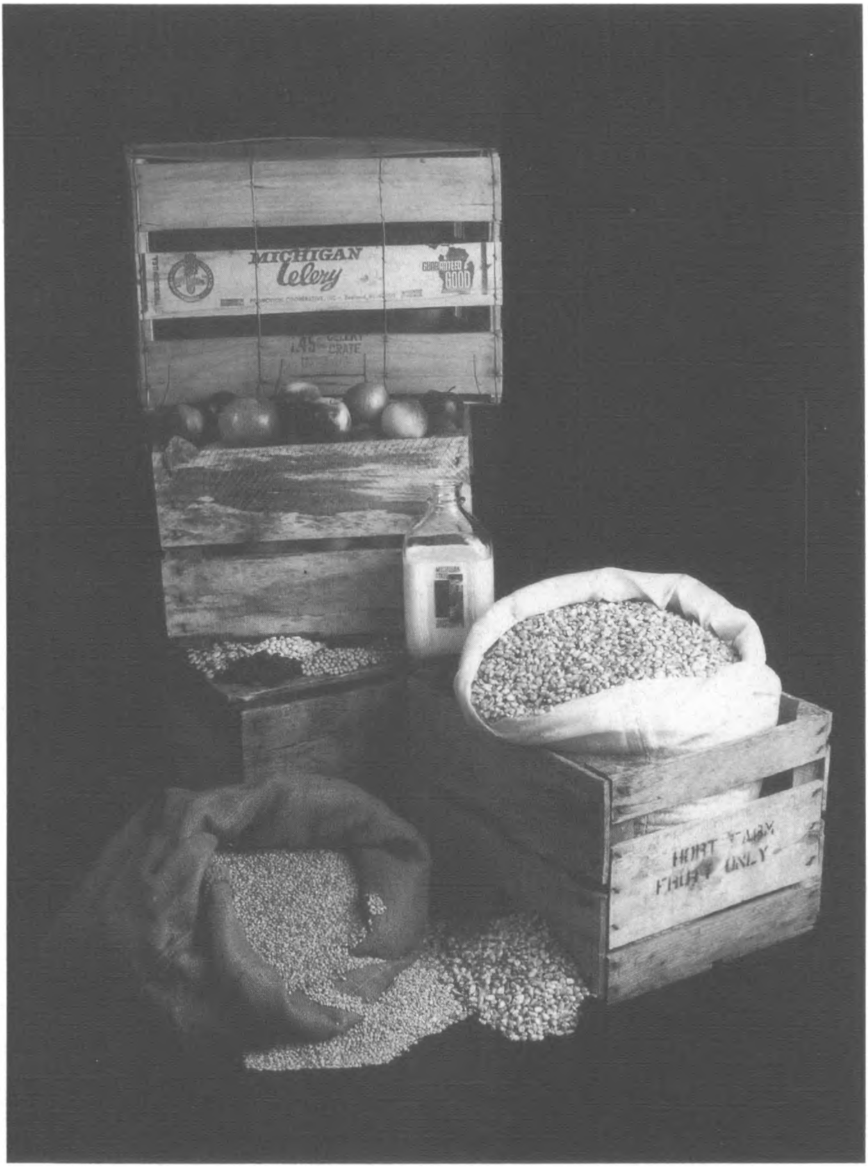
NABC REPORT 6

Agricultural Biotechnology & the Public Good



NATIONAL AGRICULTURAL BIOTECHNOLOGY COUNCIL REPORTS

NABC Report 6

Agricultural Biotechnology & the Public Good

The National Agricultural Biotechnology Council provides an open forum for the discussion of issues related to the impact of biotechnology on agriculture. The views presented and positions taken by individual participants in this report are their own and do not necessarily reflect the views or policies of NABC.

Photos on cover and pages 145, 163 and 201 courtesy of Michigan State University Outreach Communications. Photos on pages 1,31, 181 and201 courtesy of Cornell University Photography. Photo on page 93 by Sam Fujisaka provided by Susan McCouch, Cornell University.

Additional copies are available for $5
please make checks or purchase orders payable to:

NABC / BTI
159 Biotechnology Building
Cornell University
Ithaca, NY 14853-2703

ISBN: 0-9630907-5-5
Library of Congress Catalog Card Number 94-067408

@ printed on recycled paper

NABC REPORT 6

Agricultural Biotechnology & the Public Good

Edited by June Fessenden MacDonald

published by
NATIONAL AGRICULTURAL BIOTECHNOLOGY COUNCIL
ITHACA, NEW YORK 14853-2703

National Agricultural Biotechnology Council

Providing an open forum for exploring issues in agricultural biotechnology.

NABC is a consortium of not-for-profit agricultural research, extension and educational institutions established in 1988.

Member Institutions

Boyce Thompson Institute

Clemson University

Cornell University

Int'l. Service for the Acquistion of Agri-biotech Applications

Iowa State University

Michigan State University

North Carolina State University

The Ohio State University

Oregon State University

The Pennsylvania State University

Purdue University

Rutgers, The State University of New Jersey

Texas A&M University System

University of California System

University of Georgia

University of Guelph

University of Minnesota

University of Missouri, Columbia

University of Nebraska, Lincoln

University of Saskatchewan

University of Wisconsin, Madison

Other Reports by NABC:

NABC REPORT 1, Biotechnology and Sustainable Agriculture: Policy Alternatives (1989)

NABC REPORT 2, Agricultural Biotechnology, Food Safety and Nutritional Quality for the Consumer (1990)

NABC REPORT 3, Agricultural Biotechnology at the Crossroads: Biological, Social and Institutional Concerns (1991)

NABC REPORT 4, Animal Biotechnology: Opportunities & Challenges (1992)

NABC REPORT 5, Agricultural Biotechnology: A Public Conversation About Risk (1993)

ACKNOWLEDGMENTS

Many people contributed to the success of the sixth annual NABC meeting and the preparation of this report. NABC gratefully acknowledges the diligent oversight of Michael Thomashow, Chair and members of the NABC 6 organizing committee at Michigan State University: Lawrence Busch, Richard Harwood, John Ohlrogge, Allan Schmid and Patricia Traynor.

Very special thanks goes to Eddie Hansen, the meeting organizer who made our coordinated efforts go so smoothly. Other members from the Michigan Agricultural Experiment Station staff who assisted with the NABC 6 meeting include Maxine Ferris, communications coordinator, and workshop rapporteurs Cheryl Howell, Robin Millsap, Susan Peterson and Jamie DePolo, MAES information officer who was also a contributing writer to the *NABC News* and the overview in this volume.

Once again, special recognition goes to Kate O'Hara, NABC graphics production coordinator for the overall design of this report and her coordination of the overall production. Special thanks also to Loren Mooney who assisted with the editing and proofreading of the final draft.

Finally I want to acknowledge the leadership provided by Bill R. Baumgardt, Purdue University, NABC Chair '93-'94, and Robert G. Gast, Michigan State University, current NABC Chair.

June Fessenden MacDonald

June Fessenden MacDonald
Executive Director, NABC
Editor

PREFACE

The National Agricultural Biotechnology Council (NABC) was formed in January 1988 by four not-for-profit agricultural research, extension and educational institutions as a consortium concerned with agricultural biotechnology for the benefit of all sectors of society. Membership in 1994 has grown to 21 institutions in the U.S. and Canada with expanded interest in global issues related to agricultural biotechnology.

NABC was organized to provide a neutral forum for open dialogue about agricultural biotechnology and to promote increased understanding by all stakeholders of the science, the technology and the social, ethical and policy issues. The consortium's principal objectives are to:

- *provide an open forum for persons with different interests and concerns to come together to speak, to listen, to learn and to participate in meaningful dialogue and evaluation of the potential impacts of agricultural biotechnology*
- *define issues and public policy options related to biotechnology in the food, agricultural and environmental areas*
- *promote increased understanding of the scientific, economic, legislative and social issues associated with agricultural biotechnology by compiling and disseminating information to interested people*
- *facilitate active communication among researchers, administrators, policymakers, practitioners and other concerned people to insure that all viewpoints contribute to the safe and efficacious development of biotechnology for the benefit of society*
- *sponsor meetings and workshops and publish and distribute reports that provide a foundation for addressing issues*

As NABC continues to grow in membership, so too does meeting participation grow, with the 1994 meeting having the largest member of the registrants thus far. Agricultural biotechnology is also growing, with new products and processes affecting the entire world—both in developed and developing countries.

Recognizing this international dimension, the sixth annual NABC meeting included an organized session and workshop on the impact of agricultural biotechnology on less developed countries and their public, and the global interdependence critical to the development of biotechnology for the public good. The discussion was intense and seemed to impact on all participants and alert many to this transnational dimension of agricultural biotechnology. By the end of the meeting, it was clear that future discussion of issues related to agricultural biotechnology would have to include a global perspective. This expanded focus was also reflected in the diversity of meeting participants who came from 8 countries, 2 provinces, 24 states and the District of Columbia, USA.

As always, speakers and the other participants presented a range of views on agricultural biotechnology—from strong supporters to questioning critics. The lecture-workshop format was conducive to vigorous discussions following the plenary talks, in the workshops and at breaks and meals, and offered a broad range of learning experiences for most attendees.

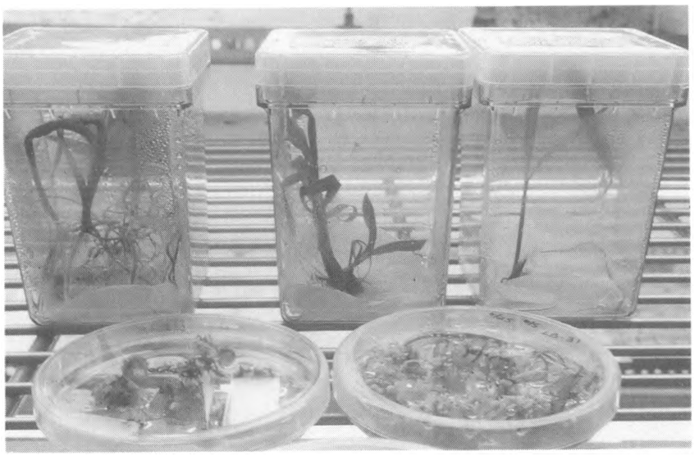
This volume gives the reader a flavor of the meeting and, in Part I, a synopsis of the viewpoints presented, issues discussed and recommendations generated. For the reader who wants more in-depth information, the keynote addresses defining public good are found in Part II, while the background papers and workshops reports on global interdependence are found in Part III. Parts IV through VI include background papers and full reports from the workshops on *Setting the Agricultural Biotechnology Agenda, The Structure of Agriculture* and *Environmental Stewardship,* respectively.

Hopefully, this volume will contribute to not only increased understanding of the many issues and viewpoints and background for improved dialogue, but also provide a foundation for addressing issues of public good related to agricultural biotechnology.

June Fessenden MacDonald
Executive Director, NABC

CONTENTS

PART i: AGRICULTURAL BIOTECHNOLOGY
AND THE PUBLIC GOOD



NABC 6: An Overview

Michael F. Thomashow
NABC 6 Planning Committee Chair
Crop & Soil Sciences and Microbiology
Michigan State University
with
Loren A. Mooney
NABC Staff

The agricultural biotechnology revolution is upon us! On May 18, 1994, the U.S. Food and Drug Administration (FDA) approved the first genetically engineered food product for commercial sale, Calgene's Flavr Savr™ tomato. And dozens of other products are in the pipeline. Indeed, biotechnology has arrived with the potential to provide a vast array of new agricultural products. But is this powerful technology developing along lines that are in the best interest of the public? This was the central unifying question addressed at the National Agricultural Biotechnology Council's (NABC) sixth annual meeting, *Agricultural Biotechnology & the Public Good,* held at Michigan State University, East Lansing, Michigan on May 23-24, 1994. The timeliness of the meeting, which took place just five days after the FDA's approval of Flavr Savr™ tomato, was evident from the lively, and at times passionate, discussion. Also, there were a record number of registrants, 190, who came from eight countries and 25 states. Participants were a diverse group: farmers, processors, environmentalists, educators, consumers, journalists, academic and industrial scientists, economists, sociologists, administrators, government agency professionals and outreach specialists.

A major highlight of NABC 6 was the in-depth discussions and recommendations about international aspects of agricultural biotechnology. This was the first NABC meeting to specifically address the global nature of agriculture. Given the importance of the topic and response to it, it seems certain that the subject will be included in future NABC meetings. Indeed, some 60 issues were identified by the workshop participants as being important to the international agriculture community. From this set, eight comprehensive key issues were formulated and discussed in depth. These ranged from ownership and access to germplasm; to the social, economic and political impacts of agricultural biotechnology on developing nations; to the need for more unified biosafety standards. As stated by Richard Sawyer, President, International Fund for Agricultural Research and President, Fundacion Peru, "We are globally interdependent with our problems and we must be globally interdependent with our solutions." The land-grant universities and research institutions that are members of NABC have roles in developing such solutions. A continuing dialogue on global agricultural biotechnology at future NABC meetings should contribute to the process of developing these solutions.

As with previous NABC meetings, NABC 6 consisted of plenary sessions, which were open to the public at no charge, and workshops. The workshops, the participatory exercises that have become the heart of all NABC meetings, gave registrants an opportunity to discuss key issues in depth and formulate recommendations. Plenary speakers provided a wide range of opinions on the concept of public good in terms of biotechnology achievements and potential future developments, and their presentations succeeded in sparking lively participation from the audience. Robert Fraley and Ralph Hardy described current and future biotechnology products and their potential to increase the public good. They placed consumer preference characteristics high on their agenda for increasing public good and stressed potential health benefits to be gained from future biotechnology products. James Cook and Hope Shand supported the idea that biotechnology can have enormous positive impact on public good, but both cautioned that policy issues are critical in determining who benefits from the technology.

As noted by Hope Shand, it is impossible to discuss current and future biotechnology without considering the global perspective, both in terms of the global impact on public good and the transfer of technology across national boundaries. John Dodds and Magdy Madkour discussed projects they are involved in which work to facilitate technology transfer between institutions and between nations. Their respective programs strive to aid developing countries in the implementation of plant biotechnologies for the good of the developing nation. Jose de Souza Silva presented his view of how biotechnology has begun to have international impact. He expressed concern about policy issues and their potential impact on developing nations and suggested possible policy strategies to insure that biotechnology truly does promote international public good.

The after-dinner address at this year's meeting was given by Deborah Fitzgerald, Historian and Professor of Science, Technology and Society at MIT. In her insightful and stimulating talk, entitled *Choices from the Past,* she discussed how technology is related to the culture that creates it. She noted, as did other speakers at NABC 6, that biotechnology, while being labeled as a new scientific phenomenon, is actually the latest in a continuum of technological advances. New technologies, she said, along with scientific "reductionism" and a single-minded concern with production, has limited consumer and producer options. New scientific advances have "replaced rather than joined" the old technology, she said. As a prime example, Fitzgerald cited the U.S. Department of Agriculture's (USDA) discontinuation of funding for research on open-pollinated corn after the development of hybrid corn in the 1920s. She stressed that it is vital to "keep old strategies available," to keep creativity in research and development and "to reward innovation" instead of narrowing options if one is to serve the public good.

Eight workshop speakers (two per workshop) presented a variety of viewpoints, indeed sometimes opposing perspectives, about the idea of public good especially relating to the environment; policy; setting an agenda, both nationally and internationally; and public participation. The highlights of the plenary and workshop sessions are summarized below.

PLENARY SESSION HIGHLIGHTS

There were three plenary sessions: *Current and Next Generation Agricultural Biotechnology Products, Biotechnology and the Public Good* and *Agricultural Biotechnology in Developing Nations.* In these, the invited speakers discussed the nature of present and future agricultural biotechnology products and presented a wide range of opinions on the effects that agricultural biotechnology might have on society and agriculture. These presentations sparked a series of spirited question and answer periods which, on a few occasions, included heated dialogue and pointed challenges. Areas of particular concern for certain members of the audience were negative effects that agricultural biotechnology might have on human health and the environment, and whether or not biotechnology can truly bring universal benefit to developing countries. These were critical issues that some participants felt were being glossed-over by the agricultural biotechnology establishment. Though these interactions were emotion-filled, they, along with the plenary presentations, were immensely fruitful, bringing important issues out on the table for consideration. A principal objective of the NABC meeting is to provide an neutral forum for persons with different interests and concerns to participate in meaningful dialogue on issues regarding agricultural biotechnology. This objective was met in full at NABC 6!

Current and Next Generation Agricultural Biotechnology Products

Robert T. Fraley, Group Vice President and General Manager, New Products Division, Monsanto Agricultural Group and Ralph W.F. Hardy, President and CEO of the Boyce Thompson Institute for Plant Research, Inc.

Robert Fraley began his talk by noting that the world's population is expected to double over the next 40 years. To feed this growing population using current agricultural practices, the amount of land used for agriculture would have to be expanded from a land mass about the size of South America, the current land usage, to that of Eurasia. Given this scenario, the benefits of increasing agricultural productivity per acre are obvious. Fraley said that biotechnology is not a panacea for increasing agricultural productivity, but does provide a powerful new tool, in a continuum of improved methods, to expand agricultural potential while minimizing environmental impact. He stressed the benefits of forthcoming biotechnology products such as better insect- and weed-resistant crops and the development of animal growth promoters. Biotechnology will also lead to new opportunities in food processing such as new flavors, food textures and storage properties, and for the improvement of health. There are all kinds of possibilities, he said, including making plant oils specifically designed to reduce health problems associated with some of the oil products today, or removing natural carcinogen from a food. He noted, though, that there are controversial dimensions to biotechnology. While federal agency approval has come relatively quickly, public acceptance remains uncertain. To increase the likelihood of public acceptance, Fraley believes that arguments about biotechnology need to be made rationally, using sound science, rather than appealing to consumer emotion.

The next speaker, Ralph Hardy, said that the highest priority in achieving public good in the U.S. is freedom of choice. He noted, though, that the opportunity to choose carries with it the responsibility to keep informed. "This challenges the agricultural biotechnology community to provide the information necessary for decision-making," he said. Hardy stated that after freedom of choice, the U.S. public places human health, economics, the environment and sustainability high on their public good list. Present and future biotechnology products with enormous potential for public good include: chymosin, DNA probes for food-based microbial contaminants, self-nitrogen fertilizing plants, biodiesel and biopolymers, transplant organs in transgenic animals, and oral vaccines incorporated into fruits or other foods, he said. But a major obstacle for biotechnology continues to be the transition from technology to marketable product, a process Hardy referred to as the "valley of death." He offered the USDA's Alternative Agriculture Research and Commercialization (AARC) project as a model program designed to help bridge that gap. The AARC program provides funds for precommercialization development of new non-food uses of agriculture and forestry materials and requires a financial return to AARC based on the success of the project. It is in this way that AARC intends to become a self-sustaining program.

Biotechnology and the Public Good

R. James Cook, Chief Scientist, USDA-NRI Competitive Grants Program and Hope J. Shand, Research Director, Rural Advancement Foundation International.

James Cook, like Fraley and Hardy, placed consumer demand high on the agricultural agenda importance list. He suggested that scientists' touting of biotechnology as a powerful new technique, rather than as the latest step in the development of tools for agricultural research, has contributed to public mistrust of biotechnology. In order to emphasize a technological continuum, Cook outlined the importance of previous innovations in genetics and breeding which spawned such widely accepted products as seedless grapes and Russet Burbank potatoes. He said that the primary concern with biotechnology is who will benefit, and that public policy should focus on public gain. He expressed concern that "the number of plant breeding programs supported by the USDA and State Agricultural Experiment Stations is on the decline" and that private sector researchers might take over and fund products with large profit potential to the neglect of local projects. Recent developments in intellectual property rights may restrict access to resources and trade for the public good, he noted. Cook concluded that the technology itself has great potential for public benefit, but that the application can lead to misappropriation of benefit.

Hope Shand, describing herself as a critic, but not an opponent of biotechnology, agreed with James Cook that the central issue is "who will control these technologies and who will benefit from them." The "genetic interdependence" of the world makes a discussion of biotechnology without keeping the global scope in mind inadequate, she said. Global genetic diversity is important to maintain the capacity for new crop development and food productivity. Her main concerns were the shrinking of biodiversity and the possibility that those providing genetic resources for biotechnology, mainly farmers and citizens from developing nations, may be denied proper credit and compensation.

Shand then presented her view of how financial potential has led to injustice in patenting, access and trade of new biotechnologies and products. According to Shand, a "biopiracy" has developed in which companies patent as a reward for research investment while "farmers and consumers of the developing world have to pay royalties on products which are based on their own biological resources and knowledge." She cited thaumatin, a super-sweet protein made by certain plants in West Africa that is being developed by Lucky Biotech Corporation, as an example. In conclusion, Shand shared Cook's opinion that biotechnology products are not dangerous to human health, but that the possible economic and environmental impacts of biotechnology deserve serious consideration.

Agricultural Biotechnology in Developing Nations

John Dodds, Managing Director of the Agricultural Biotechnology for Sustainable Productivity (ABSP) project, Michigan State University; MagdyA. Madkour, Director of the Agricultural Genetic Engineering Research Institute (AGERI) in Egypt and Josie de Souza Silva, Head, Brazilian Public Enterprise for Agricultural Research (EMBRAPA), Secretariat for Supporting State Agencies for Agricultural Research.

John Dodds described how the project that he directs, Agricultural Biotechnology for Sustainable Productivity (ABSP), attempts to meet the various agricultural needs of developing nations. ABSP works with the scientists of developing countries to solve local agricultural problems using public and private sector resources from universities and corporations. ABSP "promotes interaction among institutions and individuals," with emphasis placed on the development of insect- and virus-tolerant crops. Dodds stressed that the transfer of information to developing countries does not stop with the technology itself. ABSP representatives collaborate with developing country officials and managers to draft international agreements including specification of licensing and intellectual property rights, and the development of biosafety regulations.

In one program ABSP collaborates with is the Egyptian Agricultural Genetic Engineering Research Institute (AGERI) in Egypt which is directed by Magdy Madkour. Madkour discussed the need for agricultural biotechnology in Egypt and other Middle Eastern and African countries highlighting AGERI's role in efforts to implement biotechnologies. AGERI attempts to expand and diversify agricultural biotechnology and train professionals with the goal of applying new technologies to agricultural challenges in Egypt, he said. He outlined a number of ongoing projects such as the development of *Bacillus thuringiensis (Bt),* transgenic pest-resistant cotton, transgenic virus-resistant potatoes and the mapping of the rapeseed genome to identify genes involved in environmental stress-tolerance. AGERI works from the developing country perspective to promote institutional linkages both within Egypt and between nations.

Jose de Souza Silva asserted that the global and multidimensional phenomenon of the biorevolution, while having the potential to provide many benefits, poses problems for developing nations. While programs like ABSP and AGERI are empowering for developing nations, they may not be enough to ensure widespread public good as a result of biotechnology. One concern was that biotechnology will indeed increase agricultural efficiency and productivity, but in turn cause a dissociation of agriculture from food production, he said. The changing nature of production could displace agricultural work forces, rendering the agricultural systems of many developing countries, and even entire economies, antiquated and ineffectual, de Souza Silva further claimed that profit-minded scientists are imposing agricultural colonialism on less developed nations and that there are contradictions between the rhetoric and practices of the biotechnology industry in developing countries. Proponents claim biotechnology is a solution to world hunger, yet hunger persists because "excess does not equal access," he said. He also suggested there was a disparity between the social goals extolled by the biotechnology industry and the private gains it seeks. For instance, there is the "cooperation-competition" paradox in which the biotechnology industry claims the need for international sharing of resources and technology, yet industries and nations have become more competitive with each other regarding intellectual property. In closing, de Souza Silva suggested a number of agricultural biotechnology policy strategies for developing countries to help preserve the public good in their nations: expand their own biotechnology industries, keep their own resources, develop national bargaining power, cooperate with tropical country policies to increase "South-South" solidarity, strengthen public sector biotechnology projects to benefit local areas, and make investment policies in science education.

WORKSHOP HIGHLIGHTS AND RECOMMENDATIONS

The plenary sessions provided the framework for four workshop sessions: *Setting the Agricultural Biotechnology Agenda, Biotechnology and the Structure of Agriculture, Agricultural Biotechnology and Global Interdependence* and *Environmental Stewardship and Agricultural Biotechnology.* Workshop participants discussed a variety of topics related to public good, ranging from the strengths and weaknesses of processes used to set the biotechnology agenda to the impacts of agricultural biotechnology on the farming community, the environment and the agriculture of developing nations. These discussions resulted in the identification of numerous key issues and the formulation of recommended actions to be considered by government agencies, concerned citizen groups, corporations, universities, research institutes and the general public. While the list of workshop recommendations is quite diverse, a central theme does emerge: a need for greater public participation in decision-making about agricultural biotechnology and a need to better inform the public about the agricultural biotechnology issues. In fact, fully half of the recommendations made by NABC 6 workshop participants relate to either greater public participation, greater public understanding or better dissemination of information regarding agricultural biotechnology. As concluded by those people in the workshop on *Setting the Agricultural Biotechnology Agenda,* decisions about the application of biotechnology are more likely to be for the public good when there is a greater participation by an informed public. The NABC 6 workshop recommendations provide suggestions for how to accomplish this goal.

Setting theAgricultural Biotechnology Agenda
(see p. 157 for complete report)
Co-chairs: Thomas L. Thorburn, Program Director, Food Systems, Rural Development and Water Resources, Kellogg Foundation and Patricia Traynor, USDA National Biological Impact Assessment Program Coordinator, Michigan State University.

Speakers: I. Garth Youngberg, Executive Director of the Henry A. Wallace Institute for Alternative Agriculture and Susan Offutt, Executive Director of the Board on Agriculture, National Research Council.

Setting the stage for workshop discussion, Garth Youngberg described various public and private "dialogues"—conferences, papers, organizational activities, pronouncements, etc.—that have been vital for the agricultural community's acceptance of biotechnology. The next step, he said, is to promote public participation in order to involve the public in the planning and decision-making phases of biotechnology research and development. As one of the founding principles of the U.S., direct citizen involvement in policy issues would not be a radical step for biotechnology, he said. He suggested that companies take a serious look at how to bring farmers, public interest groups and other citizens into strategic agenda planning. He said that incorporating producer and consumer ideas into the agenda "would result in more comprehensive and enlightened planning" and would lead to public support of agricultural biotechnology rather than mere acceptance.

Next, Susan Offutt discussed how to improve the decision-making process used to set the agricultural biotechnology agenda. Traditionally, she said, market forces such as profitability and consumer demand tend to direct innovation. Quality, safety and efficacy are market criteria currently considered in agenda setting. But with biotechnology, this process needs to be modified to include consideration of non-market aspects of technology adoption and use, or "the fourth criterion," she said. Socioeconomic and environmental impacts of agricultural biotechnology are being evaluated alongside market factors.

She cited recent debates in the U.S., Europe and Canada about bovine somatotropin (bST) as examples of how the agenda-setting process has expanded.

The fundamental conclusion that emerged from participant discussion was that participatory decision-making was essential to ensure that applications of biotechnology served the public good. The approximately 50 participants thought that reaching this goal would require improvements in three key areas: public participation; availability of information; and implementation of an accessible, equitable and consistent regulatory system.

Recommendations

Public Participation

There is a need to increase public participation in both public and private sectors of the agricultural biotechnology community to create an agenda-setting environment (process) that more accurately reflects the diversity of values, interests and priorities in our society. Recommendations that were strongly supported by the entire workshop group were:

Review and assess existing public and private advisory structures and modify them as necessary to ensure representative input into the development of the agricultural agenda including biotechnology applications.

Review and define the mechanisms for establishing truly responsible public participation with input focusing on broad areas of societal concern that may benefit from agricultural biotechnology.

Encourage the integration of environmental and social sciences into biological sciences programs.

Availability of Information

Participants concluded that the promotion of ready access to, and active dissemination of, information relevant to agricultural biotechnology issues would not only enhance public awareness, but it may be the first step in establishing a system of feedback between the public and those who set the biotechnology agenda. The following recommendations were strongly or unanimously supported:

Send a representative to the National Association of Biology Teachers (NABT) and the National Science Teachers Association (NSTA) annual meetings to provide a list of resources and experts in agricultural biotechnology that teachers may contact locally.

Include agricultural biotechnology in K-12 science curricula.

Develop an agricultural bioethics course for land-grant institutions and establish it as a requirement for USDA training grant programs.

Continue and expand research on risk assessment and the socioeconomic impact of agricultural biotechnology.

Regulations

The group felt that it was important to implement a regulatory system that was accessible, equitable and consistent. However, there was only one recommendation that was strongly supported by the group:

Implement prior recommendations on regulations put forth at the NABC 4 meeting in 1992 (see page 160).

Three other recommendations were highly controversial:

Codify statutory requirements for socioeconomic analysis (about half supported, half opposed).

Require that regulators consider equitable allocation of intellectual property rights so that the regulatory process includes consideration for individual compensation (about half in favor, half opposed).

Establish a single regulatory agency clearinghouse monitoring Environmental Protection Agency (EPA), FDA and USDA for biotechnology applications (majority strongly opposed).

There was concern about creating another level of bureaucracy that could undermine existing authorities). Clearly, regulatory issues remain an important, but thorny area of agricultural biotechnology.

Biotechnology and the Structure of Agriculture
(see p. 173 for complete report)
Co-chairs: Frederick H. Buttel, Professor of Rural Sociology, University of Wisconsin and Tom Guthrie, Farmer and Vice President, Michigan Farm Bureau.

Speakers: Dean Kleckner, President, American Farm Bureau Federation and William P. Browne, Professor of Political Science, Central Michigan University.

About 60 participants in this workshop heard Dean Kleckner outline the farmer's role in food production. He spoke with pride about how family farmers are responding to marketplace forces that demand greater efficiency while remaining responsive to consumer preferences. A consequence, however, has been a trend towards larger farms and a change in the structure of agriculture. Kleckner suggested that world population growth will make it necessary for American farmers to become even more efficient, to produce more and to rely more on science-based advances such as those now beginning to come from biotechnology. But even with farmers' increased use of biotechnologies and the trend towards "industrialization," there is still a place in American agriculture for traditional, individually owned farms, Kleckner said. Along with challenges, biotechnologies create new profit opportunities, he said. With effective public policy and continued response to consumer demand, farmers can prosper in the age of biotechnology.

William Browne discussed possible public policy strategies in response to biotechnology. The most important factor in predicting public policy trends is policymaker perception which is based on information available to them, he said. Members of the U.S. Congress and other federal policymakers, he noted, are concerned that biotechnology might increase structural inequities in agriculture, enabling the big producers to get even bigger and putting the smaller producer at a greater disadvantage. However, Browne suggested that the decision makers are not sure how, or if it is wise, to stop the process.

Many policymakers hold out hope that biotechnology can lead to large profits for the agricultural sector and new production methods such as biopesticides and biofertilizers, that may help resolve conflicts between farmers and environmentalists, he said. For these reasons Browne predicted that most policymakers will be inclined to take a "hands-off" approach with regard to new regulations on the applications of agricultural biotechnology. Consolidation and the structural imbalance in agriculture will continue, Browne suggested, and there will be little political debate to stop this trend.

A number of key issues were raised and discussed by the workshop participants. There was a general consensus that agriculture must be responsive to the consumer, that there must be equitable access to biotechnology, that biotechnology will contribute to the continuing vertical integration of the food system, and that a system for analyzing long term impacts of biotechnology on the structure of agriculture must be developed. Many of the workshop participants also felt that there needs to be a balance between the necessity of increased economic performance and social equity. There was concern that new technologies might accelerate the trend toward the industrialization of the food system resulting in a further decline in self-employment, an increase in the scale of production, a growth in specialization and vertical integration, and decreased control by farmers and consumers within the food system. However, other workshop participants, while sympathetic with equity concerns, thought that the efficiency, coordination and competitiveness of the food system were the most important criteria. Several participants expressed the opinion that a food system that produces safe food in an efficient manner is the most equitable system from the larger societal standpoint.

Recommendations

After discussing key issues, participants developed and strongly supported the following recommendations:

Equity of Access to Biotechnology Innovations

It was concluded that decisionmakers must insure the widest possible access to biotechnology so that it does not, itself, come merely to validate, or contribute further to, the structural imbalances in the agriculture and food system.

Provisions are needed to take into account the costs incurred in regulatory procedures in the creation of products/processes for minor/local uses.

The utility patent system was not designed with plants and animals in mind. There is a need for a new Intellectual Property Rights (IPR) system designed specifically for living organisms, or parts thereof. The new system should balance profit with the public desire to encourage invention in general.

There is a need to strengthen public sector research and technology delivery systems.

A forum involving all stakeholders needs to be created in which issues of international access are discussed and attempts at resolution are made.

Vertical Integration of the Food System

Participants believed that biotechnology will contribute to greater vertical integration in the food system. They recommended that:

Land-grant universities should be encouraged to form public/private partnerships to encourage the use of biotechnology and to develop products.

Land-grant universities should remain neutral in the debate on vertical integration in the food system.

Land-grant universities should increase public good research for which there is an inadequate profit motive.

Land-grant universities should seek a broader support base for public good research.

Responsiveness to the Consumer

Participants agreed that agriculture as part of the food system needed to be responsive to information needs. There was no disagreement with the recommendation that:

Information should go out to both consumers and producers.

Two other recommendations on the development of national standards for clear communication and guidelines for information on labels, in brochures and by the media received little support.

Evaluation of Long-Term Impacts

The participants concluded that there is a need to evaluate the long-term impacts of biotechnological innovations in research and product development on the structure of agriculture. They recommended (but with strong disagreement by four participants) that:

Land-grant colleges or equivalent institutions should take the lead in convening broadly representative stakeholders to develop standards and procedures for the long-term sustainability of the agriculture and food system. These principles should be applied to all levels of the system. A wide range of criteria—sustainability, health and safety, and social and economic equity—should guide these evaluations.

Agricultural Biotechnology and Global Interdependence

(see p. 139 for complete report)

Co-chairs: W. Ronnie Coffman, Associate Dean for Research, Cornell University and Jim Germida, Professor of Soil Microbiology, University of Saskatchewan.

Speakers: Richard L. Sawyer, President, International Fund for Agricultural Research, and President, Fundacion Peru and William H. Lesser, Acting Executive Director, International Service for the Acquisition of Agri-biotech Applications AmeriCenter.

The workshop began with Richard Sawyer and William Lesser discussing public good issues of importance to the international agricultural community. Sawyer asserted that the ever-increasing human population poses a fundamental problem for agriculture. He noted that with grain stocks at the lowest levels since 1972 and fish catches decreasing, we are becoming increasingly dependent on land resources for food. He said that agricultural biotechnology can be a force to help Earth sustain the population, but it is difficult to apply and its potential is hindered by the low priority given to agriculture by governments. He suggested that those in agricultural science have not adequately prepared the global community for the importance of biotechnology products; it is necessary to promote these products in a language that all members of society, both in developing and industrialized nations, can understand. Sawyer concluded by asserting that it is essential for biotechnology to be universal.

Lesser then focused on intellectual property rights and the flow of technology and resources between nations. The private sector provides two-thirds of the funds for biotechnology research worldwide with many of the products of this research ultimately delivered in seed, he said. Intellectual property rights are a key means of private sector compensation. Some 70 developing countries are working to enhance intellectual property rights over the next few years, but more than 30 developing countries do not permit patents on plant and animal research. This poses problems for the free-flow of technology and resources. Lesser suggested that the private sector needs to formulate a clear position toward developing countries with regard to the choices and consequences of technology transfer. He stressed the importance of educating the public about intellectual property rights and for developing international intellectual property rights policy to reflect global interdependence.

Recommendations

Equity, Rights and Access

To ensure access to new biotechnology products and resources and to protect equity and intellectual property associated with these technologies, the following strongly supported recommendations were made:

Harmonize existing or develop new systems of Intellectual Property Rights (IPR) which will maximize access to biotechnological and genetic resources while providing equitable compensation to developers of biotechnology and countries of germplasm origin.

As *a supplement to such negotiations, multi-country agreements based on existing, successfully operating systems, e.g., EPO (European Patent Office) and UPOV (International Union for the Protection of New Varieties of Plants), should be established between groups of developing nations to facilitate handling of IPR.*

One mildly controversial recommendation was put forward:

Extreme variation exists in the political and economic status between and among developed countries and developing countries. Therefore, material and intellectual property transfer agreements must now be negotiated on an individual basis between political, academic and industrial institutions. A nonpartisan international panel is needed to address grievances derived from such negotiations.

Institutional Linkages in Capacity Building

To speed the development of tools of biotechnology, and given the importance of linkages in their transfer to solve the problems of food and environment globally, the following strongly supported, multi-part recommendation was made:

NABC should:

- *broaden its base to include other countries and regions*
- *gather information on databases regarding biotechnology on an institutional basis and make it available to the membership*
- *encourage multidisciplinary team-building in the broadest sense*

Socioeconomic

To protect the health, safety and economy of producers and consumers the following unanimous recommendation was made:

An ex ante *and* ex post *system, comprised of representatives from public institutions, agribusiness, consumers and producer groups is needed to assess the potential impacts of biotechnology products and processes on:*

- *the environment*
- *food production and prices as well as consumer acceptability*
- *wealth distribution*
- *farmers/labor*

and identify ways to:

- *reduce negative environmental impacts*
- *compensate disadvantaged groups*
- *train agriculturists in the proper management of biotechnology products/processes*

Environmental Stewardship

(see p. 195 for complete report)

Co-chairs: Richard Harwood, C.S. Mott Professor of Sustainable Agriculture, Michigan State University and Jerry DeWitt, Associate Dean for Extension, Director to Agriculture, Iowa State University.

Speakers: John Bell Clark, Biochemist and Organic Farmer, Roseland Farms, Michigan and Sandra S. Batie, Elton R. Smith Professor of Food and Agriculture Policy, Michigan State University.

John Clark began the workshop by admonishing those in biotechnology to use extreme caution when transferring products from the laboratory to the field and to marketable product. Environmental impacts have been predicted, he said, but no large-scale evidence exists to insure environmental safety and human health. He stated that to view biotechnology as a "silver bullet" cure for agricultural challenges is to engage in inappropriate scientific reductionism. Several biotechnology products present inadequate solutions to agricultural problems or address "non-problems." And institutions such as corporations, and even universities, are pushing technology into marketable products as fast as possible because of potential financial gain, Clark said. He went on to suggest that "without holistic (cradle to grave and beyond) analysis of its products, this industry is doomed to failure."

Sandra Batie urged, as did Clark, that biotechnology products should be carefully scrutinized before approval, noting that the environment could pay the price for hasty decisions. She agreed that biotechnology has the potential to enhance pubic good and benefit the environment, but that critics have legitimate counter-arguments which frame the biotechnology debate. For example, critics doubt the environmental motives of profit-minded corporations pushing herbicide-resistant crops and believe instead that such crops will lead to the use of more, not less, herbicides. Some also claim that developing nitrogen-fixing, or herbicide- or insect-resistant plants may unpredictably change the ecosystem and have unforeseen environmental consequences, Batie said. Much of the argument about biotechnology and the environment has not centered on risk, but instead, on who should bear the burden of any costs to the environment. She asked, "Should biotechnology products be readily approved for use, placing the burden of error on the environment? Or should the products be very cautiously screened, placing the burden of error on the inventors and users of the products?" Public participation in this debate is essential, she said.

The 40 workshop participants engaged in broad discussion on a variety of issues related to the environment and biotechnology. One area of strong agreement was that the public should be involved in safety and environmental considerations of biotechnology with public education playing a vital role. There was also agreement on the importance of integrated production systems (IPS) in minimizing adverse environmental impact from agriculture, although there was disagreement over the degree to which such integrative effects could be maximized. A major concern raised about biotechnology was the possible reduction of diversity within production systems and the possibility that greater genetic or cultural uniformity could lead to increased risk of pest or pathogen outbreak. The group strongly agreed that the goal of biotechnology should be to increase the options available for farmers and farming systems, not limit them.

After discussion of the key issues, recommendations were formulated in three areas: integrated production systems, environmental impact, and education and communication. There was also a strong consensus that assessment of long-term impacts of agricultural biotechnology on the environment is essential, but there was little agreement on how this could be achieved, and thus, no recommendations received group support.

Recommendations

Integrated Production Systems

There is a need for both scientists and farmers to know how and when to use biotechnology products in IPS. The following recommendations received strong, but not unanimous, support.

The public sector should fund and conduct more systems research and testing on the potential positive and negative environmental, economic and social impacts and consequences of biotechnology products. The results of the research *must be effectively communicated to producers and consumers in a timely and objective manner (as results are available).*

Cooperative Extension Service directors and other appropriate public agency administrators should be given a mandate to devote resources to assist producers in a manner consistent with environmental stewardship (e.g., through comprehensive crop and animal management advancement programs that deal with whole-enterprise management and offer continuing educational update). Biotechnology options should be presented within this systems framework.

Environmental Impact

Agricultural biotechnology carries with it social and political implications. Therefore, it is imperative that a public role be recognized in the debate over areas where biotechnology should be focused and how its products should be incorporated into sustainable agricultural systems. Moreover, the public must be involved in the consideration of safety, of environmental protection and/or stewardship, and the myriad social issues. Participants strongly supported the following recommendations to improve agricultural products and benefit society, scientists working on biotechnology products should:

Identify, evaluate and anticipate risks prior to release. Safety claims should be supported with both public and private research. Assessment criteria should be used.

Focus on development of agricultural biotechnology processes and/or products that will promote long-term environmental health by:

- *maintaining biodiversity*
- *enhancing soil, water and air quality*
- *increasing reliance upon renewable energy sources.*

Recognize the public's concern for this new technology and work with them to understand its complexity and potential.

Bring biotechnology products to the market with reasonable expectations.

Public and private funding institutions, including USDA, EPA, NIH (National Institutes of Health) and private foundations should:

Take action to identify means and instruments to promote biodiversity as a key objective of publicly-conducted agricultural biotechnology research and development.

Education and Communication

Enhanced education and communication about the role of agricultural biotechnology in environmental stewardship will require major public effort. The goal would be to improve the ability of diverse groups to participate in the decision-making process about the impacts of biotechnology and to increase their involvement in environmental stewardship. A majority of participants favored the recommendations in this area, but there was some dissent based on the broadness of the recommendations.

The Cooperative Extension Service and the Agricultural Experiment Stations, under the auspices of the National Agricultural Biotechnology Council (NABC), should form a committee to develop a public education plan for biotechnology education.

- *the participants should include grassroots members of various communities: consumers, producers, activists, local government, media, retailers, extension staff members and educators.*
- *the subjects of the workshop/focus group discussions should include a base of information about the environmental issues and solicit reaction to these issues from the participants.*
- *the information gathered at these workshops should be accumulated by NABC and published for distribution to statewide and national decisionmakers.*
- *special effort should be made to package and distribute this information to K-l2 educational institutions.*
- *the committee should reconvene each year for a minimum of two years and then review accomplishment each year after at the discretion of the workshop/focus group.*
- *this effort should lead to a systematic and sustained educational plan to help the public debate and understand the issues surrounding agricultural biotechnology.*

SUMMING UP

NABC 6 concluded with a final panel session in which four NABC Council members summarized their thoughts about the meeting *(see following paper, p. 21)*. Expressing what has become a common view of first-time attendees, Peter Day, Director of the AgBiotech Center at Rutgers University, said that he approached the workshops session with mixed feelings. “I didn’t know what we were going to talk about and I was doubtful that we would have a product that was interesting,” he said. “I was wrong. The conversations were sparkling and interesting. Once we got to know each other, there was free exchange which was extremely important. It emphasized to me what NABC is all about—open dialogue and listening to other people.” Larry Milligan, Vice President for Research at the University of Guelph and also a first time attendee, had similar thoughts and stressed the value of speaking with people who are not within his usual realm of interaction.

Pleased with the productive workshop discussions and the wide scope of views expressed, panelists reiterated several recurring themes from the meeting. Bobby Moser, Vice President for Agriculture at The Ohio State University, commented that, regardless of the topic at hand, discussion ended up focusing on three similar issues: economic feasibility, environmental impacts, and the social impacts and acceptability as biotechnology reaches the consumer. He predicted that the same three issues will continue to be critical ones for the future. This was also noted by Patricia Swan, Vice Provost for Research and Advanced Studies at Iowa State University, who placed this sixth annual meeting in context with previous NABC meetings. She said that four themes dominated discussion at this annual meeting: 1. access to technology; 2. rights to biological material; 3. the integration of social, economic and environmental issues; and 4. growing concern about public participation in agricultural biotechnology discussions. As her fourth NABC experience, this meeting, she noted, represented a turning point in the agricultural biotechnology dialogue, a shift from preliminary questions and speculations to broader issues and a broader concept of the agricultural sector. Finally, panelists offered a challenge to participants: to take back to their daily lives their personal NABC experience, to expand the circle of dialogue on agricultural biotechnology, and to work to implement the recommendations they had developed.

The meeting concluded with a request from a member of the audience that NABC further address the issues raised at NABC 6, especially those concerning public access to new agricultural biotechnologies. Recognizing this concern as a major issue, the NABC Council, at its meeting preceding NABC 6, had endorsed the theme proposed by the University of Missouri, Columbia for NABC 7, *Genes for the Future: Discovery, Access, Ownership.* When announced, the audience felt this was clearly an appropriate and timely topic. Indeed, NABC 6 was only a beginning; the work has just begun.

Looking to the Future

Peter R. Day
Director, AgBiotech Center
Cook College, Rutgers, The State University of New Jersey

Bobby D. Moser
Vice President for Agriculture
The Ohio State University

Larry P. Milligan
Vice President for Research
University of Guelph

Patricia B. Swan
Vice Provost for Research and Advanced Studies
Iowa State University

The concluding plenary session at the Sixth Annual National Agricultural Biotechnology Council Meeting was a panel presentation by representatives from four NABC member institutions: Iowa State University, The Ohio State University, University of Guelph and Rutgers, The State University of New Jersey. Each panelist discussed their impression of the NABC meeting from their perspective as a participant and what they as individuals expected to take away from the meeting. Their remarks seemed to express the feeling of many of the other attendees.

SPEAKER: PETER DAY

What did I learn? This was my first NABC meeting and I learned a great deal from it. Like many of you, perhaps, I approached the workshop sessions with mixed feelings. I had not met most of the individuals I was going to be talking with and knew little or nothing about them. I did not know what we were going to talk about and I was doubtful that we would have a product that was interesting. I was wrong. The conversations were sparkling and interesting. Once we got to know each other, there was a free exchange which emphasized to me what NABC is all about—open dialogue and listening to other people. I congratulate our hosts on the structure they imposed on the workshops. The dynamics of the small groups were good, and the discussions went very well.

I am not going to discuss the workshop conclusions, but I would like to say a few things about the plenary sessions and the overall impressions that I am carrying away. We had two interesting and alluring perspectives, from Robert Fraley on food and feed products, and Ralph Hardy who emphasized non-feed, non-food products like human organs, oxygenated gasoline, and other exotic things that are around the corner. One area that was not mentioned in the non-food, non-feed area is the potential for biotechnology in environmental bioremediation. There was little mention of biotechnology applied to microorganisms other than means of combating them by engineering resistance into host plants. Microorganisms are important. We tend to think only of the risk of released microorganisms and overlook the benefits that microorganisms afford in the environment and how we can do more with them.

Another thing I thought important, and Jim Cook focused our attention on it, was to stress that agricultural biotechnology is part of a continuum. I would put it in a slightly different way. In some respects agricultural biotechnology is like the icing on a cake; it is the most visible part of agricultural change and as a result the critics, with some justification, focus on it. But agricultural biotechnology is based on a continually changing system that we all too often take for granted. When we think of the perceived environmental threats of biotechnology we neglect the fact that agriculture has probably had the single greatest impact on the surface of the earth of any human activity. Agriculture's impact is often far from benign. I think of salinization from irrigation, soil erosion, slash and burn agriculture, and so on.

Biotechnology is like working with windows at a computer. You look at the window in front of you which is biotechnology. You forget that it is based on all the other systems that are not on the screen that we tend to take for granted. John Clark, an organic farmer, spoke to our workshop group in a very interesting and provocative way, but I am left wondering why, for example, given the concern for the Flavr Savr™ tomato, we did not give even a small amount of concern to broccoflower when it was first introduced. Those of you who are not familiar with broccoflower may recall that it is a hybrid between broccoli and cauliflower that hit the marketplace two or three years ago.

Another concern arises from Ralph Hardy's interesting account of Ogalala down. I guess your imaginations leapt, as mine did, at the idea of all of those millions of acres planted with milkweed. However, I venture to say that the impact of that unengineered crop planted even on a small fraction of the acreage that Ralph Hardy suggested would have a far greater impact environmentally than the introduction of, say, a mosaic virus-resistant tomato that had been engineered to express a viral-coat protein gene.

I do not want to discount the concern for the products of agricultural biotechnology in the recombinant DNA sense, but ask that we keep a sense of proportion and recognize that we are pounding a nail on the head. The head of the nail is agricultural biotechnology, and let us hope it is tough enough to take the pounding for the body of the nail is agriculture itself.

In the third plenary session, we heard about the opportunities for agricultural development in the developing world. Those opportunities are immense. I was particularly struck by John Dodds' example of a family unit producing 800,000 plant propagules. It was an example of Shoemaker's hypothesis set out in a book he wrote about 20 years ago, based on his experience in Africa, called *Small is Beautiful.* Jos6 de Souza Silva's equation—excess does not equal access— was memorable. Earlier in the meeting, Hope Shand had focused our attention on who is going to benefit from versus who will end up controlling biotechnology and the impact of this outcome on developing nations.

But perhaps the most important thing I am going to take with me is the need for dialogue and education. At Rutgers University we give a course for undergraduates on concepts and issues in biotechnology. One of the things we do is invite the students to play the parts that many of you ladies and gentlemen in the audience have taken at this meeting. Some are assigned roles as industrial scientists, regulators, city officials, outraged citizens, journalists and so on. We encourage them to argue, having provided them with magazine and newspaper articles to consider. It is enlightening, interesting and important. Also, it makes what might otherwise be a dry, esoteric subject come closer to home which is, after all, what NABC is all about.

SPEAKER: LARRY MILLIGAN

This has been my first opportunity to attend an NABC annual meeting. My comments reflect, to some considerable degree, my own individual experience at this particular meeting. First of all, I think that we are at a stage of development in biotechnology that allows for some issues to actually be bigger than life. At the beginning of new developments, anticipation often magnifies many aspects of what you think may be coming down the pipe. Often the anticipation of problems tends to make those problems look really big before they actually, if ever, appear. The anticipation of benefits easily leads to unrealistic expectations. At times, we need to stand back and say: Can we be a little more careful about assessing some of the realities? I think that needs to come out in some of our discourse. Some of the products and processes we are thinking of and some of those alluded to during the meeting really are not yet feasible. They are a very long ways off. We are going to have a long time to see the many intermediate steps with any problem happening and developing before we get these products to the consumer.

Another observation that I have is that we seem to assume a common definition of our topic, but actually we may not all be referring to the same concept. I think sometimes we are not. For example, I have found during the meeting that I am not really certain what is meant by the term "agricultural biotechnology." If we really mean biotechnologies encompassed in agriculture, then that is one thing. But I have encountered the connotation that agricultural biotechnology is genetic engineering, or at least entails only the techniques of molecular biology. This may be a narrower viewpoint than is appropriate. A number of biological technologies are extremely familiar in agriculture and have been around a long time. We will and do develop those technologies. Indeed, I suspect there will be a number of biological technologies with some genetic engineering element involved in them that we are going to soon see coming along and that we will accept them fairly readily. Chymosin, as Ralph Hardy pointed out, is an example of a product we have all encountered but we have heard little about. There are some products that just do not seem to impact on the feelings of people and we use them without much concern. There are others, however, that seem to more forcefully influence our feelings. We have heard about a number of these during this meeting. If, in fact, there is some line of sensitivity within the breadth encompassed by agricultural biotechnology, I think there needs to be focus on that, and its understanding, in order to move ahead.

I suspect the issues that will come up about agricultural biotechnology will, as the future develops, become more focused on specific products and specific outcomes rather than more generally on the techniques of biotechnology as a whole. At the same time, however, I have detected issues at this meeting that may not be unique to agricultural biotechnology per se. With this modern set of tools, we now view some things as intellectual property that we might not have 10 or 15 years ago. Therefore, we have new problems of ethics, conflict and ownership to deal with. This is, however, an outcome of new capabilities rather than an issue limited to only agricultural biotechnology. I am not exactly sure which concerns underlie the feeling by some that agricultural biotechnology per se threatens biodiversity. I think we need to be more precise about what we mean and how we deal with issues.

One of the points that has come up during this meeting that impacts on me very directly and very personally is that of accountability to and understanding by a wider range of the public, particularly at the early stages of our research. I work at a publicly funded institution, and in the agricultural area we have more consultation about our directions in research than any other area of research in Canada. I think in large measure that is probably true in the U.S. as well. And yet, there remains a great deal of public concern about the adequacy of input into research directions and approaches! I think we need to reexamine the effectiveness of our consultation.

As a result of having attended this meeting, I wonder about the future directions of NABC. I have attained value as a result of my attendance, mostly because I was able to learn from, listen to and talk with people who have a range of views that I do not often get a change to interact with—and that is very valuable. But in some ways it is a bit of a luxurious exercise. There were only about 200 of us here. How do we expand the circle? How do we create broader dialogue? Certainly, the Reports from NABC are extremely valuable to me and they need to be continued. I have also learned things that I will take home and will have an impact on what we do at the University of Guelph. And maybe in that fashion the circle is expanded. But there may be other steps that we could think about that would be effective. The experience of the workshops is important because that is where discussion happens. That is where we really exchange views. The need to come to recommendations in the workshops is a vehicle in and of itself that gets you to some point of saying "we can agree." Otherwise, we would be inclined to procrastinate making any decision or showing any position. I do think it is important, though, that in the process of discussion we pay more attention to where those recommendations might go. Perhaps there can be greater influence (again expand the circle) by being sure that we have a place or target in mind for recommendations that come out of the meeting.

SPEAKER: BOBBY MOSER

As I approached this task of looking to the future, I tried to listen to all the workshop groups discussing the topics at hand and attempted to capture the most pertinent topics being discussed. Regardless of the workshop topic, each group came around to talking about some similar kinds of things. I heard discussions about the economics of biotechnology. Is it profitable? Is it economically feasible? I heard discussions about the environmental impacts of agricultural biotechnology. Then I heard discussions about the social impacts and acceptability of that technology as it reaches the marketplace and as it reaches the public. I found them quite interesting because, I believe, regardless of whether you are talking about agricultural biotechnology or all of agricultural research, in the future we will be asking ourselves those same three questions: Is it economically feasible? Is it environmentally sound? And is it socially acceptable? These three questions will prevail as we develop the technology. In the past in agricultural research, we focused some on environmental and social impacts, but mostly on the economic impacts. In the future we will focus more on the last two.

One of the areas of concern raised in all of the workshops was the need for public education and communication. I would like to focus on that in my comments, in terms of how I see what NABC, land-grant universities and colleges of agriculture can do as we look to the future in this particular area. Public education can be directed to a wide audience, from decisionmakers and legislators to the general public.

In terms of the decisionmakers, it is important that we make sure they have the scientifically-based information so that, as the policy decisions are made, they are made with factual information and not with emotions or opinions. Sometimes science does not prevail, as it should. It is important for us, as land-grant universities, colleges of agriculture or groups such as NABC, to make sure that those decisionmakers have the appropriate scientifically-based information at hand.

In terms of education, we have an obligation to try to educate everyone about this area called agricultural biotechnology. As scientists, this is our obligation. Currently, few scientists have public perception of their work on their minds as they develop and transfer genes from one plant to another, but I really think as we look to the future, this issue will become more important. We develop the technology that can be very environmentally sound and be used very efficiently and profitably in agriculture, but if the public does not accept that technology, it will never be used. So I believe public education is very critical to the future of agricultural biotechnology.

All of us at land-grant universities have a mechanism by which we can get this information out, and that is called our extension service. We should not overlook extension; they are dealing with the public on a day-to-day basis. Anytime something gets in the newspaper about bST (bovine somatotropin) or Flavr Savr™ tomatoes or whatever it might be, among the first people to get telephone calls from the public are those in the County Extension offices. That just happened to us in our state, and I am sure in many of your states, with the above two issues. People call the county office asking the questions they have on their minds: Is it safe? Can I use it? How does it affect me? From farmers, questions of using that technology, bST: Is it profitable? Is it safe for the animals? Is it safe for the general public? From the general public asking: If I buy one of these tomatoes is it okay for me to eat it? Extension agents will get more questions directly from consumers than we will at the state level. We need to better use the Extension Service, an arm of our land-grant universities, as a way to facilitate public education. However, before we can do that, there may have to be a period of time when we educate the extension agents in this whole area of biotechnology so they feel comfortable answering those particular kinds of questions. Some of our institutions may need to develop some in-services for the extension agents to get them up to speed in this area so they can communicate intelligently about it. Also, we need more ways to get that information to trainers and teachers at all levels so they can incorporate it into their curricula. We, through NABC, can work together through extension and accomplish a great deal in this area.

It would be good if we had the available resources and information about biotechnology in some sort of a database that could be easily accessible. I do not know if that is feasible or not, but it would sure be great to have it available. With all the computer technology we have today, is that possible? I suspect that maybe it could be if we put our minds together and jointly developed a database that could be easily accessible, that really will address the kinds of questions the public is asking today about these particular issues.

Also, any material on biotechnology ought to be user-friendly. Scientifically-based, yes, but user-friendly, intended for the scientist as well as the nonscientist. What application does it have? How does it affect the real world? Often when we get into our research programs we deal with the science of the research and communicate with one another. But when we are talking to a nonscientist audience we lose the ability to communicate. That is where a lot of misunderstanding and controversy is created because the public does not understand and we, the scientists, have not really taken the time to communicate our science in a way that it can be understood. Development of fact sheets, like those used a lot in extension programs, are very important as a tool to communicate the whys of biotechnology and the ramifications that this technology might have. We need to make a point of working with high school teachers and junior high teachers to develop teacher guides to be used in their science classes. They may know about biotechnology in some ways, but do they know enough to be able to really develop a curriculum to be used in their classes? We need to build on what some have already started.

We need to target audiences such as teachers or extension agents or general consumers and find a way for them to easily access this particular database that we develop. At some point, they can start entering questions they might have. When those public questions come in they can be put into the database and answers provided.

Another important point is to establish an ongoing linkage or communication with extension agents and with teachers, with teachers of teachers, and with other information people. I think that is important, especially as we deal with current issues. Most recently, the most controversial issue we have had is probably bST, an issue everyone knew was coming at some point. We were getting questions from our extension agents asking, "How can you help us, because we know the questions are coming soon?" Our people put together a packet of information that went out to all of our county agents, where it was used very effectively. They felt comfortable about addressing questions because of this information we developed for them. We need to anticipate some of those kinds of questions and be able to develop a set of information that can be used by the nonscientist educator, such as an extension agent or teacher. An ongoing communication or linkage, a newsletter type of approach coming out from the research base, the experiment station, to the extension program could be very important in this regard.

Basically, the purpose is to have a public more literate about biotechnology. Biotechnology needs to become a part of the science that students learn in school science courses, just like protein synthesis is an accepted technology discussed widely in science classes. Biotechnology should receive that same kind of discussion and be met with the same acceptance by teachers who teach that technology in their classes. These goals, to me, are just raising the level of people's knowledge about this area and would help to diffuse some of the controversy. We will still have discussions about issues, but people will understand better why we are doing the things we are doing and why these particular technologies are going in the direction in which they are. That may be a little different charge than what some people might think is important for this organization (NABC), but, for me, it is a critical one. As I listened to the discussions, public education and understanding, or lack of understanding, or misunderstanding of biotechnology surfaced in every discussion. It is one we need to address now.

SPEAKER: PATRICIA SWAN

How many times in life would you like to be given the official last word on a subject? Often this is an enviable position, but after two days of thoughtful commentary, it is not a particularly enviable position to be in today.

This is my fourth NABC meeting, so I have tried to listen and think about trends in these conferences over the last few years. One thing is very different today as compared to four years ago. Today we are seeing products of genetic engineering and modern biotechnology techniques already being applied in the food and agriculture system. Four years ago there was much more focus on questions as to whether these techniques would be used. Could they be used? Should they be used? That is, a focus on very preliminary kinds of questions.

In this year's meeting, there was much less emphasis on speculation as to use of biotechnology. Instead, we have begun to emphasize different topics, ones that were mentioned four years ago but which have now become more important to us. They are topics that arise out of the experience we now have with products of modern biology applied to food and agriculture. First, as Larry Milligan pointed out, with our greater experience we now are dealing with biotechnology as a part of the general modern biological science approach to living systems rather than as a unique and separate set of technologies. We have accepted biotechnology as part of modern science, just part of the array of tools that we have for developing our food and agriculture system.

I want to emphasize four meeting themes that I have identified as ones receiving increased emphasis, as compared to four years ago. The first theme is that of access to the technology. Who will get it and where? Who is getting it? Are they getting it? These are much more immediate kinds of questions.

The second theme, that of rights to biological materials, is becoming dominant in our conversation. Sure, we talked about these rights four years ago but not with the same degree of urgency that we are talking about them today. Many factors account for that change, but the result is that rights to biological materials have become a much bigger issue for us.

The third theme is that of the integration of social, economic and environmental issues with the technical issues surrounding biotechnology. We spent a lot of time talking about social, economic and environmental impacts four years ago, but we discussed them as very separate issues. We talked about the "fourth criterion" as being separate from the other three. At this conference those issues were much more integrated into conversations about all aspects of agricultural research and development than they were four years ago.

Fourth, in addition to access rights and impacts, the concern for public participation is growing, and I suggest that our frustration over how to accomplish it is growing also. At this meeting we have again identified the need to make information available to all, to make education programs available to all, and to recognize the need for mechanisms for public participation in the very early stages of research and development decisions. But we need more good ideas about how to do this. We exhort more than we actually are able to design effective ways to gain public participation.

Finally, one overall trend in this meeting, from the very first session through the last session, has been the broadening of our concept of the agriculture sector. We were much more narrowly focused on agriculture production and to a lesser extent on food processing four years ago. Now we are thinking of a much broader kind of enterprise when we talk about the food and agriculture system. We are talking about industrial uses of agricultural resources (land, water, labor, capital) which once were deployed solely for food and feed and, to a minor extent, fiber production. We are now anticipating that more of those resources will be used for production of industrial products ranging from new materials, to fuels, to pharmaceuticals. This is a rather new idea, and a much broader set of issues about choices arises out of it. These new issues are, in part, what lead us to emphasize the need for broader public participation as well as the need for broader public support for research and development aimed at making the best use of resources in the food and agriculture system.

The real challenge to us all is: How shall the public sector (as defined by individuals, as defined by advocacy groups, as defined by land-grant universities and all the very many parts that make up the public sector) participate with the private sector in all its many parts as we look toward developments in the future? How will we assure that developments in this very broadly defined food and agriculture sector will be for the public good? This is a tremendous challenge for NABC and for us all.

PART II: DEFINING PUBLIC GOOD

Commercialization of Genetically Modified Plants: Progress Towards the Marketplace

Robert T. Fraley
Group Vice President and General Manager
The Agricultural Group of Monsanto Company

This is a very exciting time to be talking about the applications of agricultural biotechnology and especially the commercialization of genetically modified plants. Two events in the first months of 1994—the launch of bST and the approval of Flavr Savr™ tomato—certainly provide a wonderful setting to now talk about real products and real issues as this new industry moves forward. However, the key to putting biotechnology in perspective may not be to look at today's events but to look forward into the future in order to understand the importance of this new technology in agriculture—a technology that is urgently needed to meet the challenge of producing food in an environmentally compatible fashion.

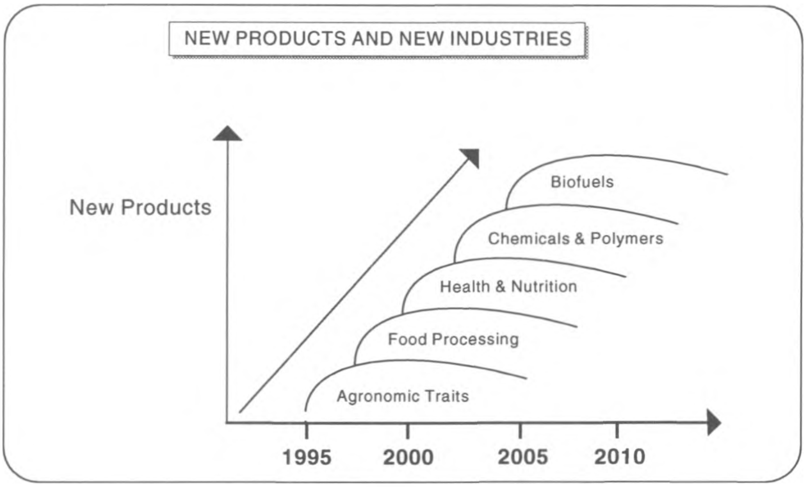
Right now, there are 5.5 billion people on the planet and, almost all experts agree, in another 40 years that number will likely double to 8-10 billion people before stabilization. Forty years is not a long time for any of us. I just had my 40th birthday celebration last year. I have a couple of small boys at home and when they are my age, they will be sharing this planet with 10 billion other people. What we do today and how agriculture prepares for that future will significantly determine the quality of their lives. Producing food—and producing it in a way that addresses both the consumption demand and environmental issues that face agriculture around the world—is a tremendous challenge that we all take very, very seriously.

The magnitude of this challenge can be appreciated when one considers that today the world feeds its 5.5 billion people by cultivating a land area of 5.8 million square miles, about the size of South America. Had we decided in 1950 not to invest in the new agricultural technologies which provided for the productivity increases over the last 40 years, we would be plowing up a land mass the size of North America and South America combined (i.e., about 15 million square miles) in order to meet today's needs for food, feed and fiber. Even greater pressures face us as we look forward. If we do not elect to use new tools that can enhance productivity for the future, 40 years from now we will be plowing up an area the size of all of Eurasia, or over 30 million square miles, to feed those 8-10 billion people. Already the world's most productive and sustainable, farmable land is under cultivation. In addition, the leading cause of species extinction is destruction of the wilderness for farming and forestry. This new technology—biotechnology—-is essential to increase the food supply without having to plow up the entire planet.

NEW TOOLS, NEW OPPORTUNITIES

Considering that the agricultural productivity increases over the last 40 years were driven by significant advances in several areas: plant breeding, farm mechanization, the use of crop chemicals, irrigation systems and modern farm management practices; we certainly need to support these tools and their continued development. In addition, biotechnology is important because it is a new tool—one that we have not yet used—and one that can have a significant impact on the future. For this reason, Monsanto and many other companies and universities around the world have put significant energy and investment into biotechnology. The impact of biotechnology is expected be very, very broad. Plant biotechnology promises to deliver a stream of new products—and new industries (Figure 1). We can already see the first wave of agronomic products as better disease-resistant varieties, new insect control options, better weed control systems, sensitive diagnostic systems are being developed. We can see clearly how biotechnology will lead to new opportunities in food processing by developing foods with different functional compositions as well as fruits and vegetables with better storage properties and flavor. We expect to see significant improvements in health and nutrition through modification of plants to reduce some of the health problems associated with certain fatty acids or removal of particular natural carcinogens. As we look to the not-so-distant future, we can see plants as micro-factories producing specialty biodegradable plastics or producing biofuels which could reduce dependence on our limited petroleum resources. Whole new industries will

FIGURE 1



be starting from the technology that is being developed today in laboratories and fields around the world.

Can biotechnology really have this impact? Over the last 15 years of research, two fundamental breakthroughs have occurred that provide the basis for developing these new products. One, of course, has been the unraveling and understanding of DNA; we now have the ability to isolate genes, study them, modify them and regulate their expression very precisely in different tissues and organs in the plant. The other important advance has been the ability to introduce genes into crops, in very facile ways using *Agrobacterium* vectors or particle gun technology that now allows for improvements using genetic engineering to be made across most of the world's major crops (Table 1).

TABLE 1

CROPS THAT CAN BE MODIFIED BY GENETIC ENGINEERING (1994)

Tomato	Soybean	Petunia	Potato
Cotton	*Arabidopsis*	Lettuce	Sunflower
Eggplant	Peas	Oil Seed Rape	Asparagus
Carrot	Flax	Yam	Cauliflower
Canola	Sweet Potato	Cabbage	Brown Sarson
Orchard Grass	Celery	Tobacco	*S. integrifolium*
Cucumber	Papaya	*H. albus*	Horseradish
Kiwi	*B. rapa*	Morning Glory	Licorice
V. officinalis	Muskmelon	Foxglove	*B. carinata*
Poppy	*M. truncatula*	Strawberry	Lotus
Sugar beet	Pear	Chrysanthemum	Alfalfa
Apple	Carnation	Rye	Apricot
Snapdragon	Rice	Grape	Orchid
Corn	Poplar	Tulip	Wheat
Walnut	Rose	Sorghum	White Spruce
Cranberry			

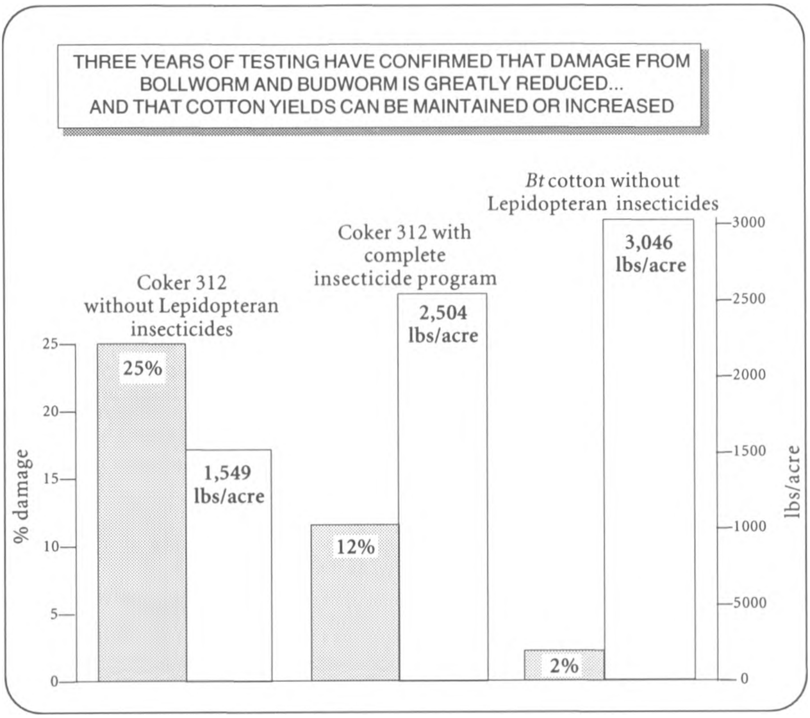
V

The pace of movement of the technology out of the laboratory into the field has been breathtaking. The first plant genes were isolated in the late 1970s—by the year 2000 we will know almost all of the genes in the model plant, *Arabidopsis*. The first field tests were done in 1987; in 1994, there will be well over 1600 field tests of genetically engineered crops. These include a broad range of species; at least 25 traits are in advanced development, about 10 of which are in the regulatory pipelines of the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA). Dozens of companies and universities are involved in developing these products. Let me briefly describe some of the new products that Monsanto expects to introduce in the next few years and the benefits they will bring to farmers, food processors and consumers.

INSECT PROTECTED CROPS

Insect protected crops will be one of the first products of biotechnology that will have significant impact on crop production. Several insect protected crops, including cotton, potato and corn will be commercialized in the next two to three years. Losses due to insect damage are still very significant with estimates ranging between 30-40 percent of the world's crop production lost due to insect damage. Nature has provided an approach for genetically engineered insect control with *Bacillus thuringiensis (Bt),* a soil bacterium that produces a protein that can kill insects. These proteins have been used in formulated microbial sprays for the last 30-40 years to control pests. Different *Bt* strains have activity against caterpillars and beetles; present microbe-based products control insects but they have shortcomings such as high costs and short half-life in the environment which have kept them from being widely-used products. They account for only one to two percent of all the insecticides that are currently used around the world. One of the ways envisioned to improve these products was to take the gene out of the microorganism and introduce it into the plant so that the plant produces a protein in its leaves that can control insects. This lowers the product's cost as well as providing season-long control of the insect pest. One of the first products that we will be launching will be the cotton plants that are resistant to bollworms, one of the most damaging pests in cotton that farmers must control to produce a crop. We have been field testing this product now for the last four years across the cotton belt in the U.S. and Australia. The data from this testing compares insect control and crop yield with *Bt* cotton to a normal insecticide regime where there is spraying once every seven to ten days. Plants containing the *Bt* protein are completely protected and show less damage than those treated with a very rigorous insecticide spray regime (Figure 2). Less insect damage translates directly to improvements in cotton yield and grower profitability.

The same approach of introducing *Bt* genes into crops has been demonstrated to be applicable for many other important pests. The Colorado Potato Beetle, a big problem in potato production, is controlled when a different *Bt* gene is placed in the potato. Plants protected against the Colorado Potato Beetle are undamaged by insects under conditions in which control plants are completely devoured. Again, we expect this technology will be introduced in the next two to three years. And finally in corn, Bf genes have now proven to be useful in field tests in controlling the European Corn Borer which is a pest that burrows inside the cornstalk. Under conditions of heavy pest infestation the crop will normally have problems standing erect that result both in yield loss as well as subsequent fungal and crop quality problems. Introducing the *Bt* gene into corn provides a new way for controlling these pests. These are important technologies that provide either new pest control systems, FIGURE *2*



substitutes for current practices or new tools that can be used to help manage insect resistance to other products. In our research laboratories, other genes are being developed that control several other important insect pests.

There is another important aspect of this technology that may be more significant to farmers outside the U.S. where many times insect control procedures are less well developed. In these areas, rather than deriving benefits from product substitution, very significant production and storage increase opportunities can be achieved in a variety of fruit, vegetable and row crops through better insect control. We are developing those applications in conjunction with a partner, Delta Pine Land Company, for cotton and with other companies for various crops.

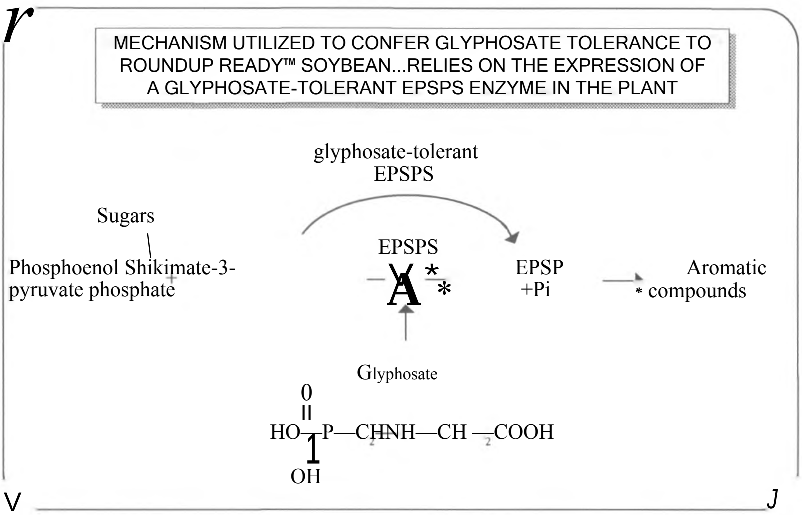
Regulatory packages for the insect-protected cotton and potato have been prepared and submitted to the EPA. Thousands of analyses have been performed to very carefully study the composition of cotton seeds and potato tubers, and no differences in composition of the starches, fats, proteins and oils in these crops have been observed. We have done feeding trials, both with laboratory models as well as with production animals, to show that the feeding and weight gain from cotton meal or potatoes is comparable to the nonengineered crop. We have looked at whether there could be changes in any of the natural toxicants, either solanine in potato or gossypol in cotton. Again, no changes. We have looked at the processing characteristics, the quality of fiber, and the chipping and frying performance of potatoes; again, no difference. The bottom line of literally thousands of pages of documentation and laboratory research conducted by our scientists and academic partners confirms that these plants are completely unchanged except for the properties that we have introduced. Based on this we have concluded that the genetically engineered crops and harvest products are comparable to crops already in production.

ROUNDUP READY™ CROPS

Probably one of the most controversial applications of agricultural biotechnology has been to improve weed control through genetic engineering of herbicide tolerance. Weeds are big problems for farmers. They not only compete with crops for sunlight and moisture but they spread diseases, act as harbors for natural pests and contaminate crop quality. Next to insects, weeds are the biggest pests in agriculture. Monsanto and other companies continue to develop improved herbicides and explore other alternatives for weed control. One of the very attractive opportunities that exists through biotechnology is to take existing products that have good efficacy and established safety and extend their use into new areas by engineering selectivity in the crops. That is the case for our product, Roundup®, a herbicide that is very effective against almost all weeds. By engineering crops to be tolerant to Roundup® herbicide, we have developed new options farmers can use to control damaging weeds. We have been able to achieve this breakthrough with an approach that replaces in the plant the EPSP-synthase target enzyme with naturally-occurring resistant versions of this enzyme that are not inhibited by Roundup® herbicide (Figure 3). This method has produced striking levels of tolerance in crops such as soybeans, canola, cotton and corn.

One of the important questions that people ask is, "Why is this an important technology and what are the benefits to growers and society at large?" In order to answer that question, we must consider one of the other great advances that is going on in agriculture in this country—the adoption of conservation tillage or "no-till" agriculture. Although conservation tillage was originally driven by regulatory compliance, farmers now see economic advantage to applying this practice to soybeans, cotton and corn. When I was growing up on a farm in the Midwest, I remember the scene quite well: deeply plowed, black fields which became very prone to water and wind erosion. Now that is all being very rapidly replaced with direct seeding of the new crop into the previous crop stubble that is being given minimum tillage. The covering mat of crop residue prevents the wind and water erosion that is a big problem for agriculture in many, many areas. So, how can Roundup Ready™ crops help? One of the problems with no-till technology is that weeds can become increasingly bigger problems. New crops with a tolerance to Roundup® herbicide

FIGURE 3



allows for more effective in-crop weed control to mitigate this concern and allow farmers to take full advantage of the many environmental and economic benefits that reduced tillage practices offer.

BETTER TASTING FOODS

The last two products I will describe have direct benefits to consumers. It seems that wherever I have talked over the last several years about biotechnology, there is always a person in the audience who asks, "Well, what are you going to do about my tomatoes, and the taste?" Tomato production in the U.S. is a very organized logistical system that starts when mature green tomatoes are harvested, processed, shipped, transported to the major cities and finally end up in the grocery stores as the red tomato you expect to see. The problem is that when tomatoes are picked green (to have enough shelf-life) they may have not developed their full set of acids and sugars that gives us the flavor of a vine-ripened tomato. So they do not taste as good as they look.

A number of companies, including Calgene, Inc., ZENECA Plant Science, DNAP Corporation and The Agricultural Group at Monsanto Company have developed ways of improving the flavor of the tomato by changing the tomato to better fit into this logistical transport system. This whole process takes about ten days to go from green to red. We have figured out ways of slowing that process down so that it now takes about two weeks. This is important because now tomatoes can be picked when they are at the pink stage where they have developed some color, but more importantly where they have developed all their flavor and can still have sufficient time to be transported to markets across the country. The improved flavor comes from being able to slow down the ripening process so the tomato can be picked at a later stage of ripening.

Biochemically, this process is well understood. The whole process of ripening, going from a green to a red tomato, is triggered by a substance in the plant called ethylene that is produced from an amino acid. We have been able to slow down the production of ethylene by shunting the pathway at a precursor step with an enzyme called ACC deaminase. Pending regulatory approval, we will be in the market in about a year and a half in partnership with a tomato company in Florida called NTGargiulo. Calgene is now in the market with their Flavr Savr™ product. We expect a couple of others. It is a big market; it is a big opportunity; and it is going to have a real benefit to consumers.

The last concept I will talk about is better tasting french fries and potato chips. The science in this case deals with the part of biochemistry—if you took the course, you probably slept through it—that is carbon metabolism and photosynthesis and how plants fix carbon and transport it to their roots and shoots and potato tubers. Let me summarize a lot of work and a really complicated pathway by saying that scientists have now figured out the key steps that actually limit the ability of plants to produce sugar and store it in the form of starch in the potato tuber. By increasing the flow through particular rate limiting steps, we have been able to produce dramatic increases in the starch content in a variety of crops. For example, potatoes normally contain about 19 percent dry weight after they have been genetically improved with the gene to increase the starch content, the starch content can go to 22-24 percent. That is a dramatic increase in tuber starch content; the improvement that has been made historically through plant breeding for comparison has been a little more than a tenth of a percent a year!

There are several benefits of having potatoes with the higher level of starch. To the food processor, having a higher starch potato produces more french fries or potato chips per truckload of potato. So there is clearly a cost savings advantage to the processor. To the consumer, there are other important advantages. Having the higher starch in the potato comes at a consequence of having less sugar in the potato. So during storage when sugars normally are produced in the potato that give rise to the brown-colored french fries or potato chips, the potatoes produced from high-starch potatoes will have the lighter color that most consumers in this country prefer. But the other important advantage of having a higher starch potato is less oily, uniformly cooked french fries or potato chips. The frying process for potatoes essentially displaces water for oil. Having higher starch gives you a faster cooking time because there is better heat transfer, and since there is more starch and less water, there is less oil needed to displace it. So the chips and fries made from genetically improved potatoes consume about 20-25 percent less oil in cooking than do normal potatoes.

CONCLUDING REMARKS

I would like to close with brief discussion of some of the issues which remain ahead of us. The overall progress on regulatory approvals for genetically engineered crops has been very positive. In the U.S., the three lead agencies—EPA, FDA, USDA—have worked together to coordinate oversight responsibilities and develop guidelines; the approval granted to Calgene for their Flavr Savr™ tomato represents a watershed event. Perhaps even more stunning has been the progress made internationally. In Europe, the United Kingdom and France have both moved forward with approvals. In Japan, regulations should be in place by the end of 1994.

Public acceptance, both in the U.S. and internationally, remains an issue—largely manifested through pressure points such as new legislative initiatives, food labeling and international trade. Labeling has been a controversial point with biotechnology products. The arguments on both sides are emotional and persuasive; the FDA has done a credible job of balancing these issues and addressing them in their new food labeling laws which support labeling when: 1. there are changes in identity when traditional standards no longer apply (e.g., broccoflower) and 2. reasons of health or safety (e.g., addition of a known allergenic protein to a new plant variety).

"Voluntary" labeling must not mislead the consumer to suggest that a safety issue or significant difference exists between the traditional and newly developed products. Labeling for process (i.e., genetically engineered) is inconsistent with the above criteria.

Commodity agricultural crops, unlike pharmaceutical products, know no boundaries. Thus even as we produce the first genetically engineered corn or soybean crops in the United States, we must make sure there is international harmonization of regulations—before these grains are shipped to international destinations. Otherwise "non-tariff barriers" could become issues in the future as we have seen happen previously for other agricultural products.

Current and Next Generation Agricultural Biotechnology Products and Processes Considered from a Public Good Perspective

Ralph W.F. Hardy
President & CEO
Boyce Thompson Institute for Plant Research, Inc.

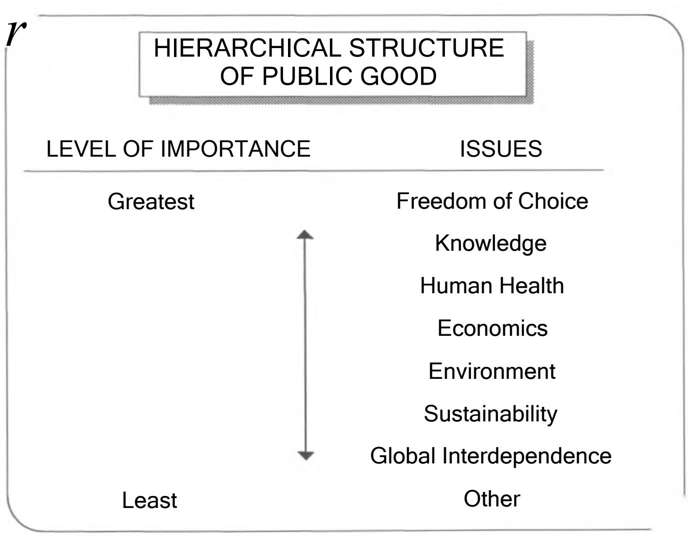
I appreciate the opportunity to provide my perspective on three interrelated topics relevant to the NABC 6 open forum on agricultural biotechnology and public good. These interrelated topics are 1. a self-generated hierarchical structure of public good; 2. selected examples of the status of current and next-generation agricultural biotechnology products and processes in the areas of food, crop production, energy, materials and human health with a listing of their public good; and 3. the need for initiatives such as the Alternative Agricultural Research and Commercialization Agency (AARC) to facilitate technology development and commercialization so that agricultural biotechnology products and processes will be available in the marketplace and thereby provide public good. Public good is the common denominator of these products. It is not only important but imperative in today's post-cold war, tight budget environment that the public good of new products and processes be communicated to the public. The public is more interested in the public good of products and processes than they are in the sophisticated tools and intellectual approaches that are used to generate the products and processes.

The public good story for those agricultural products and processes that are approved and marketed and the projection of the public good for next generation products and processes is a very positive one and, to date, has been inadequately communicated. The public good is a story of improved food safety and food quality, lower cost food, improved human health, new jobs, products made from materials produced (and in many cases also processed) in primarily rural communities, decreased subsidies, decreased environmental problems, and increased sustainability. As change occurs due to new agricultural biotechnology products and processes, society at large should benefit; at the same time, certain subsets of society that fail to or are unable to take advantage of the new opportunities will be disadvantaged. This will be no different for agricultural biotechnology than for any other technological change or change in governmental policy, trade or finance. In fact, the extensive discussion of these products and processes prior to their market introduction is providing more advance information than has occurred for almost any other technological change. Without question, there are more advance indications of the impact of biotechnology products or processes than there are for government policy, trade and financial change, to list a few that can also have major impacts on producers. It is hoped that the following perspective will help to stimulate productive discussion on agricultural biotechnology and public good.

WHAT IS PUBLIC GOOD?

If we are to address the impact of current and next generation agricultural biotechnology products and processes on public good, we need a description of public good. There is no broadly accepted description of public good. Any description is influenced by the viewpoint of the individual or the organization that produces it. The structure I will provide is based on a hierarchy of relative importance based on my personal viewpoint. This viewpoint has evolved from a career in science that has been almost exclusively in the private sector and, until the last few years, in the for-profit private sector. I also recognize the importance of the viewpoints of others, including consumers. Robert Nicholas' and my recognition of the need for a vehicle through which all viewpoints could be expressed in an open forum led us in 1987 to found the National Agricultural Biotechnology Council (NABC). I have had the benefit of participating in the open discussion at all five previous NABC annual meetings. These and other dialogues have sensitized me to a diversity of issues and viewpoints regarding agricultural biotechnology. Based on these inputs and some recent conversations with individuals outside the science community, I have generated a hierarchical structure of public good (Figure 1). My prioritization of the structure is based mainly on a U.S. national perspective.

FIGURE 1



Freedom of Choice

In my list, freedom of choice is the most important public good. Let me relate freedom of choice to agricultural biotechnology. One should have the opportunity to choose, if one wishes to do so. If one wishes to choose, one has a responsibility to become informed so that a decision is an informed one. Useful information must be provided so that one can make such an informed choice. Words like "transgenic" or "genetically engineered" may be useful, at best, to a scientist. In my view, such words are of no use for decision-making by a consumer. On the other hand, highly information-rich designations such as Flavr Savr™ tomatoes are very useful to me as a consumer wishing to make an informed choice.

We need to provide information-rich designations throughout the production and distribution system. As, for example, Monsanto's proposed designation of "Roundup Ready™" to grain farmers for crops tolerant to the herbicide Roundup®. The name Prosilac™, used by Monsanto for their bovine somatotropin (bST) product, is information-rich for dairy farmers. However, there has been a failure to provide information to the consumers of milk that will enable them to make an informed choice to purchase, or not to purchase, milk produced from cows treated with bST. I appreciate that there is no chemically analyzable difference between milk from cows treated with bST and those not treated with bST. Some consumers, though, are understandably expressing concern because they have been denied this right to choose. Personally, I would appreciate the ability to exercise the right to choose in this case. I would like to be able to choose milk from bST-treated cows because it is my understanding that average or above average dairy farm management is required for successful use of bST. As someone who grew up on a dairy farm, I would like my milk to come from the best managed dairy farms. In the same way product identification for marketing provides information for choice by the producer/user, such as the dairy or grain farmer in the above examples, there should be information for choice by the ultimate consumer, especially when a significant proportion of consumers indicate the desire to have such information.

Knowledge

Knowledge is probably the second most important public good. To exercise freedom of choice, one must be informed, i.e., have knowledge about, the object of that choice. Many organizations are involved in the knowledge area. The public trust varies with respect to information provided by different organizations (i.e., perceived acceptable knowledge provided). In January of 1994 Thomas J. Hoban IV conducted a survey for the Grocery Manufacturers of America to assess the amount of trust that individuals had in sources of information on the safety of bST. This survey was conducted in the month preceding the first commercial sale of bST in the U.S. Trust was highest (80+ percent) for information provided by organizations such as the American

Medical Association (AMA), the National Institutes of Health (NIH), the Food and Drug Administration (FDA) and the American Dietetic Association (ADA). Trust was lowest for grocery stores, activist groups and chefs.

Human Health

In my list, human health is the third most important public good. Within the human health area I include food and medical aspects of human health such as food adequacy and security, food safety, nutritional quality, food preference characteristics, food variety, food cost, wellness, diagnostics, therapeutics, vaccines and prostheses. Current and next generation agricultural biotechnology products from new foods to food-vaccines are expected to impact broadly on human health.

Economics

The next public good is the economic area. There are several economic factors from the public good perspective. A major one is new jobs in both urban and rural locations. In addition, there are issues of production, productivity, value-added, proprietariness, competitiveness, community development, imports, exports, subsidies and taxes. Agricultural biotechnology products and processes can have significant impacts on many of these economic factors. For example, it is critical that the U.S. reduce its need for agricultural subsidies and that we create jobs in rural locations. Agricultural biotechnology products, in the longer term, have major potential in both these areas.

Many of the public good issues of economics are first and foremost national issues. In the U.S. there are about 90 million acres of excess or unused agricultural land that could be used for production. Our productivity is increasing two to two and a half percent annually. There is also a continuing decline in grain exports from 150 million tons exported in the late 1970s to only 90 million tons in the early 1990s, and this continuing decline in exports will expand substantially the number of excess arable acres. The availability of this excess acreage capacity and the power of agricultural biotechnology provide the potential for major economic public good, especially in rural communities.

Most people agree that a product or process should be economically competitive to remain in the market. A growing segment of our society is sympathetic to so-called “green” products and processes. However, “green” product or process alternatives that involve a significant additional cost over traditional products without other advantages probably will not survive in the marketplace, or if they do, will only have a very small market share. There may be indirect production costs for which we need to develop systems to incorporate these costs in the selling price of a product. These indirect costs are most relevant to the next public good areas of environment and sustainability.

Environment

As the more primary and traditional public good needs of human health and economics are met, society begins to address additional public good issues. Environment, in my view, is the next public good issue. The environmentally related actions of many developed countries in the last quarter of the 20^{th} century document the public good acceptance of environment as a timely concern. There are many environmental issues including erosion, salinization, desertification, soil and water contamination, air quality (ozone [OJ, nitrogen oxides [NOJ, sulfur dioxide [$S0_2$], volatile organic chemicals [VOC]), stratospheric ozone/UVB, wetland preservation, greenhouse gases, forestry, etc. There are existing or projected examples where agricultural biotechnology products or processes favorably impact the environment.

Sustainability

The next emerging public good issue is sustainability. We are still in the process of defining sustainability. Almost all agree that use of renewable versus nonrenewable sources and resource conservation fall under sustainability. In addition, some believe that sustainability requires self-sufficiency at the local level. Agricultural biotechnology products and processes are clearly relevant to the use of renewable sources.

Global Interdependence

Increasingly, we recognize that there is, indeed, global interdependence, and it is in the national interest to address issues at a global level. These global public good issues include humanitarian ones, environmental ones such as global environmental change and pollution, and economic ones such as the global marketplace, proprietariness, sources and rights to genetic materials, technology access, trade and tariffs. It is clear that agricultural biotechnology products and processes will impact and be impacted by the above global public good issues.

Other Public Goods

There are many other public good issues that apply to limited areas or subsets of people in contrast to the above global and national ones. Some of these public good issues may be identified under the composite public good area of pride. Pride occurs at many levels: national, community, organizational, ethnic and cultural. There are religious beliefs—these are considered as a public good by those people who so believe. There are those who believe that "how things were" is a public good. I refer to these as the "way things were" myths. One of these is the family-farm myth. I grew up on a family farm. I often have fond recollections of that family farm, but then I recall only too clearly the reality of the family farm of the 1940s. The reality was that intellectually unchallenging, repetitive physical labor dominated the family farm of the 1940s. There were, though, significant opportunities for entrepreneurial family farmers in the 1940s as, I believe, there are in the 1990s.

The hierarchical structure of public good presented in Table 1 and described above is a self-generated list. You may strongly agree; you may strongly disagree. The list is a starting point that I will use in a summary of selected current and next generation agricultural biotechnology products and processes.

SELECTED EXAMPLES OF CURRENT AND NEXT GENERATION AGRICULTURAL BIOTECHNOLOGY PRODUCTS AND PROCESSES

The number of current agricultural biotechnology products and processes in the marketplace has doubled within the last year. The premier agricultural biotechnology product to date is chymosin for cheesemaking which was approved by the Food and Drug Administration (FDA) over four years ago and now has more than a 60 percent share of the market. If you have eaten cheese regularly during the last four years, it is almost certain that you have eaten cheese made with highly pure chymosin produced by transgenic microorganisms, rather than using the highly impure chymosin obtained traditionally from stomachs of slaughtered calves. The microbially produced chymosin product has been joined by microbially produced bST for enhanced milk productivity that was approved by FDA in November, 1993 and marketed in February, 1994, and by Flavr Savr™ tomatoes approved by FDA in May, 1994 which are now also in the market. Clearly, momentum is growing for agricultural biotechnology products and processes. Opponents of these products have had a losing year in their battle to keep agricultural biotechnology products either out of the marketplace or "dead on arrival" in the marketplace.

In this section I will provide synoptic tables of selected agricultural biotechnology products and processes for food, crop production, energy, materials, and health care. The tables include a general description of the product or process, its status, its advantages and a listing of public good.

Food Products and Processes

Four food or food safety products are summarized in Table 1: clotting enzyme for cheesemaking, bST for improved milk productivity, DNA-probe diagnostics for food-based microbial contaminants and improved consumer preference characteristics of fruits and vegetables, e.g., Flavr Savr™ tomato. All of the above products are already in the marketplace.

The public good benefits include the areas of economics, health and environment. The favorable public perception of high-purity chymosin produced by transgenic bacterial systems versus the unfavorable perception of low-purity chymosin from slaughtered calf stomachs probably caused the opponents of agricultural biotechnology not to express opposition to this biotechnology product in the manner they expressed concern about bST also produced

TABLE 1: FOOD PRODUCTS AND PROCESSES

	Clotting Enzyme for Cheesemaking	bST for Improved Milk Productivity	DNA-Probe Diagnostics for Food -Based Microbial Contaminants	Improved Consumer Preference Characteristics of Fruits and Vegetables
Technology	Transgenic microbes produce identical enzyme	Transgenic microbes produce a product essentially identical to bovine bST	DNA probes for ***Listeria, E. Coli, L. monocytogenes, Salmonella, Staphlococcus aureus, Campylobacter*** and ***Yersinia enterocolitica***	Antisense technology used to extend tomato shelf-life
Status	FDA approved chymosin 3/90; 60% of market; Kosher, halal, vegetarian accepted	FDA approved Monsanto Prosilac™ 11/93; Marketed 2/94 following 90-day moratorium; Used on 10-15% of cows by 4/94	GENETRAK Systems, Inc. markets kits	FDA approved Calgene Flavr Savr™ tomato 5/94
Advantages	50% cost reduction Reliable, reproducible supply; High purity; High cheese yield	10-15% increased production	Speed: 24-48 hours; Equal or better than traditional culture methods sensitivity/specificity	Increased shelf life; Improved flavor
Public Good Economics	Reduced cost; Reliable supply	Decreased cost of milk production; Lower cost to consumer	$40 billion cost/year	Premium for value added
Environment	--------------	Fewer cows-less methane and manure	----------------	----------------
Health	High purity	Neutral overall: possibly increased milk consumption with lower cost; Requires above average farm management	Reduce the 80,000 illness (death in a few cases) per year	Increased fruit/vegetable consumption
Other	Perception-microbial vs. slaughtered calf stomachs	Concern about impact on less efficient (not necessarily smaller) dairy farms	----------------	----------------

v_

microbiologically. I suggest that the concern about the impact of bST on dairy farmers really is a concern for the survivability of less efficient dairy farms whose survival may not be an overall public good. However, lower cost of milk to the consumer, that should result ultimately from use of bST, is a public good. In general, improvements in agriculture ultimately benefit the consumer. Such improvements are the basis of the very low cost of food in the U.S. and Canada. Overall, agricultural biotechnology products now in the marketplace will impact in a highly positive manner on the public good. Improvements in the methods to detect microbial contaminants in food should decrease illnesses and even deaths such as occurred in the recent case of microbially contaminated ground beef. Reduction in the major estimated annual cost of $40 billion for time lost due to these illnesses could be major. Increased consumption of fruits and vegetables is being recommended for improved health. Products such as the Flavr Savr™ tomato should promote this desired dietary change.

The progress in development and marketing of food products and processes is impressive. Chymosin, the first transgenic food product, was approved by the FDA in early 1990. Four years later it has captured a 60% market share. Furthermore, it is accepted as kosher, halal and vegetarian, thereby demonstrating the broad acceptability of a transgenic food material. It is expected that bST from transgenic organisms and Flavr Savr™ tomatoes, which were approved by FDA in 1994, will show similar acceptance within four years as that now achieved by chymosin. Within only two months of approval, bST was reported to be used on 10-15% of cows. All of the above food products and processes provide significant economic benefits and/or added value and health benefits to consumers. The above should be viewed as the earliest examples of food biotechnology products and processes with substantial overall public good.

Crop Production

Three examples of agricultural biotechnology products for crop production are summarized in Table 2. None is yet in the marketplace. Research and development for transgenic crops with enhanced or added herbicide tolerance is highly advanced, and products should be marketed within the next few years. Currently, crops with herbicide tolerance produced by traditional selection and cell culture methods are marketed. Transgenic plants with coat-protein genes or other viral genes to protect against viruses are in advanced field-testing. For example, the improvement in quality and yield of squash produced by Asgrow is dramatic. A more futuristic potential is self nitrogen-fertilizing cereal grains that contain the legume genes for symbiotic nitrogen fixation. The potential public good benefits for this product are outstanding in multiple areas: replacement of the $20+ billion annual cost for synthetic nitrogen fertilizer, decreased NOj(nitrates) in ground water and a sustainable method to replace fossil fuel based synthetic nitrogen fertilizer—all with applications in both developed and developing countries. Major research and development remains to be done. At the Boyce Thompson Institute, the biological materials to produce self nitrogen-fertilizing plants are in hand and the approach is defined. There is a reasonable chance of success within the next fifteen years if the needed investment is made now.

TABLE 2: CROP PRODUCTION PRODUCTS

	Transgenic Crops with Enhanced or Added Herbicide Tolerance	Trangenic Plants with Coat and Other Viral Genes	Self -Nitrogen Fertilizing Cereals
TECHNOLOGY	Tolerance genes for Bromoxynil, Glyphosate, Sulfonylureas, Imidazolinones and others	Virus-resistant fruit and vegetable crops: cucumber, squash, papaya, etc.	Transgenic cereals with legume genes for symbiotic nitrogen fixation
Status	Many successful field trials; Bromoxynil cotton (Calgene, Inc.) deregulated status by USDA/APHIS	Field trials by Asgrow show major improvement in quality and yield of squash	Early research, but approach is defined and doable; 30+ single gene pea mutants for *sytn* genes generated and being located, isolated and characterized
Advantages	Increased efficacy of and flexibility in weed control	Quality and productivity	---------------
Public Good Economics	Reduced cost of weed control	Reduced cost	Reduce $20 billion synethic nitrogen fertilizer cost with transgenic seed (corn, wheat, rice) and microbes
Environment	Enable use of more effective herbicides with less residue; Safer use of safer herbicides (see *NABC Report* 3); Reduce cultivation and soil erosion; Development of herbicide-tolerant weeds is often expressed as concern.	Concern regarding viruses with expanded host range	Decreases in: NOj ground water pollution; greenhouse gases (N_20, $C0_2$) and impact on global N cycle
Health	Reduced soil/water residues of long-lived herbicides	Increased consumption of fruits and vegetables due to reduced cost	Improved drinking water quality
Global Interdependence	---------------	e.g., Papaya in Brazil	Applicable to both developed and developing countries
Sustainability	---------------	---------------	Replace fossil use

ENERGY PRODUCTS

Two examples in the energy area are summarized in Table 3. Biodiesel, which is the methyl esters of plant or animal oils or fats, is being proposed as a 20 percent component of diesel fuel. This 20 percent biodiesel fuel reduces substantially particulate emissions without the need for major capital costs in engine or vehicle modification. The Environmental Protection Agency (EPA) is reviewing information to determine if 20 percent biodiesel in diesel fuel can be designated as substantially similar to diesel. With such a designation, this 20 percent biodiesel product could be used without delay, which should enable public transport buses to reduce particulates in diesel exhaust for the January 1, 1995 requirements of the Clean Air Act. With required approvals, biodiesel could be a commercial product within the year providing multiple public good benefits. Another energy example is oxygenated gasoline. Lignocellulosics are an abundant part of agricultural wastes and forestry materials. Much research has focused on producing an economic process to produce ethanol for oxygenated fuels from these low-cost materials. About 30 percent of lignocellulosics is hemicellulose. A biotechnological process invented by the University of Florida is being developed by Bioenergy International for the highly efficient conversion of hemicellulosics to ethanol. Added value and reduced cost are the key benefits from this process. There are other energy products in the pipeline but space does not allow their review; the above examples should be viewed as illustrative.

TABLE 3: ENERGY PRODUCTS

	Biodiesel	Oxygenated Gasoline
Technology	Methyl esters of plant oils or animal fats, e.g., soydiesel	Hemicellulose to ethanol by transgenic microorganism
Status	20% biodiesel in diesel fuel reduces particulate emision without engine/vehicle modification; Many tests in process with city buses and other; EPA reviewing regarding substantially similar designation	Process being developed by Bioenergy International
Advantages	New use for plant oils with environmental and economic benefits	Value added to waste material
Public Good Economics	Reduce capital costs for retrofit but increase operating cost; Expanded market for plants/oils	Added value/reduced cost
Environment	Reduce particulates in diesel exhaust to meet 1/1/95 requirement by Clean Air Act	Ethanol and clean air; Recycle carbon dioxide
Health	Cleaner air	Reduce air pollution
Sustainability	Renewable vs. fossil	Renewable vs. fossil

HUMAN HEALTH CARE PRODUCTS

Therapeutics and vaccines are major human healthcare products. Transgenic animals with human genes are being developed to produce human therapeutic proteins in milk or blood. Table 4 lists several that are in the experimental stage. The value-in-use per animal is very high, but the number of animals needed will be limited. Such therapeutic-manufacturing animals, though, may be very relevant for the production of drugs in developing countries since it is the transgen ic an imal itself that is the production facility. A longer-term agricultural biotechnology effort is the production of edible vaccines by transgenic fruits and vegetables. This program at Texas A&M University is in the early research stage. It is suggested that the cost of such edible vaccines could be as low as six cents per "vaccine" food. The public good to developed as well as developing countries would be major, to say nothing of the benefit to the vaccine consumer who no longer must endure an injection.

Materials

Materials, both organic and inorganic, are huge total-volume markets. Prior to the era of cheap and consistently available fossil materials, agricultural and forestry materials were the primary source of most of the carbon-based

TABLE 4: HEALTH CARE PRODUCTS

	Human Proteins	Oral Vaccines
Technology	Transgenic animalswith human genes produce human proteins in milk/blood	Edible vaccines produced by transgenic fruits (bananas) or vegetables
Status	All are experimental; tx-l-anti-trypsin to treat emphysema by sheep; tPA for early treatment of heart attack by goats; Protein C to keep blood from clotting by pigs; Hemoglobin as a substitute for red blood cells; Lactoferin, a mother's milk protein for baby formulas by cows	Early research; Transgenic plants produced Hepatitis B vaccine
Advantages	Milk in most cases as the starting material for purification	Low cost and delivery in a normally consumed food
Public Good Economics	Very high value-in use animal products, e.g., $ 100,000/yr. animal	Low cost; 6 cents per "vaccine" fruit
Health	Therapeutic or beneficial	Immunization, especially for chi Idhood diarrheal diseases in developing countris
Global Interdependence	May be very relevant to developing countries	Especially appropriate to children in developing countries but could also be used in developed countries

materials. New technology and increasing concerns about the negative environmental impacts of fossil-based materials is generating a reemphasis on materials from agricultural and forestry products (see Table 5). A high-value polyester called Biopol™, produced by bacteria, is being marketed by ZENECA, Inc. as a non-wettable paper coating and moldings for bottles. Transgenic plants are also being developed to produce this and other polymers; the potential is large, but the research is at an early stage.

Nature already provides large quantities of materials that are used extensively. For example, worldwide cotton production in 1992 was about 19 billion kilograms (kg) out of a total worldwide fiber production of both synthetics and naturals of about 42 billion kilograms. An exciting example of a relatively undeveloped natural fiber is milkweed floss (Table 5). Natural Fibers in Nebraska has commercialized milkweed floss for the pillow and comforter market. They see potential for milkweed floss in nonwoven yarn and other markets. Successful utilization of milkweed floss fiber in these markets could lead to the domesticated production of millions of acres of milkweed The possible economic benefits in the materials area are huge.

The above examples illustrate the major public good that exists or is expected to flow from agricultural biotechnology products and processes. The breadth of the products and processes—from food to energy to materials to human health—is enormous. The potential is well beyond that recognized by the informed public, and even many scientists who probably think of agricultural biotechnology as being relevant only to crop and animal production, or possibly to food. The diversity and strength of the public good for these agricultural products and processes needs to be communicated. The next section discusses a government initiative to improve our success in delivering these products and processes to the public.

COMMERCIALIZATION OF AGRICULTURAL BIOTECHNOLOGY PRODUCTS AND PROCESSES

For public good to occur, the products and processes generated by research and development, for the most part, must be commercialized. This critical step is the limiting factor for most areas of technology, and biotechnology is no exception. Some describe this limiting factor as the "valley of death" which dramatically communicates our failure, in too many cases, to convert science and technology to successful commercial products and processes. In recent years the U.S. government increasingly has recognized the importance of improving our success in crossing the "valley of death" and has generated some initiatives to facilitate technology development and precommercialization activities. Two government initiatives have been established recently: one is the Alternative Agricultural Research and Commercialization (AARC) agency in the U.S. Department of Agriculture (USDA) and the other is the Advanced Technology Program (ATP) in the National Institute of Standards and Technology (NIST) in the Department of Commerce.

TABLE 5: MATERIALS

	Biopolymers by Microbes	Phytopolymers by Transgenic Plants	Natural Phytopolymers /Fibers
Technology	---------------	Transgenic plants to produce polymers/fibers with functionality that meets or exceeds that produced by synthetic chemistry; Opportunities for polyesters, cellulosics and amides	Milkweed floss for down, non-woven yarn and other markets
Status	Biopol™[1] is produced and marketed by ZENECA, Inc. as non-wettable paper coating ($15/lb) and molding for bottles for high value products (cosmetics and shampoos) ($8/lb); ProNectin™byProteinPolymerTechnologies; Cellulon™ by Weyerhauser Company	Early research; Polyester synthesis by transgenic *Arabidopsis* and Canola (0.1%)	Methods and equipment developed by Natural Fibers to grow, harvest and process milkweed with production of comfortors and pillows marketed as Ogalala Down™; Cultivar improvement
Advantages	Biodegradable but processing cost high	Yet to be demonstrated; Infinite variations with designed genetic template; Solar energy	Opportunity for major new crop with substantial value-in-use
Public Good Economics	Reduces disposal cost of non-biodegradable polymers	High performance?; Lower cost?; Domestic production	Major potential for agriculture; Very high to good value-in-use; Potential major new crop: reduces need for subsidies and offers rural opportunties; Jobs; Domestic vs. imported materials
Environment	Biodegradable	Renewable vs. fossil; Biodegradable; Decentralized manufacture	Perennial crop; Low water and nitrogen use; Opportunity for additional crop rotation
Health	---------------	---------------	Hypoallergenic vs. goose down
Sustainability	Renewable source	Renewable	Renewable

[1] Biopol™ polyester copolymer of (3-Hydroxy Valerate and Butyrate

AARC was created in the 1990 Farm Bill. Its two major proponents were the former Secretary of Agriculture and the New Uses Council. The role of AARC is to provide risk investment to the private sector for support of pre-commercialization activities for new added-value, non-food and non-feed uses of agricultural and forestry materials. The private sector must provide at least a 1:1 dollar match for the funds provided by AARC. AARC's primary objective is to utilize the excess U.S. agricultural production capacity or U.S. surpluses of agricultural and forestry materials for industrial products for domestic and international markets and to reduce simultaneously and substantially the need for agricultural subsidies. There are other expected benefits from AARC investments of public funds. Overall economic development should occur within the agricultural and forestry sectors. Production, processing and distribution of these added-value industrial products will create, for the most part, jobs in rural areas since the bulky raw materials are located in rural areas and are expected to be processed near their origin.

I am one of the nine members of the original AARC Board appointed in 1992. Based on my experience on other national committees, boards and commissions, the commitment and enthusiasm of the AARC Board members to the AARC mission is unprecedented. The Board believes that AARC is the right thing to do and that government has set it up the right way. These industrial products from agricultural and forestry materials should expand the use of renewables and reduce fossil use. The environmental impact from the bio-based industrial products should be reduced relative to those based on fossil sources. Also, the bio-based system should be more sustainable.

The operation of AARC is unique and may represent a model for management of future government investments in development. The AARC board is appointed by the Secretary of Agriculture with input from the National Science Foundation (NSF) and the Department of Commerce. The Board is composed of nine members with eight from outside of government representing technical, business and entrepreneurial expertise. This Board is not an advisory committee but rather an operating board that has total responsibility for the operation of AARC and reports directly to the Secretary of Agriculture. The Board operates AARC as a business, not as a government grant program. The Secretary of Agriculture can override decisions of the Board but must do this in writing. To manage investments in development, AARC utilizes the experience mainly of entrepreneurs from the private sector rather than government bureaucrats. There are five presidents or vice presidents of private corporations on the original Board.

The composition and experience of the AARC Board is one of the keys to the novel operating structure of AARC. The other major key is the financial management of AARC investments. The government funds allocated to AARC are placed in a revolving fund. AARC investments are made so that the AARC revolving fund will receive a return on its investment based on the financial success of the products or businesses. This return may come from equity, royalties or other appropriate methods negotiated at the time of the AARC investment. It is the goal of AARC that the revolving fund will become financially self-sustaining, maybe within ten years. Society talks about sustainability in many areas. Why should government programs not be set up to be sustainable? The taxpayer provides the key start-up funds, but the activity must become self-sustaining if it is to continue. Thus the taxpayer will not need to provide continuous financial input. AARC aims to bring self-sustainability to a government program.

AARC seeks and evaluates proposals through broad solicitation and in-depth competitive reviews. There is external review by technical and business experts. The Board uses these external reviews and its own evaluation to select the most promising preproposals to be submitted as full proposals. Prior to funding, at least one Board member visits the site to meet with management, review the plan and facilities, and negotiate the basis for financial return to the AARC revolving fund. Board members and staff monitor the businesses on a regular basis. AARC has made investments in at least three of the examples described above.

The major limitation of AARC at this stage is the level of funding. Annual funding of less than $10 million enables AARC to invest in only a fraction of the promising opportunities. The U.S. must continue to fund and substantially expand our funding of research for new uses of agricultural and forestry materials. Even more importantly, the U.S. must increase substantially the investment in precommercialization activities. Such investments will serve the public good through new jobs, rural development, reduced subsidies and a self-sustaining investment fund for businesses based on agricultural and forestry materials.

Another government initiative to facilitate technology transfer across the "valley of death" is the Advanced Technology Program (ATP). Its objective is economic development by improving the competitiveness of U.S. industry with new high-value products/processes/services for domestic and international markets. It, like AARC, also hopes to create jobs. ATP focuses mainly on the urban non-agricultural area with investments in, for example, the electronics industry. The goals of AARC and ATP are similar, although the former is focused, for the most part, on rural communities and expanding the opportunities for agricultural and forestry materials. The operation of the AARC and ATP are very different. ATP operates as a traditional government program with management by government bureaucrats and no requirement for a return to the program from successful investments. ATP identifies technology or product deliverables, as does AARC, but does not seek a financial return so as to become self-sustaining. I believe that the AARC style of operation with decisions made by experienced, private-sector entrepreneurs and with a financial return to enable sustainability is a step in the right direction and consistent with the proposal of the current administration to reinvent government. ATP is growing at 80+ percent per year based on government funding and will shortly have 50+ times the annual funding provided to AARC. Both are excellent, timely programs. AARC needs to grow in the way ATP is growing so that AARC has funding consistent with the level of biobased opportunities, estimated to be at least ten percent as compared to ATP, not one to two percent as reflected in current funding. Both ATP and AARC can be important to the public good.

IN SUMMARY

A hierarchical structure of public good based on relative importance is presented. The issues, arranged starting with the greatest to level of importance, are: freedom of choice, knowledge, human health, economics, environment, sustainability, global interdependence and other. The other public good category includes issues that apply only to limited subsets of people. Fourteen selected examples of current and next generation agricultural biotechnology products and processes, crop production products, energy products, healthcare products, and materials were presented. A brief statement of technology status and advantages for each example is presented as well as the identification of public good for the relevant issues such as economics, health, environment and sustainability. The selected examples range from a transgenic product for cheese making, initially marketed in 1990 and presently with a dominant market share, to now marketed and much debated bST and Flavr Savr™ tomato products and processes in development such as biopolymers and a process for ethanol production for oxygenated fuels to products in the very early research stages such as self nitrogen-fertilizing cereals and edible plant vaccines for humans. Major public good exists or is expected for the above products or processes that are in the market, in the development stage, or in the research stage.

Public good requires the transfer of technology from the research and development arena to products and processes in the marketplace. Without commercialization or equivalent delivery to the users, there is no public good. A new federal program, the Alternative Agricultural Research and Commercialization Center, located within USDA, is described. Its mission is to invest in commercialization by the private sector so as to facilitate the marketing of new industrial (non-food or non-feed) value-added products from agricultural and forestry materials.

Biotechnology for the Public Good

R. James Cook
Chief Scientist
National Research Initiative Competitive Grants Program
USDA/CSRS, Washington, DC;
Research Plant Pathologist, Root Disease and Biological Control Research Unit
USDA/ARS, Pullman, WA

As Americans, we expect and even take for granted that the supply and choices of quality, affordable food will keep pace with the growth of our population while also generating a positive balance in international trade. There is further expectation that growth in this supply and choice of food and other products of agriculture will be sustained with decreasing use of pesticides. We also expect to have access to agricultural lands for our freeways, housing developments, shopping malls and recreation, and that some agricultural land will be returned to a natural state for the benefit of certain necessary ecosystem functions. These multiple expectations must be met in the context of another issue—sustainable agriculture. Agriculture must convert from a resource-based to a knowledge-based enterprise. The new tools of biotechnology offer the latest means to this knowledge base and meeting the many expectations of agriculture. And as with previous technologies used in agriculture, it is us, our children, and our children's children who will benefit.

I have never and do not now consider biotechnology as a "technical fix" to the continuing and emerging problems for agriculture, farmers or the environment. Rather, I consider biotechnology as part of the natural progression in knowledge and the application of knowledge in the ongoing efforts of society to maintain or improve the standard of living for all people without compromising the ability of future generations to do the same. My concern for biotechnology, as I will bring out in more detail at the end of this paper, is whether the benefits of this technology will be widely available for the public good.

Much of the mistrust of biotechnology stems from a disconnect between benefits of the so-called classical methods of plant and animal breeding, which are widely accepted as for the public good, and the molecular methods of breeding which are not widely accepted as for the public good. Scientists—myself included—have perpetuated this disconnect by playing up the new biotechnology as "powerful" and "different" while not emphasizing enough until recently the continuum, interdependence and common goals of molecular and classical methods of breeding.

Indeed, the new crop varieties and breeds of livestock, new products and new practices based on new knowledge from biotechnology should be just as much for the public good as have been the crop varieties, breeds of livestock and practices developed solely through the use of traditional breeding based on classical genetics in the past. It would also appear, now that we have about 20 years experience, that the new foods and other products of biotechnology raise no safety, ethical or social issues that could not have been raised for food produced by the more traditional tools of breeding and genetics.

GENETICS AND BREEDING: THE FOUNDATION OF U.S. AGRICULTURE

The U.S. during this century has made an enormous investment through a network of public and private research programs in a genetics approach to improving and solving problems for crops and livestock. The U.S. grows about 150 crops and some 80 breeds of livestock, nearly all of which were introduced from a foreign country and then subjected to breeding and selection to further develop varieties or breeds adapted to U.S. conditions and suitable to U.S. consumers. Every form of U.S. agriculture, including "organic farming," depends on and uses these varieties of crop plants and breeds of livestock. And improving crops and livestock is an ongoing effort to meet ever-changing markets and consumer demands, fit with new farming practices and stay ahead of the ever-changing populations of pests and diseases.

As one example of the payoff, virtually all the potentially devastating leaf diseases of the eight to ten most widely grown crop plants and many minor crop plants grown in the U.S. are held to minimal effects by the use of varieties deliberately bred for resistance to them. U.S. wheat, corn and soybean crops are grown today with virtually no fungicides other than as treatments to protect the germinating seeds or the occasional emergency foliar treatments in response to threats from severe disease outbreaks on older plants. Wheat-stem-rust has been kept under increasingly better control in the U.S. and Canadian Great Plains through plant breeding since the last major epidemic in 1953. Similarly, southern-corn-leaf-blight has been controlled genetically since the epidemic of 1970.

The success of the genetics approach to solving problems for crops in particular has been through our ability to make and deliver tens or hundreds of thousands of unique genetic changes through hundreds or thousands of varieties to fit local environments, control local diseases and solve local problems while meeting national needs. Farmers have benefited by the lower risks to their operations formerly presented by these unmanageable production hazards. Consumers have benefited from higher quality, safer and lower cost of food. The U.S. as a nation has benefited from the greater efficiency, and hence competitiveness, of agricultural industries based on technology in the form of improved seeds and breeds.

Thus far, however, it has not been possible to develop crop plants with "resistance" to weeds or to very many of the important insect pests, viruses and soilborne plant pathogens. New methods are needed to both accelerate and extend or expand the application of genetics research to solve many of the remaining, emerging and intractable pest problems.

BENEFITS OF ACCOMPLISHMENTS IN THE POULTRY AND DAIRY INDUSTRIES

The development of the U.S. poultry industry during the past 20 years is among the most remarkable in the history of agriculture. It was at Michigan State University where Richard Witter led the team of U.S. Department of Agriculture (USDA) and Michigan State University scientists in the development of a vaccine to control Marek's disease. Without a means to control Marek's disease, the poultry industry as it is today probably could not have developed.

The poultry industry is cited as an example of "industrial agriculture," where the producer, processor and wholesaler are "vertically integrated" as a single enterprise. Some view this method of agriculture as the antithesis of sustainable agriculture. Yet this method of agriculture has made poultry meat available to the American consumer at remarkably low prices and may even be changing the eating habits of Americans. It would be unimaginable, in hindsight, to have stopped research aimed at controlling Marek's disease in order to have prevented industrialization of the poultry industry.

The U.S. dairy industry is another example of how research and new technology has produced remarkable benefits for consumers. The first and possibly most important technological breakthrough was the development of the milking machine. This machine opened the way for rapid and concurrent developments in improved nutrition, breeding with superior sires through artificial insemination and other emerging innovations aimed at improving production, efficiency and economic return per cow. When my first child was born in 1960, a gallon of milk cost about $1.00 and the minimum wage in this country was about $1.00 per hour. When my first grandchild was born Nathan Randal Cook in Tacoma, Washington on May 22,1994, a gallon of milk cost about $2.40 but minimum wage is up to $4.90 in the state of Washington. In 1994 a person on minimum wage for an hour of work can buy a gallon of milk and have $2.50 left over for other purchases.

The concentration of the livestock industry into fewer but larger operations has created problems for waste management. Each herd of 200 cows produces the waste equivalent to a town of about 5,000 people. This problem must and will be solved in the same way it had to be solved for the concentration of people in towns and cities. Some of the solutions to waste management in the livestock industry will come as new products are developed through biotechnology, such as a microbe genetically modified for ability to decompose feathers. Consider further that it would take twice as many cows—another 15-20 million—and more land to feed them to produce today's milk supply using the genetic stock and technology available in the 1950s. Total nutrient intake by the cow must increase to support an increase in production of milk, but nutrients required by the cow for maintenance remain unchanged regardless of the amount of milk produced. Thus, a cow producing 30 pounds of milk per day needs the same amount of nutrient intake for maintenance as a cow producing 60 pounds of milk per day. The extra nutrient required by the more productive cow is virtually all for production of milk (Bauman 1992).

Dairy cows produce 10-15 percent more milk when administered bovine growth hormone/bovine somatotropin (bST) as a supplement to their natural endogenous supply of bST. The technology to produce bST "synthetically" is similar to that used to produce human insulin for diabetics, namely, the relevant gene is spliced into the genome of a bacterium which then produces the hormone (or insulin) in fermentation culture.

One concern for bST is the prospect of more infections (e.g., mastitis because of higher stress levels) and therefore more use of antibiotics in association with milk production. I recall clearly as a farm youth in Minnesota that the introduction of the milking machine resulted in more udder infections, but this was addressed by better herd management rather than by rejection of the milking machine. Each new technology tends to create new problems that must then be solved or the new technology cannot or should not be widely adopted. It is the nature of technology, and agriculture is certainly no exception.

SEEDLESS GRAPES: A CASE STUDY

Seedless grapes are not new, but seedless types comparable in quality and yielding ability to seeded types have become available to consumers only during the past 10-15 years. The new seedless grapes are developed by seedless X seedless hybridizations followed by tissue culture of embryos (or vestigial seeds) to produce plants for testing and selection of desirable types. The seedless grapes in our grocery stores today were mostly developed by public-supported researchers for the public good, namely USDA Agricultural Research Service (USDA/ARS) scientists at Fresno, California and state Agricultural Experiment Station scientists at the University of California, Davis. The development and the consumer demand for seedless grapes is an interesting case study.

Impact on small farms has been raised as an issue that should be taken into account before using the new products of biotechnology. Consider that because of demand for the modern seedless grapes as a new food product, growers must replace their vineyards of seeded varieties with seedless varieties. For small farms, this could mean no paycheck and even going out of business while waiting for the newly planted (or grafted) vines of seedless types to reach full production. Present predictions are that seeded types will be replaced almost entirely by seedless grapes within the next 10 years. Impact on small farms as a consideration could have prevented the release of modern varieties of seedless grapes, but not releasing the new seedless types available would have denied this "convenience food" to consumers.

This kind of product transition with costs and benefits to producers has been repeated time and again during this century as growers compete and make adjustments to meet the needs of their customers.

Safety has been raised as an issue for fresh fruits and vegetables produced with the new tools of biotechnology. The safety of seedless grapes was established based on familiarity with the crop and trait. This familiarity predicted that if seeded grapes are safe, then seedless grapes are also safe or safer. For the same reasons, the concept of familiarity would predict that if, because of a cell-wall degrading enzyme, tomatoes that get soft quickly after ripening are safe to eat, then tomatoes that remain firm longer after ripening because the gene for production of that enzyme has been inserted to read antisense are also safe as food. Yet this approach to assuring safety was not used with Calgene's Flavr Savr™ tomato. Instead, Calgene worked with the U.S. Food and Drug Administration (FDA) over five years to satisfy the issue of safety, not because of the properties of the tomato, but because of the method of genetic modification used to develop this tomato. This is contrary to the conclusion and recommendation produced by a 1987 study of the National Academy of Sciences that the product, not the method to produce the product, determines safety.

High costs associated with meaningless tests to prove safety can have major negative effects on the application of innovations based on the new tools of biotechnology. Not only are precious resources diverted from useful research and development (R 8; D), delay in return on investment for companies can lead to lower investments by the private sector, bankruptcies or limitations of this technology to those applications representing big markets. These developments are not in the best interests of the public good.

SUPPLYING CONSUMERS WITH PREFERRED FRUITS AND VEGETABLES

The advantages of seedless grapes are obvious to consumers, and the greater flavor of tomatoes that can be picked when pink, rather than while still green, will also be obvious once they are on the market. We consumers are more willing to accept new products of biotechnology in which the advantages are obvious and of direct benefit to us.

On the other hand, breeding varieties of crop plants for resistance to pests and diseases is perceived as advantageous to the producer or the seed company, but not the consumer. Yet the very use of molecular methods to produce disease and pest-resistant varieties of some fruits and vegetables is being driven by consumer demand. I am referring not only to demand for fruits and vegetables produced without pesticides, but also the demand for certain preferred and familiar varieties of fruits and vegetables that should be replaced by varieties better adapted to environmental stresses or with better resistance to pests.

The Russet Burbank variety of potato is now more than 100 years old and is "obsolete" by standards based on the need of producers to change varieties in response to new and evolving pressures from pests. Yet the Russet Burbank is the most popular variety of potato in the U.S. Restaurants prefer this variety for baking almost to the exclusion of other varieties. Processors also prefer this variety because of its shallow eyes, large size and oblong shape.

To meet the market demand for Russet Burbank potatoes, growers have turned to management, including the use of several pesticides, to produce these potatoes economically. Useful sources of disease resistance are available in wild relatives of potato, and varieties expressing this resistance have been developed. Some of these varieties can supply niche markets but they do not meet the needs of the large markets for potatoes in the U.S. Potato genetics and ploidy levels are complex and transfer of resistance by wide-cross or other methods of classical breeding can take years.

With biotechnology, genes can be isolated and cloned by relatively precise molecular methods and inserted into the genome of the Russet Burbank potato while still preserving the desired tuber type. Molecular methods can therefore be used to update a variety while leaving the marketable product horticulturally unchanged. Similar situations and opportunities exist for apples developed for resistance to apple scab and fireblight, grapes developed for resistance to powdery mildew, and many others. Biotechnology could usher in a new approach to updating varieties without having to create new markets.

BENEFITS OF A SINGLE GENE ILLUSTRATED WITH WHEAT

The benefits to the public and worldwide of just one particular gene deployed in a crop plant is illustrated by the *RHt* gene for dwarf growth habit in wheat. Orville Vogel of USDA/ARS at Washington State University, with his Norin-10 X Brevor-14 cross in the 1940s, made the first successful transfer of an *RHt* gene into a line of wheat that could be widely used in breeding programs. Previous attempts to transfer this gene into lines that could be used in breeding programs were unsuccessful. They met with problems of sterility, or the lines produced were agronomically too poor to merit the long investments of time and resources required as backcrosses to produce useful germplasm. The wheat line produced by Vogel was fertile, agronomically acceptable and produced higher-yielding plants because of a significantly higher ratio of grain to straw. Within 20 years, this gene for short stature was used in an estimated 50 percent of the wheat varieties worldwide. Norman Borlaug used Vogel's new lines to produce the high-yielding semidwarf wheats credited with sparking the Green Revolution. In Washington Sate alone, where the first semidwarf wheats were released to farmers in 1961, income to the economy of the state because of the higher yields is placed at more than $50 million each year. Semidwarf varieties using either the *RHt-1* or *RHt-2* genes are now widely grown in the U.S. It would take about 70 million more acres of cropland to produce today's U.S. wheat crop with 1950s varieties and technology.

The introduction of semidwarf wheats required the development and implementation of new management practices in order to achieve the full yield potential of these varieties. One of the new practices was earlier seeding in the fall—August or September rather than October or November. Early seeding on summer fallow also helped control soil erosion, but the lush fall growth of early-sown wheat created a microclimate at the soil surface highly favorable to sporulation of the eyespot-foot-rot fungus, *Pseudocercosporella herpotrichoides.* This disease created havoc by rotting stem bases and made harvest slow and difficult due to lodging.

The upsurge in importance of eyespot-foot-rot in wheat is another example of a problem made important by a new technology, but where the solution came from further innovations and better management and not from rejecting the new technology. By 1964, a method was developed to screen wheats for resistance to this disease. It takes a minimum of 15 years to produce a new wheat variety by classical methods, provided that useful genetic variability for the desired traits are already available. Fortunately, researchers in France, where the eyespot-foot-rot disease was also important, were successful in transferring the *pch* gene for resistance from the wild tetraploid *Aegilops ventrocossum* into hexaploid wheat by wide cross. Like the semidwarf wheat line produced by Vogel, this germplasm can be used in other breeding programs for classical breeding regardless of the method or difficulty of introducing the gene once the gene is introduced into an agronomically acceptable breeding line. The germplasm with the *pch* gene for resistance to *P. herpotrichoides* was made available to the breeding programs at Washington State University, and in 1991, two new semidwarf wheats with this gene were released to farmers. Fungicides were used as a temporary method to control this disease on as many as one million acres during peak use, but are now being rapidly phased out with the adoption of the new varieties resistant to this disease.

Weediness has been raised as a safety issue for crop plants developed by biotechnology. This same issue might also be raised in relation to use of the *pch* gene which, together with attendant unwanted genetic material, was transferred by wide-cross into wheat *from a weed.* Plant breeders have been safely managing crop plants with genes, chromosomes and entire genomes from weeds for decades, and the same or similar approaches to assuring safety can be used to manage crop plants with genes introduced by molecular methods.

Gene transfer by outcrossing with a weedy relative has also been raised as a safety issue for crop plants developed by biotechnology. Again, this same issue might be raised in relation to use of the *pch* gene in wheats in the Pacific Northwest. Jointed goatgrass *(Aegilops cylindrica),* a relative of wheat, is among the most common and difficult to control weeds in the wheat-growing areas west of the Mississippi River. Occasional hybridizations occur between wheat and goatgrass, but the progeny are sterile. Seed fields are inspected, and the detection of even a single wheat-goatgrass hybrid plant in the field (even though the plant is sterile) will result in failure to certify the seed from that field. Like weediness, gene transfer by outcrossing with a weedy relative cannot be dismissed as a safety issue, but rather, methods to manage these risks are and must be used and continually improved.

POTENTIAL SOLUTIONS TO WHEAT ROOT DISEASES

Root diseases, namely take-all, rhizoctonia root-rot, and pythium root-rot, are the latest problems faced by the wheat industry as a consequence of another "new" technology, the use of conservation tillage (including no-till) to limit soil erosion. Besides lower yields, wheat with diseased roots also leaves nitrogen fertilizer unused in the soil profile.

Root diseases are best managed by extending the crop rotation to include noncereals and fewer wheat crops, but even wheat in a three-year rotation is affected by root diseases when no tillage is used. These pathogens are especially adept at survival in the cool, dry soils typical of the prairie soils of the Pacific Northwest and Great Plains. These are also the soils and regions particularly suited to cereal-based agriculture. It has not been possible to produce wheat varieties with resistance to root diseases because there are no useful sources of genes for resistance within the normal pool of wheat germplasm. Some progress has been made in the management of these diseases through agronomic changes in the way wheat is planted and fertilized, but the high production capability of wheat grown without tillage will not be realized without a major scientific breakthrough in a biological/genetic approach to the management of these diseases.

In nature, certain disease-suppressive bacteria associate naturally with the roots of wheat, but they occur at populations too low to provide adequate protection in all but rare situations. My USDA/ARS group at Washington State University has characterized and cloned the potentially useful genes in these bacteria which are for production of antibiotics. We have shown further that elevations in populations of these bacteria introduced with seed, or greater expression of antibiotics through gene manipulation, leads to better protection of wheat roots against take-all, the most important root disease of wheat worldwide. We now have a choice: express these useful traits by molecular breeding in the roots of "transgenic" wheat; or deploy them in the strains of bacteria introduced with the seeds of wheat.

For many reasons, we have elected to deliver this disease defense mechanism as a live bacterial seed treatment. We already have evidence that the effectiveness of some naturally occurring strains can be improved by genetic manipulation. Through genetic alterations we can eliminate undesirable traits, combine desirable traits and customize strains of microbes for specific applications.

My father as a Minnesota farmer collected and restored old farm machinery as a hobby. He had a one-bottom plow that looked like a walking plow but had two wheels, a seat and a pole to hook up two horses. He had a sign on that plow that read:

First Ride-on Plow: What a Great Day for the Farmer

The majority of farmers in wheat-growing areas continue to use the moldboard plow to control weeds because wheat yields are higher compared to minimum and no-till systems largely because there is less root disease. A new means to control root diseases would make the wheat more competitive with weeds, improve fertilizer-use efficiency and raise yields without depending on the moldboard plow. This would be an even greater day for the farmer, a great day for the environment and a great day for sustainable agriculture.

PLANT-ASSOCIATED MICROBES AS AID TO SUSTAINABLE AGRICULTURE

The discovery of plant-associated microbes as a potential defense mechanism against pests is a major breakthrough for sustainable agriculture. Plant-associated microbes are like an extension of the plant's own morphology, physiology and genetics. Some may serve as genes for future plant improvement. Used as organisms themselves, they offer still another dimension for plant improvement. Not all genes need to be in the seed if some can be effectively delivered in microbes with the seed.

Among the many potentially useful plant-associated microbes are fungi known as endophytes which are harbored in the leaves of some grass species. These specialized fungi produce substances, such as alkaloids, that are toxic to leaf-feeding insects. Many plants produce their own chemicals as a defense against insect pests, whereas other plants and their endophytes coexist in a symbiotic relationship in which the plant provides nutrients and a home for the endophyte, and the endophyte protects the plant against insects.

Unfortunately, ryegrass with endophytes causes a problem in cattle known as ryegrass-staggers. And certain fescue grasses with endophytes cause a problem in cattle known as fescue toxicoses. It is a relatively simple matter to produce grass seed without these endophytes, but the grass plants are then subject to more damage from insects. Potentially, genetic alterations could produce endophytes with the ability to protect the host grasses against insect attack but no longer cause harm to cattle that feed on the grass.

The work with ice-minus bacteria illustrates another use of genetically altered microbes for plant defense. Pathogens are used to produce nonpathogens, then these nonpathogens are used to control their parent pathogens. The principle is similar to the use of disarmed strains of pathogens as vaccines to control diseases of humans and animals. Nonpathogens derived from pathogens potentially can be used to block infection sites on plants, compete with pathogens for nutrient sources and induce plants to express resistance to pathogens. This area of research has enormous potential.

Microbes also have potential to protect poultry and livestock against infections. As an example, newborn piglets are highly vulnerable to neonatal scours caused by a strain of *Escherichia coli,* which has the ability to both attach itself to the inner lining of the intestine and produce a toxin responsible for the disease and often death of the piglet. Certain strains of *Lactobacillus* have the ability to occupy the attachment sites used by *E. coli,* but they do not produce the toxin. A product has been developed in the U.S. consisting of cells of the *Lactobacillus* species that can be administered to piglets immediately upon their birth, swamp the attachment sites and preempt the pathogenic *E. coli.*

AGROBACTERIUM RADIOBACTER STRAIN K84, A MODEL MICROBIAL BIOCONTROL

Agrobacterium radiobacter strain K84 is a plant-associated microbe discovered by Allen Kerr at the Waite Agricultural Research Institute in Adelaide, Australia. It is a bacterium closely related to *Agrobacterium tumefaciens,* the cause of crown gall of fruit and nut trees such as peach, apple and almond. Kerr and his associates discovered strain K84 in soil around trees that were susceptible to, but surprisingly free of, crown gall. They showed that simply dipping the bare roots of transplant trees into a bucket of strain K84 cells suspended in water is sufficient to protect the roots against infection by the soil-inhabiting *A. tumefaciens* when the transplants are planted into the natural soil. This strain is now in use for biological control of crown gall literally all over the world.

Strain K84 illustrates many of the points regarding the discovery, development and use of microbes for biological control of pests and diseases, including how gene manipulation can be used to reduce a risk. As a plant-associated microbe, it occurs naturally on plants susceptible to crown gall, but the populations are too low or usually not in the right places or at the right times to provide adequate natural biological control. The crown gall pathogen infects through wounds created during transplanting. Hence dipping the bare roots in a cell suspension of K84 assures an adequate population on the roots, and especially in the wounds, exactly when and where the protection is needed.

Strain K84 is thought to protect against infection by *A. tumefaciens* by occupying potential sites otherwise occupied by the pathogen and by production of an antibiotic inhibitory to the pathogen. It is common in nature for microbes to evolve mechanisms by which to inhibit their nearest kin since they, being ecologically and physiologically so similar, represent the most likely and serious competition for sites and limited supplies of nutrients. Crown gall is caused when the pathogen transfers a segment of its own DNA into the plant genome thereby genetically engineering the plant to produce the galls. This transfer of bacterial DNA into the plant genome also confers ability on the galls to produce novel amino acids that it—the crown gall pathogen, but not very many other common soil microbes—can use as a source of nutrients and energy.

Strain K84 lacks the genetic mechanism needed to induce crown gall, but it can use the novel amino acids. It therefore allows the pathogen to induce the galls and then it takes over by inhibiting the pathogen. Of course, if K84 acts too quickly it limits its own food supply. This is how the biological control works; by use of the root dip, K84 enters the scene before rather than after infection thereby preventing crown gall, but in the process ends up with no new source of food for itself.

Strain K84 has one genetic mechanism for production of the antibiotic and another closely linked genetic mechanism for insensitivity to its own antibiotic. Through natural matings with the pathogen in soil or on roots, in rare cases, it is possible that strain K84 can transfer the genetic mechanism for insensitivity to the antibiotic to the pathogen, whereupon the pathogen would acquire resistance to biological control by K84. Researchers at the Waite Agricultural Research Institute used molecular methods to develop strain K1026, a derivative of K84 with the trait for transferability of resistance to the antibiotic genetically deleted. This deletion does not affect biocontrol activity, but it precludes the possibility that resistance could be transferred to the pathogen. The genetically altered strain is now used commercially in Australia.

Strain K84 is used worldwide, but it is no exception to the principle that biological control is highly specific. For example, it does not control the strains of *A. tumefaciens* responsible for crown gall on grapes, nor has it represented a major market potential. It works on several kinds of trees and ornamental plants but controls only one disease and needs only to be applied once—at the time of transplanting—during the life of these trees or ornamental plants. The demand for cells of this microbe in any one state, or any one country for that matter, can be and usually is provided by a single supplier. Initially, Kerr provided the cells as a service of the Waite Agricultural Research Institute, but today a small company grows and packages the microbe for distribution to growers in Australia. Another small company provides strain K84 for use in the U.S.

Strain K84 illustrates how the use of microbes introduced into the environment for pest and disease management can meet some of the most fundamental goals of sustainable agriculture and forestry—renewable, nonpolluting, nondisruptive ecologically, and of potential benefit to local and rural communities by creating local business opportunities. Many more examples of this kind should be forthcoming from public and private research.

ENSURING FULL BENEFITS OF AGRICULTURAL BIOTECHNOLOGY FOR THE PUBLIC GOOD

Products such as the Flavr Savr™ tomato will expand into national and even international markets. Other applications such as a genes for resistance to locally important pests or pest-specific microbial biocontrol agents are not likely to attract large markets, but they would still be of great importance to local communities or entrepreneurs. As pointed out above, the success of the genetics approach has been the ability to make and use as many genetic changes in crop plants and breeds of livestock as necessary to solve problems for agriculture, food and the environment while also meeting the needs of consumers. It will not be in the public interest if the use of these products and practices is limited to "big ticket" items.

Washington State University scientists developed a variety of winter wheat (Sprague) by classical breeding to control one disease (snowmold) that was important only in northeastern part of the wheat-growing region of Washington state. Sprague wheat saved the wheat industry and economic means of the people in these few counties. This variety was then adopted for use by wheat-growers in snowmold-prone counties in southern Idaho with similar benefits. Plant breeding programs, whether public or private, must be able to use the best tools available to produce the best possible varieties for the network of local and regional environments.

The application of biotechnology, if made difficult and expensive, could seriously limit the biodiversity available for use in agriculture. The risk with conferring herbicide resistance is the potential overuse of resistance to the same herbicide in crops, or varieties of the same crop, resulting in the natural selection of herbicide-resistant weeds. Experience with classical breeding has made it abundantly clear that overuse of the same gene for resistance to a disease or insect pest in varieties of the same crop relatively quickly selects for populations of that pathogen or insect pest with the ability to attack the new varieties with the gene. This risk is made even greater with the ability to deploy the same gene for pest resistance in several unrelated crops as well as several varieties of the same crop.

We should be especially concerned with the "threat" to biodiversity as the foundation for integrated pest management systems (IPM). Once-diverse cropping systems already have been mostly replaced in the U.S. by simple two- and three-year crop rotations or by monocultures. The number of plant breeding programs supported by the USDA and the state agricultural experiment stations is on the decline. Private plant breeding programs will take their place only where justified by market size and profit potential. And the higher the costs for research and development, the larger the market required for return on the investment, thereby further excluding minor but important applications. Intellectual property rights, costs of licensing and possible regulatory approvals for disease and pest resistance mechanisms and associated genetic material could force the widest possible use of the fewest possible genes, further undermining diversity in IPM. Limitations on collections, importation and use of biological resources including germplasm and natural enemies of insect pests are already slowing the use of these kinds of resources for the public good.

These concerns are not unique to the products of biotechnology but are becoming more serious concerns because of biotechnology. There is the further concern that the high costs of obtaining regulatory approvals for scale-up of crop plants developed by biotechnology will limit public programs to classical breeding. Many applications needed to help solve local and regional problems are also important to our nation's food security and sustainability of agriculture. But they will be forthcoming mainly or only through public-supported research programs. Moreover, the strength of the U.S. investment this century in a genetics approach to solving problems for agriculture, food and the environment has come from the network of public and private breeding programs. Every effort must be made, both as policy and in setting priorities for research and extension, to help ensure the widest possible benefits of agricultural biotechnology for the public good.

REFERENCES

Bauman, D. 1992. Bovine Somatotropin: Review of An Emerging Animal Technology. *J. Dairy Science.* 75:3432-3451.

Agricultural Biotechnology and the Public Good

Hope J. Shand
Research Director
Rural Advancement Foundation International

By way of introduction I want to explain that the Rural Advancement Foundation International (RAFI) is a private, nonprofit organization that works on the interrelated issues of agricultural biodiversity and biotechnology. We are an international research and advocacy organization with offices in North Carolina, USA and in Ottawa, Canada. Since 1986, my own work has focused on the social and economic impacts of emerging biotechnologies, particularly as they affect poor farmers and rural communities—especially in the developing world.

I come here today as an activist and as a critic of biotechnology. But I want to stress that I am not against biotechnology or genetic engineering. I think it is impossible to assign labels such as "good" or "bad" to a new technology. The more fundamental issue is who will *control* these technologies and who will *benefit* from them.

I cannot think of a more appropriate or important theme than *Biotechnology and the Public Good* for this sixth annual meeting of NABC. It seems to me that the format of the workshops scheduled today and tomorrow will allow for an interesting discussion of many topics—whether it be under the title of structure of agriculture, global interdependence or environmental stewardship. Today, I would like to make some brief comments on each of these three general topics.

GLOBAL INTERDEPENDENCE

The theme of global interdependence is especially relevant to the topic of biotechnology and the public good. It is virtually impossible to talk about biotechnology without looking at the global dimensions and without an appreciation for the interdependence of all nations. One of the common denominators, of course, is our genetic interdependence. Access to biological resources is the lifeblood of agricultural biotechnology. The genes from plants, animals and microorganisms of the developing world, in particular, are the "strategic raw materials" for the development of new food, pharmaceutical and industrial products. But these genes are seldom "raw materials" in the traditional sense because they have been selected, nurtured and improved by untold numbers of farmers and indigenous peoples over thousands of years.

All major food crops, the staple crops grown and consumed by the vast majority of the world's population, have their origins and centers of diversity in the tropics and subtropics of Asia, Africa and Latin America. Over the past 12,000 years, Third World farmers selected and domesticated all major food crops on which humankind survives today. Fresh infusions of exotic germplasm are vital for the ongoing maintenance and improvement of agriculture.

Whether they are used in traditional farming systems, conventional breeding or modern biotechnology, genetic resources are a global asset of incalculable value—now and in the future. As genetic diversity erodes, our capacity to maintain and enhance agricultural productivity decreases along with the ability to respond to ever changing needs and conditions. If we are to adapt food production systems to rapidly changing climatic conditions in the next century, plant and animal genetic resources will offer the single most critical resource for doing so. Biological resources are the key to increasing food security and environmental stability, and to improving the human condition.

But I want to stress that the knowledge of farmers and indigenous peoples and their role in conserving and developing biodiversity is *not* ancient history. Today, for example, the Ifugao of the Philippine island of Luzon can name more than 200 varieties of sweet potato. Jivaro farmers in one Amazonian community grow over 100 varieties of manioc. In one Liberian village, Kpelle women maintain over 112 varieties of upland rice.

These plant genetic resources reflect the ingenuity, inventiveness and sophistication of what we call "informal innovation systems." There is increasing recognition worldwide that the indigenous knowledge of thousands of human cultures is of utmost importance in understanding, utilizing and conserving biological diversity for agriculture and sustainable development. The subject of biodiversity assumes utmost urgency today because we are losing biological resources at an unprecedented rate. A great deal of progress has been made in bringing the issue of biodiversity to the global policy arena. In late 1993, the Convention on Biological Diversity gave us the first legally-binding framework for conservation and sustainable use of biodiversity.

Life Patenting

Unfortunately, international cooperation to conserve biodiversity and to ensure its equitable and sustainable use is jeopardized by the efforts of some industrialized countries to obtain exclusive monopoly control over genes, plants, animals and other living organisms—including human genetic material. With the advent of genetic engineering, the biotechnology industry has successfully promoted the extension of industrial patenting regimes to *all* biological products and processes. It has happened in less than 15 years. Many of you are familiar with the landmark decisions, but let me review them quickly:

—In 1980, the U.S. Supreme Court ruled in the groundbreaking case of Diamond vs. Chakrabarty that genetically engineered microorganisms are patentable.

—In 1985, the U.S. Patent Office ruled that plants could be patented under industrial patent laws.

—In 1987, the U.S. Patent Office ruled that genetically engineered animals are also patentable.

As a result of these decisions, virtually all living organisms in the U.S.—including human genetic material—became patentable subject matter just like toasters or light bulbs. Genes, plants, animals and microorganisms—whether simply discovered in nature or manipulated by genetic engineers—could be rendered the intellectual property of private interests.

The biotechnology industry is lobbying vigorously, and quite successfully, to see minimum standards of intellectual property enforced worldwide. The European Parliament is currently debating the "Directive on the Legal Protection of Biotechnological Inventions" which proposes to extend life patenting in Europe. The recently concluded General Agreements on Tariffs and Trade and Trade-Related Aspects of Intellectual Property Rights (GATT-TRIPs) agreement will obligate signatory states to adopt intellectual property laws covering both microbial materials and plant varieties. This means that many developing nations will be forced to adopt plant intellectual property rights under the threat of trade sanctions. In many cases, these laws may be entirely inappropriate for some nations' needs and level of development.

Proponents of patenting argue that it stimulates innovation by rewarding patent holders and enables companies to recoup their research investment. But for farmers and consumers of the developing world, in particular, this means having to pay royalties on products which are based on their own biological resources and knowledge. Let me give three brief examples of what we call "Biopiracy."

The first example is the case of thaumatin, the super-sweet protein derived from a West African plant. Genetic engineers from Lucky Biotech Corporation and the University of California recently received U.S. and world patents for any plants that are genetically engineered to express super-sweet natural proteins derived from thaumatin.[1] The thaumatin plant protein is the sweetest substance known to humankind—scientists say it is 100,000 times sweeter than sugar. (For background on thaumatin, see Shand 1987a.) It grows in the humid tropical forests of West Africa where local people have used it for centuries as a sweetener and flavor enhancer. Imagine the potential commercial market for a low-calorie, natural sweetener that can be inserted into the genetic makeup of any fruit or vegetable! (In the U.S. alone, the market for low-calorie sweeteners is $900 million per annum, but West African people will have rights to none of it.)

---

[1] International Patent, Publication Number WO 92/01790, dated February 6, 1992 and U.S. Patent Number 5,234,834.

The second example is the U.S. patent on genetically engineered or transgenic cotton.[2] (For a complete analysis, see Shand 1993a.) Even biotechnology industry representatives were shocked in late 1992 when Agracetus, Inc., a biotechnology subsidiary of W.R. Grace Corporation, received a patent for *all* genetically engineered cotton varieties. The first-ever "species patent" gives this company the right to decide when and if it chooses to license its technology—for how much and under what conditions—until the year 2008. In other words, transgenic cotton varieties cannot enter the commercial marketplace without payment of royalties to Agracetus. But the impact of this patent is not limited to the U.S. Agracetus applied for similar patents in India, China, Brazil and Europe, hoping to gain monopoly control over transgenic cotton in areas accounting for 60 percent of the world's cotton production. Cotton was first domesticated and improved by farmers in Central and South America. The notion that Agracetus "invented" transgenic cotton is offensive and unjust. Modern plant breeders and genetic engineers are literally building on the accumulated success of generations of anonymous farmers. Under the industrial patent system, however, it will be *illegal* for farmers to save seed from transgenic cotton plants without payment of royalties. In addition, utility (industrial) patents do not automatically give permission to researchers to use protected plant varieties for research purposes or to develop new commercial varieties.

The patenting of a major industrial crop is disturbing enough, but in March 1994, the same company, W.R. Grace Corporation, received a European patent on *all* transgenic soybean.[3] (For further details, see Mooney and Shand 1994.) RAFI is officially challenging this patent on a major food crop, for we view the patent as a threat to world food security. Geoffrey Hawtin, Director-General of the International Plant Genetic Resources Institute based in Rome, refers to the species-wide patents claimed by Agracetus as "economic highjacking." He states:

> The granting of patents covering all genetically engineered varieties of a species, irrespective of the genes concerned or how they were transferred, puts in the hands of a single inventor the possibility to control what we grow on our farms and in our gardens. At a stroke of a pen the research of countless farmers and scientists has potentially been negated in a single, legal act of economic high jack.[4]

---

[2] U.S. Patent Number 5,159,135, dated October 27, 1992. Title: Genetic Engineering of Cotton Plant and Lines.

[3] European Patent Office Publicaton Number 0 301 749 Bl, dated March 2, 1994.

[4] Quoted in RAFI Press release, ***Food Patent Challenged,*** dated March 30, 1994.

Patenting the Human Cell Lines of Indigenous Peoples

The third and perhaps most disturbing example of biopiracy involves patent applications by the U.S. government on the human cell lines of indigenous peoples. A year ago, RAFI discovered that the U.S. government had applied for U.S. and international patents on the human cell line of a 26-year old Guaymi Indian woman from Panama (Shand 1994). A blood sample was taken from this woman by a National Institutes of Health (NIH) researcher, who then established a cell line—this refers to cells that are capable of sustaining continuous, long-term growth in cultures, i.e., they can live indefinitely under artificial conditions. The sample was of interest because some Guaymi people carry a unique virus, and its antibodies could prove useful in AIDS and leukemia research. The scientist who took the DNA sample from the Guaymi woman followed the standard regulations for what is known as "oral informed consent." But informed consent does not require that you tell the research subject that you intend to patent genetic material derived from their DNA, or that someone stands to profit *if* a commercial product should someday be developed from the patented cell line.

Representatives from the Guaymi Congress in Panama were shocked to learn that the U.S. government could apply for patents on the human genetic material, let alone the cell line of a foreign national. The Guaymi Indians do not object to medical research or to making contributions that will improve the human condition, but they were morally outraged that the U.S. government would seek monopoly control over human cell lines and potentially profit from the genes of poor people. Isidro Acosta, President of the Guaymi General Congress, made this statement at a press conference in Geneva last October:

> I never imagined people would patent plants and animals. It is fundamentally immoral, contrary to the Guaymi view of nature, and our place in it. To patent human material...to take human DNA and patent its products...that violates the integrity of life itself, and our deepest sense of morality.[5]

As a result of protests by the Guaymi Congress, other indigenous peoples' organizations, nongovernment organizations (NGOs) and the European Parliament, the U.S. government silently withdrew its patent claim late last year.[6] But the issue is far from being resolved. In January, 1994, two more patent applications, again in the name of the U.S. government, were pending in Europe.

---

[5] Translated from Spanish. Quoted in RAFI press release ***Indigenous People Protest U.S. Secretary of Commerce Patent Claim on Guaymi Indian Cell Line,*** dated October 26, 1993.

[6] Express Abandonment Pursuant to 37 C.F.R. Sec. 1.138, for Human T Lymppho-tropic Virus Type 2, from Guaymi Indians in Panama. Letter dated November 1, 1993 from the Office of Technology Transfer, NIH to the Commissioner of Patents and Trademarks. Letter submitted by Susan S. Rucker, Attorney.

This time the cell lines come from citizens of the Solomon Islands and Papua New Guinea.[7] The cell lines are now on deposit at the American Type Culture Collection in Washington, DC. But since patent claims are still pending, access to these materials is restricted—even to the governments of Papua New Guinea and the Solomon Islands.

Private ownership of human biological materials raises many profound social, ethical and political issues. The patenting of human cell lines of indigenous peoples is clearly a violation of fundamental human rights—some have dubbed it a new form of "bio-colonialism." If these cell lines, or products derived from them, should someday result in commercial products, U.S. courts have ruled that the people from whom the genetic material is taken do not have rights of ownership over their own cells after they have been removed from their bodies[8] (see Annas 1993). According to corporate interpretations of the Biodiversity Convention, signatory states are obliged to recognize the ownership of genetic materials by countries or companies, but there is no mechanism to compensate the individuals or communities from whom the DNA samples were taken.

Well, some of you may be wondering what patenting of human genetic material has to do with agriculture. 1 mention this case because it clearly has a great deal to do with biotechnology and the issue of life patenting, and it clearly relates to the public good. The point I want to make is that there is enormous controversy and debate over the ownership of genetic resources. We do not hear as much about it here in the U.S., but it is an extremely hot topic in the rest of the world. And it is a subject we cannot ignore (Khor 1993). The ultimate danger is that the exchange of genetic material and information which is so vital for food security will be severely constricted, undermining efforts to conserve biodiversity and guarantee access to it. Under this scenario, everyone loses.

I will return to the issue of intellectual property rights, but I want to comment briefly on structural changes in agricultural production and trade, particularly in the developing world.

BIOTECHNOLOGY-STRUCTURAL CHANGES IN AGRICULTURAL PRODUCTION AND TRADE

There is little doubt that in the near future biotechnologies will profoundly shape our economic and social structures and our natural environment. In agriculture, biotechnology will change not only *where* our food is produced, but *how* it is produced and by whom. Although commercial biotech-

---

[7] WO93/03759 and WO/92/15325-A. Information on these patent applications came from Miges Baumann, SWISS AID, a development NGO based in Bern, Switzerland, dated January 14, 1994.

[8] Moore vs. Regents of the University of California, 793 P2d 479, 271 *Cal. Rptr.* 146 (1990).

nologies are being developed primarily by food, agrochemical and pharmaceutical corporations in the industrialized world, farmers and consumers of the developing world will be profoundly affected. Early in the next century we will see dramatic changes in global agricultural production and trade—with many negative implications for the Third World.

One very real threat is the transfer of production. The ability to produce high-value tropical products in the laboratory will ultimately transfer production out of farmers' fields into industrial bioreactors. This could mean massive displacement of agricultural workers and disruption of Third World economies.

Vanilla

One classic example is the case of vanilla. In California, a biotechnology company called Escagenetics is now producing natural vanilla in the laboratory using a cell culture technique. (For details see Shand 1991.) Instead of cultivating the vanilla orchid which produces the vanilla bean, this company is growing cells from the vanilla plant and getting those cells to secrete the natural vanilla flavor. No need for soil, sunlight or farmers.

Natural vanilla flavor is, traditionally, an expensive flavoring that can only be grown commercially in a few developing countries. Three-quarters of the world's vanilla bean production comes from the island of Madagascar, the Comoros and other small islands off the East Coast of Africa where about 100,000 small farmers are engaged in production of this high-value crop.

It is no exaggeration to say that, i/commercially successful, biosynthetic vanilla has the potential to displace vanilla bean exports on a massive scale. The last report that I am aware of is that a division of the Unilever Corporation, Quest International, had entered into an agreement with Escagenetics to determine the potential for scaling up the production of biosynthetic vanilla.

Of course, I am not suggesting that these islands should continue to be dependent on export crops like vanilla. But it takes time to diversify economically and it takes a great deal of planning. Remember, too, that the germplasm that makes possible the biosynthetic production of vanilla in the laboratory originated in the developing world.

I want to stress that vanilla is just the tip of the iceberg; it represents only one of thousands of plant-derived substances and primary export commodities which may be future targets of biotechnology. Other tropical products like coffee, cacao, pyrethrum and rubber are among the commodities now being targeted.

Biotechnology will also make it possible to *substitute* one raw material for another in modern food processing; the food industry calls this "multiple sourcing." The potential is especially dramatic in genetic modification of oils and fats. The industry's goal is to reduce reliance on high-priced, imported oils. Several companies are pursuing the goal of converting cheap oils such as palm or soybean into high-quality cocoa butter (Shand 1987b). One California-based company, Genencor Company, has patented a process to convert palm oil into expensive cocoa butter. Fuji Oil Co. of Japan has a patented process to develop cocoa butter substitutes from olive, safflower and palm oil. This is good news for food processors, and perhaps for consumers as well, but extraordinarily bad news for Third World cacao producers whose annual cocoa butter exports are valued at approximately $540 million.

These examples offer a glimpse of some long-term structural change in global food and agricultural systems with unintended, though very negative, consequences for many developing countries. New, natural substitutes as well as novel production processes will alter, reduce or eliminate the need for traditional cultivation of major food and industrial crops. At stake are not only foreign exchange earnings but the livelihoods of literally millions of agricultural workers who currently produce these products.

These examples are particularly important in light of the fact that the biotechnology industry so readily promises that genetic engineering will solve problems of hunger in the developing world. And, it is usually the promise of technology transfer that is so often mentioned as the reward for developing nations who make available their biological resources. Despite what other presenters indicated, I do not believe that commercial biotechnology is about feeding hungry people.

While new biotechnologies do have potential to address food and agricultural problems in the developing world, it is critically important to look at the social and economic as well as ecological risks associated with the introduction of these new technologies.

Of course, I do not mean to imply that U.S. farmers will be immune from these trends. As I mentioned earlier, under the industrial patent system it becomes illegal for farmers to save seed from patented varieties, or to sell offspring from patented livestock, without payment of royalties. This is just one example of how the role of farmers in society is changing and will be dramatically affected by emerging biotechnologies. Way back in 1986, Roger Salquist, the outspoken president and CEO of Calgene, made an important prediction about the impact of commercial biotechnology on agriculture (Salquist 1986). He said:

> The major thing that's going to happen in terms of biotechnology in agriculture, I believe, the single most startling thing is a strategic restructuring of the industry to vertical integration...Historically the processors of products from agriculture have purchased them on the commodity markets. What's going to happen with biotechnology is that you're creating *proprietary* products out of commodities.

Mr. Salquist was right. The biotechnology industry of the future will control a product from raw material to the point of consumption. As biotechnology firms gain control over every phase of production, processing and marketing—

from "seed to supermarket" as they say—the role of the farmer is reduced to that of a worker who grows crops and livestock under contract. In the development of new transgenic crops, for example, the trend is toward the development of "use-tailored, identity-preserved" seed varieties that are genetically tailored to meet specific needs—*not of the farmer,* but of the food processor (Wheat 1991, Wheat 1992). Under this scenario, the American farmer becomes a "renter of germplasm," rather than an independent, owner/operator. The trend is not new, but it will likely accelerate with the commercialization of transgenic plants and livestock. Agricultural economists such as Michael Boehlje (1992) predict that up to 40 percent of U.S. farmers will be growing "value-added" crops under contract by the year 2000.

ENVIRONMENTAL CONCERNS

Well, what about environmental stewardship? Will the biotechnology industry deliver on its promise to bring us a more environmentally friendly agriculture? Will new biotechnologies promote sustainable agriculture? These are issues that have been the subject of intense debate over the past years.

I am not an expert on the environmental impacts of biotechnology, nor is it the area I focus on day to day, but we *do* have concerns about the potential ecological risks involved with genetic engineering. RAFI and many other farm advocacy organizations continue to question whether or not the biotechnology industry will deliver on its promises to bring us a more sustainable system of agriculture. Several years ago, I coauthored a report entitled *Bitter Harvest: Herbicide Tolerant Crops and the Threat to Sustainable Agriculture* (Goldburg et al. 1990). This report is four years old, but our basic analysis remains the same. The bottom line is that agrichemical corporations are not developing herbicide-tolerant varieties because they want to clean up the environment, but because they are interested in selling more herbicides. Rather than moving us away from chemical dependence in agriculture, herbicide-resistant crops will entrench our reliance on toxic chemical weedkillers.

The biotechnology industry assures us that herbicide-tolerant crops will be engineered to resist only newer, less toxic herbicides. We reject that claim (Shand 1993b). The U.S. Department of Agriculture's (USDA) recent approval of Calgene's bromoxynil-resistant cotton is a case in point.[9] Bromoxynil is a known cause of birth defects in laboratory animals and is highly toxic to both fish and wildlife. With commercial sale of bromoxynil-resistant cotton, farmers can use a post-emergent herbicide on cotton for the first time. Here we see biotechnology being used to create new uses for a dangerous herbicide. It is a far cry from environmentally benign. Worldwide, herbicide tolerance is the trait most commonly tested in transgenic crops. In the U.S. approximately 40 percent of the field test applications for transgenic plants have been for herbicide tolerance.

[9] USDA/APHIS approved Calgene's petition for its bromoxynil-resistant cotton varieties for nonregulated status under USDA regulations on February 15, 1994.

Overall, we think it is important to acknowledge that genetic engineering of plants and microorganisms *is* new and still untested on a large scale. With genetic engineering the species barrier has been broken—allowing scientists to fashion new organisms that are not found in nature or in traditionally bred organisms. At this point, we have very limited experience with the use and behavior of novel transgenic plants, animals and microorganisms.

Of course, there is a great deal of important research being done in the area of biological insecticides as well as plants genetically engineered for beneficial traits such as insect and virus resistance. But published reports in the past few weeks remind me of how little we know, even in those cases where the end products are deemed the most socially beneficial and environmentally benign.

In March 1994, for example, scientists at Michigan State University published their findings that genetic engineering of plants to resist existing viruses may actually stimulate the evolution of new viruses (Greene and Allison 1994). While some scientists believe that the risk of creating new and harmful viruses is practically nil, the findings of Richard Allison and Ann Greene signal the need for further research on genetically engineered virus-resistance in plants. After all, approximately 18 percent of the field tests approved by USDA are for crops genetically engineered to resist viral diseases. Given the fact that the next step is commercialization of these crops, it is prudent to continue research designed to carefully assess the potential risks.

In the May 1993 issue of *Bio/Technology* magazine, there is an interesting editorial by Bernard Dixon, entitled *Keeping an Eye on* Bacillus thuringiensis (Dixon 1993). He begins his commentary by quoting scientists who describe *Bt* as "totally safe" and "nontoxic," an agent of biological insect control that could never pose a threat to human health. But he goes on to describe recent reports in the literature that suggest, *not conclusively,* that "nonpathogenic" members of the genus *Bacillus* can trigger human disease, especially among immunocompromised individuals under special circumstances. Based on these reports, he suggests that there may be particular grounds for concern about the dissemination of *B. thuringiensis* in areas of Africa with a high prevalence of immunosuppressive infections such as childhood measles in, malaria and AIDS.

I am *not* suggesting that we should discontinue research on genetically engineered virus-resistant plants or that Bt is harmful to human health. But these examples illustrate, I think, how little is known about the possible adverse impacts of introducing genetically engineered plants and microorganisms into the environment—*even* for those products that are considered the most environmentally benign and that clearly offer tremendous benefits for agriculture and human health.

In case you have not seen it, I urge you to take a look at the Union of Concerned Scientists' recent report entitled *Perils Amidst the Promise: Ecological Risks of Transgenic Crops in a Global Market* (Rissler and Mellon 1993). The report describes many of the potential ecological risks of transgenic plants and offers an innovative approach for scientifically assessing two aspects of risk—weediness potential and gene flow. The report calls on the U.S. to establish a strong federal program to assess and minimize the risks of transgenic crops before they are commercialized. It does a particularly good job, I think, of describing the potential threat to centers of crop genetic diversity, both in the U.S. and in the developing world.

In light of these risks, I find it particularly disturbing that the Biotechnology Industry Organization (BIO), a trade group, is lobbying the Clinton Administration to oppose the development of an international biosafety protocol under the Convention on Biological Diversity (Feldbaum 1994).

CONCLUSION

So, what can be done to address the issues of biopiracy and inequities that may result from the development of new biotechnologies that are based on both genetic material and informal innovation of the South (i.e., southern hemisphere)? I want to mention a few areas of policy reform that we think are important.

First, the whole notion of intellectual property rights over living materials needs broad societal review. New biotechnologies are being developed at a rate far faster than responsible social policies can be devised to guide them, or legal systems can evolve to adequately address them. Public debate has lagged far behind.

Intellectual property laws are designed to promote innovation, but it is clear that the system is out of control in regard to biological products and processes. Patents are a legal monopoly given by government in exchange for societal benefits. I would argue that there is *no* benefit for society when a single company is given exclusive monopoly control over an entire agricultural species. Patents are clearly an important marketing tool for biotechnology firms. Instead of promoting innovation, however, they may be stifling the free flow of information and genetic resources that are so vital to the biotechnology industry, public researchers and agricultural development worldwide.

We believe that there is an urgent need for the U.S. Congress to reevaluate the role of intellectual property rights as it affects agriculture and the public good. Unfortunately, every time in recent history that plant intellectual property rights have been amended, it has been to strengthen the rights of industry at the expense of farmers and society. The seed industry is lobbying very hard to take away the right of farmers to save and sell proprietary seed. And they want the U.S. government to ratify an international convention that makes it *optional* for signatories to allow farmers to save seed harvested on their own land.[10]

---

[10] Amendments to the Plant Variety Protection Act, H.R. 2927. Hearing held before the House Agriculture Subcommittee on Department Operations and Nutrition. May 24, 1994.

Secondly, there are two major shortcomings in the Biodiversity Convention that need to be addressed by contracting parties in future negotiations: 1. *ex situ* gene bank material; and 2. farmers' rights.

The Biodiversity Convention specifically excludes *ex situ* gene bank material collected before the enactment of the Convention. This means that the comparatively huge stockpile of agricultural germplasm held in gene banks around the world, most of it gathered from tropical and subtropical countries, remains outside the agreement. Two-thirds of gene bank collections are controlled by the North (i.e., developed countries in the northern hemisphere). Well over four-fifths of livestock and microbial collections are also controlled by the North. Because it is usually inventoried and catalogued, this is generally considered to be material of most immediate value. There is concern that germplasm provided freely by the International Agricultural Research Centre (IARC) gene banks could become subject to exclusive monopoly, and this, in turn, could constrain free exchange of germplasm.

There are some positive developments in this area. Last year, IARCs of the Consultative Group on International Agricultural Research (CGIAR) initiated discussions to place IARC gene banks under the auspices of the Food and Agriculture Organization (FAO) of the United Nations (UN). This move is intended to guarantee that genebank samples cannot be subjected to exclusive monopoly control under an intellectual property system.

There is also an urgent need for an international funding mechanism, under the auspices of the UN, that will recognize, reward and protect the innovations of farmers, indigenous peoples and their communities. FAO made important progress in this respect by recognizing the principle of farmers' rights. Basically, farmers' rights recognizes that farmers—past, present and future—have contributed greatly to the conservation, use and development of plant genetic resources, and that they should be recognized and rewarded for those contributions. The principle of farmers' rights has not been implemented in any meaningful way, but it could be strengthened and implemented as a protocol to the Biodiversity Convention.

Many NGOs, as well as governments, support the creation of a sustained international fund, provided for by governments via the standard UN formula and administered through a UN agency governed on the basis of one nation, one vote. Such a fund would not make payments to individual farmers or communities, but would direct practical support of specific programs and projects, such as training of plant breeders, construction of gene banks, etc., to bring about rural development and to conserve and enhance agricultural genetic resources.

Ultimately, the goal of such a fund is to enable all countries to share the rights and responsibilities of conserving and using biodiversity. The aim is to allow even the poorest countries to develop indigenous capacity to exploit their own genetic resources and to develop greater self-reliance in food production.

Similar resolution is needed on the issue of patenting of human genetic material. We believe that the contracting parties to the Biodiversity Convention should respond to the requests of indigenous peoples' organizations for protection from patent claims.

The U.S. government should drop all claims to the human cell lines of foreign nationals, and repatriate the materials to the indigenous communities or national governments involved.

Finally, international protocols should be developed by the appropriate UN bodies for protecting and broadening the rights of human subjects from commercial exploitation and patent claims.

REFERENCES

Annas, G.J. 1993. *Standard of Care: The Law of American Bioethics.* Oxford University Press, NY. pp. 167-177.

Boehlje, M. 1993. reported in Year 2000 Agriculture Predictions. *AgBiotechnology News No. 2.* 10(February):2.

Dixon, B. 1994. Keeping an Eye on *Bacillus Thuringiensis. Bio/Technology.* 12(May):435.

Feldbaum, C.B. 1994. Letter from the President of the Biotechnology Industry Organization to all members of the Senate Foreign Relations Commitee re: Convention on Biological Diversity, dated March 9.

Goldburg, R., J. Rissler, H. Shand and C. Hassebrook . 1990. *Biotechnology's Bitter Harvest: Herbicide-Tolerant Crops and the Treat to Sustainable Agriculture.* Report of the Biotechnology Working Group.

Greene, A.E. and R.F. Allison. 1994. Recombination Between Viral RNA and Transgenic Plant Transcripts. *Science.* 263:1423-1425.

Khor, M. 1993. *India: 500,000 Farmers Rally Against GATT Proposals and Patenting of Biomaterials.* Press release distributed by Third World Network, dated October 2.

Mooney, P. and H. Shand. 1994. "Species" Patent on Transgenic Soybeans Granted to Transnational Chemical Giant—W.R. Grace. *RAFI Communi que.* March/April.

Rissler, J. and M. Mellon. 1993. *Perils Amidst the Promise: Ecological Risks of Transgenic Crops in a Global Market.* Union of Concerned Scientists, Cambridge, MA.

Salquist, R. 1986. *The Future of Biotechnology in Agriculture.* Presentation at the Industrial Biotechnology Association annual meeting, October 24.

Shand, H. 1994. Patenting of Human Genetic Material. *RAFI Communique.* January/February.

Shand, H. 1993a. Control of Cotton: The Patenting of Transgenic Cotton. *RAFI Communique.* July/August.

Shand, H. 1993b. Comments to the Chief of Regulatory Analysis and Date, re: docket number 93-116-1, dated November 1, 1993.

Shand, H. 1991. Biotechnology and Vanilla. *RAFI Communique.* July.

Shand, H. 1987a. Biotechnology and Natural Sweeteners: Thaumatin. *RAFI Communique.* February.

Shand, H. 1987b. Cacao and Biotechnology: A Report on Work in Progress. *RAFI Communique.* May.

Wheat, D. 1992. *The Seed Industry in the Year 2000.* Presentation made for the Kansas Seed Industry Association, Wichita, Kansas. January.

Wheat, D. 1991. How Biotechnology Has Revolutionized the Seed Trade. *Seed World.* December, pp. 32-33.

Choices from the Past

Deborah Fitzgerald
Science, Technology and Society
Massachusetts Institute of Technology

As something of an outsider to this group, I am going to take the liberty of offering you a story from my "tribe," which is made up of historians and sociologists of the history of science and technology. One of the big questions in this tribe has to do with the relation between scientific knowledge and the culture that creates it. As we learn more about the actual circumstances that led to past scientific innovations, we become aware of the larger than expected role of serendipity, luck and ambiguity. Scientists increasingly look like architects of truth rather than mere discoverers and collectors of facts. And if this is an accurate portrayal of what scientists are, then one might reasonably expect that different cultures develop different ways of solving scientific and technical problems and, in some cases, might disagree with other cultures about which facts are real and which are spurious.

In our graduate program at MIT, we have a number of students working on some variation of this problem. One of them, Slava Gerovitch from the former Soviet Union, is studying the differences in the ways Russians and Americans have defined the field of artificial intelligence. He has found that although both Russian and American scientists "based their AI (artificial intelligence) models on their understanding of the process of *human* thinking, taking it as something homogenous, ahistorical and natural, the "humans" that they took as universal categories were, in fact, people who belonged to specific cultures." Thus, Americans and Russians approached problem-solving differently, and so understood the world in fundamentally different ways. And, most importantly, their models of intelligence were different.

Slava offered several examples. In America, predictability and causality are treated as social norms: when you go into a restaurant, you typically do what the waiter expects and the waiter typically does what you expect, as if you are both following a script. This predictability is also built into computers (it is called causal chaining inference rules) and people's expectations of causality are met in a culturally identifiable way. For Russians, on the other hand, it is difficult to follow such a script, or even to describe "normal" life. They are more inclined to describe life in terms of risks and unexpected emergencies. As Slava describes it, "people have to take risks because the environment is irregular, but it is irregular precisely because everyone is taking risks. Under these circumstances, any planning is impossible." Slava points out that, for an American in Russia, making an appointment to see someone only slightly improves one's chances of actually having such a meeting, rendering the ubiquitous American appointment book rather useless. Thus, where models of intelligence in the U.S. tend to be roughly linear, in Russia they tend to be roughly branching. Slava's other example of different problem-solving techniques focuses on the notion of choice. Americans are inured to the reality of making hundreds of choices every day from millions of options (grocery shelves, multiple-choice exams, quadraplex movie theaters, menus, department stores, etc.). But for Russians who go shopping, "the problem was not how to choose, but how to find anything at all." Indeed, where Americans view choice as a sacred right, Russians refer to choice as a burden. Where "Americans are accustomed to have such a wide range of alternatives that it is commonly perceived as a complete set of *all* possibilities, the main problem is merely to make the right choice." Russians "deal mostly with a narrow spectrum of alternatives and usually perceive it as inherently incomplete. They feel it necessary to widen the spectrum, to create a new, yet unknown, solution." I came upon an example of this very thing recently when reading about Americans who advised the Soviets on collectivization in 1929. Mordecai Ezekiel, a young farm economist in the U.S. Department of Agriculture (USDA), described efforts to teach Russian peasants how to thresh soybeans using a combine. He wrote, "One of the American specialists suggested how to set the teeth in the cylinder and adjust the speeds to do the job properly. Later he found the machine set as had seemed right to the workers, running full blast and churning the beans into an excellent imitation of soybean-oil butter. Again the workers announced proudly that they had discovered something. No one had ever had the idea of threshing beans with a combine—they were the first on earth to try it. The engineer's statements that it had been done for twenty years in America and could be done with the same combine far better than they were doing it, fell on deaf ears. The Russians thought they had discovered something new under the sun—and both the joy and the arrogance of discovery was theirs." Returning to AI modeling, then, while the Russian would be more comfortable with models that emphasize creative solutions to emergencies, the Americans would prefer a predictable sequencing of events. Neither model would be natural or universal to the other.

While Slava's notions of scientific thinking may seem far afield from biotechnology, I would like to suggest that these ideas of predictability and choice can help us think more critically about biotechnology, and particularly about its historical context. As a historian observing the emergence of agricultural biotechnologies, I have been struck by the way in which the discourse regarding the meaning of each new innovation is generally ahistorical; that is, both researchers and critics seem unaware of the scientific, technical and social precedents for the innovation. The particular characteristics of each innovation—hybrid corn's high yield, bovine somatotropin's (bST) increased production of milk, Flavr Savr's™ longer shelf-life—are emphasized, while its institutional and political relationship to earlier innovations is ignored. I do not mean to suggest that all such innovations were dreamed up by the same company or university, or that they are directly linked in any way. Rather, my point is that they all represent a generally singular pattern of relationships between federal research laboratories, corporate sponsors, individual scientists, regulatory agencies, universities and the public. Further, these relationships are historically grounded in institutional developments, so that scientific products are functionally quite similar despite their wildly different characteristics. While Flavr Savr™ tomatoes and hybrid corn might seem totally unrelated, they were both made possible, and some might say predictable, by virtue of the negotiations and collaborative arrangements that were set up with the Hatch Act of 1887 and the Adams Act of 1906—acts that defined the public good not in a misty-eyed, Jeffersonian America but in a steely-eyed, Gilded Age America.

While time does not permit a full-scale discussion of these arrangements, I would like to highlight the way in which such institutional deals served to push agriculturalists to model themselves on nonagricultural areas of science and engineering with the result that agriculture now finds itself stuck between the Scylla of the public and the Charibdys of the research establishment. As a way of illustrating this trend, I will consider how public and private choices in agriculture have been increasingly reduced over the years, despite the general feeling that we have an overabundance of choices. To do this, we will venture beyond the sphere of biotechnology per se because the historical precedents come from some surprising directions.

Looking at the trajectory of scientific and technological developments over the last hundred years, one is immediately struck by the trend towards making nature more rational, simple, tractable and more amenable to human control and understanding. In the life sciences this has been called "reductionism" and refers to the fact that since the turn of the century and the rediscovery of Mendel's laws, biologists have been inclined to study ever smaller increments of life and to extrapolate their findings to larger forms of life. One particularly striking example of this was the idea, developed in the first decade of this century, that if genes were responsible for the inheritance of such things as eye color and stature in humans, then they must also be responsible for the inheritance of other human traits such as alcoholism, lewdness, atheism or simple idiocy. The eugenists, as scientists who believed this were called, also believed that more promising characteristics were likewise inherited, such as high intelligence, kindness and good health. This was an attractive philosophy to those well-bred members of the scientific community who were uncertain how to manage the growing immigrant population, urban overcrowding and the increasing tendency of some to challenge the elite and its privileges. And eugenics was attractive because it promised a course of action, a capability for change, as had all successful scientific paradigms. If social and psychological characteristics were heritable, the logic went, then people with good characteristics should have lots of children and people with bad characteristics should not. By the early 1920s many states had passed laws allowing mental institutions to sterilize adolescents exhibiting such traits as feeblemindedness, epilepsy and promiscuity.

This reductionist approach was also operative in the drive to create hybrid corn in the 1920s. As the first biotechnological artifact, hybrid corn seemed to promise a much simplified commodity, a plant that had predictable and uniform features, that would harbor no nasty surprises, and that would look and act the same anywhere, anytime it was planted. The notion that Mendelian genetics led to all kinds of new corn plants hid the fact that, in their effort to create specialized plants that fit a niche for, say, short seasons or deep roots, scientists reduced both the strains available and the features of each strain. But the reductionism was not merely biological. Institutionally, USDA-sponsored institutions quit funding research on open-pollinated plants by the mid-1920s, confident that hybrids were the wave of the future and that maintaining and crossing open-pollinates would be a waste of time. By 1940, seed companies like Funk Brothers did not even offer open-pollinates for sale. While we are all aware of the genetic difficulties this caused in later years, I want to emphasize that the reduction of research capabilities through funding cuts, organizational changes and institutional realignments had just as tragic an effect. The pattern was established where new discoveries yield not an increased number of options for researchers, but a decreased number of options because the new *replaced*, rather than joined, the old.

While these new scientific forms grew out of the new Mendelian predictive capabilities, they also reflected broader trends in agricultural thinking. With the end of World War I, agricultural markets for American farm products closed with a bang. The ensuing farm depression was the most severe on record. With farm costs high, prices low and a flood of products on the market, thousands of farmers lost their farms and lots of banks and insurance companies found themselves owners of farms. Agricultural leaders such as Henry A. Wallace were perplexed: how to stabilize agriculture, how to guarantee farmers a fair profit, how to control the amount of corn or wheat or hogs farmers produced each year? For urban leaders, however, the answer was clear—make farming industrial. In their minds, there was nothing inherently rational or orderly about manufacturing either; however, J. J. Hill and Henry Ford and Thomas Edison had made it rational. The same should be done for farming, the last great romantic form of production.

The move towards large-scale farming in the 1920s was born of this belief that simplicity, rationality and standardization were proper ideals for agriculture, and that the manufacturing arena was a proper model. In manufacturing, this trend was fairly recent and involved replacing craft production with machine production. For example, before the 1910s most of the metal trades were still dominated by highly skilled craftsmen who fashioned each part on a piece by piece basis, hired and fired their own assistants, owned their own tools, followed their own work rules and kept their own hours, which often seemed anarchic to factory managers. When corporate observers were admiring Henry Ford's Highland Park assembly line in 1915, they were impressed not only with the number of cars Ford could produce, but with the way Ford had all but eliminated skilled and unionized workers from his shop, replacing them with unskilled immigrants and skilled machines.

While to us the differences between agriculture and manufacturing appear rather obvious, they were seen as challenges to be overcome by enthusiastic urbanites such as John D. Rockefeller and J. P. Morgan who financed some of the largest experiments in industrial farming. Weather was a real problem, but farmers need not just accept Nature's variations and impediments which, with a little ingenuity, could be made less troublesome. Just as Ford had economized by making only one kind of car, farmers could grow just one crop, such as wheat or oranges. Rather than worry about lack of rainfall in the West, farmers should consider changing Nature itself with massive irrigation projects. Rather than settling for Nature's parsimonious arrangement of fields, farmers could fill ditches, cut trees, flatten hillsides and join fields together to make a smoother tableland on which to operate big combines. Rather than relying on unreliable laborers, farmers should invest in such machinery. And, of course, farmers who were not very skilled in this new agriculture should consider some other line of work.

So-called corporate farms sprang up all over the place. Some were characterized by their vastness such as Thomas Campbell's 95,000 acre wheat ranch in Montana. Campbell had been trained as an engineer, not as a farmer, and produced wheat much as Henry Ford produced cars. He installed time clocks on his tractors and ran machinery three shifts a day around the clock. He was the model of the new agriculture, a hardheaded businessman who believed that farming was a productive enterprise, not a romantic way of life. Other examples of corporate farms included a livestock farm in Texas that boasted four towns, churches, a hospital, schools, roads, electricity and running water in workers' houses—in short, everything a skilled industrial worker could want. Other examples were a mint farm in Michigan, a turkey farm in California, wheat farms in Kansas, and so on.

One of the reasons for this sudden interest in industrialized farming had to do with the role of banks and insurance companies, which found themselves owning farms but not really knowing what to do with them. Desperate to improve these farms for resale, many such institutions hit upon the idea of hiring agricultural extension agents from the colleges and setting them up as farm managers. Such agents found that they could manage ten or twenty farms if they could simplify and rationalize operations across the board. It was simply too much work to treat each farm as an isolated and intrinsically unique entity; if they could be thought of as units of one big farm organization, or if their needs could be made similar to each other, then the job of managing them was much easier. Within a few years the field of farm management was created as a subset of farm economics.

Coming back to Slava's discussion of choice and his notion of the "burden of choice," one can understand how the variation and choice of a farmer's field and home became a bank's "burden of choice," and why an institution might wish to radically reduce the variations and choices a client might have. This has long been a country bank's prerogative. In Montana, for example, the agricultural experiment station designed a scorecard for bankers to use when deciding whether to loan money to farmers in 1930. Linking risk with modernity, bankers were encouraged to loan money to farmers who had expanded their acreage, purchased new machinery, electrified their homes and practiced monoculture. In such a scenario, farmers were not troubled with too many choices. If history is any indicator, bankers in dairy states will have a modern version of this scorecard very soon.

Those of you who spend your time thinking about the future of agricultural science and technology, then, should beware the seduction of thinking that we, as citizens, are awash in choices. Selecting a plain old tube of toothpaste at the drugstore can be a paralyzing and stupefying experience thanks to the ridiculous number of options. But these are trivial options and their absence would not represent anything very important. We need to be concerned about the actually important options, the fruitful relationships that have forged between citizen groups, federal researchers and policymakers, scholars and donors, and so on. We need to be certain to keep old strategies available, for example, to students who will think of new applications for them, or for corporate sponsors who get bloodied on the cutting edge. We need to be careful to keep old solutions, as well as old problems, available, to recognize creativity both at the lab bench and in the field, and to reward innovation, both material and magical.

PART in: AGRICULTURAL BIOTECHNOLOGY AND GLOBAL INTERDEPENDENCE

Agricultural Biotechnology for Sustainable Productivity: A USAID Initiative for Plant Biotechnology in the Developing World

John Dodds
Department of Horticulture
Managing Director, Agricultural Biotechnology for Sustainable Productivity (ABSP)Project
Michigan State University, USA

Significant changes in world geography and politics and an ever-growing world population continue to put increasing pressure on food producers to deliver more food grown in the same or less space with greater nutritional value and less effect on the environment. At the same time, the understanding of plant biology and agriculture also has grown, providing the scientific community new tools with which to contribute to the resolution of these challenges.

One contribution of agricultural research is the development of new and improved germplasm and cultivars. The emergence of biotechnology and its integration with conventional plant breeding provides a new approach in addressing challenges to sustainable productivity not yet resolved by solely conventional means.

In the past decade, there has been a dramatic increase in the application of biotechnology in research programs supported through the international agricultural research system. Combining biotechnology and international crop improvement along with the means to integrate and apply new technologies will, in the long-term, provide new opportunities to bring the products of research to farmers and consumers around the world.

The capacity to take advantage of these new research opportunities has rapidly advanced among industrialized countries while developing countries are often unable to keep pace. The U.S. Agency for International Development (USAID) addresses the discrepancy in national science and technology capabilities through programs of collaboration among developed and developing countries which seek to enhance the sustainability of agricultural productivity.

HISTORICAL PERSPECTIVE

The first USAID centrally-funded initiative in this area was the Tissue Culture for Crops Project (TCCP) based at Colorado State University, Fort Collins, Colorado, USA, which sought to produce crops (wheat, rice and sorghum) tolerant to an array of stresses including salinity, drought and acid/aluminum soil conditions. Some of the more significant accomplishments from TCCP were the registration and release of sorghum germplasm with improved tolerance to fall armyworm and to acid/aluminum soil conditions (other work on salt and drought tolerance is ongoing) and the construction of the International Plant Biotechnology Network (IPBNet).

In 1989, the USAID Office of Agriculture began a multistage review of opportunities to support biotechnology. External evaluation of TCCP was undertaken followed by the convening of an expert panel under the direction of the National Research Council (NRC). This panel produced a report, *Plant Biotechnology Research for Developing Countries,* published by the NRC in 1990, which looked at constraints on productivity in the developing world and relevant technologies to address those constraints in the near future.

The combined results of those investigations were then reviewed by USAID missions in developing countries and national and international agricultural programs. A new project in plant biotechnology was then designed which would bring together public sector and commercial research efforts in an integrated product-development program.

A NEW FOCUS, A NEW APPROACH: AGRICULTURAL BIOTECHNOLOGY FOR SUSTAINABLE PRODUCTIVITY INITIATIVE

The peer review process for proposals submitted to USAID through a formal "request for applications" resulted in the award of a cooperative agreement to Michigan State University, East Lansing, Michigan, USA, in September 1991, to implement the emergent new phase in USAID support for plant biotechnology. The purpose of the Agricultural Biotechnology for Sustainable Productivity (ABSP) project is "to mutually enhance U.S. and developing country institutional capacity for the use and management of biotechnology research in developing environmentally-compatible, improved germplasm through exchanges and training courses with developing country scientists."

MANAGEMENT APPROACH

Unlike basic research programs, ABSP takes an integrated approach to the development of specific research products and their transfer to developing country partners. In order to achieve integration, ABSP has set for itself the following management guidelines:

- Maintain a highly focused research program concentrating on specific crops and technologies.
- Implement a product-oriented research style which links public and private sector institutions in the U.S. and developing countries.
- Link product-oriented research to policy analysis of intellectual property and biosafety to ensure product commercialization in an environmentally and socially responsible manner.

•Maintain a geographical focus on specific centers of expertise; develop a critical mass for the multidisciplinary team which will transfer technology to national programs.

•Build a global network that provides access to information for developing and developed countries worldwide and serves as a forum for the exchange of ideas and information on biotechnology in relation to sustainable agriculture.

•Establish linkages with other organizations such as the Consultative Group for International Agricultural Research (CGIAR), U.S. Department of Agriculture Agricultural Research System (USDA/ARS) and the Biotechnology Industry Organization (BIO).

RESEARCH FOCUS

The goal of ABSP project research is to assist developing countries in adopting a wider application of biotechnology in order to address priority problems which represent specific constraints on agricultural productivity.

With a primary emphasis on working with developing country scientists to genetically engineer pest and pathogen resistance, ABSP focuses on the potential to reduce chemical input and produce high-quality plant material at a lower economic and environmental cost than conventional methods alone. The integration of new technologies, such as plant genetic transformation and bioreactor micropropagation, into the mainstream of international agriculture is envisioned. In achieving this goal, the economic and environmental sustainability of agricultural production systems will be improved and the quality of life enhanced by increasing the availability of food for consumption and marketing.

The research problems identified for inclusion in ABSP are those which conventional plant breeding alone cannot resolve. From the three regions of collaboration—Asia, Africa and Latin America—crops were chosen based on economic and nutritional significance coupled with severe pest or pathogen constraints on productivity. Targeted crops and constraints include: potato, constrained by potato tuber moth; sweet potato, constrained by sweet potato weevil; maize, constrained by the maize stem borer; cucurbits, constrained by zucchini yellow mosaic virus and other cucurbit potyviruses; and tomato, constrained by tomato yellow leaf curl virus and/or beet curly top virus.

ABSP has set research objectives which, when considered in their entirety, will reduce the constraints on productivity and broaden the application of biotechnology in developing countries:

• Transfer scientific knowledge and techniques to developing countries through postdoctoral fellowships.

• Assemble minigenes containing insect resistance genes *(Bacillus thuringiensis [Bt]* and proteinase inhibitor) driven by plant-specific regulatory elements.

• Genetically engineer potato, sweet potato and maize for resistance to insect pests in developing countries.

• Genetically engineer cucurbits with a virus coat protein gene for development of resistance to potyviruses.

• Genetically engineer tomato for resistance to viruses causing tomato yellow leaf curl disease.

• Demonstrate pest resistance of transgenic crops at the laboratory, greenhouse and field level, and integrate this into sustainable agricultural systems via collaborations with plant breeders, agronomists, statisticians, virologists and entomologists (with expertise in insect resistance management and integrated pest management).

• Transfer DNA Plant Technology Corporation's bioreactor micropropagation technology to private sector collaborators for the propagation of banana, pineapple, coffee and ornamental palm.

The U.S. Public Sector Research Team

ABSP is the first and only comprehensive biotechnology program to utilize collaborative research teams which encompass the public and private sectors, field agronomists, breeders, entomologists, virologists, molecular biologists, experts in biosafety and intellectual property protection, and other specialists committed to the equitable use of biotechnology in agricultural research globally. These teams provide the flexibility to implement partnerships in commercially-oriented research as easily as research at land-grant institutions, and through national and international agricultural research centers.

A consortium of three U.S. universities (Michigan State University, Cornell University, Texas A&M University) has developed a team of scientists with considerable expertise who will lead the research and training components set forth in the project objectives.

Mariam Sticklen, research director for the ABSP project, is a somatic cell geneticist and faculty member in the Departments of Crop and Soil Sciences and Entomology at Michigan State University (MSU). She has developed techniques in plant protoplast, cell and tissue culture (protoplast fusion by polyethylene glycol treatment, confirmation of the hybridity of fusion products by RFLP and enzyme analysis). Sticklen has transformed plant species using *Agrobacterium tumefaciens,* regenerated a significant number of fertile gramineous crops from *in vitro* cultures, and has transformed gramineous crops using the microprojectile bombardment system.

Developing country maize genotypes will be improved through plasmids constructed by Ray Wu, a biochemist, molecular geneticist and faculty member in the Section of Biochemistry, Molecular and Cell Biology at Cornell University, Ithaca, New York, USA. He has focused on isolating and characterizing cereal regulatory elements and using those elements to increase the expression of foreign genes in cereal crops.

Systems to transform plants from shoot apices have been developed by Roberta Smith, the Eugene Butler Professor in the Department of Soil and Crop Sciences at Texas A&M University, College Station, Texas, USA. She is a plant tissue culturist who has worked with the regeneration and development of salt-tolerant sorghum and the regeneration of several dicots. Potato, sweet potato and cucurbits will be engineered via the *Agrobacterium tumefaciensTi* plasmid method. Cereal crops are normally engineered via either biolistic tissue bombardment or the protoplast/polyethylene method of transformation; however, should a reproducible *Agrobacterium*-based transformation system be developed for maize, then the regulatory elements of a conserved gene will be used (such as rice actin, isolated by Ray Wu).

Transformation systems for cucurbit crops, which are of significant value to many developing country producers, have been developed by Rebecca Grumet, molecular virologist and faculty member in the Department of Horticulture at MSU, who has cloned viral coat proteins and transferred those genes into crop species.

Dave Douches, potato geneticist, breeder and faculty member in the Department of Crop and Soil Sciences at MSU, is carrying out research using *Bt* genes to transform potato germplasm, adapted to conditions in North Africa and the Middle East, for resistance to potato tuber moth. The MSU potato breeding program is positioned to integrate transformation technologies toward varietal development and commercialization.

ABSP/AGERI Collaboration

With the recent implementation of a cooperative agreement between ABSP and the Agricultural Genetic Engineering Research Institute (AGERI) in Cairo, Egypt, a number of collaborative research activities have resulted in the addition of Roger Beachy and Claude Fauquet, co-directors of the International Laboratory for Tropical Agricultural Biotechnology (ILTAB) at the Scripps Research Institute in La Jolla, California, USA to the research team. They will investigate the causal agent in tomato yellow leaf curl disease. Also, under the cooperative agreement with AGERI, Henry Munger, Rosario Prowidenti and Molly Kyle of Cornell University will team with Rebecca Grumet to develop transgenic cucurbits resistant to polyviruses. Ed Grafius, from the MSU Entomology Department will team with Dave Douches to develop transgenic potato germplasm resistant to potato tuber moth.

Public/Private Sector Relationships

Recently, many USAID foreign assistance programs have begun to effect a more active involvement on the part of private sector entities in the U.S. and its client countries. This involvement has particular benefit for programs in biotechnology since much of the technology is based in the private sector. USAID and its clients have a continuing interest in realizing the full scientific and institutional benefit of past investments in agricultural research. ABSP has the capability to assist in that realization in a number of ways.

Biotechnology is a cross-cutting science with orientation in both basic research and product development. ABSP is geared directly towards a transfer of technology leading to product development, with discretionary funds in the budget allocated as seed money for commercial product development of promising research results. The project fosters direct linkages between the public and private sectors including the U.S. university community (Michigan State University, Texas A&M University, Cornell University, University of Arizona) and other public sector institutions (Scripps Institute) as well as the private sector (DNA Plant Technology Corporation [DNAP], Cinnaminson, New Jersey, USA and ICI Seeds, Inc., Slater, Iowa, USA). Linkages with developing country institutions also include a variety of public institutions (KARI, Nairobi, Kenya; Central Research Institute for Food Crops [CRIFC], Bogor, Indonesia; University of Costa Rica; and AGERI, Cairo, Egypt) and the private sector (Agribiotecnologia de Costa Rica S.A., Alajuela, Costa Rica and Fitotek Unggul, Jakarta, Indonesia).

ABSP is attractive to developing countries which are seeking to move into the biotechnology arena but are unable to access technology which is quickly becoming more proprietary and "privatized." Private sector linkages have been established in ABSP from its initiation, so involvement with the project gives developing country programs direct access which can serve to drive reform within their own research system.

For example, DNAP has established two joint projects with private biotechnology companies under the ABSP project. The first joint project is with Agribiotecnologia de Costa Rica S.A., to explore advanced micropropagation methods (bioreactor cloning) for banana, pineapple, coffee and ornamental palms. The second involves a micropropagation company, Fitotek Unggul, and focuses on pineapple micropropagation.

The goal of these partnerships is to reduce the unit cost of the cloned plants by improving the micropropagation efficiency in each target species. If successful, these associations will create an opportunity for expansion of the micropropagation business and open doors toward vertical integration between producing and consuming markets.

A collaborative ABSP project between CRIFC and ICI Seeds, Inc. which through genetic engineering will develop insect-resistant tropical maize for Indonesia, is led in the U.S. by Martin Wilson, cell biologist and project leader at ICI Seeds, Inc. CRIFC is a public sector, developing country ABSP partner and ICI Seeds is a U.S. private sector partner.

The immediate goals of the three-year CRIFC/ICI collaboration are: 1. to produce commercially important insect resistant maize germplasm for Indonesia and 2. to train a team of Indonesian scientists in the genetic engineering enabling technology. In the longer term, it is hoped that commercialization of the germplasm can be achieved through partnership with a private company in Indonesia. ABSP represents an opportunity for ICI Seeds, Inc. to address a target, in a developing country, in circumstances of shared cost and, as a consequence, lowered commercial risk. There is clearly synergy between the goals of USAID and ICI Seeds, Inc. in the development of a market for tropical maize in Indonesia. The outcome of a successful project could be an improvement in maize yields of up to 40 percent. The stability of yield would also be enhanced and, therefore, bring about a significant improvement in the reliability of the maize crop's contribution to the food supply in Indonesia.

NETWORKING

The research focus of ABSP is purposely narrow. Essentially, it addresses genetically engineered insect and virus resistance and the transfer of the bioreactor technology. There are three constraints on nine crops in four countries with 21 participating institutions. The management approach to networking is quite different. While services remain focused, an invitation to join the network is open to anyone who is interested.

The ABSP network publishes a quarterly newsletter, *BioLink;* provides access to literature; builds connections and promotes interaction among institutions and individuals through print and electronic media; organizes country-specific, regional and global workshops, conferences and symposia; coordinates internship programs in biosafety and intellectual property rights; and facilitates the building of linkages to other USAID projects such as the Bean/Cowpea Collaborative Research Support Program (CRSP) as well as the International Agriculture Research Centers (IARCs) and other institutions involved in international agricultural biotechnology research and development.

Promoting Human Resource Development

ABSP fosters an integrated approach to the promotion of biotechnology in developing countries by supporting human resource development and technology transfer through postdoctoral fellowships in research areas and through internships in technical and policy areas such as intellectual property and biosafety, which may have a direct impact on the success and adoption of the technology. By supporting consultants and developing country interns in biosafety and Intellectual Property Rights (IPR), ABSP hopes to establish a policy environment which encourages the growth and realization of the commercial potential of biotechnology. This support is important to developing country programs which recognize that increased capability in these areas is critical to the success of fledgling biotechnology programs.

Intellectual Property Rights

Licensing and intellectual property problems that arise in connection with the transfer to developing nations of technologies developed under the collaborative programs is addressed by John Barton, George E. Osborne Professor of Law at Stanford Law School, Stanford, California, USA. He works with developing country officials and ABSP cooperators to assist in the drafting of international agreements between developed and developing country affiliates.

The ABSP management team works with developing country institutional leaders to identify candidates to participate as interns, under the direction of Barton, in intellectual property training programs. The program provides interns with access to expertise and information regarding IPR, not only from a legal perspective but also from the business perspective of private biotechnology companies. Interns receive hands-on training and develop case studies based upon current and expected situations in their home countries.

Biosafety

The USDA Animal and Plant Health Inspection Service (USDA/APHIS) Biotechnology, Biologies, and Environmental Protection (BBEP) division, Washington, DC, USA, is represented on the ABSP Technical Advisory Group by Sivramiah Shantharam. Scientific, technical and regulatory advice on matters related to biosafety, environmental safety, and the exportation and importation of genetically engineered organisms is provided by Shantharam through consultation on an institutional basis and through individual interaction as part of a biosafety internship program.

Biosafety interns from developing countries are trained at MSU and ICI Seeds, Inc. in the safe handling of transgenic materials in the laboratory, the greenhouse and the field. Interns design, plant and evaluate field test plots of transgenic crops and participate in a three-day workshop organized by Shantharam on the regulatory procedures and policy developed by USDA/APHIS-BBEP, the U.S. Environmental Protection Agency (EPA) and the U.S. Food and Drug Administration (FDA). Based upon their experiences, interns develop a draft set of biosafety regulations for their home country situation. The ABSP management team works with the developing country institutions to promote an active role for the interns in developing and implementing biosafety systems in their country and region.

Bio Link

The ABSP network office at MSU publishes a quarterly newsletter, *BioLink,* which disseminates information with regard to current activities and progress made in ABSP and other biotechnology research and development programs. It contains articles from the international centers, information services and agricultural biotechnology research programs from around the world. The original mailing list was derived from the IPBNet directory taking advantage of the efforts made by those who coordinated IPBNet and compiled the global database of active tissue culturists. The ABSP network has broadened its readership to include individuals and institutions involved in all phases of agricultural plant biotechnology. Currently, *BioLink* is distributed to 115 countries and over two thousand individuals and institutions; approximately half of that distribution is to developing countries. The cost of producing the newsletter is covered by funding within the project so there is no subscription fee. New subscribers to *BioLink* from around the world are always welcome.

Trade Association Relationships

The ABSP commitment to building diverse linkages is exemplified in the project's role as sponsor of memberships in the Biotechnology Industry Organization (BIO), Washington, DC, USA. Developing country and U.S. institutions collaborating in ABSP, both public and private, were originally provided membership in the Association of Biotechnology Companies (ABC), a not-for-profit trade association, formed in 1983, with more than 350 members from 29 countries. ABC members include companies, universities and research institutions from throughout the world.

On July 1, 1993, ABC merged with the Industrial Biotechnology Association (IBA) to form the Biotechnology Industry Organization (BIO), the largest biotechnology trade association in the world. Institutions collaborating in ABSP, who had memberships in ABC, automatically became members of BIO. BIO facilitates interaction between member institutions through access to the organization's database and meetings, seminars and workshops. Current information on issues within the biotechnology industry is provided through informational videotapes, access to BioTechNet and BIO publications, and special attention by BIO's new Food and Agriculture Section. In addition, BIO will continue to organize an annual international exhibition and meeting similar to those sponsored in the past by ABC. At the 1993 ABC meeting, ABSP collaborators from focus countries held a session on the development and implementation of the project. At the 1994 BIO meeting, ABSP sponsored a concurrent session on building institutional linkages.

Industrial Seminar Series

Government, private sector and public institution leaders from ABSP focus countries have participated in a prototype Industrial Seminar Series. The purpose of the seminar series is to expose leaders in biotechnology research and development from developing countries with agricultural plant biotechnology programs of U.S. companies in order to interact with technical and business specialists responsible for the implementation and integration of those programs into the corporate structure. The prototype series met with enthusiastic reviews by participants, and a future series is being planned.

ACCESS TO ABSP THROUGH IN-COUNTRY USAID OFFICES

USAID is a complex and highly decentralized organization which gives support and assistance to developing countries in a number of ways. Central (core) funding through the regional and central bureaus, located in Washington, DC, USA, provide financial support to projects which are globally or regionally focused. ABSP is such a project and receives its funding from the

USAID Office of Agriculture, Bureau for Research and Development. Regional focus in ABSP, by virtue of the core award, is in Asia (Indonesia), Africa (Kenya) and Latin America (Costa Rica).

Individual USAID offices (missions), located in each country, retain a separate budget and portfolio of activities. Additionally, missions may access centrally funded projects, such as ABSP, through a process internally called a "buy-in," which involves a transfer of mission funds into a centrally located project's account. Buy-ins are designed to accomplish the specific initiatives mandated by the project in accord with the interests of the missions and their respective countries.

To date, ABSP has been enthusiastically received by various USAID missions and developing country national programs. A number of activities have been initiated whereby additional countries (e.g., Egypt), which were not designated for inclusion in ABSP under central funding (the core award), are being included through mission buy-ins, and countries which originally participated through central funding (e.g., Indonesia) have expanded their involvement through the buy-in process.

ACKNOWLEDGMENTS
I wish to acknowledge support provided by the Office of Agriculture, Bureau for Research and Development, U.S. Agency for International Development, under Cooperative Agreement Nos. DAN-4197-A-00-1126-00, LAG-4197-A-00-2032-00, and 263-0152-1-3036-00. I also wish to acknowledge the following cooperators for their contribution to this article: Bruce Bedford, Judith Chambers, Joel Cohen, Maro Sondahl, Mariam Sticklen, and Martin Wilson.

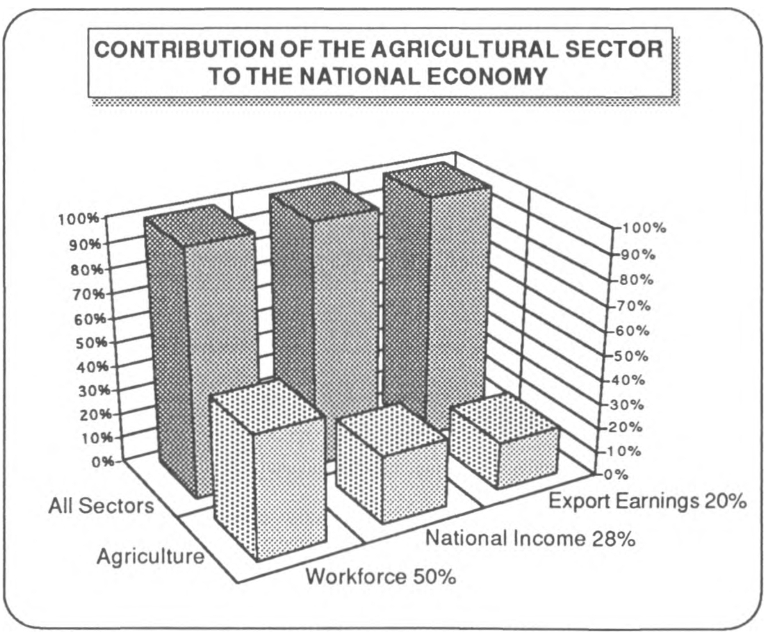
Addressing Agricultural Development in Egypt; A National Program Perspective

Magdy A. Madkour
Director, Agricultural Genetic Engineering Research Institutes Agricultural Research Center
Giza, Egypt

The challenge facing the world today is to provide food, fiber and industrial raw materials for an ever-growing world population without degenerating the environment or affecting the future productivity of natural resources. Meeting this challenge will require the continued support of science, research and education. A high demand for attention to these problems lies in developing countries where 90 percent of the world's population growth will take place within the next two decades.

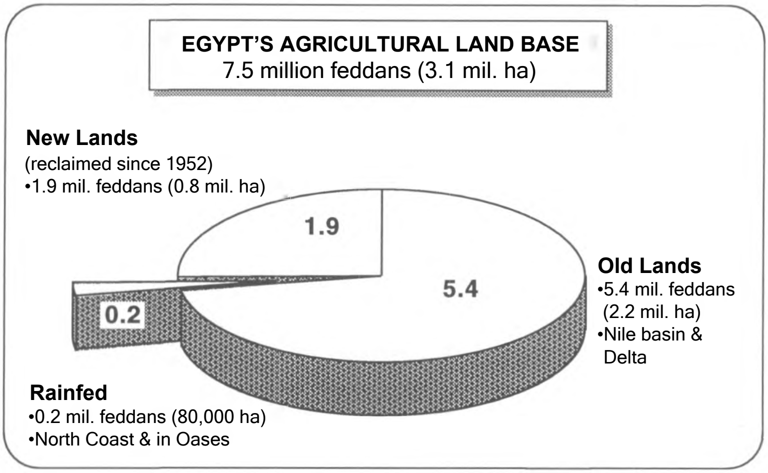
In Egypt, agriculture represents the spearhead of socioeconomic development: accounting for almost 28 percent of the national income, employing almost 50 percent of the workforce and generating more than 20 percent of the country's total export earnings (Figure 1). A limited arable

FIGURE 1



land-base (Figure 2) coupled with an ever-growing population with an annual birth rate of 2.7 percent are the main reasons for the ever-increasing food production/consumption gap. Egypt's population will grow to about 70 million by the year 2000 and swell to 110 million by the year 2025.

FIGURE 2



In recent years, only 15 percent of production for total agricultural commodity exports in Egypt has been exported which is indicative of the increased domestic demand due to increased population growth. Increasing the agricultural land base from 7.4 million feddans (about 3.1 million hectares[ha]) to 14 million feddans (about 5.8 million ha) cropping area would only satisfy 50 percent of the requirement for a current population of 59 million. To bridge the food gap and to fulfill the goal of self-reliance, expanding the land-base and optimizing agricultural outputs are urgently needed.

NATIONAL PERCEPTIONS

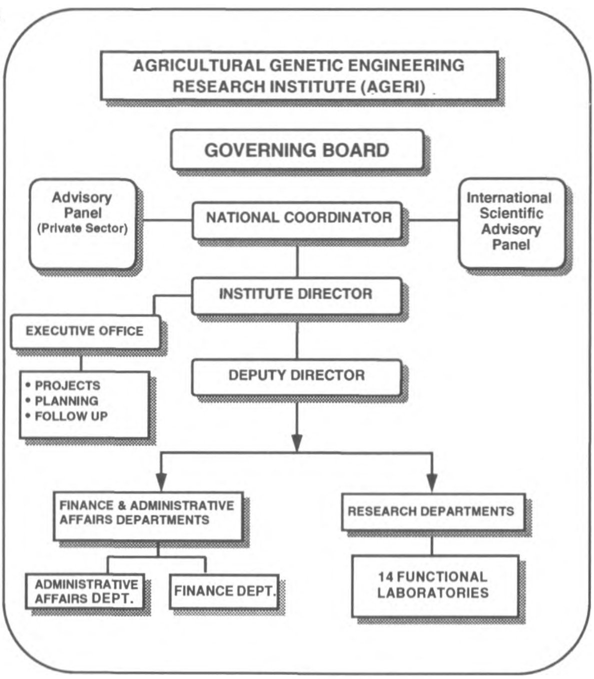
The government of Egypt is increasingly aware that it must use its own limited resources in a cost effective way. Failure to develop its own appropriate biotechnology applications and inability to acquire technology developed elsewhere could deny Egypt timely access to new, important advances that could overcome significant constraints to increased agricultural productivity.

A very significant contribution to increased food production could be achieved by protecting more of the crops currently grown from losses to pests, pathogens and weeds. The total loss of worldwide agricultural production ranges from 20 to 40 percent including both pre-harvest and post-harvest losses which occur despite the widespread use of synthetic pesticides.

It is in this area of crop protection that biotechnology, especially genetic engineering, could offer great benefits to the environment by replacing the present policy of blanket sprayings of crops with herbicides, fungicides and pesticides with plants that have a combination of genetically engineered resistance to pests and diseases. Thus, genetic engineering is very suitable to agriculture in the developing world since it is "user-friendly." If it is applied in a sensible manner, there can be no doubt that this technology is "green." One of the major targets is the production of transgenic plants conferring resistance to 1. biotic stress resulting from pathogenic viruses, fungi and insect pests and 2. abiotic stress such as non-favorable environmental conditions including salinity in the soil, drought and high temperatures. All these are major agricultural problems leading to deleterious yield losses in a large variety of economically important crops in Egypt.

The Agricultural Genetic Engineering Research Institute (AGERI) represents a vehicle within the agricultural arena for the transfer and application of this new technology. The original establishment of AGERI in 1990 was the result of a commitment to expertise in agricultural biotechnology. At the time of its genesis, AGERI was named the National Agricultural Genetic Engineering Laboratory (NAGEL). The rapid progress of its activities during the first three years encouraged the Ministry of Agriculture and Land Reclamation to authorize the foundation of AGERI (Figure 3) which is phase two of the national goal for excellence in genetic engineering and biotechnology. AGERI is now moving to adopt the most recent technologies available worldwide and applying them to address existing problems in Egyptian agriculture.

FIGURE 3



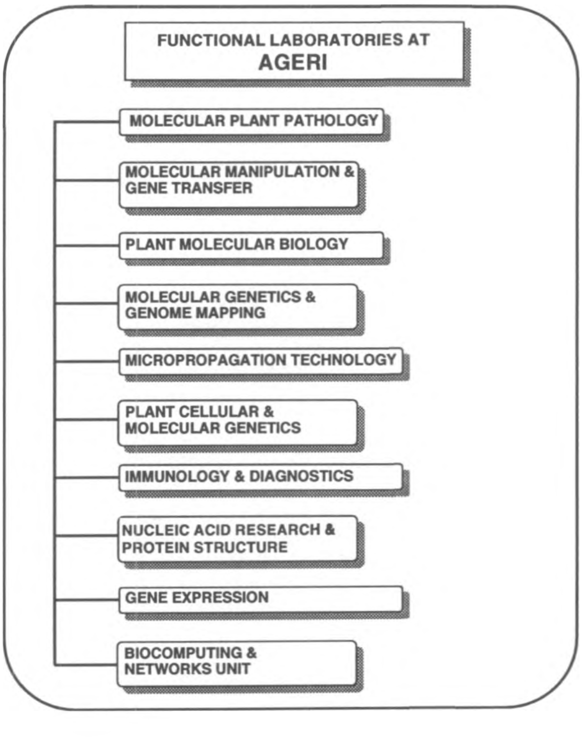
CAPACITY BUILDING

The physical location of AGERI is within the Agricultural Research Center (ARC). This not only facilitates an interface with ARC's ongoing research programs but also provides a focal point for biotechnology and genetic engineering for crop applications in Egypt.

AGERI has upgraded the existing laboratory on its premises and has used two floors to house the project for a total net area of 1116 square meters (m^2) consisting of 14 modernly equipped laboratories (Figure 4); a BioComputing and Networks Unit, a central facility; a preparation/washing facility; and a supply repository.

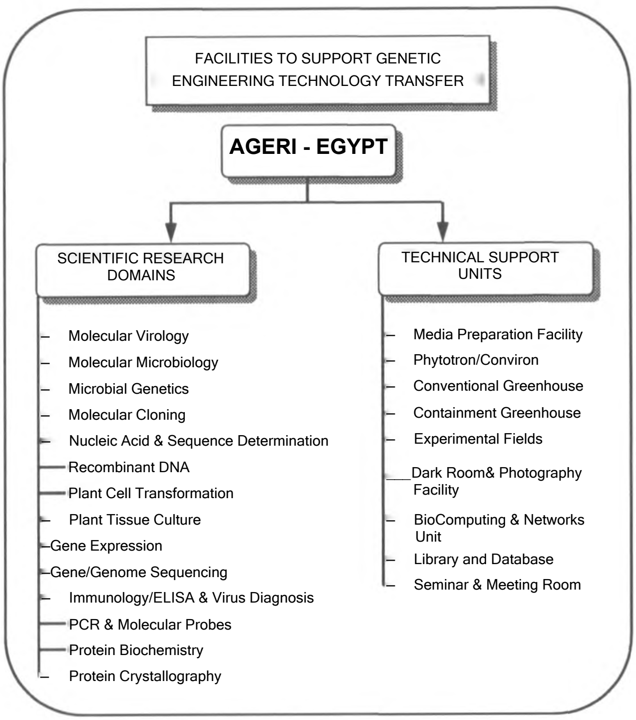
- The recently completed controlled-environment chambers (140 m^2) are used to host transgenic plant material for acclimatization.
- A fiberglass greenhouse (307 m^2) has been recently added to AGERI's property.
- A containment greenhouse (412 m^2), consisting of eight units, three laboratories and a headhouse which will comply with biosafety and USDA/APHIS-EPA (U.S. Department of Agriculture/Animal Plant Health Inspection Service-Environment Protection Agency) regulations, is now under construction. This greenhouse will host various lines of locally-produced transgenic plants with new traits. Also experiments dealing with testing the level of gene expression in transgenic plants will take place in this modern facility.

FIGURE 4



For the establishment of a core nucleus of biotechnology in Egypt, AGERI is adopting the most recent technologies available worldwide and applying them to address existing chelanges in Egyptian agriculture (Figure 5). This includes employing the BioComputing & Networks Unit which is an information center supporting the research activities at AGERI. Services provided by the unit include providing worldwide networking capabilities to access databases and biotechnology information centers located abroad, as well as providing a forum for discussion of technical issues with experts from all over the world through the e-mail facility. The unit provides electronic literature search on CD-ROM and maintains a software library to meet the biocomputing and publishing needs of the institute.

FIGURE 5



HUMAN RESOURCES DEVELOPMENT

One of many vital contributions AGERI has accomplished is the identification and recruitment of a collective group of 17 senior scientists of high scientific accomplishment and work ethic. Each one is a vital link in the program's goals for crop improvement. The senior scientists have institutional affiliations and disciplines within Egypt as well as their scientific responsibilities within AGERI. They are representatives and active faculty members from six Egyptian universities as well as various national agricultural research centers. They work at

AGERI on a joint-appointment basis which maximizes their interaction between the academic and research domains. Their high level of international training, in conjunction with their enthusiasm to invest their talents into AGERI's biotechnology programs, is an encouraging addition toward Egypt's agricultural technology development.

Another vital contribution of AGERI has been its role as an interface between the international scientific community and Egypt. Once AGERI became fully commissioned, the research and post-doctoral education components of the project commenced. Various seminars and conferences have been held at AGERI with highly qualified international consultants. Numerous study tours (40) have taken both senior scientists and junior assistants of AGERI to various international biotechnology centers in Europe, North America and Asia to attend conferences or training courses. During the years 1993-1994, another 20 missions to different parts of the world took place.

Condensed, short courses and seminars concentrating on vital basics of biotechnology have been held by members of our local staff. Educational activities have been promoted as a result of this linkage and cooperation with international researchers and laboratories. Opportunities have been supplied for the exchange of genetic probes, DNA libraries and vectors. Such contacts with centers worldwide have been encouraged and initiated to facilitate meaningful interactions. Training courses conducted at AGERI include:

• An international training course on the use of RFLP's (restriction fragment length polymorhisms) and PCR (polymerase chain reaction) for crop improvement, November 1991.

• A regional training course on the application of PCR and ELISA (enzyme-linked immunosorbent assay) in plant virus diagnostics, May 1992.

• A course in modern methods in microbial molecular biology, April 1993.

• A regional training course on tissue culture and micropropagation in plants with special emphasis on date palm, May 1994.

RESEARCH AND SCIENTIFIC COLLABORATION

AGERI has been successful in attracting funds to sponsor its research from the following international organizations:

• United Nations Development Program (UNDP) as a co-funding agency which supported the initial research at NAGEL, currently AGERI.

• A cooperative research agreement between AGERI and the Agricultural Biotechnology for Sustainable Productivity (ABSP) project based at Michigan State University, USA, which is funded by the U.S. Agency for International Devlopment (USAID) in Cairo under the National Agricultural Research Project (NARP). This activity will allow interaction between AGERI's scientists and researchers from a number of eminent American Universities, i.e., Michigan State University, Cornell University, University of California and the Scripps Research Institute. Moreover, other ongoing USAID funded research is collaboratively executed with the University of Maryland, University of Wyoming , University of Arizona and the USDA/ Agricultural Research Service (ARS), Beltsville, Maryland, USA.

• Recently, the International Center for Agricultural Research in the Dry Areas (ICARDA), located in Aleppo, Syria, has contracted AGERI for conducting research on their mandated crops.

The projects carried out at the Agricultural Genetic Engineering Research Institute (AGERI) (Figure 6) are based on the concept of maintaining a program that is focused on the problems of Egypt. The immediate objectives are to develop and deliver transgenic cultivars of major economically important crops in Egypt. Therefore, the most recent and successful genetic engineering technologies are used to address this need.

FIGURE 6

Research Fields at AGERI p

Discipline	Potato	Tomato	Cotton	Maize	Fava	Cucurbits
Virus Resistance	y	y			[illegible]	/
insect Resistance	y	y	y	y		
Stress Tolerance		y	y		/	
Genome Mapping		y		y		
Protein Engineering					/	
Fungal Resistance		y	y	y		

These projects also represent a spectrum of increasingly complex scientific challenges which require state of the art technologies of genetic engineering and gene transfer. Gene manipulation techniques such as cloning, sequencing, modifications, construction of genomic and cDNA libraries, and plant regeneration in tissue culture are just a few examples of the cellular and molecular biology methodologies that are utilized for the production of transgenic plants.

The successful implementation of these projects would build a national capacity within Egypt for the sustainable production of crops crucial to the economy and a safer, cleaner environment. Examples of projects carried out at AGERI are:

• Genetic engineering of a potato resistant to the most important viruses in Egypt (PVX, PVY.PLRV); production of transgenic tomatoes resistant to geminiviruses such as tomato yellow leaf curl virus (TYLCV); introducing virus resistance in squash and melon against zuccini yellow mosaic virus (ZYM V); and the production of transgenic fava bean conferring resistance to bean yellow mosaic virus (BYMV) and fava bean necrotic yellow virus (FBNYV).

• Engineering of insect-resistant plants with *Bacillus thuringiensis (Bt)* crystal protein genes. *Bt* genes are used for the transformation of cotton, maize, potato and tomato plants to resist their major insect pests.

• Genetic engineering for fungus resistance using the Chitinase gene concept for the development of transgenic maize, tomato and fava bean expressing resistance to fungal diseases caused by *Fusarium sp., Alternaria sp.* and *Botrytis favae.*

• Enhancing the nutritional quality of fava bean seed protein by the successful transfer of the methionine gene to fava bean plants.

• Cloning the genes encoding for important economic traits in tomatoes, fava beans and cotton, especially those related to stress tolerance (i.e., heat shock proteins and genes responsible for osmoregulation).

• Mapping the rapeseed genome in order to develop cultivars adapted to the constraints of the Egyptian environment and thus securing a good source of edible oil.

• Developing efficient diagnostic tools for the identification and characterization of major viruses in Egypt.

These projects are relevant for Egyptian agriculture since they reflect a significant positive impact on agricultural productivity and foreign exchange. To illustrate, Egyptian Bt transgenic cotton, resistant to major insect pests, would result in substantial savings of the U.S. $50 million spent annually on the purchase of imported pesticides. Mapping of rapeseed genome has a potential to substantially reduce the 400,000 tons of edible oil which is imported into Egypt annually. Similarly, transgenic potato varieties resistant to selected viruses and insect pests would prevent the expenditure of approximately U.S. $33 million per annum in the import of seed potatoes. The goals of AGERI in the agricultural community can be summarized as follows:

• Advance Egyptian agriculture using biotechnology and genetic engineering capabilities available worldwide to meet contemporary problems of Egyptian agriculture.

• Broaden the research and development (R&D) capabilities and scope of the agricultural research center in the public and private sectors (i.e., initiation of new program areas and application to a wider array of crop species).

• Expand and diversify the pool of highly qualified trained professionals in the area of biotechnology and genetic engineering.

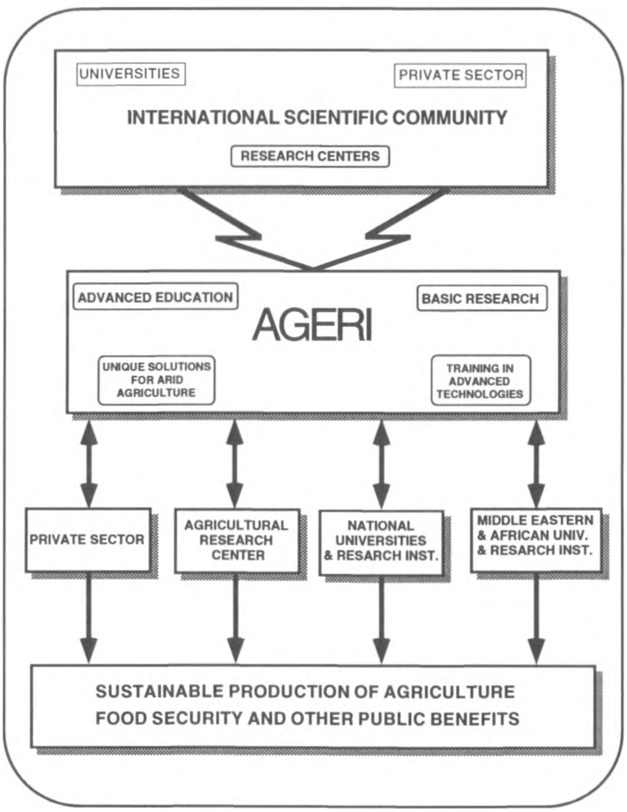
• Provide opportunities for university trained professionals (e.g., faculty, researchers and teachers), the Ministry of Agriculture's professional researchers, and private venture companies to cooperate in agricultural genetic engineering research.

• Promote opportunities for private sector development.

• Achieve the desired level of self-reliance and self-financing within AGERI to mobilize the funds necessary for maintaining laboratories.

Figure 7 highlights the role that AGERI is seeking to fulfill in Africa and the Middle East as an emerging center of excellence for plant genetic engineering and biotechnology. AGERI will act as an interface between elite centers and laboratories from the international scientific community and research centers, universities and the private sector in Egypt, the Middle East and Africa. The major goal is to assist and provide the mechanism for proper technology transfer to benefit their relevant agriculture mandates.

FIGURE 7



*Agricultural Biotechnology in Developing Nations: Place, Role and Contradictions**

JOSÉ DE SOUZA SILVA
Head, EMBRAPA's Secretariat for Supporting State Agencies for Agricultural Research
Brasília, Brazil

> *"Scientific activity, the scientists role and the scientific community have always been dependent; they exist, are valued, and are supported insofar as the State or its various agencies see point in them."* (Steven Shapin and Simon Schaffer in *Leviathan and the Air–Pump*; 1985, p. 339)

> *"Collaborative research with the Third World has benefited U.S. agriculture...through the infusion of yield–producing genetic materials into seeds of our cultivated crops....Continued scientific and technical assistance to the developing countries is essential and in the long run will provide expanded trade opportunities for U.S. agriculture and industry....Countries such as Taiwan, Korea, Brazil, and Nigeria, which were recipients of U.S. technical assistance, are now among the major purchasers of U.S. food exports."* (Nyle C. Brady, Senior Assistant Administrator for Science and Technology, U.S. Department of Agriculture (USDA), in *Science*, November 1, 1985, p. 499)

Scientific neutrality is a myth; over time, science has become a factor of both development and inequality. Historical evidence clearly demonstrates that the unequal development pattern of agricultural research between developed and developing nations has been associated with the way Western science spread in the New World and has always been shaped by strategies influenced by the level of (under)development of science and technology over time. Thus, the contemporary place, role and contradictions of agricultural biotechnology in developing nations are largely a historical outcome of a process which is shaped by socioeconomic and political forces and has evolved from the era of economic botany to the era of Mendelian genetics to the era of molecular genetics.

The contemporary dependent and distorted state of the development of agriculture and of agricultural biotechnology in developing nations can

* The view and opinions in the paper are those of the author, not necessarily representing those of his institution, the Brazilian Public Enterprise for Agricultural Research (EMBRAPA), or of his country, Brazil.

be linked back to their colonial past; a historical process where collusion and the dialectical interplay of external and internal socioeconomic and political factors have had a bearing on agricultural research. This paper

1. traces the historical formation of agricultural research in developing nations; 2. synthesizes the present state of agricultural biotechnology development in African, Asian and Latin American nations; and 3. unravels the major contradictions of such reality in developing nations with regard to the global and multidimensional phenomenon of the biorevolution.

WESTERN AGRICULTURAL RESEARCH IN HISTORICAL PERSPECTIVE

Western European science spread throughout the New World as an extension of geographical exploration where only the sciences closely related to the project of colonial expansion predominated (Basalla 1967). The role of science was to understand how the physical dimension of geographical variation would support or inhibit the incidence of species in different favorable environments in order to permit the transfer of commercially profitable species from one part of the world to another. That was an *era of economic botany*—then a descriptive science, when scientists, amateur botanists, priests, physicians and missionaries were hunting new plants to be scrutinized for their use as food, fiber, timber, dye or medicine (Brockway 1979).

Western European empires created an extensive network of botanical gardens; these were the first systematic efforts to establish monopolies on tropical plants. By 1800 there were over 1,600 botanical gardens in tropical colonies aiming at advancing the political and economic interests of European empires disguised as scientific interests (Brockway 1979). In Brazil, the Rio de Janeiro Botanical Garden, created with the suggestive name of Esta^ao de Aclimaifao, was an example of that past kind of institutional effort (de Souza Silva 1989). Later, following the success of Justus Liebigs agricultural chemistry after the mid-19th century, there was a worldwide experiment station movement which affected the original importance of botanical gardens. By 1930 there were over 1,400 experiment stations. In Europe these stations emerged in response to a changing socioeconomic environment and tended to focus on domestic crops. In contrast, they were forced upon tropical nations as a result of colonization and tended to focus on export crops, such as sugar, jute, rubber, coffee, cocoa, tea and bananas (Busch and Sachs 1981). The Instituto Agrondmico de Campinas (IAC), originally called Imperial Esta<^ao Agronomica de Campinas, was Brazil's first agricultural experiment station created as part of that European institution-building movement (de Souza Silva 1989).

Early in this century, the reinterpretation of Mendel's work made it possible for genetics to offer society its most famous product, hybridization, which led to the genetic patent. Then, design replaced accident in plant breeding. But hybridization gained its momentum only with its use in the so-called "Green Revolution," the most far-reaching and systematic application of Mendelian genetics to crop improvement to date. Mendelian genetics deals with the whole plant, and selection is the major force behind production of desired traits. With its birth rooted in politics[1] (Lewontin 1983), the Green Revolution has altered a large part of the sociotechnical and economic basis of world agriculture through its achievements (Borlaug 1984), negative impacts (Byres 1972) and contradictions (Cleaver 1972). Late in the *era of Mendelian genetics,* experiment stations lost their relative importance to the emerging strategic leadership of the International Agricultural Research Centers (IARCs). Created under the leadership of the U.S. most IARCs were established in tropical nations located in the world regions of greatest biodiversity, institutionalizing the process of access to tropical genetic resources by developed nations (de Souza Silva 1989).

Despite all the positive claims regarding the increased world production and productivity of grains as a result of the application of Mendelian genetics (Borlaug 1984), most of the Green Revolution economic contributions were appropriated by the transnational chemical industry. For instance, the former chief economist of the U.S. Department of Agriculture (USDA), J.W. Mellow, believed that the entire program for the Green Revolution was in the first place a fertilizer project (quoted in Shilling 1982:42-43). Indeed, as a representative of the chemical corporations declared in *U.S. News & World Report.* one of the most important results of the Green Revolution is the increased demand in U.S.-made agricultural machines, fertilizers, pesticides, irrigation installations and agricultural equipment (quoted in Shilling 1982:43).

Today, agricultural research in developed and developing nations is again being shaped by global changes (Busch 1992) entering now into the *era of molecular genetics* (de Souza Silva 1994). Under the umbrella of biotechnology, science is now providing scientists with the tools to enter the plants and scrutinize their molecules and cells. While Mendelian genetics allowed plant breeders to perform some genetic transformations in a few crops, molecular genetics provides the key not only to the manipulation of the internal structure of plants but also to their crafting according to plan (Busch et al. 1991). Modern biotechnologies—techniques that use living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop microorganisms for specific uses—include a wide range of technologies from fermentation to genetic engineering. This is why developments in biotechnology can be divided into three generations. The first generation of biotechnologies incorporated the productive use of microbes such as bacteria, yeast and mold in making, for instance, beer, wine, bread and cheese. During the 50s, 60s and 70s, the second generation of biotechnologies came into existence—the developments in molecular biology and the use of microorganisms

[1] Politics was a very important dimension of the Green Revolution since its beginning. Later, Norman Borlaug, also known as the father of the Green Revolution, became a Nobel recipient for Peace, not for biology. And this is politics.

for the production of antibiotics. During the 1970s onwards, the third generation of biotechnologies were developed, comprising a set of different technologies of which the most important is recombinant DNA technology (Commandeur et al. 1993; Sasson 1993).

Biotechnology makes use of basically two sets of technologies: culture and genetic transfer technologies. *Culture technologies* function at the cellular level and above, and involve regenerating entire plants from protoplasts, single cells, tissues, organs or embryos. *Genetic transfer technologies* function at the subcellular level and involve the transfer of one or a few genes between cells, usually of different species. Thus, in contrast with traditional plant breeding, biotechnology 1. utilizes molecular genetics, 2. focuses on the cellular and subcellular levels and 3. uses knowledge about the interior of cells to direct and manipulate the products made (Busch et al. 1991). Again, developing tropical nations witness the growing importance of their genetic resources to fulfill several economic interests of developed countries. For instance, molecular genetics has magnified the existing possibilities in the modern business of biodiversity prospecting—the screening and exploration of biodiversity for commercially valuable genetic and chemical resources (Reid et al. 1993). Because of their biochemical potential for industrial profit, life forms (plants, animals and microorganisms) are now seen by the pharmaceutical industry as biochemical-synthesizers, and forests, like Amazonia, as biochemical industrial complexes (de Souza Silva 1994).

It is following the logic of this historical context that this paper identifies the present role, place and contradictions of agricultural biotechnology in developing nations.

AGRICULTURAL BIOTECHNOLOGY IN THE DEVELOPING WORLD[2]

Developing nations do not form a homogeneous block. They do not have similar social formations, equal scientific-technological capacities and/or convergent socioeconomic and political goals and interests (de Souza Silva 1989). There is no such thing as an average developing country that would allow one to make generalizations about the nature and direction of what developing nations are doing in agricultural biotechnology and about how they will benefit from and be affected by agricultural biotechnology and the impacts of the biorevolution. Thus, developing nations have unequal capacities to develop agricultural biotechnology and to deal with its overall impacts. Actually, they are divided into developing nations with and without such ca-

[2] For restrictions of space, this paper focuses only on those countries which are better off with regard to their capacity to develop agricultural biotechnology and to couple it with the overall impact of the world application of the new biotechnologies. The most detailed description of the development of biotechnology in African, Asian, Latin American, Caribbean and Arab countries can be found in Sasson (1993). An excellent analysis of the overall impacts of the new biotechnologies on developing nations can be found in Commandeur et al. (1993).

pacity. That is why, according to Commandeur et al. (1993), 1. Brazil and Malaysia which are net exporters of agricultural products and have a high technological potential are better off than 2. India and China, countries that are net importers of agricultural products and have a high technological potential, which in turn are better off than 3. most African and Caribbean countries that are net exporters of agricultural products and have low technological potential, which in turn are better off than 4. Bangladesh and Ethiopia, countries that are net importers of agricultural products and have low technological capacity.

Following the same logic, according to the development stage of their involvement in biotechnology, developing nations may be categorized as follows:

1. Countries which have an interest but no direct involvement in modern biotechnology as yet;

2. Countries with a national policy and a research program in, mainly, conventional biotechnology, but with little in-country biotechnology as yet;

3. Countries with a national policy and a research program in, mainly, conventional biotechnology, combined with established linkages with industrialized countries for the training of scientists and technology transfer; and

4. Countries which have a national policy and a research program in modern biotechnology together with strong international linkages in both public and private sectors (Sasson 1993:25).

Within this categorization, Bangladesh, Bhutan, Burma, Nepal, Sri Lanka and Viet Nam fit into category 1; Indonesia, Malaysia, Pakistan, Philippines and Thailand fit into category 2; Argentina, Brazil, China, India and Mexico fit into category 3; the Republic of Korea fits into category 4 because its programs, infrastructure, support to the private sector, patenting regulations, etc., are almost analogous to those in developed nations (Sasson 1993). Although most developing countries belong to categories 1, 2 and 3, some of them, such as Argentina, Brazil, India and Mexico have been able to move quickly towards category 4.

AGRICULTURAL BIOTECHNOLOGY IN AFRICA

Africa is by far the world region where agricultural biotechnology is least developed, especially for factors associated with the long standing economic recession affecting the continent, along with the low capacity in more conventional research areas such as conventional plant breeding, which are fundamental for supporting the development of scientific capacity in agricultural biotechnology (Commander et al. 1993; Sasson 1993). In a few countries, such as Kenya and Zimbabwe, biotechnology programs and priorities are currently defined; Kenya gives high priority to the micropropagation of disease-free planting materials, and Zimbabwe expects to develop high-yielding crops, food technology, improved horticultural crops and improved animal breeding.

Nigeria has defined the reduction of food imports as a major goal for agricultural biotechnology. Sasson (1993:647-745) has written detailed information about the development of agricultural biotechnology in most African countries.

AGRICULTURAL BIOTECHNOLOGY IN ASIA

Most Asian countries have a large involvement in modern biotechnology, though the goals for its application and the means for stimulating its development are highly different in the various countries. South Korea, Singapore and other Asian newly industrialized countries (NICs) have moved from a labor-intensive to a technology-intensive economy in which modern biotechnology is being applied for the production of high added-value products, mainly pharmaceuticals (Commandeur et al. 1993).

By their size, natural resources and large population, India and China deserve some attention. Among Asian developing nations, India has one of the most impressive research efforts in the public sector regarding agricultural biotechnology (Sasson 1993). State-owned companies play a strategic role in India's industrial and agricultural sector. One of the greatest comparative advantages of India regarding the development of agricultural biotechnology is its large capacity in traditional plant breeding. With the recent move towards economic liberalization in India, however, the trends are 1. the decline of public sector and the rise of private sector research in agricultural biotechnology; 2. opening of new sectors for private investments; 3. adaptation of the legal framework; and 4. stimulus to foreign investments in biotechnology (Commandeur et al. 1993).

Starting in 1986, China's economic policy defined biotechnology research and development (R&D) as a national priority. What is most impressive about China with regard to its capacity to enter the biotechnology race is its enormous experience and long established scientific capacity in traditional forms of biotechnology such as the production of antibiotics, biopetrol, alcohol, etc. However, in order to stimulate the development of the new biotechnologies, China has become too dependent on foreign technology. Moreover, scarcity of highly skilled labor, limited property protection, difficulties with foreign exchange and political instability have restricted foreign investors' enthusiasm (Pistorius 1991). See Sasson (1993:45-371) for detailed information on agricultural biotechnology in most Asian nations.

AGRICULTURAL BIOTECHNOLOGY IN LATIN AMERICA

Most Latin American countries established national biotechnology programs in the 1980s for the coordination of research in order to channel international cooperation and to stimulate linkages with industry. Argentina, Brazil, Cuba and Mexico have long-established, special R8cD institutes. Argentina, Brazil and Chile are the countries holding the most important stimulation programs on the continent, emphasizing the introduction of agricultural biotechnology within applied research and having created special biotechnology centers within their national agricultural research systems (Correa 1992). However, the relationship between public biotechnology research and industry is still weak due mainly to the scarcity of personnel qualified to convert laboratory results into production at an industrial scale and the scientific bias of public research which prevents the traditionally strong basic biological research capacity in this region from producing concrete applications useful to agriculture and industry (Commandeur et al. 1993). Nevertheless, Latin American countries already present a substantial industrial activity in biotechnology, and about 75 percent of the existing industry is locally owned. In Latin America, increasingly, industry has been seen as the motor of biotechnology policies where the emphasis is being put on technological innovation of industry instead of on the stimulation of the science and technology sector. Thus, national technology policies focus more on access to global biotechnology than on the development of a national biotechnology (i.e., biotechnology developed in the country itself through basic research). Though limited by scarcity of capital, Argentina, Brazil, Cuba and Mexico are among the few nations consciously investing in basic research. Argentina, Brazil, Chile, Colombia, Cuba, Mexico and Uruguay are the Latin American nations where agricultural biotechnology is most developed. See Sasson (1993: 373-586) for detailed information on agricultural biotechnology in most developing nations of Latin America and the Caribbean.

CONTRADICTIONS OF THE BIOREVOLUTION FOR DEVELOPING NATIONS

Potentially, agricultural biotechnology may contribute to developing nations with positive, quantitative as well as qualitative changes. However, all the promises made in the name of biotechnology are based on its scientific/technological potential. Generally, the political process through which economically strong social factors influence the nature and direction of the development of agricultural biotechnology in developed and developing nations is either underemphasized or simply neglected. Agricultural biotechnology, like most other technological breakthroughs before it, will lead to considerable structural changes in food and fiber production, international trade and cooperation. Historical evidence demonstrates that such processes have not occurred without contradictions. The biorevolution with its scientific/technological, social, economic and political/ideological dimensions is also producing some major contradictions which will affect developing nations differentially (de Souza Silva 1988). Four of these contradictions are discussed below.

Social Problems and Technical Solutions

In most of the literature regarding the potential contributions of the biorevolution to developing nations, socioeconomic problems have been reduced to their technological dimension so that agricultural biotechnology seems to be the most plausible technical solution. However, reality shows that socioeconomic problems are multidimensional problems. For instance, hunger still persists even in countries which produce more than their population can eat such as the U.S.—the world largest food producer, exporter and donor. Also, Brazil, considered the world's third or fourth largest exporter of agriculture-based products, holds the sixth or seventh most ill-fed population on the planet (de Souza Silva 1988). Thus even excess does not guarantee access to food. Income distribution problems are not solved by production technologies such as agricultural biotechnologies.

Industrial and Agricultural Revolutions

The biorevolution promises an industrial revolution, mainly in developed countries, at the same time as it promises an agricultural revolution, mainly in developing nations. However, the achievement of both revolutions will promote 1. the separation of crops from their natural environments; 2. the separation of crops from their intrinsic characteristics; and 3. the separation of agriculture from food production (Commandeur et al. 1993). For example, genetic engineering may weaken the tropical-temperate dichotomy in agriculture making possible the horizontal dislocation of food and fiber production from developing to developed nations. Also, the appropriation of scientific/technological advances in biotechnology by the food and fiber industry makes possible the vertical dislocation of food and fiber production from agricultural fields to industrial assembly lines. Horizontal as well as vertical dislocations may not just disrupt the market of some specific tropical products, they may also lead to the collapse of entire developing economies. Massive labor displacement is the least that may happen in the tropical world (de Souza Silva 1988; RIS 1988; Busch et al. 1991; Hobbelink 1991; Commandeur et al. 1993).

Social Goals and Private Gains

Some of the world's most pressing social goals that could be achieved with the support of agricultural biotechnology are not necessarily economically attractive. Yet one of the most striking characteristics of developments in agricultural biotechnology is its trend towards privatization. With the increasing establishment of strong property-protection systems worldwide, the biorevolution has been strengthened as a profit-driven business. Now, humankind is witnessing the trend towards the commodification of nature—the extension of the commodity logic and form to the natural and cultural resources of biodiversity. Is the commodification of nature compatible with developed countries' claims regarding biodiversity conservation? Their claims to save the rainforests sound like the ideology of philanthropy. The most powerful chemical and pharmaceutical industries from developed nations are willing to invest and support conservation in tropical countries because this is the best policy strategy to assure their continuous access to crucial tropical genetic resources (de Souza Silva 1994).

The Cooperation-Competition Paradox

We are living through the era of the cooperation-competition paradox: the situation in which any country in the world needs to cooperate with their actual or potential competitors and to compete with nations from which it needs cooperation (de Souza Silva 1989). However, not all countries are aware of that. Although most of the existing literature regarding agricultural biotechnology talks about the need for cooperation between developed and developing nations, reality shows that competition and temporary alliances are prevailing over cooperation and continuous partnerships in the international arena. The most striking example of such a posture is the well-known attempt made under the leadership of the U.S. to press developing-nation governments to introduce strong intellectual property-protection systems. Why impose equal property-protection procedures in developing nations which have unequal scientific/technological capacities? It is ironic that most developed countries did not have strong legal systems for intellectual property protection while they were developing. The U.S. in the 19th century and Japan through most of the 20th century were engaged in technology/product piracy. For instance, industrialized nations refused to grant product patents on drugs until their pharmaceutical industries were well established: France in 1958, West Germany in 1968, Japan in 1976, Switzerland in 1977 and Italy in 1978. As late as 1990, Finland, Norway and Spain did not patent pharmaceutical processes and products. More recently, the four tigers of East Asia—Taiwan, South Korea, Hong Kong and Singapore—became industrialized with the support of weak intellectual property protection (Chudnovsky 1983; Lesser 1990; Vellvé and Hobbelink 1992).

These are just a few examples of major contradictions permeating the development of agricultural biotechnology in developed and developing nations. For further analysis on these and other contradictions see, for instance, de Souza Silva (1988), RIS (1988), Juma (1989), Busch et al. (1991), Hobbelink (1991) and Commandeur et al. (1993).

CONCLUSION

Agricultural biotechnology holds the scientific/technological potential to deliver many benefits to developing nations; yet, its present development worldwide is not without contradictions. This paper has presented historical evidence to demonstrate that, as with other previous technological revolutions, there is a socially constructed political process through which powerful socioeconomic and political forces interact to shape the nature and direction the biorevolution will take regarding its positive as well as negative impacts on tropical agriculture. In such a context, agricultural biotechnology is a necessary, but not a sufficient, condition to assure access to food by all social groups. If agricultural biotechnology is to be developed for the public good, developing nations should address at least eight policy strategies to deal with the present unequal situation regarding agricultural biotechnology to establish:

- "Early warning systems" to monitor major developments in agricultural biotechnology worldwide in order to have the strategic information to project their likely impacts on tropical agriculture so that special policies could be set up to take advantage of the emerging opportunities and to avoid or reduce the emerging negative implications;

- A set of national as well as transnational cooperation policies which could increase South-South solidarity aiming at improving scientific/technological capacity with regard to the development of agricultural biotechnology and the conservation of tropical biodiversity. National capacity to develop and use agricultural biotechnology and to transform genetic resources for the benefit of society must be the major goal;

- A set of negotiation mechanisms to strengthen developing nation bargaining power in agreements with developed countries and with international aid agencies;

- Concrete mechanisms to assure the direct participation of organized social segments of society in the decision and policymaking processes regarding the nature and direction that agricultural biotechnology development should take;

- Motivation/development programs aiming at mobilizing and maintaining the intelligence/creativity of the existing national human talents regarding agricultural biotechnology in order to avoid a brain-drain from developing to developed nations;

- Effective mechanisms to increase national integration between public and private sectors aiming at strengthening domestic industrial capacity in order to reduce the existing dependence on multinational industries;

- Specific policies to strengthen public sector agricultural biotechnology aimed at taking care of research and development agendas which are not economically attractive to the private sector; and

- Intelligent investment policies; policies which promote investments in factors that hold the power to transform other factors. In this perspective, investments in education, science, and technology if well articulated by a set of converging national development policies, may be the difference between the present development distortions and technological dependence in tropical nations and a future with relatively greater national self-sufficiency in those matters.

REFERENCES

Basalla, George. 1967. The Spread of Western Science. *Science.* 156:611-622.

Baumgardt, B.R. and M.A. Martin, eds. 1991. *Agricultural Biotechnology: Issues and Choices.* Purdue University Agricultural Experiment Station, West Lafayette, IN.

Borlaug, N.E. 1984. Contributions of Conventional Plant Breeding to Food Production. In P.H. Abelson, ed. *Biotechnology and Biological Frontiers.* American Association for the Advancement of Science (AAAS), Washington, DC. pp. 159-168.

Brockway, L.H. 1979. *Science and Colonial Expansion: the Role of the British Royal Botanic Gardens.* Academy Press, New York, NY.

Busch, L. 1992. *Agricultural Research in a Time of Change.* Paper presented at The Agricultural Research Institutes' 1992 International Conference of Agricultural Research Administrators, McLean, VA.

Busch, L., W. Lacy, J. Burkhardt, and L. Lacy. 1991. *Plants, Power, and Profit: Social, Economic, and Ethical Consequences of the New Biotechnologies.* Basil Blackwell, Cambridge, MA.

Busch, L. and C. Sachs. 1981. The Agricultural Research Sciences and the Modern World System. In L. Busch, ed. *Science and Agricultural Development.* Allanheld Osmun, Totowa, NJ. pp. 131-156.

Byres, J.T. 1972. The Dialectics of Indias Green Revolution. *South Asian Review.* 5(2) :99—116.

Chudnovsky, D. 1983. Patents and Trademarks in Pharmaceuticals. *World Development.* 2(3): 187—193.

Cleaver, Jr., H.M. 1972. The Contradictions of the Green Revolution. *Monthly Review.* 24(June):80—111.

Commandeur, P., G. van Roozendaal, and G. Junne. 1993. *The Impact of Biotechnology on Developing Countries: Opportunities for Technology-assessment Research and Development Cooperation.* A Study commissioned by the Biiro für Technikfolgen-Abschatzüng beim Deutschen Bundestag (TAB). Amsterdam. September-December.

Correa, C.M. 1992. Pollticas sobre Desarrollo Biotecnol6gico en America Latina. In Walter R. Jaff and Maria E. Zaldvar, eds. *Formulacidn de Politicas para el Desarrollo dela Biotecnologia en America Latina y el Caribe.* IICA, San José, Costa Rica, C.A. pp. 123-146.

de Souza Silva, J. 1994. *From Medicinal Plants to Natural Pharmaceuticals: The Commodification of Nature.* Paper presented at the Pan American Health Organization-Inter-American Institute for Cooperation in Agriculture (PAHO-IICA) Symposium on Biodiversity, Biotechnology, and Sustainable Development, April 12-14. San Jos6, Costa Rica, C.A.

de Souza Silva, J. 1989. *Science and the Changing Nature of the Struggle over Plant Genetic Resources: From Plant Hunters to Plant Crafters.* Unpublished Ph.D. Dissertation, Department of Sociology, University of Kentucky.

de Souza Silva, J. 1988. *The Contradictions of Biotechnology for Agriculture in the Third World.* Unpublished Master Thesis, Department of Sociology, University of Kentucky.

Hobbelink, H. 1991. *Biotechnology and the Future of World Agriculture.* Zed Books, London and Princeton, NJ.

Juma,C. 1989. *The Gene Hunters: Biotechnology and the Scramble for Seeds.* Zed Books, London and Princeton, NJ.

Lesser, W. 1990. *An Overview of Intellectual Property Systems.* In W.E. Siebeck, ed. Strengthening Protection of Intellectual Property in Developing Countries. World Bank Discussion Paper 112. World Bank, Washington, DC.

Lewontin, S. 1983. *The Green Revolution and the Politics of Agricultural Development in Mexico Since 1940.* Unpublished Ph.D. Dissertation, Department of History, University of Chicago.

Pistorius, R. 1991. Biotechnology Policy and Research in China. *Biotech, and Dev. Monitor.* 6:11-15.

Reid, W.V., S.A. Laird, R. Gamez, A. Sittenfeld, D.H. Jansen, M.A. Gollin, and C. Juma, eds. 1993. *Biodiversity Prospecting: Using Genetic Resources for Sustainable Development.* World Resources Institute, Washington, DC.

Research and Information System (RIS). 1988. *Biotechnology Revolution and the Third World: Challenges and Policy Options.* Research and Information System for the Non-Aligned and Other Developing Countries, New Delhi, India.

Sasson, A. 1993. *Biotechnologies in Developing Countries: Present and Future, Vol.l: Regional and National Survey.* UNESCO, Paris, France.

Shilling, H. 1982. The New Seed Monopolies. *Raw Materials Report,* 1 (3) :41—51.

Vellvé, R. and H. Hobbelink. 1992. Intellectual Property Rights on Life Forms: Opportunities and Concerns. *ATAS Bulletin No. 9.*

Biotechnology-Global Interdependence

Richard L. Sawyer
President
International Fund for Agricultural Research
President, Fundacion Peru

Multiple interests and pressures on planet Earth today are moving us rapidly towards problems and progress. As major gains are made on some fronts, new problems emerge on others. No longer is there a cold war with the potential confrontation of super powers. However, unresolved religious, tribal and ethnic differences are causing confrontations which may be far more difficult to resolve than cold wars. The Green Revolution of the 1960s allowed food production to catch up temporarily with the food requirements of a growing population. However, the increases in cereal yields have slowed and decreases are now being reported in some areas highly dependent on these crops. Scientists at the International Rice Research Institute (IRRI) are attempting now to engineer a new rice to help keep yields abreast of population needs for the immediate future. Only through biotechnology does such a possibility exist.

Planet Earth has become a global village due to advances in the science of communications and travel. A problem of any kind/anywhere becomes the immediate concern of the whole global village. The same holds true for progress wherever it is made and for its potential application. Scientists from countries which were engaged in major conflict against each other forty years ago are now sharing the same spaceship in explorations beyond the global village. We have become one community with our problems and our scientific advances. The question is: which will win, the problems or the advances?

Most of the problems of today orient around the lack of knowledge and programs to adjust population to the levels that can be sustained adequately on a planet with finite resources. During this decade world population is increasing by 90 million people annually with no end in sight. Grain stocks which have provided food security to the planet are at their lowest level since 1972. No surpluses exist in North America or Europe today at a time when some communities in the global village are facing famine. Fish catches are diminishing and placing a greater dependency on land production. A number of countries with high population density have utilized all available good land without balancing food production with population requirements. Few countries have information about the numbers of people that might be maintained within their boundaries in a healthy condition and a sustainable environment.

Concern for the environment first highlighted by Rachel Carson in *Silent Spring* in 1962 was followed in the 1980s by the United Nations World Commission Report on Environment and Development, known as the Brundtland report. Agenda 21 provided a more recent global focus at the Earth Summit meeting held in Rio de Janeiro, Brazil, in 1992.

Unfortunately the recommendations coming from this meeting are more political than scientific and do not adequately link environment to agriculture. The problems of both the environment and agriculture are triggered by population levels being out of balance with what planet Earth can healthily sustain. For many communities in the global village, survival must continue to be at the expense of environment until economic development has eliminated the masses below the poverty line of existence. The key to economic development in almost all countries up until now has been through the improvement of agriculture. Thus the problems of environment and agriculture are intimately entwined across the global village and must be addressed together. In my opinion, biotechnology, with its new tools, is the single major force in sight to help provide solutions to the problems of food and environment until the population can be maintained at a level which planet Earth can healthily sustain.

Environmental problems do not stop at country boundaries; hungry people in any community have become a responsibility of the whole village. The great potential of biotechnology is needed across the whole planet. The tools, however, are expensive to develop and few can afford to produce them; once available, all countries need the ability to apply them. A new generation of young scientists is ready to utilize the new tools, but too frequently they return from training to institutions not concerned with practical applications, institutions far removed from conventional breeding approaches. Furthermore, the potential of biotechnology is very much limited by the low priority given to agriculture today by our political leaders.

Tremendous gaps exist along the agricultural production chain between the institutions in which the tools of biotechnology are developed and a farm level application providing visible economic and environmental benefits. Programs such as Agricultural Biotechnology for Sustainable Agriculture (ABSP) at Michigan State University, East Lansing, Michigan, USA; The International Service for the Acquisition of Agri-biotech Applications (ISAAA) headquartered at Cornell University, Ithaca, New York, USA; and the International Laboratory for Tropical Agricultural Biotechnology (ILTAB) at Scripps Research Institute, La Jolla, California, USA, are essential building blocks for the utilization of the potential of biotechnology. The differences in their objectives need to be adequately explained and linkages developed so that complementariness, and not competition, is evident to the decisionmakers controlling funds. Communication capabilities and a strategy must be in place which will orient political leaders to the potential which exists with biotechnology for programs aimed at a healthy global village.

Recently at a breakfast meeting with the administrator for the U.S. Agency for International Development (USAID) I voiced the concern many of us have about the low priority apparently given agriculture as available resources are reorganized to address the USAID's present priorities of environment, economic development, population and democracy. My question indicated that economic development and environment depended on agricultural improvement. Brian Atwood, Administrator, USAID, stated that many of the resources going for the environment and economic development would be earmarked for agriculture. In my opinion this answer was inadequate, making agriculture an indirect objective with little recognition that it is the fundamental building block for programs aimed at economic development and sustainable food production in a healthy environment.

We in agricultural science have not prepared the global village for what we have to offer to its communities. We have been poor sales people for our products. Space scientists have developed a protected existence as they look outward from the village. An exploratory rocket explodes on takeoff at a cost of a billion dollars, four times the annual budget of all the international agricultural research centers combined, and there is little reaction. In contrast, budgets for agricultural science nationally and internationally have been decreasing for a decade. Agricultural scientists have communicated well with each other but have not communicated well with the general public, the decisionmaker and the politician. In comparison, the environmentalists have been excellent salespeople for their ideas. Their support groups are many, as evidenced by the daily mail and well-organized requests for funds to attend their concerns. How can agriculture become organized and supported so that priority programs to address the problems of food and environment have a similar protected existence as space scientists have had for their work?

The global village badly needs the tools of biotechnology put to use in solving the problems of food and environment. We are globally interdependent with our problems, and we must be globally interdependent with solutions. We must utilize the comparative advantages already in place within institutions across the communities in the village and link them together. The biotechnologists must become joiners and offer their services to the conventional breeders as tools are put to practical use. Furthermore, the biotechnologist must learn to communicate in a language the average agricultural scientist and breeder understand. Even more important is the need for all scientists to communicate well with the general public, the politician and the decisionmaker. A global interdependence is necessary in biotechnology, but even more important is the interdependence of advances in science on the whole community. As long as scientists have mainly the ability to communicate their potential and their programs and progress to other scientists, they will be understood by scientists. Their funding support, however, will be lacking until they are understood by the rest of society.

Global Interdependence and the Private Sector

William H. Lesser
Acting Executive Director
International Service for the Acquisition of Agri-biotech Applications, AmeriCenter

Richard Sawyer in the preceding paper made two points of particular relevance to my comments. First he stated, in agreement with a broad spectrum of observers, that biotechnology provides perhaps our best opportunity for maintaining and increasing agricultural yields into the 21" century. Second, he notes that public support for agricultural research is in decline, in places in steep decline, at virtually all levels from bilateral to local. Perhaps the hardest hit are the Consultative Group for Agricultural Research (CGIAR) centers with funding down about 35 percent over the past three years. In the U.S. we are relatively fortunate to have had our reductions in Federal funds largely limited to the controlled but relentless force of inflation; nominal allocations have held constant while the real value sinks.

Clearly, something must be equating the promise with the reality, and that something is the private sector. This obvious deduction is readily supportable by the available data. Although figures vary, estimates are that the private sector provides three quarters of the funding for agricultural biotechnology, or roughly U.S. $900 million worldwide in 1985 (James 1991; Persley 1990). Nor is this research cheap. Private estimates are that over U.S. $20 million are needed for a single application of a transgenic crop (quoted in Altman 1994). A portion of that cost is regulatory approval with expenditures in the U.S. verging on U.S. $2 million per application. Other countries, including developing countries, need not consider that cost except to the degree they require or demand U.S. approval prior to consideration for national use.

Clearly, the private sector will require a return on this significant investment. About that there is nothing new. What is new is the self-reproducible nature of much of the technology, meaning that intellectual property rights protection (IPR) in the form of patents and Plant Breeders' Rights (PBR) is an essential component in capturing a return. Second, the commercial life of many of these products may be short. They are commercially vulnerable to the breakdown of resistance in some cases and, for all, competition from new and improved products. A response to limited, temporal markets is the expansion of geographical markets. Taken together these mean that technology access for developing countries is going through a revolution of its own. More technology is becoming available and overseas markets are being avidly sought. At the same time, much will be available only on a commercial basis and then only when the internal systems, notably IPR legislation, are satisfactory to the technology suppliers.

Such a scenario describes technological dependence, not interdependence. However, that ignores the key input into genetic engineering—the genetic resources. Genetic resources, as has been well established, originate predominately from developing countries. Those resources until recently have been treated as the common heritage of humankind as was formally recognized in the Food and Agriculture Organization (FAO) publication *Undertaking for Plant Genetic Resources.* The Convention on Biological Diversity forever altered that presumption by declaring genetic materials to be the sovereign right of the government where they occur to exploit (Article 3). That is interdependence.

Countries have been utilizing that option, the best publicized being the agreement between Merck Research Laboratories in Rahway, New Jersey, USA and the Institute Nacional de Biodiversidad in Costa Rica, Central America (Merck/INBio), but there are others (Reid et al. 1993). Those agreements however are based on a contractual arrangement among the parties. Contracts are an effective mechanism for such agreements (see Simpson and Sedgo 1992), but are limited by placing no obligations on third parties. Anyone but the signatories who acquire a product legally, such as purchasing a transgenic potato in a local market, may treat it as being public property. Contracts fundamentally work from secrecy, and secrecy is neither generally possible nor really appropriate for agriculture (see Lesser 1994).

What then appears to be the situation is the interdependent parties are willing to pay each other, but lack a mechanism. The juxtaposition in the Biodiversity Convention of the articles treating the commercialization of genetic resources (Article 15) and the acquisition of technologies (particularly biotechnologies) (Article 16) could suggest a barter arrangement using the two. Barter implies a direct exchange of equal value without the use of money. However, barter is an extremely complex exchange arrangement, especially as regards enforcement of the conditions. The appropriate mechanism is intellectual property rights, but my position is that they are at present inadequate in most developing countries for acquiring biotechnologies and essentially nonexistent everywhere for claiming remuneration for genetic materials.

OBJECTIVE

What exists then in my view is a global interdependence lacking a facilitating mechanism. A portion of this, and that portion to be addressed here, is the apparent position by many developing countries that IPR on balance do not serve national interests, nor do they provide equity in either its moral or practical sense. The purpose of this paper is to set forth in outline my assessment of what is needed to structure an international system of rights which recognizes and responds to this interdependence. That assessment will by necessity consider both developed to developing, and developing to developed, country exchanges, referred to here as North-South (N-S) and South-North (S-N) exchanges. We begin with N-S transfers.

My institution, ISAAA, the International Service for the Acquisition of Agri-biotech Applications, facilitates such transfers and is the source of several examples; ABSP (Agricultural Biotechnology for Sustainable Productivity) among other groups could provide additional examples. The examples are the transfer of virus resistance (PVX and PVT) using a Monsanto technology into Mexican potato varieties, and the transfer of papaya ringspot virus resistance, a Cornell University technology, to several countries including Brazil and Thailand.

NORTH-SOUTH TECHNOLOGY TRANSFER

Geographical Scope of IPR Protection

Intellectual Property Rights (IPR) protection is national, meaning that it applies only in those countries where protection is held. As of 1990, 63 countries explicitly excluded patents for plants, about half of which are developing countries (WIPO 1990). The situation for animals is slightly more restrictive. The ban on plants is not as complete in all these countries as might appear to be the case because the prohibition reads to "plant varieties," not plants per se. This has allowed the European Union (EU) to state the option of defining "variety" narrowly and to grant patents for plants not in a "fixed form" (see Crespi 1992). Potentially, any other countries using similar exclusionary language could act similarly. At minimum the protection situation is complicated.

Plant Breeders' Rights (PBR) legislation is similarly limited in geographic scope with only 23 countries and but one developing country (South Africa) signatory in April 1993 to the International Union for the Protection of New Varieties of Plants (UPOV), the international convention. Several countries have national laws—including Argentina, Chile and Zimbabwe—but the particulars are difficult to come by. Thus, presently, the geographic scope of IPR as applicable to biotechnology applications in living organisms is very limited.

Some of this will change under the recently adopted text of the Uruguay Round of the General Agreements on Tariffs and Trade (GATT) which over one hundred countries, some 70 of which are developing countries, have signed. One aspect of the agreement, known as Trade-Related Aspects of Intellectual Property Rights (TRIPs) requires all countries within a five to ten-year period to provide the following forms of protection (MTN/FA II-A1C):

- Contracting parties shall provide for the protection of plant varieties by patents and/or an effective *situ generous* (meaning separate law like UPOV) system (Section 5, Article 27[3b]).

• Plants and animals other than microorganisms and "essentially biological processes for the production of plants and animals" may be excluded from protection (Section 5, Article 27 [3b]).

• Patents maybe prohibited to protect *order public* or morality, provided there is a justification exceeding the mere prohibition in domestic law (Section 5, Article 27[2]).

Other stipulations exist, but lie further outside our scope. In my judgment, these requirements even when fully implemented will leave gaps in coverage which might be of significance for agricultural biotechnology applications. It is quite evident that countries may exclude plants and animals from patent protection by choice. Even the terminological issues discussed above regarding the exclusions in the EU would seem not to apply. In the EU, as noted above, the legislation refers to varieties whereas under TRIPs, reference is made to plants and animals. The public morality provision is a further delimiter if desired. Countries can be expected to adopt PBR; indeed India is presently in the process. However, PBR does not protect an engineered gene which can be transferred to another variety by backcrossing. Thus PBR alone may be considered by some owners of genetic technologies as being insufficient. More encompassing laws, however, will come only when countries, and in particular developing countries, consider it in their advantage to pass such laws.

ROLES OF IPR IN DEVELOPING COUNTRIES

The principal justification of IPR is as an incentive for private investment (e.g., Machlup 1958). Evidence of its effects, while by no means complete, is generally supportive of that expectation for the industrialized countries. For the developing countries the issue is somewhat different, as legitimate questions have been raised about their competitive position as producers of world class technologies. I personally believe that matter can be answered in the positive (see literature review in Lesser 1991, Chap. 4), but the issue to be addressed here is not production but access. What role does IPR play in the willingness of private firms to make available easily copied technologies like plants?

About that we have little specific evidence primarily because the subject is only now arising with potentially very valuable agricultural biotechnologies nearing the commercialization stage. Moreover it is not clear that the major proprietary suppliers have a clear policy, probably because there are larger markets to be considered first. Offers have, I understand, been made (e.g., to India) to give blanket rights for an upfront fee described as ten cents on the dollar. Yet few countries are willing or financially able to enter such a deal. Among its unattractive aspects is the shifting of product performance risk to the user.

Similarly, many countries are hesitant to allow protection, which implies the payment of royalties for what can in all probability be acquired free once marketed. Presumably a similar recognition led the investor to offer (unsuccessfully) blanket rights at a large discount. Yet acquisition in that manner, even when legal, involves a time cost. Backcrossing *Bacillus thurengiensis (Bt)* genes into a locally adapted cotton variety takes about four years, four more years of heavy pesticide applications, followed by the biosafety review. And then the seeds must be propagated for wide use. What should developing countries be doing? ISAAA, which must eventually assist in identifying a response, has no real answer.

There is another class of IPR issues which poses even less clear issues. It can be typified by the DuPont Corporation, Wilmington, DE, USA "gene gun" case. Where the gene gun is patented, I understand, DuPont (operating through its licensee Agracetus Inc., Middleton, Wisconsin, USA) requires rights to resultant products as a condition for a license. Where the gene gun is not patented (e.g., in Brazil) it is said to be manufactured at a significant level which is perfectly legal. But what are the possible costs to Brazil? Is there a moral obligation? Can it legitimately be argued that there is no moral obligation to private companies or to "rich" multinationals? Can the products be imported into countries (like members of the European Patent Union) where direct and indirect products of patented technologies cannot be sold without permission? Probably not. What will happen if in the future Brazilian scientists seek other technologies directly from DuPont or from other private firms? Will/can DuPont hold a commercial grudge? Should this concern Brazil? How will the World Bank and other bi/multilateral donors respond, as much project funding will, directly or indirectly, be coming from those sources?

Possible Action

In order to meet their GATT/TRIPs commitments, some 70 developing countries will over the coming several years be modifying their IPR systems substantially. Concurrently, many new agricultural biotechnology applications are expected to become available. This is the proper time to consider the appropriate forms of those laws. The format can be similar to the assistance which ISAAA, ABSP, SEI (Stockholm Environment Institute, Sweden), the Dutch Government and other groups have provided for biosafety regulations.

To me what is lacking is a clear concept of the program content. This is primarily because the ultimate issue is between countries and the private sector, and secondarily between countries and university licensing groups. Thus I am calling on private interests to develop positions and share those positions with developing countries. Clearly the private sector has expectations of what developing countries should do; those expectations must be both clear and realistic. Many in the public sector, including ISAAA, can help with the delivery of those positions, but we cannot generate them. At the same time it is appropriate to begin thinking about ways to simplify access to materials. Present trends suggest a not-distant future when any technology may have multiple claimants making the process of identifying the owners and negotiating with them onerous. Consider the papaya ring spot virus technology ISAAA is brokering. Aspects are potentially claimable by Upjohn Company in Kalamazoo, Michigan, USA, Cornell University and DuPont, and this is only the beginning. True, this already occurs for other technologies, but those technologies are generally not directed to multiple users in scores of countries. Some kind of simplification, possibly including a clearinghouse agency or prestated royalty rate structure for many of the more minor innovations, is needed.

SOUTH-NORTH TRANSFERS

As noted, this form of exchange is presumed to include the utilization of genetic materials for agricultural developments and other uses. For simplicity, materials currently held *ex situ* will not be discussed because their legal status is unclear; the Biodiversity Convention (Article 15 [c] [3])makes special note of its applicability to materials acquired before it went into effect in December 1993.

In an earlier effort I attempted to characterize the limited protection for genetic materials under existing laws (Lesser 1994). That evaluation covered not only patents and Plant Breeders' Rights, but also possible extensions through Codes of Conduct and (proposed but not enacted) folklore rights. All were found lacking in providing meaningful protection, protection leading to possible collection of royalties. The principal confounding issue is the identification of just what is being protected. An absence of a clear delineation creates broad ambiguity over who is claiming what. That in turn interferes with research access and creates the likelihood of conflict among countries (presuming they are the titleholders) with identical or similar protected materials. Technical solutions have been proposed, but they are costly for materials—the bulk of which will have little commercial value.

The current course of legal activity is along the lines of access laws. Many countries have these for pharmaceutical purposes while others (e.g., Queensland, Australia and, I believe, Brazil) are adopting them for all product access. Some legal stipulation is required if countries are to prevent someone from simply carrying off materials as in most cases they presently have full legal rights to do. Access laws are a means of implementing the "sovereign rights" to genetic materials specified under the Biodiversity Convention (Article 3). Indeed, modes and modalities for legislation will be discussed at the first Meeting of the Parties of the Biodiversity Convention in late 1994.

For me, the discussion of particular text is premature because objectives remain unclarified. They are often proposed in terms of equity, but equity has many aspects. One form is equity for past contributions, the multigenerational selection needed in the creation of a landrace, for example. Another form involves payments for future contributions, whether for research and development leading to new useful products or for conservation activities. Either or both to some degree are possible and justifiable, but the matter must be discussed forthrightly, or at least identified. For myself, I see the additional benefits to humanity of payments for future contributions.

A second major question is the functioning of the laws. Major IPR laws operate through exclusion, the right to refuse access. Indeed, that is really the only benefit they provide. Some countries, however, allow so-called licenses-of-right, blanket compulsory licenses for everyone meeting the requirements, (e.g., the payment of a royalty). Compulsory licenses remain an anathema to many supporters of IPR, but to me they are the only reasonable solution for the mass of materials likely to be protected under these new systems. Licenses of right emphasize access which is critical for agricultural applications. At the same time a streamlined system will be less costly to operate, returning more to the owners by absorbing less in transactions costs.

Possible Actions

Steps are being taken for the preparation and subsequent adoption of legislation controlling access to genetic resources. While those laws might be justified largely by the understandable desire to collect payments from private firms, they will also affect access for research and other uses. For that reason it is critical that a broader group becomes knowledgeable about and involved in the process. A change of venue is also desirable. Presently, much will be conducted within the auspices of the Biodiversity Convention which, while appealing at one level, is not really appropriate with its 300+ delegates for the consideration of such a detailed topic.

CONCLUSIONS

With biotechnology now near to having numerous applications in developing countries, it is abundantly clear that little of that technology will be available without charge. Developing countries need those materials and must pay for what is used. At the same time, and in partial response, developing countries are seeking payment for their own genetic materials, these in the form of largely unimproved germplasm. In many regards, placing access on a cash basis facilitates the process, since at least what is being requested can be readily understood and negotiated.

However, we do not presently have a real market for these materials/technologies, a market which operates efficiently as do markets for major agricultural commodities. Inefficient markets absorb much of the value of the products exchanged, value which should go to the owners. Principal limitations, in my viewpoint, are: 1. the weakness/lack of Intellectual Property Rights in many recipient countries and 2. the virtual absence of laws controlling access to genetic materials. We are all dependent on the outcome of the process of rectifying those gaps; it is time that more of us become knowledgeable about and involved in the process of filling them.

REFERENCES

Altman, D. W. 1994. Technology Transfer Initiatives of the International Service for the Acquisition of Agri-Biotech Applications. *AgBiotech News and Information.* 6(6):131N-134N.

Crespi.R. S. 1992. Patents and Plant Variety Rights: Is There an Interface Problem? *Int. Rev. Industrial Property and Copyright Law.* 23:168-84.

James, C. 1991. The Transfer of Proprietary Agricultural Biotechnology Applications From the Industrial Countries to the Developing Ones: The International Biotechnology Collaboration Program. In A. Brandolini, ed. *Revista de Agricoltura Subtropicales e Tropicales.* Istituto Agronomico per L'Oltremare, Florence, Italy, pp. 5-24.

Lesser, W. 1994. Institutional Mechanisms Supporting Trade in Genetic Materials: Issues Under the Biodiversity Convention and GATT/TRIPs. *UNEP Environment and Trade No. 4.* Nairobi, Africa.

Lesser, W. 1991. *Equitable Patent Protection in the Developing World: Issues and Approaches.* Eubios Ethics Institute, Tsukuba, Japan.

Machlup.F. 1958. *An Economic Review of the Patent System.* Study of the Subcommittee on Patents, Trademarks and Copyrights. Committee on the Judiciary, U.S. Senate. Study No. 15.

Persley, G. J. 1990. Beyond Mendel's Garden: Biotechnology in the Service of World Agriculture. *Biotechnology in Agriculture No. 1.* CAB International, Oxford, England.

Reid, W.V., S.A. Laird, C.A. Meyer, R. Gamez, A. Sittenfeld, D.H. Janzen, M.A. Gollin and C. Juma, eds. 1993. *Biodiversity Prospecting: Using Genetic Resources for Sustainable Development.* World Resources Institute, Washington, DC, USA.

Simpson, R. D. and R. A. Sedgo. 1992. Contracts for Transferring Rights to Indigenous Genetic Resources. *Resources.* 109:1-6.

World Intellectual Property Organization (WIPO). 1990. *Exclusions from Patent Protection.* HL/CM/INF/I, Rev. Geneva, Switzerland.

Workshop Report

Jim Germida
Department of Soil Science
University of Saskatchewan

W. Ronnie Coffman
Associate Dean for Research
Cornell University

BACKGROUND

The Agricultural Biotechnology and Global Interdependence Workshop was made up of a diverse group of people from many cultures and backgrounds. Our goal was to identify the area of international agriculture in which agricultural biotechnology will probably have major impacts and to form ulate recommendations to maximize the likelihood that all involved will benefit. The workshop opened with speakers Richard Sawyer and William Lesser providing commentary on the workshop theme and focal points for the development of specific issues for subsequent discussion.

Richard Sawyer is the founder of the International Potato Center and is now with the International Fund for Agricultural Research. His talk centered around the fact that the global community is a single community with its own problems and scientific advances. The foremost problem we face is feeding an ever-increasing global population. With grain stocks at the lowest levels since 1972 and fish catches decreasing, we are becoming more dependent on land resources. Agricultural biotechnology is a force to help Earth sustain the population. The tools are difficult to develop, and their potential is hindered by the low priority given to agriculture by governments. We in agricultural science have not prepared the global community for the importance of the biotechnology products we are developing which need the support of all. Finally, biotechnology must offer products and services for use by developed and developing countries. And it is essential that we promote these products in a language all scientists and the rest of society can understand.

William Lesser is Acting Executive Director, International Service for the Acquisition of Agri-biotech Applications AmeriCenter (ISAAA). The focus of his talk was intellectual property rights. He noted that the private sector provides two-thirds of the funds for biotechnology research worldwide with many of the products of this research ultimately delivered in seed. The commercial life of these products will be rather brief, so companies will look for broad geographical markets. There is a need to protect intellectual property, and at the same time develop a system for the free-flow of technology and resources. Looking at North-South flows, 35 developing countries do not permit patents on research on plants and animals, and 70 developing countries are working to enhance intellectual property rights over the next few years. Intellectual property rights are a key issue in accessing technologies from the private sector. The private sector needs to formulate a clear position to developing countries with regard to the choices and consequences of technology transfer. Finally, legislation controlling access to genetic resources is essentially lacking. The laws that come into place should be non-exclusionary. Research access is critical, so it should not be too difficult to get. It is extremely important that we educate society on this subject and decide how to handle intellectual property in the developed and in developing countries.

IDENTIFICATION OF PRIORITY ISSUES

After listening to the speakers, the workshop participants were divided into three groups and asked to identify and discuss two issues they felt were key to the workshop. During this discussion time 60 issues were identified by the three breakout groups. These issues covered a wide range of social, political and economic aspects addressing the global interdependence of agricultural biotechnology. Examples of some of these issues are in the appendix (page 143).

Each group then prioritized topics of greatest concern, resulting in the following eight issues being brought forward for discussion by all workshop participants.

Equity

Divided into three components:

- Developing countries stand to lose export commodities, an issue to develop.
- Intellectual property rights (IPR).
- Regulatory. A large company can put up with the time, effort and money needed in developing regulations, but a small company may not have the same resources.

Institutional Linkage

Including: Gaps that exist between tools developed to where they are applied and utilized; gaps between developed and developing countries; and gap linkages needed between the public and private sector.

Biosafety

The U.S. and Europe have biosafety factors in place, but some form is needed in other countries, especially in relation to the use of transgenic plants. Each country needs to have regulatory procedures in place, with some homogeneity between countries.

Socioeconomic Studies

Prospective studies are needed to identify the actual and potential impacts of biotechnology products, including social, economic and political, not just the technology dimension. The debate is that many people have difficulty seeing this. It is not a question of producing more, but of having the access.

Intellectual Property Rights
Evaluate existing and/or new systems of IPR which will maximize access to biotechnologies and generate resources while providing equitable compensation to developers and protectors of these materials. Intellectual property rights are with us for the duration, whether they are popular or not. Systems need to be re-evaluated as more products come into society.

Negotiated Access
Recognized biotechnology products and process availability are needed in developing countries. Also needed is access to germplasm by developed countries.

Agenda Setting
Biotechnology products are being developed in the U.S., but we need to know what developing countries need and want. Developed countries need to work with them to this end.

Communication Between Government and Farmers
Everyone needs to know about biotechnology products. Farmers need to know how to use them effectively to a safe and productive end.

DEVELOPMENT OF RECOMMENDATIONS
After considerable discussion it was agreed that these issues could be condensed and addressed in three priority issues:

Equity, Rights and Access

Institutional Linkages in Capacity Building

Socioeconomic

The workshop was then asked to divide into three breakout groups, each one to consider one specific issue and, after discussion and debate, bring forward specific recommendations to address that issue. The issues and recommendations of each affinity group were then presented to the entire workshop for discussion and clarification. Finally, a workshop consensus was reached on each issue and recommendation by allowing participants to vote on each recommendation. Twenty-seven participants voted on all recommendations indicating whether they strongly agreed (SA) or strongly disagreed (SD) with that recommendation or found the recommendation acceptable. Numbers in parenthesis indicate those participants who either strongly supported or were against that recommendation.

RECOMMENDATIONS
Equity, Rights and Access
To ensure access to new biotechnology products and resources, and to protect equity and intellectual property associated with these technologies, the following recommendations were made:

Harmonize existing or develop new systems of Intellectual Property Rights (IPR) which will maximize access to biotechnological and genetic resources *while providing equitable compensation to developers of biotechnology and countries of germplasm origin.* (11 SA-1 SD)

Extreme variation exists in the political and economic status between and among developed countries and developing countries. Therefore, material and intellectual property transfer agreements must now be negotiated on an individual basis between political, academic and industrial institutions. A non-partisan international panel is needed to address grievances derived from such negotiations, (mildly controversial [5 SA-4 SD])

As *a supplement to such negotiations, multi-country agreements based on existing, successfully operating systems (European Patent Office [EPO], International Union for the Protection of New Varieties of Plants [UPOV]) should be established between groups of developing nations to facilitate handling ofIPR.* (16 SA-OSD)

Institutional Linkages in Capacity Building

To speed the development of tools of biotechnology, and given the importance of linkages in their transfer, to solve the problems of food and environment globally, the following recommendations were made:

NABC should:

- *Broaden its base to include other countries and regions.* (17 SA-0 SD)
- *Gather information on databases regarding biotechnology on an institutional basis and make it available to the membership.* (14 SA-1 SD)
- *Encourage multidisciplinary team-building in the broadest sense.* (19 SA-0 SD)

Socioeconomic

To protect the health, safety and economy of producers and consumers the following recommendation was made:

An ex ante *and* ex post *system, comprised of representatives from public institutions, agribusiness, consumers and producer groups is needed to assess the potential impacts of biotechnology products and processes on:*

- *The environment*
- *Food production and prices as well as consumer acceptability*
- *Wealth distribution*
- *Farmers/labor*

And identify ways to:

- *Reduce negative environmental impacts*
- *Compensate disadvantaged groups*
- *Train agriculturalists in the proper management of biotechnology products/processes.* (SA 18-SD 0)

APPENDIX

Workshop Issues

Who forms the intellectual property policies—scientists, lawyers, politicians, the general population?

•Identify model legislation based on wide deliberation determining access to natural genetic resources.

•International policy in support of breeders' rights is needed to ensure product development (industry will not target products toward markets that will not provide investment return).

•Bridge building and communication: 1. within programs, 2. between programs, 3. broad-based, and 4. training.

•Develop mechanisms for regional and global cooperation in biotechnology, intellectual property rights (IPR) and biosafety. There is a need for training (i.e., human resource development) between countries to facilitate understanding, biosafety and practical application of recombinant DNA technology.

Will biotechnology promote global interdependence or dependence of developing countries on developed countries?

•Funding agencies for international research should coordinate to: 1. establish common research priorities, 2. maximize efficiency of available research resources, and 3. put forward unified rationale for increased research funding.

•The potential benefits vs. possible disruptions of agriculture in developing countries, especially those that rely on one specific crop (also ensuring biodiversity).

•To establish communication mechanisms aimed at improving national, regional, and global cooperation within programs, between programs, and broad-based.

•Coordination of priorities (combined with funding) for product development that will benefit society, but will not return value to developers, is needed. For example, vitamin-enriched grains or legumes would be useful worldwide, but nowhere can value be captured for developers.

•Evaluate existing and/or new systems at IPR which will maximize access to biotechnologies and genetic research while practicing equitable compensation to the developers and producers of these materials.

How can biosafety be regulated in the developing countries?

•Rights to use of genes and technologies within developing countries. Can we hold the diversity of agricultural systems which determine a lot of productivity, diversity of products, and choices of commitments? Can the private sector use its power to choose the topics network and the way in which to rouse them, the access to techniques?

• What should be done to assure that scientists in developing countries gain training in biotechnology and also are able to set research agendas in these areas rather than simply respond to them?

• Establish methods to create communication and understanding of biotechnology in agricultural issues of: 1. the public, 2. policymakers, and 3. developing countries.

• Harmonization agreement for movement of biotechnology products internationally.

Social and technological innovations: complements and substitutes?

• Are scientific and/or environmental issues judged for minor consequence in the U.S. (e.g., escape of potentially harmful genes) being appropriately evaluated elsewhere?

• Assess technology transfer from developed nations to the developing countries for improved food products.

• Harmonization of biosafety regulations to help develop biosafety registration guidelines in targeted developing countries.

• Linkages between institutions from tool development to grower fields in the whole global village.

Who will speak to the public for/about agricultural biotechnology?

• Commitment: If the private sector is to become a participant in biotechnology/seed research in the developing countries can it be relied upon for continuity, competitive prices, quantity?

• Satisfying concerns of genetically engineered foods (perception). Public awareness and understanding of biotechnology.

• Balance of public vs. private investment—does an increase in public involvement ease the sharing of resources with developing countries?

• The development of guidelines for the protection of property rights and environmental safety.

PART IV: SETTING THE AGRICULTURAL BIOTECHNOLOGY AGENDA

Moving Beyond Dialogue

I. Garth Youngberg
Executive Director, Henry A. Wallace Institute for Alternative Agriculture

For nearly two decades, the subject of this workshop, as well as the general theme of this meeting, has been a central and recurring issue in the protracted agricultural biotechnology "dialogue." Enormous efforts have been made to investigate, discuss and propose ways to ensure that the applications of biotechnology address and promote the public good. Equally impressive are the many conferences, papers, books, official pronouncements, organizational initiatives and various other public and private "dialogues," aimed at discovering, analyzing and suggesting agenda-setting mechanisms designed to enhance the sustainable agriculture community's understanding and acceptance of the products of agricultural biotechnology. Many of the best minds in agriculture have repeatedly grappled with these issues with intelligence, sincerity and often enormous insight.

It has been an important and necessary debate. It has identified and clarified issues; exposed constituency interests; fostered improved communications among those constituencies; revealed important areas of common ground; and created the framework, climate and process for a continuing dialogue.

Despite these considerable accomplishments, we gather at NABC 6 in the backdrop of enormous controversy and divisiveness created by the application of agricultural biotechnology's bovine somatotropin (bST). And we do so to explore the two most enduring and global issues surrounding agricultural biotechnology: its relation to the public good and how best to set its agenda. After all these years, why have these issues not been more satisfactorily resolved? Why does the sustainable agriculture community remain suspicious of the goals and motives of the proponents of biotechnology? How can the costly and counterproductive miscalculations of situations such as happened with bST be avoided in the future? What new strategies, processes and mechanisms are needed now to move beyond "dialogue" to the rational and workable development and application of agricultural biotechnology acceptable to both the biotechnology industry and the sustainable agricultural community? The answer, in my judgment, is to create new and effective mechanisms for direct public participation in the process of informing and setting the biotechnology agenda.

Before exploring this idea, I turn first to a brief review of the agricultural biotechnology dialogue to date. In proposing new strategies, it is important to understand 1. why past ones have fallen short of the needs and 2. why the "dialogue" must evolve to a new level of citizen involvement if it is to succeed in truly setting an acceptable agricultural biotechnology agenda.

THE AGRICULTURAL BIOTECHNOLOGY DIALOGUE IN PERSPECTIVE

In reading the agenda-setting literature of the agricultural biotechnology debate, several observations come easily to mind. First, those persons interested in the development of a more effective agenda-setting process have focused almost exclusively upon ways to improve the biotechnology dialogue. Second, analysts and proponents of such a process stress the need for the dialogue to be inclusive. For example, they note that the dialogue must "consider all viewpoints," "include a broad range of interests and issues," "review the ethical dimensions of biotechnology" and "analyze biotechnology's socioeconomic, health, and environmental impacts." Third, the need for open and candid conversation is emphasized. Fourth, it is said, participants in the debate should reflect diversity in background, education and experience. Fifth, the dialogue should serve to "educate" all parties in the debate about the potential benefits and dangers of new applications. Sixth, the dialogue should be conducted at multiple levels and under the auspices of both public and private institutions. Seventh, the dialogue should seek to foster consensus, whenever possible. And finally, the process should create improved understanding and mutual respect among dialogue participants.

But even those analysts who believe in the importance of dialogue and recognize its limitations have noted, for example, that "Important questions remain regarding education and communication, as well as policy formulation for the development and introduction of genetically engineered products" (Lacyetal. 1991:156). These authors point out that an effective dialogue must address a number of critical questions: "1. What should be the content, scope, and audience for an information and education agenda? 2. Who are the credible spokespersons to both raise and discuss the range of issues surrounding biotechnology? 3. Who should outline and articulate the broad responsibilities that come with powerful technologies like biotechnology? 4. Who should make decisions regarding the products, processes, and regulation of biotechnology? and 5. How can we stimulate a productive and meaningful dialogue among the relevant constituencies?" (Lacy et al. 1991).

Thus, despite widespread agreement on the goals and process-type questions surrounding an effective dialogue on agricultural biotechnology, not to mention the enormous resources and energy devoted to the process to date, important gaps and questions remain in our efforts to develop an acceptable agenda-setting framework. In my view, the most basic reason for this puzzling situation is that public involvement has not progressed sufficiently in either our minds or to the level necessary to recognize and deal with such questions.

It is time to move beyond our preoccupation with the dialogue process and begin to explore new and innovative ways to involve the sustainable agriculture community in the biotechnology decision-making process itself. There is, after all, a critical difference between broad participation in the dialogue about biotechnology, actual involvement in the planning and decision-making phases of agricultural biotechnology research and development, and the introduction of these technologies into the market place.

MERGING THE BIOTECHNOLOGY AND SUSTAINABLE AGRICULTURE AGENDAS: A RADICAL PROPOSAL?

As mentioned earlier, the agricultural biotechnology dialogue has made important contributions to our understanding of many of the underlying issues surrounding this powerful technology. It has helped create the climate and lay the factual groundwork, not only for continuing discussions but also for the consideration of new and more effective agenda-setting strategies and mechanisms. Before outlining some possible new approaches, however, I will briefly review the nature of policy agendas.

According to Cobb and Elder (1972), there are two analytically distinct policy agendas. First, there is the systemic agenda which "consists of all issues that are commonly perceived by members of the political community as meriting public attention and as involving matters within the legitimate jurisdiction of existing governmental authority" (Cobb and Elder 1972:85). The systemic agenda is thus merely a discussion agenda. The second phase of the agenda-setting process involves the so-called action or governmental agenda. According to Anderson (1979:56), this agenda is "more specific and concrete than a systemic agenda..." and "is composed of those problems to which public officials give serious and active attention." Placing an issue or problem on the systemic agenda is much easier than achieving a similar status on the governmental or action agenda.

Although these authors are describing policy agendas in the public domain, their distinctions between discussion and action agendas offer important insights into the limitations of the current agricultural biotechnology dialogue. While the dialogue has been remarkably effective in placing biotechnology issues and perspectives on the agricultural systemic or discussion agenda, it has failed to devise ways to ensure that decisionmakers give "serious and active attention" to the claims and priorities of the sustainable agricultural community, broadly conceived.

PARTICIPATORY DECISION-MAKING: PLANNING THE AGRICULTURAL BIOTECHNOLOGY AGENDA

The idea of direct citizen involvement in the formulation of specific policies and broad policy agendas in both public and private arenas is not new (Kariel 1966). The value of such participation has formed one of the most enduring and embracing themes in American political philosophy since the founding of the republic (Grimes 1955). Indeed, much of our fascination with direct citizen involvement in policymaking stems from the writings of Thomas Jefferson and has come to be embodied in the notion of Jeffersonian democracy. For our purposes, it seems relevant to note that Jefferson's agrarian leanings "inclined him to the view that the farmer was the best subject for self-government" (Grimes 1955).

In the brief space remaining, I wish to suggest that the time has come for the biotechnology industry to begin exploring the principles and processes of participatory decision-making, and to initiate a serious assessment of ways to implement concrete decision-making opportunities involving all elements of the agricultural biotechnology constituency including farmers, public interest group representatives and other citizens. These individuals should be involved in the strategic phases of basic and applied agricultural biotechnology research, development and marketing. Given the conceptual nature of the scientific strategic planning process, I know of no reason why ordinary citizens could not contribute to this critical activity.

Unlike the dialogue, which offers only sporadic, short-term opportunities for interaction (and no opportunities to literally participate in setting the agricultural biotechnology agenda), the ongoing, relatively intimate interactions characteristic of participatory decision-making would create authentic opportunities to directly influence the biotechnology agenda. Furthermore, I believe such a process would have multiple additional benefits for all parties involved: it would create trust; it would result in more comprehensive and enlightened planning; it would very likely save time, money and resources; and it would make possible public endorsement, not mere acceptance, of new agricultural biotechnology products. It would, in effect, move agricultural biotechnology from the realm of dialogue to acceptable action.

REFERENCES

Anderson, J.E. 1979. *Public Policy Making, 2nd ed.* Holt, Rinehart, and Winston, New York, NY.

Cobb, R.W. and C.D. Elder. 1972. *Participation in American Politics: The Dynamics of Agenda Building.* Allyn & Bacon, Boston, MA.

Grimes, A.P. 1955. *American Political Thought.* Henry Holt and Co., New York, NY.

Kariel, H.S. 1966. *The Promise of Politics.* Prentice-Hall, Inc., Englewood Cliffs, NJ.

Lacy, W.B., L. Busch, and L.R. Lacy. 1991. Public Perceptions of Agricultural Biotechnology. In B.R. Baumgardt and M. A. Martin, eds. *Agricultural Biotechnology: Issues and Choices.* Purdue University Agricultural Experiment Station, West Lafayette, IN.

How the Agenda is Set

Susan Offutt
Executive Director, Board on Agriculture
National Research Council

The question of how the biotechnology agenda is set has most interest when the outcome of that agenda-setting is in question. To ask what agricultural biotechnologies might be beneficial and how their development and implementation might be expedited supposes that the existing institutions and incentives are somehow inadequate or unreliable. This brief discussion considers how decisions about new technologies for food and fiber production and processing are made and at what point, if alternative outcomes are desired, intervention might be contemplated.

THE TRADITIONAL PARADIGM

In the traditional paradigm of economists, the marketplace is both the instigator and the arbiter in the contest among new technologies. Unless supplying firms profit, and consumers find utility in the new technology or its products, there can be no success. Questions about quality, safety and efficacy are largely answered in the market exchange, with oversight by public authorities in some cases. Technological innovation is induced by economic signals as embodied in the relative costs of inputs and prices of outputs. Induced innovation can explain the transformation of American agriculture by observing that the post-World War II economic expansion made labor relatively more expensive compared to other major factors of farm production. Consequently, technologies were developed that substituted for labor with the use of capital in the form of purchased inputs such as large-scale machinery and later through organic-synthetic pesticides. In the traditional view, market signals set the agenda—from start to finish.

As with most constructs of economic theory, reality is more complicated, particularly in the case of the agricultural sector. First, there is significant government intervention in agricultural markets, interventions that intentionally distort market prices. For example, U.S. commodity subsidy programs inflate land values because acreage set-asides artificially restrict the supply of land and so raise its price relative to other factors. As a consequence, technological change that saves land is induced, again reinforcing the capital-intensity of production. Second, much agricultural research and development (R & D) has had "public good" attributes, that is, displayed characteristics that make private sector participation unlikely even though societal benefits could be had if a technology were to become available. So, for example, a technology such as contour plowing was developed largely by the public sector because the benefits from its adoption could not be restricted to participants in a market transaction. Anyone driving by a contour-plowed field could figure out how to implement the technique without paying the originator for the knowledge. Whether there are more such public good opportunities in agriculture than in other sectors is a good question, but it has historically been the case that significant public sector resources in the land-grant colleges and U.S. Department of Agriculture (USDA) have been devoted to both basic and applied research. Third, not all relevant aspects of agricultural technologies are reflected in market prices—another familiar form of market failure. Environmental effects and human nutritional implications are two well-known examples. Fourth, the distribution of the costs and benefits of a new technology follows market signals, implicitly valuing welfare equally across individuals. So, for example, from the market's perspective, a dollar of profit to a small farmer is the same as a dollar of profit to a large farmer.

The existence of such market distortions and failures has contributed largely to the emergence in public dialogue of the "fourth criterion" in assessing agricultural biotechnologies. In this conception, socioeconomic and environmental impacts of a technology or its products are evaluated alongside its quality, safety and efficacy. Manifestations of the significance of the fourth criterion, particularly in the debate over the use of bovine somatotropin (bST), have been seen in the U.S., in the European Union and in Canada. According to the May/June 1994 issue of the *Agbiotech Bulletin,* the Canadian House of Commons agriculture committee may "recommend the federal government conduct social/economic/environmental impact studies on all new biotechnology products before they come up for public scrutiny and that biotech companies be charged with the job of getting out information." Such recommendations essentially represent calls to modify the way the agenda is set, to explicitly consider non-market aspects of technology adoption and use.

Not surprisingly, it is generally easier to agree on the need to the change the agenda-setting process than on the definition of a beneficial outcome. Here, the discussion concentrates on how the agenda is set in order to identify possible forms of intervention or modification with the ultimate goal of changing outcome. The agenda-setting process can be altered *ex ante* or *ex post,* that is, before development choices are made or after a technology has emerged but before it appears on the market.

EX ANTE INTERVENTION

The question of how choices are made is a fruitful one for discussion, especially as an alternative to the "Monday morning quarterbacking" that currently characterizes the debate over agricultural biotechnology agenda-setting. In addition to signals sent by the market, R & D directions are determined by the opportunities afforded by the scientific frontier and by a host of non-market signals. External private market signals to researchers are accompanied by external signals from public agencies (as through funding or regulatory decisions) and by internal values and characteristics of researchers. The role of the external market signals has been extensively considered, as discussed, but less attention has been paid, in agriculture anyway, to the public and internal signals that determine problem choice.

The question of how a researcher's experience, background and competence affect problem choice is complicated. I recently considered the case of agricultural economists, starting from the intuitively appealing premise that generational change in the population of scientists will have an impact on the discipline's research agenda (Offutt 1993). As was typical of most agricultural science disciplines, the agricultural economics area was comprised of white men from farm backgrounds who were trained at land-grant universities. However, the post-World War II generation became more diverse: more women and minorities from suburban and urban backgrounds educated at land-grant universities, as well as liberal arts colleges and private universities. Without going into depth about the analysis, suffice it to say that I found it worthwhile to explore the implications of changes in characteristics of agricultural scientists at a time when the relevance of the traditional research agenda is being challenged.

To turn to the question of public sector signals, it is perhaps ironic to note that the public agricultural research agenda-setting process is the envy of some other parts of the scientific community. The multilayered system of priority-setting that links state and federal efforts is seen as transparent and participatory. However, this admiration is not universally shared. As but one example, consider the animated dialogue between advocates of sustainable agriculture and the managers of USDA's Competitive Grants Program—the National Research Initiative (NRI). Considerable effort by both groups has been devoted to modifying grant proposal review to reflect the goal of sustainability—an effort which is in no small way complicated by the lack of a working definition of the concept. And, in starting a major study, the National Research Council's Board on Agriculture has expressed its concern for the future effectiveness of the land-grant colleges of agriculture, a very large component of the public system. These process-oriented efforts more generally reflect a concern about the nature of the outcome of agenda-setting for agricultural biotechnology and agricultural research.

EX POST INTERVENTION

It will be impossible to eliminate controversy over whether a technology is beneficial or not. Consequently, *ex post* (post-development, pre-market) intervention will remain a live, if costly, option. To return to the traditional paradigm, economic theory says that such intervention in the market is inappropriate as a means of achieving non-market goals. Instead, non-market tools should be employed such as compensatory payments to those who might be adversely affected by a market outcome. If the problem were perceived to be uneven income distribution among farmers, which might be exacerbated by the adoption of a new technology, then the most efficient intervention is a transfer payment from the public treasury directly to poorer farmers. This approach recognizes that, while technologies have undeniable positive and negative socioeconomic impacts, it is hard to "reverse-engineer" the development process to predict the outcome of technology adoption well enough to allow control from the start. Sometimes even the best intentions go awry. To draw an example from outside agriculture, consider the development of labor-saving devices for housework like the vacuum-cleaner, which, one might have supposed, would have freed women from having to spend so much time cleaning. Alas, there is considerable evidence that has not been the case.

Ex post intervention potentially involves acting on the fourth criterion, moving beyond a regulatory consideration of quality, safety and efficacy. Implementation can be tricky, however. What actions would be taken—prohibition of a technology or restrictions on its use? Imposition of taxes or subsidies? Who would be empowered to take these actions—appointed or elected officials? Permanent civil servants? Citizen groups? Given that intervention of this nature would be unprecedented, the question of how, or perhaps whether, existing rules and institutions could be modified to cope is a good one to ponder.

CONCLUSIONS

In considering the agenda-setting process for agricultural biotechnology, the initial question of problem definition seems key. How are needs identified or perceived? Given the complexity of the food and agricultural system, how can the contributions, and limitations, of numerous perspectives be appreciated? The advent of biotechnology has hastened the day of reckoning by accentuating the linkages among farming practices, the natural resource base, food processing, and consumption requirements and desires.

The most pressing need is to be more analytical about understanding how technologies evolve. This process is not strictly a function of personalities; there are behavioral patterns that can be understood, and presumably modified, just as there are policy instruments in place or on the shelf that affect market and non-market signals. Any reconsideration or redesign of the process has to accommodate the continued prospect of argument over the beneficial nature of new technologies because benefits will always be accompanied by risks and costs. As a practical matter, we will likely not have the option of repeatedly denying use of any technology that adversely affects one or another member of society. Political judgments about acceptability will have to be made. This is necessarily a messy process and perhaps one unfamiliar to agriculturalists who have enjoyed 100 or more years of relative consensus about what they do and why. Institutional innovation, not personal attack, would seem to be the order of the day.

REFERENCES

Offutt, S.E. 1993. Ensuring Hybrid Vigor in the Agricultural Economics Profession. *Amer. four, of Ag. Econ.* 75:1150-1154.

Workshop Report

Patricia T. Raynor
Coordinator, USDA National Biological Impact Assessment Program, Michigan State University

Thomas L. Thorburn
Program Director of Food Systems, Rural Development and Water Resources, Kellogg Foundation

The stated purpose of this workshop was to identify areas of agriculture in which biotechnology is most likely to be beneficial to the public, and to formulate recommendations that could encourage such applications. Two invited speakers presented background material with thought-provoking views of how decisions that shape the agricultural biotechnology agenda are made and who should be making them. Susan Offutt, Executive Director of the Board on Agriculture of the National Research Council, described how a fourth criterion has been added to the public dialogue of agricultural biotechnology. In addition to quality, safety and efficacy, the socioeconomic and environmental impacts of agricultural biotechnology must also be evaluated. In other words, the agenda-setting process needs to be modified to consider non-market aspects of technology adoption and use.

Garth Youngberg, Executive Director of the Henry A. Wallace Institute for Alternative Agriculture, noted that public involvement has not progressed into the planning and decision-making phases of biotechnology research and development. He emphasized that companies need to take a serious look at how to bring farmers, public interest groups and other citizens into their strategic planning.

These ideas set the stage for subsequent discussions during the workshop sessions. Rather than identify agricultural products or research areas in which biotechnology is most likely to be beneficial to the public, the group focused on the process of setting the agenda. The unifying theme that emerged from the discussions was that participatory decision-making was essential to ensure that applications of biotechnology serve the public good.

Nearly fifty people participated in this workshop. Five breakout groups were formed to present and discuss individual issues; from these, the entire workshop group identified three issues of greatest interest or concern: public participation, availability of information, and the regulatory framework. Each was then addressed by a breakout group which developed recommendations.

PUBLIC PARTICIPATION

There is a need to increase public participation in both public and private sectors of the agricultural biotechnology community to create an agenda-setting environment (process) that more accurately reflects the diversity of values, interests and priorities in our society. Public participation would enhance communication among interested parties, promote better understanding of issues from all perspectives, and encourage the development of mechanisms to open up the agenda-setting process.

This issue raises further questions that need to be addressed such as: who should define the public good? who is accountable to the public good? how do you involve people who are affected by the outcome of decisions, but lack the expertise to contribute meaningfully to the process? These questions prompted a comment that in a democracy, government is the entity is responsible for defining the public good.

Recommendations

All of the recommendations for increasing public participation formulated by the breakout group were strongly supported by the entire workshop group.

Review and assess existing public and private advisory structures and modify them as necessary to ensure representative input into the development of the agricultural agenda including biotechnology applications.

Review and define the mechanisms for establishing truly responsible public participation with input focusing on broad areas of societal concern that may benefit from agricultural biotechnology.

Encourage the integration of environmental and social science into biological sciences programs.

AVAILABILITY OF INFORMATION

There is a need to promote ready access to and active dissemination of information relevant to agricultural biotechnology issues. There is also a need to foster educational reform that will enhance the effective use of that information in the decision-making abilities of all citizens. Enhanced availability of information will increase effective dialogue and lead to better decision-making by establishing feedback to, and cooperation with, those who set the agenda.

Education should address both specific issues and broader processes associated with setting the agricultural biotechnology agenda. Procedures need to be developed that will integrate biotechnology information into overall agriculture policy and address the impact of funding sources and allocations. It was noted that information about opportunities to participate in decisionmaking is an important component of education efforts.

Funding to support information and education programs needs to be provided. Because education is distinct from advocacy, the source of funds is important. Information for the public needs to be made available by agencies or organizations that do not have a vested interest in the outcome. Otherwise, decisions that shape the agricultural biotechnology agenda will, by default, be made by the advocacy groups having the biggest bankrolls.

Recommendations

Recommendations proposed by the breakout group were strongly or unanimously supported by the entire workshop group.

Send a representative to the National Association of Biology Teachers (NABT) and the National Science Teachers Association (NSTA) annual meetings to provide a list of resources and experts in agricultural biotechnology that teachers may contact locally.

Include agricultural biotechnology in K-12 science curricula.

Develop an agricultural bioethics course for land-grant institutions and establish it as a requirement for U.S. Department of Agriculture (USDA) training grant programs.

Continue and expand research on risk assessment and the socioeconomic impact of agricultural biotechnology.

IMPLEMENTING AN ACCESSIBLE, EQUITABLE AND CONSISTENT REGULATORY SYSTEM

The agricultural biotechnology agenda encompasses not only research directions and priorities but also the regulatory framework within which the technology is applied. Does the existing regulatory system ask the right questions and give the right answers? In the ensuing discussions far-ranging ideas were proposed to address some of the deficiencies in the current regulatory system.

Difficulties in obtaining bureaucratically held information could be improved by providing access to information using innovative technologies that allow information on demand. Inequitable distribution of benefits derived from biotechnology products, developed in part by publicly supported research, could be remedied by revamping regulatory agency mandates to include consideration of who profits. In other words, agencies could exercise conscience as well as oversight.

The fragmented regulatory framework, in which the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA) and USDA share overlapping authorities for biotechnology products, could be streamlined by establishing a centralized monitoring agency to serve as a clearinghouse for information from all the agencies. In order for people to have information about how new technologies will affect their daily lives, regulatory agencies could be required to address the socioeconomic aspects of biotechnology applications. It could be argued, however, that such a requirement would effectively result in political decisions being made by government officials who, not being elected, do not represent the political will of the electorate.

As noted below, the recommendations put forth by the breakout group received variable support from the entire workshop group.

Recommendations

Implement prior recommendations on regulations put forth at the NABC 4 meeting in 1992. (This call for action had almost unanimous endorsement.)

Those recommendations (Fessenden MacDonald 1992) were:

- The regulatory gaps delineated deserve serious investigation NABC may wish to establish a committee or other mechanism to assist this investigation.
- A more acceptable policymaking process for rules of broad applicability would be clearly understood or known (not ad hoc), transparent and participatory. The group viewed the process leading to the recent FDA food safety decision as falling short of the goals for an acceptable process.
- Social, economic and ethical questions need to be explored. What role do/should these issues have in research, development and approval processes for commercial use of new products? When should these factors be considered, relative to, but not necessarily as a part of the regulatory process?
- With broader representation (such as food processors and consumer groups), NABC should conduct further exploration of the relationship between the government's regulatory role, particularly the safety statutes and issues of choice such as labeling provisions.

Codify statutory requirements for socioeconomic analysis, (strongly controversial; about fifty percent of the participants supported this recommendation and fifty percent were opposed)

Require that regulators consider equitable allocation of intellectual property rights so that the regulatory process includes consideration for individual compensation, (strongly controversial; the group was divided, with about half in favor and half opposed)

Establish a single regulatory agency clearinghouse monitoring EPA, FDA and USDAfor biotechnology applications. (The majority of the group was strongly opposed to the recommendation. Concerns were raised that it would simply create another level of bureaucracy, or that it would undermine existing authorities)

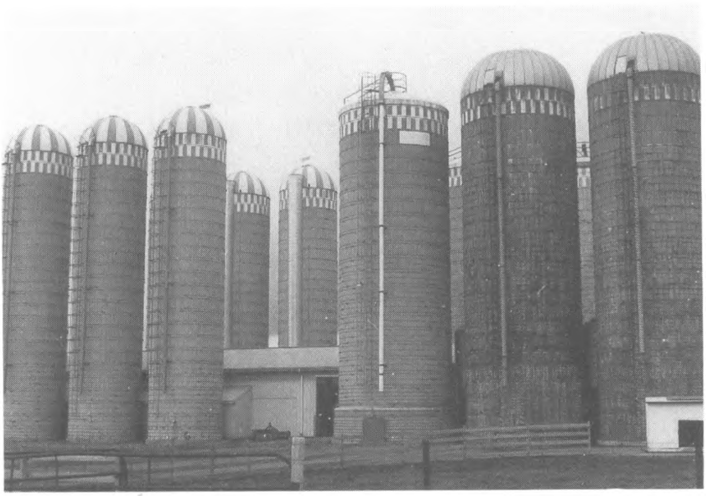
CONCLUSION

At the outset, the stated purpose of this workshop was "to identify those areas of agriculture in which biotechnology is most likely to be beneficial to the public and to formulate recommendations that could encourage such applications." In actuality, however, the discussions addressed the process of setting the agenda rather than the identification of specific products or areas of research. This broader focus produced very general recommendations for improving what was termed “the decision-making process.” Most participants agreed that decisions about the application of biotechnology are more likely to be for the public good when there is greater participation by an informed public in setting the agenda.

REFERENCES

Fessenden MacDonald,]. 1992. *NABC Report 4, Animal Biotechnology: Opportunities & Challenges.* National Agricultural Biotechnology Council. Ithaca, NY.

PART V: BIOTECHNOLOGY AND THE STRUCTURE OF AGRICULTURE



Agriculture in the 1990s and Beyond

Dean Kleckner
President
American Farm Bureau Federation

Agriculture is changing in response to many influences. Biotechnology is one of the most talked about and least understood of the changing forces. As a farmer, I read and hear about some of the newest innovations, most of which are as startling to me as reports of mechanical advances were to my grandfather or chemical advances were to my father.

Biotechnology by another name is agricultural research. And agricultural research is one major influence that forged U.S. farming and made the U.S. farmers, as producers, the envy of the world. There is always a need for more research. Still, the farmer's basic role will not change. We have to provide food and fiber so society can function. It is predicted that the world population will double in the next 50 to 60 years, but the acreage of productive farmland will not keep pace. I suggest that this is a challenge and an opportunity, not a threat.

The world's farmers are feeding twice as many people on the same total farmland acreage used in 1960. This has been accomplished with improved seeds, irrigation, fertilizer and pest control. Just as in 1960, farmers in the 1990s and beyond must produce more and better food if the expected demand is to be met. Jim Moseley, formerly of the U.S. Department of Agriculture (USDA), said that to do this, the world's farmers will have to produce as much food in the next 40 years as we have grown in the entire 14,000-year history of agricultural production. U.S. farmers are up to the challenge. The U.S. will continue to export ever-increasing tonnage and dollar amounts of higher value products.

This movement toward increased agricultural exports is pushed by increasing demand from higher standards of living around the world, based on the recognition of the quality and value of U.S. farm products and the product enhance- ment done by agribusinesses. It is a change symptomatic of the term "industrialization."

There are other movements—such as the decline in the number of farms—from 6.7 million in the 1930s to 2.1 million today. Included in these numbers is any place that sells $1000 dollars worth of agricultural products a year. To me, that is like calling a person a professor if he tutors one child, or calling a person a journalist if she sells one story a year. You could sell two steers or a dozen hogs or backyard garden produce and qualify as an official USDA-declared farmer.

Less than 400,000 of the 2.1 million USDA-recognized farms produce most of the food and feed grains, oilseed, livestock, dairy and poultry raised in the U.S. Long term, the number of farms continues to decrease, and per-farm acreage continues to increase.

Another, but not so well-known trend in agriculture is the increasing number of small, part-time farms. There are several reasons for this. Starting small is about the only way a person can enter farming without marrying or being born into the operation. Also, some people prefer a smaller operation—one with less financial pressure and worries. Others like the aesthetics of living in the country, farming a little but depending on outside sources for income. Urban investors are attracted by income tax advantages for real estate ownership, especially with the current fear of rising personal income and business taxes. Finally, small part-time farm numbers are increasing because some middle-sized farms are now being forced to down-size their operations to just hold onto the farm.

AMERICAN FARM BUREAU GOALS

The American Farm Bureau Federation has two goals to pursue as these changes continue. We constantly strive to increase net farm income and work to improve the quality of rural life. That way, we respond to the needs and desires of all of our farm and rural residents. Some in agriculture are more aware and more affected by industrialization than others. That is because certain sectors are more concentrated than others. Look, for example, at livestock. There are about 45,000 cattle feedlots in America today. About 75 percent of the fed cattle move through just 600 lots.

As a hog farmer, I hear coffeeshop concerns about consolidation of our industry. About one million less farms raise hogs now than were in the business just 20 years ago. Some hog producers say we are going the way of the broiler industry—offering our buildings and sweat to the highest contract bidder.

Some states have enacted anticorporate farming laws to thwart the trend of piglet-to-pork chop integration, but the laws do not thwart the trend. Corporations planning to go into a large-scale hog business simply begin operating in states where they are welcomed as a job creator and a tax revenue source. The hog industry is paralleling the industrial path of poultry concentration. The 30 largest integrated broiler operations represent 80 percent of the chicken now sold in the U.S. The 30 largest integrated turkey operations produce 70 percent of the turkeys sold in the U.S.

NEW PROFIT PATHS

Despite this evidence of concentration, I believe individual farmers have a future in U.S. agriculture—if the proper policies are implemented and if we remain alert to market opportunities and consumer demands. The key is profitability. U.S. farmers will be more innovative and productive than can be imagined if the opportunity to make a profit is present. First of all, profit must be available to those who remain engaged in what I view as traditional agriculture. Thus, the American Farm Bureau will work to ensure the future profitability of agriculture. Several avenues are now hailed as new profit paths for farmers as alternative uses of major farm commodities attract attention (e.g., ink from soybeans). In time, improvements will lead to greater use, requiring 100 million bushels of soybeans to meet annual demand. Likewise, ethanol from corn is becoming a profitable alternative use. Corn growers eagerly promote ethanol use since it provides an additional 20 cents to the farmer for every bushel of corn sold. Ethanol, produced from a renewable crop like corn, substitutes for nonrenewable oil. Crop-based, disposable products will not end up in a dump, but instead will be fed to animals or composted. Maybe something like a disposable plate would end up as the dessert. It is a matter of research and development. It is a matter of economics.

Ethanol, packing material and other industrial uses of corn could require 850 million bushels a year. Paints and fiberboard and medicines—you name it—could also contain farm products. Greater alternative uses will occur, will contribute to a farmer's income and will offer other benefits.

Biotechnology is also hailed as a profit factor. Farmers will raise pharmaceuticals in specially bred cattle, human blood substitutes in hogs, or antibiotics in tobacco or lettuce or cherry tomatoes. Already we have transgenic plants that protect themselves from disease and insects and the use of recombinant growth hormones enhance milk and lean meat productivity. Many companies are hard at work developing slower ripening tomatoes, insect-resistant tobacco and herbicide-tolerant crops. Farmers will adapt and adopt—looking to the marketplace for production signs. Our goal as farmers is no longer to sell what we produce, but to produce what we can sell. We will be responsive to consumer demand whether it involves producing leaner meat or color-coordinated cabbage. We will deliver products aimed to please the consumer's specific demands which could rapidly make obsolete traditional food grades and standards. America's agribusiness powerhouse, including production agriculture, will be price and quality competitive with anyone, anytime, anywhere.

WORLD MARKETS

My remarks presuppose a worldwide arena that encourages and rewards growth, an arena that offers profits to those who best their competition. Markets must be open. Products must not be subsidized in a way that distorts trade. Let products, not national treasuries, compete. Consumers can and will decide a product's merits with price and quality more important than a product's national pedigree.

The American Farm Bureau was closely involved with recent world trade negotiations. U.S. farmers must be involved because exports are now vital to our bottom line. Foreign sales account for about one of every four dollars U.S. farmers earn. The elimination of unfair trade barriers would increase U.S. farm exports by as much as $8 billion a year.

More equitable trade with Mexico alone is expected to add $2 billion a year to our export sales. Trade with Canada improved after the U.S. and Canada signed a trade agreement in 1988. Since then, our agricultural exports north of the border have increased 125 percent. And Canada's farm exports to the U.S. increased 25 percent. Farmers in both countries are better off, and so are consumers.

Similar gains could result from the successful implementation of the Uruguay Round of the General Agreement on Tariffs and Trade (GATT). The American Farm Bureau will work with the administration and U.S. Congress to get equitable international trading rules. We supported the North American Free Trade Agreement (NAFTA), even though some of our members believe they will be adversely affected. We are asking the U.S. Congress for safeguards to enable U.S. producers to adjust to new competition.

The American Farm Bureau's role in all trade negotiations is to look out for the interests of U.S. farmers—all U.S. farmers. We know that limiting production just does not work. Other nations will happily grow what we will not. We are better off growing at full capacity and selling "the whole load" at a profit. With reduced barriers on our bulk products and increasing demand for our higher-valued farm goods, our export future is bright.

IN CONCLUSION

Industrialization presents many opportunities and challenges to America's farmers. We will be alert to capitalize on those that offer the most promise. We are also alert to changes that are coming due to the "institutionalization" of agriculture, a topic for another presentation.

As farmers, we are seeing a steady erosion of personal freedoms, a growth of penalties in place of incentives, increased government spending and higher taxes, more costly environmental restrictions and more blundering bureaucrats. Farmers and other entrepreneurs, society's creators and doers, are under ever-greater pressures. Only after we successfully address and remove these domestically imposed restraints, can we truly take advantage of the benefits offered by industrialization.

Public Policy, Biotechnology and the Structure of Agriculture

William P. Browne
Political Science
Central Michigan University

There are numerous perspectives on the relationship between emerging biotechnology innovations and the structure of agriculture. Some emphasize what can be done to influence that relationship. The perspective presented in this paper precedes any such prescriptions. It argues that the historic interplay of public policy and marketplace forces will continue pretty much unabated, extending most trends but adding to them new expectations.

The next few years will see a proliferation of new products that offer increased productivity and environmental gains. These will foster a general consolidation of farms and ranches at a rate somewhat lower that in the past. Government will do little to intervene. As always, public policies will not encourage smaller-scale production agriculture. Nor will there be a return to production control practices. But a new policy dimension will be added—-a reliance on biotechnology to reduce environmental hazards.

EXPECTATIONS FOR NEW PRODUCTS

In forecasting public policy trends, the most important things to examine are policymaker perceptions. Perceptions guide process decisions. Such views are created as public officials and their staffs both systematically search and more randomly scan their environments for policy-relevant information. No one has been looking for a great debate on this topic. Biotechnology discussion and analysis have been a part of those environments for nearly a decade, nonetheless, some quite specific expectations have been created.[1]

Three policymaker beliefs that are generally shared stand out about biotechnology's future in agriculture. First, officials commonly understand that U.S. agriculture is soon to be changed, perhaps dramatically, by the advent of a plethora of new products. Some will be crop specific, others will influence production practices. Second, these products are expected to bring significant increases in the supply and availability of numerous commodities from such major ones as dairy to minor crops like strawberries. Along with greater supply, officials also have been led to expect improvements in affected commodities, ranging from better flavor and texture to improved food safety.

[1] The primary sources for this analysis are policymaker interviews. See Browne (1995).

Particularly interesting to many officials, especially from areas where growers and other residents share space, are products that produce positive environmental impacts: less water use, reductions in fertilizers and other chemical inputs, and a switch from intensive use of highly erodible and other fragile lands to ones that better sustain production.

The third belief is that biotechnology will bring important new profits to the sector, both for entrepreneurial agribusinesses and innovative growers. The expectation is that U.S. leadership in agricultural biotechnology will bring international gains in marketing both technology and food products to the world. Part of that belief is premised on the notion that the international marketplace will be increasingly short of food (Brown 1994).

The reasons why these beliefs are shared are easy to understand. On the one hand, biotechnology products—both in medicine and agriculture—have weathered substantial tests in the regulatory process (Browne and Hamm 1988).[2] On the other, most of those who provided policy information combined effectively to discredit the science of biotechnology opponents, most notably Jeremy Rifkin. As a consequence, the shared beliefs of public officials are near what policymakers find as an appealing consensus—biotechnology means a better and largely irreversible future for U.S. agriculture.

ACCEPTABLE TRADE-OFFS

Two other expectations worry policymakers, but not much. First, they fear that consumers will avoid biotechnology products because individuals such as Rifkin will continue their opposition. Public officials, however, see that as a marketplace problem: let retailers work that dilemma through with their customers. The decisions of some grocers to offer "bST-free" milk is thought of as a reassuring event, one that shows that public policy actions are unnecessary.

The second worry is that growers will continue to exit the sector as they encounter economic losses, exaggerated by the costs of new biotechnology and its practices. For most policymakers who at least nominally appreciate over 140 years of public policy efforts to keep farmers in business, that concern is more important than the consumer problem. Public officials understand that efforts will be made to limit biotechnology introduction, use and its gains. But, intuitively, they feel these will be unsuccessful.

Very few policymakers, therefore, are moved by this farm problem. There are three reasons why they are not. First, farm losses have been understood to be slowing. While nearly 30 percent of farms were lost in the 1950s, just over 25 percent in the 1960s and about 18 percent in the 1970s, only 12 percent were lost in the 1980s (Browne 1993:4). Second, policymakers find it relatively easy to deal with the economics of the sector, but they know it is

[2] An often overlooked point is the degree to which biotechnology's medical value, and glamour, rubs off on its acceptance in agriculture. Its allure is hard for public officials to resist.

hard to keep individual growers in business. Farm losses continued during the past four decades even when net farm incomes rose.

Third, public officials recognize that farm losses are most severe at the mid-sized farm level. Those producers, it seems, simply face structural disadvantages that are beyond the historic emphasis of farm income policy. Regulating biotechnology will not alter that fact. In contrast, large farms that are the most likely biotechnology adapters are suffering fewer losses. And small farms, which rely mostly on off-farm incomes, have generally stabilized in number. Biotechnology need not be adopted by these small-farm growers for them to continue in their businesses.

Added to the limited concern of policymakers for farm effects are the attitudes of growers. Farmers themselves have shown almost no willingness to limit their use of new technologies. On the contrary, even farm protest leaders of the 1980s were willing technology adapters and advocates (Browne 1993). Family-farm activists, who were also active in the late 1980s, favored limitations but found few supporters in farm ranks. Nor did environmental interest groups, that once seemed natural allies, support them. The consequences are that demands to limit technology lack credibility in all but the most isolated places. So growers, like consumers, are left to market forces and some added federal income transfers that help some of them afford innovation.

POLICY RESULTS

These conditions make it unlikely that public officials will move against biotechnology innovations. Quite the reverse seems true. To facilitate economic gains from investing in product research, policy efforts to protect business' intellectual property rights will intensify. On another front, regulations that emphasize zero-risk tolerance for product use will be subject to greater scrutiny. Already the thrust of federal regulation, in general, has moved away from the strict policies of the 1970s to an emphasis on considering costs to the regulated industries in the 1990s (Eisner 1993). At the very least, this means that major biotechnology manufacturers and users will be looked to for more policy information. This, of course, will only reinforce currently prevailing perceptions of public officials.

Thus left to the market, the agricultural sector will face an ever greater structural imbalance in the future. Both public reliance on the largest farms and government tolerance of the smaller ones will continue.

But it seems the market will not be the only facilitating mechanism for encouraging this structural imbalance. The major policy debates about agriculture and its future are over issues of the environment and property use. These are among the most contentious, and certainly the most difficult to resolve, policy contests in the history of U.S. agriculture (Browne 1995). Because policymakers understandably want such conflicts to abate, solutions are being actively sought to reconcile grower and environmentalist differences.

Biotechnology, which looks so promising for making environmental gains while fostering production, has even more than normal appeal as a result. What seems likely to occur are policy initiatives which encourage biotechnology product use. "Green payments" may be one mechanism, but regulatory penalties for relying on traditional practices appear more affordable in a budget conscious environment. Any such efforts to facilitate biotechnology use, unless accompanied by substantial assistance, will work to the advantage of the largest producers as those most likely to afford them. Regulations will be hard to bear for middle and small sized growers.

CONCLUSION

It seems evident that, given current policymakers' perceptions and pending public policy problems, biotechnology will only add to the farm structure problem of continuing consolidation. But for many, this brief analysis carries another point as well. What also is evident is just how little serious policy debate these trends seem likely to create. Political noise and analytical evidence rallied in protest against structural trends are not likely to be well-received.

REFERENCES

Brown, L.R. 1994. *State of the World 1994.* Worldwatch Institute, Washington, DC.

Browne, W.P. 1995. *Cultivating Congress: Constituents, Issues and Interests in Agricultural Policymaking.* University Press of Kansas, Lawrence, KS.

Browne, W.P. 1993. Challenging Industrialization: The Rekindling of Agrarian Protest in a Modern Agriculture, 1977-1987. *Studies in American Political Development.* 7(Spring):l-34.

Browne, W.P. and L.G. Hamm. 1988. Political Choice and Social Values: The Case of bGH. *Policy Studies Journal.* 17(Fall):181—192.

Eisner, M.A. 1993. *Regulatory Politics in Transition.* Johns Hopkins University Press, Baltimore, MD.

Workshop Report

Frederick H. Buttel
Rural Sociology
University of Wisconsin
Tom Guthrie
Farmer and Vice President
Michigan Farm Bureau

The structure of agriculture is a broad notion that pertains to the organization, performance and social implications of the food and fiber system. The term was first employed in the 1970s, primarily by social scientists. But following the publication of *A Time to Choose: A Report on the Structure of Agriculture* by the U.S. Department of Agriculture (USDA) in 1980, the structure of agriculture notion came into more common usage.

While the concept of the structure of agriculture has been employed for about two decades, it can mean many different things. The conventional definition grew out of the U.S. Department of Agriculture's work in the late 1970s (USDA 1980; Economics, Statistics, and Cooperatives Service 1979) and related activities of U.S. Congress (Committee on Agriculture, Nutrition, and Forestry 1980). The traditional farm-structure-oriented use of the phrase "structure of agriculture" involves parameters such as farm numbers, the size distribution of farms, farmland tenure and ownership, labor patterns, enterprise-level and regional specialization of production, the incidence of off-farm employment and so on. In recent years, however, the structure of agriculture has increasingly been understood in broader—essentially food-system—terms. This broader, food-system conception of the structure of agriculture includes the aforementioned farm structure factors, and in addition is concerned with the nature of the linkages across each of the segments of the food and fiber system from research and development, farm input manufacturing, and on-farm production and reproduction to food processing, storage and distribution, marketing, retailing, preparation, consumption, and disposal. As with the traditional conception of the structure of agriculture, the food-systems oriented one is concerned with the performance and other implications of how the system is organized.

Participants' Views

The participants in the NABC 6 workshop on biotechnology and the structure of agriculture generally embraced this broader conception of structure. But while there was general agreement that the future of biotechnology should be considered in terms of this more encompassing definition of the structure of agriculture, the workshop participants exhibited a wide range of views about the implications of biotechnology for the structure of agriculture.

Many of the workshop participants tended to see the structure of agriculture as necessarily involving social equity as well as economic performance dimensions. In this view, equity aspects of the structure of agriculture (e.g., the implications of new technology for the viability of family farming and for the distribution of land ownership) are critical because of widespread public support for moderate-scale, family-operated farms and for the notion that public researchers have a special responsibility to serve this clientele. Put somewhat differently, there is concern that new technologies may reinforce or accelerate the trend toward the industrialization of the food system. Industrialization of the food system involves: declining self-employment, an increased scale of production, growing specialization and vertical integration, and decreased control by farmers and consumers within the food system.

Other workshop participants, while often sympathetic with equity concerns, tended to see the efficiency, coordination and competitiveness of the food system as being the most important set of criteria for assessing biotechnology and the structure of agriculture. It was noted by several participants that a food system that produces safe food in an efficient manner is the most equitable system from a larger societal standpoint. From this perspective, food system industrialization can often be a mechanism for ensuring that this system produces safe, abundant, inexpensive food.

It was also noted by several observers that many issues about the relationships between biotechnology and agricultural structure are neither unique to biotechnology nor "new." Rapid structural changes in agriculture have occurred continuously since the 19th century, and particularly since the end of World War II (Cochrane 1993). Technology has played a significant role in propelling and shaping these historic structural changes (Committee on Agriculture, Nutrition, and Forestry 1980; Rodefeld et al. 1978). It was generally agreed, however, that the fact that the connections between technologies and the structure of agriculture were ignored in years past does not imply that the implications of biotechnology for agricultural structure can safely be ignored in the 1990s.

Nonetheless, it is clear that the rise of biotechnology has served as a lightning rod for catalyzing interest in and concern about the structure of agriculture on the part of citizens, scientists, research administrators, land-grant universities, federal legislators or U.S. Congress/Canadian Parliament, and society as a whole. As public funds for agricultural research become more scarce, citizens and policymakers are demanding increased accountability for how public research funds are spent. Whether and how public investments in biotechnology help to achieve public and/or community goals such as creating opportunities for self-employment in farming, assisting family farmers, increasing the efficiency of food production and distribution, and ensuring safety and nutritional quality of the food supply are aspects of accountability of public research that require increased attention.

Presenters' Views

These differences in viewpoint were amply reflected in *both* of the workshop presentations. Dean Kleckner, President of the American Farm Bureau Federation, spoke with pride about America's family farming heritage and how family farmers are responding to marketplace signals and in the process are becoming more efficient while responding to consumer preferences. But he acknowledged that, as farmers respond to the marketplace when making decisions about what they grow and how they grow it, trends such as larger farms and farm consolidation are occurring. Kleckner suggested, however, that world population growth makes it necessary for American farmers to get even more efficient, to produce more and to rely even more on science-based advances such as those now beginning to come from biotechnology.

William Browne, Professor of Political Science at Central Michigan University, summarized how federal policymakers, especially members of the U.S. Congress, view biotechnology and agriculture. He noted that, on one hand, there is considerable concern that biotechnology will play a role in increasing structural inequities in agriculture—enabling the big producers to get even bigger and putting the smaller producer at a greater disadvantage. But Washington policymakers do not know what they can do to stop the process. Browne stressed that many policymakers also hold out hope that biotechnology can lead to new production methods, such as biopesticides and biofertilizers, that will help resolve conflicts between farmers and environmentalists. For these reasons Browne predicted that most policymakers will be inclined to take a "hands-off" approach with regard to new regulations on the applications of agricultural biotechnology.

IDENTIFICATION OF PRIORITY ISSUES

With this background, the workshop group of nearly 60 members went through the standard process for identifying issues and formulating recommendations. During the first day's workshop process the four breakout groups brought a total of eight priority issues to the attention of the entire group. The eight priority issues are given verbatim (as recorded on sheets by each breakout group) since the way an issue was expressed (e.g., as a question, as an interpretation, as a statement of facts; briefly or at length) can help to convey the meanings intended by the workshop participants. The eight priority issues were:

1. How do we encourage democratic citizen participation in biotechnology? What are the ethical/social issues attached to biotechnology? Who has the responsibility for communicating/acting as a consultant about the issues to people? There is a need for balanced information—when scientists presented

extreme viewpoints on either side of an issue, it alienates the average person and they become discouraged. There is a need for forums—different types and on different issues. Who are the stakeholders in agricultural biotechnology? How do you include all people and how do you weight their representation? There is a need for conflict resolution. How do we deal with a lack of consensus? There is a need for international representation.

2. Who has access to biotechnology? Can access be equalized? Is it fair? Should it be fair? Who decides these things? Who determines what sort of role developing countries play? Should everyone have an equal stake?

3. The degree to which public/consumer concerns are addressed has determined how biotechnology affects the structure of agriculture—always has and always will.

4. Distribution issues: the distribution of individual rights (by social class or wealth among different types of farmers) determines how biotechnology affects agriculture.

5. Will biotechnology contribute to further vertical integration in the food system, and what are the consequences for various sizes and types of producers?

6. Biotechnology will change the definition of "food system" to include a broader set of firms, markets and institutions, e.g., pharmaceutical companies if pigs become "insulin factories." What are the implications of agricultural biotechnologies for producers and firms already in the system?

7. Biotechnology is another technology that is part of the industrialization of the food system. We need to better understand consumer preferences using current social science research results and techniques, and asking new questions. We need a clear system of risk assessment, starting from consumer demand.

8. Assessment of the scale of biotechnology—Does biotechnology speed up food-system industrialization? There is a need to do impact assessments on the scale impacts, economics, and other measures of biotechnology and use this information as the basis for public policy in private and university settings.

The workshop participants then agreed by acclamation that the eight issues could be combined into four major issues, as follows:

• Agriculture, as a part of the food system, must be responsive to the consumer. Is biotechnology impeding or improving the ability of agriculture to be responsive? (Issues 1, 3, and 7 above)

• The responsibility of decisionmakers is to insure the widest possible access to biotechnology so that it does not, itself, come merely to validate or contribute further to the structural imbalances in the agriculture and food system. (Issues 2 and 4 above)

• Biotechnology will contribute to greater vertical integration in the food system. (Issue 5 above)

• There is a need for evaluation of the long-term impacts of biotechnological innovations in research and product development on the structure of agriculture. (Issues 6 and 8 above)

DEVELOPMENT OF RECOMMENDATIONS

The four breakout groups' deliberations led to a number of recommendations that were ultimately discussed by the entire workshop. After the discussion, each participant in the workshop was asked to assess the recommendations by indicating whether s/he strongly agreed with, was neutral toward or strongly disagreed with each of the recommendations.

For each of the recommendations listed below, there is a notation regarding the nature of the overall vote. A "consensual" recommendation is one for which there are several (6 or more) expressions of strong agreement and few (two or fewer) expressions of strong disagreement. A "neutral" recommendation refers to one for which there were few (<3), if any, expressions of either strong agreement or strong disagreement. A "controversial" recommendation is one for which there were many (> 10) expressions of strong disagreement (though it was the case that each of the two controversial recommendations had 4 or more expressions of strong agreement as well). Finally, recommendations were judged to be "mildly controversial" if there were many (> 15) expressions of strong agreement and a few (3 to 4) expressions of strong disagreement. For each recommendation, the number of persons expressing strong agreement or support (SA) and the number expressing strong disagreement or opposition (SD) is given in parentheses. Note that since there were approximately 60 persons in the workshop, three expressions of strong agreement or strong disagreement with a given recommendation represented the views of about 5 percent of the total group.

RECOMMENDATIONS

Biotechnology and Responsiveness to the Consumer

Agriculture as a part of the food system must be responsive to the consumer. Is biotechnology impeding or improving the ability to be responsive? There were three recommendations for addressing this issue.

There is a need to develop national standards for consistent, clear communications to give balance to information. Standards would give the information credibility, (controversial recommendation [4 SA; 16 SD])

To get information out, use labeling, media and brochures at supermarkets. NABC could be used as a forum for developing guidelines and recommendations.

(controversial recommendation [6 SA; 10 SD])

Information should go out to both consumers and producers, (neutral recommendation [0 SA; 0 SD])

Equity of Access to Biotechnology Innovations

The responsibility of decisionmakers is to insure the widest possible access to biotechnology so that it does not, itself, come merely to validate or contribute further to the structural imbalances in the agriculture and food system.[1] There were four recommendations:

Provisions are needed to take into account the costs incurred in regulatory procedures in the creation of products/processes for minor/local uses, (mildly controversial recommendation [19 SA; 3 SD])

The utility patent system was not designed with plants and animals in mind. There is a need for a new Intellectual Property Rights (IPR) system designed specifically for living organisms, or parts thereof. The new system should balance profit with the public desire to encourage invention in general. (consensual recommendation [23 SA; 0 SD])[1 2]

There is a need to strengthen public sector research and technology delivery systems. (consensual recommendation [10 SA; 2 SD])

A forum involving all stakeholders needs to be created in which issues of international access are discussed and attempts at resolution are made, (consensual recommendation [12 SA; 0 SD])

Biotechnology and Vertical Integration of the Food System

Biotechnology will contribute to greater vertical integration in the food system. There were four recommendations:

Land-grant universities should be encouraged to form public/private partnerships to encourage the use of biotechnology and to develop products. (consensual recommendation [7 SA; 0 SD])

Land-grant universities should remain neutral in the debate on vertical

---

[1] Two persons who were not members of the workshop but who reviewed the first draft of this report strongly expressed the view that the influence of private funding on experiment station research priorities tends to lead to new technologies that are more responsive to the needs of large farmers and agribusiness firms than to smaller operators and rural communities.

[2] Note that while there were no SD responses among workshop members, one meeting participant who reviewed the report expressed very strong disagreement with this recommendation. This person felt that while the current IPR system may require amendments (e.g., to exempt "farmer-saved seed" from patent coverage), these changes can readily be accommodated within the current patent system.

integration in the food system, (consensual recommendation [13 SA; 0 SD])

Land-grant universities should increase public good research for which there is an inadequate profit motive, (consensual recommendation [19 SA; 1 SD])

Land-grant universities should seek a broader support base for public good research, (consensual recommendation [21 SA; 0 SD])

Evaluation of the Long-Term Impacts of Agricultural Biotechnologies

There is a need for evaluation of the long-term impacts of biotechnological innovations in research and product development on the structure of agriculture. There was one overall recommendation for addressing this issue:

Land-grant colleges or equivalent institutions should take the lead in convening broadly representative stakeholders to develop standards and procedures for the long-term sustainability of the agriculture and food system. These principles should be applied to all levels of the system. A wide range of criteria—sustainability, health and safety, social and economic equity—should guide these evaluations, (mildly controversial recommendation [19 SA; 4 SD])

SUMMARY

Strong disagreements usually prevail in discussions about biotechnology and the structure of agriculture, and the range of views represented in the NABC 6 structure of agriculture workshop was particularly broad. Significant differences of opinion remained at the end of the workshop. Nonetheless, workshop participants agreed that the future impacts of biotechnology on the structure of agriculture are an important dimension of whether and how these new agricultural technologies will contribute to the public good, and that the nature of these impacts will be a crucial component of public perceptions of the accountability of the research system. The workshop was particularly successful in its having yielded a number of recommendations involving strong consensus, neutrality, or only mild disagreement.

ACKNOWLEDGMENTS

We would like to thank Jamie DePolo for her assistance in summarizing the discussions. Several members of the workshop group, particularly Dawn Jones, Lavon Bartel, Patricia Swan, and Laura Hoelscher, provided detailed, helpful comments on the initial draft.

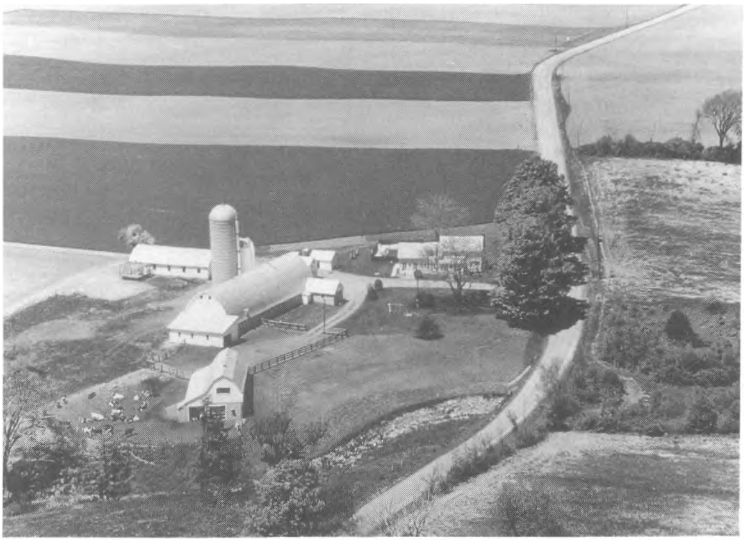
REFERENCES

Cochrane, W.W. 1993. *The Development of American Agriculture.* University of Minnesota Press, Minneapolis, MN.

Committee on Agriculture, Nutrition, and Forestry. 1980. *Farm Structure: A Historical Perspective on Changes in the Number and Size of Farms.* 96th

Congress, 2nd Session. U.S. Government Printing Office, Washington, DC.
Economics, Statistics, and Cooperatives Service. 1979. *Structure Issues of American Agriculture.* Agricultural Economic Report 438. Economic Research Service, U.S. Department of Agriculture, Washington, DC.
Rodefeld, R.D., J. Flora, D. Voth, I. Fujimoto, and J. Converse, eds. 1978. *Change in Rural America.* C. V. Mosby, St. Louis, MO.
U.S. Department of Agriculture (USDA). 1980. *A Time To Choose: Summary Report on the Structure of Agriculture.* U.S. Department of Agriculture, Washington, DC.

PART Vi: ENVIRONMENTAL STEWARDSHIP
AND AGRICULTURAL BIOTECHNOLOGY



Biotechnology and the Environment

Sandra S. Batie
Elton R. Smith Professor in
Food and Agricultural Policy,
Agricultural Economics
Michigan State University

The nature of the relationship between biotechnology products and the environment is highly controversial. While agricultural biotechnology has great promise for the obtaining of both more food and a higher quality environment, there is currently much anxiety as to whether this promise is an illusion.

There are those who argue that there are no new nor unique hazards that accompany biotechnology, that it is a natural extension of past plant and animal breeding successes. Any risks that might occur are similar to those associated with those risks accompanying plants and animals from more traditional agricultural breeding. Thus, there are neither different nor greater safety concerns presented by biotechnology than we have dealt with in the past (GAO 1993; Tiedje et al. 1989).

Many vehemently disagree and assert that biotechnology is a radical new method posing unknown and unpredictable risks. Therefore, there must be extraordinary caution in the development and use of biotechnology products (GAO 1993; Rissler and Mellon 1993). There is much to examine within this topic, including issues of food safety.[1] However, this brief discussion explores (without attempt at validation) only the arguments that frame the debate of the environmental impacts of agricultural biotechnology.

THE POTENTIAL OF AGRICULTURAL BIOTECHNOLOGY

Hindmarsh (1991) asserts that the proponents of biotechnology base their claims of environmental compatibility on four major promises. These are: 1. that herbicide-tolerant or herbicide-resistant crop research will enable hazardous herbicides to be replaced with environmentally friendly ones; 2. that genetic engineering will enable the reduction of agrichemical use to counteract the growing resistance of insects and weeds by offering more precision than broad-spectrum insecticides; 3. that the development of nitrogen-fixing plants will reduce the use of chemical fertilizers; and 4. that there is a low risk

[1] The food safety issues include an increase in levels of naturally occurring toxins or of allergens in the food supply; an adverse change in the composition, absorption or metabolism of important nutrients; or a reduction in the effectiveness of some antibiotics because of the use of antibiotic-resistant marker genes (GAO 1993).

of adverse environmental impacts. Rogoff and Rawlins (1987) add another dimension to this list: that biotechnology will raise yields and standards of living for the world without requiring more natural resources. This increase in food security, they assert, may come from the conversion of biomass that can be grown without high inputs of nonrenewable resources—indeed, maybe even without soils.

THE ANXIETIES OF BIOTECHNOLOGY

The critics of these arguments rebut them with arguments of their own.

Fewer, Less Harmful Chemicals?

The critics are highly skeptical that biotechnological products will result in the reduced use of harmful chemicals. They point to current biotechnology investments as evidence. Many critics assert that with herbicide-resistant crops, herbicide use will increase (e.g., Busch et al. 1991; Hindmarsh 1991; Russell 1993). They note that herbicide-resistant croplines are mostly the product of transnational corporations that are moving quickly to develop plants resistant to herbicides still under patent. The critics are concerned about the dominance of large transnational firms such as Monsanto, which is engineering into plants a tolerance to glyphosate and marketing the end result as “Roundup-Ready®” products.[2]

In another example, Calgene, Inc. is petitioning the U.S. Department of Agriculture (USDA) for approval of bromoxynil-tolerant cotton for commercial use; a move the environmental groups fear will lead to increased use of bromoxynil.[3] Bromoxynil has been implicated with birth defects in laboratory mammals, is considered a developmental toxicant in humans, and is highly toxic to fish and plants *(The Gene Exchange* 1994). Another example is the development of plants in Australia that are 2,4-D resistant (Hindmarsh 1991).

Critics also fear the transfer of the engineered genes of herbicide-resistant crops to wild relatives or to weeds, or that the transgenic plants themselves will become weeds (Ellstrand 1993; Rissler and Mellon 1993). Hinkle (1992) points out that the reason for the existence of a market for herbicide-resistant plants is because weeds have become herbicide resistant over time. If there is a transfer of bioengineered resistance to weeds, weed populations will increase and cause “the pesticide treadmill to accelerate” (Hindmarsh 1991:198).

Tiedje et al. (1989) summarizes the concerns of many ecologists that gene transfer is possible. They note—in boldface type—that:

> The available scientific evidence indicates that lateral transfer among microorganisms in nature is neither so rare that we can

---

[2] Roundup is Monsanto’s trade name for glyphosate which is the world’s largest selling herbicide (Busch et al. 1991).

[3] Rissler and Mellon (1991) estimate that if current uses of bromoxynil are maintained, then the adoption of the bromoxynil-resistant cotton with only one-half of the cotton acreage in the U.S. would more than double the use of the chemical.

> ignore its occurrence, nor so common that we can assume the barriers crossed by modern biotechnology are comparable to those constantly crossed in nature (p. 304).

Ecologists in particular worry about the release of new products that they view as analogous to the release of "exotics"—animals or plants not native to a region—into an area. While many such releases have proven quite valuable (much of the North American food supply is from exotics); unfortunate outcomes have been all too frequent, causing habitat or crop damage or the extinction of indigenous species. Undesirable exotics, have, for example, included rabbits in Australia, zebra mussels in the Great Lakes, starlings in America, tumbleweeds in western North America. Thus, there is concern that bioengineered products—be they corn and soybeans engineered to withstand a rain forest climate or marine fish engineered to tolerate colder waters—may replace valued native species, such as the tropical forests or cold water fish, or otherwise disrupt existing ecological communities (Drake et al. 1988).

This concern is heightened by the perception that transgenic organisms are things that nature could never create (Witt 1985). Drake and colleagues summarize this concern by noting that "biologists" ability to manipulate an organism's genome has far outstripped knowledge of the ecology of those species" (1988:422). While many of these concerns involve biotechnological manipulations for weed protection, analogous arguments apply to disease or insect pest protection. For example, genetic resistance in insects to pesticides is well documented (Georghiou 1989). As one observer noted, "insects as a group have never met a chemical they couldn't take to the mat" (Hinkle 1992 quoting Fred Gould). One concern, then, is that transgenic biopesticides will exert strong selection pressures in favor of pests with a resistance to the natural biotoxins; thus ultimately accelerating pesticide resistance and encouraging more insecticide use (Hindmarsh 1991). There is an additional concern, propelled by recent research findings at Michigan State University, that peanuts engineered to resist viruses may ultimately produce new, more deadly viruses (Schneider 1994).

Feeding The World Using Less Fertilizer?

The critics of biotechnology are also skeptical of the claims concerning nitrogen-fixing advances as well as those that suggest biotechnology will solve the world's food problems. Despite some evidence to the contrary (Busch et al. 1991), some critics find little progress to praise in increasing the nitrogen-fixing capacity of plants (Russell 1993). Hindmarsh (1991) believes that the engineering of nitrogen-fixation is lower on the corporate research and development agenda than is herbicide-resistance engineering. Furthermore, even if nitrogen-fixing plants were successfully developed such transgenic properties might infect other species, for example, conferring advantages to weeds. Another expressed concern is that the development of plant varieties that absorb more nitrogen will lead to over-application of fertilizers (Busch et al. 1991).

There is also considerable skepticism that biotechnology breakthroughs will "feed the world." The accusation is that a substantial effort will be expended on the development of products that can be sold to farmers and others in the industrialized world and that these products will not necessarily, or even usually, translate into improved distribution of world food products (Rissler and Mellon 1993; Russell 1993).

More fundamental, perhaps, is the critic's concern that biotechnological products might undermine the sustainability of other countries' agriculture. First, there is a concern that the First World countries are using genetic material from Third World nations with little or no compensation (King 1993). Second, there is concern that biotechnology might transform where and how crops are grown. For example, inexpensive bioengineered vanilla or cocoa could devastate some Third World economies (King 1993).

In addition, some critics fear that the biotechnology industry will exacerbate the world's loss of genetic material by further narrowing the genetic base of the major crops. There is little faith that seed banks provide enough protection from this narrowing process:

> Without wild or local strains the world's food crops may be dangerously vulnerable to devastation. Gene banks around the world are already storing and preserving this genetic wealth, but the banks are vulnerable to inadequate funding and lack of attention (King 1993:27).

Coupled with the fear of the loss of biodiversity is the fear that corporate domination of biotechnological products will intensify the dependence of farmers on purchased inputs (Busch et al. 1991).

> Farmers who want to use bromoxynil as a cotton herbicide will have to buy a "package" of bromoxynil and bromoxynil-tolerant cotton seeds from Rhone-Poulenc—a major manufacturer of bromoxynil and a leading international seed manufacture. On the other hand, farmers who want to buy open-pollinated seed will find it increasingly hard to do so. Consequently, the current trend of farmers switching to ecological methods of farming, like permaculture, organic and biodynamic farming, could be seriously retarded (Hindmarsh 1991:203).

In addition, the bias of biotechnology toward "products" tends to divert attention from the "systems approach" that is required in a truly sustainable farming system (Mellon 1991). Some assert that biotechnology is just another "technological fix" in a long chain of the same that tries to circumvent problems without "questioning the flawed assumptions which gave rise to the problems in the first place" (Hindmarsh 1991:204).

PUBLIC POLICIES

To most critics, the regulatory structure surrounding biotechnology development is far from adequate. Mellon (1991) refers to the system as being in "shambles," and for some products like fish, the regulatory oversight is simply nonexistent. Busch et al. note that "important aspects of biotechnology have been omitted from the current regulatory framework" (1991:231). Most agree that it is at best an inadequate patchwork (Lyman 1993; Marois et al. 1991). For example, the General Accounting Office (1993) concludes that it is time for a thorough review of the regulatory structure. Tiedje and his colleagues conclude that "our past 40 years of experience with chemicals in the environment make it reasonable and indeed desirable that genetically modified organisms be introduced cautiously" (1989:307). They continue:

> Consequently, an overall record of little or no hazard stemming from the release of the products of traditional agricultural breeding does not legitimately warrant exemption from oversight for future introductions of transgenic organisms that these traditional techniques could not have produced (p. 306).

The lack of a consistent coordinated regulatory environment is thus of particular concern to those involved that there may be more adverse environmental impacts from biotechnology than the optimists suggest.

CONCLUSIONS

The arguments with respect to biotechnology and the environment as presented here are reflected throughout the literature in varying degrees of concern and urgency. The critics' arguments also meet with disagreement and rebuttals (see, for example, Hauptli et al. 1985 or Harlander 1991). Nevertheless, these are the issues that are framing the debate.

Like many environmental arguments, much of the debate is not so much about the nature and magnitude of the risk, but rather, who should bear the costs if a course of action proves to be in error. Should biotechnology products be readily approved for use, placing the burden of error on the environment? Or should the products be very cautiously screened, placing the burden of error on the inventors and users of the product?

At times an argument over a single biotechnology product or issue might be a proxy for an entire philosophy about the role of technology in society, the organization and structure of agriculture, and about the relationship of people to nature. That alternative philosophies underlie many of the arguments (Batie 1992) is all the more reason to understand and engage the debate because, in a very real sense, the technology we adopt today determines and defines our future (Wenk 1986).

REFERENCES

Batie, S.S. 1992. *Biotechnology and Science: The Imperatives of Choice.* The James C. Snyder Memorial Lecture, March 11. Purdue University, West Lafayette, IN.

Busch, L., W.B. Lacy, J. Burkhardt and L.R. Lacy. 1991. *Plants, Power and Profit: Social, Economic and Ethical Consequences of the New Biotechnologies.* Basil Blackwell, Cambridge, MA .

Drake, J.A., D.A. Kenny and T. Voskuil. 1988. Environmental Biotechnology. *Bioscience.* 38(6) June: 420-422.

Ellstrand, N. 1993. How Ya Gonna Keep Transgenes Down on the Farm? *The Amicus Journal.* 15(1)Spring: 1—31.

General Accounting Office (GAO). 1993. *Food Safety and Quality: Innovative Strategies May be Needed to Regulate New Food Technologies.* GAO/ RCED-93-142. Government Printing Office, Washington, D.C.

Georghiou, G.P. 1989. Implications of Potential Resistance to Biopesticides. In D.W. Roberts and R.P. Granados, eds. *Biotechnology, Biological Pesticides and Novel Plant-Pest Resistance for Insect Pest Management. (July 1988).* Boyce Thompson Institute for Plant Research, Cornell University, Ithaca, NY. pp 18-20.

Harlander, S.K. 1991. Biotechnology—A Means of Improving Our Food Supply. *Food Technology.* 45(4)April: 84-92 and 95.

Hauptli, H., N. Newell and R. M. Goodman. 1985. Genetically Engineered Plants: Environmental Issues. *Biotechnology.* 3(May): 437-441.

Hindmarsh, R. 1991. The Flawed "Sustainable" Promise of Genetic Engineering. *The Ecologist.* 2 l(5)Sept/Oct: 196-205.

Hinkle, M. 1992. *Limits of Technology.* A Presentation Before the Southern Agribusiness Council, January 23. New Orleans, LA.

King, J.W. 1993. Breeding Uniformity: Will Global Biotechnology Threaten Global Biodiversity? *The Amicus Journal.* 15(l)Spring: 25—30.

Lyman, F. 1993. The Splice of Life. *The Amicus Journal.* 15(1 JSpring: 19—20.

Marois, J.J., J.I. Grieshop and L.J. Butler. 1991. *Environmental Risks and Benefits of Agricultural Biotechnology.* Leaflet Series, Agricultural Biotechnology, Purdue University Agricultural Experiment Station, West Lafayette, IN. pp. 1-7.

Mellon, M. 1991. Biotechnology and the Environmental Vision. InJ. Fessenden MacDonald ed. *NABC Report 3, Agricultural Biotechnology at the Crossroads: Biological, Social, and Institutional Concerns.* National Agricultural Biotechnology Council, Ithaca, NY. pp 65-70.

Rissler, J. and M. Mellon. 1993. *Perils Amidst the Promise: Ecological Risks of Transgenic Crops in a Global Market.* Union of Concerned Scientists, Washington, D.C.

Rissler, J. and M. Mellon. 1991. National Wildlife Federation comments to the USDA/APHIS on two applications from Calgene, Inc. to field test cotton plants genetically engineered to tolerate the herbicide bromoxynil or resist insects and tolerate bromoxynil. National Biotechnology Policy Center, National Wildlife Federation, Washington D.C.

Rogoff, M.H. and S.L. Rawlins. 1987. Food Security: A Technological Alternative. *Bioscience.* 37(11) December:800-807.

Russell, D. 1993. Miracle or Myth: Is Biotech the Coming Alternative to Chemical Agriculture, or a Clone of the Past? *The Amicus Journal.* 15(1) Spring:20-24.

Schneider, K. 1994. Go Ahead on Altering Crops Prompts a Go-Slow. *The New York Times,* May 25.

The Gene Exchange. 1994. Union of Concerned Scientists. 4(3/4).

Tiedje, J.M., R.K. Colwell, Y. L. Grossman, R.E. Hodson, R.E. Lenski, R.N. Mack, and P.J. Regal. 1989. The Planned Introduction of Genetically Engineered Organisms: Ecological Considerations and Recommendations. *Ecology.* 7(2)April:298—315.

Wenk, E. Jr. 1986. *Tradeoffs: Imperatives of Choice in a High-Tech World.* Johns Hopkins University Press, Baltimore, MD.

Witt, S.C. 1985. *Biotechnology and Genetic Diversity.* California Agriculture Lands Project, San Francisco, CA.

Genetic Engineering ("Biotech"): Use of Science Gone Wrong

John Bell Clark
Biochemist and Owner
Roseland Organic Farm, Michigan

The manipulation of gene fragments has been fraught with ethical and unknown risks since the tools for this technology were first "discovered." Such discovery came in the course of basic biochemical research investigations in the last 40 years, starting with the discovery of the structure of DNA and RNA, together with characterization of the command these genetic materials have over metabolic machinery in living cells.

These discoveries have been very useful to biochemical investigation and have great potential for further development of diagnostic and research tools. However such powerful and novel tools and technology should be accompanied by great caution when taken outside the research laboratory. Great care should be exercised both within the research community and in developing products for sale. Science has been derailed somewhere along the line in the evolution of genetic engineering because, 20 years ago, the future of this field looked so promisingly bright—perhaps too good to be true. Furthermore, *the underlying assumptions have not been tested.*

Lack of prudence in commercializing "genetic engineering" has been fueled by a colossal money grab on the part of industry and universities which, driven by a curtailment of public funding and seduced by a speculative "rainbow chase," have abandoned the traditional prohibition against commercial involvements in technologies.

In a very real way, universities are at risk, and some have committed misuse of funds in "gambling" on biotechnology as a direct investment. Since when do publicly-funded universities invest in speculative stocks? Since when do their research priorities get skewed by vested interests? Academic freedom is at risk here. Yet the university community sees it as just the opposite—that any restraint on full release of the technology is an affront to "academic freedom." *In vitro, in vivo* and *"in eco"* understanding of the mechanisms of molecular biology has not been achieved just because we can "crack" the code and manipulate gene fragments!

What we have then is an institutionally accelerated release of untested and untried products which jeopardize the environment, human health and the liability of the academic institutions which have become *promoters* of questionable technology. The scientists and teachers involved have become arrogant, even if not economically self-serving, about our understanding of life processes.

This then, accelerates the rush toward reductionist, "silver bullet," curative (rather than preventative) approaches to health, environment and social problems. It has also truncated the comprehensive and diversified approach to biological research and development—the very basis for a "university" approach to this science.

More specific criticism of "biotech" products is rooted in the predominance of products tied to inappropriate solutions to agricultural problems—problems which are avoidable simply by changing farming practices. Biotechnological solutions are therefore directed, with huge expense and investment, at non-problems. Those producing these resulting products are generally completely oblivious to serious consideration of side effects or simple alternatives. Without holistic (cradle to grave and beyond) analysis of its products, this "biotech" industry is doomed to failure.

Here are a few examples of predominant categories of genetically engineered products for non-problems and the consequences:[1]

PRODUCT	CONSEQUENCE
Herbicide-tolerant plants	Enhanced and accelerated pollution of the environment, water, soil and food by herbicides. Accelerated development of resistance to herbicides by targeted weeds. Possible toxic characteristics of novel varieties to humans, livestock or wildlife.
Disease (decay)-resistant crops	Accelerated resistance development by disease organisms. Indigestibility of decay-resistant plants. Possible toxic characteristics of novel varieties to humans/livestock/wildlife.
Pest-resistant plants	Accelerated resistance development by pests; unbalancing of natural controls.
Food and drug substances differing "only slightly" from their natural counterparts.	These are especially novel compounds and the "priesthood" of genetic engineering should not be allowed to pretend that their variants are "safe" while nature's varieties are "suspect."

[1] The solutions to the "non-problem" have invariably resided in farm-plan and farm redesign, cooperating with nature, timing, biodiversity enhancement and restoring balances in production agriculture.

The tacit assumptions surrounding these products are that:

- there is only one effect of the product—that of "solving" the targeted problem;
- the problem has no other solution, i.e., the farming community cannot change from the chemical treadmill;
- nature has no limits and that, if it does, there are no consequences to violating these limits;
- genes control only one phenotypical trait and do not interact in expression;
- holistic ecological interactions are trivial; and/or
- there are no synergisms in nature.

None of these assumptions appears to be true, and there are few visible efforts to test the assumptions for fear of losing the foundations of the technology. This inevitably leads to bad science and misuse of science.

Even if genetic engineering does not lead to unforeseen mutations and runaway alien varieties, the disruptions to balances in nature are predictable—a genetic characteristic always results in an end product or products in the organism, substances which nature assimilates gradually over time. By natural selection, nature eliminates its mistakes. Without allowing for natural corrections, we are placing ourselves above nature, accelerating this assimilation process and rushing to market questionable products, recognizable as mistakes only after generations—a Faustian bargain at best.

Workshop Report

Richard Harwood
Professor and C.S. Mott Foundation Chair of Sustainable Agriculture, Michigan State University

Jerry DeWitt
Associate Dean for Extension Director to Agriculture Iowa State University

This workshop dealt with several general "themes" of the environmental impact of biotechnologies. Of greatest concern were the indirect and long-term effects, such as possible reduction in levels of biodiversity from some applications. These effects are less understood, most difficult to measure and are, therefore, more difficult to quantify and to control. The direct effects, and particularly those measurable immediately, such as change in pesticide use, are potentially more easily dealt with. But there was not general consensus within the group that even these potential impacts are being adequately assessed. The workshop participants represented a broad cross-section of interests, including persons from institutions at the federal and state levels, environmental activists, public policy advocacy participants, educators, farmers and representatives from organic and other alternative groups.

PRIORITY ISSUES

There was strong agreement on the importance of integrated production systems (IPS) in minimizing adverse environmental impact from agriculture. Those systems must preserve soil productivity, contain and recycle nutrients, optimize crop and animal growth, and have appropriate diversity and structure to moderate pest and disease occurrence to levels which can be controlled with environmentally acceptable levels of additional inputs. The group disagreed over the degree to which such integrative effects could be made effective, with opinions ranging from modest utility to a minority viewpoint that most, if not all, production problems could be solved through structuring and integration, as in organic agriculture. There was strong agreement that biotechnology should be directed toward solution of problems within a context of integrated systems, and that such technologies should then be applied within the context of sustainable systems. Good technologies inappropriately applied can often cause environmental problems. A major concern of indirect effects of biotechnology having adverse environmental impact was the possible reduction of diversity within production systems, leading to greater genetic or cultural uniformity. If the genetic base for herbicide-resistant or disease- or insect-resistant cultivars is narrow or the released varieties displace a range of cultivars, the resulting lowering of genetic diversity will increase risk of pest or pathogen outbreak. Likewise, if a narrowed range of economically viable options for cultural practices is available, genetic shifts in weeds, pests or diseases may be accelerated. The group felt that biotechnologies must increase, not decrease, viable options for farmers and for farming systems.

A second theme for discussion concerned assessment of short-term, direct effects of biotechnology on the environment. Examples of questions raised by participants included: Will the technology lead to greater or less pesticide use? Do biotechnology-based transfers of pest resistance usually involve single-gene or other forms of resistance which lead to greater rates of pest resistance development? Will nutrient loss to surface and groundwater be enhanced or reduced as a result of changed crop nutrient use or nitrogen-fixation capacity?

A third area of concern centered around long-term impacts on the ecosystem of engineered genetic materials becoming a part of the natural "gene bank." It was felt that for most new genetic materials it is not a question of *if,* but of *when* such materials become a permanent part of the ecosystem. For some materials the time span is long, perhaps measured in decades, while for others it may be a few years. There was disagreement among participants as to the availability of scientific data on the rate of spread, on extent and eventual gene frequency, and on the eventual impact of such genes within the ecosystem. For some of the more common transgenic plant technologies, such as the use of insecticidal proteins from *Bacillus thuringiensis (Bt),* there is a better database. Where such materials are either new to the plant or animal kingdom or from exotic sources, the long-term spread and impact are less known. It seems apparent that research in the area of gene spread, as well as knowledge about the scientific capability to assess such impact is not widely known to scientists working in related fields, and certainly not by the public-at-large.

The final thematic area concerned that of "public" education concerning environmental risk and biosafety. There is need for education and information flow at several audience levels, including scientists, activist leaders, policy-makers, science educators and the general public.

RECOMMENDATIONS

These general areas include most of the concerns voiced within the workshop. These were then consolidated in the second phase of discussion into specific priority issues, with recommendations for each.

Integrated Production Systems

There is need for both scientists and farmers to know how and when to use biotechnology products in IPS. If a decision is made to use products, how will they be managed within the context of an IPS so that environmental stewardship objectives are met?

The public sector should fund and conduct more systems research and testing on the potential positive and negative environmental, economic and social impacts and consequences of biotechnology products. The results of the research must be effectively communicated to producers and consumers in a timely and objective manner (as results are available).

Cooperative Extension Service directors and other appropriate public agency administrators should be given a mandate to devote resources to assist producers in a manner consistent with environmental stewardship (e.g. through comprehensive crop and animal management advancement programs that deal with whole-enterprise management and offer continuing educational update). Biotechnology options should be presented within this systems framework.

Environmental Impact

Agricultural biotechnology is not simply science but has social and political implications. Therefore, it is imperative that a public role be recognized in the debate over areas where biotechnology should be focused and how its products should be incorporated into sustainable agricultural systems. Moreover, the public must be involved in the consideration of safety, of environmental protection and/or stewardship and the myriad social issues. To improve agricultural products and benefit society, scientists working on biotechnology products should:

Identify, evaluate and anticipate risks prior to release. Safety claims should be supported with both public and private research. Assessment criteria should be used.

Focus on development of agricultural biotechnology processes and/or products that will promote long-term environmental health by:

- *Maintaining biodiversity*
- *Enhancing soil, water and air quality*
- *Increasing reliance upon renewable energy sources*

Recognize the public's concern for this new technology and work with them to understand its complexity and potential. Bring biotechnology products to the market with reasonable expectations.

Public and private funding institutions, including U.S. Department of Agriculture (USDA), the Environmental Protection Agency (EPA), the National Institutes of Health (NIH) and private foundations should take action to identify means and instruments to promote biodiversity as a key objective of publicly-conducted agricultural biotechnology research and development.

Resulting integrated production systems should maintain high biodiversity.

Public policy should be made consistent with these goals.

(Note: All recommendations for the two areas above had strong but not unanimous consensus.)

Assessing Long-Term Effects

How can the long-term environmental effects of biotechnology products be assessed? There was strong consensus that long-term impact assessment is essential. There was little agreement on how this should be done, and not sufficient time was available for negotiation. There were strongly held but diverse opinions on all sides of this issue.

A tax should be placed on biotechnology products to ensure long-term public support for research on ecological risk assessment. (The majority of workshop participants opposed this recommendation, based partly on opposition to product taxation in general, and partly on the assumption that lack of funds may be only one reason why the research is not now being done.)

The U.S. President should appoint a broadly representative blue-ribbon panel to establish a binding regulatory framework for dealing with agricultural biotechnologies. (The majority opposed this recommendation.)

Education and Communication

Major public effort is needed to enhance education and communication relative to the role of agricultural biotechnology in environmental stewardship. The goal would be to improve the ability of diverse groups to participate in the decision-making process about the impacts of biotechnology and their role in environmental stewardship.

The Cooperative Extension Service and the Agricultural Experiment Stations, under the auspices of the National Agricultural Biotechnology Council, should form a committee to develop a public education plan for biotechnology education.

The participants should include grassroots members of various communities—consumers, producers, activists, local government, media, retailers, extension staff members and educators.

The subjects of the workshop-focus group discussions should include a basis of information about the environmental issues and solicit reaction to these issues from the participants.

The information gathered at these workshops should be accumulated by NABC and published for distribution to statewide and national decision makers.

Also special effort should be made to package and distribute this information to K-12 educational institutions.

The committee should reconvene each year for a minimum of two years and then review accomplishment each year after at the discretion of the focus group.

This effort should lead to a systematic and sustained educational plan to help the public debate and understand the issues surrounding agricultural biotechnology. (A majority favored the recommendations on this issue, but there was dissent, based partly, at least, on the broadness of the recommendations.)

PART VII: LIST OF PARTICIPANTS

Aldwinckle, Herb
Cornell University
Geneva, NY 14456

Allison, Richard
Botany And Plant Pathology
166 Plant Biology Building
Michigan State University
East Lansing, MI 48824

Armitage, David
Ontario Federation of Agriculture
491 Eglinton Avenue West
Toronto, ON, Canada M5N 3A2

Aronoff, Marilyn
Sociology; 401 BerkeyHall
Michigan State University
East Lansing, MI 48824

Baker, Esther
Outreach Communications
312 Agriculture Hall; MSU
East Lansing, MI 48824

Bartel, Lavon L.
UVM Extension System
601 Main Street; University of Vermont
Burlington, VT 05401-3439

Barton, Ken
Agracetus, Inc.
8520 University Green
Middleton, WI 53562

Batie, Sandra S.
Food and Ag Policy, Ag. Economics
204 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Baumgardt, Bill
Director, Ag. Experiment Station
1140 AGAD Building, Room 116
Purdue University
West Lafayette, IN 47907-1140

Bedford, Bruce
ABSP
412 Plant Soil Science Building
Michigan State University
East Lansing, MI 48824

Beerlandt, Hannelore
K.U. Leuven
Kardinaal Mercierlaan S2
3001 Heverlee, Belgium

Benedict, John
Route 2, Box 589
Texas A&M University
Corpus Christie, TX 78406-9704

Bivens, William
MSU Extension
412 Erie Street
Jackson, MI 49269

Breinling, James
Gerber Products Company
445 State St.
Fremont, MI 49413

Bremel, Robert
850 Animal Sciences Building
University of Wisconsin
Madison, WI 53706-1284

Brown, Harold L.
Cooperative Extension Service
Room 202, County Building
Muncie, IN 47305

Browne, William
Department of Political Science
Central Michigan University
Mt. Pleasant, MI 48859

Burke, Michael
Ag. Academic Programs
137 Strand Hall
Oregon State University
Corvallis, OR 97331-2202

Busch, Lawrence
Sociology; 422A Berkey Hall
Michigan State University
East Lansing, MI 48824

Butler, Bees
Department of Agricultural Econ.
University of California
Davis, CA 95616

Buttel, Frederick
Department of Rural Sociology
1450 Linden Drive
University of Wisconsin
Madison, WI 53706

Byrne, Joyce
Agriculture and Agri-Food Canada
59 Camelot Drive
Nepean, ON, Canada K1A0Y9

Carter, Hal
Agricultural Issues Center
University of California
Davis, CA 95616-8514

Chapin, Julie
MSU Extension, 6-H Berkey Hall
Michigan State University
East Lansing, MI 48824

Chase, Richard
274 Plant Soil Science Building
Michigan State University
East Lansing, MI 48824

Chippendale, Michael
Department of Entomology
1-87 Agriculture Building
University of Missouri, Columbia
Columbia, MO 65211

Clancy, Kate
Department NF; 34 Slocum Hall
Syracuse University
Syracuse, NY 13244

Clark, Merrill
League of Women Voters
27427 M-60 West
Cassopolis, MI 49031

Clark, John
Roseland Farms
27427 M-60 West
Cassopolis, MI 49031

Clark, M. Sean
Entomology
243 Natural Science Bldg.
Michigan State University
East Lansing, MI 48824

Coffman, W. Ronnie
Research Dean's Office
245 Roberts Hall, Cornell University
Ithaca, NY 14853

Condon, William A.
Animal and Nutritional Sciences
University of New Hampshire
Durham, NH 03824

Conkling, Mark A.
Biotechnology Building
Box 7512; NC State University
Raleigh, NC 27695

Cook, R. James
USDA/CSRS; 901 D Street, SW
323 Aerospace Building
Washington, DC 20250

Cookell, Gordon
Ontario Farm Animal Council
7195 Millcreek Drive
Mississauga, ON, Canada L5N 4H1

Dakers, Sonya
Science and Technology Division
Research Branch
Library of Parliament
Ottawa, ON, Canada K1Z7H7

Day, Peter R.
AgBiotech Center
Enviro. & Nat. Resource Sciences Bldg.
Cook College/Rutgers University
New Brunswick, NJ 08903-0231

de Souza Silva, Jos6
Embrapa-SSE; Cx. Postal 040315
Brasilia, DF 70770-901
Brasilia, DF, Brazil

Dekkers, Hans
Ministry of Agriculture
P.O. Box 20401
The Hague, The Netherlands

DeLind, Laura B.
Department of Anthropology
302 Baker Hall
Michigan State University
East Lansing, MI 48824

DePolo, Jamie
Outreach Communications
310 Agriculture Hall
Michigan State University
East Lansing, MI 48824

DeWitt, Jerry
Extension; 108 Curtiss Hall
Iowa State University
Ames, IA 50011

Dillon, Will
Extension; 1026 Powl, Box 208
Purdue University
West Lafayette, IN 47907-1026

Dodds, John
ABSP; 324 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Dornbush, Laurie
Michigan Christmas Tree Association
Okemos, MI 48805-0256

Douches, Dave
Crop and Soil Sciences
486 Plant Soil Science Building
Michigan State University
East Lansing, MI 48824

Driesen, Liliane
K.U. Leuven
Kardinaal Mercierlaan 92
3001 Heverlee, Belgium

Dunn, Peter E.
1158 Entomology Hall
Purdue University
West Lafayette, IN 47907-1158

Ehrle, Lynn H.
Midwest Pure Food Campaign
8888 Mayflower Drive
Plymouth, MI 48170

Eicher, Carl
Agricultural Economics
205 Agriculture Hall, MSU
East Lansing, MI 48824

Fehr, Elinor L.
Iowa State University
2804 Northwood Drive
Ames, IA 50010

Fehr, Walter R.
Office of Biotechnology
1210 Molecular Biology Building
Iowa State University
Ames, IA 50011-3260

Ferguson, Anne E.
Anthropology; 354 Baker Hall
Michigan State University
East Lansing, MI 48824

Fischer, James R.
AES; 104 Barre Hall
Clemson University
Clemson, SC 29634-0351

Fitzgerald, Deborah
Massachusetts Inst, of Technology
Building E51-201g
Cambridge, MA 02139

Folk, William
Department of Biochemistry
University of Missouri-Columbia
Columbia, MO 65211

Foster, Harry A.
Michigan Asparagus Advisory Board
2133 University Park Drive, Suite 700
Okemos, MI 48864

Fox, Cheryl
Minnesota Department of Agriculture
90 West Plato Blvd.
St. Paul, MN 55107

Fraley, Robert
The Agricultural Group of Monsanto
800 North Lindbergh Blvd.-03E
St. Louis, MO 63167

Futakuchi, Kinya
Sandoz Agro, Inc.
1300 East Touhy
Des Plaines, IL 60018

Garlitz-Powell, Carol
Cooperative Extension
624 West Foster Road
University of California
Santa Maria, CA 93455

Gast, Robert
Director, Ag. Experiment Station
109 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Gay, Pete
Indiana Farm Bureau Inc.
225 East Street, P.O. Box 1290
Indianapolis, IN 46206-1290

Germida, Jim
Department of Soil Science
University of Saskatchewan
Saskatoon, SK, Canada S7N 0W0

Gould, Alan
DowElanco
9330 Zionsville Road
Indianapolis, IN 46268

Gray, J. Ian
AES, 109 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Grobbelaar, Johan
Embassy of South Africa
3201 New Mexico Avenue, NW
Suite 300
Washington, DC 20016

Guthrie, Tom
Michigan Farm Bureau
7301 Milo Road
Delton, MI 49046-9432

Hansen, Mark
Extension; 11 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Hansen, Eddie
AES; 109 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Hanson, Sarah
Int'l. Food Information Council
1100 Connecticut Avenue, NW; #430
Washington, DC 20036

Hardy, Ralph W.F.
President and CEO
Boyce Thompson Institute
Tower Road
Ithaca, NY 14853-1801

Harris, Craig
Sociology; 429B Berkey Hall
Michigan State University
East Lansing, MI 48824

Harwood, Richard
260 Plant Soil Sciences Building
Michigan State University
East Lansing, MI 48824

Heitner, Bess
NHK-TV Japan Broadcasting Corp.
305 Lexington Avenue, Suite 10C
New York, NY 10016

Hoelscher, Laura
Agricultural Communications
1143 AGAD Building; Purdue Univ.
West Lafayette, IN 47907

Hokanson, Stan
A324 Plant Soil Sciences Building
Michigan State University
East Lansing, MI 48824

Horton, Fiona
214 Agriculture Admin. Building
2120 Fyffe Road
Ohio State University
Columbus, OH 43210

Hou, Guoquan
139 Food Science Building
Michigan State University
East Lansing, MI 48824

Howell, Cheryl
Outreach Communications
310 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Hughes-Lazzell, Terri
The Journal-Gazette of Fort Wayne
600 West Main Street
Fort Wayne, IN 46802

Hunt, Ann
Citizens for Alt. to Chem. Contamination
8735 Maple Grove Road
Lake, MI 48632-9511

Her, Susan
Ontario Soybean Growers'
P.O. Box 1199
Chatham, ON, Canada N7M 518

Jackson, Constance
Extension; 106 Ag. Admin. Bldg
2120 Fyffe Road; Ohio State University
Columbus, OH 43210

Jones, Dawn
Stephan 8t Brady
1850 Hoffman Street
Madison, WI 53704

Jones, Mary Ellen
Ctr. for Study of Science in Society
Virginia Tech
Blacksburg, VA 24061-0247

Keegstra, Kenneth
Plant Research Lab
Michigan State University
East Lansing, MI 48824

King, Dave
Agricultural Communications
1143 AGAD Building
Purdue University
West Lafayette, IN 47907-1143

King, Alan
University of Guelph
P.O. Box 740; 15 Waulron Street
Etobicoke, ON, Canada M9C 5H3

Kirk, Kevin
Michigan Farm Bureau
P.O. Box 30960
7373 West Saginaw Hwy.
Lansing, MI 48909

Kleckner, Dean R.
American Farm Bureau Federation
225 Touhy Avenue
Park Ridge, IL 60068

Klein, Janet
Wisconsin Agriculture Department
801 Badger Road
Madison, WI 53713

Klyczek, Karen
410 S. Third Street
University of Wisconsin-River Falls
River Falls, Wl 54022-5001

Kneen, Brewster
The Ram's Horn
125 Highfield Road
Toronto, ON, Canada

Knezek, Bernie
Kellogg Biological Station
Michigan State University
East Lansing, MI 48824

Knudsen, Henrik
Centre for Development Research
Gammel Kongevej 5
DK-1610 Copenhagen V
Denmark

Korson II, Philip J.
Cherry Marketing Institute
2220 University Park Drive
Suite 200
Okemos, MI 48864

Krauskopf, Dean M.
MSU Extension, Wayne County
640 Temple, 6th Floor
Detroit, MI 48201

Krueger, Charles
229 Agricultural Admin.Building
Penn State University
University Park, PA 16802-2600

Krueger, Dave
Ag. and Extension Education
410 Agriculture Hall, MSU
East Lansing, MI 48824

Kudwa, Ben
MI Potato Industry Commission
13109 Schavey Road
Dewitt, MI 48820

Laurie, Jack
Michigan Farm Bureau
7373 West Saginaw Highway
Lansing, MI 48909

Lawrence, Robert H.
U.S. Tobacco Company
100 West Putnam Avenue
Greenwich, CT 06830

Lee, George E.
Coordinator of Agricultural Research
204 Kirk Hall
University of Saskatchewan
Saskatoon, SK, Canada S7N 0W0

Lee, Charles
Agriculture and Life Sciences
Texas A&M University
College Station, TX 77843-2142

Lehnert, Dick
Farmer's Exchange
Box 45
New Paris, IN 46553

Lesser, William
Acting Director, ISAAA AmeriCenter
258 Emerson Hall
Cornell University
Ithaca, NY 14853-1902

Lewis, Carrol
AES; 2-44 Agriculture Hall
University of Missouri
Columbia, MO 65211

Lommel, Steven
NCARS; Box 7643
North Carolina State University
Raleigh, NC 27695-7643

Long, Richard
MSU Extension
151 East Huron Avenue
P.O. Box 110
Rogers City, MI 49779

Louws, Frank
Botany and Plant Pathology
166 Plant Biology Lab
Michigan State University
East Lansing, MI 48824

MacDonald, June Fessenden
NABC
159 Biotechnology Building
Cornell University
Ithaca, NY 14853-2703

Madkour, Magdy
Ministry of Agriculture and Land Reclamation
AGERI
9 Gamma Street
Giza, 12619, Egypt

Manning, Richard A.
U.S. Tobacco
800 Harrison Street
Nashville, TN 37203

Maredia, Karim M.
ABSP
416 Plant Soil Science Building
Michigan State University
East Lansing, MI 48824

Maredia, Mywish
Agricultural Economics
32 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Martin, Robert
217A Curtiss Hall
Iowa State University
Ames, IA 50011

McSpadden, Brian B.
306 Plant Soil Science Building
Michigan State University
East Lansing, MI 48824

Meagher, Laura
AgBiotech Center; P.O. Box 231
Cook College, Rutgers University
New Brunswick, NJ 08903

Mercer, Nathan
Michigan Environmental Defense
503 East Grand River
East Lansing, MI 48823

Mesko, John
215 East 9th Street
Purdue University Extension
Auburn, IN 46706

Middendorf, Gerad
Sociology; 316 Berkey Hall
Michigan State University
East Lansing, MI 48824

Miller, Steve A.
Michigan Dept, of Natural Resources
P.O. Box 30028
Lansing, Ml 48909

Milligan, Larry
Vice President for Research
414b University Centre Building
Gordon Street, University of Guelph
Guelph, ON, Canada N1G2W1

Millsap, Robin
Outreach Communications
312 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Mitchell, Roger
Dean, College of Agriculture, Food
and Natural Rescources
2-69 Agriculture Building
University of Missouri
Columbia, MO 65211

Moffat, Anne S.
Science Magazine
1203 East 50th Street
Chicago, IL 60615

Mooney, Loren
NABC, 159 Biotechnology Building
Cornell University
Ithaca, NY 14853-2703

Moser, Bobby D.
Vice President for Agriculture
The Ohio State University
100 Ag Administration
Columbus, OH 43210

Neilson, John
AES, University of Florida
1022 McCarty Hall
Gainesville, FL 32611-0200

Nielsen, Niels
Department of Agronomy
1150 Lilly Hall
USDA/ARS
Purdue University
West Lafayette, IN 47907-1150

O'Hara, Kate
NABC
159 Biotechnology Building
Cornell University
Ithaca, NY 14853-2703

Offutt, Susan
National Research Council
2101 Constitution Avenue
Washington, DC 20418

Olson, Ken
AFBF
225 Touhy Avenue
Park Ridge, IL 60068

Parsons, Rolle
Purdue University Cooperative
Extension Service
2003 East Pleasant Street
Noblesville, IN 46060

Patterson, John A.
Animal Sciences; 3-101 Lilly Hall
Purdue University
West Lafayette, IN 47907-1151

Payne, Thomas
OSU/OARDC
1680 Madison Avenue
Wooster, OH 44691

Pearson, Harry
Indiana Farm Bureau Inc.
225 South East Street
Indianapolis, IN 46206-1290

Pendick, Daniel
Food Chemical News
P.O. Box 261
Madison, WI 53701

Peterson, Susan
Outreach Communications
310 Agriculture Hall, MSU
East Lansing, MI 48824

Pierro, Louis J.
1376 Storrs Road
University of Connecticut
Storrs, CT 06040

Porteous, Ken
Ontario Tender Fruit Board
Rural Route 1
Simcoe, ON, Canada N3Y 4J9

Price, Tim
Indiana Farm Bureau, Inc.
225 South East Street; P.O. Box 1290
Indianapolis, IN 46204-1290

Qian, Xuemei
Food Science and Human Nutrition
309 Food Science Building
Michigan State University
East Lansing, MI 48824

Rabino, Isaac
Suny-Empire State College
666 Broadway
New York, NY 10012-2396

Rahardja, Utami
Bll Pesticide Research Center
Michigan State University
East Lansing, MI 48824

Reich, Richard C.
Sunrise Biosystems, Inc.
Bowman Gray Technology Center
Reynolds Blvd.
Winston-Salem, NC 27127

Reilly, James H.
Reilly Enterprises, Inc.
7345 Wilcox Rd.
Brown City, MI 48416

Rule, A.O.
Environmental Growth Chambers
510 East Washington Street
Chagrin Falls, OH 44022

Rusike, Joseph
Ag. Econ.; 202 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Sawyer, Richard L.
Int'l Fund for Agricultural Research
1547 Hidden Lake, Carolina Trace
Sanford, NC 27330

Schmid, Allan
Department of Agricultural Econ.
36 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Schweikhardt, David
Agricultural Economics
35 Agriculture Hall, MSU
East Lansing, MI 48824

Scott, Norman
Vice President for Research
314 Day Hall
Cornell University
Ithaca, NY 14853

Scriber, Mark
Entomology; 234 Natural Science Bldg.
Michigan State University
East Lansing, MI 48824

Shand, Hope J.
Rural Advancement Foundation Int'l
P.O. Box 655
Pittsboro, NC 27312

Shelton, Robert N.
410 Mrak Hall
University of California-Davis
Davis, CA 95616

Shimoda, Sano
Bioscience Securities, Inc.
2 Theatre Square, Suite 210
Orinda, CA 94563

Sigurdson, Chris
Public Affairs; 1143 AGAD
Purdue University
West Lafayette, IN 47907-1143

Smalley, Susan
MSU Extension; 11 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Smith, Jeffrey
Cooperative Extension Service
9245 North Meridian Street, Suite 118
Purdue University
Indianapolis, IN 46260

Sood, Praim
Michigan Department of Agriculture
Pesticide and Plant Management Div.
P.O. Box 30017
Lansing, MI 48909

Steele, Robert
1450 Linden Drive
136 Agriculture Hall
University of Wisconsin-Madison
Madison, WI 53706

Stepnitz, Kurt
S-20 Plant Biology Building
Michigan State University
East Lansing, MI 48824

Stevens, Hannah
MSU Extension
21885 Dunham Road
Clinton Township, MI 48036

Sticklen, Mariam
ABSP, 206 Pesticide Research Center
Michigan State University
East Lansing, Ml 48824

Stokes, Harold
26345 W. Seven Mile, #226
Redford, MI 48240

Stoltzfus, Jon
Genetics; Plant Research Lab
Michigan State University
East Lansing, MI 48824

Surgeoner, Gord
Environmental Biology
University Of Guelph
Guelph, ON, Canada N1G2W1

Sutrisno
Central Research Inst, for Food Crops
Ji. Merdeka 147
Bogor, Indonesia

Swan, Patricia
Vice Provost for Research
211 Beardshear Hall
Iowa State University
Ames, IA 50011

Thomashow, Michael
Crop and Soil Sciences, MSU
A291 Plant Soil Science Building
East Lansing, MI 48824

Thompson, Paul
Center for Biotech. Policy & Ethics
Texas A&M University
College Station, TX 77843-4355

Thorburn, Tom
W.K. Kellogg Foundation
One Michigan Avenue East
Battle Creek, MI 49017

Traynor, Patricia
NBIAP; Botany and Plant Pathology
110 Biological Research Center
Michigan State University
East Lansing, MI 48824

Van Aken, Michael C.
U.S. Tobacco
100 West Putnam Avenue
Greenwich, CT 06830

Vidos, Constance
Mongoven, Biscoe & Duchin
1100 Connecticut Avenue, NW, #300
Washington, DC 20036

Weaver, Bill
Ontario Federation of Agriculture
491 Eglinton Avenue West, # 500
Toronto, ON, Canada M5N 3A2

Whale, Deborah
Agriculture Research Institute
Rural Route 2
Alma, ON, Canada NOB 1A0

Whalen, Tom
Michigan Dept, of Agriculture
1615 South Harrison
East Lansing, MI 48823

Wiersma, Catherine
Sociology, 316 Berkey Hall
Michigan State University
East Lansing, MI 48824

Wilson, Jeff
Ag Care
491 Eglinton Avenue West
Toronto, ON, Canada M5N 3A2

Woodward, Doreen
Agricultural Experiment Station
109 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Worosz, Michelle R.
331C Natural Resources
Michigan State University
East Lansing, MI 48824

Wosje, Walt
Michigan Milk Producers
41310 Bridge Street; P.O. Box 8002
Novi, MI 48376-8002

Wrubleski, Martin
Saskatchewan Agriculture and Food
3085 Albert Street
Regina, SK, Canada S4S0B1

Wysocki, Allen
Agricultural Economics
2B Cook Hall
Michigan State University
East Lansing, MI 48824

Youngberg, Garth
Henry A. Wallace Institute for
Alternative Agriculture
9200 Edmonston Road, Suite 117
Greenbelt, MD 20770-1551

Zeikus, Greg
Michigan Biotechnology Institute
3900 Collins Road
P.O. Box 27609
Lansing, MI 48909

Zielke, Richard
Michigan Sugar Company
P.O. Box 247
Carrollton, MI 48724

NABC Report 6

Agricultural Biotechnology & the Public Good

0-9630907-5-5