Genes and Genomes: Impact on Medicine and Society

Genes, Genomes, and Society
October 17, 2003

Jeffrey Sachs, Ph.D., Columbia University
Plant Genomes, Food, and the Developing World

Introduction by Jonathan R. Cole

Jonathan R. Cole: Welcome back. It's now my real pleasure to introduce two of my distinguished colleagues at Columbia. First we shall hear from Jeffrey Sachs. I could go through the many features of Jeffrey's meteoric rise to preeminence within his chosen discipline of economics. I won't do that, but let me just briefly summarize some of his attributes in the past. Educated at Harvard, Jeff was at the time the youngest person in Harvard history, I believe, to receive tenure, although I think Larry Summers disputes that somehow by a matter of a couple of weeks. At Harvard, Jeffrey was a member of the Society of Fellows and the director of the Center for International Development. Of course Jeffrey has become a counselor to many nations on problems of economic development; he has become a trusted colleague and special advisor the UN Secretary-General Kofi Annan. He has been elected to many honorary societies, including the American Academy of Arts and Sciences. He has published and continues to publish scores of scholarly articles, over two hundred thus far, and takes his responsibility as a public intellectual to write on matters of economic policy for a broad audience. But that would not capture what Jeffrey is trying to do and who he is.

Jeffrey came to Columbia from Harvard only recently to become director of the Earth Institute, and the Quetelet Professor of Sustainable Development and professor of Health Policy and Management. The Earth Institute, which Jeffrey directs, is one of the largest interdisciplinary or multidisciplinary projects at Columbia, and perhaps one of the most ambitious academic experiments in the United States. There is no one that I know who understands better the interdependency of knowledge generated in various scholarly fields, if we are to address the most complex and most important social problems that are crying out for solution.
What makes Jeffrey so unique is his deep appreciation for the depth of knowledge that comes from mastering at the very highest levels a single discipline, while he also understands that without combining the knowledge discovered by these disciplines, we are not apt to solve the world's most vexing problems. Consequently Jeff has learned the language of many disciplines and collaborates with leading scholars and scientists in a number of them.

Jeffrey Sachs is interested in economic development, and cares deeply about the social, economic, scientific, technological, and medical challenges faced by the poorer nations of the world as they seek better life chances and opportunities. He is also interested in sustainability of the planet and the interdependence of biological, geophysical, and social systems. Because of all these activities, Jeffrey Sachs has been one of the most influential economists in the world, not only because of the brilliance of his scholarly work but because of his active role as an advisor to leaders of many developing nations. In my 14 years as provost and dean of faculties at Columbia, we made a great number of extraordinary appointments of scholars and scientists of the very first rank. I know of none more significant than that of Jeffrey Sachs, who will speak to us today on the subject "Plant Genomes, Food, and the Developing World." It's a pleasure to give you Jeffrey Sachs.

Science and Technology in World Society

Jeffrey D. Sachs: Ladies and gentlemen, thank you so much for including me in this wonderful workshop and celebration. And Jonathan, thanks especially for including me in this wonderful university, because you played a unique role in this, of course. This move that I've been so fortunate to experience in the last year and a half is certainly the most thrilling and exhilarating part of my recent life, without question, and Columbia is everything and much more than I could have imagined and hoped it to be. The dynamism of the thinking at the university and the readiness of the university to confront the challenges of the world are simply startling and as empowering as is conceivable, and I just could not be more pleased that a year and a half ago Jonathan gave me a call, almost out of the blue as I had started to commute to advise Kofi Annan and said, "How about coming by for a chat? And I think Jonathan would also confirm that he laid out his vision of Columbia and his vision that he had championed and pioneered of the Earth Institute. It was within that meeting itself I said, "This is a good idea. Give me a few weeks to check it out but I think I'm going to do it." And it was just what he promised it would be, an environment of unparalleled intellectual commitment and more collegiality I can say and more readiness to work across disciplines than I had ever seen in the academic world before. And so I just want to thank you for this tremendous chance.

We're talking about genes and genomes and society, and I want to talk about the society part, because first I am an economist and I understand comparative and absolute advantage. I certainly have no absolute advantage in this room perhaps
in almost any aspect of this topic, but my comparative advantage certainly lies on the society end.

And I want to talk about world society. We spend a tremendous amount of our time talking about our own society, our own immediate environment, and what we sometimes think of as the world, the world of the United States or the world of the rich countries dominates our thoughts, except when we're worrying about what other places are doing to us, and we don't spend enough time in the world, unfortunately, understanding the nature of a world of 6.3 billion people living in extraordinarily diverse conditions, and some in extraordinarily adverse conditions. And we have not really come to grips with how science has a fundamental role in shaping a world of such diversity and perhaps ameliorating the conditions of such extreme want in many parts of the world.

We're living at a time of a great scientific revolution that we've been hearing about from all of the speakers and that scientific revolution is already making wondrous changes in our own lives in raising life expectancy, in improving the quality of life in many ways and, yes, of course, in throwing up new and unparalleled challenges of ethical dimensions that were unimaginable even a few years before. And that scientific revolution is diffusing, as scientific revolutions do, it is diffusing to other parts of the world. In fact genetics, in its more traditional variance, has, of course, played an enormous role all through the world in the twentieth century, and genetics discoveries, even in their most practical and particularly in their most practical forms—for instance, in how to improve plant varieties—did diffuse to much of the world from the United States, from the epicenter of science in the second half of the twentieth century. But, just as with the traditional genetics and now the new biotechnologies, that process of diffusion is haphazard, incomplete, and so critical in its character and nature that we need to understand much more deeply how it works and how it doesn't work; we need to understand that the scientific enterprise is also a social and an economic enterprise, as well as a purely knowledge-driven enterprise; and, therefore, one that is susceptible of improvement and guidance for the sake of the human needs.

I want to talk this morning, therefore, about how the new biotechnologies and the new genomic sciences could do vastly more to play a fundamental role in improving the quality of life in the world, but why they will not on the trajectory that we're currently on. We can predict, unfortunately with a high degree of certainty that, if we continue in the manner of our public policies with respect to the science enterprise at large, that the failures to help to spread the benefits of science more widely will mean year-in and year-out the continuing, unnecessary mass suffering of large numbers of people on the planet. And yet, on the other hand, if we simply think a bit harder about this, at relatively low cost to us as I'll stress, we could have a monumental effect on improving the human condition more widely, so powerful are the new tools of science that we've been hearing about in the last two days.
Fighting Infectious Diseases

While we meet today, about 16 thousand people will die in Africa of AIDS, TB, and malaria. It's ironic to begin with, of course, that even under the current scientific conditions all three diseases are to a significant extent preventable, and all to an important extent are treatable. There's actually no excuse, even aside from the scientific issues, for us to be as complacent as we are day-in, day-out at the mass deaths, which amount to 6 or 7 million per year in Africa, and add another 2 or 3 million from those diseases in other parts of the world, despite the fact that they could already be addressed with existing technologies.

But the technologies that we're talking about also have brought us to the threshold of potentially huge advances as well in finding new drugs, new vaccines, and other approaches to the control, and perhaps even one day effectively the elimination, of these diseases. But as I'll stress, we are not on a direction to cross that threshold. Science can take us so far, social action, collective will, political choice is needed to take us across the threshold.

In addition to those 16 thousand or so Africans that will die of the three diseases, another 5 to 10 thousand Africans will die today of undernutrition. And of course some of the deaths from AIDS, TB, and malaria are multifactorial, where chronic undernutrition plays an extremely important role. But undernutrition will play an even more dramatic role in deaths from diarrheal disease that would be passed off as transient and far from fatal episodes in properly nourished populations. As with deaths from other infectious diseases, the million children or so that will die of measles this year in developing countries will die in significant part because of the immunosuppression that has accompanied chronic undernourishment of very poor communities. So we face a mass crisis that is almost unrecognized, or is taken for granted, of extraordinary suffering from preventable and treatable diseases, diseases that could even be addressed much more fundamentally by further scientific advance now at hand. And similarly in a world of ample aggregate food supply, not just hunger and the pangs of extreme poverty, but actually mass death when you take a hard and cold look at it, that come from the fact that approximately 1 billion people on the planet still lack access to reliable diets, certainly reliable even in the macronutrient sense of caloric protein intake, perhaps up to two and a half billion people when one adds the micronutrient deficiencies of iron, vitamin A, and other micronutrient deficiencies. And again areas where scientific knowledge and current technologies could massively ameliorate the conditions, and where the new promises of biotechnology could change fundamentally these risks.

It's often summarized, as you know, by the fact that at this point southern and eastern Africa probably has a life expectancy little more than half of the United States. We're pushing eighty years now with our continuing advances in longevity, increasingly based on a deeper understanding of our biology, nutrition,
and the increasingly sophisticated interventions for extending life. And at the same time, Africa's life expectancy in southern and eastern Africa is falling to around 40 years now, on the back of an absolutely unconfronted AIDS pandemic, unconfronted not only by Africa itself but by us, because we are the ones that have the technologies and the resources that could help African countries to confront this, but aside from one good paragraph in one speech of one president of the United States, we have almost nothing to show for our role in this pandemic in more than twenty years in the poorest of the poor countries. So if you feel good about our 15-million-dollar program, understand that not a penny has been spent, and that the United States has to this day, 22 years after the start of the AIDS pandemic, put fewer than one hundred people on antiretroviral drugs invented by modern science in the United States, Britain, and the rest of Europe. We've done nothing except the president has made us feel good that we're doing so much. So I unfortunately am here to make you feel not so good.

Science and Technology and Economic Advance

Now the essence of economic development when you look at it, ladies and gentlemen, is really science. The essence of advances in economic well-being, which began in an unprecedented way two hundred years ago, because up to that time while there were ebbs and flows of economic well-being, there was no such thing as sustained economic growth. Those advances over the last two hundred years have come to societies that have been able to master science and technology. It's science that brung us to where we are. We shouldn't forget it as we imperil the scientific venture every day with the mythologies, with the attacks of irrationality, that are so profound and seemingly growing in our societies as well.

Science can't be measured so easily in its direct inputs to rising standards of living, but about fifty years ago the Nobel Laureate Robert Solow created an ingenious method to ask how much of economic growth could be understood on the basis of things that economists usually talk about, like saving and investment and capital accumulation. Well, economists didn't necessarily pick up on Professor Solow's lesson to us in that Nobel Prize-winning paper of 1957. What he found was that only 13 percent of the rise of per capita income in the first half of the twentieth century could be explained by what we call capital deepening, a rising ratio of observed physical capital per person in the country, and 87 percent was the advance of technology that wasn't explained simply by saving and investment. So Professor Solow told us that what we know today is a cliché but what we don't necessarily reflect in our public policy or in our way of thinking about the world more generally, that 87 percent wasn't the thing we argue incessantly about of whether the tax cuts are going to give this or that incentive for rich people, who already probably have more than they know what to do with, but whether we could stimulate the advance of knowledge. We don't talk about that even though we live, as a cliché, in the knowledge economy, we don't talk adequately about it. Well, 87 percent seems to be from the advance of
knowledge, and hundreds of studies since then have confirmed that it is science and technology which provides the fundamental force of economic advance.

But the great lesson for the world, a striking lesson, is that that advance has been so remarkably varied across the planet, and for complex reasons, so that what is the underlying impulse of development differentially reaches the human family in dramatic ways. I brought you a couple of numbers just to give you an idea of this.

In the year 2001, the most recent data, 166,000 patents for new inventions were taken out in the United States. This is a pretty good indicator of science and technology reaching a commercializable base, commercializable state of advance. Now, the U.S. Patent Office gives patents for American as well as foreign inventors. Of those 166,000 patents, 87,000 were taken out by U.S. resident inventors, and the balance, about 70,000 by foreign inventors. Of those foreign inventors, the 70,000, Germany had 11,000, Japan about 30,000, South Korea about 3,500, Israel 1,000, all of tropical sub-Saharan Africa with its 500,000,000 people had 10 registered patents for the year. And that was up from the previous year, which is a good sign. It was 2 the previous year.

Essentially the part of the world that is struggling for survival. And it's not only Africa. It's the Andes region, which is in explosion these days from Bolivia through Peru, Colombia, Ecuador, It's central Asia, which is in explosion from Afghanistan, Nepal, Kazakhstan, Turkmenistan, Tajikistan. You name it, it's not a pretty picture. These are places that are cut off from the world of economic advance, and fundamentally cut off from the world of science and technology which is the prime mover of long-term economic change.

Poverty and Geography

Now, it behooves us to understand these facts because without understanding them we make terrible mistakes. And the most important we make in our world to our own disadvantage, I'm afraid, is that we blame the poor for their problems without understanding either the roots of our success or the paths out of extreme crisis of the poorest of the poor. We believe that the problems are necessarily problems of bad governance or corruption or other mismanagement of the poorest countries, rather than fundamental shortcomings in existing technology, the lack of ability to mobilize science in appropriate ways, and the lack of efforts to get to the deeper problems which afflict the places which have been unable to make the breakthrough to economic development.

The evidence is clear, for example, that in regions with holoendemic malaria on the planet, with high transmission burdens of malaria, there has been almost no economic advance. And those regions more than anything else are ecologically determined. Malaria transmission is based on climate and mosquito vectors. High temperatures, adequate precipitation for breeding sites, and specific species of
Anopheles vectors that like to bite humans rather than animals are the recipe for holoendemic transmission of malaria. It turns out that one can look through the whole historic record through the genetic record indeed of humanity to understand that far before there was economic growth, technology, capitalism, the United States, or anything else, already West Africa was the epicenter of global malaria. We know it from the hemoglobin-S anomalies, which tell us that the burden of disease of malaria has been a thousands-of-year phenomenon in West Africa in a uniquely burdensome way, well before any of the current factors which we use to blame Africa for its problems existed.

When you have populations where 10 or 20 percent of the children are carrying the sickle-hemoglobin anomaly, you know that the deaths due to malaria by simple genetic principles are extraordinarily high, as they are in the humid tropical forests of West Africa, up to 40 or 50 percent of all deaths attributable to malaria, if you have population density so high of these mutant traits, which are killers in their homozygous form. And so one can look at the record and understand that the problems of the poorest of the poor, to a very important extent, result from deep geographical forces of climate or soils or disease ecology or other forces which contributed to the isolation, impoverishment, high mortality rates, and other burdens of places to prevent them from benefiting from a more general advance in the global society, which began economically around two hundred years ago.

And once one starts to realize how geographically conditioned so many of the problems of the poor are, then the question of the nature of the science-and-technology enterprise becomes more clear. The reason is that so much of the science and technology that is produced in the world by the richest countries diffuses along ecological gradients and does not diffuse across ecological space where it's not relevant. We are doing a lot of work in our country at NIH and at Columbia University and in other leading scientific and academic centers on diseases that affect Americans, on diseases that affect the whole world incidentally, such as many of the diseases now conquerable by immunization which are worldwide transmission diseases, but we do almost no scientific research or technology development on diseases that are specific to ecologies distinct from our own.

So on malaria, for example, perhaps the greatest barrier to economic development in Africa in the long historical dynamic, the amount of worldwide research underway on malaria control is probably on the order of 50 to a 100 million dollars a year right now, out of an annual biomedical research budget on the order of 75 to 80 billion dollars a year. By simple calculations, one crude measure which I think underestimates the reality considerably, puts the burden of disease due to malaria at about 3 percent of the worldwide disease burden, which would suggest an annual spending on R and D, if you made the simple calculation of a comparable portion of total biomedical research spending, to be
on the order of two and a half to 3 billion dollars a year. We're running at one twenty-fifth to one-thirtieth of that amount of research right now.

**Worldwide Diffusion of Innovation**

Fundamentally, in my view, what's happened in shaping of the world economy in the last two centuries is that for a whole range of reasons that we need the full university to properly understand, a scientific and technological revolution did get started in England, and it spread to other parts of Europe. The Industrial Revolution spread to the early United States. It was for many reasons both intrinsically and by dint of historical accident a temperate-zone phenomenon; the technologies improved as the markets grew, and as the markets grew the incentives and capacity to advance the technological revolution grew further. Science was driven by markets, and markets drove science, in very subtle, important and complex ways, both through pure private market forces, as well as through public economics of an increasingly share of public and collective action, whether formal federal and state budgets or philanthropies and foundations or donor beneficence, enabling the growth of the market to support the growth of science, and then an ongoing dynamic positive feedback process, which economists call endogenous growth.

The vast proportion of global scientific advance, including the genetic revolution and the genomics revolution, was centered in the rich countries. And as wide apart are the gaps of rich and poor, in wealth today a gap of, say, one hundred to one as the little illustration about patents suggests, the gap of scientific organization is orders of magnitude greater than that.

These technologies did diffuse for the benefit of the world in many cases, where they could from a geographical and ecological point of view. Many vaccines can work anywhere. Penicillin can be of service for the entire world. But many of the most critical conditions of poverty, and principally two areas where the biotechnology revolution is most essential, public health and agricultural productivity, are strongly, if not fundamentally, ecologically centered. So only a partial public-health revolution took hold throughout most of the tropics, because the suite of tropical diseases never was addressed with the extent nor the success, nor the investment is the point I'm making, of the suite of worldwide or temperate-zone-specific diseases.

**Steering Crops to Poor Nations**

And in agriculture the same phenomenon is plainly evident and a wonderful study by Robert Evenson of Yale University last year has documented this more clearly than ever before. The agricultural revolution of the twentieth century, aside from the chemical revolution of fixation of nitrogen through the Haber-Bosch process, the part due to improved varieties of crops to better germ plasm, was a revolution born in the temperate-zone world for temperate-zone crops, and only incidentally
diffused to other parts of the world, except in rare episodes where there was a conscious attempt to steer that development.

Asia's green revolution started in Iowa in the 1920s. It started with the development of dwarf varietals where plants were bred through traditional genetic mechanisms to put more of the biomass in the edible part of the crop and to have shorter stalks so that the crop wouldn't lodge, wouldn't collapse, as it grew at a faster rate under the beneficent nutrient bed of higher fertilization and irrigation. And through that breeding these high-yield varieties of dwarf plants for wheat and hybrid corn were developed in the United States. In the 1950s the Rockefeller Foundation had the wonderful insight to appreciate that in a world of rapid population growth and poverty, these same techniques needed to be extended to poor countries, and the first project, of course, was asking Norman Borlaug in Mexico to adopt the wheat high-yielding varieties to the Mexican context. And Borlaug did that in the 1950s, and then took that to the International Rice Research Institute in the Philippines in the 1960s, and they developed the variety IR8, which is the short-stalk rice which saved Asia and which at the core was the trigger of China's and India's dramatic escape from poverty in the last generation. Without the preceding green revolution of East Asia, there would be no Chinese economic miracle, and without the green revolution, India would have continued to be subject to the famines on a repeated basis that were expected of India even just 25 years ago, which India has completely superceded now to the point where India is a food exporter and just mildly tripped over last year's monsoon failure as if it was a passing curiosity, where it would have been a human disaster thirty years ago.

Rockefeller Foundation, Norman Borlaug, took a ready stock of technologies to these new conditions but for temperate-zone crops. Rice, while obviously a subtropical and in many cases tropical crop, fortunately has a very large inventory of technology in the temperate-zone world, from Japan, United States, and was able to be transmitted, and wheat and maize even more directly so. But there is no backlog of cassava high-yielding varieties for Africa. There is no backlog of millet and sorghum high-yielding varieties for the arid tropics of Africa. And what Evenson and Golan and collaborators found on this really wonderful study that they completed last year was that one could trace the speed of diffusion of these traditional genetic advances across the ecological zones, depending on where the translational work was less or more, and where the gap was too great, which is almost always Africa for almost every aspect of these biologically, ecologically based problems. The work often of scientific translation from basic principles to working, on-the-ground technologies has hardly gotten started.

In my opinion, this basic mechanism of science being an increasing returns-to-scale proposition—where science promotes markets and markets promote science, and science being largely an imperfect diffusing mechanism, where science diffuses in neighborhoods or in shared ecological and geographical
space, but not so effectively across very different ecological and especially disease-ecological and agroecological conditions—is the most important shaper of the divides of the world today. Because the developing world, to the extent that it catches up, catches up largely by diffusing technologies developed elsewhere, translating them for local applicability, and advancing on that basis and, if they're good and lucky and very self-conscious about it, passing through the phase of translational work to innovation in their own right, as China's clearly doing right now, and as Israel, Korea, Taiwan did a generation ago, but almost no other developing countries have been successful in that. But the countries farthest away in the world in geographical and ecological space, countries that are too remote to interest anybody, usually in the hinterlands of the great continents, whether it's Bolivia in extreme disarray and chaos this morning, landlocked in the Andes Mountains at 12,000 feet above sea level, or whether it's Afghanistan, continually in disarray for about the last five hundred years, since Vasco da Gama did them the disfavor of finding a better trade route between Europe and Asia, and it's been all downhill for Asia since then. Or the interior of Africa stretching from Mali through Chad, Niger, Sudan, in the Sahel or Central African Republic, places too remote, too ecologically distinct, too poor to be able to adopt the technologies, just find themselves falling farther and farther behind.

**Mobilizing Science for World Benefit**

What the Rockefeller Foundation accomplished in the last century was probably more for economic development than any other organization in the world, much more, I would say, than the World Bank or than other official donor agencies. They got the idea to take science and put it to operation for development. They kept the *Anopheles gambiae* out of Brazil in the 1930s, they developed the yellow fever vaccine, and they supported the green revolution, just to name a few things that rolled off the fingertips. But the basic model of that foundation, which the Gates Fountain is now pioneering in a way in the twenty-first century, is to recognize that if knowledge really is at the core of economic development, then mobilizing knowledge through our universities, through our scientific institutions, through NIH, through our private sector, which has to be made interested in some way, because it's not interested in it on normal market grounds, may be the most effective key for finding the long-term solutions. And in my view it is the right approach because the problems that I'm discussing are not problems that markets can or will solve. Markets view the problems of the poorest of the poor as no problems at all, thank you, because one should understand that perfectly efficient markets are designed to ignore the poor. They're only designed to respond to people with purchasing power. And if you're owning shares of companies devoting huge amounts of money to impoverished people, sell the shares, and give prizes instead to these CEOs, but markets are not designed to handle these problems by themselves.

So when we think about the genetic revolutions and the genomic revolution and society, and by society I mean world society, the point I want to leave you with is
that this remarkable revolution, which will do so much for our benefit, only accidentally or incidentally will reach those in most need of what it offers, unless we absolutely consciously plan for it to be brought to bear to the needs of the poorest of the poor. We have to overcome market forces, not rely on them, if this is to be done. Extending intellectual-property rights, that may have merits in certain circumstances within rich countries, but that doesn't bring medicines to the poorest of the poor, nor does it generate research within those countries. The markets are too small, the scientists are here rather than there, because the other aspect of science is that scientists like to do their work in communities, such as this wonderful university, not in isolation, because science itself in its own production function is an increasing-returns-to-scale proposition, so it's better to have communities together, which is why the lone inventors and the lone scientists in Africa don't flourish, they leave. It's not good to be the only one and somehow expect to have the high productivity, which is true in other fields where you don't want the competition, but it's not true in science. You need your competitors as your colleagues in order to get your own work done.

So we have to think of mechanisms, both in the public-health world and in the agricultural-biotechnology world, to make it possible to translate these benefits for those who won't otherwise have them. I'd mention in health very briefly that the pharmaceutical industry and the NIH has essentially looked aside from these issues during the past generation. Even the NIH itself is perhaps devoting only 1 percent of its overall budget to tropical disease, to those diseases specifically within the tropical ecologies. And for the large patent-based pharmaceutical industry and the smaller biotech industry hoping to sell to the large pharmaceutical industry, there's almost no work underway in that whole range of issues that are heavily focalized within the poorest of the poor countries.

The Example of Agrobiotechnology

In agriculture the telling fact from my perspective is that the wisdom forty years ago of establishing a worldwide network of tropical-agriculture research centers, the so-called CGIAR, the Consultative Group on International Agriculture Research, which included the units CIMMYT in Mexico, IRRI in Los Baños, Philippines, that made the translation of the green revolution to Latin America and to Asia, that wonderful conception is so starved for cash that the total operating budget of the 16 CGIAR units for the whole world of the 2 to 3 billion people who depend on the tropical crops and agroforestry and livestock that they investigate, total operating budget is about 350 million dollars which is roughly 60 percent of Monsanto's R and D budget alone. So one biotech agriculture firm, a firm I rather like, as much as it's despised in many other parts of the world, I think they're doing excellent science and deserve the praise for it, not the opprobrium that they've received. It's still one company, which is a modest part of the overall agriculture research enterprise of the United States, is roughly 1.6 times the entire combined tropical-agriculture research budget of the public system in the world. What we're seeing, therefore, in agrobiotechnology, the same way as in
medical technology, is markets driving science, science driving markets, and the goods not reaching the poorest of the poor.

The agrobiotechnology advances in recent years have been almost entirely temperate zone. They have involved two major discoveries and innovations commercially, implanting a bacterium gene, the Bt gene, which is a disease-resistance gene from the particular bacillus that holds this, it fights off the corn bore and other known attackers of major crops, that was successfully implanted into corn, cotton, and other crops by Monsanto, it turns out. And also the introduction of herbicide-resistant genes against something that is done and was done through normal genetic manipulation, but now is done in a much more targeted way through targeted identification and transfer of specific gene sites. So it's old breeding methods simply updated, nothing new it terms of its actual nature within the plants. Both of these have been introduced to tens of millions of hectares of planting in the United States, Argentina, China, and soon Brazil. Why those countries? Temperate-zone crops, temperate-zone application. We see the same process of diffusion taking place that where the backlog exists is where the rich world has made the backlog. But the amount of work that could go on to get transferred saline-resistant genes that mangrove crops have, that could be used for the saline-stressed environments of tropical irrigated rice plots, or genes to target specific bacterial rust threats for the crops of the tropics, that has hardly begun to this point.

And similarly the advances, which we know again are on the threshold of bio-fortification, for example, genomic transfers of genes that can produce the pro-vitamin A, that we metabolize into vitamin A, we know how to . . . we! —I always . . . how nice, the economists really know a lot . . . I'm told that the scientists know it and I've seen the labs where they do it, but it's not being done again, because the places that need that bio-fortification lack the funding to do it.

The Need for Collective Action

I'll just end by saying that this misshapen world in which at the same time we have the prospects of unparalleled and unrivaled scientific advance, and at the same time we have 1 billion people fighting for daily survival, and thousands every day losing that fight because of extreme poverty, is an understandable situation. I hope I've helped to clarify it analytically, but it is a shockingly inadequate situation for the world. It leaves a world of immense suffering and pain, and it leaves a world of immense instability in its wake. We find ourselves inevitably dragged into the problems of anywhere in the world. If you would ask an American three years ago "Where's the place in the world least likely to bother you?" you would've put your pointer in the middle of Eurasia, said "Well, at least that place is too poor and too far away and too remote to reach us," probably right at Kabul. And the world, however, doesn't operate that way anymore. The diseases come to haunt us, the AIDS pandemic which began as a zoonosis seventy years ago in the jungles of West Africa, according to the best genetic
clocks we have, didn't respect Africa's continental edge, it has traveled through the world. And the instability of extreme poverty also finds its way, not only through terrorism but mass migration, refugee movements, disease, state failure, criminality, drug trafficking, and a hundred other ways, to affect our interests most directly.

We have to understand how much we have the opportunity to help shape our own future. One foundation, the Rockefeller Foundation, probably did as much as anything to feed billions of people on the planet, and that was a relatively small, extremely well-targeted investment. Bill Gates is doing his part right now, but I've had the enormous pleasure to be able to say to him on several occasions, "Bill, even you can't do it by yourself," which is a very empowering feeling, because he comes as close as anyone in the world literally to being able to do it, but he can't. His foundation spends about a billion dollars a year in total, roughly 800 million dollars a year for global health and related activities right now. It's monumentally important. What's shocking is that he single-handedly outcompetes the United States in this effort as a whole.

We have a lot to do, and the evidence is that for much smaller amounts than we're devoting to keep those soldiers in Iraq, we'd be able to change the tide and save millions of lives abroad every year, and truly make the world a safer one for the twenty-first century. Scientists are the ones that have brought us to this point, but it's going to be all of us that take us across the threshold.

Thanks very much.