs, and XJTU followed suit. We have found that we go back to these initial agreements again and again when we have questions about what we have invested or what expectations may or may have not been met.

5. Create a physical presence

For both of our signature programs with XJTU, our primary investment is at UNL, but we have a physical presence at both institutions. For the partnership degree program, we are recruiting freshman and sophomore students at XJTU City College, in China, who will come to UNL in their Jr. year. XJTU CC is an affiliate institution with XJTU; it enrolls students who have applied to XJTU and for whom there is not room in programs offered on the main campus. The primary UNL contacts for our student recruits at XJTU CC are an English instructor, hired and paid by UNL, who receives two weeks of intensive training at UNL on our systems and procedure and an office manager, who resides in a program office on the XJTU City College campus. Both personnel are crucial to success of the program: Our English instructor was

hired in an international search and we were fortunate to find a qualified candidate who had attended UNL and knew and loved Nebraska. Our on-site manager has become one of our greatest recruitment assets. We initially thought we'd rely on our English instructor to advise our students, but her office is distant from our institutional office space, intentionally so, as we felt it important for her to be located with other English instructors on the campus. Our highly capable and enthusiastic UNL office manager soon became the go-to person who served as a point of contact for students, potential students, parents, UNL and XJTU. She has arranged parties for our students, helped them make connections by internet to our campus, and developed a sense of "school spirit" among the recruiting class. This summer we invited her to spend three weeks on the UNL campus where she became more involved with student affairs personnel and more knowledgeable about life in Lincoln.

Although a permanent UNL office space would seem not be absolutely necessary for this program in China, it has become so. Our UNL office is the Nebraska home for these students before they come to the U.S. Our office space in Xi'an is filled with UNL flags, posters, photos, and a good internet connection where students can view our website. Although UNL paid for incidentals, our Chinese partners have provided the space, furniture, computers and phone lines.

At UNL, we have created a dedicated space for our Confucius Institute, with a front office, an office for our Director, Dr. David Lou, two faculty offices, a conference room and a library. As part of our Confucius Institute grant, Hanban has provided us with an extensive library of Chinese language books and XJTU has generously provided artwork for the space.

Most important are frequent visits by university officers and faculty to each institution. When this article is printed, I will have made my fourth visit to China in two years, and my third to XJTU. Dr. Lou visits nearly monthly, and more than a dozen other UNL representatives have visited, including a political science professor who, with her family, is doing a sabbatical in Xi'an; the chancellor, our vice chancellor for research and economic development, numerous faculty and deans, admissions representatives, and others. We bring UNL students to Xi'an each summer for cultural programs and classes in business and engineering, and these students are encouraged to meet with our XJTU CC student recruits and give them a personal, face-to-face introduction to student life at UNL.

Our XJTU partners are equally committed to a physical presence, and bring XJTU students to UNL for English classes and cultural tours. Susan Song has spent several months with us, assisting with summer programs for our Confucius Institute and learning American administrative practices; and we have with us year-round two Chinese teachers from XJTU who teach non-credit Chinese language classes for children and adults, associated with Confucius Institute.

For our Chinese partners and for us, USA/China has almost become a

"commute." We are careful to plot out the purpose and outcomes of all of these trips, and, too, we are mindful of our travel budget. That being said, we cannot over emphasize the importance of this kind of investment in mutual exchange to the success of the partnership.

6. Develop a shared story

UNL and our Chinese partners have shared expectations and goals, articulated up front, which continue to help drive decision making. Our immediate goals were to take advantage of the Chinese Government's eagerness to launch Confucius Institutes and to increase our undergraduate student enrollment through a partnership degree program. We worked consistently to achieve these mutual goals. Furthermore, we developed a common narrative about what was distinctive about our partnership, which highlighted the detailed involvement and commitment of university officers, faculty members and staff at several levels in the organization, from the moment of deciding to partner to developing the full-fledged programs of the Confucius Institute in Lincoln whose programs serve UNL students and Nebraska communities, and degree completion program for Chinese undergraduate students coming to UNL in their junior year to complete a variety of majors.

We found it very important to celebrate together beginnings and anniversaries: The dedication event for our Confucius Institute was enriched by a group of 18 student musicians from Xi'an Jiaotong University, who played a concert of traditional Chinese music the day before the event and also played at the event. As our first year progressed, we used several on-going occasions to feature the partnership. For instance, many faculty and administrators were accustomed to attending UNL's annual Chinese New Year festival, sponsored by our Chinese Student Association, which typically sells out months in advance and attracts 800to 1,000 people. We linked this event to the Confucius Institute, and as chief academic officer, I opened the event, speaking a few words of Chinese which I learned in one our non-credit courses offered by the UNL CI. This small gesture was received with overwhelming enthusiasm. A University Communications video production team taped the event and created a video segment for our "Real Nebraska" series, which is an ongoing student recruitment project. The resulting segment was downloaded to computers used by our students at XJTU CC and received with great enthusiasm by our student recruits there.

We also have used numerous occasions to feature our shared values, and, too, to demonstrate that we were forming a "mutual admiration" society, an important step toward stabilizing the partnership. Here are some UNL examples: When attending the 2nd Annual Confucius Institute conference, held in December in Beijing, we met our partners there and attended every event with them. We also took the opportunity while there to visit XJTU, several hundreds of miles away. At the conference, officials from other institutions and Hanban remarked on the visible strength of our partnership, something that wasn't as apparent

among other university representatives and their Chinese partners. The following February, UNL's Chancellor Harvey Perlman invited President Zhen of XJTU to give a talk on higher education at UNL, to which we invited all deans, Vice Chancellors, faculty and students to attend; similarly, XJTU has invited me and Chancellor Perlman to attend XJTU and where we will speak to their faculty on higher education administration. (Incidentally, Chancellor Perlman challenged President Zheng to a ping pong match—little does he know that Perlman was a high school champion!)

Finally, we have taken numerous opportunities to develop and publicize shared leadership. For the UNL Confucius Institute we have developed a shared governing board, including the UNL chancellor and XJTU President, chief academic officers, our director and associate directors, and external supporters; for the partnership degree program we have developed a partnership team of university personnel in the U.S. and China who keep in contact by e-mail and a blackboard site. We have developed a website for the Confucius Institute and frequently publish updates on on-going activities in newsletters campus-wide and in the Office of Academic Affairs; XJTU conducts a series of similar publicity efforts on their campus and the campus of XJTU City College as well.

7. Practice patience

Team efforts require patience, and international partnerships are no exception. Along with the usual challenges of working together, we have had various technical difficulties that have worn the patience of our professional and support staff. Visa difficulties are the norm: For the opening ceremony of the Confucius Institute, the student band had difficulties obtaining their U.S. visas and also were delayed due to weather/airline problems.

We have had difficulty getting work visas for on-site staff, as well; in addition, these matters have strained the patience of our international programs staff. We have been lucky to find excellent teachers, both to send to China, and to teach Chinese at UNL. Professor David Lou was a key player in ensuring that this occurred. We extensively interviewed all candidates on both sides. In the case of the Chinese teachers who came from XJTU to teach here, Professor Lou watched them teach English-speaking students in China before recommending them to us.

And finding suitable housing for staff is also difficult: Again, our institutional broker, Professor Lou, was of invaluable assistance. He secured off-campus housing for our Chinese teachers in Lincoln and helped secure suitable accommodations for our English teachers in China as well. Having someone to really pay attention to these comforts for visitors here and abroad was crucial.

For the partner degree program, we had assumed we would have syllabi translated into English to work from. Although our partner institution worked diligently to produce them, inconsistency in format and various translations for a single course title (e.g., Are English I, Freshman English, First-year English all the same?) have tripped us up. And, too, staff have felt burdened

by the extra attention required to address these details. Group meetings in which we have stressed the importance of all of us committing to the success of the partnership have helped keep staff on course.

Communications of all sorts have required interminable patience. We discovered that our first and second year students in China are not allowed internet access in their dorms. Our office manager there has helped them find access in labs and other sites. Although the internet can be "immediate", the 13-hour time difference is frustrating when decisions must be made quickly. Also, the detail required for proper attention to ceremony and ritual is significant and necessary to keep communications friendly and on track. Our Chinese partners were much more attuned to this than we were; we have had expectations for social involvement that surprised us. Each UNL staff member who has visited our partner institution has been asked to deliver numerous little "talks" and presentations on how things are done at our university, for instance, in addition to attending a seemingly endless spate of banquets and luncheons. And we make the most of genuine and intense social interactions. Face to face time is critical and needs to be maximized—and this goes a long way toward easing strained relationships. When we were wooing Hanban to win a Confucius Institute for UNL, we wined and dined, but we also took the time to express our genuine commitment to each person who visited us from the Chinese embassy, XJTU, and Hanban. The Hanban representatives' officials from the Chinese embassy were impressed by this, and, frankly, we moved ahead of a competition on the list directly because of the success of these interactions.

At UNL, we have involved everyone from the Chancellor to the Admissions Office to the Budget office to "make things work." We have found it necessary to have involved from the get-go folks in the institution who understand how to recruit, what the needs of undergraduate students are, who can plan events, who have publications in hand; equally important are ESL specialists, career services personnel, writing specialists. As we have said several times over, the partnership has been an exercise in team-building.

Paying attention to costs is also critical. The declining dollar has meant that things are costing more than we anticipated and budgeted. For our partnership degree program, we are not expecting a "payout" or even breaking even for two to three years. Yet at the same time, unexpected benefits have developed. What started as an academic partnership is now extending to a research partnership. In October 2008, we hare holding a two-day conference at XJTU featuring research faculty from both institutions who will talk together about ways to collaborate and partner to secure national and corporate funding for their international research.

Conclusion

Partnering with China can be rewarding and beneficial for research universities here and in China. The benefits to UNL have been visible and immediate. We have extended cultural diversity on our campus, adding a Confucius Institute that provides non-

credit culture and language classes. We are in the process of adding a China Studies concentration to our curriculum, and we have greatly expanded efforts to engage in international activities—we are quickly becoming a global campus. The presence of the Institute also has led to our revival of Chinese language study for credit. When all our partnership degree plans with XJTU CC are fully realized, we will add 500 new Chinese undergraduate students to UNL each year. Because we are under capacity in our undergraduate operations, this means a substantial increase in tuition revenue as well as an economic boost to Lincoln. We have now institutionalized the partnership, involving nearly every office of the university, insuring that it will grow and outlast the original players. And we have significantly increased faculty and student interest in study abroad to China; four separate trips were scheduled for faculty and students in 2008 and more are on tap. Furthermore, we have extended the academic partnership with XJTU, using similar methods and procedures, to another major Chinese university near Shanghai and have started a research partnership there as well.

This case study, as a single instance of collaboration, has been filled with anecdotal detail, but, as we have said many times here, it is attention to this detail that has insured the success of our university-to-university partnership. We hope our experience provides useful information for others who hope, like us, not merely to collaborate but also build together through international partnership.

The Tribolium Genome Project: An International Collaboration

Susan Brown
Professor of Biology
Kansas State University

Global collaborations come in all shapes and sizes. Some are mandated federally, others as new initiatives of institutional administration, and still other by researchers linked by a common need or interest. Large-scale projects are the mainstream in high-energy physics, but are not so common in the field of biology. The large data sets produced by genome sequencing projects, which requires many different types of expertise for comprehensive analysis, have spurred the formation of global collaborations that are highly interdisciplinary. The Tribolium Genome sequencing consortium is an example of such a collaboration. As large scale data analysis enters the mainstream in the biological sciences, more such global, interdisciplinary groups will form and strengthen all the institutions involve. These international collaborations also strengthen the interactions between our regional institutions, and raise all involved to a new level of competitiveness on a global scale.

Introduction

The genomic sequence of a eukaryotic organism provides a wealth of information, but, to be useful, the sequence must be annotated with additional information such as the location of genes, and chromosomal landmarks. In today's research world, it takes an international consortia of scientists to organize their efforts: first to justify a genome sequencing project, and then to coordinate the annotation efforts once the sequence is in hand. Computational and manual annotations are combined to provide an initial analysis of the genome, which is released to the public in several forms: published reports, specialized databases and websites, and national databases. In the following narrative, I describe the efforts of the International Tribolium Genome Sequencing consortium, from white paper to publication in the journal, *Nature*, to sequence, assembly and analyze the genome of the red flour beetle, an insect model for developmental genetics and pest biology. Interactions between consortium members have lead to several federally and internationally supported projects, some of which continue today, past the formal conclusion of the genome sequencing project.

Why sequence the genome of a flour beetle?

With the completion of the first draft of the human genome in 2001, the

National Human Genome Research Institute (NHGRI) considered white paper requests to sequence additional genomes that would provide insight into the function and evolution of the human genome. The relatively small genome of the fruit fly, *Drosophila melanogaster* had already been sequenced as a proof-of-concept for the whole genome shotgun approach to genome sequencing. We proposed sequencing the genome of the red flour beetle *Tribolium castaneum*, a world-wide pest of stored grains. Sequencing of the honey bee and the silkworm moth genomes were already underway; with the addition of Tribolium, we would have representative genomes from the four largest orders of holometabolous insects, those that develop as worm-like larva and pupate into winged adults, both of which can be agricultural pests and/or beneficials. Over the past two decades, we have developed several molecular and genomic tools for Tribolium including balancer chromosomes and genetic maps, as well as transformation and RNAi methodologies. As a result, the red flour beetle is now the third best invertebrate model organism for genetic studies of development, physiology and toxicology after Drosophila and the free-living nematode, *C. elegans*. In addition, Tribolium is the first mandibulate insect (a chewing rather than sucking insect) recommended for genome sequencing. Furthermore, sequencing the Tribolium genome provides our first insight into a Coleopteran genome, and there are more species in this order than in any other.

Several research groups, predominantly in the US and Europe, use Tribolium as a model system in which to study the genetic regulation of development; Evo-Devo studies. Our understanding of insect development is largely based on genetic studies conducted in fruit flies. However, their development has become highly specialized as they adapted to the specialized niche of rotting fruit. The red flour beetle is also specialized in its own right, but displays many traits shared by lower insects and other arthropods. It is the supposition of Evo-Devo researchers that these traits as well as their genetic regulation are likely to be ancestral features. For example, the fly larva hatches from the egg as a headless, limbless maggot, while the beetle larva emerges with a true head equipped with eating appendages adapted for chewing and antennae and a thorax equipped with three pair of walking limbs. Development of fruit fly body plan is quite specialized; all the segments of the body are produced simultaneously by a hierarchy of regulatory gene interactions. In most other insects and arthropods, segments are added on at a time at the posterior end of the embryos, more like somite development in the vertebrate backbone. Analysis of the Tribolium genome was expected to provide insight into developmental studies in both fruit flies and vertebrates.

Genome sequencing projects require funding from multiple sources

Academic, industrial and federal agencies contributed to the Tribolium Genome project. Our rationale for sequencing the genome was explained in a white paper to the NHGRI, which included letters of support from across the breadth of the scientific community.

The white paper was formally approved by the NHGRI in Sept 2003. Soon thereafter, we started working with the Human Genome Sequencing Center at Baylor College of Medicine to generate the sequence data and assemble it. With the completion of the human genome sequence, this center has focused, in part, on insect genomes including two other Drosophilid species and Honey bees. The USDA provided funds to jump-start the sequencing efforts. As part of the Tree of Life project, the National Science Foundation supports distribution of Tribolium BAC library (Bacterial Artificial Chromosomes contain large fragments, ~350 kb, of genomic DNA), which was constructed by Exelixis, an integrated drug discovery and development company in South San Francisco and is currently archived at the Clemson University Genomics Institute. The Kansas INBRE and the KSU plant Biotech Center supported our efforts to obtain Expression Tagged Sequences (ESTs) and the KSU Arthropod Genomics Center supports Beetlebase, the community resource for information about the Tribolium genome.

We supplied a few milligrams of beetle eggs, and after several small sequencing runs to verify sample quality, the HGSC at Baylor required less than one month in the Fall of 2004 to deposit 1.8 Gb of Tribolium genomic sequence in the Trace Archives at the National Center for Biomedical Information (NCBI). As with every new genome sequencing project, the raw, unassembled sequences provided researchers around the globe with a rich resource from which to piece together specific genes of interest to them. However, once the raw reads were assembled into contiguous sequences representing large regions of the genome and organized into scaffolds representing the chromosomes, (which required several months) it was time to annotate the genome, associating gene structure and function with different regions of the genome.

It takes a global village to annotate a genome

Computational analysis of the genome revealed more than 16,000 gene models. A subset of these needed to be manually evaluated to determine the quality of the genome sequence and the value of the computer generated gene models. More than 100 scientists from 67 institutions world-wide provided the initial analysis of the Tribolium genome. Some of the scientists in the group who used Tribolium as a model system analyzed genes or pathways directly relevant to their research. Others, interested in genome architecture or gene families and gene evolution, were delighted have another dataset to complement their previous work and joined the foray. Manual curation efforts were largely voluntary as federal agencies have chosen (wisely) not to fund additional genome annotation projects beyond those already established for the most important model organisms. The enthusiasm of the group waxed and waned as we discovered just how tedious genome annotation can be. However, excitement was maintained throughout by weekly conference calls during which one group would report its progress to the others. The difficulty of scheduling conference

calls that span the globe was surmounted by holding the calls on Wednesday mornings at 9 AM. This turned out to be a convenient time during morning coffee break for those of us in the Midwest and late afternoon tea for our European counterparts, but colleagues in Japan, India and Australia had to forego a good night's sleep to join in, and even our California colleagues had to wake with the dawn to participate.

The final report, published in the April 24 issue of the journal *Nature*, was truly a collaborative effort. Most of the detailed information in the first draft was relegated to more than 100 pages of supplementary data as we were required to restrict the paper to briefly describing the highlights. More than 25 companion papers were written and complete issues of two different journals were dedicated to our description of the Tribolium genome. There were many surprises to be found in the genome sequence. For example, comparing a large set of conserved proteins resulted in a new phylogenetic tree, placing honey bees, instead of Tribolium, at the base of the holometabolous insects. Second, several genes, conserved in beetles and vertebrates, but not found in fruit flies, were added to the list ancestral genes. We also found that beetles contain more p450 detoxifying proteins and orderant receptors than any most other insect analyzed to date. These finding have brought up new perplexing questions, such as trying to imagine why a beetle that prefers caches of grain stored in dark, dry environments, needs a more finely-tuned sense of "smell" than a honey bee foraging in a meadow.

The future of genome sequencing projects

The first wave of genome projects was federally funded and their progress was followed in detail by the entire research community, as befitting a new research paradigm. The second wave of projects was also justified by white papers. With the advent of new sequencing technology that greatly reduces the price of obtaining the sequence data, genome sequencing projects are now in the realm of individual research grants. Soon a genome sequence may be considered preliminary data for a research project grant, and some even speculate that in the not too distant future, it may rest within the purview of a Master's level research project. Even when it reaches this stage, sequencing the average eukaryotic genome will be an international collaboration, uniting researchers world-wide, through their interest in the next genome.

An International Initiative in Biomedical Research Training

Salvatore Enna

Associate Dean for Research and Graduate Education
University of Kansas Medical Center

One stimulus for internationally coordinated educational programs is the need to preserve fundamental research technologies that might otherwise be lost. Such is the case for integrative and organ system pharmacology (IOSP). A sub-discipline of pharmacology, IOSP encompasses techniques critical for the identification and development of new drugs. Included are methods for defining the effects of chemical agents on isolated organs and organisms. Described in this article are the historical reasons for the decline in academic IOSP research and training, the implications for the loss of expertise in this area, and national and international efforts undertaken to preserve the skills necessary to conduct experiments in isolated tissues and intact animals.

Evolution of Drug Discovery

The identification of substances that relieve pain and suffering has been ongoing since at least the appearance of *Homo sapiens.* For most of the past 200,000 years, drug discovery was an empirical enterprise (Fig. 1). Thus, if an ancient obtained some symptomatic relief (efficacy) of an ailment while dining on a particular animal or plant, and survived (safety) the experience long enough to relate this finding to others, curative properties might be attributed to that particular meal. If, over time, his neighbors reported similar findings, the item would become a permanent part of the therapeutic armamentarium. Thus, paleo drug discovery was a linear process, with all experiments conducted in humans, and the only endpoints being efficacy and safety. While random, slow and cumbersome, and fraught with many false positives, there are therapies still available today that originated from this approach. Included in this group are the salicylates, opioids, cardiac glycosides, gold salts, and ergot alkaloids.

Modern drug discovery began in the 19th century as a result of advances in chemistry and physiology (Fig. 2). The ability to purify plant and animal extracts, and to characterize chemical structures, made it possible to identify the active constituents of natural materials that display medicinal properties. Moreover, the synthesis and testing of chemical analogs of these substances made possible a systematic classification of drugs on the basis of their chemical properties and physiological effects. This in turn

allowed for the design and execution of the hypothesis-driven experiments needed to begin defining drug mechanisms of actions and the pathophysiology of disease. This approach to drug discovery lasted for approximately 100 years. It is termed the Physiological Period (Fig. 2) because the biological testing of old drugs and new chemical derivatives almost exclusively involved the use of isolated organs and intact animals. This work established the methodologies and principles of IOSP.

By the mid-20th century it was clear that drugs exert their effects by interacting with biochemical pathways, and that the physiological and clinical responses to these agents result from effects at the cellular level. This led to a shift in emphasis for drug candidate testing from physiological to biochemical systems. Besides being less costly, biochemical assays make possible the screening of hundreds of chemicals to quickly identify those with the most promising mechanistic profiles before advancing them for analysis in the more time-consuming, and laborious, physiological and behavioral tests. This era, the Biochemical Period (Fig. 2), was the favored approach for a generation.

Towards the end of the 20th century, advances in molecular biology opened new avenues for drug discovery. As it was now established that most drugs act by attaching selectively to receptors or enzymes, artificial systems could be constructed using cloned genes to express a desired target, and thousands of compounds assayed rapidly for their ability to interact with the site (high

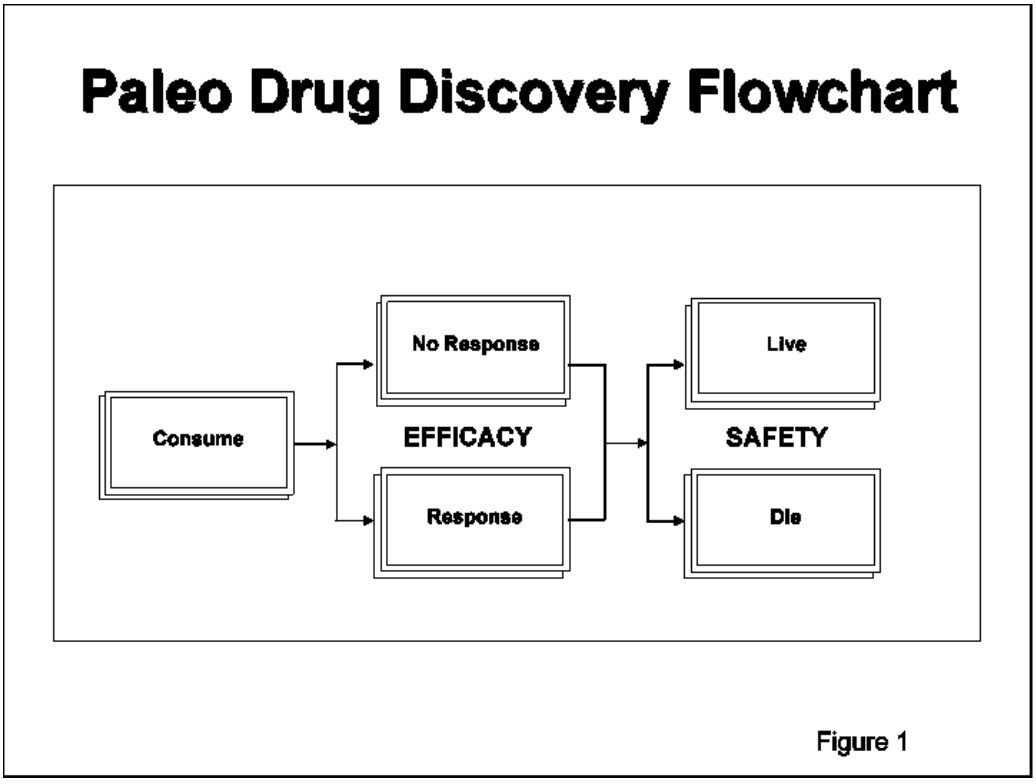

Figure 1. The drug discovery process in the prehistoric world.

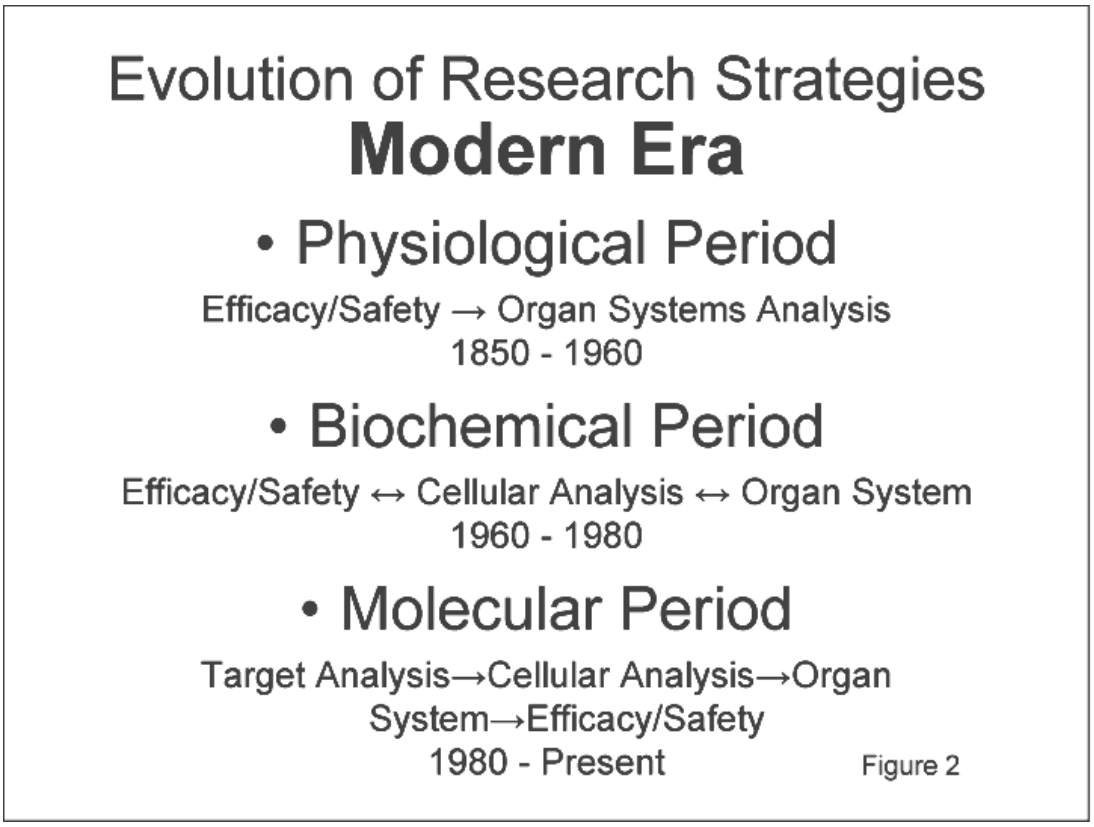

Figure 2. Categorization of predominant drug discovery techniques in the modern world.

throughput screening). Identified leads are then examined in biochemical assays to ensure they affect cellular function, after which they are tested in organ systems and intact animals to determine whether they are safe and display pharmacologically meaningful effects. Thus, the Molecular Period (Fig. 2), which began in the 1980's and extends to the present, is characterized by a shift in the initial objective of drug discovery from first identifying agents that display efficacy and safety, and therefore likely clinical activity, to first identifying agents on the basis of their target selectivity, which may or may not ultimately prove to be of any clinical benefit.

Decline in Organ System Training

Changes in the approach to drug discovery reflected shifts in research emphasis and training in the academic community. Whereas in the 1950's and 1960's physiological, behavioral and biochemical studies were awarded the bulk of federal biomedical research funding, by the end of the 20th century research in the molecular sciences was favored. As federal support for physiological research waned in comparison to molecular studies, investigators and academic departments abandoned work in the former to concentrate on the latter. Besides slowing advances in the physiological sciences, over time this change of priorities reduced the number of faculty with interests and expertise in this area, thereby diminished training opportunities in the field (Fig. 3).

A decline in the use of laboratory techniques is not unusual given the dynamic nature of the scientific enterprise. Indeed, obsolescence is to be expected as new technologies are developed that are more efficient and make possible a more in-depth and precise analysis of the subject than older methodologies. To the extent that molecular studies are yielding the most novel and exciting insights into the mechanisms of disease and drug action, it is not surprising such work is generously funded and that students are interested in pursuing careers in this area. However, while IOSP techniques are no longer widely employed in academic laboratories, they remain an essential part of the drug discovery and development process. Because of this, the decline in IOSP training has led to manpower shortages in the field in the pharmaceutical industry and government regulatory agencies (Fig. 3). While new recruits to pharmaceutical companies are adept at cloning, expressing and sequencing genes, many have no hands-on experience working with organs or intact mammals, a required skill for identifying drug candidates and for evaluating and monitoring new drug applications and clinical trials. It is speculated this lack of expertise and the steady erosion in the population of those capable of teaching IOSP are responsible, at least in part, for the decline in the number novel drugs reaching the market. Thus, the techniques utilized by physiologists and pharmacologists to study isolated

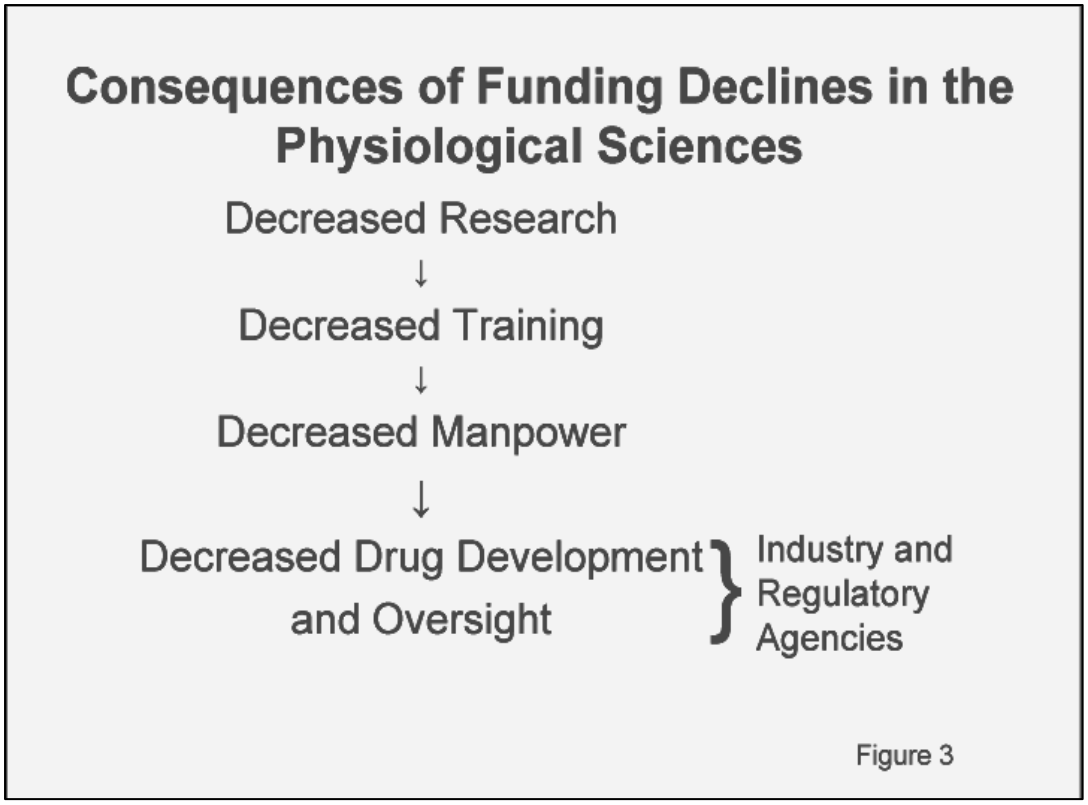

Figure 3. Sequential ramifications of reductions in IOSP-related research support.

organs and intact organisms remain relevant and important for contemporary drug discovery programs, as do the scientific principles that underlie them.

Training Initiatives

For over a decade both academic and industrial scientists and administrators warned of the consequences of a decline in IOSP training. As the number of experts in the field dwindled, the pharmaceutical industry established in-house programs, or funded courses at local universities to provide instruction in the area. The growing shortage of physiological pharmacologists, and their important role in academic and industrial research, was ultimately noted by government and private agencies. Following meetings with representatives of the pharmaceutical industry and of professional organizations, such as the American Physiological Society and the American Society for Pharmacology and Experimental Therapeutics, in 2004 the United States National Institutes of Health (NIH) began funding short courses in integrative and organ system pharmacology. The NIH interest in IOSP is not only driven by the needs of industry and regulatory agencies, but also by the realization that such expertise is critical for transferring basic research discoveries to the clinic. For example, lack of IOSP training limits the ability to phenotype fully genetically modified animals, one of the major tools of the molecular biosciences.

Currently, the NIH supports summer IOSP short courses at four institutions: University of Nebraska, Michigan State University, University of North Carolina at Chapel Hill, and the

Table 1: Topics Covered in Typical IOSP Training Program

- Intensive Exposure to Animal Experimentation
- Training in Organ System Techniques
- Behavioral/Physiological Phenotyping
- Pharmacokinetics/Pharmacodynamics

University of California, San Diego (http://www.nigms.nih.gov/Training/IOSP.htm). Enrollees include graduate students, university faculty, and industry scientists, both foreign and domestic. Topics covered during these two-week offerings include principles of pharmacokinetics, the effects of the body on drugs, and pharmacodynamics, the effects of drugs on the body (Table 1). Much of the instruction is laboratory-based, with extensive exposure to whole animal experimentation and organ system techniques. The students receive instruction on methods for characterizing the behavioral and physiological phenotype of genetically modified or drug-treated laboratory animals (Table 1).

While this brief exposure to IOSP does not produce experts in the field, it does increase student awareness about methodologies available for undertaking such studies, and about resources for obtaining additional information. The courses also provide instruction on the ethical treatment of animals, and the proper handling and maintenance of these subjects. In addition, students are made aware of the importance of such studies for determining the clinical relevance of their work.

As drug research is a worldwide enterprise, the lack of IOSP-trained scientists is an international concern. This is especially true in those countries with large pharmaceutical companies such as the United States, the United Kingdom, France, Switzerland, and Japan. In those with a growing presence in pharmaceutical research, including China, India, and Hungary, a lack of access to IOSP skills is hindering the development of this industry and the discovery of new drugs. Even regions with little or no pharmaceutical research, such as most of the African continent and Southeast Asia, are also affected by the decline in IOSP training as it slows the development of new drugs elsewhere that are needed to treat medical conditions prevalent in these areas. While the countries with more developed research enterprises are now funding IOSP training programs, this is not the case in most of the world. To address this issue, the International Union of Basic and Clinical Pharmacology (IUPHAR) assembled a task force to assess the global need for IOSP training and to design programs to meet the demand for such instruction at strategic locations around the world. The task force is composed of representatives from Europe, Asia, Africa, North America, South America, India, and Australia. Because the type and method of IOSP training will differ among the countries in these regions, programs will be customized to meet local needs. Nonetheless, all will include instruction in specified learning objectives to establish an international standard for basic instruction on this topic.

Conclusion

As the IUPHAR program involves collaboration among academic institutions around the world, it is a prime example of a global research and training initiative. In this instance the impetus for the undertaking is provided by a practical need for specially trained scientists that requires maintaining the didactic and research programs necessary for this purpose. This

undertaking exemplifies how academia, industry, and federal governments can work together in pursuing a common goal. As an ancillary benefit, it is likely the relationships forged in establishing this program will lead to other types of international research collaborations among the participants. From these will grow a greater appreciation for the infrastructural and instructional needs of other countries. This is especially important for rectifying such deficiencies in the developing world, as it faces the greatest challenges in providing medical services and educational opportunities for its inhabitants.

International Medical Research Infrastructure: KUMC and Beyond

Paul Terranova

Vice Chancellor for Research
University of Kansas Medical Center
Senior Associate Dean for Research & Graduate Education
University of Kansas School of Medicine

A global research arena has developed since research and education are important to many nations. In fact, many of the rising economies in the world are knowledge-based and thus, technologically oriented. As indicated by Thomas L. Friedman in his book '*The World is Flat: a brief history of the twenty-first century*', the advent of the internet has enabled researchers to communicate without geographic bounds and thus research is no longer geographically restricted. Worldwide research has increased, especially in Asia. Universities world-wide are competing for the same research funds and talented students as well as the same faculty in highly competitive similar disease areas. US universities must have a global presence in order to remain competitive. It is clear that many world wide advanced degree graduates cannot find jobs in their home country. In fact, some graduate schools are less advanced and lack the means for standard evaluation. Funding for research and education are also insufficient, coupled with increased enrollment.

The topic of building academic health center infrastructure worldwide has been recently reviewed by the Association of Academic Health Centers (www.aahcdc.org/policy/meetinghighlights/spring08/index.php) and an International Forum 2008 was held in Washington, DC. In addition, a brief synopsis of global academic health centers was recently published (The Multinational Academic Health Center, AAHC, modified from the presidential address 2007 Spring Dialogues). The following is a summary of those reports.

Benefits

There are several benefits of developing an international research network. The expertise provided by the various partners will allow broadening of the research goals and technologies utilized in the research. Thus, the whole becomes greater than the sum of the parts. Additional benefits include enhancing one's competitiveness for grant opportunities and engaging new students, staff, and faculty with outstanding credentials. For clinical trials, the patient base may be increased.

Recently, Duke University wanted to extend its brand to another part of the world, Singapore's National University, in hope that this would differentiate Duke from other academic health centers and would facilitate some of Duke's research goals. Similarly, the National University was interested in increasing its prestige of academic medicine in Singapore. Thus, they developed the health workforce by specifically increasing the number of physician scientists and physician entrepreneurs in their knowledge-based health care industry. From Duke's view, the National University collaboration provided an opportunity for Duke to experiment with research and educational methods. Duke organized faculty around educational teams and signature research programs in major disease areas. The development of new models at National University allowed transfer of methods back to Duke's program in the US. Other examples, summarized at the AAHC International Forum were international collaborations with individual schools such as Johns Hopkins, Mayo Clinic, University of Toronto, and the University of Pittsburgh.

Basic Principles

International collaborations will enhance discovery, strengthen and protect research programs by integrating basic and clinical research and, where feasible, encourage translational research. One major goal is to establish long lasting relationships with the international collaborators. In establishing international collaborations high standards should be set with a solid vision including short and long term goals. Clear expectations should be evident and solid leadership is also important. The needs of each participant should be delineated and met.

Drug Discovery: Open Source Concept

International collaboration in the drug discovery arena has taken a recent turn as described in an interesting article by Seema Singh in Cell 133, April 18, 2008 entitled: *India Takes an Open Source Approach to Drug Discovery*, which is summarized below. India is launching an open source drug discovery initiative to accelerate development of new drugs to treat infectious diseases of worldwide importance. In addition, there is a need for new low cost drugs. Because drug discovery is so complex and challenging, India is establishing a web-enabled interactive open source platform that will list the current design challenges for developing drugs to treat drug resistant tuberculosis, malaria and HIV. Volunteers contribute solutions to the posted drug design challenges and microcredits are given to the contributors. Once a certain number of microcredits have been accrued, the contributor will receive a monetary award (reward).

Examples

Open source software started 17 years ago by Linus Torvalds, who developed the Linux operating system. Biologists borrowed from the Linux concept and started development of bioinformatics tools such as BioJava, BioSPice, and BioRuby as well as others. The sharing of bioinformatics know-how has paved the way for additional projects. For example, CAMBIA was launched by molecular biologist, Richard Jefferson in Australia as an

international nonprofit institute for creating new technologies and tools to enable innovation in health, food security and natural resource management for the developing world. Several spin-off were formed including BIOS (Biological Innovation for Open Society: www.bios.net/daisy/bios/about/3.html), BIOS also developed a gene transfer technology called TransBacter that can be used instead of the costly *Agrobacterium* for genetically engineering plants and Patent Lens (patentlens.net/daisy/patentlens.html) that searchers the full text of over 8 million patents and applications world wide. Patent Lens has a server that extracts DNA, RNA and protein sequences from US patents and links them to GenBank and BLAST searchers. This team is working on launching an international open innovation platform to assist searching patents filed world wide.

Successes

Several examples of open source successes exist. There has been improvement of the drug used to treat schistosomiasis. This required the drug to be enantiopure rather than racemic. Via the web a suggestion was made for the synthesis. The team has taken the suggestion and is in the process of producing the enantiopure drug. Another example includes the drugs to treat malaria. Two compounds are somewhat active against malaria. Three groups across the US participated with one group producing the docking calculations, one group did the synthesis and the other group did the testing.

Innocentive is an open source drug discovery company spun out of Eli Lilly. Users can select an R&D challenge posted by a company or a not-for-profit and attempt to solve the problem for a cash award ranging from $5,000 to $1 million. Among their successes are included new methods to synthesis fluorinated ethers, butanoic acid, and identification of new drug targets for treating Muscular Dystrophy. Currently, there are posted challenges to find a diagnostic biomarker for ALS. Lastly, Novartis has made all information about genes implicated in type 2 diabetes obtained from genome-wide association studies freely available on the web in an effort to speed up elucidation of the mechanisms underlying this complex disease. Harvard and Lund University (Sweden) are participants in this study.

Rationale and Challenges

One might ask: why use open source and what are the associated challenges? First, the goal is to help resolve key scientific and drug discovery problems with multiple inputs thus accelerating drug development/ discovery in specific disease areas. In fact, the European Union's Innovative Medicines Initiative, EU-IMI, a partnership between the European Community and the European Federation of Pharmaceutical Industries and Associations, is addressing this issue also. The open source concept allows investigators to view specific drug discovery problems and pose solutions. Solutions are proposed by individual investigators or teams of investigators from the same or collaborative institutions. One driving force for using open source is that many drug discovery problems are complex, requiring many labs for insights. Several challenges exist such as assigning appropriate credit and ownership of the

intellectual property. In addition, the timing of disclosure, protection of the discovering scientist(s), and subsequent product patent filing limitations may all be formidable issues.

KU and Beyond

The KU School of Pharmacy has a high national ranking as evidenced by their continued success with NIH funding, training of students, and the esteemed nature of their faculty. Major strengths are in the areas of Chemical Methodologies Library Design and Drug Discovery, Development and Delivery. KU also has a very solid connection with major pharmaceutical and biotech companies. Currently, Drug Discovery has more than 70 projects in the drug pipeline. This is largely due to their superb organizational structure that includes outstanding high and medium throughput screening facilities which produce numerous leads. In addition, the Office of Therapeutics and Drug Discovery has more than 100 years of pharmaceutical industry experience.

This group is further developing their translational research by securing funding from NIH, foundations, and industry in order to support biomedical and clinical proof of concept development. Whether an open source discovery program would facilitate the movement of drugs through the pipeline is uncertain at this time. However, enhancement of collaborations at the local, national and international levels is critical for future success. KU will need to further establish a system that supports entrepreneurship, rewards faculty for their drug discoveries through a traditional promotion and tenure system, and garners more investment for drug discovery, development and delivery that are all consistent with THE TIME IS NOW: a 10-year vision & strategy to advance the life sciences.

The Global Land Grant University: What Does That Mean at Mizzou?

Brian Foster
Provost
University of Missouri

My topic for today is to try to see how our land grant status has impacted our international initiatives—or, at least some of our initiatives. Like all of the universities represented here today, MU is a very complex institution with a complex mission. I'll keep coming back to the point that we're a lot more than land grant—but that land grant status impacts all of what we are. So, let me start with the question of how we are a land grant university.

MU: In what sense are we land grant?

Of course, technically we are an 1860 land grant university and all that that means. Some of the underlying ideas are robust—have changed very little. But operationally, the "land-grant" idea has changed profoundly—even since 1960.

One of the most profound symptoms of change is the urban land grant movement. It is well known that urban universities have a mission much like land grant universities. They are very strongly oriented to serving the urban society in which they are located, providing support for urban social needs through educational programs and providing services. The "Urban 13," now expanded to include more urban schools, has put forward the idea of an urban land grant program analogous to the 1860 land grant act. It certainly is true that the 1860 land grant schools' mission is not strongly fixed on urban communities, and to the extent that it is, the land grant schools sometimes seem to compete with the urban university mission. Although it is unsure what will come of the urban land grant initiative, the discussion is symptomatic of a gap in the historic land grant movement on the one hand, but an affirmation of the significance of the movement on the other.

Another symptom of land-grant change is the significant change in Extension, one of the key elements of the land grant university. Perhaps most visible, the place of agriculture in the land-grant university has changed. It is still a very prominent part of Extension, but Extension is no longer "Ag Extension" in the sense that it once was. 4-H, for example, now has very large urban programs in Missouri. At MU, distance education support is housed in Extension—a very natural fit with the Extension mission, oriented toward public service, bringing education to the broad public. Similarly, support for small businesses has become a large element of Extension at MU—

developing business plans, marketing plans, implementing IT systems, and other business functions. Again, this is very much a land-grant function, reaching out to the community in a direct and supportive way.

The point of these examples is, perhaps, that "land grant" is a mind-set. The organization has changed and will continue to change, but the mind-set is robust. Land grant is about public service. It involves cooperation with local communities. A land grant university is very outward looking. A big emphasis on bringing state-of-the-art knowledge to the public is central. Local application of state-of-the-art knowledge is a key element of the land grant university.

Having said all of this, it is important to note that the land-grant mind set is not all that MU is; it's a big piece, but it's not all there is. Even in relation to our traditional land grant constituency, MU is faced with a constant challenge of appearing elitist. We pay a big political price for this apparent elitism—a loss of the confidence of a key constituency. But even more important, we are often seen as the enemy of rural Missouri communities—or of inner-city communities, for that matter. From the standpoint of such communities, the University is an enemy in the sense that young people who attend MU are likely to get jobs outside their home—in Chicago, Denver, or other such places—abandoning home, community, church, family businesses, elder care responsibilities.

At least as important, universities are not good at communicating with the non-academic community. Academics talk in "academic speak"—a strange language that just doesn't make much sense to normal people. It's not just a matter of esoteric vocabulary—though that is a big part—but it's a cultural environment that just doesn't make sense to most people. We can't talk in a sensible way about liberal arts education—education that doesn't lead to a clear outcome like a good job. We cannot talk about research in a way that make sense to people—especially about basic research that has no obvious application. And in any case, many see the university as a home for a liberal/radical leftist faculty that violate all of their basic values.

What is "Global Land Grant" about MU?

This is an important question. Everyone in higher education is throwing around terms like "globalization," "global strategies," "international initiatives", and "global land grant." But the question is, how do these "ideas" really affect the organizational culture, structure, incentives, and real outcomes of comprehensive research universities? Plainly, what difference do these terms make?

I think the answer is "not much." You will see shortly that MU's international activities are extensive. They involve research, graduate and undergraduate instruction, Extension, and economic development. They are diffuse and deeply embedded across all colleges, and they flow from long and productive histories. Nevertheless, international programs are often marginal to the institution. They lack

continuity, organizational support, centrality and a compelling narrative to build adequate political support. In short, they are interesting, challenging, productive—but they are not a key priority by consensus! We are global—but under the radar.

Nevertheless, MU has a long history of international involvement. Consider the following.

- 1500 international students in 2007-08—about 5% of total enrollment
- Numbers are dramatically up from 2001, especially at the graduate level
- About 70% of international students are graduate students
- Students come from 100 countries, approximately 70% from China, India, and Korea
- The international graduate students are critical to the STEM disciplines
- 1,000 international visiting scholars traveling on J-1 visas
- Visitors from 60 countries, most from China and Korea
- Most visiting scholars from College of Agriculture, Food, and Natural Resources, Journalism, Life Sciences and Asian Affairs
- More than 1,100 students earned academic credit abroad in 2007-08
- This is an increase from 450 in 2000
- Growth is due to rapid development of faculty-led courses, particularly in summer and intersession
- There is especially large growth in College of Agriculture, Food, and Natural Resources (CAFNR), the Journalism School, and the Trulaske College of Business.
- Ten years ago programs were mainly in Western Europe; now there are programs on all continents, with rapid increase in China.
- MU has dual degree programs with international partners in CAFNR, Engineering, Education, Nursing, and Public Affairs in Korea, Taiwan, Russia, and South Africa.
- Agricultural Extension has programs in New Zealand, Thailand, Australia, Ireland, and in other countries.
- MU has major externally-funded projects in China (seismology and water treatment), South Africa (seismology and phytology), East Africa (development and institutional capacity building), and India (nanosciences).
- MU has active agreements with over 160 international universities and government agencies.

These international activities are extremely diverse in content, in location, in the nature of the collaborators, and in other dimensions as well. It seems that they can be grouped under four core global land grant themes at MU.

- Global citizenship
- Prepare students for cross cultural communication and professional practice…and for the pursuit of great opportunities and challenges

that can be understood only at the global level (e.g., carbon dioxide emissions, energy, poverty, immigration, health disparities, and terrorism).

- Pursuing knowledge frontiers
- As at all other research institutions, academic scholarship has become a global practice. To advance and generate new knowledge, we must be able to reach, collaborate, and compete with colleagues and peers throughout the world. At Mizzou, our work in phytology, life sciences, nanosciences, seismology, geology, ecology, psychology, public health, archaeology, visual and performing arts, and humanities is deeply embedded in institutional relationships we forge across the world—on all continents.
- Building connections (for Missouri) to the global economy
- As a public university, one of our biggest responsibilities and challenges is to serve as an engine and a catalyst for the Missouri economy. We cannot really do that in the 21st century without global reach, and without offering direct opportunities for linking Missouri constituents in the public, private, and non-profit sectors with our key international partners.
- Focusing on applications for local benefit
- The central land grant principle is to bring state of the art knowledge directly to people for application in their day to day lives. There is, thus, strong emphasis on local applications that benefit communities, families, local businesses, and other constituencies.

What the University of Missouri does to seed, cultivate, sustain, and harvest global initiatives is critical for the future of the University, the State of Missouri, and our citizens. These initiatives will be essential for recruitment and retention of the best and brightest faculty, staff, students, sponsors, and other key constituents at the University.

Not only is there a great deal going on at MU, but there is a long history of international initiatives. I can't give a comprehensive history of these activities, but it is important that we consider a sample of activities to give a sense of the diversity and continuity of international initiatives at the University.

- 100 years of the MU School of Journalism in China
- The School's first dean, Walter Williams, travelled extensively in China in the early 1900s.
- The first graduating class of the Journalism School included a Chinese student.
- Edgar Snow—very well respected—wrote key works on Chinese culture to American audiences.
- The Journalism School has remained active in China in consulting, training, and exchange.
- More than 50 Journalism students constituted a key part of the media coverage of the Olympics in China this year.

- CAFNR has for decades pursued International Development Assistance, Extension, and research (see below for current programs)
- Extensive programs in Korea in the 1950s;
- A major presence in India for the Green Revolution;
- CRSP projects in North and East Africa, Indonesia, and Latin America;
- This work continues on a large scale in Kenya and Southern Sudan despite major funding reductions and changes at USAID.
- UM in South Africa at University of Western Cape (see below for details)
- More than 22 years ago, a strong collaboration with the University of Western Cape was established.
- Over 350 faculty from 40 departments have participated in exchange and research collaborations.
- Major NIH-funded research is now underway (see below).

This inventory of MU's international initiatives could be expanded dramatically. The point is that there are long-standing, robust international initiatives that constitute a strong foundation for our future as an international land grant university.

Current International Projects

With all of the above as background, let me turn to examples of the current projects in the "global land-grant arena" at MU. I have chosen four very different kinds of projects that illustrate the points outlined above. Here are four quintessential "land grant" projects, all international, all with substantial longevity, and all with the land-grant mind-set that I've described above.

FAPRI in Ireland and the UK.[1] In the mid-1990s, in an academic meeting, the Prime Minister of Ireland learned about the work of MU's Food and Agricultural Policy Research Institute's (FAPRI's) analysis of agricultural policy in the United States. Upon the invitation of the Prime Minister, FAPRI began a long-term project that addressed the implications for Ireland of a series of agricultural policy reforms that the EU was considering. Ireland has a very large agricultural sector and is a major exporter of food products throughout the world. The EU policy objectives had implications for the Irish economy, and analysis of these changes for the Irish economy was essential. Upon the Prime Minister's invitation, the FAPRI project began in 1997.

Initially, the project was centered in Ireland—with the Irish Food and Agriculture Development Authority in Dublin and the Queen's University in Belfast, with strong connections to the Department of Agriculture, to industry, and to producer groups. With an MU faculty member (Bob Young) assigned full time in Ireland, the project trained new personnel and guided the early part of the policy analysis project. A strong team was formed that did the basic policy analysis of the Agenda 2000 reforms of the Common Agricultural Policy in 1998.

Since 1998, the FAPRI project has grown from a partnership with Ireland to a broader UK project. A variety of

analyses have been conducted concerning the Common Agricultural Policy proposals of the trade liberalization under the Doha Round of the World Trade Organization, concerning greenhouse gas emissions and other topics, and in 2007 FAPRI's contracts for these policy analysis projects was extended for another three years.

The FAPRI analyses are based on models developed by research teams at MU. The project provides training, world price projections, and a general economic model for the rest of the EU. An important part of the methodology involves engagement of policy makers and industrial leaders. More recently, the Irish/UK participants in the project have engaged a broader set of EU participants, building models that have broader EU application.

Pasture-based Dairying in Missouri.[2,3,4,5] Dairy production is a significant element of the Missouri economy. The state ranks 21st in total milk production among states, but 7th in the total number of licensed dairy operations. Dairy farmers earned $298 million revenue in 2005 from milk, which translated into a total economic impact of $929 million; moreover, there were 8,299 Missouri jobs, including direct, indirect, and induced multiplier effects in the dairy industry.

A new kind of dairy farm is emerging in Missouri, modeled on a pasture-based system of dairy production, much of which was developed in New Zealand. Since 2004, these pasture-based dairies have produced more than $12 million in annual milk sales, with more than $37 million in total economic impact, and 330 new jobs. By 2008, significant growth in this sector is expected, with projections of new investment at $63 million, $28 million in annual sales, $87 million in annual economic impact, and 777 new jobs.

The social and environmental impacts of pasture-based dairying are as significant as the economic impact. It produces an environment with much less stress for families and the cattle than conventional dairy techniques. It also lowers the financial barriers to entry in the industry. Environmental impact is more positive as well.

The pasture-based dairying has been supported by a strong MU Extension project in Southwest Missouri. The program is taught through "core groups", training dairy farmers to become "expert producers," who then go on to help educate their neighbors. A valuable web resource has been developed that calculates pasture growth and utilization on a whole farm basis.

Moreover, the Missouri Extension team organized an international trip in 2008 to Australia and New Zealand, continuing the research that examines how producers there deal with drought stressed pastures, control animal heat stress, and study business processes such as transfer of ownership.

In short, the New Zealand connection, facilitated by MU Extension, has opened a new kind of dairy production that has had significant impacts on the Missouri economy, on local communities, and in general, on the quality of life in Missouri.

MU Programs in East Africa.[6] For thirty years, MU has had significant programs in Sub-Saharan Africa, particularly in western Kenya and, more recently, in Southern Sudan. In general, these programs arise from International Agricultural Programs, several of which are completed.

- A small ruminant research program from 1980 to 1998 sponsored by USAID. The program was designed to develop a system of goat production suited to small farms in Western Kenya. MU's part was the socio-economic components of the initiative.
- The Kenya Natural Agriculture Research Project, from 1989 to 2004, focused on enhancing the capacity of the Kenya Agricultural Research Institute (KARI). This $30 million effort, led by MU, included technical assistance, graduate training, and upgrading equipment. A related project trained Ph.D.s for KARI scientists.

MU's current project in Southern Sudan follows twenty-five years of civil war that has left millions of casualties and an extremely unstable political environment. In 2001, President Bush made it a high priority to broker an end to the conflict. He appointed John Danforth, former U.S. senator from Missouri, as envoy to the peace talks. In January 2005, a treaty was signed that creates a Government of National Unity and a semi-autonomous government for the Southern Sudan. In 2011 or 2012 a referendum will determine whether Southern Sudan will remain within the Khartoum government or will become an independent nation.

MU's current project, the Southern Sudan Revitalization Project, will manage about $4 million per year in facilitating activities of USAID in the area. Among other activities, MU will conduct a census that is necessary for the upcoming election. In addition, there will be work on such issues as land title laws and on creating viable government agencies. The MU project in Southern Sudan is seen as a possible model for addressing issues in Darfur.

University of Missouri and University of Western Cape.[7,8] In the 1980s, MU, like other universities, saw significant campus pressure to divest investments in firms that did business with apartheid South Africa. A series of contentious events, including arrest of some students who were subsequently released on grounds of free speech, led to the formation of a committee to recommend whether the University of Missouri should divest its investments in firms that did business with South Africa. The Committee's response was that the University should divest…and, in addition, should establish a strong relationship with a university in South Africa. After some investigation of potential relationships, it was recommended that the University of Missouri pursue a relationship with the University of Western Cape.

A group of Missouri faculty and administrators visited the University of Western Cape, spending approximately two weeks on campus. They found significant resistance to a relationship with an American university, but they also saw a positive response to the

visitors' extended stay on campus and their seemingly genuine interest in collaboration. A subsequent visit of Western Cape visitors to Missouri, though also showing some tensions, resulted in an agreement to collaborate in a variety of exchange arrangements.

This relationship has now lasted for more than twenty years, with several hundred exchanges. The MU Law School has a joint summer school project with courses that are co-taught by MU and UWC faculty; classes are half MU and half UWC students. The MU School of Health Professions' students can complete clinical internships in South Africa at UWC.

Currently, perhaps the most prominent MU program in South Africa builds on the remarkable array of 30,000 plant species, with more than 3,000 used in traditional, holistic medicine. A large majority of South Africans receive treatment from traditional healers, using traditional therapies developed over centuries, treating conditions ranging from the common cold to HIV AIDS. The effectiveness and safety of these therapies have not been scientifically addressed. The TICIPS program (The International Center for Indigenous Phytotherapy Studies), under direction of PI William Folk (MU Professor of biochemistry), is pursuing such studies, with the goal of incorporating these traditional therapies into conventional health care systems. The study is a randomized, placebo-controlled study looking at the safety and effectiveness of Sutherlandia for 124 volunteers at an early stage of HIV infection.

The study has engaged traditional healers in a central way. Dr. Kathleen Groggin, Associate Professor of Psychology at the University of Missouri, Kansas City, says: "The traditional health providers are helping us in so many ways. They have helped give legitimacy to the study. They partnered with us in translation and in developing outcome measures. They will be helping us with patient retention. Above all, they are willing to try…Our colleagues are trusting that we…will work hand in hand." The study complies with all U.S. and South African regulations about the conduct of research, including conflict of interest and international property rights.

Conclusion

MU is a major research university with a very complex mission. The land-grant mind set is pervasive, including especially a profound commitment to serving the people of Missouri. Similarly, MU's international commitment is broad and long-standing—though perhaps not always focused and coherent. But it is clear that this international commitment shows a strong land-grant mind set. There is much more at MU than the land-grant mind set and mission—basic research, liberal arts education, and professional education, for instance. But the land-grant mind set has enriched all aspects of the complex MU mission.

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CONFERENCE PARTICIPANTS 2008

Keynote Speakers

David Lightfoot, Ph.D., Assistant Director, NSF. Directorate for Social, Behavioral, and Economic Sciences

Marion Müller, Ph.D., Director, North American Office, German Research Foundation

Kansas State University

Susan Brown, Ph.D., Professor of Biology

Jim Guikema, Ph.D., Associate Vice President for Research

The University of Kansas

Salvatore Enna, Ph.D., Associate Dean for Research and Graduate Education, University of Kansas Medical Center

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

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

Steven F. Warren, Ph.D., Vice Provost for Research & Graduate Studies, and Merrill Board member

University of Missouri

Brian Foster, Ph.D., Provost

Jack Schultz, Ph.D., Director, Christopher S. Bond Life Sciences Center

University of Nebraska - Lincoln

Barbara Couture, D. A., Senior Vice Chancellor for Academic Affairs

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

Other Participants

Melinda Merrill, Merrill Advanced Studies Center Board Member

Kate Wolff, Office of the Governor of Kansas