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STRENGTHENING NSF SPONSORED
AGRICULTURAL BIOTECHNOLOGY RESEARCH:
H.R. 2051 AND H.R. 2912

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH
COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

ONE HUNDRED SEVENTH CONGRESS

FIRST SESSION

SEPTEMBER 25, 2001

Serial No. 107–36

Printed for the use of the Committee on Science

Available via the World Wide Web: http://www.house.gov/science

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C O N T E N T S

U.S. House of Representatives
Written Statement

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Written Statement

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Discussion

STRENGTHENING NSF SPONSORED AGRICULTURAL BIOTECHNOLOGY RESEARCH: H.R. 2051 AND H.R. 2912

TUESDAY, SEPTEMBER 25, 2001

House of Representatives,

Subcommittee on Research,

Committee on Science,

Washington, DC.

The Subcommittee met, pursuant to call, at 2:05 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Nick Smith [Chairman of the Subcommittee] presiding.

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HEARING CHARTER

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SUBCOMMITTEE ON RESEARCH

COMMITTEE ON SCIENCE

U.S. HOUSE OF REPRESENTATIVES

Strengthening NSF Sponsored Agricultural

Biotechnology Research: H.R. 2051 and H.R. 2912

TUESDAY, SEPTEMBER 25, 2001

2:00 P.M.–4:00 P.M.

2318 RAYBURN HOUSE OFFICE BUILDING

I. Purpose

On Tuesday, September 25, 2001, at 2:00 p.m. the Subcommittee on Research of the House Committee on Science will hold a hearing on *Strengthening NSF Sponsored Agricultural Biotechnology Research: H.R. 2051 and H.R. 2912.* The purpose of the hearing is to receive testimony regarding legislation that aims to expand the National Science Foundation's investment in research related to plant genomics. Witnesses will discuss current advances and concerns, as well as future needs, in plant genomics and related research and will comment on the role that the National Science Foundation (NSF) should play in plant biotechnology research.

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2. Background

National Science Foundation Plant Genome Research

Recombinant DNA technology, or biotechnology, describes a number of tools and technologies that allow researchers to transfer individual genes from one organism to another. Plants that have been derived using plant biotechnology are often referred to as genetically modified organisms (GMOs).

Plant Genome Program. Since the early 1980s, NSF has been the lead agency in the support of research using the plant *Arabidopsis thaliana*. *Arabidopsis*, which is a relative of plants such as broccoli and cauliflower, has been used by scientists as a model organism for plant biology studies for many years. An effort to sequence the entire *Arabidopsis* genome—analogous in many ways to the Human Genome Project—was completed in December 2000, ahead of schedule. The effort involved the work of a consortium of scientists from six different countries. NSF led the effort for the United States with support from the Department of Agriculture (USDA) and the Department of Energy (DOE).

While having the complete DNA sequence of an organism is an important step in understanding how that organism functions, just knowing the sequence of all of an organism's genes is not enough to gain a full understanding of it. Central to scientists' efforts to better understand plants is a clearer understanding of what individual genes in the organism actually do—information that cannot be derived from DNA sequences alone. NSF recently launched a research program aimed at determining the functions of all 25,000 *Arabidopsis* genes—the "2010 Project", which began in FY 2001. Better understanding the specific roles of various plant genes and how they contribute to the overall function of the plant provides the foundation for all aspects of plant biotechnology. NSF provides federal support for this research through grants to individual plant biology researchers and consortia of scientists including large, comprehensive virtual research centers. In fiscal year 2001, NSF will provide nearly $100 million in funding for the Plant Genome program including $15 million for Project 2010 and $31 million for Plant Genome Virtual Centers.

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H.R. 2051 and H.R. 2912

The promise of a program such as NSF's 2010 Project is in the ability to harness fundamental knowledge to solve additional research questions and, eventually, to help solve problems related to plant production and utilization. While understanding the biology of *Arabidopsis* will provide insight into the basic genetics and physiology of all plants, additional research is required to better understand the unique features of more complex plants including commercially-valuable crop plants such as corn and wheat. The legislation being considered at this hearing is aimed at expanding NSF's support of genomics research to include new agriculturally-important species and applications of knowledge derived from studies of genomics.

H.R. 2051 authorizes the National Science Foundation to establish regional plant genome and gene expression research and development centers to: (1) develop capabilities in basic plant genome research; (2) extend basic plant genomics research through plant breeding programs and accelerate its application to the development and testing of new varieties of enhanced food crops and crops that can be used as alternative energy sources; (3) develop alternative uses of agricultural crops; and (4) serve as centers for scientific and safety information on plant genomics. H.R. 2051 was authored by Subcommittee Chairman Nick Smith and authorizes appropriations in the amount of $3 million for fiscal year 2002 and $4.5 million for fiscal year 2003.

H.R. 2912 authorizes the National Science Foundation to establish research partnerships for supporting the development of plant research targeted to the needs of the developing world including: (1) basic genomic research on crops grown in the developing world; (2) development of plant biotechnologies that will advance and expedite the development of improved crop species, including those that are pest-resistant, produce increased yield, or demonstrate increased tolerance to stress; (3) development of technologies to produce pharmaceutical compounds such as vaccines and medications in plants that can be grown in the developing world; and (4) research on the impact of plant biotechnology on the social, political, and economic conditions in countries in the developing world. H.R. 2912 was authored by Subcommittee Ranking Member Eddie Bernice Johnson and authorizes appropriations in the amount of $6 million for fiscal year 2002, $9 million for fiscal year 2003, and $9 million for fiscal year 2004.

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Plant Genome Science—Future Directions

The completion of the *Arabidopsis* genome sequencing project and the development of commercially available genetically modified crops are hailed by many as accomplishments that bear witness to the potential of plant biotechnology. However, many questions remain regarding specific gene function in plants and the limits of current biotechnology tools, and significant gaps still exist between basic research and advanced applications. In addition to research aimed at better understanding the underlying biology of plants such as *Arabidopsis,* current and future research will be focused on improving the technologies utilized to generate genetically modified plants, including the development of more precise methods of inserting new genes into a plant and regulating the expression of those genes. In addition, many plant researchers would like to see more efforts placed on increasing the numbers of plant species for which plant biotechnology techniques can be applied and utilizing information technology for the study of biology—the emerging field of bioinformatics.

Food for the Developing World. The "Green Revolution" of the 1960's is credited with saving a billion lives through the implementation of novel agricultural technologies—selective breeding and hybridization techniques, the introduction of inorganic fertilizers, and utilization of controlled irrigation procedures—in parts of the developing world. The Green Revolution, however, was not a permanent solution to feeding the ever-increasing world population. In his acceptance speech for the 1970 Nobel Peace Prize, Dr. Norman Borlaug cautioned that the Green Revolution had only "won a temporary success in man's war against hunger", given the globe's burgeoning population. While the world's population has grown significantly over the past 4 decades, natural resources and cropland have not. In addition, subsistence farming has led to mineral depletion, erosion, and increased salinity or acidity of much of that land. While technological developments have resulted in improved crop yields, many people in the developing world still go hungry every day.

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Extremes in pH pose one of the greatest stresses to world agricultural yield, with 40 percent of arable land being too acidic and another 20 percent too alkaline to support optimal crop growth. Beyond that, water may be the most limiting resource for crop production, and irrigation practices have rendered much of the once-arable land too salty to support optimal production. Biotechnology has already shown promise for producing more tolerant plants, for example, by creating cultivars that can export salt out of plant cells or varieties that can reduce the loss of water that normally occurs when plants convert carbon dioxide to oxygen. Biotechnology also holds promise for development of plants that can resist insect, fungal, and viral infections.

Biotechnology has also proven successful in improving the nutritional content of food. The "golden rice" project, which involved the incorporation of genes able to lead to the production of vitamin A in rice, created a nutritionally-enhanced plant that could potentially reduce the effects—such as blindness—of endemic Vitamin A deficiency in the developing world. Other nutritionally-enhanced food products, such as those with increased levels of cancer-fighting compounds, for example, could also potentially be produced. Balancing these promising technological developments, however, are concerns that the introduction of new compounds to a given plant could upset the biochemical balance of the plant in a way that renders the plant harmful for human consumption. Additional research, including that aimed at better understanding the underlying biology of plants and the effects of introducing new biochemical pathways, will continue to develop our ability to assess any risks to the environment or to human health these new varieties may pose.

Agricultural Production of Pharmaceuticals. The utilization of genetically modified plants to produce pharmaceuticals is another promising area of plant biotechnology research and development. Scientists report that plants are efficient producers of antibodies including those effective in the prevention of dental caries and microbial infections. Historically, pharmaceuticals have been produced through fermentation processes, which are relatively expensive, labor-intensive, and dependent upon the availability of specialized equipment. Plant production systems show promise in their ability to cost-effectively boost production, perhaps even to levels that would allow developing nations to produce and purify their own pharmaceutical products thus reducing their reliance on corporate vaccine donations or philanthropic support for vaccine distribution programs.

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Beyond plant-based production of pharmaceuticals, researchers are also using biotechnology to develop foods that are a direct source of edible vaccines. These vaccines are genetically incorporated into food plants, need no refrigeration, and require no sterilization equipment or needles for delivery. Edible vaccines are undergoing clinical trials to determine their efficacy in the prevention of a variety of diseases including Hepatitis E. Still, additional research is needed to better understand the mechanism by which edible vaccines are absorbed and utilized by the body to stimulate protective antibody production and to develop methods that insure accurate dosage delivery systems. Beyond technological concerns, there are also socioeconomic concerns related to resource distribution in nations that may have to choose between production of pharmaceutical-producing plants and food on limited parcels of farmable land.

Agricultural and Sustainable Resources. The U.S. uses approximately 13.9 million barrels of oil each day with approximately 2.6 million barrels used for the creation of chemicals and industrial building blocks. Fossil fuels are in finite supply, but of more immediate concern is that the U.S. relies on import of oil from the Middle East for approximately 50 percent of its supply. Without oil imports, some scientists speculate that the U.S. could only meet its petroleum-based energy and processing demands for 28 years. Unlike nonrenewable fossil fuels, plant biomass may prove to be a sustainable source of organic fuels, chemicals, and materials. However, for plants to be used efficiently as a replacement for fossil fuels and petroleum-based products, organisms and enzymes that can efficiently degrade complex starches into simpler carbohydrate molecules must be developed.

Corn has been used for some time as the feedstock for grain-based ethanol production and now additional sources of plant biomass, including corn stover (stalks and other non-edible corn crop residues), hold promise as even more efficient starting materials for ethanol production. Beyond energy production, however, research has shown that plant biotechnology can facilitate the production of "green" chemicals and renewable substitutes for petroleum-based products. For example, the Cargill-Dow Company has developed the technology to convert corn sugar into a biological compound that can substitute for petroleum-based chemicals used in many manufacturing processes including the production of plastics. This process relies on genetically-engineered microorganisms to produce the necessary enzymes to perform this conversion. To fully exploit the potential of plants as sources of industrially-important natural compounds, much additional research is required, for example, to optimize the levels of the desired biochemical building blocks in plants such as corn, to produce enzymes capable of digesting large starch molecules in plants, and to improve efficiency so that green technologies are cost effective when compared to traditional petroleum-based technologies.

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3. Witnesses

The Subcommittee will hear from four witnesses who have expertise in the scientific, technical, political, and economic questions related to plant biotechnology and the cultivation of transgenic crops in the developed and the developing world:

1. Dr. Mary Clutter, Assistant Director, Biological Sciences Directorate, National Science Foundation. Dr. Clutter directs NSF programs that support plant biotechnology and genomics research including Project 2010 and other plant biotechnology programs.

2. Dr. Catherine Ives, Director, The Agricultural Biotechnology Support Project, Michigan State University. Dr. Ives' USAID-funded work focuses on improve agricultural yield in the developing world and assisting developing nations in the areas of technology transfer, intellectual property, and biosafety.

3. Dr. Charles Artzen, Professor of Plant Biology, Arizona State University. Dr. Artzen is a leader in the field of edible vaccines and is interested in plant production of biopharmaceuticals including monoclonal antibodies. Dr. Arntzen is currently involved in several clinical trials to bring plant-based vaccines to market.

4. Dr. Robert Paarlberg, Professor of Political Science, Wellesley College. Dr. Paarlberg's research is on the socioeconomic and policy impacts of transgenic crops in the developing world.

Witnesses will be asked to comment on the potential impact of H.R. 2051 and H.R. 2912 on their fields of research, including the relevance of the proposed programs to advancing plant science, promoting basic research, encouraging technology transfer, and filling any funding gaps that currently exist within the Federal research funding portfolio.

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In addition, witnesses have also been asked:

1. What are the potential economic and political ramifications that must be considered before embarking upon a research program to utilize biotechnology in developing new crops, pharmaceuticals, or raw materials?

2. Given your knowledge of current research funding related to plant biotechology, plant genomics, and related technologies, are there funding gaps in the federal research portfolio that could be satisfied by a dedicated program at the National Science Foundation? What special expertise could NSF contribute to the overall research effort and how could NSF complement existing programs?

3. What are some effective research strategies that could be implemented to better answer questions related to the potentially negative environmental, socioeconomic and health impacts of plant biotechnology?

Chairman **SMITH.** The Subcommittee on Research will come to order. Before we officially start the meeting, I would like to congratulate and say goodbye from our Science Committee staff to Peter Harsha. Peter will be leaving for a new job, but still in the area of science and the computer effort that we are striving to achieve in this country. So, Peter, best of luck and thanks for all your help.

Today the Subcommittee on Research meets to examine Strengthening the NSF Sponsored Agricultural Biotechnology Research and really to look at two bills designed to do that. The use of biotechnology to produce new varieties of plants for food and other uses, has been of great interest to this Subcommittee in the past. And during the 106th Congress, this Subcommittee held a series of hearings and briefings aimed at understanding the technology and its implications.

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We received testimony and information from scientists and other interested parties from this country and around the world on all sides of the issues. The information provided helped us come to some conclusions about technology, conclusions that I spelled out last year in a Chairman's report, entitled, "Seeds of Opportunity: An Assessment of the Benefits, Safety, and Oversight of Plant Genomics and Agricultural Biotechnology."

In that report, we noted biotechnology's incredible potential to enhance nutrition, feed a growing world population, open up new markets for farmers, and reduce the environmental impact of farming.

Biotechnology has been used safely for many years to develop new products. More than a thousand products have now been approved, many more are being developed. These products include human insulin for diabetics, growth factors used in bone marrow transplants, products for treating heart attacks, diagnostic tests for AIDS, hepatitis, and other infectious agents, and enzymes used for food production. And this is only the very beginning of a great potential if we have the willingness and the creativity to follow through and move on.

In agriculture, new biotech plant varieties will offer foods with better taste, more nutrition, longer shelf life. Farmers will be able to grow these improved varieties more efficiently and with less pesticides, leading to lower costs for consumers and lower use of chemical pesticides and herbicides. Crops designed to resist pests and tolerate herbicides, freezing temperatures, and drought will make agriculture more sustainable by reducing the use of synthetic chemicals and irrigated water, promoting no-tillage farming practices and reducing the pressure to convert valuable ecosystems to agricultural production.

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New varieties may also serve as alternative energy sources, provide inexpensive industrial precursors, or supply needed vaccines. Its potential benefits are limited only by the imagination and resourcefulness of our scientists.

The two bills that we will consider today both attempt to help unleash some of that imagination and resourcefulness. My bill, H.R. 2051, authorizes funding for the establishment of Plant Genome Expression Centers, centers for extending plant genomics research through plant breeding programs and accelerating the development of some of these new varieties. These centers would bring together some of the best resources in the field and should use the latest in technology, including supercomputers.

IBM's "Blue Gene" computer, with a design goal of 1,000 trillion calculations per second—the last time I think I used the word quadrillion, I was very proud of being able to use that word when I was about 7 years old, and I think this is almost the first time since. This is 80 times faster than our best computer now and it is designed—it will be designed according to our Federal labs and IBM to use much less energy than our current supercomputers. This kind of increased capacity in biotechnology could lead to both the cure of some existing diseases and be important in the development of vaccines to help us resist future biological threats, natural or man-made.

Ms. Johnson's bill that she will talk about is H.R. 2912, is similar to H.R. 2051, that it moves us ahead, but with more of a focus on the developing world. Both bills, however, have the similar intent of focusing resources on basic research in order to encourage and accelerate the development of these new potentially very beneficial varieties.

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Set against these benefits are the largely hypothetical risks of agricultural biotechnology. As I made clear in my report, however, the weight of the scientific evidence suggests that plants developed using biotechnology are not inherently different or more risky than similar products of conventional breeding. In fact, modern biotechnology is becoming so precise, and so much more is known about the changes being made, that plants produced using this technology may even be safer than the traditional crossbreeding and hybrid breeding.

I think it is an important issue. This Committee can play a critical role in the development of the technology by continuing to insist that the debate surrounding it remain firmly grounded in science. And I wanted to thank the witnesses for appearing today. I look forward to hearing your testimony. And with that, I would call on Ms. Johnson for her comments.

[The prepared statement of Mr. Smith follows:]

PREPARED STATEMENT OF CHAIRMAN NICK SMITH

Today the Subcommittee on Research meets to examine *''Strengthening NSF Sponsored Agricultural Biotechnology Research''* and to look at two bills designed to do just that. The use of biotechnology to produce new varieties of plants—for food or other uses—has been of great interest to this subcommittee in the past. During the 106th Congress, this subcommittee held a series of hearings and briefings aimed at understanding the technology and its implications. We received testimony and information from scientists and other interested parties from around the world, on all sides of the issue. The information provided helped me come to some conclusions about the technology, conclusions that I spelled out last year in a Chairman's Report entitled *''Seeds of Opportunity: An Assessment of the Benefits, Safety, and Oversight of Plant Genomics and Agricultural Biotechnology.''*

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In that report, I noted biotechnology's incredible potential to enhance nutrition, feed a growing world population, open up new markets for farmers, and reduce the environmental impact of farming.

Biotechnology has been used safely for many years to develop new products. More than a thousand products have now been approved, and many more are being developed. These products include human insulin for diabetics, growth factors used in bone marrow transplants, products for treating heart attacks, diagnostic tests for AIDS, hepatitis, and other infectious agents, and enzymes used in food production.

In agriculture, new biotech plant varieties will offer foods with better taste, more nutrition, and longer shelf life. Farmers will be able to grow these improved varieties more efficiently, leading to lower costs for consumers and lower use of chemical pesticides and herbicides. Crops designed to resist pests and tolerate herbicides, freezing temperatures, and drought will make agriculture more sustainable by reducing the use of synthetic chemicals and irrigated water, promoting no-tillage farming practices, and reducing the pressure to convert valuable ecosystems to agriculture. New varieties may also serve as alternative energy sources, provide inexpensive industrial precursors, or supply needed vaccines. Its potential benefits are limited only by the imagination and resourcefulness of our scientists.

The two bills we'll consider today both attempt to help unleash some of that imagination and resourcefulness. My bill, H.R. 2051, authorizes funding for the establishment of Plant Genome Expression Centers—centers for extending plant genomics research through plant breeding programs and accelerating the development of some of these new varieties. These centers would bring together some of the best researchers in the field and should use the latest in technology, including supercomputers. I recently had the pleasure of learning about one such machine being built to tackle fundamental genomics problems, IBM's "Blue Gene." With a design goal of 1,000 trillion calculations a second—80 times faster than existing supercomputers—it should provide great capacity to increase our understanding of proteins and genes. I hope that, in the future, researchers who participate in gene expression centers will have access to resources as robust.

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Ms. Johnson's bill, H.R. 2912, is similar to H.R. 2051, but with a focus on the developing world. Both bills, however, have the similar intent of focusing resources on basic research in order to encourage and accelerate the development of these new, potentially very beneficial varieties.

Set against these benefits are the largely hypothetical risks of agricultural biotechnology. As I made clear in my report, however, the weight of the scientific evidence suggests that plants developed using biotechnology are not inherently different or more risky than similar products of conventional breeding. In fact, modern biotechnology is so precise, and so much more is known about the changes being made, that plants produced using this technology may even be safer than traditionally-bred plants.

This is an important issue. This committee can play a critical role in the development of the technology by continuing to insist that the debate surrounding it remain firmly grounded in science. I want to thank the witnesses for appearing today and I look forward to hearing your testimony.

107**TH CONGRESS**

1**ST SESSION**

H. R. 2051

To provide for the establishment of regional plant genome and gene expression research and development centers.

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IN THE HOUSE OF REPRESENTATIVES

JUNE 5, 2001

Mr. **SMITH** of Michigan introduced the following bill; which was referred to the Committee on Science

A BILL

To provide for the establishment of regional plant genome and gene expression research and development centers.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. CENTERS.

The National Science Foundation is authorized to make grants for the establishment of regional plant genome and gene expression research and development centers, the purpose of which shall be to——

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(1) develop capabilities in basic plant genome research;

(2) extend basic plant genomics research through plant breeding programs and accelerate its application to the development and testing of new varieties of enhanced food crops and crops that can be used as alternative energy sources;

(3) develop alternative uses of agricultural crops; and

(4) serve as centers for scientific and safety information on plant genomics.

SEC. 2. GRANT AWARDS.

Grant awards under this Act shall be made through an open, peer-reviewed competition. When making awards, the National Science Foundation shall ensure that as many different agronomic environments as possible are represented.

SEC. 3. MATCHING FUNDS.

The National Science Foundation shall not provide under this Act more than 50 percent of the cost of establishing any research and development center.

SEC. 4. AUTHORIZATION OF APPROPRIATIONS.

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There are authorized to be appropriated to the National Science Foundation $3,000,000 for fiscal year 2002 and $4,500,000 for fiscal year 2003 to carry out this Act.

107**TH CONGRESS**

1**ST SESSION**

H. R. 2912

To authorize the National Science Foundation to establish a grant program for partnerships between United States research organizations and those in developing countries for research on plant biotechnology.

IN THE HOUSE OF REPRESENTATIVES

SEPTEMBER 20, 2001

Ms. **EDDIE BERNICE JOHNSON** of Texas introduced the following bill; which was referred to the Committee on Science

A BILL

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To authorize the National Science Foundation to establish a grant program for partnerships between United States research organizations and those in developing countries for research on plant biotechnology.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. FINDINGS.

The Congress makes the following findings:

(1) The National Science Foundation has made important contributions to advance the knowledge base for plant biotechnology.

(2) Plant biotechnology research has the potential to help developing countries increase food security.

(3) Plant biotechnology research can be used to improve the quality and nutritional content of food.

(4) Biotechnology offers the prospect of delivering vaccines to immunize against life-threatening illnesses through agricultural products in a safe and effective manner that overcomes the infrastructure and cost limitations faced by traditional vaccination methods in the developing world.

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(5) Research partnerships between scientists in the United States and developing countries will help strengthen the capabilities of those countries to develop and implement applications of plant biotechnology.

(6) Research funding levels at the National Science Foundation and elsewhere are obstacles to the use of plant biotechnology to address problems in the developing world.

SEC. 2. GRANT PROGRAM AUTHORIZED.

(a) **ESTABLISHMENT**.—The National Science Foundation shall establish a program to award grants to institutions of higher education (as defined in section 101 of the Higher Education Act of 1965 (20 U.S.C. 1001)), nonprofit organizations, or consortia of such entities to establish research partnerships for supporting the development of plant biotechnology targeted to the needs of the developing world.

(b) **PARTNERSHIPS**.——

(1) **DEVELOPING NATION PARTNERS**.—In order to be eligible to receive a grant under this section, the grantee shall enter into a partnership with 1 or more research institutions in 1 or more developing nations.

(2) **FOR-PROFIT PARTNERS**.—Partnerships may also include for-profit companies involved in plant biotechnology.

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(3) **SPECIAL CONSIDERATION**.—In making awards under this section, the National Science Foundation shall give special consideration to partnerships that include a Historically Black College or University, a Hispanic serving institution, or a tribal college or university.

(c) **USE OF FUNDS**.—Grants awarded under this section shall be used for support of research activities in plant biotechnology targeted to the needs of the developing world. Such activities may include——

(1) basic genomic research on crops grown in the developing world;

(2) development of plant biotechnologies that will advance and expedite the development of improved cultivars, including those that are pest-resistant, produce increased yield, or increase tolerance to stress;

(3) development of technologies to produce pharmaceutical compounds such as vaccines and medications in plants that can be grown in the developing world; and

(4) research on the impact of plant biotechnology on the social, political, and economic conditions in countries in the developing world.

(d) **COMPETITIVE MERIT REVIEW**.—Grants under this Act shall be awarded on a merit-reviewed competitive basis.

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SEC. 3. AUTHORIZATION OF APPROPRIATIONS.

There are authorized to be appropriated to the National Science Foundation $6,000,000 for fiscal year 2002, $9,000,000 for fiscal year 2003, and $9,000,000 for fiscal year 2004 to carry out this Act.

Ms. **JOHNSON.** Thank you very much, Mr. Chairman. And I want to thank you for convening a hearing on this important subject. I know that we share a strong interest in seeing the promise of plant biotechnology realized. And I, too, would like to thank the witnesses for being here today.

Currently, the world population is 6.2 billion. By 2025, there will be an additional 2 billion people in the world, mainly in developing countries. Food demand is expected to increase between 50 and 100 percent in the next 25 years. Undoubtedly, food security will be the most important social issue of the 21st century.

Today, 800 million people are malnourished and go hungry each day. That number is equivalent to 2.8 times the number of people in the United States. Each day, 40,000 die of malnutrition. Half are children. The number of people who die worldwide each year from hunger is slightly more than the entire population of the State of Illinois. As the world population grows, the number of men, women, and children dying from hunger will only increase unless world food production rises dramatically.

I believe that plant biotechnology has the potential to help the developing world increase food security and move food—and move toward food self-sufficiency. That is why I introduced H.R. 2912. Ultimately, it will certainly save this country foreign aid—a bill to authorize the National Science Foundation to establish a grant program for partnerships between the U.S. research organizations and those in developing countries for research on plant biotechnology targeted to the agricultural needs of the developing world.

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In a recent New York Times article, Dr. Florence Wambugu, an expert in plant biotechnology at the Kenya Agricultural Research Institution, wrote about the need for agricultural biotechnology in Africa and technical assistance from the developed world. She wrote, "African growers desperately need to access the best management practices, fertilizer, better seeds, and biotechnology, to help improve the crop production, which is currently the lowest in the world per unit area of land. Traditional agricultural practices, which continue to produce only low yields and poor people, will not be sufficient to feed the additional millions of people who will inhabit the continent 50 years from now. The priority of Africa must be to feed its people and to sustain agricultural production and the environment. America and other developed nations must act now to allocate technologies that can prevent suffering and starvation."

Dr. Wambugu is right. It is now time for the United States and other developed nations to step up to the plate. We need to work side by side with scientists from poor countries to develop crop varieties that are resistant to insects and viruses, that can be grown in drought stricken lands with only minimal amounts of water, and have improved nutritional content, and that vaccinate against life-threatening illnesses.

The National Science Foundation has already made an important contribution to advance the knowledge base for plant biotechnology. I see H.R. 2912 as a way to build on the base and to use plant biotechnology to address agricultural problems in the developing world.

I invite the views and recommendations of our witnesses on the proposed legislation we are considering today. I am also interested in any thoughts they may have on ways to increase the effectiveness of current federally supported research on plant biotechnology.

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Mr. Chairman, I thank you again for this hearing and I join you in welcoming our expert witnesses, and I look forward to our discussion. Thank you.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF EDDIE BERNICE JOHNSON

Agricultural Biotechnology in the Developing World

Mr. Chairman, I want to congratulate you for convening a hearing on this important subject. I know we share a strong interest in seeing the promise of plant biotechnology realized.

Currently the world population is 6.2 billion. By 2025 there will be an additional 2 billion people in the world, mainly in developing countries. Food demand is expected to increase between 50 and 100% in the next 25 years. Undoubtedly, food security will be the most important social issue of the 21st century.

Today, 800 million people are malnourished and go hungry each day. That number is equivalent to 2.8 times the number of people in the United States. Each day, 40,000 die of malnutrition. Half are children. The number of people who die worldwide each year from hunger is slightly more than the entire population of the state of Illinois. As the world population grows, the number of men, women, and children dying from hunger will only increase unless world food production rises dramatically.

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I believe that plant biotechnology has the potential to help the developing world increase food security and move toward food self-sufficiency. That is why I introduced H.R. 2912, a bill to authorize the National Science Foundation to establish a grant program for partnerships between U.S. research organizations and those in developing countries for research on plant biotechnology targeted to the agricultural needs of the developing world.

In a recent *New York Times* article, Dr. Florence Wambugu, an expert in plant biotechnology at the Kenya Agricultural Research Institution, wrote about the need for agricultural biotechnology in Africa and technical assistance from the developed world. She wrote:

"African growers desperately need access to the best management practices, fertilizer, better seeds and biotechnology to help improve crop production, which is currently the lowest in the world per unit area of land. Traditional agricultural practices, which continue to produce only low yields and poor people, will not be sufficient to feed the additional millions of people who will inhabit the continent 50 years from now.. . . The priority of Africa must be to feed its people and to sustain agricultural production and the environment.. . . America and other developed nations must act now to allocate technologies that can prevent suffering and starvation."

Dr. Wambugu is right. It is now time for the U.S. and other developed nations to step up to the plate. We need to work side by side with scientists from poor countries to develop crop varieties that are resistant to insects and viruses, that can be grown in drought stricken lands with only minimal amounts of water, that have improved nutritional content, and that vaccinate against life-threatening illnesses.

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NSF has already made important contributions to advance the knowledge base for plant biotechnology. I see H.R. 2912 as a way to build on that base and to use plant biotechnology to address agricultural problems in the developing world.

I invite the views and recommendations of our witnesses on the proposed legislation we are considering today. I am also interested in any thoughts they may have on ways to increase the effectiveness of current federally supported research on plant biotechnology.

Mr. Chairman, I join you in welcoming our expert witnesses, and I look forward to our discussion.

Chairman **SMITH.** Representative Johnson, we thank you. If there is no objection, all additional opening statements will be submitted by Committee members and will be added to the record. Without objection, it is so ordered.

At this time, I would like to again welcome and introduce our witnesses today. Our first witness has appeared frequently before this Subcommittee, Dr. Mary Clutter. And Mary is Assistant Director of the National Science Foundation and Head of the Biological Sciences Directorate. Her directorate oversees the Plant Genome Research Program at NSF.

And our next witness is from my alma mater, Dr. Catherine Ives, currently Director of the Agricultural Biotechnology Support Project at Michigan State University, a program supported in part by the U.S. Agency for International Development. And Dr. Ives shared some of her work with members of this Subcommittee during our visit to MSU last year.

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Our third witness is Dr. Charles Arntzen, a Distinguished Professor of Plant Biology at Arizona State

University. And Dr. Arntzen, formerly at Cornell University, is one of the country's—world's leading researchers in the field of edible vaccines.

And our final witness is Dr. Robert Paarlberg, a Professor of Political Science at Wellesley College, and Associate at the Weatherhead Center for International Affairs at Harvard University. His principal research interests are international agriculture and environmental policy.

I thank you all very much for being here today to give us some of your guidance and your time. And, as you may know, your spoken testimony is limited to 5 minutes, after which the members of the Committee will have each 5 minutes to respond to questions. Your full written testimony will be entered into the record. And with that, we will start with you, Dr. Clutter.

STATEMENT OF DR. MARY E. CLUTTER, ASSISTANT DIRECTOR, BIOLOGICAL SCIENCES DIRECTORATE, NATIONAL SCIENCE FOUNDATION

Dr. **CLUTTER.** Good afternoon, Chairman Smith, Ranking Member Johnson, and other members of the Research Subcommittee. I am very pleased to be able to represent the National Science Foundation at this important hearing.

I believe that NSF's major strength is in its support of fundamental research. That support produces basic knowledge about the biology of plants, develops new technologies and tools for plant biotechnology research, that can be applied and adapted to meet the specific needs of the developing world.

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In my written testimony, I have provided several examples of cutting-edge research on plant genomes and gene expression and have also illustrated some of the important ways in which NSF-sponsored fundamental research is of value to agriculture, both in the United States and abroad. In my remarks this afternoon, I wish to emphasize four major points from the written testimony.

First, I want you to realize that the biology of the 21st century is markedly different from the biology of only a decade ago. Biology we all learned in school is total outmoded. The confluence of information technology and biotechnology has resulted in a transformation that has changed the biological sciences forever. The advent of genomics and all of the other -omics has created massive data and research resources. New information technology allows easy and real-time access to data anywhere in the world. In this new biology, research is multi-disciplinary and can be conducted by groups of researchers from many different disciplines, from genetics and physiology to mathematics and computer sciences. Disciplinary, institutional and geographical boundaries disappear.

Second point—highly trained scientists are now found everywhere, not just in the so-called research universities. They are a major resource for our country and it is imperative that we involve them in research projects of great importance, such as plant genome research.

Third, perhaps, our largest challenge is to educate the next generation of scientists who will reflect the diversity of our country. Through the funding of multi-disciplinary research and education activities of scientists, ecologists, and universities across the United States, it is now possible for students to participate in major research projects regardless of their location. These exciting opportunities will hopefully attract many students from a broader pool.

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Finally, we must recognize that science is truly a global activity. The same technologies that foster communication and collaboration among U.S. institutions can and should be used to interlink scientists and students anywhere in the world. Through such mechanisms as virtual centers and research coordination networks, students and faculty located at all institutions can be involved in cutting-edge research.

Perhaps, the single most effective way to work with the developing world in solving problems in agriculture is to provide training and long-term sustained collaboration in true partnerships.

Mr. Chairman, in conclusion, the National Science Foundation appreciates the Committee's support and interest in plant biotechnology and genomics research, as well as the Committee's confidence in our ability to take on additional activities in these areas. Thank you.

[The prepared statement of Dr. Clutter follows:]

PREPARED STATEMENT OF DR. MARY E. CLUTTER

Chairman Smith, Ranking Member Johnson, members of the Research Subcommittee, I appreciate the opportunity to be here today to discuss plant genome and gene expression research and development centers, and research and development programs in agricultural biotechnology in partnership with the developing world.

Central to the discussion is NSF's role in support of research in plant biotechnology, especially in plant genomics. I would like first to describe NSF's Plant Genome Research Program, and "center" activities that are being supported by the Program. I will then present the Foundation's views on how we might best utilize our strengths in contributing to plant biotechnology research and development activities in the developing world.

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The Plant Genome Research Program:

The Interagency Working Group (IWG) on Plant Genomes, established in 1997, outlined a broad plant genome initiative. Funding for a plant genome research program, to be developed in consultation with the IWG, was first appropriated in FY 1998. The IWG developed a five year plan for the initiative, identified science-based priorities, and planned a coordinated interagency approach.

NSF's Plant Genome Research Program supports projects that make significant contributions to our understanding of plant genome structure, organization and function. Emphasis is placed on plants of economic importance, as well as plant processes of potential economic value. Some of the anticipated long-term benefits from support of this research include both fundamental breakthroughs in our understanding of plant biology and practical applications that will improve crops and develop novel, plant-based products.

Since FY 1998, the Plant Genome Research Program has held four open competitions and supported a total of 78 projects, involving approximately 300 investigators at 80 institutions scattered across 38 states in all regions of the country. Examples of research being supported include:

Infrastructure development including production, mapping and sequencing, construction of physical and genetic maps of genomes in economically important plants such as corn, soybean, wheat and cotton, and support for databases for plant genome data

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Functional genomics research such as the structure-function relationships of maize genome centromeres, identification of genes involved in plant tolerance to environmental stresses, and the molecular basis for quantitative traits such as fruit size

Technology development research including gene discovery methods, visualization of chromosome movement during cell division, gene mapping methods, and microarrays

Training for the next generation of young scientists who have learned completely new ways of conducting scientific research in biology.

As you are aware, projects are selected for funding based on two review criteria, the intellectual merit of the project, and the broader impacts of the proposed activity. It is this second criterion that is especially important in selecting projects that will advance the potential of this research.

Plant Genome Virtual Center:

During the last decade, the confluence of information technology and biotechnology has resulted in a paradigm shift in the biological sciences. The advent of genomics has created massive data, information, and research resources that make it possible for scientists to ask questions in a manner very different from the traditional one-gene-at-a-time approach. The advent of information technology has allowed easy and real time access to these data from anywhere in the world. This systems approach to biology, allows scientists to study complex questions and is often carried out by groups of researchers from multiple disciplines rather than individuals. Unlike the structure-based research centers of the 20th Century, centers in the 21st Century are frequently "virtual", i.e., centers without walls. This trend is reflected in proposals received by all of our programs at NSF. The Plant Genome Program currently supports 23 virtual centers.

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Characteristic features of plant genome virtual centers are:

Project PIs and Co-PIs initiate and assemble a virtual center based on the project goals and needs

They comprise a range of expertise from breeders to sequencers

They involve a range of approaches from genetics and physiology to mathematics and computer sciences

They are flexible—expertise or approaches can be added or dropped as a project evolves

There are no geographical, institutional, disciplinary boundaries

They provide cross-project training opportunities

They facilitate interactions with other non-plant research programs (e.g., human genome), international community and industry

The outcomes are shared with the entire research community

Awardees meetings and other mechanisms allow sharing and encouragement for broadening participation.

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Examples of virtual centers are:

''Tools for potato structural and functional genomics''—Combines the expertise of genomics researchers, plant pathologists, evolutionary biologists, and informaticists with a link to breeders. Will provide tools and basic biological knowledge for developing resistance to late potato blight, an economically important disease in the U.S. and Central and South America. Investigators are located at U.C. Berkeley, Cornell U., U. Wisconsin, U. Minnesota, and The Institute for Genomic Research. The center works with European and South American collaborators.

''Gene discovery in aid of plant nutrition, human health and environmental remediation''—Investigates the roles of plant gene in multiple aspects of metal metabolism from nutrition to bioremediation. Expertise includes physiology, biochemistry, metal biophysics and informatics. Links with non-plant research in related organisms added mid-way as needs arise. Leverages *Arabidopsis* genome sequence to crop plants such as cereals. Center members are located at Dartmouth College, Purdue U., U. Missouri, Scripps Institute, U. Minnesota, U.C. San Diego, and the San Diego Super Computer Center.

''A functional genomics program for soybean''—Brings powerful genomics tools to important resources for legume biology researchers as well as soybean breeders. Leverages *Medicago* work to an economically important relative. Investigators are located at U. Illinois, Northern Arizona U., Iowa S.U., U. Missouri, U. Minnesota, and the United Soybean Board.

''Structure and function of the expressed portion of the wheat genomes''—Produces tools (databases, expressed sequence tags, DNA probes, and maps) for identifying wheat genes of economic importance for the entire research community. Addresses the biological question of evolution of modern cultivars of wheat from wild ancestors. Involves all major U.S. wheat researchers located at U.C. Berkeley, U.C. Davis, U.C. Riverside, Colorado S.U., Cornell U., Kansas S.U., North Dakota S.U., Texas Tech U., U. Minnesota, U. Missouri, and U. Nebraska. The center is connected to the International *Triticeae* Mapping Initiative, a 10-

year old group of wheat/barley/oats researchers.

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Arabidopsis Genome Research Project and the 2010 Project—A case study of a successful interagency and international research collaboration:

Last year, *Arabidopsis thaliana*, a small mustard plant, became the first flowering plant to have its entire genome completely sequenced. The sequencing was the result of a well-coordinated international effort.

The availability of the entire genome sequence of *Arabidopsis* has provided an unprecedented opportunity for the scientific community to advance our understanding of the biology of plants in ways that were not possible before. The sequencing project identified approximately 25,000 genes in the *Arabidopsis* genome. Knowing the number of genes is only a first step to knowing their function, which is the ultimate goal of any genome project. The 2010 Project is a 10-year effort to determine the function of all 25,000 genes. Because all flowering plants are closely related, knowing the function of 25,000 *Arabidopsis* genes helps us understand the function of other flowering plant genes. NSF hopes that the long-term outcome of the 2010 Project will be a virtual plant which one could observe growing on a computer screen, stopping a process at any point in its development, and with the click of a computer mouse, accessing all genetic information expressed in any organ or cell under a variety of environmental conditions.

The 2010 Project is a worldwide effort and will be coordinated by the international community of scientists. The results from the 2010 Project will provide a tremendous resource to all areas of plant biology research including development of new and improved crop plants, and of new plant-based products. Understanding how some of the regulatory genes work to control gene expression under drought conditions will help breeders to develop drought tolerant crop plants. Identification of genes involved in biosynthesis of industrial hydrocarbons and their regulatory mechanisms will be used by industry to develop plants that produce valuable chemicals.

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Partnership with the Developing World in Plant Genomics:

Perhaps the single most effective way to help the developing world in solving problems in agriculture is to provide the solid scientific knowledge base and efficient research tools, including trained scientists, that can be applied to local problems.

For such an effort to be effective in transferring genomics technology to the developing world in the long term, sustained research collaborations are essential. In this regard, NSF's efforts to help the developing world with agricultural biotechnology applications should be coordinated with the activities of other involved agencies and organizations. NSF's role should be based on our unique mission and be defined in a way that takes full advantage of what we do best.

Through our Plant Genome Research Program, NSF contributes basic biological knowledge, new research tools, and opportunities for training. Examples are:

NSF-supported projects provide the fundamental knowledge necessary to provide solutions to the problems of the developing world, such as pest and disease resistance, environmental stress tolerance, yield under low input conditions, higher nutritional quality, post-harvest management, etc.

NSF-supported projects develop new technologies (new gene mapping strategies, easily reproducible transformation technologies, new breeding strategies, ways to increase production of valuable chemicals in plants) that will help the developing world to devise their own solutions

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NSF-supported projects provide opportunities to train scientists from the developing world

The Plant Genome Research Program works closely with NSF's International Division in identifying and supporting the need for international collaboration

Societal impacts of biotechnology in the developing world need collaborative research that is based in the developing world. Some of that is already being done through NSF-supported research.

I would like to emphasize the importance of training the next generation of scientists who reflect the diversity of America. First-rate scientists and science can be found at any institution in the U.S., not just at Research I Universities. Through the funding of research activities of scientists at colleges and universities across the U.S., opportunities are being made available to many students. Virtual centers provide a mechanism whereby students and faculty located at all institutions can be involved in cutting edge science. In the Plant Genome Research Program, young scientists are being trained in new ways of doing science. They are in high demand from industry, which utilizes the basic genomics knowledge to develop plant-based products. It would be valuable to extend these same opportunities to young scientists and students from the developing world. As they go back to their home countries and establish research programs, they can be part of a virtual center or connected through research coordination networks.

Conclusion:

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Mr. Chairman, in conclusion, NSF appreciates the Committee's support and interest in plant biotechnology and genomics research, as well as the Committee's confidence in our ability to take on additional activities in these areas.

I would like to take a moment to respond to your request that NSF provide comments on the potential impact of the bills being considered here today, H.R. 2051 and H.R. 2912. While both bills are consistent with activities currently funded through NSF, they do not appear to provide NSF with authority it does not already have. In addition, legislation was not requested by the Administration in these areas. NSF would be happy, however, to provide more details on H.R. 2051 and H.R. 2912 prior to further consideration of these bills.

I believe that NSF's major strength is in its support of basic research. That support produces basic knowledge about the biology of plants, develops new technologies and tools for plant biotechnology research, and can be applied and adapted to meet the specific needs of individual developing countries. One of the most effective ways to foster knowledge and technology transfer to the developing world would be to make all the data, information and materials freely available through the training of scientists from the developing world and the networking of scientists worldwide.

Thank you.

BIOGRAPHY FOR MARY E. CLUTTER

Dr. Mary E. Clutter is Assistant Director of the National Science Foundation (NSF). She is responsible for the Biological Sciences Directorate that supports all major areas of fundamental research in biology.

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Dr. Clutter came to NSF from the Department of Biology at Yale University to be Program Director of Developmental Biology. She has held a number of positions at the Foundation including Division Director of Cellular Biosciences, Senior Science Advisor to the Director, and Acting Deputy Director, NSF.

Dr. Clutter is the U.S. Chair of the U.S.-European Commission Task Force on Biotechnology, a member of the Board of Trustees of the international Human Frontiers Science Program, a member of the Board of Regents of the National Library of Medicine, a member of the National Agricultural Research, Extension, Education and Economics Advisory Board, Chair of the Biotechnology Subcommittee of the Committee on Science of the National Science and Technology Council (NSTC), co-chair of the Subcommittee on Ecological Systems of the Committee on Environment and Natural Resources/NSTC and co-chair of the NSTC Committee on Science's Interagency Working Group on Plant Genomes. She is also a member of numerous professional societies, and has served on the Board of Directors of the American Association for the Advancement of Science (AAAS). She is a Fellow of the AAAS and the Association for Women in Science.

Dr. Clutter received the Bachelor of Science degree in biology from Allegheny College and her Masters and doctoral degrees from the University of Pittsburgh. She received honorary doctorates of science from Allegheny College and Mount Holyoke College and the Bicentennial Medallion of Distinction from the University of Pittsburgh. She has received numerous Senior Executive Service Awards including the Meritorious and Distinguished Executive Presidential rank awards from President Ronald Reagan, President George Bush and President William Clinton.

Chairman **SMITH.** Thank you. Dr. Ives.

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STATEMENT OF DR. CATHERINE L. IVES, DIRECTOR, THE AGRICULTURAL

BIOTECHNOLOGY SUPPORT PROJECT, MICHIGAN STATE UNIVERSITY

Dr. **IVES.** Thank you, Chairman Smith, Congresswoman Johnson, and other members of the Committee for inviting me here to speak today on H.R. 2051 and H.R. 2912. I am, as was mentioned, the current Director of the Agricultural Biotechnology Support Project, or ABSP, at Michigan State University. And I commend the Committee for proposing these two initiatives which will contribute to the advancement in basic and applied plant research to increased food security and economic growth, both in our country and abroad.

One can rightly ask why the United States should invest in programs to elucidate fundamental mechanisms of plant production. And first and foremost, because history has shown us that technological innovation is essential for human progress. The Green Revolution, by conservative estimates, saved the lives of over 400 million people. But even with those technological innovations, as was mentioned, there is still today almost a billion people living in absolute poverty and suffering from persistent hunger.

So what can we do to help those people that are still locked in this vicious cycle of hunger and poverty while at the same time a revolution in biotechnology is improving the health, well-being, and lifestyle of those of us in the developed world? We know today that technological innovations, as was just mentioned, have a global reach, and a breakthrough in one country, particularly in the area of international public goods, can be a breakthrough to all. And the elucidation of the rice genome, for example, will probably be of more benefit to China than it is to the United States.

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More of this type of public funding to be spent on creating new partnerships among public institutions, the private sector, and other nonprofit organizations, is needed to solve problems of particular interest to the poor. There are a lot of challenges in addressing international research and development efforts and there are many constraints. And these include a mistrust or inexperience in working with the private sector, an inexperience in intellectual property and management of new technologies, non-existent or poor regulatory systems, poor laboratory and communications infrastructure. And I think we just heard how important the communications infrastructure is with the new science. And a relatively small number of trained scientists.

And these two proposed bills would, I think, most directly address the last two challenges. And that is, improving communication infrastructure and networking, and increasing the number of trained scientists through research partnerships. The ability of any country's scientists to independently assess new biotechnology-derived crops is vital to the food security and economic prosperity of that country. And developing an increased knowledge of, and experience with, the techniques of modern biotechnology would greatly assist countries in the formulation of scientifically sound policies, legislation, and regulations.

However, support to the basic plant sciences would actually and indirectly benefit all those constraints because a fundamental knowledge and understanding of plants and cooperative research strategies are the foundation for addressing food production and nutrition problems. Increased basic knowledge about orphan crops, such as cassava and bananas, will require the investment of the public sector and the United States should be at the forefront of this effort, given the strength of its research community.

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Let me take just a little moment to talk a little bit about the ABSP project, which is funded by USAID, and has worked for the last 10 years to assist developing countries in accessing biotechnology to develop crops that are resistant to insects and disease. This program focuses not only on technical training and applied research, but also on helping countries develop national institutional policies that will permit access to and development of agricultural biotechnology.

Two very quick examples. We worked with the Agricultural Genetic Engineering Research Institute in Cairo, Egypt to develop a specific variety of potato used by small farmers for domestic consumption, with resistance to Potato Tuber Moth, which is an important insect pest worldwide, primarily in the tropical areas. Without applications of insecticide, losses can be up to 100 percent of stored potatoes.

We developed new transgenic potatoes that in field trials in the United States and Egypt have shown tremendous protection against this insect without the need for insecticide. We will shortly begin field trials in South Africa and are currently working with Egyptian regulatory authorities to gather the appropriate environmental health data to register these potatoes for commercial use.

That work could not be done without initial fundamental inputs from basic research. This is also brought out in another collaboration that we have just started, with the TATA Energy Research Institute of India and Monsanto Company to develop and adopt enhanced oil from mustard seed. This project, called the Golden Mustard Project, has the potential of helping hundreds of thousands of children suffering from Vitamin A deficiencies, particularly in northern and eastern India where mustard oil is commonly used for food preparation and cooking.

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Monsanto has been working since the mid-1990's to elucidate the biosynthetic pathway that allows the plant to produce beta-carotene, the precursor to Vitamin A. And the main point is that without investment in this basic research, we couldn't move forward with adapting this technology on behalf of a developing country and developing country—the poor in a developing country.

I think it is important to note that we should not expect that funding research programs alone will result in improved technologies available to the poor. It will be important for NSF to develop strong linkages with those programs, particularly USAID, that are—have the primary task of adapting and transferring technology abroad. This may involve joint meetings, participation in review panels, and joint priority-setting. Hopefully, this would allow us to build upon synergies and reduce redundancies in funding.

Let me conclude by saying that the National Science Foundation, through its support of basic research in plant biotechnology, plays a critical role in helping all countries increase food production and improve food quality, and in promoting a knowledge-based economy. Research centers and partnerships between scientists will improve our understanding of complex plants and strengthen the capability of developing countries in producing and distributing new, more productive and nutritious crops.

That concludes my remarks and I would be happy to answer any questions.

[The prepared statement of Dr. Ives follows:]

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PREPARED STATEMENT OF CATHERINE L. IVES

ABSTRACT

H.R. 2051, a bill to establish regional plant genome and gene expression research and development centers, and H.R. 2912, a bill to establish a grant program for partnerships between U.S. research organizations and those in developing countries; will contribute, through advances in basic and applied plant research, to increased food security and economic growth in our country and abroad. Fundamental knowledge about the basic biology of plants, and cooperative research strategies, will lay the foundation for addressing food production and nutrition problems around the world. Public sector investment will be required to elucidate the unique features of complex plants, including orphan crops, and the U.S. should be at the forefront of this effort, given the strength of its research community. These proposed programs would contribute to that effort.

Good afternoon Congressman Smith, Congresswoman Johnson, and other members of the committee. My name is Catherine Ives, and I am the Director of the Agricultural Biotechnology Support Project (ABSP) at Michigan State University. Thank you for asking me here today to testify on H.R. 2051, a bill to establish regional plant genome and gene expression research and development centers, and H.R. 2912, a bill to establish a grant program for partnerships between U.S. research organizations and those in developing countries. I commend the committee for proposing these two initiatives. They will contribute, through advancement in basic and applied plant research, to increased food security and economic growth in our country and abroad.

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One may ask why should the U.S. research community invest in programs to elucidate fundamental mechanisms of plant production? First and foremost because history has shown us that technological innovation is essential for human progress. From the domestication of animals and the advent of agriculture to today's advances in biotechnology, people have developed tools for improving public health and nutrition, as well as raising productivity and facilitating learning and communication. However, despite these improvements, there are still today almost a billion people living in absolute poverty and suffering from persistent hunger. Seventy percent of these individuals are farmers—men, women and children—who eke out a living from small plots of poor soils, mainly in tropical environments that are increasingly prone to drought, flood, bushfires, and hurricanes. Crop yields in these areas are stagnant and livestock suffer from chronic parasitic diseases.

While many around the world are still locked in a vicious cycle of hunger and poverty, a revolution in biotechnology is improving the health, well-being and lifestyle of those of us in the developed world. What must be done to harness this revolution to address the food and nutrition needs of the poor? Technological innovations today have a global reach—a breakthrough in one country can be used around the world (the elucidation of the rice genome, for example, is of benefit to the USA and China alike). More public funding, to be spent on creating new partnerships among public institutions, private industry and non-profit organizations, is needed to solve problems of particular interest to the poor. Advances in basic and applied research on orphan commodities (defined as subsistence food commodities or commodities of little interest to the private sector) will contribute to improved lives.

So what are the main challenges in addressing international research and development efforts? There are many including:

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A lack of understanding regarding the importance of agricultural biotechnology amongst policy makers in many countries;

Mistrust and/or inexperience in working with the private sector;

Inexperience in intellectual property and the management of new technologies;

Non-existent or poor regulatory systems;

Poor laboratory and communications infrastructure and;

A small number of trained scientists.

These two bills would, I think, most directly address the last two challenges—improving communication, infrastructure, and networking, and increasing the number of trained scientists through these research partnerships. The small number of trained personnel in developing countries makes the work of the ABSP especially difficult. The development and deployment of biotechnology-derived crops in these countries depends, in part, upon those countries having the appropriate national policies and regulatory structures. Scientists in those countries are called upon to provide technical input into legislation or regulations and are often unprepared or unqualified to do so. The ability of a country's scientists to independently assess new biotechnology-derived crops is vital to the food security and economic prosperity of that country. Developing an increased knowledge of, and experience with, the techniques of modern biotechnology would greatly assist countries in the formulation of scientifically sound policies, legislation and regulations.

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However, I would like to stress that all the challenges I mentioned earlier would benefit, even indirectly, from support to the basic plant sciences and development of new partnerships between scientists from different parts of the world. Fundamental knowledge and understanding of plants, and cooperative research strategies, are the foundation for addressing food production and nutrition problems. Increased basic knowledge about orphan crops, such as cassava and bananas, will require the investment of the public sector and the U.S. should be at the forefront of this effort, given the strength of its research community. These programs would contribute to that effort.

I believe these programs fill an important funding gap in the current research environment. While the U.S. Department of Agriculture (USDA) funds basic research, that effort is primarily focused on crops of national interest. The U.S. Agency for International Development (USAID), on the other hand, is mandated to assist developing countries and provides technical assistance in many areas. However, they do not have a basic research mandate. These programs, aimed at expanding genomics research and applying that knowledge to crops in the developing world, will directly assist the work conducted under the ABSP.

The ABSP, a consortium of public and private sector institutions in the U.S. and around the world, is funded by the USAID, and has worked for the last 10 years to assist developing countries—and developing country scientists—in accessing biotechnology to develop crops that are resistant to insects and disease. This is a comprehensive program that focuses not only on technical training and applied research, but also on helping countries develop national and institutional policies that will permit access to, and deployment of, agricultural biotechnology. Permit me to give two examples of how we have worked to assist countries in improving their agricultural production and increase the health of their citizens. I should note that all of our projects are ongoing, as development of a new cultivated plant, especially one created through the use of modern agricultural biotechnology, takes time as well as government structures that are often lacking in developing countries.

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We have worked extensively with scientists at the Agricultural Genetic Engineering Research Institute (AGERI) outside of Cairo, Egypt. Researchers at MSU and AGERI have developed a specific variety of potato, used by small farmers for domestic consumption, with resistance to Potato Tuber Moth, an important insect pest worldwide, primarily in tropical and subtropical areas (although there have been outbreaks in California, Texas and New Mexico). The current method of controlling the insect relies primarily on multiple applications of insecticides in the field, and 3–5 direct spraying of insecticide on the potatoes during storage. Without insecticide, losses can be up to 100% of stored potatoes. ABSP has tested these new types of potatoes in field trials in the U.S. and Egypt, and will shortly be testing them in South Africa. Initial results have demonstrated greatly increased moth resistance in the field, and in storage for 2–3 months. We are currently working with Egyptian regulatory authorities to gather the appropriate environmental and health data to register these potatoes for commercial use. This will likely take several more years and require new partnership with local industry and government to ensure the optimal delivery of the potatoes to small farmers.

However, as mentioned, the ABSP is an integrated development program, and it is not enough to expect that research results will magically transport themselves onto a small farmer's field. National and institutional policies have to be amended, government and/or private sectors engaged, and farmers and consumers adequately informed. With these objectives, the ABSP has given assistance for the development of intellectual property policies at the institutional and national level. We have trained scientists in the new field of intellectual property management, and linked scientists and legislators together. We also recognize that the regulatory structures in many developing countries are lacking. Therefore, in Egypt, we have and are continuing to provide training in the development of biosafety systems, including assistance in drafting national guidelines.

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Another ABSP initiative that has recently begun is a collaboration with the TATA Energy Research Institute (TERI) of India and Monsanto Company to develop and adopt enhanced oil from mustard seed. This collaboration, known as the "golden mustard" project, has the potential of helping hundreds of thousands of children suffering from vitamin A deficiencies, particularly in northern and eastern India, where mustard oil is commonly used for food preparation and cooking. Recent estimates reveal that more than 18% of the children in India suffer some level of Vitamin A deficiency. The World Health Organization estimates approximately 250 million people suffer significant illnesses, including vision impairment, inability to absorb proteins and nutrients, and reduced immune function because of vitamin A deficiency.

Monsanto has been working since the mid-1990s to enhance the carotenoid levels of oilseed crops with a focus on the accumulation of beta-carotene—the precursor to Vitamin A—in the seed of canola (also known as oilseed rape). As a result, researchers have been able to achieve concentrations of beta-carotene in oil from crushed canola seed greater than currently available in any other oil or vegetable. In March 1999, Monsanto announced it would share at no cost this gene transfer technology to developing countries. While this collaborative project is less than a year old, the basic research conducted by Monsanto to elucidate the biochemical pathway of carotenoid biosynthesis was crucial to adapting this technology for use in a crop of importance to a developing country.

As I mentioned earlier, we should not expect that funding research programs alone would result in improved technologies available to the poor in developing countries. It will be important for NSF to develop strong linkages and information sharing procedures with USAID and USDA's Foreign Agricultural Service to prevent duplication of effort and instead provide synergies with existing projects and programs. Perhaps this would involve joint meetings, participation in review panels, and joint priority setting. Progress made in one area of research and development should be available to build upon by other funding agencies whose role is adaptive research and technology transfer. It should not be NSF's role to support the development and transfer of specific technologies, but rather to promote the generation of knowledge and innovation. That said, these programs would fill an important gap in the federal research system, and provide those agencies and organizations mandated to transfer technology with new tools in their arsenal.

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Let me conclude by saying that the National Science Foundation, through its support of basic research in plant biotechnology, plays a critical role in helping ALL countries increase food production and improve food quality, and in promoting a knowledge-based economy. Research centers, and partnerships between scientists, will improve our understanding of more complex plants, and strengthen the capability of developing countries in producing and distributing new, more productive and nutritious crops.

That concludes my remarks and I'd be happy to answer any questions. Thank you.

BIOGRAPHY FOR CATHERINE L. IVES

Address: 319 Agriculture Hall, Michigan State University, East Lansing, MI 48824; Tel: 617–718–0480; Fax: 775–201–8727; E-mail: ivesc@msu.edu

Experience

1996–Present   Michigan State University, East Lansing, MI

Director, Agricultural Biotechnology Support Project
[http://www.iia.msu.edu/absp]

Led and managed an international consortium of eleven public and private sector research projects in six countries

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Designed and successfully secured research project funding, with a projected value of nearly $8 million, from public and private sources

Coordinated the activities of scientists, administrators, technology transfer and regulatory personnel

Initiated and implemented work plans and budgets

Supervised a core administrative team of five professionals

Negotiated and expedited technology transfer agreements (MTAs, Research/Option Agreements) between public and private sector institutions in the U.S. and overseas

Organized, conducted, and invited speaker in workshops and conferences on biotechnology and related policy issues, such as intellectual property rights and regulatory issues

Requested commentator for print, radio and TV interviews in USA and overseas

1993–1996   U.S. Agency for International Development (USAID), Washington, DC

Biotechnology and Technology Transfer Specialist

Member of USAID's Intellectual Property Protection Working Group

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Liaison between USAID and the White House National Science and Technology Council on biotechnology research

Performed site assessments on biotechnology research and infrastructure for Indonesia, Egypt, South Africa and the Philippines

Member of technical advisory panel evaluating USAID-funded research projects in agriculture and medicine

1992–1993 U.S. House of Representatives, Washington, DC

Congressional Fellow in Office of Congressman Edward J. Markey

Proposed and drafted legislation, wrote policy briefs, press releases and floorspeeches

Coordinated meetings with constituents

Advised Congressman on scientific (NASA, NSF, NIH, USDA), governmental (Bayh-Dole Act) and educational policy

1990–1992 New England Biolabs, Beverly, MA

Post-doctoral scientist

Researched the molecular characterization of restriction enzymes, using cloning, DNA sequencing, PCR and biomolecular analysis

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Supervision of one technician and three students

Education

1983–1990 University of North Carolina, Chapel Hill, NC

Ph.D., Department of Microbiology and Immunology, UNC Medical School. Dissertation Title: "Gene Amplification and Associated Tetracycline Resistance in *Bacillus subtifs"*

1979–1983 Virginia Tech, Blacksburg, VA

BSc., Biology, Summa cum laude, in honors

Other Achievements

2001, Young Professional Award, Association for International Agriculture and Rural Development
2000, Certificate from University of North Carolina, Kenan School of Business, Executive Education Program, *"Managing Agribusiness in a Global Economy"*

1999, Certificate from University of Michigan Business School, Executive Education Program, *"Management II: A Mid-Managers Development Program"*
1993, Certificate from the Association of University Technology Managers, *"Basic Licensing Course"*
1988–1989, Fulbright Fellowship to study microbial biochemistry at the University of Glasgow, Glasgow, UK

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Membership in numerous professional associations: Association of University Technology Managers, American Society for Microbiology, American Association for the Advancement of Science

Interests

Co-Editor, Michigan Biotechnology Association—Quarterly (1999–2000)

Domestic and International Travel, Reading, Sports, Cooking, Music, Photography

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Chairman **SMITH.** Thank you. Dr. Arntzen.

STATEMENT OF DR. CHARLES J. ARNTZEN, DISTINGUISHED PROFESSOR OF PLANT BIOLOGY, ARIZONA STATE UNIVERSITY

Dr. **ARNTZEN** The overhead on, please. Mr. Chairman, and, Ranking Member Johnson, thank you very much for the invitation to join you here today. I should also say thank you, Mr. Chairman, for the Seeds of Opportunity issue. I have used it in teaching and it is really a great summary of what is going on in agricultural biotechnology.

Drs. Clutter and Ives have really touched on many of the key points that are to be brought up, and you also had an excellent background briefing document here. So rather than spending a lot of time repeating things, let me go to a case study on plant-based vaccines that both you and Congressman Johnson have mentioned.

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My colleagues and I have spent quite a lot of time developing the technology, really based upon the scientific studies that have been done in the past, to take a gene from a pathogenic organism, like enterotoxic E. coli or various viruses that cause human disease, and use the sophisticated techniques of agricultural biotechnology to move that gene into a plant and into an individual cell and regenerate those plants back so that now every cell of that plant has a new gene that is capable of producing a protein from the pathogen.

We have grown those plants up and they, for our studies that have been done to date, it is primarily potatoes or tomatoes. On your lower left is a picture of the head nurse in Baltimore at the NIH, one of the NIH national vaccine testing centers. First—this was the first time she had every brought her potato peeler to work. We had driven down with potatoes from the Cornell University, and they were peeled, diced. And the young man on the right is—with the plastic bag is—these are cut up, whole, uncooked potatoes, and he is getting his vaccination.

To our delight, we have had successful human clinical trials, approved in advance by the Food and Drug Administration, in every case, for two different prototype vaccines for diarrhea, and one for Hepatitis B. We have seen an appropriate and excitingly active human immune response.

We are not going to get kids in India or Africa or South America, or even the United States to eat raw potatoes. I understand that. So over the last few years, my colleagues and I have focused on how we can take this technology and use simple approaches, particularly food processing, to reduce a potato or a tomato into something for which we can get controlled dosages and we could have controlled delivery.

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This slide summarizes an experiment we did last summer in the greenhouses on the campus of Cornell University. We had 30 tomato plants. Once a week, we would harvest tomatoes, wash them, and bring them down the street to the Cornell Food Science Department, where students are trained in the technologies used in the food industry. The first thing was take the washed tomatoes, grind them up in a big blender, pour them out in cold trays, and slide them into a freeze drier. Two-and-a-half days later, we were able to get from 30 tomato plants, 4,000 doses of an oral Hepatitis B vaccine.

We have in the process been able to look at various aspects of importance for vaccines, such as the shelf life of the material. Shown in the lower left here is freeze-dried tomato juice. We can start thinking about the cost of processing to get a unit dose. And bioburden is just contamination. When making sure that you have no contamination by human pathogens. But since it is a food product, that is really easy.

On the right-hand side of the slide is some technical data, but it simply says our—in this case, a Hepatitis B antigen or the vaccine actually is highest level in the breaker stage of tomatoes, which is nice for food processing. So we can begin to think about the cost actually now of producing materials. This is right from the USDA web site. And the column labeled processing in the center right, shows the U.S. acreage in processing tomatoes. When you get down to the bottom, the average value at the farmer's gate is about $54 a ton for tomatoes. That is fully loaded U.S. costs, which comes out to about 5 cents per kilo. Based upon the amount of vaccine we were producing last year, that gets the cost of a Hepatitis B oral vaccine down to a quarter of a cent. I would remind you if you have had your Hep B vaccines in the United States recently, it is $75 a shot and you need three shots.

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About 40 to 50 percent of the world's population doesn't get the very effective vaccine we have available today and it is largely a cost issue. And it is also a problem of needle delivery.

So in conclusion, I would say we have, at the present time, a new technology, a technology we believe is transferable to developing countries, but a technology that is also going to be of importance for new vaccines for different types of infectious diseases here in the first world, in the United States, Europe, etcetera. Thank you very much.

[The prepared statement of Dr. Arntzen follows:]

PREPARED STATEMENT OF CHARLES J. ARNTZEN

Thank you, Mr. Chairman, for the invitation to appear today before the Subcommittee on Research. My name is Charles Arntzen. I am the Founding Director of the Arizona Biomedical Institute (AzBio) at Arizona State University. I am also the president emeritus of the nation's largest not-for-profit research institute devoted to the study of plants and associated organisms—the Boyce Thompson Institute for Plant Research, which is located on the campus of Cornell University.

I will try to make three major points in my testimony:

1. Application of recombinant DNA technology (genetic engineering) to plants has the potential to create many new products that are designed to improve human health.

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2. In addition to American producers and consumers, people in the developing world will be major beneficiaries of many of the new biotechnology-derived products.

3. The human health benefit of new plant biotechnology products may be delayed because advancement from prototype to product for new plant-based pharmaceuticals is hindered by two factors: an incomplete information base relating to regulation of gene expression and cellular accumulation/stability of foreign proteins in commercially viable crops (*i.e.*, not model organisms), and an emerging but as yet inadequate regulatory framework for new product introduction that must be accompanied by public education efforts (including companion efforts of relevance to countries outside the U.S.).

The opinions I provide are based upon my background experience. I was born on a family farm in Minnesota at a time when my father still planted some crops using horses rather than mechanized equipment. I grew up when new technology was greatly increasing crop yields and farm profitability. My college education was at land grant universities, which are historically centers of technological innovation related to plant biology and related outreach education (extension programs). My employment with USDA, academia and industry (DuPont) has been related to plant biology and biotechnology. I want to express my appreciation to the Committee for its support of scientific research that has given my colleagues and I in the plant sciences the ability to make discoveries leading to new crops of wide benefit to humankind.

In the last two-to-three decades, scientific research has spawned a new wave of technology that is having a global impact in both medicine and agriculture. Highly sophisticated methods are now available to analyze DNA sequences, which are the basis of all genetic traits, and the regulation of DNA expression in different cells and tissues. The results are dramatically influencing our understanding of basic principles of biological development and of factors which define the differences between healthy and diseased conditions in plants, animals and humans. And, they are creating opportunities for novel product development.

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To a large extent, our genetic research tools for plant biology are derived from medical research. The human genome project is one striking example. The needs for increased speed of DNA sequencing of human genes have lead to remarkably rapid, and increasingly simple methods for analyzing DNA and the functioning of genes in all organisms—from man to maize. There are already dramatic results from application of these new analytic tools to crop improvement research. Regional crop breeding stations, which previously lacked sophisticated biological style laboratories, are now adding DNA diagnostic tools that are adapted from those being introduced into hospital laboratories. Crop geneticists now use DNA marker-assisted breeding methods to speed the creation of new varieties with superior traits. The speed at which new basic scientific research findings are translated into improved varieties of crops is increasingly rapid, and is a key factor to maintaining United States competitiveness in global agriculture.

A very important aspect of our current plant biotechnology is the fact that it is now possible to move genes among different species. Nearly twenty years ago, a few pioneers in crop genetics began experimenting with recombinant DNA technology. In 1983, the first success in DNA transfer into plants was reported, and a new technique was added to the crop breeder's "tool box". The concept of moving DNA was first developed by microbiologists for transfer of DNA (genes) into bacteria. The approach rapidly gained importance as a tool for pharmaceutical development and was a driving force for creation of American dominance in the biotechnology industry.

As was documented in the background materials for this hearing, the creation of transgenic plants (genetically modified or GM crops) increasingly have an important impact on agricultural profitability for commodity crops in the U.S. It is important to note what factors were the most important determinants of the agricultural research agenda in the U.S. in the early 1980's as recombinant DNA techniques were being developed for crop breeding. It was a period of increasing crop subsidy costs and public concern about excessive pesticide use and cropland degradation and erosion. It is therefore not surprising that the first agricultural products of recombinant DNA technology were insect-resistance seeds (Bt-corn, Bt-cotton as examples that provide farmers a means to reduce use of chemical insecticides), and crops tolerant to post emergence herbicides (which aide farmers in conservation tillage; Round-up Ready Soybeans, for example). These products have at least partially met their objectives if we judge by farm sales of the new seeds. They went through multiple years of development and testing before product launch. This timeframe is not surprising. It is a characteristic of seed improvement for food, fiber or feed crops that eight to fifteen years of time lag occurs between the first product concept and its availability to producers.

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Because there are long periods of research and development that precede the introduction of any new crop involving genetic improvement, it is of value to examine the current "pipeline" to estimate the value and impact of new products, and to determine if they will enter commercial distribution in a timely manner. It seems certain that significant improvements in "production traits" (insect, herbicide, disease, and drought tolerance) will be available over the next decade. Background information for this committee hearing has discussed some of these traits and their importance; this is a very significant justification for expanded government investment in basic studies of plant genomics. Because the background information is already before you, I will focus my testimony on the dramatic potential of plant genetic engineering in areas other than production traits. Specifically, I will focus specifically on genetically modified crops, which are designed to directly be used as human pharmaceuticals. The discussion will emphasize a "case study" example of plant-based oral vaccines.

Vaccines are one of the great success stories of modern medicine. Ten of millions of lives have been saved by the successful eradication of smallpox from the globe, the nearly complete eradication of polio, and the great reduction in some other infectious diseases. At least forty new vaccines are under currently under evaluation by U.S. regulatory authorities; nearly all of these have resulted from the use of new tools of biotechnology. However, the likely success of immunologists in identifying new vaccine candidates has posed a problem for public health officials in the World Health Organization (WHO). They are concerned about the potential cost of "high-tech recombinant DNA" vaccines, their availability to developing countries where infectious diseases are the greatest threat, and availability of the vaccines in a convenient form for universal use. With respect to the latter issue, there has been a general call for more oral vaccines and new products that do not need costly refrigeration.

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I have documented the need for improved vaccines in an article published in the journal *Nature Medicine* ("Pharmaceutical foodstuffs—Oral immunization with transgenic plants," *Nature Medicine*, Vol. 4, pages 502–503; *Vaccine Supplement* issue.) In this article, I document the need to develop vaccines for enteric diseases, recognizing that each year diarrhea kills about two and one-half million children under the age of five. Most of these deaths are in the developing world. Since these children and their parents are at the low end of the economic scale, little industrial research has targeted new vaccines for this public health segment. To respond to this unmet need, my colleagues and I have designed a new approach to the creation of modern, oral vaccines. We have genetically modified plants in a way that each cell of the new plants has the capacity to accumulate "subunit vaccines" to prevent diarrheal disease. (Subunit vaccines are comprised of only one or a few proteins of the pathogen that causes disease; these proteins are non-infectious, but are capable of stimulating our immune system to give a protective response before we are exposed to the actual pathogen.) The methods we,have employed involve addition of a new gene to all cells in a plant, wherein this gene causes plant cells to produce a protein that holds the "fingerprint" of a human pathogen (virus or bacteria). Furthermore, subsequent generations of the plant retain this protein production capability because the genes have become part of the plant "genome" (or genetic identity). The protein(s) by itself is harmless, but when plants containing it were provided as food to test animals, it acted as a vaccine dose and an immune response occurred. In the absence of disease, the animals' immune system was triggered to mount a defense against the actual disease-causing agent. (Our pre-clinical studies with animals, although intended as a component of vaccine development for humans, have revealed a new strategy for vaccination of animals. Plant-based vaccines for farm animals may provide a convenient and less costly means of preventing disease and thereby a safer food supply. For pets, the strategy could provide a less traumatic immunization.)

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Since 1997, my colleagues and I have collaborated with two leading U.S. medical schools to determine if our plant-based vaccines are effective in humans. We requested and received approval from the U.S. Food and Drug Administration (FDA) to conduct human clinical trials in which volunteers consumed our genetically engineered vaccine-containing food. The results of three studies are now in hand. In every case, we have found a human immune response when volunteers simply ate raw potatoes that were engineered to contain a vaccine. We recognize that our results are, as yet, preliminary and that further studies with human volunteers are needed to determine proper dosages of plant-based vaccines. In particular, we know we must work out protocols by which subunit vaccines can be produced in edible parts of plant species that are amenable to cost-effective processing to yield a processed end product. We need such material to deal with issues such as packaging for uniform dose delivery, storage for shipment (especially to remote parts of the globe where refrigeration is problematic), and product quality assurance (measured by standardized protocols).

I have frequently been asked when a plant-based, oral vaccine will be available from doctors or pharmacists. (The questions are often accompanied by a statement such as "my kids can't wait for an alternative to needles" or "this would be wonderful for immunizing children in poor countries.") I have to respond that the situation is complex. First, our work to date has used uncooked potatoes as the vaccine delivery tool. Second, we recognize that vaccines must be regulated medical products and we need to make define ways in which plant materials meet existing product standards. Lastly, I acknowledge that some members of the general public (especially in Europe) have demonstrated resistance to GM-crops (Genetically Modified crops). Vociferous members of this critical community do not differentiate between any classes of plants, and I recognized that these groups could interfere with the introduction of plants that would serve as vaccine "manufacturing systems" and thereby add an unknown period of delay in the introduction of new products. As a result, I must therefore say that I can not make a firm prediction of when plant-based vaccines will be available for children in the U.S., Bangladesh, Vietnam or anywhere else in the world. In the following material, I'd like to touch on issues that create uncertainty and relate them to NSF's role in funding research.

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We know that raw spuds won't be accepted by infants in Asia (or anywhere else, probably), and are not the vaccine delivery system of choice. But, we chose potatoes as an experimental system since it is an edible food in a commercial crop species, and since there was an adequate science information base on ways to cause foreign proteins to accumulate in tubers. In addition, it was "fast," meaning that we could put a new gene into a potato cell and regenerate plants that would yield a pot full of potatoes in about four months, and be conducting pre-clinical or clinical trials 'a few weeks later. When a scientist such as myself is doing research with government funding on a "three year grant" we need to get data in a timely manner!

We have also explored the potential use of other crops for vaccine delivery. Bananas, for example, have great potential for developing countries. They are grown in almost all tropical or subtropical countries, the fruit is eaten uncooked by infants and adults (avoiding vaccine destruction by heating), and the fruit can easily be processed into a puree (baby food) or dried "chips" for delivery of uniform doses. From a grant-getting standpoint, however, bananas are difficult since it takes at three-four years from the time a gene is inserted into a banana cell until the genetically modified fruit can be harvested (T.R. Ganapathi, N.S. Higgs, P.J. Balint-Kurti, C.J. Arntzen, G.D May, J.M. Van Eck. 2001. *Plant Cell Reports* 20:157–162). And, even more importantly, there has been almost no genomic research or analyses of genetic regulation of protein accumulation in this crop (largely because it is not grown by farmers in the developed world but not in the "first world").

To date, there has been understandable hesitancy by established vaccine manufacturers to explore the use of genetically engineered plants as a "manufacturing/delivery" system for a new class of oral vaccines. Several factors lie behind this hesitancy, including: differences between the importance of vaccine manufacturing and delivery costs in the developed vs. the developing world (with costs being much more important in the developing world), an uncertain regulatory environment related to pharmaceuticals produced in plants, and evidence of public uncertainty related to "genetically modified food stuffs that creates the perception of risk by potential investors in new technology. In addition, there is an inadequate information base related to fundamental aspects of plant cell biology and gene expression in the commercial cultivars of crops (as opposed to model "laboratory varieties") that create uncertainties in our ability to project the cost to develop additional, new plant-based vaccine candidates. All of these factors, which cause existing large companies to have hesitancy to enter a new product arena, can be solved by a combined effort to do research where crucial information gaps exist. However, this must also be coupled with educational programs to prepare the general public for a new generation of genetically engineered crops that can be very important tools for public health and individual patient treatment.

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In conclusion, I would like to emphasize several key points. Molecular genetics using recombinant DNA is a new and powerful tool for plant biologists and crop improvement specialists, but new products created with this tool take many years to progress from the research bench through periods of extensive testing before product introduction. The very few products now available, known to the public as genetically modified organisms, represent only a fraction of the potential pipeline. The next generation of products will increasingly have immediate uses that relate to human therapeutics, vaccines and other macromolecular drugs. This is a new area of fundamental science in the U.S. and the world, and a new area of commercial opportunity in which the U.S. can extend its dominance in biotechnology while providing great benefit to health programs on a global basis. However, the new area is not yet embedded in existing corporate structures and needs to be cultivated to succeed in a timely manner. There is an urgent need to promote multidisciplinary scientific efforts that will ensure that this new area of science is successful. Such efforts must include outreach education (including bioethics and social responsibility in use of new technology). The efforts need to include participation by representatives of developing countries so that leadership in the evaluation of new technology related to plant-based pharmaceuticals will become embedded in the government programs of emerging countries. And, the efforts need to link academic science to the commercial sector in the U.S. and the world.

The National Academy of Sciences offers many features upon which a new research effort can flourish to ensure the success of plant-based production of new health care products. The NSF has been successful in creating "Centers" that promote multidisciplinary research, which is needed to link scientists in plant biology to immunology to product development. The NSF has the process to conduct per review of scientific proposals to identify "Centers" that are based upon very sound science. And, the NSF has experience in educational programs that are essential for the success of an emerging area of plant-based macromolecular drug production, involving international dimensions, bioethics, and education of the general public about the importance of this new technology for a global community.

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This Distinguished Committee is providing a valuable service to the public by inviting independent scientists who conduct research using biotechnology to provide information that could assist the Committee and the general public in making informed decisions related to the value of new research programs and new products, including those involving recombinant DNA technology. This information will allow enlightened risk-benefit analyses. I hope I have conveyed to you today the excitement I feel for increased NSF funding to create "Centers" that will ensure the progression of basic plant biology to human and animal health products of global importance!

BIOGRAPHY FOR CHARLES J. ARNTZEN

Charles J. Arntzen is the Florence Ely Nelson Presidential Chair in Plant Biology, Arizona State University, Tempe, Arizona and the Founding Director of the ASU Biomedical Institute. He also serves as the President/CEO Emeritus of the Boyce Thompson Institute for Plant Research, Inc., a not-for-profit corporation which is affiliated with Cornell University.

Dr. Arntzen held previous faculty positions at the University of Illinois and Michigan State University, and visiting professorships in the Laboratoire de Photosynthese du CNRS in France, the Department of Applied Mathematics in Canberra, Australia, and the Academia Sinica in Beijing, China. He also served as a research scientist with the USDA and as the Director of the Michigan State University-Plant Research Laboratory funded by the Department of Energy. In 1984 he joined the DuPont Company in Wilmington, Delaware as Director of Plant Science and Microbiology and was later promoted to Director of Biotechnology in the Agricultural Products Department. In 1988 he was appointed Dean and Deputy Chancellor for Agriculture of Texas A&M University, and subsequently served as Director of the University's Plant Biotechnology Program of the Institute of Biosciences and Technology. Dr. Arntzen served as President and CEO of Boyce Thompson Institute from 1995 to 2000.

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Dr. Arntzen was elected to the U.S. National Academy of Sciences in 1983 and to the National Academy of Sciences in India the following year. He is a fellow of The American Association for the Advancement of Science, received the Award for Superior Service from the U.S. Department of Agriculture for international project leadership in India, and received the degree of Doctor of Science honoris causa from Purdue University in 1997. He has been a member of numerous national and international committees that serve general scientific interests. He was a member of the Executive Committee of the Board of Governors of the

University of Chicago for the Argonne National Laboratory and served as chairperson of their Science and Technology Advisory Committee. He served as chairman of the National Biotechnology Policy Board of the National Institutes of Health, as chairman of the National Research Council's Committee on Biobased Industrial Products, and on the National Research Council's Committee on Space Biology and Medicine. He served for eight years on the Editorial Board of *SCIENCE*.

Dr. Arntzen served until 1998 on the Board of Directors of DeKalb Genetics, Inc. and is currently on the Board of Directors of Third Wave Agbio, Inc., on the Advisory Board of the Burrill and Company's Agbio Capital Fund and The Nutraceuticals Fund, and on Scientific Advisory Boards for Sumitomo Chemical Company, Ltd., Phytera, Inc., and Valigen, Inc. He also serves as a Distinguished Advisor on the Council for Biotechnology.

Dr. Arntzen's primary research interests are in plant molecular biology and protein engineering, as well as the utilization of plant biotechnology for enhancement of food quality and value, for expression of pharmacologically active products in transgenic plants, and for overcoming health and agricultural constraints in the developing world. He has been recognized as a pioneer in the development of "edible vaccines" which are particularly targeted for health improvement in developing countries.

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Dr. Arntzen received his Bachelor's and Master's degrees from the University of Minnesota and his Ph.D. from Purdue University. He is married and the father of one son, an attorney with the Baker and Botts law firm in Houston, Texas.

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Chairman **SMITH.** Thank you. Dr. Paarlberg.

STATEMENT OF DR. ROBERT PAARLBERG, PROFESSOR OF POLITICAL SCIENCE, WELLESLEY COLLEGE

Dr. **PAARLBERG.** First, I would like to thank Chairman Smith and Ranking Member Johnson for scheduling these hearings. And I would like to thank Chairman Smith for his Seeds of Opportunity report, which I have used profitably and even cited in a recent publication.

To introduce myself, I am an independent scholar who has recently conducted research on policies toward genetically modified, or GM, crops in developing countries. And one central challenge in my research has been to understand why the planting of GM crops has not yet spread in any significant way to the developing world.

We are all aware that GM crops have been grown widely and successfully for the last 5 or 6 years in the United States, in Argentina, and in Canada. We are all aware that in Europe and Japan farmers are not yet growing GM crops. Regulators there gave GM crops official approval on biosafety and food safety grounds, but because of consumer resistance in Europe and Japan, farmers have not yet used these crops.

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But what explains the failure of this new technology so far to spread in any significant way into the developing world? Today, there are no countries anywhere in Africa, other than the government of South Africa—no countries that allow the planting of any GM crops. There have been no developing countries anywhere in Asia that allow any GM crops to be grown, other than China, and more recently, Indonesia. And China and Indonesia mostly allow an industrial crop, Bt cotton, to be grown. In South and in Central America, the only country, other than Argentina, that has planted a significant area to GM crops, is Brazil, and farmers there are planting Roundup Ready soybeans, even though it is not yet legal for them to do so.

So this isn't much of a record yet of technology dissemination into the developing world. As of last year, 98 percent of all the world's GM crop acreage was still confined to just three countries, the United States, Argentina, and Canada, the same three countries that launched this GM crop revolution 5 or 6 years ago.

Over the last 2 years, I have conducted field research to try to understand why more governments in the developing world have not approved the planting of GM crops, and at least three reasons have emerged. First, governments in some poor countries, especially in Africa, have not yet approved GM crops because of their weak capacity to give those crops a case-by-case screening for biological safety. Many regulators in poor countries in Africa just haven't the technical or the financial capacity to provide the meticulous biosafety screening that donor agencies and international environmental NGOs now insist upon. So these regulators err on the side of offering no biosafety approvals at all for any GM crops.

Second, in some developing countries, the technical capacity to regulate for biosafety may be strong, but approvals are being delayed because of political pressures from local and international anti-GM activist groups. In Brazil, for example, regulatory authorities tried to approve Roundup Ready Soybeans in 1998, but were blocked from doing so when a lawsuit was filed by local and European-based anti-GM activists. And in India, regulatory authorities are competent, and yet they have not been able to give final approval to Bt cotton despite several years of highly successful field trial results, in part because of intense opposition there from local and European-based NGOs.

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A third reason—some developing countries are also holding back on approving GM crops because of uncertainties regarding consumer acceptance of GM products in international commodity markets. These various institutional and political and commercial explanations for this slow spread of GM crops to poor countries raise a question here for research policy. How can such barriers as these be overcome through larger NSF investments in crop biotechnology research?

Well, I strongly support the legislation that is before this Committee because I am convinced that only by funding more crop biotechnology research through the public sector can we overcome some of the political inhibitions that are now keeping useful applications of modern biotechnology out of the hands of poor farmers in poor countries.

It is important to realize that crop technologies that are created in the private sector and sold through private multinational seed companies are often difficult for poor countries to accept on political grounds. In much of the developing world, policy precaution regarding GM seeds has been partly an outgrowth of long-standing local resistance to the presumed power of foreign multinational corporations.

Even before the advent of GM crops, the presence of giant, U.S.-based seed and agribusiness companies always generated suspicion and anxiety in poor countries. The fact that most GM seeds have recently been developed in corporate laboratories and offered to the developing world as commercial products by large multinational business firms has, at times, tended to stigmatize the technology locally, and make approvals more difficult to secure.

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One reason, in Kenya, that the National Biosafety Committee has not yet given final approval to a virus-resistant sweet potato that has performed well, is that the technology originally came from the Monsanto Company. One reason that it has been hard in Brazil to get approval for Roundup Ready Soybeans is that this is a Monsanto product. One reason in India that it has not been possible yet to get a final release of Bt cotton is that, once again, this is a Monsanto product.

So it is clearly time to rebalance agribiotechnology research away from the private sector and back into the public sector. I see the two proposed pieces of legislation before this Committee as a good way to pursue that objective. The small proposed increase in NSF funding that is envisioned here certainly won't remove all of the impediments that are currently standing between modern applications of crop biotechnology and poor farmers and poor countries, but it is a useful start. So I salute the authors of both bills for their leadership. Thank you very much.

[The prepared statement of Dr. Paarlberg follows:]

PREPARED STATEMENT OF ROBERT PAARLBERG

First I would like to thank Chairman Nick Smith and Ranking Member Eddie Bernice Johnson for scheduling these hearings on agribiotechnology research, and for giving me an opportunity to make a statement. To introduce myself, I am an independent scholar who has recently conducted research for the International Food Policy Research Institute (IFPRI) on policies toward modern agribiotechnology, and especially genetically modified (GM) crops, in developing countries. One central challenge in my research has been to understand why the planting of GM crops has not yet spread in any significant way to the developing world. This is the question I would like to address today in my statement.

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We are all aware that genetically modified crops (such as glyphosate tolerant soybeans or Bt corn and cotton) have been grown widely and successfully by farmers in the United States, Canada, and Argentina for the past five or six years. Farmers have been attracted to these crops because they save production costs by allowing weeds and insects to be controlled through use of fewer, less toxic, or less persistent chemical herbicides and insecticides.

We are also aware that farmers in Europe and Japan have decided not to plant GM crops. Government regulators there initially gave GM crops complete approval on both on food safety and biosafety grounds, but because of significant consumer resistance farmers have so far decided not to use this technology. In Europe and Japan because most farmers are prosperous and food supplies are abundant, it is perhaps no great loss that this new technology is meeting a hesitant reception.

But what explains the failure of this new technology to spread into the developing world? There are today no countries anywhere in Africa growing any GM crops commercially other than the one nation of South Africa, which has allowed the planting of Bt cotton and corn. There are no developing countries anywhere in Asia growing GM crops other than China, which has since 1997 been growing Bt cotton, and Indonesia which is just now starting to grow some Bt cotton as well. In South or Central America, the only country other than Argentina that has planted a significant area to GM crops is Brazil, yet here the farmers planting GM crops have been doing so illegally, in defiance of a Brazilian federal court order.

This failure of the GM crop revolution to spread more widely into the developing world is surprising. As of last year, 98 percent of all the world's GM crop acreage was still confined to just three countries—the United States, Argentina, and Canada—the same three countries that originally launched the GM crop revolution 5 years ago.

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One problem in the developing world has been a shortage of research on the basic tropical food crops grown by poor people in these countries. The private companies that have led so far in GM crop research feel little commercial incentive to invest shareholder funds in improved varieties of cassava, millet, or cowpea. Yet this can't be a full explanation, because many poor farmers in the tropics do grow crops such as corn and cotton, and attractive GM varieties of such crops are now readily available.

In the last two years I have conducted field research on this question of why GM crops have not spread more quickly in the developing world. My complete findings are published in a new book available just this month from the Johns Hopkins University Press.(see footnote 1) If I may summarize these findings very briefly, I find that a mix of at least three different factors has so far prevented poor countries from embracing GM crops:

1. Governments in many poor countries (especially in Africa) have not yet approved GM crops for use by farmers because of their weak capacity to give those crops a case-by-case screening for biological safety.

Poor countries seeking productive new technologies have traditionally paid only marginal attention to the issue of biological safety, but in the case of GM crops foreign assistance agencies (including USAID), international environmental organizations (such as UNEP), and countless environmental NGOs have been telling biosafety regulators in poor countries that they must be just as careful as regulators in rich countries. Unfortunately, most regulators in poor countries haven't the technical, financial, or infrastructural capacity to measure up to such high standards, so they are erring on the side of giving no approvals for any GM crops at all.

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2. In some developing countries the technical capacity to regulate for biosafety is strong, but approvals for GM crops have been delayed under political pressures from local and international anti-GM activist groups.

In Brazil, regulatory authorities wanted to approve Roundup Ready soybeans in 1998, but were blocked from doing so when a lawsuit filed by two anti-GM activist groups (a local consumer protection organization joined by the Brazilian office of Greenpeace) challenged the authority of Brazil's national biosafety committee to make an approval decision on constitutional grounds. Three years have now passed and this legal challenge has still not been resolved. In the meantime it remains illegal for farmers to plant any GM crops in Brazil.

In India, competent national regulatory authorities have not yet given final approval to Bt cotton despite several years of highly promising field trial results, in part because of intense opposition from local and European-based NGOs. Anti-GM activist groups have intimidated regulators by filing public interest litigations, by making inflammatory but erroneous charges about terminator genes or the alleged inability of farmers to save and reuse GM seeds, and by staging media events such as illegal invasions of field trial plots to uproot and burn GM cotton plants.

3. Uncertainty regarding consumer acceptance of GM products in international markets.

Government officials in some developing countries which export commodities are now hesitate to approve GM crops for fear of losing export markets. They worry not only about reduced export sales to Europe and Japan, where consumers have an aversion to GM foods, but also loss of sales to other developing countries, some of which have officially announced themselves—in response to NGO pressures—as "GM-free."

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If these are the most fundamental reasons why GM crops have not yet spread in any significant way into the developing world, then what can we hope to gain from the larger public investments in crop biotechnology research here in the United States that are envisioned in the legislation before this committee?

I strongly support the legislation before this committee, because I am convinced that only by funding more crop biotechnology research through the public sector can we overcome some of the political inhibitions that are now keeping useful applications of modern biotechnology away from poor farmers in poor countries. Relying on the private sector does not work for this purpose, for several reasons.

First, the private sector does not have enough incentive to conduct research on poor people's crops, as noted earlier.

Second, new GM crop technologies when created by private companies tend to be encumbered by privately held intellectual property rights, which can restrict technology transfer to poor farmers in poor countries.

Third, GM crop technologies created in the private sector and offered for sale by private multinational seed companies are often more difficult for poor countries to accept politically.

In much of the developing world, resistance to GM seeds is in part an outgrowth of local resistance to the presumed power of foreign multinational corporations. Even before the advent of GM crops, the presence of giant U.S.-based multinational seed and agribusiness companies always generated suspicion and anxiety in poor countries, especially among those on the political left and among -anti-corporate NGOs. The fact that most GM seeds have recently been offered to the developing world as commercial products by large multinational business firms has helped stigmatize the technology.

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If at the outset more GM crops had been developed using philanthropic or public sector resources, rather than corporate resources, and if more of the intellectual property rights had been placed in the public domain, and if the focus had been on improved varieties of tropical subsistence crops such as cassava, sorghum, or cowpea, rather than on commercial crops grown mostly by prosperous temperate zone farmers (such as soybeans), less political or ideological resistance to this technology would have grown up in the first place.

In trying to steer the modern "gene" revolution toward helping poor farmers in poor countries we should take a lesson from the justifiably celebrated "green" revolution of four decades ago. When the starving countries of Asia needed improved wheat and rice seeds in the 1960s and 1970s nobody waited for private companies to take the lead—and it is a good thing because they never did. The job had to be financed instead by private philanthropic foundations (like the Rockefeller Foundation), plus public sector donor governments (especially USAID) and international financial institutions (like the World Bank). This non-corporate funding not only ensured the appropriate emphasis on poor people's crops; it also greatly eased the task of gaining acceptance for the new seeds. It would have been far more difficult for authorities inside India's Ministry of Agriculture to say yes to importing these new seed varieties if they had come not from private foundations or the international assistance community, but instead from profit-making private western seed companies.

I found in doing my research last year that it is extremely difficult for politically cautious leaders in poor countries to be seen welcoming GM seeds if they are coming from a private corporate lab in the United States. In fact, a strong pattern emerges. One reason the National Biosafety Committee in Kenya has not yet given final biosafety approval to the virus-resistant sweet potato is that the technology came originally from the Monsanto Company. One reason it has been hard in Brazil to get approval for RR Soybeans is that, once again, this is a Monsanto product. One reason India has not yet given a final release to Bt cotton is that it is, once again, a Monsanto product. And one reason China did go ahead with a biosafety approval for Monsanto's Bt cotton in 1997 was the fact that it could also approve, at the same time, Bt cotton varieties which it had developed with public sector resources within its own national agricultural research system.

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So it is clearly time to rebalance agribiotechnology research away from the private sector and back into the public sector. I see the two proposed pieces of legislation before this committee as a good way to pursue that objective. The small proposed increase in NSF funding envisioned in this legislation certainly will not remove all of the impediments currently standing between modern applications of crop biotechnology and poor farmers in the developing world, but it is a useful start.

BIOGRAPHY FOR ROBERT PAARLBERG

Robert Paarlberg is Professor of Political Science at Wellesley College and Associate at the Harvard University Weatherhead Center for International Affairs. He received his BA from Carleton College in 1967 and his Ph.D. in International Relations from Harvard University in 1975.

Robert Paarlberg is a researcher and consultant on international agricultural policy. He has written books on food trade and foreign policy (Cornell University Press), on agricultural trade negotiations (Council on Foreign Relations), on U.S. foreign economic policy (Brookings Institution), on sustainable agriculture (Overseas Development Council), on U.S. agricultural policy reform (University of Chicago Press). His latest book entitled *The Politics of Precaution: Genetically modified Crops in Developing Countries*, is published by the Johns Hopkins University Press in September 2001.

Discussion

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Chairman **SMITH.** Thank you all very much. I will start with the 5 minutes and then we will go back and forth from both sides. It was interesting, Dr. Paarlberg, last year and last fall down in Cuba, they had had some problems with a disease on their tobacco, and they had developed a biotech tobacco seed product that would resist that rust or whatever it was. But additionally had good characteristics in quality and taste, yet they weren't going to use it because Europe was their biggest market and they were afraid they would lose their cigar market to Europe.

So what you suggest is probably—suggest in that resistance and overcoming the resistance in many parts of the world is as great an obstacle as our lack of effort on research in terms of moving biotechnology for agricultural renewable resources ahead.

Meeting with the European Parliament—and I chaired a meeting just the week before last. And one of the issues still was is their contention that this was a free market decision, but it seems like if there is a lack of good scientific information, and the information of those consumers is based on emotions from environmental groups rather than good scientific information, then it probably doesn't meet the criteria of a real free market. Do you see—what are your suggestions for overcoming that resistance?

Dr. **PAARLBERG.** It is interesting. Officials in the European Union approved GM crops on food safety and biosafety grounds back in 1995 and yet consumers, particularly following the completely unrelated, but traumatizing BSE scare, decided that they wanted to be very cautious about any new food product that officials said was safe. Officials had said it was safe to consume meat from cattle diseased with BSE, and that proved to be erroneous and now they weren't going to believe officials if they said it was safe to eat Roundup Ready Soybeans.

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I am not quite sure how to break through those kinds of consumer anxieties. It is—in a wealthy region, like Europe, where consumers are already well-fed and where farmers are already prosperous, it may not be much of a loss to see that kind of highly precautious view of this new technology arise. What troubles me, though, when those European attitudes are projected, either through commodity markets or through the activities of European-based NGOs, or through international organizations under the influence of European ——

Chairman **SMITH.** Maybe part of it is simply doing what we are suggesting and that is what some of the European scientists said. Instead of producing something that might lower the cost a penny or two and that advantages producers and seed company sellers, why don't you do—why don't you develop something that is really going to help people. And that is—I think that is what Representative Johnson and I are partially after.

Dr. Arntzen, do you see it conceivably possible or scientifically possible to develop the kind of vaccines that might be widespread to give us some degree of protection against the weapons of biological warfare?

Dr. **ARNTZEN.** In answer to that question, very definitely. We are currently supported by Department of Defense for research, publicly funded and publicly known research, to develop a strategic reserve for a plague vaccine. It is part of the strategy that there could be a number of biological agents for which we wouldn't necessarily want to immunize the entire population, but we would be—want to be ready to respond rapidly if there were a threat.

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Let me go back and answer—or not answer a question, but make a point about one of your earlier statements. The idea of producing plant biotech products, which have a more immediate effect for the general consumer, I think is very, very important. The Europeans haven't seen value in reducing pesticide use in the United States or increasing profitability of the American farmer. We can appreciate that, but they don't necessarily see it the same way.

If we can introduce more products that have an immediate value for human health, and, I think, for benefit for children's health around the world, and especially in developing countries, that is something that everyone can appreciate. And I think we need to promote the sorts of things that are in Ms. Johnson's bill, that of linking the developing world with the United States and agricultural biotechnology. I think it is a great idea.

Chairman **SMITH.** Well, and I think for the second round, Mary, Catherine, we will—I will try next round. And with that, my 5 minutes are up and I will turn it to Representative Johnson.

Ms. **JOHNSON.** Thank you very much. Dr. Clutter, you indicated that the National Science Foundation-funded projects provide opportunities to train scientists from the developing world. To what extent is this opportunity now being realized? Because I think, in my judgment, that that is one of the ways that we can generate confidence in the product as having some of the people involved.

Dr. **CLUTTER.** I always forget to do that. I don't know why. In fact, if you look at our program announcement, in which we solicit proposals, you will find language that says we encourage students, scientists from developing countries, to take part in plant genome projects. And we do have a number of participants from the developing world taking part in the plant genome virtual centers that we now support. I don't have specific numbers. But, yes, there aren't enough of these students, but they are there.

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Ms. **JOHNSON.** Is there a way that we can improve the international collaboration and have joint activities? What is needed to encourage that kind of activity?

Dr. **CLUTTER.** Well, I think one of the ways was suggested by Dr. Ives. In fact, what we can do is promote more cooperation and coordination with some of the other agencies that have a direct responsibility for supporting some of the activities in the developing world.

Ms. **JOHNSON.** Thank you very much. You know, private companies have invested rather heavily in agricultural biotechnology research. How does what they do affect the nonprofit researchers and institutions and visa versa in the United States, Europe, or other developing countries—developed or developing?

Dr. **CLUTTER.** Were you asking me that question?

Ms. **JOHNSON.** Well, anyone on the Panel. Yes. Dr. Ives.

Dr. **IVES.** There is no doubt that the balance has been primarily with private sector companies investing more in the plant biotech side than the public sector research community. And I agree with Dr. Paarlberg that we need to address that imbalance. Certainly, a lot of the science coming out of the private sector and, I should say, the public sector, is proprietary in nature. The Bayh-Dole Act has allowed universities to patent their technologies and they are doing that very aggressively.

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I think one of the things that we need to look at, and we have worked very hard in our project, in working with consortia members, is to keep in mind, in looking at putting together collaborative projects, in how you are going to transfer propriety technology. This does not necessarily mean free, but it can also mean on concessional terms. Thinking of these kinds of things up front, using some of this proprietary research to actually help put collaborations together, as opposed to always viewing them as a blockage. It can be a problem. There is no doubt about that.

But I think keeping up front an idea that you want to make new technologies available to the developing world—and we have a couple of examples at Michigan State where we have put in licensing deals with private companies that they will make the technology available. And the companies, by and large, have been cooperative with that. They wouldn't protect these technologies in many parts of the world we are interested in anyway. And as long as you clearly define what you are talking about, it doesn't have to be a hindrance and, in fact, can help define your partnership.

Ms. **JOHNSON.** Yes, Dr. Arntzen.

Dr. **ARNTZEN.** In response to that question, I think one of the things that has happened, in part because large companies are involved, but just because of our own self-interest, we focus on U.S. crops, so it is corn, soybeans, to some extent, wheat, but it is not cassava, sweet potatoes, bananas, plantains, etcetera. Our own research has tried to focus on bananas because we want to use that as a delivery system of vaccines for kids in a developing world.

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When we started this, even though many other crops had been transformed, there was no means to put a gene into bananas. No one had ever cloned a gene from bananas. And we had the first dozen genes that were cloned at a time when there were tens of thousands of other genes from the corn, soybean, etcetera. So we have to focus, I think, one of the opportunities from a joint genomics third-world perspective, is to offer the opportunity to fund research that moves us in different directions. Ultimately, it also will benefit us.

Ms. **JOHNSON.** Thank you. My time has expired.

Chairman **SMITH.** Thank you. Representative Hart.

Ms. **HART.** Thank you, Mr. Chairman. I am sorry that I didn't hear the testimony of the first three, although I promise you I will read it. I have a great interest in this issue, as I think many of the members of the Committee do. I was somewhat stunned, though, to hear the testimony of—I think it is Dr. Paarlberg. Right? Yeah. Regarding the necessity for us to fund research that is already being done by the private sector because there is some concern that it came from a private company. That seems kind of silly to me. If the research is already being done by the private sector and we are getting our results, we could certainly find a better way to convey it to developing countries. And I would like you to shed light on something that I may be missing from what I seem to have concluded from your statement.

Dr. **PAARLBERG.** No. I don't want public funding for research that is now being done by the private sector. I would like public funding for the research the private sector is not doing on the orphan crops that Dr. Arntzen spoke about, cassava and millet, cow peas, sorghum. Big private companies aren't going to invest shareholder's money in improved varieties of those poor people's crops grown in tropical countries where there isn't a commercial seed market. If that isn't done by the public sector or by philanthropic foundations, it is not going to be done at all.

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If we had waited for private companies to fund the Green Revolution, they wouldn't have done it. This was openly pollinated varieties of wheat and rice, and there was no incentive for the private sector to do it. It had to be done through public sector agencies and through philanthropic foundations. And I would like to get back to that model.

Also, if things are done through the public sector rather than the private sector, there are less likely to be the kinds of intellectual property rights encumbrances that Dr. Ives referred to. So you have an opportunity to move toward the orphan crops, toward fewer IPR encumbrances, and you also have, as I tried to point out in my testimony, an opportunity to relieve anxieties in developing countries about who is going to profit from this new technology.

In developing countries today, there are misgivings—if a multinational seed company shows up, it is often easy to characterize such a company as there simply to profit for itself. Opponents of this technology would find it harder to make those arguments if the technology were being extended through a public sector partnership between a research organization university in the United States and a local research organization. So that was my hope.

Ms. **HART.** Okay. Let me dig into that a little bit. I understand the first half of the answer and it makes more sense to me than the second half. So let me go back to that. Okay. Monsanto—let us use them since you brought them up as an example—creates this great corn or whatever, that can be grown in these developing countries. It is offered to them directly by the company. They reject it because they have suspicions about the company and the profits. They have a low comfort level with buying seeds from someone who may make a profit.

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Dr. **PAARLBERG.** Well, one example might be the virus-resistant sweet potato that has been developed by the Kenyan Agriculture Research Institute. It has—it is based on a Monsanto technology that was given to the Kenyans on a royalty-free license basis for use in Kenya and elsewhere in Africa——

Ms. **HART.** Okay.

Dr. **PAARLBERG** [continuing]. For poor subsistence farmers. But that technology has encountered local resistance because some of the KARI scientists, including Florence Wambugu, who was quoted earlier here today, were trained at Monsanto. And they are easily criticized within Kenya as extensions of the influence of a United States-based multinational corporation rather than courageous, dedicated Kenyan scientists working for the benefit of poor women farmers growing sweet potatoes.

Ms. **HART.** But where is that generated from?

Dr. **PAARLBERG.** It is generated from the political left, from NGOs.

Ms. **HART.** All right. So the United States then should be required to somehow buy them off so that they will take this wonderful technology.

Dr. **PAARLBERG.** No. Actually, I would rather that the money hadn't been spent by Monsanto to find this virus-resistance gene that it might be able to apply to a sweet potato in Kenya. I would rather there was an NSF grant program that would allow——

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Ms. **HART.** Okay. So——

Dr. **PAARLBERG** [continuing]. Scientists dedicated to the needs of small farmers in the tropics with subsistence crops that need to be approved—I would rather it started that way so there wouldn't be any confusion at all so that the crops that need the attention the most—and sweet potato isn't the crop that needs the attention the most in Kenya—I would like to see the crops that need the attention the most, get the attention first through a public sector grant program. The private sector is never going to do it.

Chairman **SMITH.** The gentlelady's time is expired.

Ms. **HART.** Okay. I just have a——

Chairman **SMITH.** Dr.——

Ms. **HART** [continuing]. Philosophic disagreement with you. Thank you, Mr. Chairman.

Chairman **SMITH.** Dr. Arntzen, for your comments on that same question of Representative Hart.

Dr. **ARNTZEN.** Just a clarification. That same technology could have come out of an academic setting. It did not because there is no funding mechanism by which academics in the United States can work with a scientist in Kenya. There was money available for scientists in the Monsanto Corporation to work with the Kenyans. It was good public relations. So they thought. It turned out it sort of backfired.

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Ms. **HART.** It was Monsanto money, though. Right? It was not——

Dr. **ARNTZEN.** Yeah.

Ms. **HART** [continuing]. Government money given to Monsanto to do any research.

Dr. **ARNTZEN.** That is how I understand it. Yes. And it was part of their promotion efforts, product development efforts, for good public relations. But in spite of that, NGOs and others have some suspicions. If that had come from an academic setting, where the research really started——

Ms. **HART.** Uh-huh.

Dr. **ARNTZEN** [continuing]. And if there had been an NSF program to link people together or a philanthropic program, such as the McKnight Foundation ran for a number of years—if that technology had flowed from academia, I think it would have been much more difficult for the NGOs and anti-biotech critics to attack the virus-resistant sweet potatoes.

Chairman **SMITH.** Mr. Etheridge.

Ms. **HART.** Thank you. Thank you, Mr. Chairman.

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Dr. **IVES.** Can I just correct the record just for a minute? Part of that money did come from USAID for the Monsanto sweet potato, although Monsanto put in the bulk of that funding.

Mr. **ETHERIDGE.** Thank you, Mr. Chairman. Let me thank you and the Ranking Member for pulling this together today. And let me approach this a little differently. But having come from a state where I was involved at the state level when we created the first biotech center, I think, in the country, in Research Triangle Park, it is very difficult—there are a lot of private funds in, but there aren't many places that basic research gets done if you don't have the link back to the academic institutions in this country. I can't speak for overseas.

My question is this—and, Dr. Clutter, you may want to start and I would hope the others would maybe comment on this because I think this is one I think as we deal with it, we have research being done certainly through not only NSF, but USAID, USDA, DOE, and all these areas. And I am not critical of the funding. That is not my point. My question is more to efficiency of all the funding that is done for biotech research, specific of plant research. How was the plant research done in those various agencies in a way to complement one another without having redundancy? Do we have a mechanism so that we can get it done so we don't have the redundancy with the dollars we are putting out?

Dr. **CLUTTER.** I am glad you asked that question. You will see some of the answer in my written testimony. But we try to coordinate all of our programs. I think you have to realize that the amount of money that the Federal Government invests in research-related agriculture, very fundamental research, is not comparable with the amount of money that is invested in other kinds of research.

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Mr. **ETHERIDGE.** Right.

Dr. **CLUTTER.** And so we have an interagency working group that is composed of the agencies that support plant biotechnology and we meet regularly under the auspices of the Office of Science and Technology policy. And we try to coordinate our programs. In fact, we have some joint programs. So that I think that in that respect we really are cooperating to the best of our abilities.

Mr. **ETHERIDGE.** Anyone else want to comment on that? You indicated that the NSF-funded projects provide opportunities to train scientists from the developing world. It seems to me to be a great program. But to what extent is this opportunity now being realized in the plant biotechnology area? In particular, how many foreign scientists are involved and what are the level of resources being expended for this purpose, specifically, last year, as an example, the last fiscal year?

Dr. **CLUTTER.** I can't give you exact numbers because I don't have them.

Mr. **ETHERIDGE.** Okay.

Dr. **CLUTTER.** But let me say that we have been trying to encourage more scientists to take part in our projects. But I want to make one point very clear. We are not investing NSF funds in foreign countries. All of the funds are expended here——

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Mr. **ETHERIDGE.** On foreign projects.

Dr. **CLUTTER** [continuing]. At our universities. But we will support the stipends of the students and the researchers while they are here being trained in the research centers in our country.

Mr. **ETHERIDGE.** Let me follow that up then, if I may.

Dr. **CLUTTER.** Okay.

Mr. **ETHERIDGE.** In terms of the coordination with the other agencies that I had earlier mentioned, does that coordination deal with the same effort as we deal with the coordination of the various agencies doing the same thing, as far as you know?

Dr. **CLUTTER.** Oh, absolutely. Absolutely.

Mr. **ETHERIDGE.** Okay. That is all I have, Mr. Chairman.

Chairman **SMITH.** Thank you. Representative Gutknecht.

Mr. **GUTKNECHT.** Mr. Chairman, I came into this hearing prepared to support your bill and the more I hear, the more likely—the more—the less likely I am.

Chairman **SMITH.** Are you about finished, Mr. Gutknecht?

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Mr. **GUTKNECHT.** No. I am not. I have about 4 minutes and 50 seconds. In fact, coming into the room, I was explaining to the Chairman some basics of salesmanship. And one of the first rules of salesmanship is the customer is always right. And as I have listened to this, it is like we are trying to say that if we spend more money on research, maybe the customers will change their mind. And I was telling the Chairman that people in general, Americans in particular, do not change their mind. They will make a new decision based on additional information, but they don't change their mind.

I am really a little concerned about all of this, because back where I came from—and I understand, Dr. Arntzen, you grew up on a Minnesota farm—and particularly after the starling scare about a year-and-a-half ago, a lot of my farmers were calling me saying, well, should I plant GMO seeds or not. I couldn't give them a good answer because, you know, we still haven't worked this all out. And I don't know what the answer is. I think the GMO seed varieties are absolutely safe. And I actually have a lot of respect for the scientists both at the public institutions and the private sector that have developed these.

But, you know, if we can't convince the European Union—now, I had some meetings earlier this year with the members of the German Bundestag, and, boy, I will tell you, it was like talking to a wall. I mean, they are not interested. They are not going to buy. If they can avoid it at all, they are not going to buy any GMO crops from the United States.

In fact, I actually have customers—I have farmers in my district who are now growing non-GMO soybeans and being paid a premium for those, to be shipped particularly to Japan. And then we have got the other problem—the corporations themselves are part of the problem. And I hate to use a name, but I think to make it very clear to everybody here, there is a little company called Novartis. And a few years ago, Novartis owned two subsidiaries. One was Northrop King Seed Division and the other was a little company called Gerber Baby Food. Now, on one hand, Novartis was spending hundreds of millions of dollars developing and marketing these new seed varieties to farmers. On the other hand, they make an announcement that they are not going to buy GMO products to go into baby food.

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And I don't care how much money we spend on research. When you have corporate America—and I shouldn't even say corporate America. This is a—this is actually a world-wide corporation—but when you have large corporations like that who are sending incredibly mixed messages to consumers, I don't care how much we spend on basic research at Michigan State or Arizona State or the University of Minnesota or anywhere. It seems to me this—we are losing this battle. If we can't convince our European counterparts of the safety of this, if they continue to use, on the floors of their parliaments, terms like Frankenfood, how do we win this thing? Yeah.

Dr. **ARNTZEN.** If I can respond, I—first of all, I would hope you would support the bills. I don't think that we are trying to buy a mechanism to change anyone's mind. And I agree with you, people don't tend to change their mind. But what they can see is new opportunities. And I think that what has been available thus far are soybeans that help farmers increase their profitability or ease their application of oversight, etcetera. It hasn't resonated with many people around the world. As we—what we are hoping that we can do is come up with new research products, new research findings that will lead to new research products that will have a much more dramatic effect on the world population.

Producing things like gold and rice, which has been accepted very broadly as having an immediate impact on the health of children around the world, or being able to create vaccines will—that can help reduce diarrhea, which kills two-and-a-half million children every year—these are things that is going to be very hard for even Greenpeace or staunch anti-GMO groups to argue it.

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I have been on panel discussions in Europe with the head of Greenpeace Europe sitting side by side and he gives us vehement criticism of what we are doing. After my presentation he says, but that is the sort of thing that should be done. So it is not a condemnation of biotechnology overall. It is just a condemnation of the products and the U.S. global corporate involvement in all this thing that I think it is at the root of the issue.

So I would say what we do need to do is invest more in education, bioethics, that go along with the research, linking it with the education and training of scientists and students from the developing world. And it is a—we are dealing with a long-term issue here. We are talking 10 or more years to watch the change of public opinion around the world.

Chairman **SMITH.** I hope the gentleman has now changed his mind. And with that, we would call on the gentleman from California, Mr. Baca.

Mr. **BACA.** Thank you very much, Mr. Chair. One of the questions I have, and all of you can respond to it, there is a—as a follow-up. What is the potential associated with generally modified crops and what can be done to minimize these risks?

Dr. **ARNTZEN.** I can take a shot at responding. I think the greatest risk of genetically modified crops is they don't get widely utilized to meet the population expansion and the things that Congressman Johnson mentioned in her opening remarks. We need to find new technology that is going to expand the world food production and improve the quality of the world food supply if we are going to meet another doubling or approaching that of the world population. So the biggest risk is doing nothing whatsoever.

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Mr. **BACA.** Anybody else who would like to tackle that?

Dr. **PAARLBERG.** Yes. I could respond to the question of risks in the area of biosafety, in particular. I mentioned a number of countries that haven't yet approved GM crops on grounds of biosafety concerns. But when you look at the specifics of the crops that haven't been approved, the biosafety concerns are hard to pin down. In Kenya, they haven't yet given biosafety approval to a virus-resistant sweet potato, even though there is no danger there of gene flow to wild relative species because the sweet potato doesn't come from anywhere in Africa. There aren't any wild relatives——

Mr. **BACA.** Uh-huh.

Dr. **PAARLBERG** [continuing]. Anywhere. And besides it is propagated vegetatively anyway. So there isn't any pollen. In the case of Brazil, they haven't approved Roundup Ready Soybeans on biosafety grounds, but there is no danger of gene flow because there aren't any wild relatives of the soybean anywhere in the western hemisphere.

In India, they haven't approved Bt cotton on biosafety grounds, but the number one effect of moving to Bt cotton would be to reduce the spraying of toxic insecticides and reduce damage to non-target species and improve the environmental health of those who work in cotton fields. So I think that the biosafety concern that is being used and is an excuse to hold those slow on these products, doesn't stand up to close scrutiny, even on the crops that are being held up for that reason.

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Mr. **BACA.** As a follow-up question, you know, in reference to the increase in population over the next 25 years, I guess they assume it will be around 2 billion. Currently, the United States provides a lot of food aid to poor countries. How will the amount of food aids needed by poor countries change during the next 25 years based on research or others? Any of you who would like to tackle that?

Dr. **ARNTZEN.** Well, I can make a comment. I think back in the '50's, in India, or the subcontinent, in particular, we were largely providing food aid and we began in that period of time an energetic program of institution building, trying to help agricultural schools, transferring technology. Michigan State University and Cornell and other schools were very active and fully involved in that. I traveled a lot in India in the late '70's and '80's. And you could go down virtually any corridor of an agricultural research center and someone would come out, and if they saw you were wearing—I was at Michigan State at the time—wearing the Michigan State green, they would come over and shake your hand.

We have sort of declined down from that. But I think we did institution building and we did technology transfer very actively for a period of time. And what came of it, India became self-sufficient. Even though they doubled their population, they actually exported some of their food crops. We have to—I think America, overall, sort of went away from this over the last 15 to 20 years. And it is—in my view, it is an opportunity for us to restore our transfer of technology training of people so that we participate in making sure that poorer countries around the world can meet the food challenges that are in front of them.

The solution, I don't think, is to continue to give away food. It just suppresses the agricultural capacity within the country itself.

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Mr. **BACA.** What are you saying, though, is that we need to do additional education and training.

Dr. **ARNTZEN.** I think—I really feel that the shared activities in research and education, sharing with scientists around the world, not just in agriculture, but in other related areas, is part of American activities that we must re-engage ourselves much more vigorously than we have in the last couple of decades.

Mr. **BACA.** Thank you.

Dr. **PAARLBERG.** If I could just add very quickly to that, what avoided famine in India, in the 1960's and the 1970's, was not food aid, but higher productivity in agriculture created, in part, through public sector investments and philanthropic investments in agriculture research, the Green Revolution, wheat and rice varieties. What is going to save Africa from famine is not food aid, but higher productivity in agriculture if we can get it there.

Food production in Africa today, on a per capita basis, is 10 percent below where it was 30 years ago. Two-thirds of Africans depend upon agriculture for income and employment. Unless their productivity goes up, their income is going to keep going down and poverty and hunger will increase. The only way to avoid that isn't through food aid, but to increase agricultural productivity.

Mr. **BACA.** Thank you.

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Dr. **IVES.** And I would just like to add that that job is even going to get harder because as population increases, there is actually less land per person in which to increase your productivity. And the technological innovations that came out of the Green Revolution were not directly transferable to Africa and we need to focus more carefully on developing innovations that will benefit African productivity.

Mr. **BACA.** Thank you.

Chairman **SMITH.** We will start maybe a short second round. And, Dr. Clutter, let me begin with your thoughts and comments on the 50-percent cost sharing requirement in my bill, 2051. The National Science Board is reviewing the effectiveness of cost share. What—can you give us any recommendations or suggestions of the advantages and disadvantages of the cost share in——

Dr. **CLUTTER.** As you said, the National Science Board has been considering this issue because it has been quite controversial. There are many institutions that really cannot afford to cost share on research projects supported by the National Science Foundation. And so we are leaning toward not having any cost sharing on projects that we support.

However, on some of the big facilities projects, for example, or major instrumentation, we have a sliding scale for providing cost sharing. And so we ask for, I believe, in the instrumentation program, a 30-percent cost share. But if the institution cannot afford 30 percent, we do not ask them to provide cost sharing. So that there are plusses and minuses here. We don't want to deny institutions that are too poor to cost share the benefits of having, for example, a part of a virtual center. So that while on the one hand it may seem good to require cost sharing, one must take into consideration a variety of circumstances.

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Chairman **SMITH.** Well, we did leave the language—wrote the language in such a way as—that the Department of Agriculture or the Department of Energy could contribute to that 50-percent cost sharing. And maybe—so maybe we need to review the language a little bit, because what I hear you saying, Dr. Paarlberg, if it is Monsanto doing the cost sharing, it might have—or some commercial, multinational company that doesn't have the kind of confidence that might allow other countries to more quickly adapt the product of this research, it might end up being some disadvantage. Comment? Yeah. Dr. Arntzen, first.

Dr. **ARNTZEN.** On the cost-sharing issue, I would hope that you would also identify philanthropic organizations as a potential cost share. I think one of—I understand Dr. Clutter and the NSF's hesitancy to involve this because it could exclude some institutions. Where at the same time, if a cost share shows a real commitment by individuals other than the university. And I think there is an opportunity to attract the interest of more philanthropic organizations right now in world hunger, malnutrition, etcetera, where they have been distracted on some other things in the past. And this would be an opportunity.

Secondly, there is an opportunity to get cost sharing from other countries. I have—because of the nature of the project that we have had, I have had—in the last 2 years, I have had visiting scientists from Thailand, India, China, Argentina, Mexico, and South Africa. All have come with more than half of their salaries and some support provided by their governments. And we have been trying to work now in developing formal relationships and—which is harder to do at an individual university level. But if this was sponsored and encouraged through a Federal organization like NSF, I think it would help us draw out some other sources of money.

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Chairman **SMITH.** Dr. Ives, I said earlier that the—where we go and what we do and what we accomplish is probably only limited by the creativity and imagination of researchers. So if you were designating the research under 2051 or 2912, what would you suggest that that research be?

Dr. **IVES.** Under a competitive grants program, which is what, at least, Congresswoman Johnson's bill would address, I don't think you can too narrowly define a crop or a constraint to look at, because then you potentially leave out some incredibly bright ideas. My feeling is that what you do is you try to open the funnel pretty wide and then narrow that down in terms of setting some criteria as you move forward with developing or reaching some research results.

It is clear, at least on the developing—looking at work with the developing countries, I think we need to focus more on some of these orphan crops than we have done in the past. USDA has programs that address U.S. commodities and interests. USAID has interests in technology transfer, but they don't fund some of the basic work that underlies that. So, you know, that would be one area that I think needs to have some additional attention paid.

In addition, looking at the issue of food security, basic production constraints are still very important. You know, the ability to get enough food is still very important. And while we have these arguments with the European Union and the United States, the level of food produced is still a very important question in many parts of the world that we don't worry about here. So I wouldn't want to see those necessarily left out.

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My feeling is that you would need to have a pretty broad call for proposals that would look at generating new information, new fundamental mechanisms of plant production and understanding basic plant biology, but with the potential focus on either—certain orphan crops or looking at—if you want to combine these two bills—or looking at how down the line these may improve food security.

Chairman **SMITH.** Very briefly. I was going to ask you to give it in writing, since my time has expired, but I will take the liberty of asking for your comments on that question now.

Dr. **ARNTZEN.** I think one of the things you are doing in this activity is challenging us to think about what is research. Often times, in academia, that is test tubes and things. We also need to think about pedagogical approaches—can we do research on an approach to solving problems without just becoming a product development organization? But can we devise our research programs so we are doing research on whether we have a successful outcome where the successful outcome is, is it—is the outcome beneficial to a developing country as well as the citizens of the United States who are paying the taxes?

Can we ask questions—are there mechanisms where we can conduct research where we draw in other sources of funding? And that is really a research activity in itself. What I sense you are trying to do is not tell us what research to do, but give us some goals that you would like to see at the end of the day that are coming out of these activities and out of these funds that you think are going to be of benefit on a global level.

Chairman **SMITH.** Very good. Representative Johnson.

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Ms. **JOHNSON.** Thank you very much. As I listen to this, I continue to think about the numbers that will need food, need it now, and will need it in the future. And from the continent that offer us many of what we wear—much of what we wear every day in this form of gold and diamonds and silver, much of what we mobilize ourselves in, gas, oil, and, yet, they are hungry. Is there an alternative to this type of research that would offer the ability for the people to become independently able to generate their own food?

Dr. **PAARLBERG.** I could mention one important food crop for farmers in West Africa and Central Africa. It is a legume—cow peas. It is important to about 200 million poor farmers, many of them women. It is the best protein source that they have to feed their children and their families. It can grow even on less than 300 millimeters of rainfall. So it is one of the few protein crops that can grow in the very dry parts of Africa. It is a crop that suffers serious damage from insects, from weevils, bruchids, and other insects. And conventional plant breeders have not been able to find, in cow peas, the sources of insect resistance that could be amplified in an improved variety.

With crop transformation, we could create a Bt cow pea, similar to Bt corn or Bt cotton that would reduce the insect damage that those poor farmers suffer. They would protect their crops not by spraying an insecticide, but simply by having access to a seed that it self-contained the insect resistance.

They could—instead of losing 50 or 60 or 70 percent of their crop, save their crop. Their productivity would go up. Their family nutrition would go up. Their ability to sell cow peas for cash would go up. But who is going to invest in the basic research needed to transform cow peas. It is not going to be done by a private company because the market for cow pea seeds is not commercially sufficient——

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Ms. **JOHNSON.** Uh-huh.

Dr. **PAARLBERG** [continuing]. To justify that kind of investment. It is the kind of thing that has to be done either through the public sector or through private philanthropic efforts.

Ms. **JOHNSON.** Uh-huh.

Dr. **PAARLBERG.** And that is the kind of opportunity that I see being missed so long as the public sector holds back and advocates the job to the private sector.

Ms. **JOHNSON.** Uh-huh. Dr. Clutter, I know that the National Science Foundation encourages diversity. Are there historically black colleges and universities involved in some of that research in Africa?

Dr. **CLUTTER.** Yes. Absolutely. In fact, we have a number of historically black colleges and universities who are involved in our plant genome research program in partnership with other universities and colleges. And we are very happy about that. We would like to see a lot more of it going on.

Ms. **JOHNSON.** That is one way to generate some confidence in the people there to accept some of the genetically modified foods, I think. Thank you very much, Mr. Chairman. I yield.

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Chairman **SMITH.** Representative Hart.

Ms. **HART.** Thank you, Mr. Chairman. I had a little bit of a chance to get through some of the other testimony, and I want to address one of the things that Dr. Clutter referred to in the end of her testimony, and it was dealing with training the next generation of scientists. It was a statement made toward the end, I guess, right before your conclusion, that young scientists are being—it is important that in the plant genome research program young scientists are being trained in new ways of doing science, that they are high demand from industry, which utilizes the basic genomics knowledge to develop plant-based products.

You go on to say that it is valuable to extend the same opportunities to young scientists from the developing world. And what I guess I need to know is, what is your experience with us helping train young scientists now? Are we actually doing that? And are they being accepted in these countries, considering that they are often being trained in our universities, which are often funded by our corporations?

Dr. **CLUTTER.** That is right. I would invite you to go to any state university or college in your own district to see who the students are and what sort of research they are actually doing, because they are learning modern biotechnology. And many of them do come from develop—the developing world. And many of them stay here, but many of them return home.

And I think it is very important that we maintain ties with those very well-trained scientists when they—

by continuing to involve them in some of the major research projects that are funded out of the National Science Foundation. But they would not—we would not provide our funds to that country. We would simply provide the means by which that well-trained person could participate in a major research project.

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Ms. **HART.** The ones that have been trained now that go back to their own countries.

Dr. **CLUTTER.** Yes.

Ms. **HART.** What are they currently doing then if we are not funding them?

Dr. **CLUTTER.** Well, hopefully they are being funded through their own country's resources.

Ms. **HART.** But in your experience then, these young scientists aren't involved in any kind of private sector development in their own countries.

Dr. **CLUTTER.** I don't know the answer to that question.

Ms. **HART.** Does anybody else on the Panel have any idea about that?

Dr. **ARNTZEN.** Well, I think it is hard to make a global representation.

Ms. **HART.** Okay.

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Dr. **ARNTZEN.** In China there is relatively few private companies to go back to. And but some——

Ms. **HART.** Well, that is China. Yeah.

Dr. **ARNTZEN.** Yeah. But in India, I see in agricultural biotechnology there is an emerging credibility of private corporations that are serving the agricultural industry. So a big difference. South America, Argentina, which didn't have commercial seed corn, hybrid seed corn 20 years ago—and now it is all from private companies. And the young people who are trained, tend to go back and work for Cargill or Novartis or DeKalb or Pioneer, one of those.

Ms. **HART.** Well, it is safe to say that most nations on the earth do not have the kind of money to fund research that we do. And so I mean, if they are going back to their own countries, they are a lot less likely to be working in a government-sponsored project unless it is sponsored by us.

Dr. **ARNTZEN.** Not necessarily. I think there is a—and biotechnology is maybe too strong a term. But in the overall transition from small acreage crops to larger, more, almost, say, industrial agriculture, that is happening around the world. It is part of the transition of populations moving into cities, leaving fewer people in rural areas, getting greater efficiency of agricultural production, which makes it more common for fertilizer to be used, in some cases, pesticides, and a demand for better seed is rapidly spreading around the world. Because it isn't because somebody is out there necessarily pushing it as a commercial entity, but it is just part of the overall changing demographics of the world that is happening and making—-

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Ms. **HART.** Well, they are finally getting educated.

Dr. **ARNTZEN.** Getting educated and some are not getting educated, but they are moving to the cities. But it—their economic pressures——

Ms. **HART.** But what I am saying is agricultural advancements are finally getting around the world and they understand that it makes sense to use pesticides and all these other things.

Dr. **ARNTZEN.** Yes. Absolutely.

Ms. **HART.** And that is just the natural progression, I would hope.

Dr. **ARNTZEN.** Yes.

Ms. **HART.** Okay. To go back then to Dr. Clutter, you are suggesting that we help train, I guess, more of these people. You—do you propose that that would be part of what we would do, is a government-sponsored project here in the United States then, as far as funding?

Dr. **CLUTTER.** These projects already exist.

Ms. **HART.** Uh-huh.

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Dr. **CLUTTER.** And there are numerous students from developing countries who are participating, are being trained through projects that exist today.

Ms. **HART.** And you think it has been successful as it is today and that we should continue to do it or expand it.

Dr. **CLUTTER.** Quite obviously, yes. I believe it is very important for the future of not only our country, but the world.

Ms. **HART.** Thank you, Mr. Chairman.

Chairman **SMITH.** And it is interesting that as I have reviewed these other countries and their efforts and contributions toward research, where we put a great deal of emphasis on basic research, their governments are spending some of their money reviewing the basic research we do in this country and then spending the rest of their money trying to apply that kind of research in something that is going to be useable particularly for their industry or their country.

I am going to conclude with asking each of you to take about 1 minute, if you would like to, in sort of a wrap-up of any final thoughts that you would like to pass on to our—this Subcommittee and the full Science Committee. And maybe, Dr. Clutter, starting with you.

Dr. **CLUTTER.** Thank you very much, Mr. Chairman. I think this was a very interesting and important hearing. And I think that, as was suggested by members of the Committee, as well as people testifying, part of the problem—a major part of the problem is communication with the public. And I think that we all agree that the risks are minimal. Your own report pointed that out very well last year.

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But I think that since a lot of the problems appear to be political in these countries, the German Bundestag was mentioned. I think that the onus is on all of us, not just people in the Federal Government. People in the Congress—because you are the people who communicate with the parliaments and congresses of the rest of the world. So I think that part of the responsibility is yours, but it is all of—it is the responsibility of all of us to translate what is happening in science so that the public can understand.

Chairman **SMITH.** Dr. Ives.

Dr. **IVES.** Thank you very much, Mr. Chairman. And I also want to thank you for having this hearing. And I will just follow up from what Dr. Clutter said. And I mentioned earlier that one of the things these bills could address is assisting in the communication, and I was talking about it in a slightly different way. But the area of communication is critically important.

One of the things that I think in the training of scientists you get is, in these countries, people who are able to communicate. It has been our experience that people don't really care what it is that I have to say when I go to Zimbabwe. They care what scientists in Zimbabwe have to say. And if people haven't gotten experience and don't understand the technology and you don't have a core group of people, then decisions are made often in a vacuum and those are very rarely useful.

And so I think in looking at how these bills might be helpful, I do think the more people you have who are trained and that can communicate that to the general public, the better off we will all be in using this technology and helping increase agricultural productivity.

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Chairman **SMITH.** Thank you. Dr. Arntzen.

Dr. **ARNTZEN.** Thanks also for the invitation to come. In a sense, I am a little bit disappointed that I am not making this presentation to a House Agriculture Committee where I think there should also be an emphasis on this sort of research. But due to budget constraints and a variety of other things, I think you are to be commended, the two of you, in putting this forward through the National Science Foundation. NSF has clearly had an excellent record of setting up centers, centers that bring—that encourage multidisciplinary research.

What we are talking about here is a new level of multidisciplinary, I believe. It is multinational, international, multidisciplinary things. I believe it will be challenge for us in academia and perhaps for the folks in NSF to figure out exactly how to do that. But I am convinced we will.

I would also add I like your idea of cost sharing on some of this because I really see us needing ways to encourage philanthropic organizations and governments in other countries to match some of our investments because it is for everyone's benefit.

Chairman **SMITH.** Thank you. And I—just for your information, as a member of the Agriculture Committee, I did put language in the Agricultural bill that we will be taking up on the Floor—it has passed out of Committee and it is up for a Floor debate in the next couple of weeks. Dr. Paarlberg.

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Dr. **PAARLBERG.** Thank you. I especially enjoyed the discussion we had here this afternoon about how to help crop scientists from developing countries that have been trained at universities in the United States go back home, work in public sector research institutes there on poor people's crops, but remain in touch with the U.S. university where they got their training.

And there is one program that does a good job of that that should be mentioned in a hearing like this. And that is the Collaborative Research Support Program, the CRSP Program, that is funded through USAID. One of the CRSP programs is actually headquartered at Michigan State University. It is a very successful program for developing improved varieties of orphan crops, but historically it has been dominated by conventional plant breeders. It has not developed enough work at the molecular level in using modern crop biotechnology. And an NSF grant program would be—I think, would provide nice synergy with the CRSP Program as another source of funding for modern biotechnology on orphan crops. Thank you.

Chairman **SMITH.** Good thought. Again, thank you all. Any closing comments?

Ms. **JOHNSON.** No.

Chairman **SMITH.** With that, without objection, the record will remain open for 5 days for additional comments from members or for additional questions to the witnesses that we would hope you might consider responding to in writing. And with that, the Subcommittee is adjourned.

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[Whereupon, at 3:40 p.m., the Subcommittee was adjourned.]

(Footnote 1 return)

Robert L. Paarlberg, *The Politics of Precaution: Genetically Modified Crops in Developing Countries* (Baltimore: The Johns Hopkins University Press, 2001).

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