

Science and the World's Future

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This is a very special time for me to be addressing the members of our Academy. Not only is this the sixth and final year of my first term as president, it is the final annual report of the century. And what a century it has been! USA Today, in naming the top 100 events of the last 100 years, listed 47 that reflect advances in science and technology: from Einstein's pronouncement of his theory of relativity in 1905 to the 1928 discovery of penicillin, and from the Soviet launch of Sputnik in 1957 to the American inventions of the transistor, the integrated circuit, and the Internet. Starting from a position that Andrew Carnegie referred to in 1904 as "our national poverty in science," the United States has become the unchallenged world leader in science and technology.

This also has been a century of profound progress for our own institution. In 1899, the Academy was 36 years old, but — having moved in and out of the Smithsonian — it was still looking for a place to house its staff and hold its meetings. And almost exactly 75 years ago, we moved into this building, our first permanent home after 60 years of wandering. Although we were chartered with a requirement to provide advice to the federal government on all matters of science and technology, in our first 50 years we had carried out an average of only about one such study per year.

Though few, those early Academy studies ultimately led to the founding of the U.S. Geological Survey, the National Park Service, and a new Naval Observatory.

Today we make many vital contributions to our nation. Rather than one study per year, we publish about one report *every working day*; in all, more than 200 reports per year on a variety of critical subjects. In its 1998 session alone, Congress asked us to conduct 33 studies. For example, one was a study to develop methods for evaluating federally funded research and development programs. Another of these congressional requests has us reviewing the current policies that determine the distribution of organs for transplantation — an important study that the Institute of Medicine will complete by the end of this summer.

We can all look forward to an even greater role for the Academy in the 21st century. My enthusiasm for a productive and vital future has been fueled, in part, by a joint campaign with the National Academy of Engineering (NAE) and the Institute of Medicine (IOM) that is designed to raise private funds and increase our effectiveness. This effort has provided us with a valuable opportunity to develop major, long-term goals, and to design and implement effective strategies for achieving them. It has encouraged us to dream: to dream about a nation, and a world, that is permeated by the best representations of science and scientific values — honesty, generosity, a respect for evidence, and openness to all ideas and opinions irrespective of their source. It is true that we have a very long way to go in creating such a world. But without a strong and compelling vision of where we should be heading, it would be hard to know where to begin.

There is a challenge here for all of us. If we are to generate the world that we want for our grandchildren, we scientists will need to reach much more deeply into our own society — as well as into every hamlet and village across the world. To better understand what this goal might mean in practice, I have gone far afield to seek out opportunities that would bring me face to face with new experiences and ideas. This past year, as part of a major study of international agriculture, I traveled to Africa. There I witnessed the challenges for science in the remote fields of subsistence farmers in Kenya, when visiting an impressive set of agricultural experiments that were guided by scientists and carried out by village women on their own land. I also spent time in rural India. There I examined an imaginative set of experiments in electronic knowledge delivery designed by our foreign associate, M.S. Swaminathan, of which you shall hear more later.

But one need not go to another country to become aware of the many new opportunities for scientists. During the past year, I have also learned invaluable lessons from teachers and students in our nation's schools. A few days ago, I participated in a daylong visit to 10 of New York City's public schools as part of a public outreach effort sponsored by the Academies. The focus was on District 2 in Manhattan, an unusual public school district that provides an excellent education to 22,000 inner-city students in kindergarten through 8th grade. It is in the multi-ethnic classrooms of schools such as these that the real battle for the future of America is being fought. I am very pleased to report that, in this model district whose entire focus is on improving instruction, test scores and interviews show that even the children from high-risk backgrounds are learning at high levels, and the battle is being decisively won. The president of the NAE, Bill Wulf, and IOM President Ken Shine joined me on these school visits, as did many of our education staff. We all agreed that in this inspirational cluster of schools there is a gold mine of valuable information that is critical for researchers to study and disseminate.

Not all of my experiences have been positive. For example, I learned to my surprise that most of the international organizations established by the United Nations with the great hope of using science and technology to improve the human condition are seriously hampered by bureaucracy and a lack of energy, innovation, and resources. And it is distressing to know that many of our nation's school systems are afflicted with a very similar disease. They have become organizations that focus on providing jobs for adults — rather than pursuing District 2's laser-like focus on improving instruction and student learning. In short, an objective evaluation of many of the official institutions dedicated to the public good would find them sadly lacking in effectiveness.

These types of frustrations have led to an enormous proliferation of non-governmental organizations — or NGOs — that have the goal of improving life in societies around the globe. What might we do, in collaboration with other NGOs, to move our nation and the world in new, more favorable directions?

There is much more that needs to be said than could possibly be conveyed in this short period of time. I will be making four points today. First, I will stress how the computer and telecommunications revolution is providing the Academy, and all other scientists, with a vital new way to engage in an efficient worldwide exchange of knowledge and capacity building. Second, I will focus on our work designed to build personal networks of trust between scientists around the world — and between these scientists and their societies. Third, I will briefly describe for you a proposed international version of our National Research Council. And I will end with a sense of what the international scientific community could look like in 20 years or so, presenting a “vision” for world science in 2020.

1) Knowledge sharing and capacity building: Making the work of the Academies universally available and accessible

One of the Academy's main goals is to spread the wisdom of science, and the ability to use it, much more widely throughout our nation and the world. Achieving this goal will require that we energetically experiment with new methods of disseminating the knowledge that science generates, targeting governments and NGOs throughout the world, as well as individual citizens. Our Academy starts with an immensely valuable and unique resource: the many thousands of reports that have been produced by the National Academies. Among these million pages or so of text, there are many wise syntheses of knowledge and recommendations for action. Most of this information used to be available primarily in libraries and private offices — inaccessible to most potential users.

As a first step in widely disseminating this great store of knowledge, the National Academy Press has developed a Web site that makes the full text of well over 1,000 of our books and reports freely available through the Internet. In the next year, we are planning to add many of our older, yet enormously valuable, publications to this list. And we continue to experiment with new ways of indexing this tremendous resource to make it much more accessible to the general public. For example, anyone who clicks on the topic heading of Education on our home page is presented with a concise guide to the most important education reports for the general public.

But as Academy member Lubert Stryer's visiting committee on the National Academy Press pointed out in its visionary report, most of our studies are performed for academics and policy-makers, and they make difficult reading for the general public. As the Stryer committee urged, we are becoming much more aggressive about disseminating our work to a broader audience. There is of course our Beyond Discovery series, in which Academy members and other scientists have worked with gifted science writers to produce attractive eight-page case studies that clearly explain how scientific knowledge produces human benefit. On our Web site, each Beyond Discovery piece is augmented with direct links to a wide range of relevant information. Other publications addressed to the general public include *Every Child a Scientist*, designed to explain to parents why the National Science Education Standards call for a challenging but very different kind of science teaching than most adults have experienced in school. Last year, Academy member Donald Kennedy led the committee that produced *Teaching About Evolution and the Nature of Science*, a 150-page book aimed at helping science teachers present evolution more effectively to their students. And just last week we released the second edition of our landmark *Science and Creationism* booklet, produced under the leadership of Academy member Francisco Ayala.

Perhaps the most ambitious of our new publications aimed at the public is the book *Starting Out Right*. This book derives from a scholarly study chaired by Harvard professor Catherine Snow, but is written especially for parents, grandparents, and teachers who want to use our scientific knowledge to help young children learn to read. A free copy is available for members at a table in the Great Hall, and we encourage you to get this book into the hands of your local pediatricians and child-care providers.

Making scientific knowledge highly accessible, as I have just described, is not by itself sufficient to spread wisdom throughout the world. Equally important is the development of the public's capacity to appreciate and utilize this knowledge. Success in such capacity building will require that the Academy, as well as many others, pay much more attention to the education that we provide for young people. If the nation's best colleges and universities do not become seriously engaged in addressing this problem, our entire future will be threatened. How can we expect to remain the world's most productive nation if we have a future work force that ranks very near the bottom in international tests of science and mathematics competence?

The good news is that this problem is not one that bothers only scientists. Our nation's business leaders have identified the quality of our K-12 education system as the major threat to our

international competitiveness, and it is hard to find a state today in which the governor does not emphasize education as his or her number one priority. The National Research Council has just published an important report titled, *How People Learn*, which translates the results of research on learning for the practitioners in our nation's schools. And our Center for Science, Mathematics, and Engineering Education has recently made teacher preparation its highest priority.

I expect everyone in this audience will agree that our education system can never prosper unless we accord teachers greater respect and a higher status in our society. The process must begin in each science and mathematics department in our colleges and universities. As emphasized in our recent report, *Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology*, university faculties must assume a much greater responsibility for the pre-service preparation of all those who plan to teach science and mathematics in our schools, as well as for their continual professional development. I commend Academy member and distinguished mathematician Hyman Bass, who has been working with teacher education professionals at the University of Michigan to think deeply about exactly what type of mathematics preparation is most effective for elementary school teachers. I hope that many more distinguished scientists will follow this lead and get involved in these critical teacher preparation issues.

2) Building personal networks of trust: Connecting scientists to each other and to their local communities

During the past year, I have enjoyed many discussions with young American undergraduates, graduate students, and postdoctoral fellows. I continue to be impressed by their enthusiasm, idealism, and energy, and I am pleased that the future of our scientific community is in such good hands. But senior scientists have an obligation to create many more opportunities for these young scientists, encouraging them to apply their expertise to a wide variety of national and worldwide challenges. Last August, with the leadership of our vice president, Jack Halpern, we inaugurated two new *Frontiers of Science* programs: one with the Chinese Academy of Sciences and the other with the Science and Technology Agency of Japan. In meetings held on successive weekends at our Beckman Center in Irvine, California, we brought 40 of our best scientists under the age of 45 together with a comparable group of scientists from China or Japan. The former president of the Chinese Academy of Sciences, Zhou Guangzhao, and I attended the Chinese-American *Frontiers of Science* meeting. We both agreed that it was a tremendous success in building strong, personal ties between outstanding young scientists. We are working on developing a similar *Frontiers* program with India, and we already have a flourishing program with Germany. These *Frontiers of Science* meetings are superb long-term investments, since they are designed to create a personal network of trust between the scientists who will be future leaders in their own countries.

Our nation has benefited immensely from the talent of foreign-born scientists who later became U.S. citizens, and who now make up some 25 percent of our Academy's membership. It is imperative that we continue to maximize our contacts with our colleagues around the world.

Trust also is created whenever we bring together scientists from different countries to work together on a common issue. For example, consider this report, released in the West Bank city of Ramallah a few months ago. Titled *Water for the Future: The West Bank and Gaza Strip, Israel, and Jordan*, it represents an attempt to draw on the common culture and values of scientists to build bridges for peace in the Middle East. The process began more than three years ago at a meeting of the presidents of the Middle Eastern academies that I attended, along with our foreign secretary Sherry Rowland and Ken Shine. Afterward, we formed a committee of three Israelis, three Jordanians, and three Palestinian scientists — plus six Americans and Canadians — chaired by Academy member Gilbert White. Perhaps even more important than the report itself is the new regional community of water scientists that has formed through the trust and respect that the

nine Middle Eastern scientists have gained for each other. We have ambitious plans to continue to catalyze a collaboration on water issues there, as well as to help establish new collaborations in the areas of nutrition and health.

Within each nation, we also need to build networks of trust that extend from the scientific community to society at large: networks of scientists and journalists; scientists and policy-makers; scientists and community leaders; and scientists and all those who will educate the next generation of citizens. As in my past addresses, I call on Academy members to take special responsibility for helping with this critical task.

Let me focus today on one selected aspect of this challenge. At this time, the United States has a unique opportunity. Reports from the Department of Education suggest that the nation will need 2 million new teachers — of a total of 3.5 million — in the next decade. And yet, finding qualified teachers of science and mathematics is already difficult for many school districts.

In the abstract, there would seem to be little chance of finding the large numbers of talented people needed to teach science well and of moving them into our K-12 school systems. But these are not normal times for scientists. Over the course of the past 40 years, the flourishing scientific enterprise in the United States has created a demand for an ever-increasing influx of young people. Serving as graduate students and postdoctoral fellows, they perform most of the research that is carried out in universities and publicly funded research institutes. But in some fields today many Ph.D. graduates are not able to find permanent positions in either industry or the higher education system. The net result is an ever-increasing pool of poorly paid, but highly talented postdoctoral researchers who are spending longer and longer times in temporary positions. Our recent study titled, *Trends in the Early Careers of Life Scientists* — chaired by Academy member Shirley Tilghman — reveals that there are presently some 20,000 postdoctoral researchers in the life sciences in the United States. Moreover, with an annual production of about 8,000 life science Ph.D.s, this number is expected to grow by about 3,000 each year.

Many of us know these energetic and creative people. As I have learned from my own discussions with many of them, large numbers of these talented scientists would be willing to work as teachers and leaders in our nation's K-12 education system, under the appropriate conditions. However, at the moment there are no efficient pathways to prepare them for such a transition, and inadequate support systems for them in our schools. For this reason, the Academy has just begun a project that will survey some 2,000 of these individuals. The survey is intended to provide those who have the power to create new pathways into the K-12 system — such as governors and university presidents — with the information that they need to establish the right mechanisms to move these people into education careers, and support them once they are there. We also plan to sponsor a workshop aimed at defining the best practices for converting such scientists into effective participants in the K-12 education system.

3) Providing impartial scientific advice to the world: A new InterAcademy effort

How can our Academy move more assertively into the international arena to ensure that the type of science and technology advice that so wisely informs policy at home can help inform decisions abroad? Four years ago, we took a first step in global collaboration when we joined with other scientific academies of the world to create the InterAcademy Panel on International Issues, or IAP, an informal network now totaling 80 academies. And we have developed a Web site to promote rapid communication between these academies, as they prepare for a May 2000 Conference of Academies in Tokyo. The conference will address the many opportunities and challenges for scientists as the world accommodates an estimated 10 billion people in the 21st century. Sherry Rowland is playing a critical leadership role as co-chair of the IAP, as well as chair of the Year

2000 Conference organizing committee. And the upcoming report of our Board on Sustainable Development, titled *Our Common Journey: A Transition Toward Sustainability*, represents a major contribution to this global effort.

As our next bold step in global collaboration, we hope to create an international version of our National Research Council. We plan to help establish an InterAcademy Center, with a multinational board, as a flexible mechanism for organizing special panels of top-level scientific, engineering, and health experts. These panels of experts would be set up on demand to advise global institutions — such as the United Nations and the World Bank — on issues of critical importance to them. Why this, and why now? In the years ahead, policy-making institutions all over the world will face increasingly complicated issues involving questions of scientific validity and balance. The world badly needs an impartial mechanism, based only on science, to promote smarter decision-making on such issues as agricultural strategies for Africa, safe drinking water in Bangladesh, and energy options for Asia. The world's academies and their counterpart organizations are the ideal institutions for providing independent, credible, timely, multinational advice on a broad range of such issues — and we are presently working to help them accept this important responsibility.

4) Vision for Science in 2020: The Really Big Idea

Humans are probably hard-wired by evolutionary selection to expect the future to be just like the past. Perhaps this explains why we are so haunted by history in many parts of the world today. In a period of rapid technological change like the one we are experiencing, the academies of the world are needed to help all societies envision a different future: one that will be focused on improving the human condition and on scientific values. These values are so fundamentally important they bear repeating — honesty, generosity, a respect for evidence, and openness to all ideas and opinions irrespective of their source. These are values necessary for making our enterprise work — values that most scientists take for granted. But any look at the history of the world in this century would show that they, unfortunately, are not universally shared.

I continue, however, to be inspired by a book written more than 40 years ago about science, and I would like to call your attention to it again — “Science and Human Values” by Jacob Bronowski. His book, triggered by the trauma that he experienced visiting Nagasaki in 1945, includes this passage:

The society of scientists is simple because it has a directing purpose: to explore the truth. Nevertheless, it has to solve the problem of every society, which is to find a compromise between the individual and the group. It must encourage the single scientist to be independent, and the body of scientists to be tolerant. From these basic conditions, which form the prime values, there follows step by step a range of values: dissent, freedom of thought and speech, justice, honor, human dignity and self respect.

Science has humanized our values. Men have asked for freedom, justice and respect precisely as the scientific spirit has spread among them.

As we enter a century that will be dominated by continual advances in science and technology, the world's scientists must work together to create a communication network that is specifically designed to empower individual scientists and scientific organizations with valuable knowledge and skills. I suggest that the world's major scientific organizations cooperate to focus on the following two-part strategy:

Connecting all scientists to the World Wide Web, where necessary by providing subsidized Internet access through commercial satellite networks.

Taking responsibility for generating a rich array of scientifically validated knowledge resources, made available free on the Web, in preparation for a time when universal Internet access for scientists is achieved in both developing and industrialized nations.

I now come to what I like to call the Really Big Idea: By connecting all scientists in the world to each other and by providing them with rapid access to invaluable information stores, we aim to increase both the potential value of scientists to their societies and their status in the eyes of their governments and fellow citizens. As Bronowski emphasized, we will thereby also promote the worldwide diffusion of scientific values. And with scientific values we shall spread tolerance and democracy, until they encompass all of the people on this globe.

If we are to reach this goal, connecting scientists to each other is only the first step. Scientists everywhere must use these initial connections as a tool for spreading their knowledge, skills, and values throughout their own nations, including their local communities. By taking full advantage of new information technologies, the scientific community has an unprecedented opportunity to close the vast “knowledge gap” between all peoples. How might this be possible?

I want to highlight a wonderful example that points the way forward. As mentioned previously, the M.S. Swaminathan Foundation has established an experimental network in India that will soon connect more than 20 isolated rural villages to a wireless Internet service. About half of the population in most of these villages has a total family income of less than \$25 per month. The project is designed to provide knowledge on demand to meet local needs using the World Wide Web, and it does so through a bottom-up process. The process starts with volunteer teams that help poll the villagers to find out what knowledge they want. Particularly popular thus far are women’s health information, advice on growing local crops and protecting them from diseases, the daily market prices for these crops, local weather forecasts, and clear information about the bewildering array of programs that are provided by the Indian government to aid poor families. To participate, each village must provide a public room for the computer system, as well as the salaries for a set of trained operators. In return, the village receives the needed hardware and maintenance for the communication system, specially designed Web sites in the local language that convey the requested information, and training programs for those villagers who have been selected to run their local knowledge system.

Drawing on this concept, I envision a global electronic network that connects scientists to people at all levels — farmers’ organizations and village women, for example. The network will allow them to easily access the scientific and technical knowledge that they need to solve local problems and enhance the quality of their lives, as well as to communicate their own insights and needs back to scientists.

As in the example in the next slide, most of the system operators and volunteers in the project in India are women. For this reason, this “Information Village” program also increases the status and influence of women by making them the primary local knowledge providers. The program has been set up as a scientific experiment with computer system location, association with a preformed community group, and so on, being used as input variables. I am enormously impressed with the quality of thought that has gone into this project, as well as by the energy, dedication, and skill of

the young Indian scientists who are carrying it out. The next slide shows a picture of me with Dr. Balaji, the talented scientist who runs the project.

We have been struggling in our own Academy with the question of how we might help to catalyze programs that bring the benefit of information technology to our inner cities. In the United States, we generally design such experiments from the top down, deciding what services we will deliver to communities or schools and then searching for a partner who is willing to accept those services. My experience in India has made it clear to me that our nation would be much more successful in such endeavors if we were humble enough to incorporate the potential beneficiaries of a service into its initial planning.

At the end of the century, we can look back at almost unbelievable accomplishments in which science has played a central role in lifting billions of people out of disease, hunger, and poverty. And there is tremendous potential for many further contributions. But we also see the appalling spectacle — reminiscent of the nightmare of the first half of this century — of ethnic and religious conflict destroying the lives of large numbers of people, of terrorism and intolerance and ignorance darkening the prospects for humankind, and of a harmful spread of misinformation. And I would be remiss if I did not also call attention to the fact that this century witnessed the creation of nuclear weapons, whose threat still looms large. This continues to be the predominant concern of our Committee on International Security and Arms Control (CISAC), with their valuable long-standing connections to our Russian colleagues.

The community of science cannot be oblivious to these disasters. Instead, we must find ways to use the open, truth-based culture and community of scientists to ameliorate them. The challenges of the coming century will require the dedicated efforts of the entire scientific community; but they especially call for a much more robust engagement of the world's most outstanding social scientists.

I end by quoting from remarks made by Vernon Kellogg, one of the important early leaders of the Academy, who spoke at the inauguration of this building almost exactly 75 years ago to this day: Let science, then with all encouragement, play undisturbed its glorious role of bettering the lot of individuals.... Let it prove all things, discover truth, and teach truth and the way of its discovery. Let it attend, undistractedly and unwearingly, to its great effort to make our land a better land for our children and our children's children to live in, and the human future broader and better than the human present. To try to help do these things is the avowed purpose of the National Research Council.