SUMMING UP: CREATING A SCIENTIFIC TEMPER FOR THE WORLD

A Speech by Bruce Alberts, President
National Academy of Sciences
Presented at the Academy's 142nd Annual Meeting
May 2, 2005

Some of you may remember that it was only with great reluctance that I agreed to give up my wonderful life of research and teaching at the University of California, San Francisco (UCSF), and move to Washington in 1993 to become your president. I have never regretted that decision, because I have learned a great deal about both science and the world over the course of the last 12 years. Most importantly, I have discovered that this institution plays a much more important role in the future of our planet than I had ever imagined. This importance puts a great weight of responsibility in the hands of the Academy president, a challenge that I know Ralph Cicerone, my successor on July 1, is admirably prepared to meet.

Let me briefly mention just a few of our most recent accomplishments:

Last November, we released our third post-election report designed to advise the new administration on making the best science and technology appointments (Figure 1). This time around, a committee chaired by former Republican Congressman John Porter covered not only the most important presidential appointments, but also appointments to federal scientific advisory committees. This report has been much discussed around Washington, and it is having a positive effect.

Other reports were much in the news this past year, such as our *Assessment of Options for Extending the Life of the Hubble Space Telescope*, a report on the hydrogen economy, a report on weighing bullet lead evidence in forensic analysis, a report on air quality management in the United States, and a report from the Institute of Medicine on preventing childhood obesity. These are only a small sample of the more than 200 reports that we release and post on our Web site each year.

In our increasingly competitive world, the Academy must also make sure that the nation is doing everything it can to maximize the effectiveness of the science and technology enterprise in the United States. In part, this means ensuring that the resources provided by the U.S. government for research are distributed appropriately, with the money going to the most innovative and productive scientists. In a

Bruce Alberts, president, National Academy of Sciences

recent report, titled *Bridges to Independence: Fostering the Independence of New Investigators in Biomedical Research* (Figure 1), a committee chaired by Nobelist Tom Cech has made a series of bold recommendations aimed at reversing a dramatic increase in the age of the independent investigators supported by the National Institutes of Health. It turns out that the average age for investigators receiving first-time independent grants is now 42 years.

This report is only the latest in a series of hard-hitting efforts that have helped to keep the nation moving in the right direction. These include reports on reshaping graduate education, on enhancing the postdoctoral experience, and on facilitating interdisciplinary research — not to mention many discipline-specific efforts that outline the major research opportunities in a particular field, such as physics.

Science is crucial for policy-making.

The benefits that are derived from science extend far beyond the obvious ones — such as improved medical care, labor-saving machinery, and our rapidly increasing ability to store and access knowledge and to communicate with each other. Modern science has also provided us with such a deep understanding of the natural world that we can often predict what is likely to happen in the future. This predictive ability is what makes science so important for policy-makers, and it is central to most of our reports.

Why does our system for providing advice to policy-makers work as well as it does? First, unlike the situation in some other parts of the world, everyone in the U.S. government, on both sides of any argument, believes in science. Second, the press pays close attention to our work. We are often front-page news (Figure 2), as we were on April 27 with our report on *Guidelines for Human Embryonic Stem Cell Research*. This helps to guarantee that our advice has a major impact.

In addition, our review processes remove all non-scientifically based conclusions and recommendations from our reports, so we cannot be discredited for going beyond the science. I like to use our reports, *Climate Change Science* and *Arsenic in Drinking Water*, both published in 2001, to make an important general point. These reports do not tell our government exactly what it should *do* about carbon-dioxide emissions or about establishing appropriate limits on arsenic levels. Instead, what we say to the government is, "If you decide to allow arsenic concentrations of five, 10, or 20 parts per billion, these are the effects that you are likely to see decades from now." We take pride in simply telling the truth — the scientific

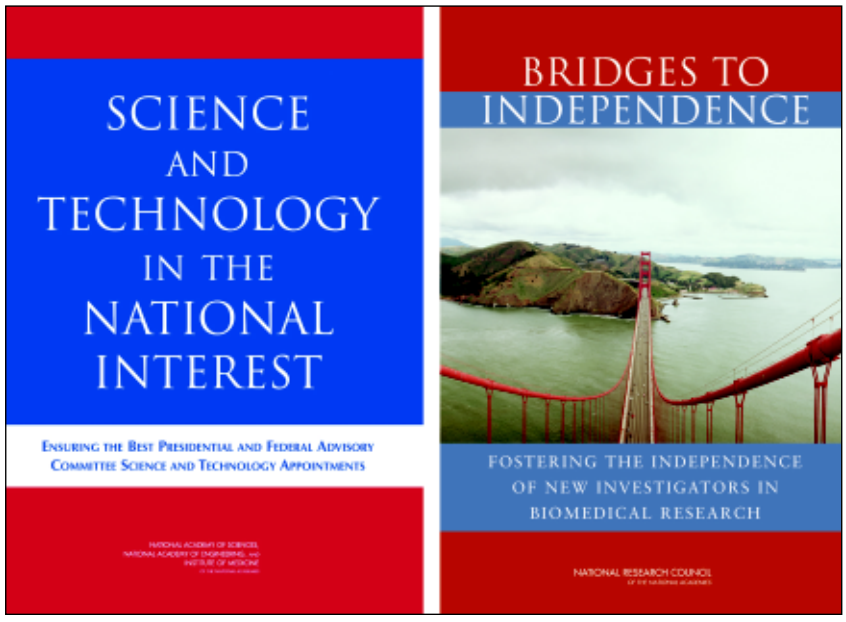


FIGURE 1

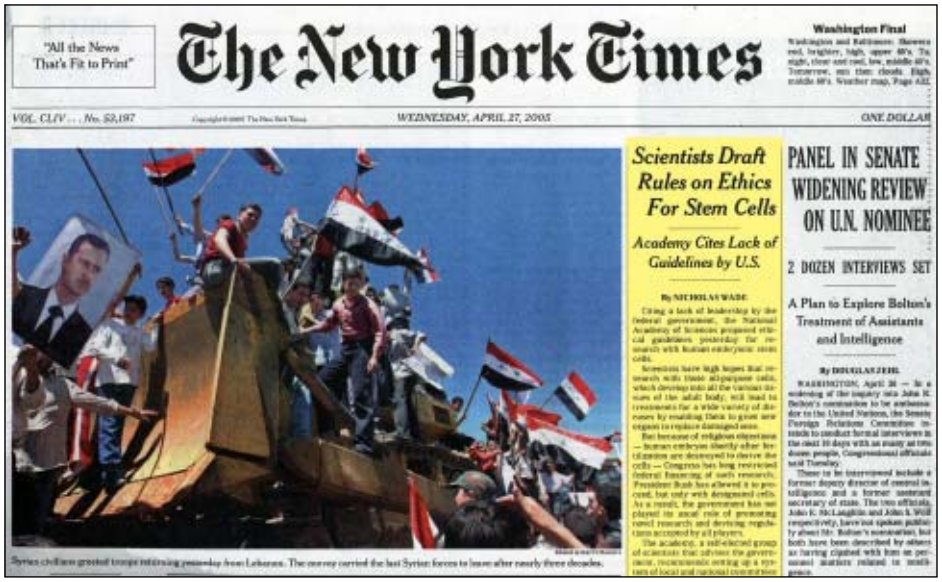
truth — to power. Finding a balance among the many competing needs in our complex society is the expertise of policy-makers, and not ours.

It is irrational for a government anywhere to make decisions without sound scientific advice. This fact motivates our new 10-year effort, funded by the Gates Foundation, to strengthen academies of science in Africa as providers of national science policy advice. Initially, our effort will be focused on Uganda, Nigeria, and South Africa — with other nations to be added later.

But what about the 50 states of our nation? Many of them would seem to be no better off than developing nations in their ability to harness science advice. From time to time, the National Academies have been commissioned by a particular state or city to provide needed science advice. For example, at the request of New York City, we provided important advice on that city's water supply. And in response to a request from the governor of Alaska, we produced a well-accepted report on their wolf and bear populations.

But many states will require their own organization to provide the local science advice that they need. For this reason, we have begun an experiment designed to help strengthen a state analogue to the National Academies, the California Council on Science and Technology. We also have been forging closer ties with the National Association of Academies of Science, representing the 43 state and regional academies in the United States.

Whether here or elsewhere, it is not enough to produce timely reports with sound recommendations — it is also crucial that there be trusted public servants in the government who are sufficiently scientifically and technologically adept to interpret our advice for the political establishment. These individuals provide invaluable links between the government and the scientific community. Acting as the "translators" between two very different cultures, they are often the initial audience for our many policy reports (Figure 3). It is hard to imagine how the U.S. government could function without them.



"All the News That's Fit to Print"

The New York Times

Washington Final

VOL. CLIV . . . No. 53,197 WEDNESDAY, APRIL 27, 2005 ONE DOLLAR

Scientists Draft Rules on Ethics For Stem Cells

Academy Cites Lack of Guidelines by U.S.

By NICHOLAS WADE

PANEL IN SENATE WIDENING REVIEW ON U.N. NOMINEE

2 DOZEN INTERVIEWS SET

A Plan to Explore Bolton's Treatment of Assistants and Intelligence

By DOUGLAS JEHL

Syrian civilians greeted troops returning yesterday from Lebanon. The convoy carried the last Syrian forces to leave after nearly three decades.

FIGURE 2

The American Association for the Advancement of Science (AAAS) deserves special recognition for its fellowship programs, which for 30 years have brought large numbers of outstanding scientists and engineers to Washington to serve for a year in the federal government. Many of these people decide to stay, and they have made a big difference by populating our government (and the National Academies) with critically important scientific expertise and talent. In recent years, we have provided help for this important effort by establishing our own Christine Mirzayan Science and Technology Policy Graduate Fellowship Program. This program brings about 80 young scientists and engineers to the Academies each year to work on policy issues (Figure 4). The young people are definitely interested: Our program currently has 10 times as many applicants as there are positions to fill!

As we work to extend the National Academies model at home and abroad, we encounter a major problem. Most U.S. state legislatures — and many foreign governments — lack the scientifically trained staff so indispensable here in Washington. We therefore hope to introduce AAAS-type fellowship programs in both California and Africa, to improve the access to science by their governments.

Strong interactions between individuals with a science or engineering background

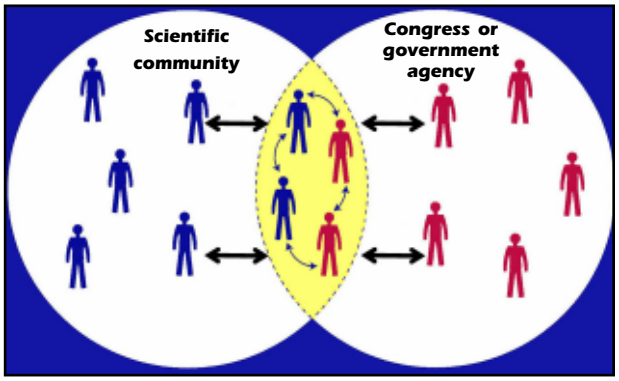


FIGURE 3

But none of this is enough to ensure that science — and scientific judgments — will create a more prosperous and rational world. Because the pace of scientific discovery continues to accelerate, the scientific and technological advances in this century will almost certainly exceed those of the past 100 years. Already, there are clear signs that our societies are ill-prepared for such changes. Witness, for example, the overwhelmingly negative reaction in Europe to genetically engineered improvements in agricultural crops — a sentiment that threatens to block the use of this technology to help poor farmers in Africa. And in the United States, far too many people are susceptible to dogmatic talk-radio hosts who promulgate simplistic solutions to complex problems. There is also a growing backlash against vaccination, and we currently face challenges to the teaching of evolution in 40 of our 50 states.

Much of today's anti-science sentiment stems, I believe, from fear that is fired by honest confusion on the part of the public. According to a recent poll, for example, a large fraction of Europeans believe that "only genetically modified plants contain genes." Most people have never encountered a working scientist, nor do they understand how science works or why it has been so successful. Far too many think that we are weird geniuses, when in fact the vast majority of us are neither.

Urgently needed are hundreds of thousands of "citizen scientists" who devote part of each week to spreading an understanding of science, its methods, and its values to non-scientists. And, if we are to have any chance of success, our university science departments must change their mission: Rather than focusing solely on training future research scientists, they must also openly encourage — and design programs for — science students at all levels who want to pursue a variety of other careers where their skills are badly needed.

One of my favorite authors is Daniel Boorstin, who wrote so beautifully about the profound ways that new discoveries have changed the course of human history. In summing up, he said:

> *In my book, 'The Discoverers,' one of my themes was that the great obstacle to progress is not ignorance, but the illusion of knowledge… There's a mystery in the works of creation and discovery. And I think that to grasp that mystery, to be prepared for the unexpected, is the task of those of us who are helping others learn about the world.*

As I will discuss next, I am absolutely convinced that the scientific community will need to devote much more energy and attention to the critical issue of educating everyone in science, starting in kindergarten, if we are to have any hope of preparing our societies for the unexpected, as will be required to spread the benefits of science throughout our nation and the world.

Bruce Alberts, Harvey Fineberg, and Bill Wulf (front row, left to right) with the interns from the Christine Mirzayan Fellowship Program. FIGURE 4

Science education can be exciting and empowering for everyone.

I came to Washington in 1993 intending to be an "education president." As things turned out, I spent an enormous amount of time in my first two years at the Academies working on the *National Science Education Standards*. This was a great learning experience for all those who participated, including some 40 members of our Academy, because it forced us to collaborate closely with outstanding teachers and other professional science educators. For the first time, I came to recognize just how difficult it is to teach well. Never again will I equate good teaching simply with good lecturing, as I did in my first 25 years at universities.

The type of science teaching called for in the *Standards* emphasizes logical, hands-on problem solving, and it insists on having evidence for claims that can be confirmed by others. It requires work in cooperative groups, where those with different types of

talents can discover them — developing self-confidence and an ability to communicate effectively with others. But this so-called teaching of "science as inquiry" demands a revolution in science teaching at all levels.

A brief anecdote may help. A few years ago, my daughter was distressed when her son reached the second grade without any sign that science would ever be part of his curriculum. She therefore volunteered to teach a few hands-on science lessons to the class. On the first day, she gave each child a hand lens and three different types of soil, and she asked them to describe what they observed in each sample. To her dismay, the class soon became paralyzed, with no one willing to write the requested descriptions. Why? She discovered that, after two and a half years of formal schooling, these 7-year-old students had concluded that the entire point of education was to learn and regurgitate the "correct answers." A fear of making a mistake prevented them from writing anything.

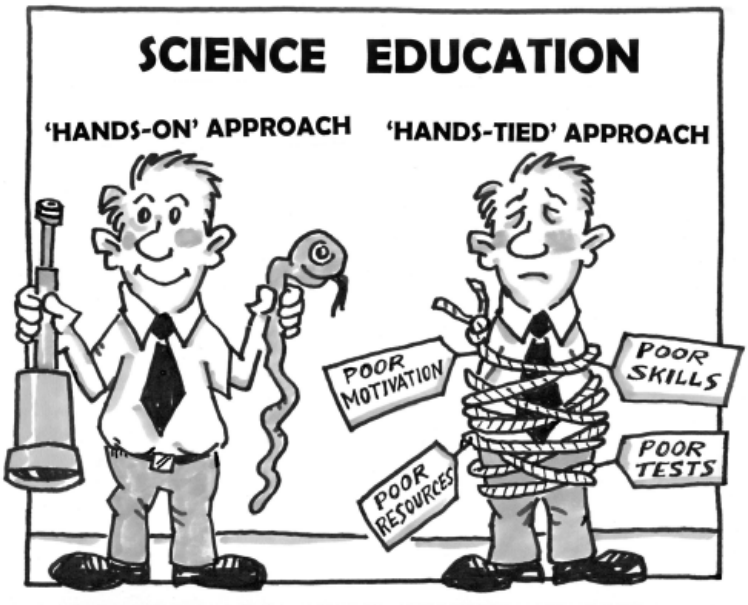


FIGURE 5 Credit: Carlton Stoiber

An education that aims to fill the heads of students with correct answers is a disaster for many reasons. For one, different cultures will have different answers, and our diverse societies will suffer greatly from intolerance. Instead, all students must learn how to learn, so that they can solve new problems and overcome the many challenges that they will encounter in their adult lives.

Some of you may be unfamiliar with the type of science education I am promoting. A cartoon may perhaps be worth a thousand words (Figure 5).

The good news is that a science education of the type we want meets major practical needs of modern societies. First, properly delivered, it can provide a nation with the type of work force that business and industry say they need: that is, workers with inquisitive, "can do" attitudes; the ability to use logic and experimental manipulations to solve problems; and the ability to function in collaborative work-groups. Second, by giving all young people the chance to function like a scientist, this type of education should enable a nation to do a much better job of encouraging and creating its next generation of scientists and engineers — people who will be absolutely essential for the nation to prosper in the global economy.

Science education can also help build a safer world.

More than a hundred years ago, John Dewey wrote, "One of the only two articles that remain in my creed of life is that the future of our civilization depends upon the widening spread, and deepening hold, of the scientific habit of mind; and that the problem of problems in our education is therefore to

discover how to mature and make effective this scientific habit."

Dewey could not have known that science and technology would soon lead to the creation of nuclear weapons, or that a mass movement promoting suicidal terrorism would arise in the 21st century. As our distinguished foreign associate Georges Charpak has emphasized in his latest book, we now face a desperate situation. Unless we can greatly reduce the dogmatism that infects our world, the eventual spread of knowledge will inevitably put nuclear technology into the hands of people who are eager to blow themselves up, along with hundreds of thousands of innocent civilians. These people will be motivated, supported, and then celebrated for this heinous crime against humanity by a large group of true believers.

This is why our Academy has put such a high priority on working closely with our colleagues in the Russian Academy of Sciences to prevent the proliferation of nuclear materials. And it is also why scientists all around the world must now band together to help create more rational, scientifically based societies that find dogmatism intolerable. More than 50 years ago, Prime Minister Nehru emphasized the importance of what he called a "scientific temper" for his new nation, India. By this he presumably meant a society that exhibits the creativity, openness, and tolerance that are inherent to science — a requirement for his diverse nation.

Well, the world has been getting smaller and smaller, so much so that it is now clear that we will need a "scientific temper" for *every* nation, if the wonderful diversity of our world is not to end up destroying civilization as we know it.

David Hamburg, one of our distinguished Public Welfare Medalists, has long stressed the worldwide need for education systems that create tolerance and reduce conflict, most recently in a book he wrote with his wife Betty called *Learning to Live Together: Preventing Hatred and Violence in Child and Adolescent Development*. In my opinion, teaching science to children in the manner called for in the National Science Education Standards, with its focus on science as inquiry starting at age 5, provides the best platform we know for this purpose. Fortunately the world's scientists agree that good science education in France, Sweden, India, China, Pakistan, or Chile is good science education anywhere. As a result, the science academies of the world have begun to work together very effectively on this problem of such crucial importance to us all.

To quote Bentley Glass, a distinguished Academy member who died a few months ago,

> *It is not safe for apes to play with atoms… For the scientific society to be democratic and to remain democratic, the people themselves must understand the nature of the scientific forces and problems that dominate their lives. For us who are teachers, this is our task and our commitment. …All levels of science instruction must change. The task will be costly and hard; but the end is not even the advancement of science, though that will accrue. The true end is quite literally the salvation of man.*

The Critical Role of the National Academies

Despite the great advantages of the type of science education I have been advocating — the promulgation of rationality and tolerance, the preparation of a competitive work force, and the production of the best possible scientists and engineers — only an estimated 15 percent of the students in the United States are currently learning science in this way. We have been making progress, but it is slow. Unfortunately, most of our schools still focus on having students learn what science has already discovered, rather than having them take part in the process of discovery so that they can understand science as a special way of knowing about the world.

What are the Academies doing to keep us moving in the right direction?

1) Stimulating Better Research

It takes much more energy to prepare and support teachers to teach science as inquiry than it does to prepare them to teach science as memorizing "facts" from a textbook. We therefore have to demonstrate the added value of inquiry-based approaches to science education with hard evidence, of the kind we get from science itself.

Based on one of our reports, the Academies have recently helped to establish a new nonprofit organization, known as SERP, the Strategic Education Research Partnership, which aims to create highly collaborative networks to carry out this type of work. Without efforts of this kind, I fear that our nation's schools will continue to flounder.

The National Academies' first major attempt to "make a science out of education" was a very popular book, *How People Learn*, which has recently been supplemented with a set of books for teachers on *How Students Learn* (Figure 6). Here our committees took what has been gained from research on human learning over the last 30 years and explored its implications for our schools. In a program sponsored by the InterAcademy Panel, we are now planning a multinational research collaboration on inquiry-based science education, in order to generate an objective analysis of what works and why.

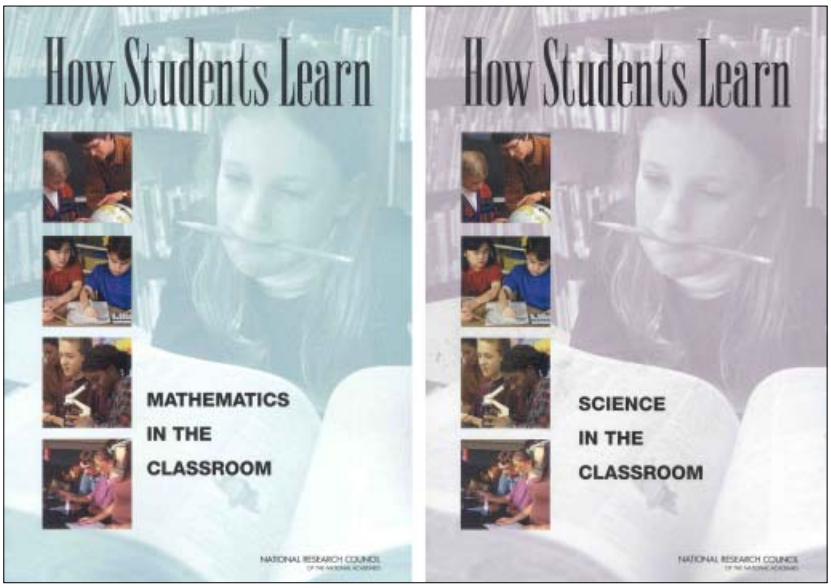


FIGURE 6

2) Improving Science Tests

In this era of increased testing and accountability, it is critical that we develop and apply the right kind of science tests. We must test students for science *understanding* rather than mere knowledge of scientific facts. Science education should not be about memorizing the parts of a cell and then taking a multiple choice exam to test scientific vocabulary. Producing good tests for science is challenging and expensive. But the wrong kinds of tests will trivialize science teaching by

sending the wrong message about what kind of teaching and learning are valued — driving even more students away from both science and scientific careers. Within the next few months, we will release a major report designed to help guide each of our 50 states, as they prepare to meet the requirements of the No Child Left Behind program for testing in science by 2007.

3) Collaborating with Industry Leaders

In general, U.S. industry doesn't adequately recognize the fit between the type of science education that is envisioned in the National Science Education Standards and the work force that industry needs. In collaboration with several leading CEOs — including Craig Barrett of Intel, who currently serves as the chair of our sister academy, the National Academy of Engineering — the National Academies are reaching out to the major industry CEOs directly, so that they can become better advocates for their own long-term interests.

4) Giving a Voice to Our Best Teachers

U.S. school systems generally pay little or no attention to the wisdom of the most important people in their schools — that is, to their outstanding teachers and principals. Nor is there a strong-enough voice for our best teachers when federal and state education policies are being designed. Three years ago, the National Academies established a Teacher Advisory Council (TAC), in an attempt to set a different example. This group of 12 carefully selected science, math, and technology classroom teachers — from elementary through high school — has been meeting three times a year, advising our staff on our education work and contributing directly to studies, projects, and reviews of products. They have also added individual teacher affiliates from nearly every state, and they are now helping to catalyze the establishment of similar state-based TACs — with the first one recently established in California, and a second currently in the planning stages for the state of Washington.

5) Improving the Teaching of Science by University Faculty

A major cause of inadequate science teaching at lower levels is our own system of higher education. Our teachers can't be expected to teach what they don't know. And the knowledge needed extends beyond disciplinary content. Most of today's teachers of science — whether at the elementary, middle, or high school level — have never experienced inquiry-based science education themselves.

If we really care about creating a "scientific temper" for the United States, we will need to completely rethink most of our introductory college courses — both to make them more inquiry based and to focus them on the goal of conveying an understanding and appreciation of science, and its relation to society, to all students. The Academy is the obvious place to catalyze such an effort, and led by Nobelist Carl Wieman, we have been increasingly active in stimulating change. I call on all of our members to support this effort at your own universities.

Unfortunately, my time is nearly up. Before closing, let me say what a privilege it has been to have had the opportunity to guide this ship for the past 12 years. But with great opportunity comes great responsibility, and what makes this job so difficult — keeping me up most nights — is the many opportunities that I know I will have missed, and the tasks remaining on my long to-do list, when I pass the baton to my successor in a few months.

FIGURE 7 An exhibit on "Putting DNA to Work" on display at the Marian Koshland Science Museum

Nevertheless, much has occurred in the past decade: the construction of the Keck Center of the National Academies and our wonderful Marian Koshland Science Museum (Figure 7); the formation of two critical international organizations — the InterAcademy Panel and the InterAcademy Council; the completion of the *National Science Education Standards*; the strengthening of our science education partnership with the Smithsonian Institution through the National Science Resources Center; the publication of a large number of landmark reports (Figure 8) — including *Allocating Federal Funds for Science and Technology*; *Our Common Journey: A Transition Toward Sustainability; The Evaluation of Forensic DNA Evidence; Teaching About Evolution and the Nature of Science; Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards; Reducing Underage Drinking: A Collective Responsibility;* the Institute of Medicine classic *To Err Is Human: Building a Safer Health System;* and the outstanding guidance of the nation's transportation efforts by our Transportation Research Board.

And last but not least, there is our tremendous success in making all of this information freely available on one of the world's best Web sites.

None of this could have been accomplished without the fantastically skilled and dedicated staff who come to work at the National Academies every day, some 1,100 employees. Nor could it have been done without our 6,000 committee members who work pro bono each year, as a tremendous service to science, our nation, and the world. I am also grateful for having such talented

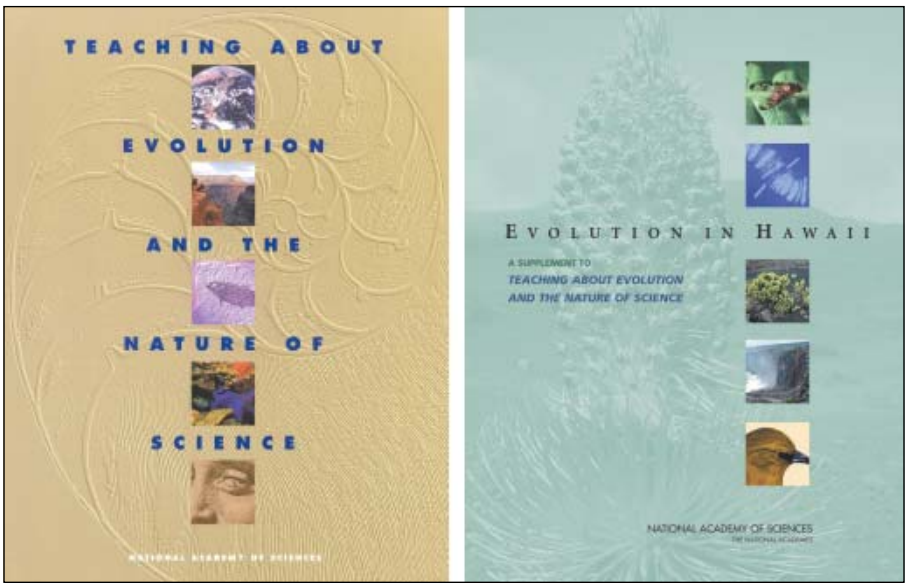


FIGURE 8

colleagues and partners in Bill Wulf, the National Academy of Engineering's president, and Harvey Fineberg, the Institute of Medicine's president. I want to thank your officers: Vice President Jim Langer, Home Secretary John Brauman, Treasurer Ron Graham, and Foreign Secretary Mike Clegg for their tremendous leadership. And of course I need to acknowledge the great patience and support of my wife Betty, who has been promised many things by me that were not delivered over the course of the past 45 years, including our return to San Francisco in 1999, after my first term.

Science, a Noble Adventure

Science is a great, noble adventure — an unending frontier in the long struggle of human beings to understand the world that surrounds us. Scientists tend to be optimists, because each of us has witnessed a remarkable parting of the curtain of ignorance that once enshrouded each of our scientific fields — as I have in cell and molecular biology. All of us who were graduate students 40 years ago would have laughed at anyone who dared to predict the spectacular increase in our understanding of the chemistry of life that has since occurred. As illustrated by the Academy's *Beyond Discovery* essays, science is a marvelous community endeavor, one that enables new knowledge to be built upon old knowledge in unpredictable ways — ways that have enabled us to understand and manipulate this world to produce great benefits for humanity.

Bruce Alberts and child, learning about science. FIGURE 9

Armed with the confidence that comes from this success, we can now face the next seemingly impossible challenge, as we devote ourselves to the ambitious but critical task of creating a scientific temper for the world (Figure 9).

It has been a great privilege for me to have served as your president for the past 12 years. Thank you.

NOTE: The text of this speech, with direct links to the full text of cited reports, is available on the Academy's Web site at <www.nasonline.org/2005address>.