PART 2

A Vision for Science in Public Policy

Introduction: Stephen D. Nelson

Stephen D. Nelson is associate director of Science and Policy Programs at the American Association for the Advancement of Science. He directed AAAS's Science and Technology Fellowship Programs for 15 years, as part of his responsibilities as program director of the Science, Technology and Government Program (1990–1999) and as manager of Science Policy Studies (1984–1999). Dr. Nelson has also co-authored or co-edited 42 volumes published by AAAS on federal funding for research and development and other issues in science and technology policy.

Before joining AAAS, Dr. Nelson was senior professional associate at the Institute of Medicine, National Academy of Sciences, working on a study of the organizational structure of the National Institutes of Health. He also served for six years as administrative officer for science and technology policy at the American Psychological Association. Before coming to Washington in 1977, he was project director at the Center for Research on Utilization of Scientific Knowledge, Institute for Social Research at the University of Michigan. He also taught in both the psychology and sociology departments at Michigan. He received his B.A. in psychology from Kansas State University and his Ph.D. in social psychology from the University of Michigan.

Good morning and welcome. Before we look ahead to the future, I want to take us back to the past a bit, really, really back to the ancient Library of Alexandria. Founded in 288 B.C., the Library of Alexandria was a wonder of the ancient world and a unique achievement of the human intellect. It represented the pinnacle of learning for more than six centuries and remained a source of inspiration even after its disappearance 1,600 years ago.

Now, you may know that there is a new Library of Alexandria, Biblioteca Alexandria, inspired by the original and located very close by the site of the original. It includes a library for up to 8 million volumes; six specialized libraries; three museums for antiquities, manuscripts, and the history of science; seven research institutes; several exhibition galleries, two for permanent exhibitions and six galleries for temporary exhibitions; a planetarium; an exploratorium for children; and a conference center that can accommodate 3,000 seats.

The library receives over 250,000 visitors a year, and it aspires to be the world's window on Egypt, Egypt's window on the world, a learning institute for the digital age, and above all, a center for learning tolerance, dialogue, and understanding. Through its various functions, the library has identified four main themes: science, with a special emphasis on the ethics of science and technology; humanities, with special emphasis on new scholarship and historical studies; arts and culture, with a special emphasis on intercultural dialogue and criticism; and development issues, with special emphases on water and gender.

What kind of person would one select to be the

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director of this marvelous institution, the first head of the Library of Alexandria in 1,600 years? Who would have the abilities and the capacity to direct this ambitious center and to deal with its many facets and many challenges? Let me tell you a little bit about the person who was selected, and you'll begin to see why he was a perfectly appropriate candidate for that job. And then after you've heard him speak, you will begin to understand why he was exactly the right person for that job.

Ismail Serageldin is an Egyptian national, born in 1944. He received a bachelor's degree of science with first-class honors from Cairo University, a master's of regional planning from Harvard University, and a doctorate from Harvard. He worked in many different capacities at the World Bank since beginning there in 1972, culminating in his service as vice president for environmentally and socially sustainable development from 1992 to 1998 and vice president for special programs from 1998 to 2000. In addition, he has led numerous international bodies and committees, primarily on issues of development, agriculture, and poverty. Dr. Serageldin has written or edited more than 50 books and monographs, as well as some 200 articles, book chapters, and technical papers. He has received at least 16 honorary doctorate degrees from institutions in nine countries on five continents. He speaks three languages fluently, Arabic, French, and English.

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Furthermore, as you will see shortly, Dr. Serageldin is a person of vision and compassion, with a burning sense of the moral tasks facing science and technology in the world of the future or, more accurately, as science and technology confront the possible futures of the world. For as we know, the task of looking to the future is not to try to predict it, which probably is not possible in any sense, but rather to clarify choices among the different paths that can be taken, so that we can make more intelligent decisions in the present. Our speaker has spent his life doing exactly that, trying to help individuals and organizations make more intelligent choices in the present so that the future can be more hopeful. Let's welcome him.

Ismail Serageldin

I'm delighted and honored to share some thoughts with you about the issues that will be facing science in 2033. People have different views on that subject, of course, and I would like to present a view that is truly global, recognizing that, if the United States is the locomotive and humankind is the train, we nevertheless are all together in this global environment.

Allow me to start by discussing the age of science and the paradox of our times—notably, the coexistence of enormous wealth with resource constraints and poverty. I will talk about the vast potential power that is arising from the new science and technology, as well as the need to temper that power with a new ethics. Finally, I will close with a few words about scientists' responsibility to engage in public debates, to bring the values of science into policy discussions, and to turn the focus of scientific inquiry to the pressing problems that we see around us today.

There are more scientists alive today than have lived throughout all of the preceding millennia. Science permeates the cultural outlook of more people than ever before, and science has yielded enormous improvements in human welfare. We are now moving into what I will term the third global revolution, a knowledge-based society in which science is central. The first global revolution was the agricultural revolution, without which there would not have been civilized human existence and cultures would not have arisen. To this day, of course, it is the surplus produced by farmers that allows the cities to exist. We can sometimes forget that our foundation is agricultural, just as our youngsters, if asked where food comes from, respond that it comes from the supermarket.

The second great revolution, of course, was the industrial revolution, which transformed the relationship of humans both to resources and to work. No longer was there an artisan who produced a finished product; the worker became part of a bigger machine, doing a specific task according to a division of labor, and it brought an enormous spurt in productivity and output.

Today, the third global revolution is really the knowledge revolution. For the first time, a Web connects knowledge and researchers around the world. People doing research in Japan know what's happening in Brazil. People doing work in India know what's happening in the United States, and vice versa. It is all thanks, of course, to both the enormous expansion of computing and the incredible extension of communications. Modern communications have made it possible to remain instantaneously in contact around the planet almost at all times, a feat that would have been unthinkable 30 years ago.

But the digital revolution goes deeper, because the ones and zeroes that make up the language of bits and bytes in effect constitute a common language that brings together image, voice, text, data, and music. As a result, we witness mergers and acquisitions of a nature we never saw before, and we see them all right on our personal computers. But, as we all know, it is not just a single computer that is the strength of the new revolution; it is the networking of these computers, their ability to connect with each other, that creates these global exchanges of knowledge, both for commerce and for science. They permeate our existence to such an extent that we really cannot believe what would happen if, for any reason, there was a hang-up. We rely every day on that network of communications, often in countless ways we don't even see or realize, whether for scheduling trains or organizing production in manufacturing, whether for checking bank transactions, or tracking deliveries, or performing any other task that requires comparing or manipulating data.

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New digital processes are also revolutionizing our most basic notions about technology. Everything seems to be getting smaller and smaller. With nanotechnology around the corner and micro machinery that is smaller than the head of a pin a reality, dramatic possibilities abound. All of those mechanical advances are overshadowed, however, by the emerging new revolution in genetics and biology.

The new life sciences revolution would not have

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been possible without high-speed computers, because nothing else could handle the massive data processing it requires. So, there's a synergistic transformation taking place. The new biology has opened new unimaginable vistas. We will be able to do so much more because we have begun to understand the common language for all living things, the genetic alphabet. Just like the digital code now shared in other data, science is gradually beginning to master the manipulation of the very building blocks of life.

So, the knowledge revolution is driven by science, and it relies on information and communication. It will transform the life sciences, creating he new agriculture and the new medicine. It promotes globalization, economic liberalism, personal freedoms, and so much more. We are just at the beginning of the knowledge revolution, and already we are seeing a very clear movement away from brawn to brains in terms of producing wealth. Only 24 years ago, in 1980, if somebody had asked how the richest man in the world at the turn of the century would have gained his wealth, nobody would have answered from the design of software for personal computers.

The third global revolution is going to require some wrenching adjustments. We are seeing it already in industrial countries, where sectors are merging that never merged before. We are seeing it in profound transformations across the planet. For the developing world, the storms ahead are going to be far greater than for the well-advanced, industrial countries that are now driving the process. About four-fifths of humanity is going to have to cope with such radical transformations.

Why make this distinction between industrial and developing countries? That question brings me back to the paradox of our times. We did in fact push back the specter of nuclear holocaust, but we discovered that nonetheless security is not ensured. We thought that stability would come after the end of the Cold War, but it didn't. We thought that science promised us much, but nonetheless, in many parts of the world, death is a daily affair. Some of those deaths are from disease, but some, especially in the developing countries, are from civil wars and internal strife. Today, we have more displaced persons than we had at the end of World War II. A legacy of past wars continues dramatically with landmines that do not have time limits, and the result is that poor farmers who try to access land are maimed long after the conflict has ended.

Human rights have advanced, and women have assumed a much bigger and rightful position in society. Nonetheless, people in many parts of the planet continue to suffer enormous discrimination. In Africa, women farmers produce 80 percent of the food, but receive 10 percent of the wages and own 1 percent of the land. A gender gap remains in basic schooling in many parts of the world.

Less dramatic, but more challenging is the reality of global economic forces that will further marginalize the poorest people striving to make their livelihoods, using whatever resources they have at hand. In parallel, our activities are having an impact on the global environment. We are polluting our air, our waters, and our land, usually in ways that are associated with enormous human degradation. Our economies grow, and people continue to survive, even if they have to live off garbage. Nonetheless, at the same time we are destroying our patrimony of the natural resources and ecological systems on which we depend. We are only now beginning to understand how in fact the delicate web of ecosystems and the relentless interaction among species are affected by our clear-cutting of forests, our burgeoning cities, and our impact on habitats around the world.

It's in the developing countries that cities are growing most dramatically. The increment to urban population in India over the next 30 years will be larger than twice the total population of France, Germany, and the United Kingdom combined. That increment is associated with grinding poverty and misery. We still have about 1.2 billion people who do not have access to clean water. We have about 2.6 billion who have no adequate sanitation. Those two figures together lead to millions of children's deaths from waterborne diseases. The World Health Organization tells us there are 1.3 billion people, almost all of them in the cities of the developing countries, who are breathing air that is unfit for humans. But even more dramatic, to my mind, is the fact that there are about 800 million people, mostly women and children, who suffer from indoor air pollution caused by burning biomass fuel for cooking and heating. That's the equivalent of smoking three packs of cigarettes a day. Much of the death and disease that afflicts the world's poor people would be avoidable but for the huge deficit of past commitments of assistance that the world has subscribed to but hasn't met.

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Urban dwellers still depend on the countryside for food supplies, and there, too, constraints are tightening. Hundreds of millions of poor farmers are unable to maintain the fertility of the soils from which they eke out a meager living. With rising populations, the amount of arable land available for planting is extremely small on a per capita basis. In Egypt, arable land per capita amounts to only 0.05 hectares; in Bangladesh, 0.09; China, 0.11; Indonesia, 0.12; Philippines, 0.13; and India, 0.18; in the United States, in contrast, the amount is 0.70 hectares per capita, or 15 times more available land per capita than in Egypt. In addition, we are diminishing the quantity and quality of topsoil in every region of the world. This is one of the least appreciated problems. The fertility of the soil on which we depend for food security is being eroded and degraded in a significant way.

Also underappreciated is the fact that the availability of water is a serious constraint on economic development and human well-being. About two-thirds of global freshwater goes into agriculture, and in developing countries the share is 80 to 90 percent. It takes about 2,000 tons of water, and sometimes as much as 4,000–5,000 tons, to produce a single ton of rice. It takes about 1,000 tons of water to produce a ton of wheat. The agricultural use of water is enormous. Freshwater from rivers and lakes is often supplemented by pumping underground water. About a quarter of the energy subsidies in India are going to pump water. And that pumping, of course, is causing the serious problem of dropping water tables. Already 10 percent of world grain production depends on unsustainable underground water withdrawals. As the water table drops, wells have to be redug or abandoned, and the lack of water may then lead on to desertification of the area, marginalization of the people living there, and many other problems. It is a sad story in a world that can provide for better management.

In addition to this stock of problems, we are confronting the challenges of adding about 70 million to 80 million people a year, a population about the size of Egypt or Mexico now. We expect that before the population of the world stabilizes, we will have another 2 billion people, every one of them in the developing world. The industrial world as a whole will not grow. Those new residents of the world, all young people coming of age, will be looking for jobs. Will they have the skills to work in the knowledge-based society? Will they put even more pressure on our fragile environment?

Now, to me, the environmental questions are inextricably intertwined with caring for people, and I have always advocated what I call people-based environmentalism. I believe the world's children are entitled to clean air, clean water, and fertile soils. It's not a question of environment versus development or environment versus livelihood, because we need both.

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We have to recognize that we are talking about not just the people in the industrial countries, who represent about 15 to 16 percent of the total population, but also everyone in the developing countries, which will be close to 80–85 percent of the global population. Today, an enormous gap exists between the rich and the poor, and it is growing. It is a stunning reality of our times. We take so many things for granted, so many brand names, so many items as part of our every-day life, in fact so many luxuries. For example, an average suburban person in the United States can see hundreds of television channels at the touch of a button. Some people are looking for ways to spend their excess money in leisure ways, while around the planet; many others are literally scrounging out an existence on garbage. In many, many cities of the world, that gross disparity is a sad fact.

Even more unbelievable and unconscionable is the fact that in a world where we have massive agricultural production, even a surplus in some areas, we still have

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800 million people going hungry. Surely, the most basic of all human rights is to have enough to eat. In the nineteenth century some people looked at the condition of slavery and said that it not only demeaned the slaves but also degraded free people to accept its existence. And they did not ask that we should at the margin improve the condition of slaves. They demanded that we should abolish slavery. One of my great heroes, Frederick Douglass, an abolitionist and also one of the first feminists, did not argue out of economic self-interest, but rather out of moral outrage. He and other abolitionists were not put off when people told them that slavery had existed from the beginning of time in every society, or that vast economic interests were arrayed against them. The abolitionists argued from moral outrage, and they succeeded in getting slavery abolished.

Today, with plenty of food and rising concern about obesity, hunger and famine are still very real around the planet. I submit that now is a time for all of us to bring the same moral outrage to our own generation's inequities and to become, each and every one of us, the new abolitionists and say that hunger in our lifetime must be abolished from this planet. The science that has brought us so much must be marshaled to solve these problems. Abraham Lincoln said, "A house divided against itself cannot stand … a nation cannot survive half slave and half free." Well, I say a world divided cannot stand, and humanity cannot survive part rich and mostly poor and miserable. It is time for us to take responsibility into our own hands and recognize that poverty is built into the current patterns of world development.

Now, we are rightly celebrating the enormous successes of the new technology and connectivity. This knowledge revolution brings massive amounts of information to everybody, anywhere and any time. It transcends the political boundaries of nation states. Never have these boundaries been so permeable to the ethereal flow of both ideas and capital as they are today. For some, the knowledge revolution brings opportunities to create trillion dollar markets, as nations and continents come closer together. But for many in the rest of the world, they see themselves being crushed by an uncaring market-driven mechanism.

The market is a good servant, but it is a bad master. Surely, the ruthless efficiency of the market must be tempered by a caring and nurturing society. That nurturing society must embrace all people and all nations; it must not leave some people to go around looking for their future amidst the garbage.

If we do not create opportunities that will give them a decent livelihood, aren't we creating a political and social time bomb out of the hundreds of millions of unemployed, half-educated youth in the filthy, poor cities of the developing world? Isn't that an enormous risk in our future? What sort of jobs will they have if they don't have the skills that are required to compete in the new knowledge-based economy?

The gap between rich and poor countries is growing even in the preparation of those skills. University enrollment in low-income countries was lagging well behind middle- and high-income countries in 1980, but by 1995 it had increased dramatically. This is without mentioning the enormous weaknesses in the school system on which the universities in those countries build. In many parts of Africa, for example, schools have no walls, not even a blackboard, no books, no chairs, no furniture, nothing. And those are the lucky ones who are in school at all.

These findings are grim, but the outlook is not hopeless, because in the right circumstances people are not locked in forever. South Korea is a case in point, where sound policies, good investments, and collaboration with the North turned Korea into a powerhouse. The rise of Samsung Electronics shows that miracles can happen. Sound policies can transform reality, but they also require collaboration and assistance from the richer countries.

The developing countries will not be able to harness the new science and technology if they don't have a science and technology base of their own. Unless we can bridge this gap, we are heading toward a form of scientific apartheid in this century. Unless we harness science to real human priorities, our science and technology could end up providing more for those few who already have much, rather than provide what is needed for the many.

Right now, the new knowledge-based society is increasing inequalities. Yes, we have rich people in the United States, but we also have poor people in the United States. The simplest measure of economic inequality, which economists know as the GINI coefficient, measures differences between households groups, so that a coefficient of zero is perfect equality and a coefficient of one is perfect inequality. From 1960 to 2000, the GINI coefficient in the United States has been going up. So, there is evidence that we are on a secular trend of increasing inequality, and the same is true on a global level, arguably even much more so (although China's enormous growth counters this somewhat). The assets of the world's three richest people exceed the combined gross domestic product (GDP) of the poorest 48 countries. The world's 15 richest people have assets that exceed the total GDP of Sub-Saharan Africa, with more than 600 million people. The gap is huge and growing in human resource capacity. If the knowledge-based economy is moving us away from reliance on brawn and resources toward greater reliance on brains, then surely human resource capacity becomes central.

Here is an example of the order of magnitude we are talking about and the power of human capital. Researchers and engineers make up about 70 to 80 workers out of every 10,000 workers in Japan and the United States; they number 40 per 10,000 workers in Europe, including southern Europe; they account for 6 out of 10,000 workers in China; and for the poorest countries, mostly in Sub-Saharan Africa, they average only 0.5 out of every 10,000 workers.

We talk about connectivity and the Web. But, who is connected? The answer is high-income people, incredibly more so than the low-income people. The availability of computers per 10,000 people averages 1,800 for the affluent countries of the Organisation for Economic Co-operation and Development. In middle-income countries, computer availability drops to 230 per 10,000 people, and in low-income countries there is only one computer for every 10,000 people. The gap in computers is 1,800 times, a much wider gap than the gap in income alone, which would be of the order of 40 times. The gap in investment and research is 220 times between the rich and the poor. And this situation, of course, puts into question what will become of those youngsters who are now coming of age, going to school, and going into a labor market. What sort of future do they have?

So, the global patterns of development need to be reassessed to conserve resources and start to close the growing gaps between the rich and the poor. Science is producing many new technologies. Our challenge is to use these technologies to address the needs of the many, rather than the wants of the few. These new areas of science and technology require that ethics guide our actions. Ethics have to be taken into account.

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A fundamental ethical issue, which people don't normally pose in those terms, is whether we are addressing the right questions. If we put effort into answering one set of questions rather than another, when the other is the important set of questions to redress the resource constraints and equity gaps I have been discussing, then we have paid a steep opportunity cost in ethical terms.

Take the new genetics as an example. Genomics opens amazing new possibilities, not just in health, but also in agriculture. It's likely, in the biotechnology of the future, that we will be able to assemble genomes like Lego blocks to build whatever we may want. Of course, some people ask what would happen to American production. If the answer is just more and bigger, then we will have lost an opportunity. What I want is something like this: a new strain of super upland rice that is high yielding, disease resistant, pest tolerant, perennial, erosion minimizing, weed suppressing, drought tolerant, adaptive to adverse soils, nitrogen fixing, and deep rooted. We can use this new technology to produce plants like that for the people who are in need in these poor habitats and environments.

It is not a commercially viable venture, however. So, who is going to do it? How are we going to harness science to address that question? Whether we are addressing the right issues is an important part of the ethical debate in setting priorities throughout the scientific enterprise.

Another fundamental issue is risk. Normal risk assessment is easy; methodologies are widely known and accepted, and insurance companies spend and make enormous amounts of money in assessing risks adequately. But consider three examples of the new technologies, which raise profound questions about other kinds of risk.

The first is what I call neurons and chips. It worked with a brilliant breakthrough, when Boris Rubinsky, a professor of mechanical engineering at the University of California, Berkeley, connected electrodes to living cells. Later, Miguel Nicolelis at the Duke University Center for Neuroengineering implanted neurochip microprocessors in the brain of a monkey, which allowed him to read and transmit the monkey's brain waves, so that, when she thought about raising her arm to grab a banana, a robotic arm would move. Furthermore, by wireless Internet a signal was sent to a lab in Cambridge, Massachusetts, 600 miles away, and another robotic arm moved in parallel. The question, of course, is, Who benefits? When we were first discussing this experiment in 2001, we thought the likely beneficiaries might be trauma victims, who could gain freedom of mobility even if they were paralyzed, or jet fighter pilots, who would be able to think and fire immediately with the speed of thought. But it turned out that science took a different twist.

By 2003, a set of experiments described in the *Journal of Neuroscience Methods* showed us a rat with an implant over its head, but instead of reading the brain waves, as experimenters were doing with the monkey, they were tingling the whiskers. They found that they could manipulate the rat's behavior by simply tingling its whiskers. If they tingled the right side, the rat turned right and then was reinforced with a pleasure signal. The rat readily turned right (or left or whatever way they wanted) every time it got tingled. Who benefits? The rats could go all sorts of places where humans would not go—perhaps into buildings after earthquakes to ferret out survivors. But are we at the beginning of mind control, where people would falsely believe they're thinking and making their own choices? Orwell's *1984* and the *Matrix* films come to mind.

The real risk posed here is not so much about destroying the environment or increasing inequities around the world, rather it is about how technology is deployed. While there should be no limits to the pursuit of knowledge, the applications and development of the new technologies must be subject to ethical guidelines.

A second example is gene therapy. It is just around the corner. Some of the risks are already clear, as you know from the case of Jesse Gelsinger, the 18-year-old who died in 1999 after undergoing experimental gene therapy. When will the risks be acceptable to deploy it and reap its benefits? DNA fingerprinting is another concern, because it will enable analysts to tell a lot about an individual's health prospects. How insurance companies—possibly even prospective parents—would use that kind of information raises profound questions as well.

The third example I want to offer comes from Wired magazine. It is called supermouse. What would become of a genetically enhanced mouse? If all the different enhancements that have been tested on mice were combined in a single specimen, will it become supermouse? It would be engineered to have the best of all worlds:

- **BRAINS.** The boost would come from extra NR2B genes, which help the brain associate one event with the other.
- **MUSCLE.** The 14 myostatine gene limits muscle growth, and by removing the gene that produces it you produce a mouse like Arnold Schwarzenegger on steroids.
- **FOOD.** James Ntambi, an associate professor of biochemistry and nutritional sciences at the University of Wisconsin–Madison, produced modified mice that can eat a rich, high-fat diet without gaining weight or contracting diabetes, and his lean machines lack the SCBI gene that fosters fat storage for long winters.
- **STAMINA.** Armed with the gene PCG1, the rodent muscles absorb oxygen and burn energy more efficiently without performing any exercise, mimicking the metabolism of a star athlete.
- **RESILIENCE.** H. Lee Sweeney, professor of physiology at the University of Pennsylvania, keeps a gene that controls muscle repair turned on all the time, producing rodents that quickly bounce back from weight-training exercises.
- **REGENERATION.** If you punch a hole in the ear of a

mouse, it stays forever, but at the University of Pennsylvania, Ellen Heber-Katz, has been able to heal such wounds through genetic modification.

- **LONGEVITY.** Gökhan Hotamisligil of the Harvard School of Public Health removed the protein AP2 from macrophage scavenger cells that normally produce arterial plaque, and he developed mice that could survive on even a morbidly high-fat, high-cholesterol diet. His mice beat heart disease.

So, there you have supermouse. All of these modifications are happening now, and the combinations can't be very far away. Now, what if supermouse escapes from the lab? We have enough problems with rodents as they are. It would be a supernightmare.

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What do we do about questions like that? Deployment of new technologies raises ethical questions, and we have to have a way of developing ethics to guide science in this area. I would like to make a call to action to scientists, both as scientists and as citizens, to engage with the public on these ethical issues. We need scientists involved in public debate more than ever. That's why this fellowship program is so important. It is so important that a real scientific outlook is brought to bear on designing approaches to these questions. We need to go forward to create a better world together.

In Alexandria we have organized several international conferences on the ethical and social responsibilities of science and technology. At a recent meeting in October 2003, attended by 1,200 people, we issued a call to action. The call to action is summarized in two sides of the coin: there should be no limit to the acquisition of knowledge, but researchers should have a duty to inform the wider public about the implications of their research.

I believe that scientists, by engaging with the public, perform a great service. They promote the values of science, the values without which scientific enterprise could not occur. The first of these is truth. Scientists are absolutely ruthless about truth. Anybody who tinkers with data or reports false data is ostracized from the scientific community worldwide. Compare that with the culture of other professions, such as politicians, journalists, or media people.

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The second most important value in science is honor. Scientists rightly regard plagiarism as a crime, and they have effective professional mechanisms to ensure that adequate honor is given to those who deserve it. The third scientific value is creativity. The prizes go to people who make the real breakthroughs, the leaps of imagination, not just small, incremental additions.

Then, there is a constructive subversiveness in the practice of science. We live for overturning the existing paradigm. If there were no impetus to destroy the existing paradigm, there would be no advances, and science would stop. The people who transform science and overturn the paradigms know no seniority. Albert Einstein was only 26 years old in 1905 when he developed the general theory of relativity, and James Watson and Francis Crick were just 25 and 31, respectively, in 1953 when they discovered the structure of DNA.

Science has a willingness to engage, and that breeds a tolerance of engagement, which is different from political tolerance. Political tolerance can be "you do your thing, I do my thing, don't bug me, I don't bug you, I don't care what you do, just stay away from me." But in science the tolerance of engagement means openness to all, because you don't know where the new idea will come from—and let me tell you, some of the ideas on quantum mechanics and astrophysics are kind of weird. Of course, they contravene what we call our common sense approaches, because common sense is built to our human scale, not the scale of the universe or the subatomic particle.

We also have in the scientific community a method for the arbitration of disputes. Cold fusion, for example, was an idea advanced by eminent professors at one point. It was arbitrated, not replicated, and set aside.

So, science is not value neutral. People who say that it is confuse the results of science—the value-neutral validity of $E = mc^2$—with the practice of science, which calls for all these values. And these values are societal values that profoundly transform society for the better. They modernize societies in backward parts of the world, and they also create a tolerant society, one that accepts diversity in the engagement of ideas with others, an engagement based on rationality, debate, and evidence.

Science can also inspire and move the imagination, and the international scientific community has truly become a cultural force. I invite you to play that role in transforming the world. How? Engage science in the pressing issues of our time. Don't leave these issues to be tackled "somehow" by others. We need the scientific community in there. Abolish hunger. Reduce poverty. Promote the scientific outlook and the values of science. Build real partnerships with scientists in the South, who are marginalized by the marginalization of their countries.

The international scientific community has truly become a cultural force. I invite you to play that role in transforming the world.

A lot can be done by harnessing the possibilities of the new connectivity, and that includes setting the agenda, building capacity, forming partnerships, and engaging in public debate. Potential partners include all the international agencies, national governments, community groups, foundations, and the private sector. Scientists' participation and involvement with the public transforms institutional performance and transforms the climate in which we work.

We tend to underestimate the corrosive effects of the scientific community's disengagement from public debate. Again, I emphasize, that is why this fellowship program is so important. If real scientists are not engaged in the debate, the decision-makers often cannot tell the difference between real science and pseudo-science. And if we are not in there actively promoting the scientific outlook as a valid approach to policy issues, we won't see those issues resolved in the spirit of truth-seeking, honor, creativity, and engagement that mark scientific pursuits.

In closing, I would like to emphasize that we don't want science and technology just to be new and powerful, but also to be relevant. I urge you as scientists to address the priority issues, involve the scientists in the South, and promote a participatory approach. We don't want communications just to be instantaneous, but also to be substantive; not just commercials about consumption, but real knowledge transfer. Work to involve the local scientific community and promote understanding. Work not only to transfer technology, but also to promote the scientific outlook and the values of science. In my work at the Library of Alexandria, I fight against obscurantism and fanaticism every day. They exist in every society, and the rational values of science are important in transforming them. If scientists will become engaged in public debates, it will change the quality of the process, promote the value of science, and promote the scientific outlook.

We don't want science and technology just to be new and powerful, but also to be relevant.

Now, implementing this agenda will fight poverty and promote sustainable development. We need capacity building for the developing world, as we have outlined in a recent report to the United Nations (InterAcademy Council, *Inventing a Better Future: A Strategy for Building Worldwide Capacities in Science and Technology,* January 2004). The key conclusion is that academies of science and the scientific community must take the lead in implementing this agenda of change. This is how we can pursue our vision of how science can transform the world. Scientists must be the local voice for the values of science and the culture of science, for science can feed the hungry, heal the sick, protect the environment, promote the dignity of work, and give space for the joy of self-expression. But all of that will not happen unless we expand the capacity of science and technology in less developed countries.

Today, we are at the crossroads. To the scientists of the North, I say: You cannot allow 80 percent of humanity to remain consumers of knowledge. They must be partners in the production of knowledge. To the scientists of the South, I say: You cannot disengage from the conflicts in your societies, where you have to promote the values of science against rampant obscurantism and harness science to the societal enterprise. You people here as Fellows, through the impact you will have on decision-makers, can transform public debate. All of us as scientists need to extend a hand that can help build true centers of excellence in the developing world, and through that collaboration we can fight poverty, bring dignity to women and to the poor, and create a better world for all.

Questions and Responses

DR. NELSON: I really regret that we only have time for just one question, so I'll ask Dr. Serageldin to address this one from the audience: The Millennium Development Goals are ambitious, but unlikely to be achieved because of the lack of resources. How can we move forward to address these goals in light of current realities?

DR. SERAGELDIN: Well, it's a good question. The Millennium Development Goals are not all that ambitious. They talk about by 2015 reducing by half the number of malnourished people and reducing by half the number of people who do not have access to clean water and sanitation. In other words, we will still have 400 million people going hungry by 2015, and we will declare that victory.

So where are the resources? We have had governments that have time and again committed to contributing 0.7 percent of GNP for official development assistance. Nobody is meeting that commitment. The United States is at the bottom of the pile. It ranks 17th out of 17 countries that pledged assistance, not in the absolute value of aid, but in the amount of aid as a percentage of GNP. The Development Assistance Committee of the Organisation for Economic Co-operation and Development (OECD) says that we are under 0.3 percent. Only four countries have honored their commitments year in and year out. They are the Netherlands, Sweden, Norway, and Denmark. May I point out that none of them has been impoverished as a result? None of them has gone bankrupt. It is not impossible to make that financial commitment.

Now that financial commitment would transform the scene in which we work. Today, we spend 14 times as much on military expenditures as we do on all development efforts worldwide. Not 1.4 times, but 14 times more on military than on development. It is not impossible to marshal those resources for other purposes.

I believe the United States is now spending about more than a billion dollars a week on military activities in Iraq and Afghanistan, or about $65 billion this year. At the same time, we're talking about what great progress it was to increase the development assistance of USAID by $5 billion for a whole year, bringing the level from $10 billion to 15 billion for the whole world. That was a great improvement, but it's not enough. We could do a lot more.

One specific area in which we could do much more is in building the science capacity of countries around the world, which is imperative for increasing agricultural productivity and achieving other Millennium Development Goals. Science is not a luxury for people in the developing world. They need a strong science and technology base to adapt new technologies to their own situations. Think about it in just this instance: A computer or a transistor works the same in Norway or in Kenya, because the hardware is the same everywhere, but a plant that grows in Minnesota will not grow in Egypt, because the gene-environment interaction, the local pathogens, and the local science capacity are all different. If you expect to take a given product of research, say a high-yielding plant variety, from one environment to another, you need a lot of adaptive work, a lot of applied research, and ultimately a lot of scientific capacity in the receiving country. And, of course, agricultural productivity is only one of many instances in which the scientific capacity is crucial, especially at the time when we are moving toward a biological revolution with enzymatic-based processes in industry, health, and agriculture broadly.

MR. NELSON: Regrettably, we must move on to the next portion of the program, and Dr. Serageldin must leave us. Please join me in extending our thanks to him.