

# The Responsibilities of Scientists in a Changing World

**Bruce Alberts**

President

National Academy of Sciences

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I have now had the privilege of serving as President of the NAS for nearly 10 months. The Nominating Committee did an exhaustive job of checking my background. So they knew that I held several strong beliefs that were sure to be played out during my term as President. In this, my first formal address to the Members, I want to outline some of these beliefs -- and give you an overview of how they affect this institution, as well as our "operating arm," the National Research Council.

I want to start with some basic premises that I believe should underlie what this institution is about. The first of these has to do with scientists, or more specifically with the behavior of the scientific community -- while the rest deal with the society in which we find ourselves, and with some problems that have arisen from the attempts of our government to govern.

Let's start with the strengths of the scientific community as I know them.

The United States presently has a tremendously vital system of education and research, a system that must be preserved. Most of the scientists whom I know are extremely talented, energetic and resourceful. This is no surprise since we select for these attributes in our young people. Moreover, scientists have many talents that could be applied to societal problems beyond their particular expertise. They are idealistic people with broad interests in society and a willingness to provide public service without compensation. Scientists also tend to share a set of values that are important for society. In particular, I would like to emphasize three of these values: honesty, generosity, and a respect for the intrinsic worth of ideas and opinions.

1) As for *honesty*, the whole scientific enterprise depends on an honest reporting of the results of experiments. A scientist's whole reputation depends on how well his or her past findings have stood the test of time. There is relatively little cheating, if only because the penalties for being wrong are so severe -- especially the loss of respect by our colleagues.

2) *Generosity*. There is a social contract among scientists that is essential to maintain the enterprise. Many of us spend as much as half of our time serving the scientific community in volunteer roles for which we receive no monetary compensation. In addition, because young scientists represent the future of our discipline, we nurture them and pay special attention to promoting their careers.

As an aside, you may be amused to hear that, after one of my recent speeches, a prominent lawyer in the audience raised his hand to ask whether there was any tradition in the scientific community of doing "pro bono" service! Obviously, we have a long way to go in educating our fellow Americans about the traditions of science.

3) The third value is a respect for the *intrinsic worth of ideas and opinions*. In my experience, the best ideas often come from students. When a voice of authority was given undue weight in the past, it often delayed progress in that field of science. As a result, most scientists will not only *listen* to anyone with an idea, but will actively seek out the ideas of others.

I believe that these three values -- honesty, generosity in support of the entire enterprise, and respect for the ideas of others -- are central features of the scientific community. These values of science are sorely needed by society at large; and it is especially crucial that they be the hallmark of this institution, which represents science to the world.

This country contains a remarkably large number of scientifically and technically trained people. According to one count, there are more than 5 million of us, spread throughout the country in a wide variety of academic, medical, and industrial settings. It is clear that these people represent a tremendous resource for the United States and the world.

Many of you in this audience have devoted your lives to public service. But if there is a problem with most scientists, it lies in our too frequent isolation as a community of individuals who enjoy interacting with each other, but have much less connection with the rest of society. The reasons for this isolation are obvious. Most of us already work very long hours.

Moreover, we often have little patience for what we see as the irrationality of other aspects of the world. When I was in high school and read *Arrowsmith* by Sinclair Lewis, I felt that the hero's retreat to a cabin in the woods was a *great* model for a scientist. But I have completely changed my mind about this.

Why do scientists -- among others -- need to become much more closely involved in matters of national concern? It seems clear to me that, if left unattended, society does not work well. Instead, unanticipated feedback loops seem to develop that create what I will call, as a biochemist, "*counterproductive energy minima*." That is, situations where the rewards of the system reinforce behaviors that are destructive for society as a whole. Society, therefore, needs the constant application of intelligence and energy to get us *out* of whatever hole we are in and set us back on course. Scientists, including all of us in the Academy, have a major role to play here. In part this is because so many of the problems of modern society require scientific and technical expertise, but also because we have spent most of our lives learning how to be analytical and unbiased in our investigations of the world.

You can all name many examples of counterproductive energy minima, but let me give you one of my favorites. Driven by the apparent "needs" of society, the precollege science textbooks that we use in our schools have seriously degenerated since the height of the post-Sputnik reforms. This is not unrelated to the fact that our school systems in this country are dysfunctional as feedback systems and rarely learn from their mistakes and successes, as required for any continuous improvement. The result has been a plethora of mediocre textbooks that continue to be recycled year after year, because no effective system of evaluation exists to kick them out of the system.

I receive and answer many letters from Members. So I know that some of you feel that societal problems are not the responsibility of scientists. Some contend that government exists to solve such problems, and that scientists are unprepared to participate in correcting the many imperfections in the world that surrounds us.

We all wish that government did a better job of dealing with the fundamental problems of our society. Now that I have been inside the Beltway for 10 months, I can offer my *personal* explanation of why it is so hard to govern from Washington.

First of all, everyone in government seems to be enormously pressured from all directions. With so many *urgent* problems to solve, there seems to be little time for careful study and analysis. In part *because* of this pressure -- and this is a favorite point of mine -- Washington often seems to be isolated from the real world that its laws and regulations will eventually affect. In our complex society, people who have the authority to make decisions often lack the detailed knowledge that is required to make those decisions correctly, and they don't have the time to obtain it.

So what is our role at the Academy and the National Research Council? By some miracle, our government believes in the idea of asking us for impartial advice. This tradition started with Abraham Lincoln and the founding of the Academy in 1863, as illustrated on the first slide. And it has continued with a series of Executive Orders, the latest in 1993. Through the National Research Council, we as scientists have a great opportunity to bring our wisdom to government. This is good for government, because we provide government with up-to-date science and technology advice through an organized and effective mechanism. And it gives scientists, as individuals, a pathway for contributing our views to the nation in ways that would otherwise be difficult or impossible.

I see the National Research Council -- as the *bridge*. A bridge that uses scientists to bring the real experiences of the world to Washington, thereby connecting us to government for matters of science policy. I first became involved with the Research Council when I was asked to chair the Committee on Mapping and Sequencing of the Human Genome in 1986. Our study took 14 months to complete, and it set out a plan for a human genome project that was largely adopted by the government. I view our committee's experience as typical for the NRC. The role of our committees generally is to reach a conclusion that is based on detailed study and intimate contact with the entire spectrum of individuals at the frontlines. And each committee consists of a diverse group of experts. In my case, the individuals on the frontlines were young laboratory scientists who we called in to testify, but in other cases they have been outstanding teachers, Vietnam veterans, or parents of children who have been adversely affected by a vaccine.

Notice that all of the arrows in this diagram go both ways. In addition to communicating the views of scientists to the government, the Academy has an important role in interpreting the concerns of government to the scientific community. It is in this latter role that our Council issued a statement on scientific conduct last February. On June 6 and 7 in this auditorium, we will join with the National Academy of Engineering and the Institute of Medicine in sponsoring a major colloquium on scientific conduct. Chaired by Gerry Fischbach from Harvard, this event will be designed to help the scientific community deal more effectively with this important issue.

What are some other major themes for the National Research Council? I had the privilege of attending a Population Conference in India last October. Some 60 different Academies of Sciences were represented there. I learned that our Academy is universally admired for the relationship that we have as an adviser to our government through the NRC. No other Academy in the world has such a relationship. Even my friends in Europe are astounded that our national government is willing to support the cost of studies whose results they cannot control!

We are currently engaged in several joint studies with the Mexican Science and Engineering Academies that have three aims: One is to provide advice on matters of importance to the Mexican government that involves science and technology. A second aim is to inculcate a group of Mexican scientists with the procedures and traditions that have been worked out at the NRC for arriving at a consensus view on an important matter of science policy. And the final aim is to help the Mexican Academy gain credibility with the Mexican government, so that the Academy will be asked by its government to carry out similar studies in the future without our help.

With the Mexican example as a model, we are presently negotiating with both the Chinese and the Indian Academies of Science to begin a similar process of catalyzing the development of NRC-like functions for the Academies in those two countries. I see such help for foreign academies as the major thrust for our Academy's future role in foreign affairs.

One of the Mexican studies presently in progress deals with the Mexico City water supply; the other deals with the application of new technologies to Mexican development. The studies presently being discussed with the Chinese and the Indians are likewise in the broad area of sustainable development. The issue of sustainable development will be an important focus for scientists for the foreseeable future, and we want to make it one of the major themes for the National Research Council.

It will come as no surprise to most of you that I see science education as another major theme for the Academy and the NRC. We have always been intensely concerned with the education of scientists, but now our focus has broadened to include science education for *everyone*. In 1985, Frank Press established two institutions that have moved us to the forefront of precollege education efforts -- one in math, the Mathematical Sciences Education Board, and one in science, the National Science Resources Center. And in 1991, we accepted the leading role in developing the National Science Education Standards, as Jim Ebert explained so eloquently from this podium last year. Currently, education occupies about 10 percent of our total effort, and we have roughly 90 staff members at the NRC who work primarily on education issues.

We expect to produce the first full draft of the National Science Education Standards this summer, with the final document due early next year. These standards will call for the kind of science that provides both an understanding of the basic concepts needed for success in our highly technological society, and the acquisition of what I will call *process skills*: that is, the ability to proceed step by step to solve a practical problem by examining the effect of changing one variable at a time. This is the type of education that one needs for success in the modern workplace, as well as for everyday living. And it needs to start in elementary school, where we can take advantage of the natural curiosity of children and their excitement for learning.

We are very fortunate that outstanding hands-on science curricula for kindergartners through sixth graders have been developed and refined over the years in the United States, some of them by our National Science Resources Center. Some of these age-appropriate, 8-week teaching kits will be on display in the Constitution Avenue foyer throughout this meeting; one is illustrated on the next slide. They have been extensively tested by teachers and in the classroom, and each explores one subject in depth -- such as plants, the life cycle of butterflies, or electric circuits. The equipment and materials are *simple and affordable*. Most importantly, by allowing reading, writing, and math to be taught as real experiences, this type of science can and has reinvigorated entire schools.

Here is the sad part. Even though this type of science teaching has been pioneered in several school districts in the U.S. for 20 years, it has not spread. As a result, probably less than one-percent of our elementary school students today are being exposed to the type of hands-on science that they need for their future. Here we come to the most fundamental flaw in our whole education system. As our fellow Academy member Ken Wilson has pointed out repeatedly, unlike the automobile or computer industries, *there is no continuous improvement cycle at work in our schools*. Instead, the bad things often drive out the good. The reason is simple: The system we have tends to select the curricula that are the easiest to teach and to give tests on. Hence an emphasis on science *words* instead of science concepts. And it is likely that, even with the science education standards, this situation will not change.

From my experiences in traveling around this country, I have come to realize that we urgently need an ingredient in each school district that is *completely new*. In Washington, D.C., for example, there are presently 80 different outside groups trying to improve the science and math curriculum, with little or no coordination between them. A much more effective approach would be for all of these groups to work together on a few major projects. But, unfortunately, the groups lack a decision-making body that both the teachers and the others respect. In each school district, we need a central platform for continuous improvement in science education that is based on a local partnership of informed scientists and other citizens, together with a group of outstanding science teachers in that district and the district's science coordinator.

Time does not permit any details here, but I believe that there is an important role for the National Research Council to play in catalyzing the types of changes that I am suggesting for science education. By combining our resources with those of the many scientific, engineering and medical societies interested in this issue, we can create an effective national network designed to inform and communicate with the type of local partnership group I have just suggested. In part, this network would rely on using already existing scientific society newsletters to mobilize scientists, and to connect them to the resources that they will need to promote major changes in their local school districts. There has also been a great deal of talk about the need for a database on the Internet, which is specifically designed to aid such scientists in their networking efforts.

I also see a special role for universities in science education reform. What we need from our universities in the 21st century are programs that first educate young people in science, but then are able to prepare them for a very broad range of highly valued careers -- as illustrated on the next slide. In particular, it is crucial for this country that one of these valued careers be precollege science teaching.

Our Committee on Science, Engineering and Public Policy has embarked on a study of advanced degree training. The many experts who have appeared before COSEPUP discussing our present education system have highlighted the fact that it is very difficult to transfer from science to science education, or to other fields. There is no smooth pathway by which a scientist can become a science teacher, even though these scientists are greatly needed -- both as teachers and as future leaders of science education reforms. Instead, our faculty members generally make it clear that a career change of this type is not valued by scientists.

Despite many disincentives such as these, I repeatedly am amazed by the number of dynamic and talented science teachers that I find in every school district that I have visited. Imagine what our school systems would be like if scientists actually *encouraged* our students to become teachers, and maintained contact and our support for them after they depart for the schools.

As I was preparing this talk, I was struck by a parallel between the two examples that I have cited for major NRC initiatives: the catalysis of NRC-like functions in other countries, and the use of local scientists to catalyze science education reforms. What we are attempting to do in education is schematically outlined on the next slide. This is very similar to the international program that I outlined, shown next. In both cases the goal is to bring an increased rationality to society through the volunteer efforts of informed scientists. In each individual school district, as in each individual country, the local conditions will be different and the situation will be much too complex for a "top-down" solution. Instead, I envision scientists as intelligent local *adaptors* -- working in groups to adapt information provided through a much larger network to a local problem: In one case, they would be improving a school system; in the other case, they would be promoting a form of economic development that has a minimal impact on the environment -- meanwhile providing feedback from their experiences that continually increases the wisdom available to everyone.

It is critical that all of the information flows in these diagrams be bi-directional, and that the scientists recruit other individuals with complementary expertise to join them as volunteers. Just as the NRC does in all of its work, these efforts would attempt to bring many different parties together as collaborators.

In each of the examples that I have given, I have described an unconventional role for scientists. Science education is usually left to local school boards and to school administrators, and economic development is generally left to politicians and to businessmen. To play these new roles, the scientists involved will need to be willing to be extensively educated and to become connected to an effective information network.

During my brief time in Washington, I have tried to keep my ear to the ground. What is it that society expects of scientists in return for the generous support that has been provided for scientific research? Of course, the public expects our discoveries to benefit society in the long run, as Vannevar Bush so eloquently explained in 1945. But now that the Cold War has ended, and our society has so many new problems that science and technology can help to solve, even more is expected from us. I paraphrase from a recent statement by one of the strongest advocates for science in Washington, Congressman George Brown:

We must shift our thinking about science and technology from a defense perspective to a broad and benevolent perspective of science and technology in the service of a humane society.... The disintegration of our communities and our family structure, the deterioration of our environment, and the absence of permanent, affordable health care are just the beginning of a new science and technology agenda for the next 40 years. We must marshal our superb research system to help solve these societal problems, and it will require the creativity and intellectual vigor of our entire scientific community.

There is a flip side to this focus on societal goals, which has been disturbing to scientists. With this country's obsession with short-term economic goals, scientists need to constantly explain the benefits of fundamental research to the general public, the Executive Branch and Congress. It is traditional for the Academy President to address this subject, and both Jack Halpern, our Vice President, and I have been spending a lot of time on it. We are very fortunate to have so many high-ranking scientists in this administration as allies. These leaders include the President's science adviser, Jack Gibbons; his Associate Director for Science, M.R.C. Greenwood; John Deutch and Anita Jones at the Department of Defense; Neal Lane at the National Science Foundation; Harold Varmus at the National Institutes of Health; and Martha Krebs at the Department of Energy. This is a terrific team, and I have been interacting very closely with them on this important issue.

In addition, Jack Halpern has been organizing a "basic science initiative," where the Academy is using some of our endowment funds to help the scientific societies prepare effective case studies for public consumption. These brief publications will be designed to take an important new product or process that everyone cares about and trace how unexpected discoveries from fundamental research were crucial for its development. I am certain that we can be much more focused and effective as a community here.

In summary, I have tried to explain how the National Research Council brings the wisdom and objectivity of the scientific community to bear on matters of great importance to the nation and the world. If we are successful, the world will be a better place. And we will be providing a dramatic demonstration of the wisdom of this nation's past support for science. This support has created a large, vigorous community of scientifically trained individuals, who have the motivation and skills required to advance civilization in the next century. Our job is to sustain this community, and to facilitate its many contributions.