15 Towards a Globally Responsible and Sustainable Scientific Culture

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As a scientist in the early stages of my career, I appreciate the opportunity to discuss with you my outlook on the opportunities and difficulties that stem from current U.S. science and technology policy.[1, 2] In addition to my current experiences as a junior faculty at the University of California at Berkeley, in the Division of Infectious Diseases at the School of Public Health, I have had the opportunity to observe and participate in both U.S. and international science for many years. It is probably this background that prompted the organizers to invite me to speak on this subject.

My scientific career has been, in certain respects, quite traditional. I received a B.A. in Biochemical Sciences from Harvard University. As an undergraduate student, I was fortunate to have the opportunity to participate in research projects at Marine Biological Labs at Woods Hole and at the Institut de Pathologie et Biologie Moleculaire et Cellulaire in Paris, France. I did research for my undergraduate thesis jointly at the University of Basel in Switzerland and at Harvard Medical School. Subsequently, I completed my Ph.D. at the University of California (UC), Berkeley in the Department of Molecular and Cellular Biology and went on to do post-doctoral research at the University of California, San Francisco.

However, during the course of this "typical" scientific career, starting when I was an undergraduate, I developed an interest in some of the broader issues surrounding international science policy. In particular, I

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became increasingly aware of the fact that the vast resources devoted to basic and applied science in the United States and Europe had little impact on advancing standards of health in the rest of the world. As such, while I was pursuing my graduate degree, I embarked upon a project to adapt and transfer technologies and build scientific capacity in developing countries. My main goal was to provide local scientists with the knowledge and experience to set their own scientific priorities and the technical capability to pursue solutions to their specific scientific and health problems.

With the help of many scientists, health professionals and other volunteers, the initial project grew, and the Applied Molecular Biology/Appropriate Technology Transfer (AMB/ATT) Program was initiated. AMB/ATT was a virtual organization of many talented volunteers who, like me, were committed to facilitating the redistribution of scientific knowledge and resources worldwide. We specifically focused on the small, least developed countries in Latin America where our efforts, though modest, were able to make an impact. After ten years, these efforts were recognized by my receipt of a MacArthur Foundation "Genius" Award in 1997, which provided me with the resources to found a nonprofit organization, the Sustainable Sciences Institute (SSI), with a core group of colleagues. The mission of SSI is to improve public health worldwide by helping scientists in developing countries gain access to the training and resources needed to address local problems related to infectious diseases. SSI is currently pursuing a variety of projects including offering on-site training programs, small research grants, and material aid support to scientists in developing countries and establishing scientific partnerships between scientists in developing and developed countries. In addition, we have become involved in developing low-cost diagnostic techniques for developing countries and are beginning to explore policy issues surrounding global access to scientific technologies. We feel that a multi-disciplinary approach is essential as we pursue international scientific capacity building for public health applications.

While I am still very much involved with the work of SSI, most of my efforts are currently focused on basic research on infectious diseases that impact global health. As an assistant professor at the University of California, Berkeley, I have pursued basic research while continuing my involvement in international science capacity building and my commitment to international public health. Although I was not formally trained as a

virologist, I have chosen to focus the research in my laboratory on dengue virus because it is such a pressing public health problem worldwide. Approximately 2.5 billion people in subtropical and tropical areas such as Latin America and Southeast Asia are at risk for infection with dengue virus, an RNA virus transmitted by mosquitoes. One hundred million cases of dengue fever and up to 500,000 cases of the potentially lethal dengue hemorrhagic fever and shock syndrome are estimated to occur annually. Moreover, despite the fact that the incidence of the disease is increasing worldwide, very little is known about the molecular virology or mechanism of disease pathogenesis, and there are no vaccines or specific treatments. My laboratory investigates various aspects of dengue—from the molecular mechanisms of dengue virus translation and the pathogenesis of the disease to its epidemiology in Latin American countries. In addition to fulfilling my many research and teaching commitments, I am currently co-director of the International Training and Research in Emerging Infectious Diseases Program at UC Berkeley, which is sponsored by the Fogarty International Center at the National Institutes of Health (NIH). This program enables us to train foreign scientists by supporting their research projects in laboratories in the School of Public Health as well as in their home countries. I feel that integration of these varied commitments is essential to confront the pressing international health issues of today's world.

The experiences that I have had throughout my career have not only catalyzed my current research interests but have also provided me with a broad view of the impact of science and technology policy on the practice of science. During the course of my career, advances have occurred concomitantly in national science policy and in scientific opportunities. Due to the efforts of scientists, teachers, science writers and, importantly, the innate attraction of scientific discovery, public interest in scientific advancement is high. Congress, in turn, has been increasingly supportive of both biomedical and basic research over the past ten years. This is clearly reflected in the doubling of the NIH budget between 1998 and 2002.

To their credit, those in governmental institutions such as the NIH are also cognizant of the fact that encouragement of diversity will greatly facilitate a sustainable scientific culture in the United States (and elsewhere). To this end, NIH has taken important steps to increasing the participation of minorities and women in science. Supplements and funding for minorities and women returning to science are essential to ensuring

diversity in the scientific workplace. In my personal experience, the personnel at the NIH have been quite responsive to suggestions and criticisms that I and others have made over the years.

In addition to increasing scientific capacity through funding, the U.S. government has taken steps to increase the commercialization of science by enabling research universities and small businesses to obtain intellectual property rights on inventions that were made during the course of federally funded scientific research. The Bayh-Dole Act, passed by congress in 1980, allows universities and small businesses to claim ownership of federally funded inventions and thereby become directly involved (and profit directly from) the commercialization of scientific discoveries. In addition, to encourage industry to pursue research and development for public good, congress passed the Orphan Drug Act in 1983 to create financial incentives for private biomedical industry to pursue development of products for diseases that affect primarily "unprofitable" markets (such as developing countries).

While the concomitant increases in federal funding in tandem with the Bayh-Dole and Orphan Drug Acts have clearly helped to create a productive biomedical/pharmaceutical industry, at this juncture it is important to question the long-term implications of this relatively new approach to science. Specifically, with the excitement over mass-throughput technologies, such as genomics and proteomics and technologies such as stem cell research, it is important to take a step back and ask if the path we are on now will get us where we want to be in 10 years. Current policies must be developed to ensure that we create a sustainable scientific culture that is responsive to the health concerns of a global society. My personal fear is not that society is unprepared for the consequences of genomics, proteomics or stem cell technologies, but that in the process of pursuing technologically-driven science and science that has clear commercial applications, we are creating a scientific system that will not be responsive to the most pressing public health needs of society. If we rely on the market to dictate avenues of scientific inquiry, we are likely to ignore important international health issues; any social contract of science will consequently be quite constrained. Policies must be put in place now to ensure that we prioritize research to achieve the maximal benefits for society.

Additionally, over the past fifteen years, excitement over first the genome project and now bioinformatics has resulted in an increasing focus on technology-driven science. Academic laboratories, forced to compete with industry for funding of large-scale projects, have sought to participate in consortia and industry collaborations. As a result, power and funding is increasingly concentrated in larger laboratories. With private and public funding concentrated in larger, technologically heavy laboratories, a substantial barrier is incurred for junior faculty and small laboratories. Moreover, as scientists seek training in labs where the classic hypothesis-driven approach to science is slowly being replaced by a more "factory" or "brute force" analysis approach to scientific inquiry, critical thinking skills and creative approaches to scientific inquiry are bound to suffer.

Also crucial to ensuring a socially responsive and creative scientific academic culture will be instituting mechanisms to increase the attraction of academic science. Currently, many talented scientists, lured by higher pay, optimal resources and the more relaxed lifestyle that biotech and pharmaceutical companies can offer, choose to forgo careers in academic science. The attrition of the Ph.D. pool in academia has resulted in decreasing diversity in academic science. Women and minorities continue to be underrepresented at the faculty level in academic science. In addition to negatively impacting the academic environment, this attrition leads to reduced pursuit of issues that may be particularly important for minority or women's health.

Moreover, as industrial-academic partnerships become more commonplace, academic science itself becomes a research partner for corporate interests, resulting in even more public resources being expended for private profit and commercial science. It is dangerous to focus research funding exclusively on the development of technologies that are relevant only to current health issues in the United States. A long-range approach to research will ensure that scientific research addresses global humanitarian problems in addition to problems specific to the United States. While scientific expertise must at times be summoned to address current emergencies, such as bioterrorism, a more balanced and prospective approach to biomedical research is important to ensure that research is prioritized to maximize long-term social benefit.

In today's world, a multidisciplinary, cooperative approach to science is necessary, as it is no longer sufficient to answer questions with only molecular biology tools, or epidemiology tools, or computer science tools. It is essential that transdisciplinary collaborations be pursued so that we may ask the far-reaching, complex questions that are central to biomedical science. Yet, since tenure committees and grant funding agencies look only at the principal investigator on a grant and the first or last author on a publication, it is essential to establish reward systems that overtly encourage and reward collaborations. In doing so, we will ensure the propagation of a vibrant scientific system.

If we are to foster a truly global scientific culture, mechanisms must be developed that encourage international collaborations. In this era of globalization, we would be extremely naïve to believe that infectious disease problems in developing countries should not concern us. As the recent outbreaks of West Nile virus attest, mosquitoes, viruses, pathogens and even genes do not adhere to international boundaries. For both humanitarian and utilitarian reasons, we must mobilize our scientific resources to initiate true scientific partnerships that enable global access to scientific knowledge, technology and products. Yet, development of international credibility requires substantial commitments of money and time; parachute science, in which investigators merely collect samples, return home and publish papers is of no real use to scientists and citizens in developing countries. Similarly, it is important that we encourage scientists trained abroad to return to their countries of origin, for example, by providing re-entry grants. In addition, as we create U.S. policies for international science, it is important at the outset to begin to formulate bioethical principles in conjunction with our international partners. Finally, I also believe that it will be well worth the time to work not only with large developing countries such as Brazil, India, and China, but to focus resources on issues in smaller developing countries as well.

In short, it is critical that we establish a social contract for science. While the current market mechanism ensures that profitable research is pursued, it does not ensure that research is prioritized according to social need. As such, it is essential that scientists' responsibility to science be directly fostered. Students and faculty must be encouraged to question the bioethical aspects and the social relevance of their research. Moreover, it is important that U.S. scientists, whose current culture largely discourages

political advocacy, be encouraged to become involved in policy development. We cannot afford for corporate pressure alone to dictate research programs nor or publications. It is essential that we encourage and expound policies that will facilitate the development of a much-needed social contract for science.

Unfortunately, the incentives to encourage the development of such a socially conscientious, creative and global culture of science, are largely lacking. In my experience, I find that in order to create even a microcosm of this culture in my laboratory, I must spend time not only on research and teaching but also on mentoring, advising students, contributing to the scientific community, outreach and service/public interest science. To do this takes a great deal of time. And, time taken away from research is not condoned by funding institutions or tenure committees. If, indeed, we are to create a socially responsive scientific culture, it is essential that activities other than research and the minimal teaching obligation are recognized and rewarded. This requires that academic and funding institutions make a serious commitment to teaching and mentoring.

In conclusion, in this era of big science, big labs and big money, it is important that we reconsider how best to encourage the development of a creative and globally responsive scientific culture that remains focused on important issues and doesn't disregard hypothesis-driven science, political involvement and the importance of mentoring and teaching. If we wish to increase diversity, gender balance, social responsiveness and retention of qualified scientists in academia, it is essential that we develop appropriate policies. To achieve this objective, I recommend that institutions begin to reward excellence in education, mentoring, outreach and contributions to public interest science, in addition to excellence in scientific research. I believe that it is important to provide support to junior faculty capable and willing to begin to pursue these objectives. For instance, by reinstating the NIH FIRST award for young investigators and establishing mentoring systems for junior faculty, it will be easier for junior faculty to establish productive research programs and, consequently, have the time and energy to devote to the social issues of science. It is also essential that we establish institutional, national and international mechanisms for encouraging and acknowledging interdisciplinary and international scientific collaborations. Finally, it is important that we change the culture of science to promote

recognition of a social contract of science, so that we overtly acknowledge that scientists have a responsibility to "give back" to society.

Endnotes

1. These remarks were prepared in collaboration with Dr. Suman Paranjape. We thank Karen Clyde for editorial revisions.
2. These comments reflect only the view of the authors, not that of UC Berkeley.