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NABC REPORT 11

World Food Security and Sustainability: The Impacts of Biotechnology and Industrial Consolidation

Edited by Donald P. Weeks, Jane Baker Segelken, and Ralph W.F. Hardy

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Providing an open forum
for exploring issues in
agricultural biotechnology

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The tremendous success of the 11th annual meeting of the National Agricultural Biotechnology Council would not have happened without the planning committee at University of Nebraska-Lincoln, headed by Donald P. Weeks, whose hard work and thoughtful oversight ensured that all details were covered. Joining Dr. Weeks were the following individuals, who enthusiastically assumed and accomplished their assignments: Sondra Atkins; Eva Bachman; Steve Baenziger; Ricardo Barrera; Sharon Beachell; Chuck Francis; Carol Hegel; Leon Higley; Jim King; Jean Klasna; Karen Henricksen; Darrell Nelson; Martin Massengale; Vicki Miller; Dick Perrin; Anne Vidaver; Rita Weeks; and Dan Wheeler. In addition, we thank Garth Youngberg of the Henry A. Wallace Institute for Alternative Agriculture for his assistance in program development.

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And finally, our sincere thanks go to James R. Fischer, Clemson University, NABC Chair 1998-1999, whose leadership, support and guidance enabled us to successfully do our jobs.

Ralph W.F. Hardy
NABC President

Jane Baker Segelken
NABC Executive Coordinator

December 1999

When the National Agricultural Biotechnology Council (NABC) was established in 1988, its goals were the early identification of agricultural biotechnology issues and their discussion in an open forum; the safe, efficacious and equitable development of the products and processes of agricultural biotechnology; and the development of public policy recommendations. Today, with a membership that includes 30 of the leading not-for-profit research and educational institutions in North America, the NABC still strives to identify and consider in open forum the major issues, and provide all stakeholders — including representatives from academe, government, industry, public interest, farming, and others — the opportunity to speak, to listen, and to learn. Through its meetings, the NABC has addressed many major issues: sustainable agriculture in 1989; food safety and nutritional quality in 1990; social issues in 1991; animal biotechnology in 1992; risk in 1993; public good in 1994; discovery, access, and ownership of genes in 1995; novel products and new partnerships in 1996; challenged environments in 1997; and gene escape and pest resistance in 1998.

In 1999, the NABC meeting was hosted by the University of Nebraska-Lincoln, with co-sponsorship by the Henry A. Wallace Institute for Alternative Agriculture, on June 6–8. The meeting focused on the impacts of biotechnology and industrial consolidation on world food security and sustainability. This was the first major national meeting in which this high profile area was discussed. Agricultural biotechnology is at least, in part, driving consolidation of the agrichemical and seed input companies and even catalyzing initial integration of these companies into the food and industrial products area. A major question both nationally and internationally is how world food security and sustainability will be affected by these major changes? The NABC11 presentations and discussions addressed this and related questions.

Leaders from relevant and diverse organizations — World Bank, consolidating agri-input companies, Institute for Sustainable Agriculture, farmer/grower organizations, Center for Rural Affairs, the Hudson Institute, the USDA, and the White House Science and Technology Policy Office — shared their views with an even more diverse group of attendees. The attendees included traditional and organic farmer/growers, industry representatives, consumers, university faculty, students and administrators, state and national agency/government representatives, elected representatives, and leaders and members of public activists groups, including, for example, a leader of the Greenpeace organization. In the workshops, each attendee had the opportunity to voice their concerns, and also to listen and to learn. This report contains the summary of the workshop discussions and the plenary presentation.

Concerns ranged from the necessity of agricultural biotechnology to meet ever-expanding world food needs to the impact of corporate agriculture on farmers and growers. Surprisingly, the workshops did not identify food safety as a concern, in contrast to concerns expressed by the popular press with respect to public interest group statements. We believe the reports in NABC11, both workshop and plenary, provide an excellent source of information and issues regarding the subject.

Candid forums such as NABC11 help to promote better understanding of the many diverse viewpoints, and provide an opportunity for addressing concerns about agricultural biotechnology. The 2000 NABC annual meeting — "The Biobased Economy of the Twenty-First Century: Agriculture expanding into Health, Energy, Chemicals, and Materials" — will be held May 11–13 in Orlando, FL. The meeting promises to provide participants the chance to dialogue and debate the impacts of emerging technologies that will fuel our economies in the near and distant futures.

In 1999, the NABC produced the *NABC Statement 2000 on Agricultural Biotechnology: Promise, Process, Regulation, and Dialogue* to provide a concise but comprehensive statement regarding agricultural biotechnology. This statement invites individuals and organizations with concerns and stakes in agricultural biotechnology to participate in an open forum discussion of pivotal issues. The goal of NABC in this effort is to ensure that society, in terms of quality of life, security of food supplies and environmental sustainability, will benefit maximally from agricultural biotechnology while incurring minimal risks. The statement is included as an appendix of this NABC Report.

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NABC Executive Coordinator

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PART I

WORLD FOOD SECURITY AND SUSTAINABILITY: THE IMPACTS OF BIOTECHNOLOGY AND INDUSTRIAL CONSOLIDATION

NABC 11: An Overview

By Donald P. Weeks
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The focus of the 1999 NABC meeting was on exploring new developments in agricultural biotechnology and trends toward industrial consolidation in agriculture. The influence of these two major emerging factors, as separate and combined phenomena, were discussed relative to the long-term ability of U.S. and world agriculture to produce adequate, safe, and healthful supplies of food — and to do so in an environmentally acceptable fashion. The potential impacts of these new developments on the production techniques, economics, and sociology of agriculture were discussed by invited speakers and by participants during two sets of workshops. A goal of the workshops was to develop consensus statements regarding the nature of current trends and the implications of these trends on the structure and sustainability of agriculture in North America as well as the rest of the world. (Summaries of workshop discussions are presented in Part Two.)

Three keynote speakers set the stage for lively discussions and deliberations. Per Pinstrup-Andersen, an economist from the World Bank, furnished perspectives on the future in regard to population, food, and agriculture worldwide. He noted that there is enough food produced to feed everyone in the world. However, at present, over 800,000,000 people are food insecure — 180,000,000 of which are preschool children. Clearly, equitable food distribution is a significant challenge. Andersen pointed out that production, too, could become limiting in future years with an extra one billion people in Asian countries by the year 2020 and an 80 percent increase in populations in Sub-Saharan Africa. To feed these people, he predicted a 60 percent increase in food demand and production by 2020. Also projected was a 200 percent increase in demand for meat, driven in part by the increasing wealth in regions like Asia and Southeast Asia. He emphasized that the increase in food supply will not come from adding more land to agricultural production; rather, it must come from increases in productivity per unit area of land and unit volume of water. He noted that in recent decades, it has been science that has allowed us to feed increasing numbers of people — and it is science that must be used if we are to stay ahead of growing food needs. Importantly, he predicted continued gradual drops in food prices over the next several years, a sobering thought for already hard pressed farmers.

Among emerging issues forecast by Pinstrup-Andersen were the following: a potentially strong backlash (especially in developing countries) to the globalization and consolidation of agricultural businesses; an absolute necessity to use modern science and technology to meet the growing food demands of the world; the likelihood that water may become the limiting factor in food production in the near future; concerns that the scare over food safety and health risks (especially in Europe) resulting from bacterial contaminations and mad cow disease may be lumped together with concerns over genetically modified foods — the consequences of which could be exclusion of people in developing countries from increased food supplies that could be made available through agricultural biotechnology; a need for better governance by corporate entities and governments that would allow a more equitable sharing of resources and rewards with people around the globe; and, finally, an increasing realization that conditions in certain regions of the world are very bad and that we must use all sources of help, including agricultural biotechnology, if the people of those regions are to be reasonably served by the rest of humanity.

John Pierce of DuPont provided a view of things to come in agricultural biotechnology in regard to products and in regard to business implications. He noted that the impacts of biotechnology will be large and are driving major changes in agricultural food production, marketing and distribution. Among the changes are consolidations to capture key information and technologies. Pierce emphasized that the issues and stakes are large. The value of the “food chain” is approximately one trillion dollars/year. Even small changes in the flow of dollars back and forth through the food chain (and involving myriad producers, suppliers, processors, distributors and consumers) can result in major shifts in wealth and well being. While acknowledging major consolidations within the agricultural industry, Pierce saw this as a reflection of previous and similar consolidations in other sectors of the economy. He predicted a slowing of consolidation activities and saw as unlikely the emergence of one or two juggernaut companies that might exert monopolistic power in the marketplace.

Pierce highlighted a few of the new products developed through DuPont’s agricultural research programs as examples of the kinds of new products that have emerged, and will emerge, in the broader marketplace. DuPont has produced corn varieties with traits such as grain with twice the normal levels of oil, increased oil quality, higher protein content (and a more nutritious balance of amino acids), better processing qualities, higher phosphorus availability, and higher resistance to microbes that produce mycotoxins. In soybeans research, DuPont has produced seeds with higher oil content and oils that are more stable during processing and storage. Soybeans aimed for human consumption have been developed that are sweeter and have dramatically reduced quantities of compounds that produce flatulence. He also highlighted several products aimed at increasing food safety for consumers.

In his summary, Pierce pointed to several ways that biotechnology is enhancing and safeguarding our food supplies. These include crops with higher yield potential, genetically modified crops that allow for more environmentally friendly farming practices, feeds for livestock and poultry that are more nutritious and more efficient, and crops that offer improved economic benefits for producers, processors and, ultimately, consumers. Finally, he noted that biotechnology will have direct benefits for consumers through enhanced food safety, availability of new types of functional foods, and development of foods with better nutritional qualities. All of these benefits from products of agricultural biotechnology, Pierce concluded, have important positive implications for the health and well being of people throughout the world as well as the security of their food supplies.

The final keynote speaker was Cornelia Flora of Iowa State University. She provided an overview of trends in social and economic conditions that are affecting the degree to which the products of agricultural biotechnology are accepted. Flora noted a dramatic change from a situation in history in which there was a close relationship between the producer of food and the end-user to the present situation in which the food system is a complex array of interactions between many stakeholders. She discussed six key trends she saw as affecting the social arena and the markets for the products of agricultural biotechnology: globalization, industrialization, decentralization, privatization, polarization, and engagement. Following this, Flora moved to a discussion of the factors that influence acceptance or rejection of new technologies by both producers and end-users. She noted that there are both positive and negative forces affecting acceptance or rejection of technology by an individual or an organization. The factors that affect this process are: internalization of the technology to determine if it does or does not fit with innate values; social pressure that motivates one to be seen as progressive by utilizing a new technology or scoffed at for embracing an unproven method or product; economics that indicate to a person or company a financial benefit or financial peril; and, finally, force that may be exerted by governments or organizations to cause people to adopt or reject a particular new technology. Flora emphasized that for any new technology to be accepted, there must be a trust built between producers, suppliers, and end-users. To facilitate the building of trust there must be transparent mechanisms put in place that build confidence on all sides. Finally, Flora cautioned that privileging any form of capital (financial, human, natural resource, etc.) over another can deplete all forms of capital in the long run.

To provide the conference with added perspective, Stan Johnson of Iowa State University provided an overview of policy and technology factors involved in industrial consolidation. He outlined the sources of value gained by companies through industrial consolidation, such as organizational efficiencies, strategic competitiveness, complementarity, strategic substitutes or coordination, and potential monopoly powers. He then discussed the implications of what he called "incomplete contracts." That is, those portions of agreements that are not fully spelled out, but which can have significant impact on one or both of the parties involved. This was followed by a description of the advantages of mergers or acquisitions verses strategic partnerships.

In summarizing what he saw as trends in industrial consolidation and its consequences, Johnson highlighted three points. First, he saw industrial consolidation continuing into the foreseeable future. Second, as a result of the consolidation, he predicted that multinational companies would have and exert more and more power. Third, he saw a decrease in funding for public research and a consequent decrease in the rate of scientific discovery and technology development in agriculture. The present flurry of new discovery and innovation in agricultural biotechnology may be strongly impeded by industrial consolidation and, in the long term, slow the development of new products that benefit people around the world. With more private control of research, Johnson concluded that the levels and direction of research in the U.S. would, in the future, be dictated in large part by company profit levels. Thus, the role of public sector investment in research may be relegated to providing the "energy" that is necessary to drive innovation in the face of lethargy on the part of the heavily consolidated industrial sector. This will require a new level of public and private sector coordination in developed countries. Johnson viewed under-developed countries as being poorly equipped to participate in this coordination — a situation with clear-cut negative implications in regard to growing differences between the have and have-not nations of the world.

James Tobin of Monsanto provided an industry perspective on agricultural biotechnology. He began by emphasizing the immense challenges that face agriculture and agricultural biotechnology in the coming years. These include the daunting task of feeding two billion more people in the next thirty years, the challenge of farming with more respect for the environment and the imperative to improve the quality and nutrition provided by crops in the future. Agricultural biotechnology was seen by Tobin as facing numerous challenges: complex patent issues; regulatory systems still in development worldwide; consumer/political acceptance in Europe; intense competition; and rapid changes in the technology. Tobin then provided several examples of Monsanto products in the market or on their way to market. These included Round-Up Ready® soybeans, corn, wheat and rice, Bt corn and cotton, wheat that is resistant to head scab, corn with higher oil content, and canola oil with higher beta-carotene content. The latter was donated by Monsanto to the Agency for

International Development (AID) to help combat vitamin A deficiencies in developing countries. As a final example, Tobin pointed to the growing use of genetically engineered plants as "factories" for production of high-value pharmaceuticals and specialty chemicals.

In regard to benefits for farmers, Tobin suggested that in the future farmers will: Have a broader range of crops to plant; see a significant increase in information and crop production options; benefit from a shift in pest management from choices of chemicals to a choice of seeds; have at their command more risk management tools; experience a shift to more contract growing of value-added crops that will require identity preservation; and witness intensification of global competitiveness both in the farming and supply sectors. Likewise, he saw a powerful effect of genomics in greatly speeding the movement of new genetic traits from the laboratory and breeding fields into the hands of farmers. Finally, he envisioned agricultural biotechnology as fostering the creation and use of new systems in both developed and developing countries to successfully address the economic and environmental challenges of providing a safe and secure food supply for the people of the earth.

Fred Kirschenmann is an organic farmer and owner of Kirschenmann Family Farms, Inc. He asked the question: What kind of future can farmers expect and what kind should they create? Kirschenmann stated that the promise of agricultural biotechnology, according to some, is threefold: The technology will increase profitability; the technology will benefit pest control in an environmentally benign way; and the technology will help feed the world. Kirschenmann saw serious flaws in all three assumptions. In regard to the latter point, he posited that hunger is not so much a problem of food supply as it is a problem of food distribution. Furthermore, agriculture biotechnology will not solve other problems associated with overcrowding such as disease, political unrest, etc. As far as technology helping with pest management, Kirschenmann noted that "therapeutic intervention" with pesticides is being questioned because such systems are inherently short lived. He encouraged adoption of a restructured approach in which natural pest management systems are employed. Finally, he questioned whether farmers will benefit from agricultural biotechnology. With the push toward consolidation of the agriculture industry into perhaps as few as four "food clusters" that will control food production, processing, and distribution, Kirschenmann saw widespread adoption of contract farming and control of farmers through contracts. In his judgment, "biotechnology gives new meaning to the term tenant farmer". He pointed to the plight of farmers in the broiler industry as a paradigm that may beset many farmers in other sectors of agriculture in the future.

Kirschenmann saw as almost inevitable the emergence of "industrial farming" controlled directly or indirectly by a few giant multinational companies. However, he predicted that such a system is likely to fail in the long run. This is due to three interrelated factors: the farms will need to be very large, highly centralized and highly specialized in the production of one or two crops; the approach to production problems will be a direct, external counter force rather than a restructuring of the farming system to deal with the problems; and, finally, genetic engineering will lead to fewer crop species and decreased biodiversity. The increased vulnerability of this system will ultimately lead to its failure with dire consequences for those people that depend on the industrial farming system for their food. Kirschenmann pleaded for recognition of these facts and the commitment of more public research funds to serve the needs of those pursuing alternate agriculture as a more dependable and secure means of producing food.

Dennis Avery of the Hudson Institute delivered a provocative talk in which he "surrendered" to those who oppose the use of new technologies, such as agricultural biotechnology, and favor the return to more natural and environmentally friendly methods of food production. He declared that the environmentalists and anti-technology groups were winning almost every confrontation by appealing to urban audiences in developed countries who are well fed and have been taught to oppose anything that is not natural, organic or that uses newly developed, not fully tested technologies. He cautioned such people, however, that there may be important consequences to their choices and demands. In particular, he pointed to the fact that there are ever mounting world populations — and that there is an increasing wealth of those populations. As a consequence, Avery predicts there surely will be an enormous increase in demand for more food and higher-quality food. If there is not increased productivity through biotechnology and other developments in agriculture, then, surely, there will have to be more land brought into play for agricultural food production. The only major source of new land presently available are the very lands that are richest in wildlife habit — the plunder of which will have dire consequences for ecosystems around the globe.

For those who blame energy-demanding agricultural practices for causing environmental damage, Avery explains that it is far easier, and less environmentally damaging, to find new sources of energy than it is to find new, productive agricultural lands. Finally, for those concerned about the plight of rural communities in the U.S., Avery suggested that the new crops and products that can be developed through biotechnology offer rural citizens new opportunities for businesses and livelihoods that can allow a reasonable number of communities to remain viable and even prosper.

A markedly different perspective of the future of rural communities and farming was provided by Chuck Hassebrook of the Center for Rural Affairs. Hassebrook contended that family farms and sustainable systems can feed the world into the foreseeable future. He stressed that how well this goal is achieved is dependent on how society invests in the research that is necessary to allow family farming and sustainable agriculture to succeed. Hassebrook pointed to three principals that must be embraced if we are to provide a secure and sustainable food supply for the people of the world. First, we must increase agricultural production. However, he cautioned that American farmers should not rely on exports to fulfill their needs for larger markets. Second, we must develop agricultural systems that create genuine economic opportunities in agricultural communities here and in developing nations. He noted that it is poverty, per se, that is the primary cause of starvation in the world. There is food available, but poor people in developing countries cannot afford it. Third, if our goal is to prevent hunger, we must develop agricultural systems that are resilient (i.e., cropping systems that are sustainable and crops that can withstand major challenges such as water availability, severe changes in climate, outbreaks of new diseases, etc.). Hassebrook asserted that as consolidation in the agricultural industry increases and there is a move to less diversity and larger concentrations of single species in a given area, the system of food production will become significantly more "brittle" (i.e, less resilient to rapid changes).

Hassebrook posed the question: What must we do to move to more sustainable and resilient systems in agricultural production? He offered two answers. First, he contended that we must secure the capacity for public good research. Profit-driven research will never meet the needs for all crops and for all people in either the developing world or in the U.S. He underscored this by saying that society must not allow the research agenda of public institutions to be set by profit opportunities (e.g., royalties, contracts, etc.). Second, Hassebrook urged that we change the focus of public university research to bring it on track with "public good" needs of people. He indicated that to-date, university research has focused largely on development of new products for the supply side of agriculture. New emphasis must be given to providing farmers with new production and management tools that can help them make a more reasonable return on their investments and their labors. Hassebrook concluded by saying the no social system can survive that does not consider all the people who have a stake in the system.

William Heffernan of the University of Missouri began his talk with the prediction that while agricultural biotechnology may have great promise for improving our means of feeding the hungry people of the world, the system into which its results must be funneled may prevent the promise from being fulfilled. He stated that it is social systems (largely the political and economic systems of the developed world) that will dictate how agricultural biotechnology is to be used. In the economic arena, Heffernan pointed to the rapid shift from a largely decentralized food production system in the past to a present day system of highly centralized control of food processing and distribution. He emphasized that in most sectors of the food processing industry, only four or fewer companies control more that 50 percent of the volume in those sectors. He noted also that most of the very large companies, such as Cargil, ConAgra, and ADM, are expanding their market share and control through company acquisitions, mergers, joint ventures, and strategic alliances. More and more, these companies are seen by Heffernan as attempting to control food production from beginning to end (i.e., through control of genes, seeds, farm production via contracts, processing, and distribution to the market shelf). The ability of biotechnology researchers to discover and patent genes, and the ability of companies to "own" these genes and associated germplasm, was viewed by Heffernan as catalyzing the rapid move toward industrial consolidation in the agricultural sector.

Heffernan stated that the rapid move of agriculture toward industrialization is much the same as that which occurred in other sectors of the economy several years ago. The goal of an industrialized system that is highly consolidated is to concentrate on, and respond to, the short-term pressures of making a profit for its shareholders. In such a system, small firms and producers become marginalized according to Heffernan. In all of this he sees government, de facto, turning over responsibility for sustainable and secure food supplies to the private sector — a circumstance with potentially devastating consequences for U.S. farmers and for the poor and hungry people of the world. He urged greater investment in sociological research on food distribution systems as a key to solving the vexing problems of today and the future. In closing, Heffernan asked two questions: Is it too much to ask to slow the process of development of agricultural biotechnology and engage public debate as to the costs and benefits according to the traditions of a democratic society? Can we slow the process until we can engage other institutions in society?

Susan Offutt of the USDA/Economic Research Service focused on the role of the consumer in driving much of what is happening in agricultural biotechnology and its associated industries. She stated that understanding consumer demand is key to understanding the move from commodity agriculture to product-driven business. According to Offutt, in mature food markets such as the U.S. and Europe, people have more than an adequate quantity of food. In such a situation, their buying patterns are dictated by the foods they learn to like and the characteristics of the product (such as flavor, convenience of preparation, and price). Thus, Offutt pointed out, for a company to gain a larger share of the market in this situation, it must rely on "product differentiation." To achieve this, companies must be in a position to control inputs, food production procedures, processing, packaging and distribution — all of which are easier in a fully integrated or coordinated industrial system. According to Offutt, biotechnology can play a key role in this scenario by providing farmers and food companies with plants and animals with improved characteristics that allow production of new or more highly differentiated foods for the consumer.

How do farmers fare in all of this? Offutt said that if farmers wish to increase income, the real question is how they increase return on farm labor. The answer that successful farmers have found, according to Offutt, is to increase the quality of labor. That is, to increase the quality of decision-making and management skills. Toward that end, Offutt encouraged farmers to realize that while many in the world are going hungry, there are others in the developing countries whose wealth is increasing steadily. As the income of these people rises, they will begin to spend more on food — especially food with high quality protein. This growing market offers opportunities for those who anticipate the increasing demand and position themselves to take advantage of it. In conclusion, Offutt cautioned meeting participants not to demonize or lionize any one factor that may be at play in the free market system, but urged everyone to understand "causality" as the driving force in the marketplace.

The role of the federal government programs and policies in agricultural biotechnology was the topic of the talk by Cliff Gabriel of the White House Office of Science and Technology Policy. He started by pointing out the key role of Land Grant Institutions in performing research that has made invaluable contributions to the nation. However, the partnership between the government and universities has been subject to growing stress in recent years. This, Gabriel observed, led recently to a new set of principles for the partnership that recognizes that research is an investment in the future, that the linkage between research and education is vital, that peer review is essential to excellence in research, and that research must be conducted with integrity. He then provided an overview of how the government sets research priorities in agriculture and how it supports a diversity of research mechanisms such as intramural research, competitive grants, formula funds, and special grants.

Gabriel then turned his attention to how the government is involved in conflict resolution, especially in regard to agricultural biotechnology. The first principle enunciated was that the marketplace should resolve most issues and that laws and regulations, special programs, and stakeholder input should be pursued only when necessary. He then discussed a list of ongoing conflicts that the government is helping to resolve. These included organic agriculture versus biotechnology, human and environment health versus chemical pesticides, labeling of foods for health and safety purposes versus the consumer's right to know, and reproductive cloning versus therapeutic cloning versus embryo research. Gabriel concluded by saying that we need to look carefully at our underlying national goals for the economy, health and the environment, and make sure agriculture is contributing in a positive way to achieving these goals. He stressed that the role of government is to help pave the way for technical winners in a manner that is consistent with these goals.

The wrap-up speaker for NABC11 was Paul Raeburn of *Business Week*. The title of his presentation was, "Where do we go from here?: A view from Times Square." Raeburn chose to emphasize the fact that his view was that of someone, like most others from urban areas, whose day to day pursuit of information does not include information of the farm scene. He noted that it is this lack of information and understanding that would make the topic of NABC11 foreign to most city dwellers. The only time New Yorkers pay attention to food prices is when there is a freeze in Florida and the price of orange juice goes up. However, the urban audience is very much in tune with the need for a healthy and safe diet. They are also mindful of the need to protect the environment. With this background, Raeburn emphasized that the bulk of urban dwellers were not at all aware that a high percentage of crops in America are now genetically engineered and that some of the foods they have been eating are derived from genetically modified plants. He did not know how these people will react when they finally realize this fact. However, he suspects that they won't be happy about being "fooled" in regard to their food. He suggested that it might be wise if the issue of labeling genetically modified foods was faced quickly and effectively.

One of the major concerns expressed by Raeburn was the need to preserve biodiversity. He noted that agriculture is quickly moving into an era when more and more pressure will be placed on land, water, and other natural resources to sustain the growing food demands of a growing world population. He encouraged there not only be preservation of wildlife habitats and forest, but that there also be strong support for the preservation of a wide variety of germplasms from which our present day crops plants have been derived. The increasing move toward monoculture fostered by developments in biotechnology and industrial consolidation could spell disaster to society if there is not a viable set of appropriate germplasms to fall back on.

Raeburn repeated that major challenges lie ahead for agricultural biotechnology. It has a mandate to help feed the world, but at the same time must face up to people in developed countries who have a fear of new technologies — especially those technologies that are perceived as potentially affecting the safety of their food supply. He also warned that perceived threats to the environment must be successfully addressed. The monarch butterfly could become as much of a symbol for those opposing agricultural biotechnology as the bald eagle was a rallying symbol for those supporting Rachel Carlson's fight against environmentally harmful chemical pesticides. Raeburn concluded by saying that there is a great need to educate people regarding agricultural biotechnology if this technology is to fulfill its potential in helping to provide people with a more secure and sustainable food supply.

PART II

WORKSHOP REPORTS

NABC 11

Workshop Reports

As is the tradition at NABC meetings, all persons attending are active participants in the proceedings. Involvement in question and answer sessions following formal presentations and lively discussions during breaks and social functions are two such mechanisms for exchange of information and ideas. However, the most direct and powerful means of participation are the direct face-to-face discussions and debates that occur during the meeting's Workshop sessions. The 1999 NABC meeting offered the nearly 200 people attending the choice of two Workshop groups. To follow is a brief summary of the deliberations in the two Workshops along with consensus views in regard to how agricultural biotechnology and industrial consolidation are affecting world food security and sustainability.

Workshop A

Promises and Problems Associated with Agricultural Biotechnology

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Participants in Workshop A addressed the following questions: What are the greatest promises offered by biotechnology for improving production of more, higher quality foods in an environmentally friendly and sustainable fashion? What are the greatest hazards to the sustainability of agricultural food production imposed by biotechnology?

Approximately 12 to 15 people in each of five different breakout groups discussed the two questions. In the first of three successive sessions, the participants initially listed over fifty "promises" offered by biotechnology to agriculture and world food supplies and, likewise, over forty potential "problems" associated with the use of biotechnology in agriculture. In a second session they identified what they considered the promises and problems of greatest significance. In the final session, delegates worked together to assemble consensus statements and potential policy recommendations upon which they could agree. Assembled below are listings of the major promises and problems that were identified in Workshop A.

PROMISES OFFERED BY AGRICULTURAL BIOTECHNOLOGY

1. Enhanced quantity, quality, and end-use value of food, feed, and biomass products:

With few exceptions, Workshop participants agreed that biotechnology offers the promise of increased agricultural productivity throughout the world by speeding the development of crops that yield more, are more resistant to biotic and abiotic stresses, and are more economic and efficient to produce. The technology also allows the creation of healthier, more nutritious foods through manipulation of key metabolic pathways in plants and animals. Modification of fruits, vegetables, and grains to ripen more uniformly, retain freshness and nutritional quality, and resist post harvest damage by insects and toxin-producing microbes were viewed as goals now within the reach of agricultural scientists using the tools of molecular biology and genetics.

Into this category of "promises" also falls the possibility for new, high-value plants and animals. Development of modified or alternative crops with specific traits and values now can be envisioned through the use of accelerated breeding techniques and genetic engineering of plants to possess new and unique characteristics. Economic production of biomass for the ever-growing world need for fuels and energy, and the creation of plants to supply specific, industrial raw products, are two goals that were viewed as closer than ever to reality due to the powerful tools of plant molecular biology.

Transgenic plants and animals are presently producing several high-value medicines in quantities unprecedented in the pharmaceutical industry. The production of specialty crops and animals was seen as one of the potential bright spots for enhancing income for farmers who position themselves to take advantage of the emerging opportunities offered by biotechnology.

2. Positive environmental impacts:

Changes in current agricultural production practices are possible through biotechnology. Development of plants genetically engineered to resist certain insects already has been widely adopted by the farming community and has resulted in significant decreases in the use of chemical insecticides in major crops such as cotton and corn. The use of herbicide-tolerant crops is allowing the adoption of conservation tillage practices at an accelerated pace while creating a favorable economic return on investment to farmers. It was pointed out that the types of herbicides for which herbicide-tolerant crops are being developed are generally those that can be used in lower quantities than earlier herbicides, have less persistence in soil, and do not create water quality concerns.

Additional promises are seen for the future in protecting and restoring the environment. Increased knowledge of plant and microbial metabolism and genomes was seen as leading to the production of plants and other organisms with enhanced ability for bioremediation of contaminated soils and water. The development of "green raw materials" for industry and for energy production can be accelerated through biotechnology. Enhanced carbon sequestration by genetically modified plants might play a role in minimizing the speed of global warming. Plants and animals that need fewer external inputs (especially those that are environmentally damaging) are likely to emerge from genetic engineering. Delegates agreed that world population would likely continue to increase over the next few decades. It was surmised that if new discoveries in biotechnology could lead to greater agricultural productivity per unit land area, there could be a concomitant decrease in utilization of certain natural resources (e.g., water) and a decrease in pressure to farm marginal or environmentally sensitive lands throughout the world.

It was the consensus of the Workshop groups that biotechnology offers promise to improve the sustainability of agricultural production. However, it was emphasized that biotechnology alone was clearly not enough. Improvements through biotechnology must be coupled with excellent farm management practices including improvements in integrated pest management, cropping and soil conservation practices, and habitat preservation. These must be coupled with increased public awareness of the challenges associated with food production and environmental preservation.

3. Accelerated pace of scientific discovery:

Several comments were offered regarding the marked increase in the rate of scientific discovery as the result of new techniques associated with biotechnology. For example, the soon-to-be-completed dissection of the genomes of several plants, animals, and microbes and the ability to rapidly modify the genetic makeup of these organisms in precise ways was viewed as leading to an explosion in the knowledge and understanding of biological systems. This knowledge inevitably will fuel an increased pace of scientific discovery and an increased ability to manipulate organisms in ways that are beneficial to society. The ability of agriculture to supply the food needs of individuals worldwide in an efficient and environmentally sound fashion is likely to be greatly enhanced. Participants concluded that bringing this promise to fruition would require increased public and private funding to support the necessary research. Even more importantly, the group felt that it was essential that there be significant improvement in cooperation between governments, industries, and people worldwide in developing fair and equitable policies governing food production systems, market structures, and distribution channels.

POTENTIAL PROBLEMS POSED BY AGRICULTURAL BIOTECHNOLOGY

1. Environmental concerns:

Uncertainties in regard to potential environmental impacts of genetically modified plants and animals were a concern in all the Workshop groups. The consensus was that significantly more research was necessary to adequately assess the magnitude of perceived dangers and to discover means to prevent or deal with those dangers determined to be real. Immediate concerns included gene drift from transgenic to nontransgenic plants, the emergence of insects tolerant to insecticidal proteins contained within "insect-resistant" plants, the emergence of microbes tolerant to the "disease resistance" provided to plants and animals genetically engineered with single, disease resistance genes, and the potential collateral to non-target organisms caused by use of these new technologies (the prime example at the time of the meeting being concern that corn pollen containing the Bt-toxin protein might harm monarch butterflies feeding on milkweed plants bordering corn fields). A concern also was raised that the need to "own" genes created through biotechnology was helping to fuel consolidation within the seed industry. Fears were expressed that fewer breeding programs and fewer commercially available varieties might lead to significant narrowing of the germplasm base for the major agronomic crops. It was posited that the resulting "mono-culture" might lead to rapid and catastrophic loss of worldwide production of one or more crops. More generally, there were mixed views as to whether biotechnology would help or hinder the goal of maintaining biodiversity on the planet.

2. Economic and legal issues:

Although effort was made not to tread too heavily into the questions being addressed by Workshop B participants, the members of the Workshop A discussion groups felt there were points that they should raise that fall into the economic, legal, and social arenas. In regard to legal matters, there were concerns that there might be reduction of free exchange of information in the academic world due to the rapidly increasing practice within universities of securing intellectual property rights for new discoveries and technologies. Likewise, there were strong opinions that ownership of new and highly valuable genes and germplasm controlled by private sector companies was likely to limit germplasm exchange and, thus, have a detrimental effect on the ability of public plant breeders in universities to maintain viable breeding programs. More importantly, economic considerations might limit the flow of new germplasm and genes to breeders and farmers in developing nations for use in endogenous crops.

With an eye to the future, questions were raised in regard to who will control the direction of agricultural research in years to come. With private industry now doing much of the cutting edge research in agriculture and controlling access to the marketplace through seeds, will it be possible for university researchers to embark on new projects with practical aims without first gaining agreement from a commercial organization to permit marketing of the research "product?"

It was noted that control of key genes or technologies by a fully integrated company (or a group of industrially coordinated companies) could lead to control of access to high-value crop varieties and control of production of these varieties. It was surmised that both of these situations could have strong negative implications for the farming community if companies are not willing to share equitably in the increased value of the crop.

3. Societal issues:

Concerns were voiced that the benefits of agricultural biotechnology may be available only to those who can afford it. If the profit motive is the prime determinant in the implementation of biotechnology, then poor people in developed and developing countries may be denied access to the benefits of biotechnology. Participants suggested that mechanisms allowing reasonable returns on investment and, at the same time, fair and equitable access to genes and germplasm need to be developed on a global scale.

The control of specific, high-value crop varieties by one or a few companies was viewed by some as opening the way for a significant increase in contract farming. In the extreme, this situation could lead to tight controls of production practices by a company, as well as control of profit margins for the contract farmer. Pressures to produce on a larger, "more efficient" scale might lead to fewer farms and fewer farm families. This was seen as leading inevitably to farm communities that are economically (and socially) nonviable. In addition, there could be a loss of choice for farmers reflected in a growing dependency on specific new technologies — and, business-wise, a dependence on the source of those technologies.

Interestingly, at the time of NABC11, there was significant concern that the "fear" of genetically modified foods in Europe might slow or block the adoption of genetically engineered crops in the U.S. and around the world. However, in none of the Workshops was the "safety" of foods derived from biotechnology raised as a potential "problem." One cannot help but wonder if the same NABC11 had been held in Europe would the discussions and conclusions have been significantly different?

Workshop B

Potential Promises and Problems Associated with Changing Business Strategies in Agriculture

The participants in Workshop B focused on the following questions: What new trends are seen in business strategies related to agricultural food production and distribution? How is biotechnology contributing to these changes? What are the perceived promises and problems associated with the new business strategies?

Five different breakout groups met to discuss the questions. As with Workshop A, the groups met in three successive sessions to progressively hone in on important questions and concerns about emerging business strategies in the agricultural industry.

Trends in the Agricultural Industry

The entire Workshop B group discussed key trends that they saw in agribusiness in the U.S., Canada, and the rest of the world. From these discussions emerged the following conclusions.

1. Consolidation within the ag industry is increasing:

There has been rapid consolidation (through mergers, acquisitions, and strategic alliances) of several large companies in the seed and agrichemical arenas to create a few dominant multi-national organizations. These companies control a significant share of advanced germplasm for the world's major agricultural crops and much of the cutting edge technology in agricultural biotechnology. In addition, there is a growing trend toward vertical integration within the agricultural sector in addition to an increasing number of strategic alliances that allow for "vertical coordination" of food production, processing, and marketing to the consumer.

2. Consumers continue to benefit — but are largely unaware of issues surrounding their food supplies:

Consumers continue to be provided with a safe, low-cost supply of reasonably healthy foods. The global seed companies are providing farmers with crops possessing new and important agronomic traits.

Present genetically engineered traits are aimed at lowering production costs for farmers and, thus, may indirectly benefit consumers by helping to maintain low food costs. In a limited number of cases to date, seed biotechnology companies have provided farmers with seeds for crops with value-added traits that command a premium price. An ever-growing list of crops with additional new and valuable traits is anticipated over the course of the next several years. Much of this is the result of research and development within the multinational companies (i.e., university research is no longer seen by some as the prime source of new agronomic and value-added traits).

It was the view of many workshop participants that many consumers in developed countries know little about how their food is produced, processed, and distributed. Thus, when questions of food safety arise, such as those in Europe associated with "mad cow" disease, consumers are ill educated and ill prepared to cope with important decisions. When something new appears, like "genetically modified" foods, these same consumers again are not fully prepared to decide if such foods are good for them and their families. Provision of accurate, easily understood information regarding genetically modified foods to a broad section of the public was seen as an important step toward potential acceptance of these foods by society. No quick and easy means for accomplishing this were identified. Nonetheless, there was a strong admonition that emphasis be placed on research (especially publicly funded research) that would quickly lead to products easily perceived by consumers as products they liked and would be demanded in the marketplace.

3. Farmers are being squeezed:

Access to fewer suppliers for inputs, licensing of needed technologies and traits, higher input costs for seeds and other supplies, lower prices for commodity crops and livestock, and increased complexity of agricultural markets are but a few of the challenges faced by farmers in North America, Europe, and the remainder of the developed world.

Biotechnology was viewed by group members as providing at least short-term promise of specialty crops and niche markets for farmers willing to take the risks associated with producing new crops under specified conditions. It was concluded that most often this would be accomplished through production by farmers under contract to a specific company that controls access to the germplasm being used. In the long term, contract farming was viewed as raising significant concerns regarding the ability of the farmer to operate a reasonably profitable, independent business — especially if there was strong dependence on one company as an avenue to the marketplace. The plight of poultry producers was the most commonly cited example of a paradigm not to be adopted. The pressure on agricultural producers to continue to enlarge operations for the sake of efficiency and uniformity was noted as a growing concern for farmers. Under such conditions, it was thought they might well find their communities and social support systems (e.g., schools, health care facilities, banks, churches, retail stores, etc.) shrinking beyond that which is acceptable for them and their families.

4. The marketplace is changing:

The advent of genetically engineered commodity crops and specialty crops is changing the dynamics of production, marketing, and distribution of agricultural products. Identity-preserved crops demand separate handling facilities. Potentially, this also may apply to genetically modified grains and processed foods destined for particular countries or regions. The “opportunity” for foreign countries to establish protectionist policies based either on fact or on misinformation was a significant concern to a number of those participating in the Workshop sessions.

Specialty crops have the potential to provide a segment of the farming community with greater sources of income and business opportunities unless, as mentioned earlier, contract farming leads to marginal returns and decreased independence. The Workshop participants considered how farmers could protect themselves from the perceived negative aspects of industrial consolidation in agriculture. Greater collective action through purchasing and marketing groups, farm organizations, and other organizations with significant economic and political clout were viewed as among the few options open to farmers and ranchers who wished to maintain a reasonably profitable business and satisfactory life style. Another possibility is farmer/grower cooperatives with ownership of value-added processing.

5. New scientific and business opportunities abound:

A strong majority of Workshop participants saw a continued flow of new discoveries in plant and animal biology that will have potential to be translated into new products of agriculture biotechnology. The sequencing of genomes for many crop plants and farm animals in the next few years will set the stage for the emergence of functional genomics techniques. These techniques will speed additional scientific discoveries and may lead, ultimately, to a more holistic understanding of how cells and organisms coordinate a myriad of chemical reactions and physiological functions. This knowledge will prove powerful in developing more and more sophisticated approaches for controlling production in plants and animals used for agriculture throughout the world. Conferees voiced concern that such “promise” could be achieved in the near future only through increased emphasis on, and funding of, university research. Indeed, several participants contended that intellectual protection of genes is fueling industrial consolidation and inhibiting progress by public sector researchers. Nonetheless, others predicted for those with the foresight, resources, and energy to exploit the newly created knowledge, there will continue to be exceptional opportunities. Finally, in the view of many participants in the NABC Workshops, it is imperative that a set of mechanisms be put in place to help ensure fair and equitable access to the fruits of this technology for food producers, input suppliers, distributors, and all persons in all countries.

PART III

KEYNOTE ADDRESSES

Securing and Sustaining Adequate World Food Production for the Third Millennium

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The doubling of grain production and tripling of livestock production since the early 1960s has resulted in a global food supply sufficient to provide adequate energy and protein for all. However, about 820 million people lack access to sufficient food to lead healthy and productive lives, and around 185 million children are seriously underweight for their age. At the close of the 20th century, astonishing advances in agricultural productivity and human ingenuity have not yet translated into a world free of hunger and malnutrition.

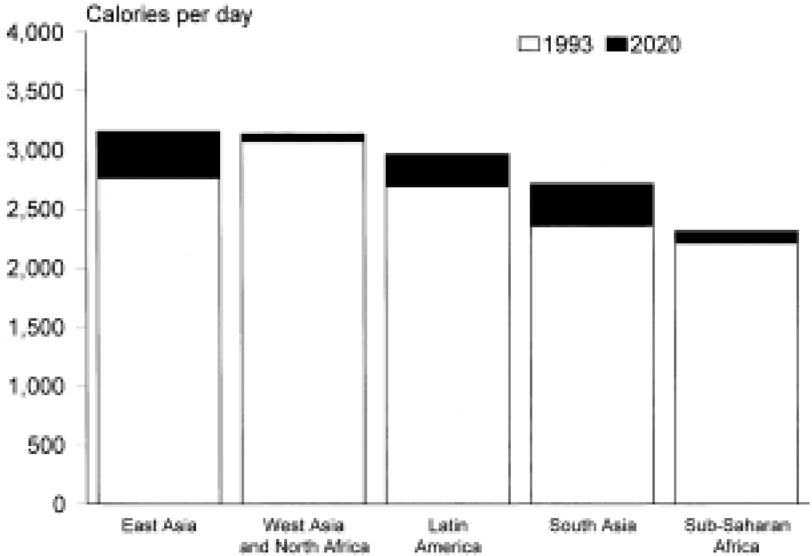
What are the prospects for global food security in the 21st century? Will there be enough food to meet the needs of current and future generations? Can, and will, global food security be attained or will food surpluses continue to co-exist with widespread hunger and malnutrition?

OUTLOOK FOR GLOBAL FOOD SECURITY

Projections of food production and consumption to the year 2020 offer some signs of progress. But prospects of a food-secure world — a world in which each and every person is assured continual access to the food required to lead a healthy and productive life — remain bleak if the global community continues with business as usual.

Worldwide, per capita availability of food is projected to increase around seven percent between 1993 and 2020, from about 2,700 calories per person per day in 1993 to about 2,900 calories. Increases in average per capita food availability are expected in all major regions. China and East Asia are projected to experience the largest increase, and West Asia and North Africa the smallest (Figure 1). The projected average availability of about 2,300 calories per person per day in Sub-Saharan Africa is just barely above the minimum required for a healthy and productive life. Since available food is not equally distributed to all,

Figure 1—Daily per capita calorie availability, 1993 and 2020



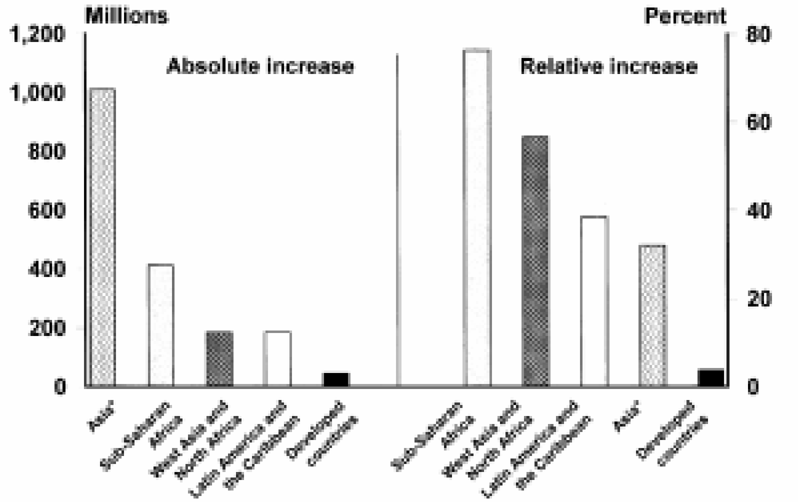
Source: IFPRI IMPACT simulations.

a large proportion of the region's population is likely to have access to less food than needed.

Demand for food is influenced by a number of forces, including population growth and movements, income levels and economic growth, human resource development, and lifestyles and preferences. Almost 80 million people are likely to be added to the world's population each year during the next quarter century, increasing world population by 35 percent from 5.69 billion in 1995 to 7.67 billion by 2020 (UN 1996). More than 95 percent of the population increase is expected in developing countries, whose share of global population is projected to increase by 79 percent in 1995 to 84 percent in 2020. Over this period, the absolute population increase will be highest in Asia, but the relative increase will be greatest in Sub-Saharan Africa, where the population is expected to almost double by 2020 (Figure 2).

At the same time, urbanization will contribute to changes in the types of food demanded. Much of the population increase in developing countries is expected in the cities; the developing world's urban population is projected to double

Figure 2—Absolute and relative population increases, 1995–2020



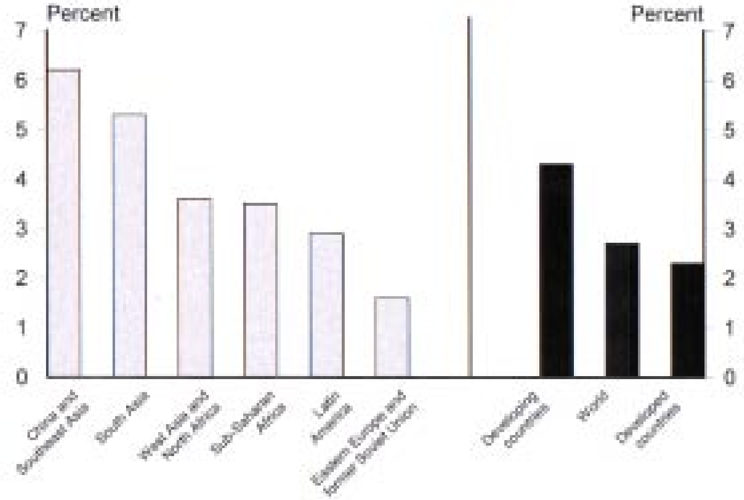
Source: United Nations Population Division, *World Population Prospects: The 1998 Revisions* (Electronic version, 1998).
Notes: Medium-variant projections. * Asia includes developing Oceana, Afghanistan, former Soviet Central Asia, and Iran; excludes Japan.

over the next quarter century to 3.6 billion (UN 1995). Urbanization profoundly affects dietary and food demand patterns: The increasing opportunity cost of women's time, changes in food preferences caused by changing lifestyles, and changes in relative prices associated with rural-urban migration lead to more diversified diets with shifts from basic staples such as sorghum, millet, and maize to other cereals such as rice and wheat that require less preparation and to milk and livestock products, fruits and vegetables, and processed foods.

People's access to food depends on income. Currently, more than 1.3 billion people are absolutely poor, with incomes of a dollar a day or less per person, while another two billion people are only marginally better off (World Bank 1997a). Income growth rates have varied considerably between regions in recent years, with Sub-Saharan Africa and West Asia and North Africa struggling with negative growth rates, while East Asia was experiencing annual growth rates exceeding seven percent (World Bank 1997b). Prospects for economic growth during the next quarter century appear favorable, with global income growth projected to average 2.7 percent per year between 1993 and

2020 (Figure 3). The projected income growth rates for developing countries as a group is almost double those for developed countries. Growth rates are projected to be lowest in Eastern Europe and the former Soviet Union. Even Sub-Saharan Africa is expected to experience positive per capita income growth between 1993 and 2020, although it will be quite low. However, unless significant and fundamental changes occur in many developing countries, disparities in income levels and growth rates both between and within countries are likely to persist, and poverty is likely to remain entrenched in South Asia and Latin America and to increase considerably in Sub-Saharan Africa.

Figure 3—Projected average annual income growth rates, 1993–2020

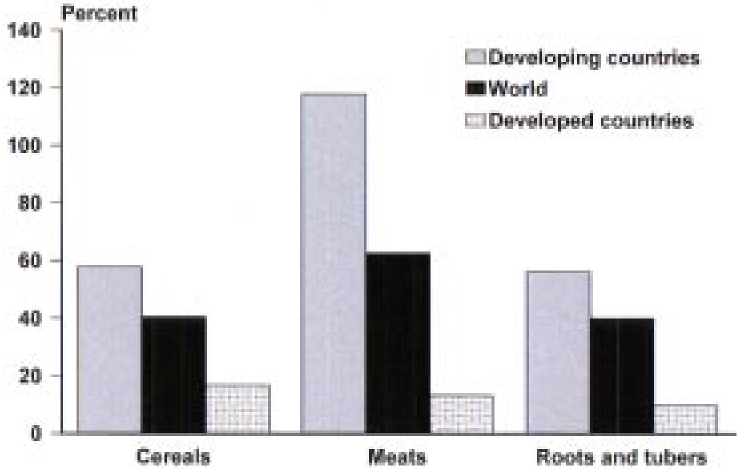


Source: IFPRI IMPACT simulations.

Under the baseline scenario, IFPRI IMPACT projects global demand for cereals to increase by 41 percent between 1993 and 2020 to reach 2,490 million metric tons, for meat demand to increase by 63 percent to 306 million tons, and for roots and tubers demand to increase by 40 percent to 855 million tons (Figure 4).

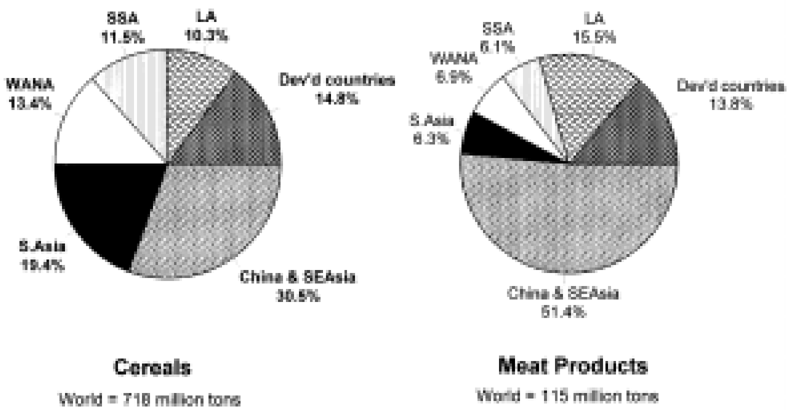
Developing countries will drive increases in world food demand. With an expected 40 percent population increase and an average annual income growth rate of 4.3 percent, developing countries are projected to account for most of the increase in global demand for cereals and meat products between 1993 and 2020 (Figure 5).

Figure 4—Increase in total demand for cereals, meats, and roots and tubers, 1993–2020



Source: IFPRI IMPACT simulations.

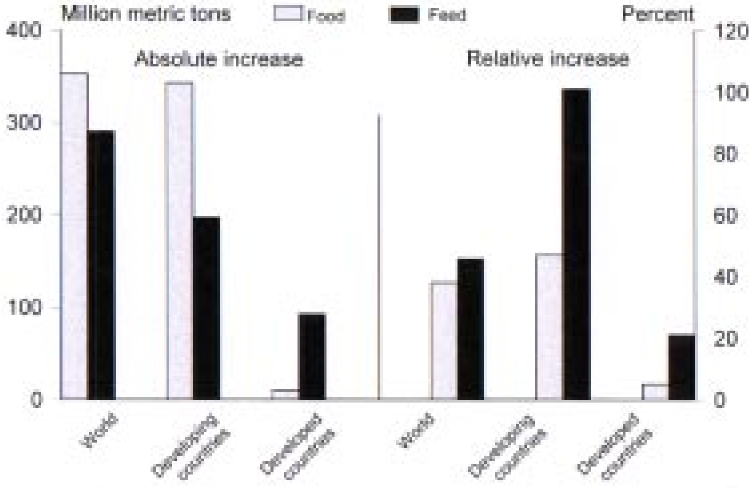
Figure 5—Increase in global demand for cereals and meat products, 1993-2020



Source: IFPRI IMPACT simulations.

Demand for cereals for feeding livestock will increase considerably in importance in coming decades, especially in developing countries, in response to strong demand for livestock products. Between 1993 and 2020, developing countries' demand for cereals for animal feed is projected to double while demand for cereals for food for direct human consumption is projected to increase by 47 percent (Figure 6). By 2020, 24 percent of the cereal demand in developing countries will be for feed, compared with 19 percent in 1993. However, in absolute terms, the increase in cereal demand for food will be higher than for feed. In developed countries, the increase in cereal demand for feed will outstrip the increase in cereal demand for food in both absolute and relative terms.

Figure 6—Absolute and relative increase in food and feed demand for cereals, 1993–2020

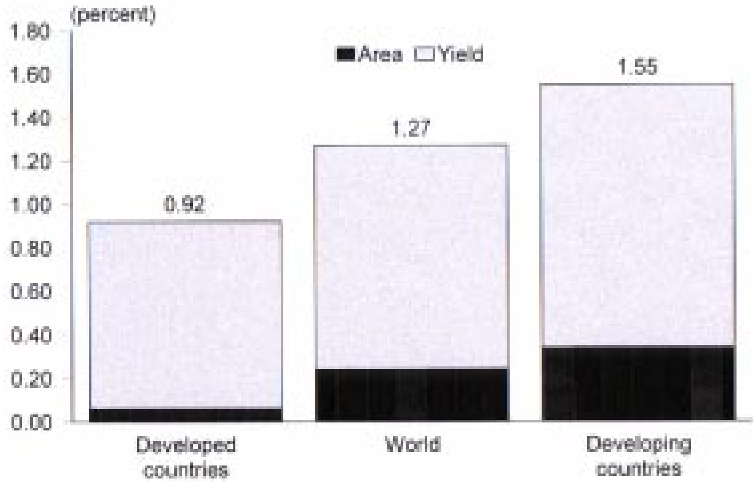


Source: IFPRI IMPACT simulations.

How will the expected increases in cereal demand be met? Primarily by productivity increases; increases in cultivated area will contribute less than 20 percent of the increase in global cereal production between 1993 and 2020 (Figure 7). Most of the growth in cereal area will be concentrated in the relatively low productivity cereals in Sub-Saharan Africa. There will be some expansion in Latin America, but cereal area will remain virtually stagnant in Asia.

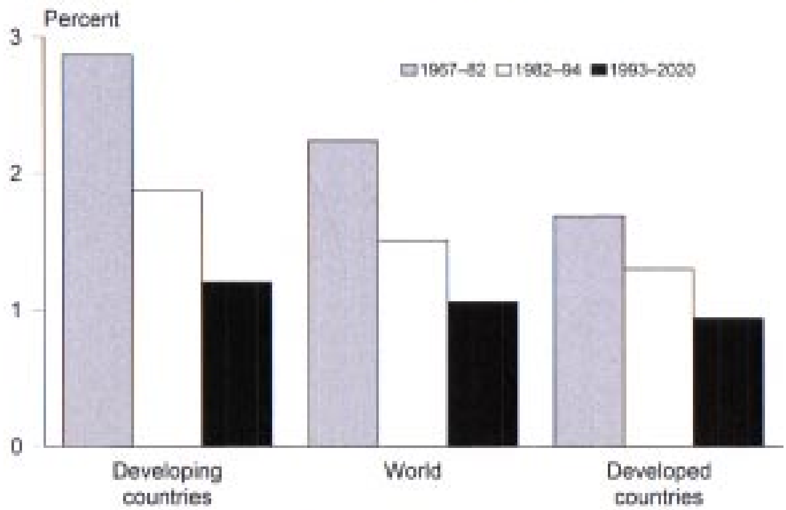
Since growth in cultivated areas is unlikely to contribute much to future production growth, the burden of meeting increased demand for cereal rests on improvements in crop yields. However, the annual increase in yields of the major cereals is projected to slow down during 1993–2020 in both developed and developing countries (Figure 8). This is worrisome given that yield growth

Figure 7—Growth in cereal production, 1993-2020



Source: IFPRI IMPACT simulations.

Figure 8—Annual growth in cereal yields, 1967–82, 1982–94, and 1993–2020



Source: IFPRI IMPACT simulations.

rates were already on the decline. The two key reasons for slow cereal yield growth rates are as follows:

(1) In regions where input use is high, such as Asia, farmers are approaching economically optimum yield levels, making it more difficult to sustain the same rates of yield gains; and

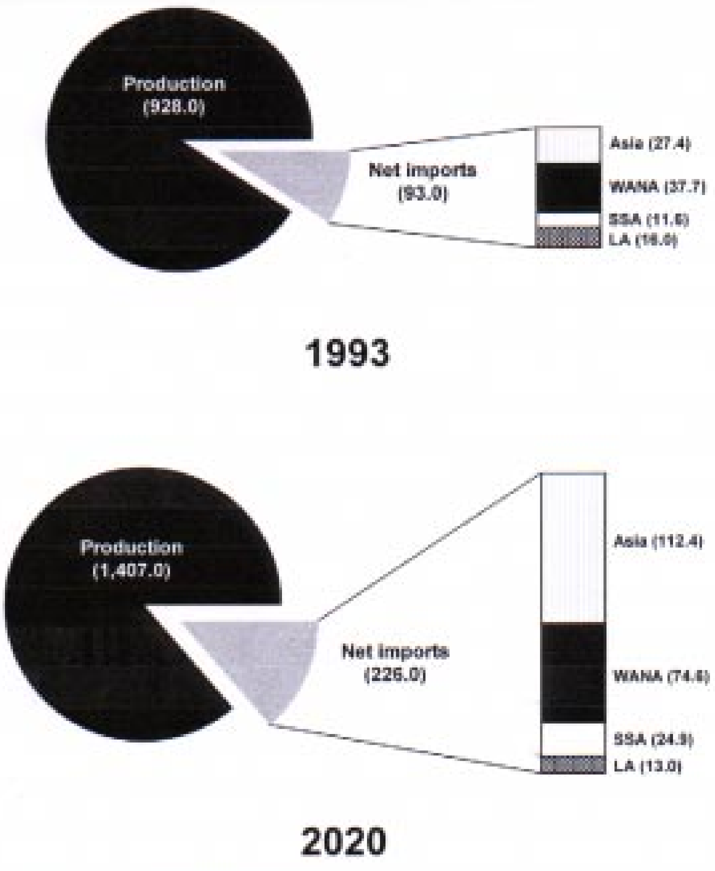
(2) declining world cereal prices are causing farmers to switch from cereals to other, more profitable crops and are causing governments to slow their investment in agricultural research and irrigation and other infrastructure.

With the projected slowdowns in area expansion and yield growth, cereal production in developing countries as a group is also forecast to slow to an annual rate of 1.5 percent during 1993–2020, compared with 2.3 percent during 1982–94. This figure is still higher, however, than the one percent annual rate of growth projected for developed countries during 1993–2020.

Food production will not keep pace with demand in developing countries, and an increasing portion of the developing world's food consumption will have to be met by imports from the developed world. The proportion of cereal demand that is met through net imports is projected to rise from nine percent in 1993 to 14 percent in 2020 (Figure 9). As a group, developing countries are projected to more than double their net imports of cereals (the difference between demand and production) between 1993 and 2020 (Figure 10). With the exception of Latin America, all major developing regions are projected to increase their net cereal imports. The quadrupling of Asia's net imports will be driven primarily by rapid income growth, while the 150 percent increase forecast for Sub-Saharan Africa will be driven primarily by its continued poor performance in food production. The United States is forecast to provide almost 60 percent of the cereal net imports of developing countries in 2020, the European Union about 16 percent, and Australia about 10 percent. The IFPRI projections indicate that long-term trends in real food prices will be falling slightly (Figure 11).

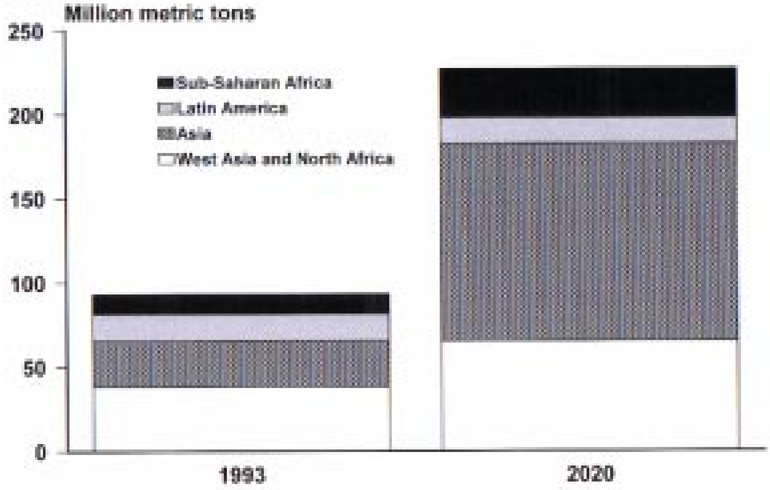
With continued population growth, rapid income growth, and changes in lifestyles, demand for meat is projected to increase by 2.8 percent per year during 1993–2020 in developing countries and by 0.5 percent per year in developed countries. While per capita demand for cereals is projected to increase by only eight percent, demand for meat will increase by 43 percent. The increase in per capita meat demand will be largest in China and smallest in South Asia; by 2020, Chinese per capita consumption of meat will be eight times that of South Asia (Figure 12). Meat production is expected to grow by 2.7 percent per year in developing countries during 1993–2020 (compared with 5.9 percent during 1982–94) and by 0.8 percent in developed countries (compared with 0.9 percent during 1982–94). Despite high rates of production growth, developing countries as a group are projected to increase their net meat imports 20-fold, reaching 11.5 million tons in 2020 (Figure 13). Latin America

Figure 9—Growing importance of net imports to meet developing-country cereal demand, 1993 and 2020
(millions metric tons)



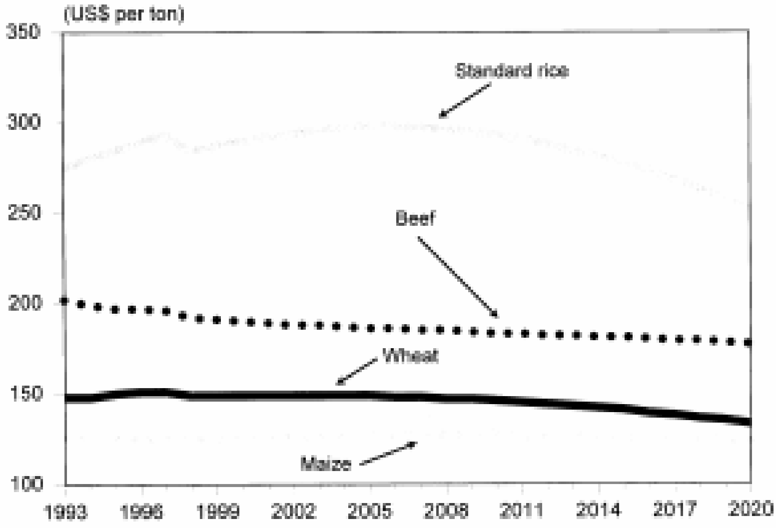
Source: IFPRI IMPACT simulations.

Figure 10—Net cereal imports of major developing regions, 1993 and 2020



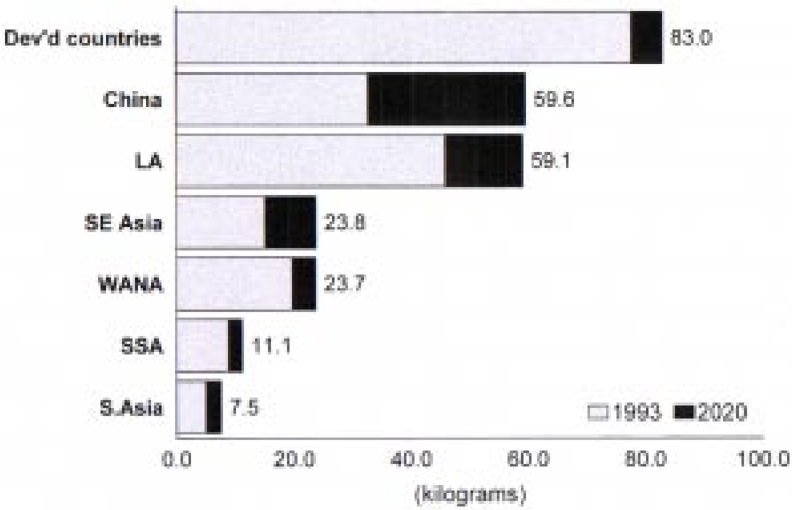
Source: IFPRI IMPACT simulations.

Figure 11—World food prices, 1993–2020



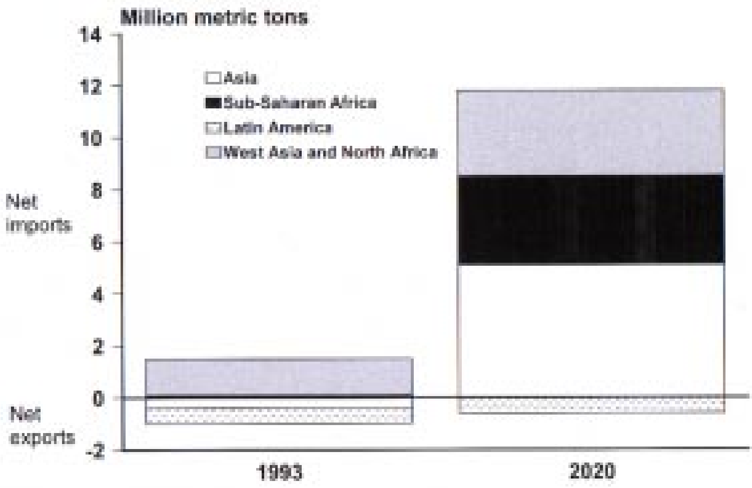
Source: IFPRI IMPACT simulations.
Note: Beef prices are per 100 kilograms.

Figure 12—Per capita demand for meat products, 1993-2020



Source: IFPRI IMPACT simulations.

Figure 13—Net trade in meat by major developing regions, 1993 and 2020



Source: IFPRI IMPACT simulations.

will continue to be a net exporter of meat, but Asia will switch from being a small net exporter to a large net importer.

Net imports are a reflection of the gap between production and market demand. For many of the poor, the gap between food production and nutritional needs is likely to be even wider than that between production and demand, because many of these people are priced out of the market, even at low food prices, and are unable to exercise their demand for needed food. The higher-income developing countries, notably those of East Asia, will be able to fill the gap between production and demand through commercial imports, but the poorer countries may be forced to allocate foreign exchange to other uses and thus might not be able to import food in needed quantities. It is the latter group of countries, including most of those in Sub-Saharan Africa and some in Asia, that will remain a challenge and require special assistance to avert widespread hunger and malnutrition.

Emerging Issues in Global Food Security

Volatile Cereal Prices

Concerns are growing that cereal prices may be more volatile than in the past (FAO 1996b). Reduced stocks and uncertainties associated with developments in China and the former Soviet Union, and increasing weather fluctuations among other factors, could increase price instability. On the other hand, market liberalization in developing countries, policy reform in developed countries, and more consistent and transparent stock-holding and trade policies will make producers more responsive to price changes and could reduce price instability. How these factors play out will determine whether cereal prices will be more volatile in coming years. In addition to price fluctuations in the international market, many low-income food-insecure developing countries suffer from large domestic price fluctuations owing to inadequate markets, poor roads and other infrastructure, and inappropriate policies and institutions. Even small changes in production resulting from better or poorer growing conditions may cause large fluctuations in food prices.

Feeding China

With one-fifth of the world's population and one of the fastest-growing and most rapidly transforming economies in the world, China has the potential to significantly affect global food markets depending on the extent of its future demand for cereals, its capacity to meet these demands through production, and the degree to which it enters world markets to satisfy its unmet needs (Rozelle and Rosegrant 1997). Views on the size and dominance of China's food economy in the 21st century vary widely, with some forecasting that China will be a major cereal exporter (Chen and Buckwell 1991; Mei 1995) and others cautioning that China might become a major cereal importer, if not the world's largest importer (Garnaut and Ma 1992; Carter and Funing 1991; Brown 1995). IMPACT projections indicate that, in the baseline scenario, total cereal demand in China will increase by 42 percent, to 490 million tons, between 1993 and 2020, and cereal production by 31 percent, to 449 million tons. At 41 million tons, China's net cereal imports in 2020 would represent 18 percent of the developing world's projected net cereal imports. While sizable, China's projected imports are unlikely to pose an intolerable burden on the global food situation. For meat, China's production is projected to almost keep up with increases in demand. A predicted increase in demand of 132 percent between 1993 and 2020 would result in net imports of only 0.3 million tons — three percent of the developing world's projected net imports in 2020.

Alternative simulations suggest that only with extraordinarily rapid income growth, severe resource degradation, and failure to invest in agriculture would China's net cereal imports increase substantially and have a significant effect on world cereal prices (Rozelle and Rosegrant 1997). China is already a significant player in world food markets and is likely to become increasingly important. However, it does not represent a major threat to world food markets.

Feeding India

With a population of 930 million in 1995, India is the second most populous country in the world after China (UN 1996). Furthermore, population growth in India continues to be high and India's population is likely to exceed China's by 2020. Like China more than a decade ago, India is in the midst of major economic reform. If it succeeds, incomes in India will rise much faster than they have in recent decades, with profound effects on food demand and food security. In the IMPACT baseline scenario, India is projected to have an average annual economic growth rate of 5.5 percent during 1993–2020.

As incomes increase, will Indians greatly increase their consumption of livestock products, or will they remain more or less vegetarian, as India's history and cultural traditions would suggest? Views are mixed. In the baseline scenario, demand for livestock products is projected to increase by 4.6 million tons between 1993 and 2020 to 8.5 million tons (the corresponding increase in meat demand in China is 51 million tons to 89 million tons in 2020). Given the extremely low initial levels of livestock consumption in India, rapid growth in absolute demand for livestock would require a dramatic change in eating patterns. In a scenario modeling the effects of such a change in Indian diets, India's demand for meat products is forecast to increase almost 10-fold from 3.8 million tons in 1993 to 36.4 million tons in 2020. This increase in demand would have to be met through trade, as meat production is not projected to increase beyond the 8.5 million tons shown in the baseline scenario for 2020. India's projected net meat imports of 28 million tons under this scenario are a far cry from the less than 0.5 million tons forecast in the baseline scenario. This increase in Indian net imports would increase world meat prices by 21 percent in 2020 relative to the baseline scenario and by 13 percent relative to 1993. If India attempts to meet potentially large increases in livestock demand through domestic livestock production rather than imports, thereby raising demand for feed grain, implications for global livestock and cereal trade and prices would be dramatically different from those predicted by the scenario that relies primarily on livestock imports to meet demand.

The Transition in Eastern Europe and the Former Soviet Union

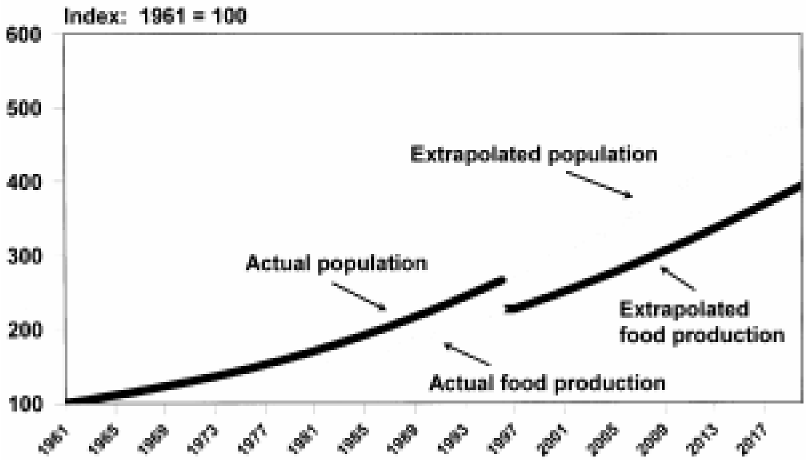
The fall of the Berlin Wall and the associated political changes in Eastern Europe and the former Soviet Union brought great promise for rapid economic growth in that part of the world. Many projected that food production in a number of countries affected, including Ukraine and the Russian Federation, would expand rapidly and significantly, causing Eastern Europe and the former Soviet Union to switch quickly from being net importers of grain to being significant net exporters (Tyers 1994). Although net grain imports by the former Soviet Union have fallen dramatically, this optimistic scenario has not materialized (FAO various years). There is still a great deal of uncertainty regarding future food production and demand in those countries.

IMPACT's baseline scenario projects that Eastern Europe and the former Soviet Union will become major net exporters of cereal by 2020, on the order of about 33 million tons. Cereal production is projected to increase by almost 40 percent between 1993 and 2020 to 341 million tons, while demand is projected to increase by 12 percent to 308 million tons. However, if incomes in Eastern Europe and the former Soviet Union grow faster than the baseline projection and crop productivity increases at a slower pace than forecast, these regions would remain net importers. For example, with an increase in income growth of 30 percent and a drop in production growth of two-thirds, crop production would increase by only 12 percent between 1993 and 2020 to 278 million tons while demand would increase to 304 million tons, resulting in net cereal imports of 26 million tons in 2020 — a very different outcome. Slow increases in crop production in Eastern Europe and the former Soviet Union could cause world cereal prices to be higher in 2020 relative to the baseline scenario. Changes in cereal production and demand in Eastern Europe and the former Soviet Union can have significant effects on the world food situation, but it would take very large declines in productivity growth in this region to dramatically drive up cereal prices.

Fragile Recovery in Sub-Saharan Africa

In Sub-Saharan Africa, the population growth rate has exceeded the rate of growth in food production since the early 1970s and the gap is widening, resulting in declining per capita food production (Figure 14). Simple extrapolations of the trends in population and food production growth since

Figure 14—Actual and extrapolated population and food production indexes for Sub-Saharan Africa, 1961–2020



Source: Data for 1961–96: Food and Agriculture Organization of the United Nations, FAOSTAT database, <http://faostat.fao.org> (accessed August and September 1997); extrapolations for 1997–2020: authors' estimates.

1961 show a further increase in the gap between population and food production. This is exactly the gap predicted by Malthus.[1] However, several recent developments suggest that Malthus' shadow over Sub-Saharan Africa could finally be waning.

First, Malthus' predictions grossly underestimated the potential of productivity-increasing technology. Where such technology has been effectively developed and utilized, such as in Asia, food production has expanded much faster than population. In Sub-Saharan Africa, the potential of appropriate productivity-increasing technology has yet to be realized. Maize yields for Africa and Asia were virtually the same in 1961, but since then they have tripled in Asia and quintupled in China while they have remained stagnant at around one ton per hectare in Africa (FAO 1997a; Byerlee and Eicher 1997). However, there are encouraging signs that productivity-increasing technology is beginning to accelerate yield growth of African food crops (CGIAR 1997).

Second, after a number of years of low or negative growth, Sub-Saharan Africa is experiencing economic recovery. However, this economic recovery is fragile. Some of the factors that contributed to the recovery are short term in nature and cannot be expected to persist; these include higher commodity prices and favorable weather conditions. Other factors, such as policy reforms, an improved macroeconomic environment, and social and political stability, can have a more lasting effect on economic growth, if properly nurtured. Moreover, economic growth rates will have to be substantially higher if they are to make a dent in Sub-Saharan Africa's poverty. Per capita incomes have fallen so much that even if economic growth were to continue at the current pace (about five percent per year), it would still take at least a decade to recover to the levels prevailing in 1980 (CGIAR 1997).

If Malthus is to be proven wrong in Sub-Saharan Africa, a much greater effort must be made to ensure that farmers have access to appropriate production technology and that policies are conducive to expanded productivity in staple food crops. Besides new initiatives and expanded support for agricultural development, more must also be done to reduce population growth. Sub-Saharan Africa's annual population growth is projected to decline between 1993 and 2020. Yet the number of people added to the region's population every year is projected to increase until at least 2020, a consequence of the past high rates of population increases. Moreover, Sub-Sahara's projected annual population growth rate of 2.33 percent during 2015–2020 will be more than double the growth rates in other regions (UN 1996). Population growths of this magnitude will severely constrain efforts to increase income and improve welfare, while at the same time it will greatly increase the need for food.

Weather Fluctuations and Climate Change

With the recent resurgence of El Niño, followed by the relatively weaker La Niña, major weather fluctuations are under way or imminent in many parts of the world. These weather fluctuations could lead to sizable food production shortfalls and deterioration in food security in many parts of the world. The 1982–83 El Niño caused severe flooding in Latin America, droughts in parts of Asia, declines in fish stocks, and other weather-related damage estimated at over $10 billion (FAO 1997a, 1997b). The 1991–92 El Niño resulted in severe drought in Southern Africa that caused cereal production to drop by 60 percent or more in several countries, and imports and food aid had to increase to meet more than half of the cereal consumption in at least five countries (Pinstrup-Andersen, Pandya-Lorch, and Babu 1997). The 1997–98 El Niño far surpassed the last two major El Niños in severity, causing severe drought in Southeast Asia, flooding in the Andean countries of South America, and drought in a wide swath across Eastern Africa, and in general diminishing agricultural production around the globe. El Niño adds a major element of uncertainty to agricultural production and livelihoods around the world. And concerns are growing that El Niños may become more frequent and more severe in the fuure as a result of climate changes.

Although the trend of global warming is becoming increasingly clear, its effects on food production are still uncertain. Some research suggests that growing conditions will deteriorate in current tropical areas (where many of the developing countries are located) and improve in current temperate areas (where many of the developed countries are located) (Rosenzweig and Parry 1994; Fischer et al. 1996). However, effects on productivity and production will occur over a long period of time and will be very small in any given year. Therefore, it is reasonable to believe that policies and technologies can be developed to effectively prevent or counter the negative productivity effects of global warming. Failure by the public sector to act, and failure by the market and the private sector to respond, could result in significant long-term effects on food supply. Such a scenario might include reduced food production in tropical and subtropical countries and increased production in temperate countries. Whether these opposing effects will cancel each other out through expanded international trade, with little or no effect on total world food supply, is yet to be determined.

Growing Water Scarcity

Unless properly managed, fresh water may well emerge as the key constraint to global food production. While supplies of water are adequate in the aggregate to meet demand for the foreseeable future, water is poorly distributed across countries, within countries, and between seasons. And, with a fixed amount of renewable water resources to meet the needs of a continually increasing population, per capita water availability is declining steadily. Today, 28 countries with a total population exceeding 300 million people face water stress;[2] by 2025, their number could increase to about 50 countries with a total population of about three billion people (Rosegrant, Ringler, and Gerpacio 1997; Population Action International 1995).

Demand for water will continue to grow rapidly. Since 1970, global demand for water has grown by 2.4 percent per year (Rosegrant, Ringler, and Gerpacio 1997). Projections of water demand[3] to 2020 indicate that global water withdrawals will increase by 35 percent between 1995 and 2020 to reach 5,060 billion cubic meters. Developed countries are projected to increase their water withdrawals by 22 percent, more than 80 percent of the increase being for industrial uses. Developing countries are projected to increase their withdrawals by 43 percent over the same period and to experience a significant structural change in their demand for water, reducing the share for agricultural uses.

The costs of developing new sources of water are high and rising, and nontraditional sources such as desalination, reuse of wastewater, and water harvesting are unlikely to add much to global water availability, although they may be important in some local or regional ecosystems. So how can the rapid increases in water demand be met? The rapidly growing domestic and industrial demand for water will have to be met from reduced use in the agriculture sector, which is by far the largest water user, accounting for 72 percent of global water withdrawals and 87 percent of withdrawals in developing countries in 1995 (Rosegrant, Ringler, and Gerpacio 1997). Reforming policies that have contributed to the wasteful use of water offers considerable opportunity to save water, improve efficiency of water use, and boost crop output per unit of water. Required policy reforms include establishing secure water rights for users; decentralizing and privatizing water management functions; and setting incentives for water conservation, including markets in tradable water rights, pricing reform and reduction in subsidies, and effluent or pollution charges (Rosegrant 1997). Failure to address the gap between tightening supplies and increasing demand for water could significantly slow growth in food production.

Escalating Concerns about Food Safety

Concerns about food safety are not new. Since time immemorial, human beings have worried about whether they have sufficient food to eat and whether the food they consume is safe and healthy. However, food safety concerns are escalating, particularly in industrialized countries, as evident by the growing demand for organic foods; by the strengthening public backlash against genetically modified organisms; by the extraordinarily high level of interest by consumers in the precise origin and modes of producing and processing the food they consume; and by the proliferation of regulations of producing, processing, storing, and transporting foods. There have been a series of well-publicized outbreaks of food-borne illnesses and massive food recalls in recent years, particularly in the United States. In developing countries, however, where food- and water-borne health risks are a major cause of illness and death, particularly among infants and children, food safety concerns do not seem to have garnered increased attention.

Yet, developing countries could be significantly affected by the increased concerns in industrialized countries in at least two major ways: first, because exports of their food commodities could be exposed to new and more demanding food safety standards partly through changes in the Codex Alimentarius and partly through unilateral demands by importers (thus, food safety requirements may become a hindrance to developing countries for realizing benefits from exports, either because unreasonable standards cannot be met or because food safety would be used as a nontariff barrier by importing countries); and second, because changing attitudes toward and legislation for food safety in industrialized countries could spill over into developing countries without due attention to local conditions and constraints and influence, among other things, availability of and access to food (for example, legislation to curtail or prohibit the use of fertilizers or chemical plant protection methods could have a negative effect on food security by increased unit costs of productions).

THE ROLE OF BIOTECHNOLOGY

Modern science offers humankind a powerful instrument to assure food security for all. Through enhanced knowledge and better technologies for food and agriculture, science has contributed to astonishing advances in feeding the world in recent decades. If we are to produce enough food to meet increasing and changing food needs, to make more efficient use of land already under cultivation, to better manage our natural resources, and to improve the capacity of hungry people to grow or purchase needed food, we must put all the tools of modern science to work.

Modern agricultural biotechnology is one of the most promising developments in modern science. Used in collaboration with traditional or conventional breeding methods, it can raise crop productivity, increase resistance to pests and diseases, develop tolerance to adverse weather conditions, improve the nutritional value of some foods, and enhance the durability of products during harvesting or shipping. With reasonable biosafety regulations, this can be done with little or no risk to human health and the environment. Yet little modern agricultural biotechnology research is taking place in or for developing countries. Most such research is occurring in private firms in industrialized countries, focuses on the plants and animals produced in temperate climates, and aims to meet the needs of farmers and consumers in industrialized countries. It is essential that agricultural biotechnology research be relevant to the needs of farmers in developing countries and to conditions in those countries, and that the benefits of that research are transmitted to small-scale farmers and consumers in those countries at affordable prices. Otherwise, developing countries will not only fail to share in the benefits of agricultural biotechnology, but will be seriously hurt as industrialized countries improve their agricultural productivity.

The attitude toward risk among the non-poor in both industrialized and developing countries is a constraint to the use of agricultural biotechnology in and for developing countries. Among people whose children are not starving, considerable resistance to agricultural biotechnology has arisen on the grounds that it poses significant new ecological risks and that it has unacceptable social and economic consequences. Although no ecological calamities have occurred, some people fear that transgenic crops will develop troublesome new weeds or threaten crop genetic diversity. Of course, any new products that pose such risks should be carefully evaluated before they are released for commercial development. But we should not forget that by raising productivity in food production, agricultural biotechnology will reduce the need to cultivate new lands and could therefore actually help conserve biodiversity and protect fragile ecosystems. Developing countries should be encouraged to adopt regulations that provide a reasonable measure of biosafety without crippling the transfer of new products into the field.

Public pressure in Western Europe is likely to move governments to introduce legislation that will constrain or prohibit full use of the opportunities offered by genetic engineering and other tools of modern science for food production and processing. There is a trend in several countries toward seeing the application of science to agriculture as part of the problem rather than part of the solution. Combined with this view is a failure to appreciate the need for productivity increases in food production. While the application of modern science, including genetic engineering and other biotechnology research, to solving human health problems is applauded and encouraged, there is an increasing suspicion that the application of such scientific methods to food production and processing will compromise agricultural production systems, food safety, and the health of current and future generations. In fact, modern science methods, including molecular biology-based methods, offer tremendous opportunities for expanding food production, reducing risks in food production, improving environmental protection, and strengthening food marketing in developing countries. Should legislation constraining modern agricultural science spread within the developed countries, the consequences for long-term food supplies in developing countries could be severe, partly because of reduced exports by developed countries and partly because similar policies might be adopted in developing countries as well.

As for the social and economic consequences of biotechnology, some are concerned that large-scale and higher-income farmers will be favored because they will have earlier access to and derive greater benefits from agricultural biotechnology. These concerns are remarkably similar to those raised about the Green Revolution. Whatever the shortcomings, real or alleged, of the Green Revolution, it did avert widespread starvation and helped many millions of people to escape hunger once and for all. With more pro-poor institutions and policies, many more poor people could benefit. Similarly, agricultural biotechnology can contribute to feeding many more people in a sustainable way. The new technologies, through appropriate policies, can be made accessible to small-scale farmers. Instead of rejecting the solutions offered by science, we should change policies to assure that the solutions benefit the poor.

The global community must keep its sights set on the goal of assuring food security for all. Condemning biotechnology for its potential risks without considering the alternative risks of prolonging the human misery caused by hunger, malnutrition, and child death is unwise and unethical. In a world where the consequence of inaction is death of thousands of children, we cannot afford to be philosophical and elitist about any part of a possible solution, including agricultural biotechnology. Modern science by itself will not assure food for all, but without it the goal of food security for all cannot be achieved.

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ENDNOTES

1. Thomas Malthus’ basic argument was that the world’s natural resources could not assure expansions in food supply that would match population growth. Region after region has disproved his prediction. While Malthus argued that the population would grow geometrically and food production would grow arithmetically, the extrapolation shown in Figure 14 are based on a nonlinear regression. Such a function showed a better fit than linear functions for either of the two variables. Extrapolations based on Malthus’s argument would result in a larger gap.

2. Their annual internal renewable water resources are less than 1,600 cubic meters per person per year.

3. Approximated by water withdrawals because of a lack of consistent data on consumptive use of water at national or regional levels.

Using Biotechnology to Enhance and Safeguard the Food Supply: Delivering the Benefits of the Technology

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The issues facing global agriculture today are issues that have been with us for a long time: Feeding an increasing world population, preserving and protecting the environment, ensuring a safe and healthful food supply, and creating value and economic viability. Against this timeless backdrop, the real challenge for biotechnology is to determine how to best utilize these new technological tools to create sustainable solutions for enhancing and safeguarding our food supply.

The factors that will determine the success of biotechnology in meeting these challenges are technological, economic, political, and social. Safe and effective implementation of the technology is the basic requirement, but this needs to be coupled with sound economics, development of markets, continued development of appropriate regulatory frameworks, and, above all, the delivery of products that are valued and used by consumers.

New crops from biotechnological approaches have already demonstrated their value to a wide variety of customers, and have proven the technology's ability to increase yields, enhance the environment, and improve farming practices. The current generation of herbicide resistant and insect resistant crops provide examples of how this technology can be used to decrease chemical usage, allow for improved tillage practices, ease the work of the farmer, and provide for profitable business activities for many. More recently, the technology has started to provide improvements in the general quality of harvested crops, with improved nutritional and health benefits.

The focus on these harvested attributes of the crop plants has caused recognition that value can be added through this technology at many points of the food value chain. This chain is enormous on any basis — geography, people involved, infrastructure, and value. Starting with the technology providers, such as seed companies, the technology is distributed to the farm, crops are grown, stored, and distributed through many intermediaries for use by food producers. These include feed formulators, livestock producers, meat, milk, and egg producers. Primary and secondary processors also handle the produce, making many products for the protein, oil, and carbohydrate fractions of the crop. Food ingredient manufacturers, branded products producers, and retail outlets are all involved before the consumer gets the product.

With the first generation of biotechnology focused primarily on transactions at the very early part of the chain — with the farmer/producer — the commercial transaction was fairly straightforward and could be handled in much the same way as seed, chemicals, and fertilizers had always been handled. To be sure, there was value migration, e.g. from crop protection chemicals to seeds as value delivery vehicles, and major research companies started to cooperate with and acquire seed companies to enable this delivery. As the technology finds increasing use in creating added value foods and feeds, the point of value accrual can occur anywhere along this large agriculture food chain — and the situation becomes much more complex. This is causing a number of changes in the industry, and in the relationships of industry players with each other.

Biotechnology is only the latest addition to the factors that contribute to changes in our food production systems. Major, long-term governmental policies that have induced freer flows of capital and goods throughout the world have increased competitive pressures and provided new incentives for new types of alliances and value chain organizations. Against this backdrop, biotechnology is causing value to migrate to different parts of the chain through its ability to create agricultural produce with specified characteristics through genetics. Another major factor is the increasing availability of distributed information and information services. This information is breaking down some of the walls that have existed between suppliers and customers, with the result that new bases for collaboration and alliances are becoming more apparent to all members of the chain.

Different players in the chain are making choices about how to best deliver technology, and where they need ownership or strong alliances to deliver and capture the value of the technology. Much is said these days — and some concern is voiced — about the integration and consolidation of the food supply chain. Of course, alliances and integration are nothing new to the food industry. Providers of a whole wide range of food products long ago integrated back to owning or specifying the genetics they require to produce their products. Historically, this integration has been largely driven by downstream companies integrating backwards to production through either contracts or ownership. Feed producers have integrated with previously separate animal production enterprises, and there are large, very effective and competitive enterprises that combine grain distribution/feed formulation/animal production activities. Based on U.S. Department of Agriculture/Economic Research Service (USDA/ERS) data, the percentage of broiler production that has been done under contract or direct ownership has been rather constant at greater than 90 percent for almost 40 years, driven by the desire of producers to differentiate their products. Vertical integration in the egg industry occurred in the late 60's, and there has been a continual rise in contract production and direct ownership in fresh vegetable production.

Perhaps what is different about the discussion today with respect to biotechnology is that we're talking about a forward integration — from technology to marketplace — and this integration is being centered around large, multi-national companies that have historically participated primarily in the very front end of the value chain. In addition, much of the integration is occurring in areas related to the production of differentiated crops — such as corn and soybean — which have long been primarily undifferentiated commodities. While notable — and involving large premiums and cash outlays — this integration is rather small relative to the whole value chain. It has been driven primarily by the technology providers sensing a requirement to be able to access or own the delivery vehicles (seed) of their value-added traits, especially for traits with on-farm value. For traits that have value beyond the farm gate, alliances with and acquisitions of primary and secondary processors, provide a way to have a point of interaction (value capture) with these downstream markets and to learn about and understand these markets. Concerning these two aspects — possessing a direct-value capture mechanism and understanding the market — my personal view is that the latter will prove to be by far the most important in the long run. If one understands the market (has competitive intelligence, good information about customer needs, etc.), one is able to design products that will provide value to that market. These will include large volume/low margin and low volume/high margin differentiated products. With the current and anticipated future structure of the complex food chain, there will continue to be a number of ways to capture value from these differentiated products, without requiring ownership every step along the way. The increasing availability and use of information technology will enable the acquisition of market knowledge and enhance its value, decrease the benefits of broad ownership, and promote the development of alliances and partnerships — creating a dynamic "virtual integration" structure to deliver value-added products to the consumer. This virtual integration will extend to alliances and relationships with major, consumer-oriented food companies, providing an improved mechanism for these companies to specify the qualities they seek in differentiated raw materials for the products their customers want. And, it will extend back to farmers as the new grains and new markets will provide farmers with increased choices for what they produce.

Integration, virtual or otherwise, will also help to link specific technologies together in a very long and wide technology supply chain, providing the mechanism to deliver enhanced value to consumers. An example might be the production of high oil corn and use of that corn in a wet-milling operation. Using corn with over twice the amount of oil of normal corn, and with major differences in physical properties, can represent quite a challenge to the wet miller. The miller may need to make additional investments to fully capture the enhanced value inherent in the proprietary grain, and the grain provider may need to alter the genetics to take into account specific processing issues. An alliance could help make this happen. Perhaps exclusivity would be given to the miller for a certain period of time so that he can recoup his investments. A premium could be made available to the grain provider to cover additional costs associated with identity preservation of the grain and to provide premiums to the farmer for growing the grain. The net result of this alliance would be the ability to deliver added value to all those who participate in the production, processing, and use of the differentiated grain.

There are a large number of products in development that add value throughout the food chain — not only to the providers of the technology, but to farmers, downstream customers, and consumers. Using soybeans as an example illustrates how biotechnology can be used to improve the healthfulness and nutritive value of products derived from this major commodity crop. For example, soybeans with high levels of mono-unsaturated fatty acids provide improved functionality, flavor stability, and health benefits. High saturated fat soybean oils — produced without trans-fatty acids — can be used in a variety of healthier foods. Soy protein with increased nutrient density and a better balance of essential amino acids will find use in improved, more nutritious animal feed. Soybeans with decreased amounts of anti-nutritional carbohydrates and increased levels of sucrose can be used to provide soybean products with enhanced flavor, palatability, and digestibility. When these soybeans are processed with new methods that accommodate their unique properties, a number of new soy-based products will become widely available to mainstream consumers. Consumers will be able to enjoy the health benefits of an increased soy protein diet in tasty, healthful products such as soymilk, cereals, and candy bars.

Our ability to provide such products requires new systems to preserve the identity of the unique grain products. These systems depend on new analytical and information systems to ensure timely and assured delivery of products from the farm to the user. These analyses include not only those for the particular trait in question, but general analyses of grain quality and specific analyses for microbial contamination. Systems are already being put into place for a variety of value-added crops — such as the high oil corn and improved soybeans mentioned previously — and require the coordinated activities of a variety of companies in the food value chain, linking farm production to consumption. Regardless of the particular nature of the grain being produced, identity preservation systems ensure the highest quality and provide a means to connect growers to end-users and consumers in a more direct manner. As we pay more attention to our production agriculture, the general quality of the grain and food is enhanced, and this value can be delivered right through the value chain all the way to the consumer.

Biotechnology is destined to have a profound and positive effect on food production, nutrition and health, food safety, and the environment. The enhanced environmental and economic benefits of the first generation of “on farm” traits are already well established. The second generation of value-added, quality trait products for the consumer is just coming off the farm, and is driving the evolution of systems and alliances to ensure delivery of these products. Anonymous, commodity-based supply is giving way to certified, identity preserved supply. With this new system, we can look forward to secure delivery of products with enhanced nutritional value and improvements in the quality and safety of the food products delivered to consumers.

Pierce

Agriculture Biotechnology: Social Implications and Integration of Landscape and Lifescape

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Humankind has long attempted to select from nature those characteristics within different species that most seemed to meet their needs, both as consumers and producers. Traditionally, this has been done through breeding programs, limited only by the laws of genetics and the life cycle period of the plant, animal, or bacteria in question. Those traits selected were sometimes based on characteristics desired by end-users and sometimes on agronomic characteristics desired by producers. Choices were made on desired expressed traits, often unknowingly associated with other traits. For example, docility and human bonding in foxes, when selectively chosen, resulted in floppy ears and curly tails.

The beginning of agriculture was the beginning of selecting plants for human-desired characteristics. The desires of the producer and end-user were identical since the producer and end-user households were usually the same. Women, the end users of potatoes, still select seed potatoes in parts of the Andes to take with them as part of the dowry they bring to a marriage partnership. Over time, as selection moved from the farm household to off-farm commercial firms, many links were inserted in the chain between producers and end-users. And when biotechnology permitted desired traits to be transferred from one species to another, the agronomic characteristics sought by those who made decisions about inputs — farm owners, farm managers, and crop consultants — were usually unrelated to characteristics sought by end-users. An end-user orientation includes processors, distributors, consumers, and citizens. End-users may look at both intended and unintended traits embodied in the biotechnology, thus raising issues quite different than the concerns of producer decision-makers.

Globalization and Consolidation

Decisions regarding the development and distribution of biotechnology are taking place in the context of a number of important changes in the market, the state, and civil society. The key trends in the market are globalization and industrialization. Decentralization, or devolution, and privatization are key trends in governments worldwide. Polarization and engagement are key trends in civil society.

Globalization, as it is currently configured, is the result of 30 years of removing international barriers. The first 15 years, between 1973 and 1988, were spent removing the barriers to international capital flow. The next 15 years into the present were spent lowering the barriers to the international flow of goods and services. Decreased barriers led to increased competition. Increased competition has lowered profit margins, particularly for undifferentiated commodities, including but not limited to agricultural commodities. Lower profit margins, in turn, have led to the consolidation of many firms throughout the economy. It has only recently impacted agricultural input suppliers and distributors. Now the agriculture input industry, as in most other areas of commerce, is controlled by a very small number of international firms. The recent push toward consolidation, as seen in financial services, telecommunications, and automobiles, is also occurring in biotechnology, food processing, and distribution. This has been accompanied by a sense of insecurity on the part of many individuals and companies.

Concomitant, but independent from globalization and its impacts, is industrialization. Industrialization is a response to increased competition and lower profit margins. An important aspect of post-Fordist industrialization is producing a differentiated product, rather than an undifferentiated commodity. Moving from commodities to products is first coming up with something unique that has more than one characteristic. When farmers purchase Bt corn or Roundup Ready® soybeans, they are buying a product, not a commodity. The major selling feature of both these products is that farmers can produce the same amount for less labor. Farmers have bought the differentiated product (biotechnology engineered seed) to produce an undifferentiated commodity (corn, canola, or soybeans). Debate swirls on whether it is to be differentiated or not. What are the options for segregation? For labeling? Unfortunately, at this point in market history, differentiating harvested of biotechnology crops decreases their value in the market place.

Commodities are generally sold based on weight or volume and sometimes based on one other characteristic, such as protein content, percent butterfat, or grade for meat products. Quality may provide a floor (for example, in wheat percent protein and the filth standard), but the multiple characteristics are merged at the grain elevator.

Industrialization is now decreasing the links in the value chain between producers and end-users, which then enables the product to more nearly meet the needs of the end-users, commanding a market place advantage. Reducing the links in the value chain is viewed in many industries as providing for more complete information flow up and down the chain, and enhancing product development. In agriculture, reducing links in the value chain has traditionally been viewed as reducing transaction costs of getting commodities to market, not a mechanism to improve the product.

Industrialization allows for capital to accumulate when there is a separation of management from ownership. This first occurred in industry with the publicly held companies and the stock exchange, where owners were very uninterested in what took place on the factory floor and very interested in the value of their stocks and the quarterly profits. Thus, management's job was to meet these two goals of the owners.

This is increasingly happening in agriculture, as fewer and fewer owners are operators. Corporations do not own most land. City-dwelling heirs of farmers and ex-farmers own land. Their bond to the land increasingly is the "wheat check."

With industrialization there is a decreasing number of core firms and an increasing number of outsourcers. The value chain becomes consolidated, and risk is pushed out to various outsourcers. This is illustrated in contract broiler production, and is emerging in some forms of hog production. The core firms choose not to use their capital to buy the capital equipment needed for production or to employ the workers and managers who grow animal protein. Instead, outsourcing (more sophisticated version of the putting out system, a way of producing before the industrial revolution), is now increasingly a part of an industrial economy.

DECENTRALIZATION

As the market centralizes, governments are decentralizing. More responsibility is going to the local level. Devolution, as this decentralization is called, is based on the principle of subsidiary: a decision should be made at the lowest possible level. Presumably, the people on the ground know the "needs" of the local population and are in the best position to mobilize the resources to meet those needs. One of the goals is to help re-legitimize the state as a social actor, to increase citizen's trust in government.

However, if this principle is not accommodated by a strong policy of democratization, it often means that local elites regain power they may have lost when federal governments demanded that excluded people become part of the local processes, from attending schools to access to credit. We have seen this in farm programs in terms of who has been able to profit by them. Thus, when democratization is not present, de-legitimization of the state is increased by decentralization. Already excluded populations view local powers as neither just nor effective.

Even with high degrees of democracy at the local level, resources often do not accompany the shift of governmental responsibility from federal to state and state to local. The famous unfunded mandate continues on, particularly by states to localities, despite rhetoric to the contrary. Federal and state governments are moving from decisions based in-part on equity to decisions based on efficiency.

Privatization is the logical result of moving from decisions based on efficiency. There is a strong belief in the U.S. that the private sector is more efficient than the public sector, despite some stunning counter examples, such as the failure of the savings and loans in the 1980s.

Across the world we see a movement away from government supported extension services. The government in the past often took the risk in introducing new technology. Extension agents gave away hybrid seed, now a private sector function. They also performed artificial insemination, which likewise has moved to private business. In terms of agricultural technology, extension is increasingly a wholesaler, working with dealers and custom operators, licensing them to apply a variety of technologies that they, in turn, can sell for a profit. This does increase the efficiency of extension, but not necessarily its legitimacy with the tax-paying public.

The move from government oversight to self-regulation is a product of the privatization trend. If there is still some government oversight, serving the public good at lower private cost can be achieved. Hazard Analysis Critical Control Point (HACCP) is a potential example of such a shift. It hopes to move from federal meat inspectors looking at each animal (extremely quickly) to HACCP outcome standards, looking at the entire process. We are moving from design standards, where one is told how to design something that will presumably give required results, to performance standards, which allows company management to determine the best way to meet food safety or pollution reduction guidelines. The move from design to results standards has been extremely effective in the industrial sector, reducing industrial emissions much faster than anticipated. In agriculture, we still seem to spend a lot of time on Best Management Practices (BMPs), with little attention to monitoring environmental performance in terms of ecosystem health.

In civil society, polarization, accompanied in some cases by social conflict, is partially due to the increasing diversity of income, ethnicity, and worldviews coupled with a decreasing ability to deal with difference. As a result, single-issue political mobilization is high. At the local level, the “bums” are thrown out over a single issue, and the reformers are only interested in changing that single issue. They know little else about general governance and the increasing responsibilities that are falling on the local level.

In terms of engagement, we are observing an increasing willingness to be involved where one makes a difference. Thus, while membership in traditional organizations may be decreasing (Putnam 1995), involvement in specific community activities, such as constructing a playground, is increasing dramatically. Engagement means the formation of flexible information and action networks as one set of individuals or associations get together to address one opportunity and re-forms with different configurations for another. Information sharing becomes an important part of this engagement, as cooperation links the civil society and the market.

Further, there is multiple community activism, with individuals often linked to the new information technology being active on local, state, regional, national, and international stages, bringing those various communities of interest together in new ways.

Biotechnology is embedded in all these trends. As a result of biotechnology, we now have products that agricultural producers value such as increased productivity, as found in BST (Bovine Somatotropin) in milk production and PST (Porcine Somatotropin) in swine production. We also have crops such as corn, canola, soybeans, and cotton with engineered genes that make them resistant to insect pests or to herbicides that kill weeds but not the herbicide tolerant crop. All of these characteristics make it possible for farmers to produce more at the same reduced costs — a situation presumably of great interest to the individual producer but of potential great harm to producers in general. Prices go down as supply goes up.

Many farmers have been convinced by the fallacious equation that the amount of food produced should be a function of the number of people inhabiting the globe. Neither the fact that almost all the countries with a high level of child malnutrition have food surpluses nor falling prices have deterred U.S. farmers from using biotechnology-produced production enhancement tools.

What are the factors that influence acceptance or non-acceptance of particular technologies, especially those that are bio-engineered? Should we automatically accept new biotechnology as a social good? Or should we immediately stop the use of products derived from biotechnology? Neither stand is defensible nor has a sound social science rationale. It is important to look at the roles of the different actors in the producer-end-user equations and the levels of motivations they have for the choices they make. It is important to consider the human element as both consumers and citizens, and look at the different ways civil society interacts with the market and the state that are related to the current and future status of biotechnology.

Grower motivation to adopt or oppose biotechnology

Motivation to use technology is related to a large number of factors that are layered in social structures and often ignored in the neo-liberal assumption of the rationale economic actor for whom the market only fails when there is incomplete information. In fact, behavior is determined and influenced by a number of mechanisms of social control, which involves both positive and negative factions.

Internalization

The first and best mechanism is internalization. Somebody wants to do something and knows how to do it. For example, entrepreneurial farmers (Salamon et al. 1997) who have traditionally been technology innovators, who are known within the community to be the first with the latest, are very likely to adopt biotechnology, just as they have embraced a number of emerging tools/inputs.

Adoption of biotechnology for such entrepreneurial farmers is simply being an innovator. And when technology adoption reduces the application of other technologies (herbicides or insecticides), buying the first round of biotechnology inputs seems self-evident. The system changes that are required — planting conventional crops on 30 percent of the acreage as a bioreserve for Bt corn — obviously decreases average bushels per acre and is counter intuitive. Maybe the farmer will do it next year, when prices are higher — or lower.

Agricultural biotechnology in widespread use today has been designed to be a rather blunt instrument, so as to do just one thing broadly. It is like a simple input substitution for many of these farmers, rather than a systems change. While deeply depressed farm prices may marginally keep inflation in check, most consumers do not identify increasing production as a personally desirable product of biotechnology. This is particularly true when the media documents farm failures as the result of overproduction and low prices and when there is implementation of huge government payments to grain farmers despite the presumed market orientation of the 1996 Freedom to Farm bill.

Despite the concerns about creating refuges when using Bt seeds to control insect pests, there is little evidence that farmers are actually putting in these reserves — or at least to the 30 percent of corn acreage recommended by the North Central research team examining this issue. Studies now underway in Canada suggest that farmers, beset by low prices, are ignoring the reserve label instructions and planting all their land to Bt corn in an attempt to reap enough short term profit to remain in farming.

Internalization also involves another group of farmers — farmers who are suspicious of altering nature, particularly moving genes between species. These are farmers who follow the precautionary principle and want some long-term evidence that it will do no harm, and feel that increased productivity generally results in lower prices and increased marginalization of the farm population. Internationalization in both these cases involves basic values and how people define themselves by what they do.

Social Pressure

When internalization is not in place, social pressure helps reinforce particular behaviors. You gain prestige by being the first with the newest, or you know you ought to adopt it because “people like us do this kind of adoption.” On the other hand, there are those same numbers of people who know they should not adopt it because of the generalized potential of negative environmental or social affects.

Social pressure can also provide negative sanctions. One example is being laughed at by being too innovative too soon. One loses respect if one does something that results in severe environmental damage. The monarch butterfly effect, first reported in Cornell University laboratories (*Science* 1999) and replicated on Iowa State University experiment stations (Hanson and Obryck 1999) if viewed as credible could increase community level negative social pressure. Civil society, through schools, churches, the family, and other formal and informal groups, provides internalization and social pressure.

Economic Sanctions

If social pressure doesn't work, economic sanctions are brought into play. Both the market and the state provide these economic sanctions. With biotechnology, the positive market economic inducement has been "produce more units, lower cost per unit" and perhaps we'll have new markets. New markets have been provided for seed companies by biotechnology characteristics that are agronomic and thus, producer-oriented. For those producing the commodity, new markets are to emerge due to increased production (cheaper price will increase "our" market share) rather than a new market because of a new product.

Negative economic sanctions include being fined (generally state imposed) or losing a sale (generally market imposed). A grower might be fined if there were actual inspections to determine if reserves are in place according to the "label" on the genetically modified (GM) seed. Both Staley and Acher Daniel Midlands (Brinkman 1999) have recently said that they are not accepting any more Bt corn. This is a definite negative sanction that discourages planting Bt corn.

Force

In general, force is only brought into play if none of the other levels of social control work. For example, land near public parks might be zoned as "genetically modified organism free" (GMO-free) in order to protect biodiversity that would occur from pollen drift and out-breeding.

Negative sanctions include physical punishment or imprisonment. These are carried out by the state. In some communities activist opponents have destroyed genetically modified field crops by uprooting them. This is legitimate use of force.

End-user motivation to use or reject biotechnology products

Motivation for end-users to either accept or reject GMOs can be seen in the same way. Few biotechnology innovations that are consumer oriented, such as the FlavrSavr™ tomato, have reached the market to date. However, it is useful to look at end-user motivations, the different levels at which they occur, and to understand the impact of the end-users on biotechnology adoption. Like producers, they have positive and negative sanctions and, like producers, the best sanctions work through internalization.

Some consumers want to try innovative things. Their identity comes from innovation. They believe in science and the governmental mechanisms to protect consumers believing that if it were bad for people or the environment, they (scientists and government officials) wouldn't put it on the market. But, particularly in Europe, where science and government are thought to be ineffectual or even corrupt in enforcing environmental and safety standards, that type of acceptance — it's good for me because they tell me it is — is low. In countries such as Denmark and the Netherlands, where there is greater transparency and participation in food safety and environmental standard setting and enforcement, there is greater trust of the quality and environmental sustainability of food.

Core Values

There are another set of consumers who are cautious about food innovation based on core values of naturalness, concern for the environment, desire for choice, and health concerns (Barling, et al. 1999). First generation GM crops used antibiotic resistance marker genes providing resistance to herbicides (with the fear that it would cross over to weeds) or insect resistance (with the fear that resistant strains would develop and that other insects would be killed, decreasing biodiversity). Many consumers did not feel they gained any benefit from such characteristics — and indeed saw definite risk involved. The general response by industry and university was to state that they did not understand the science involved, thereby heightening opposition.

A variety of surveys have shown that up to 75 percent of the U.S. population identify themselves as environmentalists. When they see that this identity can be reinforced, they look at what they eat. This may be a growing internalization that could influence the utilization of bio-engineered products. Of course, since products are currently not labeled, many people are eating GM crops without knowing it.

Social pressure and economic sanctions

Social pressure also affects consumers. You gain prestige from consuming certain things and thus, one "ought" to do it. Consumers can also be laughed at and lose respect. As consumers, we are increasingly gaining identity in society by what we consume. Some of that identity comes not only from brand and style of sports footwear, but also from what we eat.

When these forms of social control are not effective or are too effective, economic sanctions come into play. These sanctions can include giving lower prices to distributors and providing new markets. The economic costs can be fines to a distributor, for example, who has included some genetically modified crops in a shipment to Europe. However, because price, an external motivator imposed by the market, must balance the internal motivators provided by civil society, price is not always an effective motivator. A series of studies of consumer behavior demonstrate that people will pay more for a product viewed as environmentally friendly or more humane. Not all consumers have internalized values or have social groups who want to protect the environment or protect animal welfare, but enough do to suggest providing a choice pays. The extra cost of segregating by the way something is produced is thus borne by the consumer.

FORCE

Then there is force. It is almost impossible to eat any processed food today that does not contain a product from a GM crop, most likely from soybeans or corn. For consumers who want to have a choice, this is akin to being forced to participate in a production and consumption process that goes against some cherished values. It can be viewed as a positive form of force. These motivations can affect capital, which are resources to invest in new resources, particularly within society. Capital markets are maintained by contracts. Currently there is a change in the social contract between the supplier of biotechnology and the producer. This is a change from the way farmers have purchased inputs in the past and what was implicit in that sale to what is implicit, and sometimes explicit, in the sale and purchase of biotechnology products.

Biotechnology increases the importance of intellectual property rights. Part of the consolidation in the biotechnology industries occurred because it is cheaper to buy a company than to purchase a license for the technology. The purchasers of GM seeds may not replant or sell to neighbors for planting. The old “brown bag” policy of the producer being able to keep seed for use or sale is now being rigorously prohibited with news and rumors of Pinkerton agents checking to see whether farmers have resown Roundup Ready® soybeans without making the actual purchases. New information systems that link together the inputs farmers buy and circulate them to manufacturers and dealers make it easier to determine which farm enterprises might be seed savers, thereby infringing on the intellectual property rights of the seed supplier. This limited property right is a new impingement on what farmers took to be the social contract between them and their seed suppliers.

Animal welfare consequences, particularly in response to some of the productivity enhancing hormones, are being increasingly revealed. There are many consumers who are willing to pay more if they know that animals have been treated well. Since animal longevity is not a characteristic sought by most animal producers these days, the signs of premature aging as a result of growth enhancement genetic engineering is a characteristic not likely to be addressed by producers, but of concern to some consumers. As a result of these consequences to health, environment, and animal well being, there is an increasing demand to label biotechnology engineered plant and animal products.

This suggests the need to monitor the numerous aspects of the impact of biotechnology on the various capitals within the community — human capital, social capital, natural capital, and financial and built capital. These come together in a variety of communities that need a healthy ecosystem, a vital economy, and social equity.

Social equity is not the same as social equality. It does not mean that everyone has the same thing, but it does mean that all members of the community have access to the wide variety of resources available in the community if they meet universal standards to which all can aspire. Some unanticipated consequences are a decline in human capital, a decline in social capital, a decline in natural capital, and in financial and built capital.

Human capital

Human capital includes education, skills, health, values, and leadership. There is concern about the health aspects of biotechnology, both positive and negative, as the use of biotechnology-engineered nutraceuticals is getting closer to delivery. Human capital involves values, which intersect with biotechnology in a wide variety of ways. Monitoring the impacts of biotechnology involves the increased use of the knowledge, skills, and abilities of the local people. It means identifying local capacities, enhancing local capacities, and recombining local capacities.

The next generation of biotechnology products probably will be much more sophisticated, targeted, directed, and likely to be end-user oriented rather than simply producer-oriented. Using the skills of local community producers and processors to evaluate and utilize new technology will be a critical piece of biotechnology development, adoption, and utilization.

Social capital

Social capital consists of mutual trust, reciprocity, groups, collective identity, a sense of a shared future, and a working together. As we monitor this capital, we would expect to see strengthened relationships and communication, increased interactions among unlike groups within the community, increased interactions among unlike groups outside of the community, and increased availability of information and knowledge. At this time, we have seen biotechnology forming a wide variety of new networks among public and private scientists.

Other kinds of linkages, particularly those of producers and citizens groups, are not developing as rapidly. One way of building these is to help monitor the impact of biotechnology. For example, those who are concerned about negative impacts can specify what those are, and working with producers and consumer groups, negotiate indicators that can be monitored by representatives of all sides of the controversy. Other indicators to be monitored would be the benefits that the proponents feel would be gained.

Natural capital

The impact of biotechnology on natural capital is increasingly an area for greater monitoring. What happens to air quality? Water quantity and quality? Soil quality? Biodiversity? And even the landscape with biotechnology? Can these characteristics, of great interest to end-users, be part of the biotechnology design? Can we be sure that they are not the unintended victims of biotechnology adoption? Thus, we look for sustainable healthy ecosystems with multiple community benefits, human communities that plan and act in concert with natural systems, ecosystems that are used for multiple community benefits, and one where those with alternative uses of the ecosystem seek common ground.

This suggests that biotechnology should engender enormous discussions and reasoned debates in rural and urban communities so as to identify what is important to monitor, so that we can be sure any damage is minimized. These rapidly developing technologies tend to be introduced at the stage they are developed. Unless there are clear community standards, enforced by government regulation and oversight, marketing will lead science. No single company can withhold a potentially profitable innovation if there is the possibility that another may beat it to the market with a similar product.

Financial and built capital

Finally, financial and built capital includes debt capital, investment capital, tax revenue, savings, tax abatement, and grants — all involved in the development of biotechnology from the public and private sector. Does the public feel they are getting their money's worth from this? Is the worth of public money equal to an increase in value in biotechnology stock? Does this result in built capital that improves life and does not damage the environment? Does it result in appropriately diverse and healthy economies to reduce poverty, increase business efficiency, increase business diversity, and increase community resident assets? All of these questions need to be viewed in which biotechnology inputs and uses are compared with those from traditional approaches.

Concern about impacts on multiple community capitals underlines the importance of monitoring multiple impacts. Monitoring, conducted by a wide range of groups from the market, the state, and civil society, and sharing results allows for quick response to unanticipated consequences; thus, the need to monitor all the forms of capital. It involves multiple stakeholders and negotiations that lead to determination of indicators. This also helps to determine the parameters under which biotechnology innovation occurs. It provides feedback to scientists. It provides feedback to the market. It provides feedback to citizens groups.

For agricultural biotechnology to be beneficial to both producers and consumers, it is critical that there be greater communication with all links in the value chain regarding basic values and characteristics desired from food. These characteristics go beyond taste, price and nutritional value to a healthy ecosystem and even a just society. Processes need to be developed by a partnership of institutions and groups from the market, state, and civil society to build trust and public identification with decision-making processes. A more socially responsible, responsive, and accountable model for the application of food biotechnology is possible (Barling, et al. 1999) This includes consideration of a broader set of links in the value chain when developing agricultural biotechnologies, providing choices of GMO and non-GMO products (this worked well with GMO tomato paste in Europe), certification of non-GMO crops, segregation throughout the value chain, and labeling. All of this provides transparency throughout the value chain. As Barling, et al. (1999) point out, "This degree of transparency would allow consumers to make a more fully informed choice of foodstuffs, in line with their deeply felt values on such issues, and would provide for a more democratic and participatory basis for transparency."

I want to end with a caution. Privileging any form of capital over another can defeat all forms of capital in the long run. The current adoption of biotechnology, using the producer, short-term goals of the ease of pest management allowing one individual to farm more land may have long-term negative consequences, including losing a powerful biological control and further decimating biological diversity, particularly among a specific variety of insects and other invertebrates (Huang, et al. 1999)

It is not in our best interests to unilaterally reject or accept any new technology. It is very important that monitoring take place and transparent feedback mechanisms be developed in regard to technologies that are complex and multidimensional.

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Figure 1. The Producer and Biotechnology: Relevant Social Control

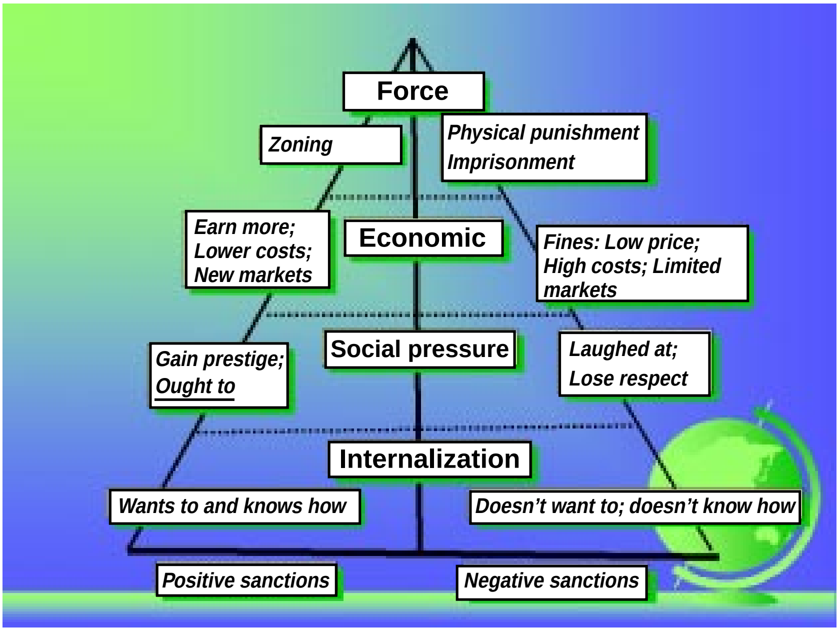
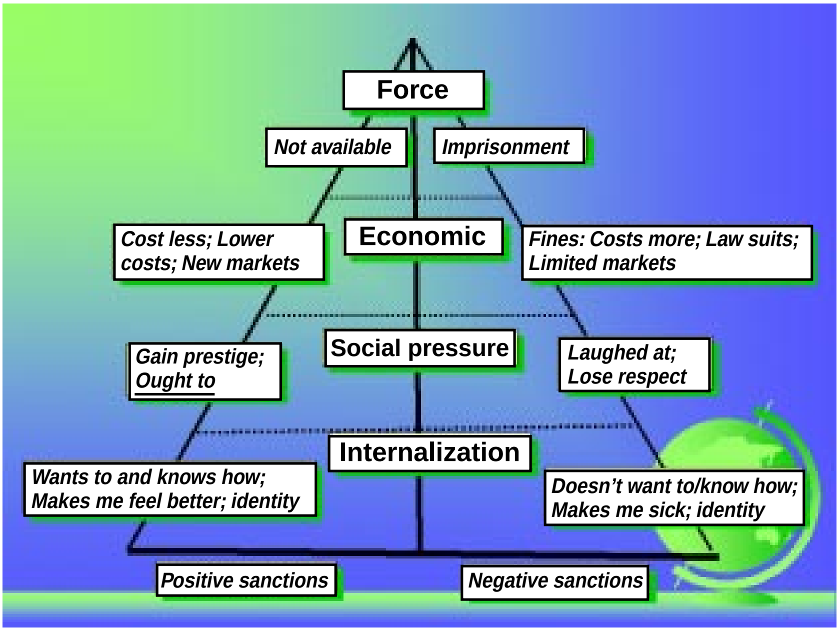


Figure 2. The Consumer, Agricultural Biotechnology, and Social Control



PART IV

PLENARY LECTURES

Policy and Technology as Factors in Industry Consolidation

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Introduction

Evidence of mergers, acquisitions, and strategic partnerships of firms specializing in biotechnology and the related product chain is widespread. Popular examples include the DuPont/Pioneer Hi-Bred International strategic partnership and acquisition; the purchase of Dekalb Genetics Corporation by Monsanto; the failed acquisition of Monsanto by American Home Products; the purchase of Holden Seeds by Monsanto; the consolidation of U.S. and European companies forming Norvatis; the consolidation of cooperatives and private firms specializing in grain and oil seed handling; and many others (Lerner and Merges 1997). The upshot of these mergers, acquisitions, and strategic partnerships is that there are currently many fewer major companies controlling most of the genetics and related developmental systems for supporting biotechnology advances in the production of major staple crops, and the processing and delivery systems for taking advantage of related traits.

What is causing the consolidation in the biotechnology industry? Many of the explanations are peculiar to the firms involved and their special circumstances. In this paper we focus on the economic aspects of these firms, and the conditions under which they operate. In addition, we emphasize the technology and policy factors responsible for consolidation. In the case of technology, there are many angles for investigation. For instance, aspects of technology that relate to the special and complex features of research and development for biotechnology products, the technology of organizations and our improved knowledge about contracts and incentive compatibility, the growth and evolution of information technology and its impacts on the development of integrated assembly, handling and processing systems for biotechnology/derived products, the scale and scope economies that emerge from various sources, and technologies supporting marketing systems that can capture the values of special traits of products.

Policy factors that are important in determining patterns of consolidation and integration are equally important compared to technology. These include: Food safety and product integrity; anti-monopoly and related measures to control competition; the more open-trading environment and associated expansion of markets for firms specializing in biotechnology; innovations in equity markets that provide access to lower cost risk capital for supporting mergers and acquisitions; restrictions on information-sharing associated with expanded opportunities for licensing and patenting; the changing roles of the public and private sectors in carrying out societal responsibilities for research and development; and the pressures resulting in shorter product cycles for biotechnology products. These are among the factors that provide increased incentives for firm integration and expansion.

We will show that at the root of many of these policy and technological factors that have been identified as influencing industry consolidation are the pervasive concepts of asset specificity, incomplete contracts, and residual property rights. Our understanding of these and related concepts has rapidly expanded during the past two decades (Hart 1991; Grossman and Hart 1986; Aghion and Tirole 1994). These results have complemented the earlier work on transactions costs and industry structure (Williamson 1985; Klein, Crawford and Alchian 1978). Combined with game theoretic formulations for characterizing strategic behavior, these developments provide plausible and instructive explanations for how firms responding to the changing policy and technological factors like those described above are motivated to form strategic partnerships, make acquisitions, and merge. The actions lead to consolidation patterns consistent with those observed in the industry developing and bringing to the market products made possible by advances in biotechnology.

Sources of Value and Industry Consolidation

A key factor in understanding industry consolidation is the idea of value-added. Specifically, firms considering strategic partnerships, mergers, and acquisitions are motivated to act by increased profits. In order for profits to increase, some kind of value must result from the consolidation. It is instructive to identify the sources of potential value as a basis for better understanding the incentives for and patterns of industry consolidation. For purposes of exposition, we classify these sources as organizational, strategic complementarities, strategic substitutes, and market power (Melkonian and Johnson 1999a; Vickers and Waterson 1991).

Organizational sources of value relate in general to the things that firms can do together more efficiently than they can do on their own. Examples of organizational sources of value include coordinated purchases of inputs, shared information on production and other technologies, cooperation in assembly and handling functions, marketing, and what we will term “investment externalities.” In the latter case we refer to a situation in which firms acting together can benefit from “public good” type joint investments. For instance, biotechnology firms may find it convenient to cooperate in meeting food security and other regulations, jointly managing information on production patterns and product traits, or in risk management, e.g. self-insurance. These value sources are important because they are relatively easily defined and obtained, if the firms are prepared to cooperate “faithfully.”

Strategic complementarities (first set out by Bulow, Geanakoplos, and Klemperer 1985) relate to efficiencies that can be achieved by coordinated investment and other activities. We take investment as the example. One firm may invest in specialized genetics while another may invest in chemical pesticides that result in reduced production costs, given success with the genetics. Processing firms may use agents that result in product traits that have special market values. If firms cooperate, again faithfully, value emerges from coordinated investment or product development strategies. In short, the firms cooperating in their decisions on investment can generate more value than if they proceed independently. Given the high research and development costs for biotechnology, the value generated by strategic complementarities can drive various forms of consolidation.

A strategic substitute (Melkonian and Johnson 1999a) is a concept referring to the converse of strategic complements. In this case, we can think of firms that are competitors in a limited market. Investments to expand output by one firm have the effect of driving down the price for both firms. Again, faithful cooperation among the firms can result in increased value and profit. These kinds of strategic substitutes are particularly important in the biotechnology industry. This is an industry with the capacity to produce products that have highly specialized markets, e.g. nutraceuticals, oils containing only particular types of fats, resistance to local pests, etc. In these segmented market situations, actions of one firm have important implications for the profitability of the competitors, and the industry.

Market power and it implications for profitability is well known from the traditional economic literature. Still, market power provides strong incentives for consolidation, whether to limit strategic substitutes, to manage product development cycles, to control pricing and inventory levels, or simply to drive out the competitors and prevent entry. In the biotechnology industry the complexities of product development, product registration and licensing, and the sharing of discoveries and patents provide opportunities for cooperation to improve market power. Firms have incentives to coordinate in meeting protocols for providing market access and for reducing the risks of sharing licenses and patents.

Of course, the regulatory environment in which the biotechnology and other industries operate may limit the opportunities for engaging in activities to generate values from these sources. From a societal viewpoint, there are potential costs associated with industry consolidation designed to exploit these value sources. At the same time, allowing firms to coordinate to achieve these improvements in value puts at their disposal increased capital for investments in new technologies and products. National and international regulatory systems are implicitly balancing the benefits of consolidation with its cost. In the US, it would appear that the current environment tends to favor consolidations and transfers from consumers to producers that are rationalized on the basis of their implications for increased investment and more rapid rates of product development and technical change.

INCOMPLETE CONTRACTS AND RESIDUAL PROPERTY RIGHTS

Given the value that can be generated by various forms of coordination simply by contracting, why is there a trend toward concentration? In an ideal world firms would recognize the value of coordination, develop the associated contracts to assure that it occurs, and gain the related value — without mergers, acquisitions, or strategic partnerships. Of course, there are legal constraints to these kinds of contracts due to the regulatory environment and national or international anti-monopoly policies. Still, it would appear that in the biotechnology industry the decision has been not to coordinate through specialized contracts, but to exchange ownership rights as a basis for cooperation.

One of the reasons for this tendency in the biotechnology industry is the difficulty in specifying and enforcing contracts. In reality when firms try to coordinate, the contracts that they write are incomplete. Simply put, they fail to anticipate all of the important contingencies and/or the specifics are not enforceable. In turn, the fact that firms understand these problems leads them to make non-optimal relationship-specific investments. Second-best solutions to coordination problems emerge as optimal strategies for firms that could benefit from fuller cooperation, if contracts are incomplete. Moreover, the residual property rights (those not anticipated in the terms of the contract) go to the owner. In the biotechnology industry where there are long lead times on investments and highly uncertain outcomes, contracts that cover all of the important contingencies are very difficult to specify.

Firms facing these contracting problems have a number of alternatives. First, they can proceed independently. This strategy results in foregoing the value that could be generated by coordination. Second, they can coordinate using incomplete contracts. This results in under investment and potential litigation and other costs associated with claims on residual property rights. Third, the firms can engage in partnerships that involve exchanges of assets, a mechanism that mitigates the problems of ill-specified contracts. These strategic partnerships are organizational mechanisms that provide compatible incentives for the cooperating firms. In this circumstance, less attention to the details of contracts governing coordination initiatives and their enforcement is necessary. By virtue of the fact that the firms have shared ownership, they mutually benefit from successes of the cooperative ventures and quite importantly, have the incentives to make individual investments that are consistent with success. Shirking and free-riding problems are greatly reduced.

The situation with incomplete contracts becomes even more complicated when it is recognized that they may include components with different levels of enforceability. In this case, the parties to the contracts are likely to focus on the fulfillment of the components that are more enforceable and to under invest in the components where enforceability is more uncertain (Bernheim and Whinston 1998). At least two problems emerge from this characteristic of contracts. First, the components of the contracts are not independent in terms of the desired outcome. Thus, under investment in the components of the contract that is less enforceable can have significant impact on the success of the joint venture. Second, the parties to the contract may have beliefs about the success of the joint venture based on different perceptions of the fulfillment of the different components of the contract. Again, investment behavior that is influenced by enforceability will be the case. The role of the dominant party in obtaining the residual property rights when viewed in this context makes the outcome even less predictable.

The firms that are entering into the contracts also may have differences in the scope of their product lines. For example, one firm with a large portfolio of biotechnology products may contract with another firm that has a much more limited product line. If there are complementarities among the product lines, investment strategies will be affected. For example, strong complementarities for the firm with more product lines could induce it to invest more than would be rational given the incomplete contract considered in isolation. Thus, there is a “portfolio” effect that determines optimal investments for incomplete contracts. Independent consideration of the contracts, even with the benefit of the most advanced concepts, could result in inconsistencies between predicted and observed behavior. Alternatively, the firm with the narrow product line could be involved in a number of incomplete contacts with different firms. Here again the portfolio contracts, somewhat like a situation with larger scope multi-product firms, will influence investment patterns, and the way that the firm negotiates and executes particular contracts. All this means that the simple application of results from incomplete contracts and residual property right must be highly specialized to the partnering firms, if outcomes are to be predictable.

The problems of contracts with components that have different enforceability and the portfolio effects observed for multi-product firms or firms dealing with multiple partners, can be argued to suggest benefits of relatively simple contracts. The more complex the contract, the more components. The greater the scope for the portfolio of products, the more opportunity for complementarities that are not covered by product specific products. The more firms with which a representative firm has contracts, the greater the possibility for opportunistic strategies. Particularly in dynamic contexts, complexities of this type have been argued to imply benefits of leaving some contractible contingencies "ambiguous" (Bernheim and Whinston 1998).

Merger or Acquisition versus Strategic Partnerships

One of the important factors affecting decisions for mergers or acquisitions compared to the development of strategic partnerships (shared partial ownership) is the impact of management on the valuation of the firm. It is instructive to think of the valuation of the firm as consisting of two components. One component is management specific, identified with a very capable entrepreneur. The second component is transferable with acquisition, for example patents and licenses, physical assets, etc. Thus, firm decisions on joint ventures must be governed by the complexities of contracting and shared ownership and by strategies designed to capture the benefits of the management component of firm valuation. In the biotechnology industry where many start-up firms are identified with many gifted managers or scientists, this is an issue of particular relevance for consolidation and ownership patterns.

Suppose one firm acquires another. If the firm that is acquired has a high management component, then the acquisition package will have to include incentives for the manager. If the acquisition package does not include these incentives the manager will leave or behave in a way that reduces the performance of the acquired firm. For these reasons, it is not always clear that the solution to incomplete contracting problems associated with multi-firm ventures is acquisition or a merger. Instead, there may be reasons to use strategic partnership in combination with simpler contracts. This assures the retention of the benefits of the management components of the two firms and sufficient incentive compatibility that the unanticipated contract contingencies or relatively less enforceable features of the contracts will be honored in a way that contributes to the benefit of the firms (and managers).

An unanswered question for strategic partnerships is the optimal ownership share. Simply put, if two firms enter into a joint venture that is covered by an incomplete contract, what is the appropriate exchange of ownership to assure that both the firms and the managers have appropriate incentives to invest to fulfill the contract. In fact, there are two related questions. One is optimal investment for each of the firms. A second is the optimal level of ownership exchange to provide the incentives for the managers of the two firms to make the optimal investments (Melkonian and Johnson 1999a). Even from this simple characterization of the joint venture problem, it is apparent that the shares of ownership required to generate incentives for optimal investment will depend on the contributions of the management and transferable components of the value of the firm. The higher the share of the transferable component the greater the incentive for merger or acquisition as a way of dealing with problems of incomplete contracts and the disposition of residual property rights.

In a dynamic setting there is the possibility that a strategic partnership can provide an opportunity for learning. In this case, a firm that is well managed may form a partnership with another firm and during the dynamic process acquire the specialized management knowledge of the second firm. Thus, strategic partnerships can be used as a pre-acquisition tactic. Of course, if this is a tactic for acquisition then the investment strategy and the ownership for the strategic partnership are affected. The firm intending to use the strategic partnership, as a tactic for acquisition, may be willing to enter into an exchange of ownership which viewed in the short run as non-optimal. The capacity of one firm to learn from another may also be related to the ability of the management to handle diverse enterprises. For example, other things equal, multi-product firms may find it less costly to acquire the management skills of their strategic partners.

These decisions on strategic partnerships, mergers, and acquisitions are clearly dependent on nature of technology and a policy environment. Different strategies can be anticipated if, for example, the joint venture involves the development of a product for which the technology is highly uncertain, compared to the situation where the technology is standard. Policy is also important in governing these strategies. For example, threats of intervention by government to reduce monopoly power may limit plans for acquisition. Expansions of patent and licensing opportunities may reduce the contribution of the management component, increasing the transferable component and providing incentives for more rapid merger or acquisition. These outcomes illustrate the factors contributing to consolidation in the biotechnology industry.

Special Features for Biotechnology

The observed rapid concentration in the biotechnology and related sectors can be viewed in part a result of problems related to incomplete contracts. Many biotechnology products are produced in highly integrated systems. These highly integrated systems may be required to assure expression of the trait that is adding value, meaning that firms along the product chain have incentives to cooperate. Experiences with the complexities of contracting appear to have led to partnerships that generate compatible incentives, and ultimately to consolidation.

Critical factors have already been identified. They include the complexity of the contracts, the uncertainties associated with technologies being used to execute the contracts, and the incentives for non-optimal behavior. These are fairly standard results from the available literature on incomplete contracts. What we have added are critical factors that appear special to the biotechnology industry. Examples include the importance of understanding the management and transferable components of firm value, strategic partnerships as acquisition tactics, the implications of differential enforceability for provisions of contracts, and what we have termed "portfolio effects related to multiple contracts of a single firm or single contracts for multi-product firms."

There is significant public participation in the biotechnology industry. In terms of agricultural research and development, public universities and research enterprises invest almost as much as the private-sector. This feature of the societal investment strategy appears to generate a continuing number of small and specialized firms. These firms are often participants in strategic partnerships with the larger firms, and ultimately are acquired. The public sector is in some sense providing innovation to a consolidated industry. The result may be a reduction in the implications of the observed concentration for innovation and product development. Public sector investments are in fact providing the source of this innovation and change. One could argue that in such circumstances the consolidation and concentration effects are being at least partially mitigated by the large role of the public sector in research and development investments.

The implication is then for increased consolidation, less limited by policy interventions and less damaging in terms of effects of concentration. Reductions in the share of public sector in research and development could significantly alter this situation, however. With high public investments there are always threats of entry and sources of new innovation. Perhaps this is one of the unanticipated benefits of the public role in research and development in sectors where contracting and other problems provide strong incentives for consolidation.

Concluding Observations

In fact, there is an "industry policy" for the biotechnology sector. A major instrument for this industry policy is the large public investment in research and development. A second instrument that is of importance is the expanded scope for patents and licensing. Anti-monopoly policy is also exercised. However, it is not clear that this industry policy is reflective of the special circumstances in the biotechnology sector. Our conclusion is that there will continue to be strong incentives for consolidation. Moreover, these forces are largely driven by advantages of integration and associated contracting problems. At least one of the implications is for better understanding of public research and development as a key component in the strategy for "managing" the sector.

We have not yet raised the question of the implications of consolidation for developed versus developing nations. In fact, implicitly, the discussion and observations have been within the context of the industry, as we understand it in the U.S., or more generally the developed nations. If public research and development expenditures are important in counterbalancing the consolidation in the biotechnology sector, there are implications for the developing nations. These nations have relatively low public investments. Impacts of consolidation in the industry could be more pervasive and/or require the use of other instruments for managing the effects of consolidation and concentration.

The opportunities for better understanding the incentives for mergers and acquisitions and, more generally, for industry consolidation, are being greatly enhanced by our increased understanding of asset specificity's, incomplete contacts, and residual property rights. We have tried to add to this understanding by investigating more carefully the features of the contracts, the role of management, and the complexities introduced when it is recognized that firms tend to have multiple contracts and multiple products.

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Evolving Business Strategies to Utilize Development in Biotechnology Supporting Long-Term Production of Adequate Supplies of High-Quality Food for the World

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In this paper I discuss agricultural biotechnology from an industry perspective, with reference to products and future trends, describing some of the new technologies and what they will mean to the farmer and to the industry as a whole.

In common with other companies, we at Monsanto realize the need to contribute to the feeding of two billion more people over the next 20 to 30 years, while respecting the environment. To rely on the methods of increasing food production that were used over the past two to three decades would be detrimental to the environment and, therefore, not sustainable in the long term. Moreover, we anticipate that increasing demands for improved food quality will influence what agricultural products reach the market place.

Challenges

Those are the challenges for agriculture, but what of the challenges for biotechnology? From an industry perspective, the state of affairs is more complex and less monopolistic than may be immediately apparent from the outside. For those who have invested in the area, there are complex issues related to patenting, for example. It is relatively easy for a small player to develop a significant patent that is required to deliver a new product to the market place. But, regulatory systems, which are still evolving worldwide, must be in place. For example, we were able to introduce new technology into Brazil only after a regulatory system was instituted there.

Consumer acceptance varies considerably from one part of the world to another. Currently, Europe is our biggest challenge and we do not expect to commercialize biotechnology products, including new crop varieties, there in the near future.

There is intense competition in getting biotechnology products to the marketplace, with investment of large sums of money necessary, much of it from other industries. The closest model, for the foreseeable future, is the electronics industry — incredibly rapid developments in technology and capability, with many players involved. I expect increasing competitiveness, a view not shared by everyone.

Changes

During a recent visit to Boston, I asked one of our research laboratory leaders about changes in productivity, regarding the sequencing of genes of agricultural crops. Seven years ago, as a graduate student at a university lab, it took him a year to sequence one gene — extensive work and a great deal of hard labor. He pointed to one of a long row of instruments and said: “That machine will sequence 2,500 genes during this 24-hour period.” What took one person a whole year now can be done 2,500 times over in one day — and that row of machines is in operation 24 hours a day! It is likely that, for the major crops, the complete sequences of their 80,000 or more genes will be known within two years. Clearly, this is a time of great change in the biotechnology industry.

Around the world, government support for crop production is declining, a trend we expect to continue. Just as with industry, growers are consolidating to meet increasing demands for food. As biotechnology brings new opportunities, information is much more available today than it was even five years ago and growers are commensurately more sophisticated. To achieve higher yields, there is a significant shift in emphasis from the chemical inputs of the last decades to crop capability. For example, weed control was formerly limited to herbicide choices with quite distinct criteria involved in the selection of a seed variety. Now these decisions are interconnected — by planting soybean containing the Roundup Ready® gene, the farmer can apply a herbicide that could not previously be used on that crop. Until recently, the chemical, biotechnology, and seed industries were distinct, but this is no longer the case and food is just the next component. Food production, and the ability to improve food quality, will be dramatically affected by biotechnology.

By 2020, there will be about two billion more mouths to feed, largely as a result of population growth in the developing world. Over this time frame, the per capita Gross Domestic Product of the U.S. and Europe are expected to double, whereas those of China and India, for example, will increase five to six fold, bringing new financial capabilities. It is likely that improved quality of food will become a priority in Asia, with shifts in preference from cereal grains to meat and milk products, creating a total increase in demand for food of 75 percent over that for 1990.

Biotechnology's Contributions

Let us consider India further. Increases in per capita consumption of milk and meat requiring more cereal grains will be comparatively higher in rural than in urban areas. Therefore, not only must we produce more food for the growing population, but satisfying demands for higher quality will necessitate increased productivity in excess of projections for population growth.

Increased needs for food must be met using farming practices that are sustainable. Of relevance are the new biotechnological tools for protecting crops from insects, weeds, fungi, and viruses. Products already on the market or in development include the following:

- Roundup Ready® corn provides new weed-control options for growers. More than two million acres were planted in the U.S. in 1999; it will be launched in a number of countries over the next two years.
- Corn protected from the European corn borer, is, essentially, a replacement for insecticides, although it is also planted by farmers who would otherwise not have sprayed because they could not properly time the spraying or achieve effective insect control. We are seeing a mean yield advantage of 13 bushels across the mid-west.
- A product in the pipeline for 2001 is corn protected from rootworm, a major pest. We have obtained dramatic effects: well over 99 percent control.
- Bollgard® cotton provides significant control of insects, saving farmers an average of approximately four sprayings, depending on location. In the mid-west, Roundup Ready® soybeans have received broad acceptance. In 1999, more than 50 percent of the U.S. soybean acreage was Roundup Ready®.
- Roundup Ready® rice is showing promise. It will give farmers a new weed-control option, and, in many places, will preclude the need to flood fields to kill weeds, presenting the opportunity to conserve water.
- Roundup Ready® wheat is expected to be available in 2003, and our data show great promise.
- Wheat with a protective gene remained healthy in laboratory tests after infection with head scab, a major disease in North America and Europe. These results promise reduced need for fungicide application, and significant yield benefits in parts of the world in which spraying is not an option.

A great deal of effort on the part of several companies is going into improving oil quality, with potential human-health benefits, and there are opportunities also to improve the seed-protein and oil values of corn to provide a better, more balanced livestock feed.

We have the ability to improve the starch content of potatoes. As french fries are cooking, the water is replaced by oil; the higher the starch content, the less oil in the finished product. So, for the fast food industry, fries with one-third less oil are possible, which, combined with improved oil quality, would be attractive to those concerned about fat and/or cholesterol. Although it would never be a recommended food, the product is more nutritionally sound, clearly, the permutations and capabilities now feasible present many new possibilities.

Lack of ß-carotene in the diet results in night blindness and, ultimately, blindness for millions of people in developing countries. The technology exists to increase the ß-carotene content of canola oil, which is used widely in India and China. It is hard for industry to justify investing in a product without the promise of a return on the investment. Through USAID, Monsanto found the opportunity to donate this technology to provide significant health benefits to people in many parts of the world. So I would argue that technologies developed by Monsanto will actually make it easier for other companies to introduce new products from minor crops to the market place.

Plants as Factories

We believe that many products that have pharmaceutical value, will, in the future, be more economically produced in plants. Although farmers are excited about this, I do not foresee vast areas planted to pharmaceutical crops; however, the acres that are planted will be very valuable. While I believe the larger value for the farmer will accrue from grains with improved protein and oil quality for human consumption, the growing of crops with pharmaceutical applications will be increasingly important. Compounds produced by fermentation today will be produced in the future by moving the appropriate genes into plants.

New Choices

Biotechnology will provide new choices for farmers. They will “vote” every year on whether to use the technology or not, which is the best competition of all. As mentioned above, conventional use of chemicals is being pre-empted by the choice of seed. The farmer will increasingly make decisions about pesticides through their purchase of seeds.

The cotton grower who would have had to spray three times, and possibly up to seventeen times in a single growing season, now can choose a product with which he is virtually assured that spraying will be necessary only once or twice, thus reducing personal exposure and environmental exposure.

We expect:

- greater production of value-added crops by contract,
- identity preservation of crops, if they have unique characteristics that have value,
- global competition, and
- intensification of farming and the farm-supply industries.

Keys to Success

Success requires the right product in the right quantities at the right price. Most of the food products of biotechnology are substitutes for others that meet current demand. Ability to produce does not guarantee a market. Economical pricing is essential, and high quality and efficient production are important. By sharing value with people in the system, their participation is encouraged.

Monsanto has entered a joint venture with Cargill. Monsanto brings the technology and Cargill brings knowledge of end-uses and how to extend the system all the way to the consumer. Cargill also has the financial resources to help fund this expensive research, which takes six or seven years from project inception to the marketplace. Thus, by combining efforts and sharing costs, the risks involved in developing new products are shared. However, even when two such large entities combine, other players must be included in the collaboration because no two companies possess the wherewithal to invent all the necessary components or reach all the markets. Therefore, cross licensing of technology and capability, and product sharing will be increasingly common.

Monsanto has invested in seed companies because seed is critical for delivering the technology to the grower. For the same reason, DuPont has invested in Pioneer.

Genomics

Having sequenced whole genomes, the next area of emphasis will be the linking of specific genes to phenotypes. Information in this area is already exploding, and the race is on to deliver new desirable traits to the market place.

We are excited because we currently use only about five percent of available corn races, whereas this technology will allow us to choose genes from any corn genotype, and other species of crops, and move specific desirable traits into commercial corn. With genomics, we could have brought Roundup Ready® soybeans to market two years earlier, and we will probably commercialize corn with rootworm protection two years earlier than initially projected.

Furthermore, in the past, it was necessary to grow out and test every line of soybean for a desired phenotype. We can now perform 10,000 tests per day to check for resistance to cyst nematodes, for example, for just 10 percent of the traditional cost. This efficient type of screening allows us to bring products more quickly and more efficiently to the market place.

Patent Protection

In the U.S., newly commercialized products have patent protection, of which growers are aware. In many developing countries there is no such safeguard. In countries like India, the use of hybrids protects our technology — cotton for example. In China we have a trademark license that the Chinese support, and, in return, we provide seed of a quality higher than they have seen before. Likewise, in Poland, we provide better seed-potato quality than previously available.

Chinese cotton growers buy seeds in 1-kg quantities. Over 500,000 of them are planting our insect protected varieties on fields as small as a tenth of an acre. They are excited about reducing their pesticide applications and increasing the productivity of their family farms.

Questions for the Future

I conclude with some questions.

- Can we help consumers worldwide understand the benefits of biotechnology?
- Will the benefits from biotechnology be shared appropriately with farmers?
- Will the rewards stimulate continued investment?
- Can appropriate linkages or networks be formed?
- How fast will demand for high-quality food increase?
- Can biotechnology help us to make increased production a more sustainable process?

Biotechnology on the Ground: What Kind of Future Can Farmers Expect and What Kind Should They Create?

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One of the central questions that any new technology poses for farmers is whether or not it will benefit them. Will it either benefit them directly by solving management problems or improving profitability? Or will it benefit them indirectly by enabling them to achieve some social goal that they wish to support?

Such a pragmatic assessment of any technology is, of course, made difficult by the cultural love affair with technology that we have nurtured in our society since the dawn of the industrial revolution. But farmers must know by now that not all new technologies will be friendly to them. Indeed, Willard Cochrane made a compelling case for the opposite view when he coined the phrase "technology treadmill." Even when a technology appears to be beneficial to farmers, like tractors replacing horses for greater labor efficiency, it will put a good number of farmers out of business (Cochrane 1958).

Whether or not such systematic elimination of farmers from farming has been, or continues to be, a social benefit is a subject of debate that we have never had in any democratic forum. But to argue that every new technology is a sign of progress and bound to benefit farmers is a proposition of mythology, not sound business or social policy.

While it is clear that every new technology benefits someone, it is equally clear that not every new technology benefits everyone. Accordingly, with respect to genetic engineering, the question farmers need to ask is whom this technology will benefit. The likely beneficiaries are the corporations developing the technologies and their investors. They wouldn't be investing billions of dollars unless there were a strong likelihood that the objectives (at least the financial ones) can be achieved.

The question that farmers must ask is whether or not the technology will benefit them.

The biotechnology industry claims that farmers will benefit — directly by solving management problems and increasing profitability and indirectly by solving social problems with which farmers can identify. These claimed benefits can generally be subsumed under three categories:

1. That the technology will increase farmers' profitability and make them more competitive in the marketplace: This claim promises direct benefits to farmers.
2. That the technology will simplify farmers' pest management problems and do so in an environmentally benign way: This claim promises to benefit farmers directly and enable them to achieve a social goal.
3. That the technology will enable farmers to feed a world of expanding human population: This claim mostly promises farmers an opportunity to achieve a social goal, but it is generally assumed that it would also provide them with economic opportunities.

Are these claims true? I will argue that the probability that farmers will experience any of these benefits, given the way the technology is currently being applied, is very unlikely.

Let's analyze each of the claims from a farmer's perspective.

That Genetic Engineering will feed the World

There is a fundamental flaw with this claim that is exposed in the conclusion of several decades work by the Nobel Prize winning economist, Amartya Sen. His simple, unassailable conclusion, based on his study of the classic famines of the world, is that hunger is not caused by food availability, but by food entitlement. In other words, hunger is not caused by an insufficient quantity of food, but by insufficient access to food. Feeding the world is therefore largely a social, not a production, problem (Sen 1981, 1986).

Continuing to assume that hunger is a production problem without wrestling with the difficult problem of entitlement ironically ends up exacerbating the problem of hunger. And, in the process, it ends up hurting farmers economically. Brazil stands as a clear example. The production of soybeans in Brazil has increased dramatically in recent years. But the soybeans are produced primarily for export to Europe and Japan where they are used for animal feed, thereby denying local Brazilians entitlement to the food production capacity of their own country. Consequently during the same time that soybean production has exploded, the number of malnourished in Brazil has increased from one third to almost two thirds of the population. And Brazil's increased food requirements will not be supplied by U.S. exports for the simple reason that malnourished Brazilians can't afford them.

Meanwhile the over production of soybeans has pushed the price of soybeans in the U.S. down to four dollars a bushel. Simultaneously, it decreased the availability of land for local Brazilian farmers who used to produce food for local Brazilian populations. This is not a formula that feeds the world, or brings benefits to the majority of farmers. And converting all of the soybeans grown in Brazil to genetically engineered (GE) varieties won't change that.

Furthermore, focusing only on more food as the single solution to expanding human populations detracts our attention from a host of other problems that further overcrowding, by still more humans on the planet, will surely create:

- increased disease,
- destruction of ecosystem services, and
- increased fragility of the entire ecosystem that a further imbalance of humans relative to other species will cause.

Besides, to my knowledge no one ever asked farmers if they wanted to take on the responsibility of feeding the world, or asked them how they wanted to do it if they did.

That Genetic Engineering will Solve Pest Management Problems in an Environmentally Benign Manner

Again, there is a fundamental flaw with this claim. The problem is that current applications of genetic engineering technologies for solving pest problems still adhere to the same paradigm that led to futility in pest management with toxic chemicals. Joe Lewis of the Agricultural Research Service's Insect Biology and Population Management Research Laboratory in Tiffon, GA, together with several colleagues, published a "perspective" paper in the National Academy of Sciences Proceedings in 1997 that clearly and succinctly lays out the problem. Our predominant paradigm for pest management, argues Lewis, has been one of "therapeutic intervention." This approach attempts to eliminate an undesirable element by applying a "direct external counter force against it." That paradigm is now being widely questioned not only in agriculture, but in medicine, social systems, and business management enterprises (Lewis 1997).

As Peter Senge points out in his work on systems dynamics, externally imposed solutions at the expense of analyzing and understanding the functions of the system, generally leads to creating the problem we are trying to solve. The reason is simple. "The long-term, most insidious consequence of applying non-systemic solutions is increased need for more and more of the solution" (Senge 1990). Farmers can certainly relate to that with respect to pest management. In fact, it is precisely that principle at work that led Robert van den Bosh to coin the phrase the "pesticide treadmill" more than twenty years ago. Applying an external solution to a pest problem generally disrupts the natural balance that keeps pests in check and develops resistance in the target pest, thereby increasing the need for more of the solution. While that certainly benefits the company selling the solution, it hardly benefits farmers.

In other words, not only is the therapeutic interventionist paradigm ineffective in providing sustainable relief from pests, it also makes the farmer more dependent on the supplier of the intervention. And as Donella Meadows points out “over time, the intervenor’s power grows” over the person who becomes dependent on the intervention. The clear result is less economic empowerment for farmers and more economic power for the provider of the therapy. One can hardly argue that, that scenario is of benefit to farmers. To assess the long-term benefit of any pest management strategy for farmers it must be measured against the “fundamental principle” that Lewis articulates so succinctly:

> . . . application of external corrective actions into a system can be effective only for short term relief. Long term, sustainable solutions must be achieved through restructuring the system . . . The foundation for pest management in agricultural systems should be an understanding and shoring up of the full composite of inherent plant defenses, plant mixtures, soil,natural enemies, and other components of the system. . . The use of pesticides and other “treat-the-symptoms” approaches are unsustainable and should be the last rather than the first line of defense. A pest management strategy should always start with the question “Why is the pest a pest?” and should seek to address the underlying weaknesses in ecosystems and/or agronomic practice(s) that have allowed organisms to reach pest status.

Lewis goes on to point out that this principle holds for molecular biology as well as for toxic chemicals. Since genetic engineering conforms to the same interventionist strategies used in the chemical pest control era, farmers should not expect any long-term pest management benefits from the technology. Resistance to Bt will develop, for example, rendering Bt corn and similar pest management strategies ineffective. That, in turn, will complicate future pest management efforts — not to mention destroy an environmentally benign pest management tool that many farmers have used effectively for more than 20 years. And if the recent study reported in *Science* magazine is correct, (demonstrating that the genes encoding resistance to Bt in European corn borer are dominant, rather than recessive as previously thought) then the high dose/refuge strategy that farmers have been told to use to postpone resistance will be useless (Huang et al. 1999).

That it Will Increase Farmer Profitability and Make Farmers More Competitive

This claimed benefit is even more questionable. The reason farmers are not likely to see much profit from genetic engineering is not rooted in the cost of planting refugia to postpone resistance, or the yield drag of some genetically engineered varieties, or even the technology fees that farmers are required to pay. Some mainline farm magazines argue that GE crops could still pencil out despite these down sides, if one takes a long-term view (Holmberg 1999). I’m skeptical, but perhaps they are correct.

But there is, again, a more fundamental principle that farmers need to consider when assessing the profitability of any technology.

Stewart Smith, an agricultural economist at the University of Maine, perhaps articulated that principle most clearly almost 10 years ago. For most of this century, farmers have been taught to believe that profitability is strictly a matter of price and yield. Indeed, Paul Thompson at Purdue University has suggested that farmers have been so indoctrinated into the higher yield school of profitability that they now operate out of a single ethical principle — "produce as much as possible, regardless of the cost" (Thompson 1995). But Smith suggests that while farmer's fortunes are, to some extent, linked to price and yield, those factors ultimately do not determine farmer profitability. Profitability is determined more by the share of the agricultural economic activity that farmer's command then by the quantity of commodities they produce or the price they get for them. And Smith points out, rather graphically, that the farm sector's share of the agricultural economic activity has steadily eroded for most of the 20th century. According to Smith's study, farm sector economic activity shrank from 41 percent to nine percent during the period from 1910 to 1990. Coincidentally, during that same period of time the input sector economic activity increased from 15 percent to 24 percent and the marketing sector from 44 percent to 67 percent (Smith 1992).

And technology plays a key role in determining who gets what share. Smith points out that "technology is the primary cause of farming activity loss."

The problem is that the kind of technology that has been promoted by both the private and public sector is technology that shifts economic activity away from the farm sector to the input sector. For the most part the technologies developed over the last 100 years have been technologies that exert an external corrective action on a problem, rather than technologies that develop self-regulating systems. Those technologies increase economic activity for input companies but decrease economic activity for farmers. The reason that the private sector develops that kind of technology is readily understandable. It increases the profitably of the corporations producing the technologies. The reason that the public sector promotes this paradigm, according to Smith, is because it is strongly influenced by private funding.

Genetic engineering advances this scenario another quantum leap. Not only does the technology conform to the same paradigm of exerting an external corrective action on the problem, but the technology is instrumental in speeding up the merger mania that is now merging the input and market sectors. Bill Heffernan predicts that by the time the mergers and acquisition process is complete, there will be just four food clusters that will control most of the nation's food supply. These developments portend a future wherein farmers become contract workers forced to contract with one of these four input/market sector clusters. The farmer's only role will be to grow out the firm's seed, into the firm's crop, for the firm's market. As Bill Bishop puts it, "Farmers will not farm; they will fulfill contracts . . . biotechnology gives new meaning to tenant farming" (Bishop 1999).

If anyone thinks that farmers will become economically empowered in this system, they haven't looked at the broiler industry lately. In this scenario, the only hope farmers may have of retaining any voice at all in their own economic welfare will be through some kind of universal collective bargaining. That may actually not be a bad idea since farmers are already paying their union dues in the form of check-off dollars, but the funds are misdirected. Farmer check-off programs seem to be based on the flawed notion that farmers can produce their way out of this problem. Airline pilots never use their union dues to get more people to fly. They use them to get a fairer share of transportation profits.

A more immediate way to empower farmers economically, however, is to implement Smith's suggestion regarding the use of public funds and the way farmers must do business. Public funds, Smith argues, must be directed "away from technologies that shift activity from farmers to non-farm firms," and toward farming systems that "displace purchased inputs." Such technologies would create self-regulating pest management systems, and on-farm nutrient cycling systems, that displace purchased inputs. Such shifts would also tend to replace economies of scale with economies of scope, and it would, to a much larger extent, put farmers in control of their own costs.

The way farmers do business has to shift from farmers being the suppliers of undifferentiated mass-produced raw materials into a global economy, to becoming the marketers of identity preserved products and marketing those products as directly as possible. Such enterprises need to be owned and operated by farmers, with direct retail links that provide consumers with identity preserved products that conform to consumers' changing demands.

What Kind of Future Should Farmers Create?

As we contemplate what kind of future farmers should create for themselves, it is important to recognize that the farm sector is developing into two very different kinds of farmers. By some estimates, there are now approximately 200,000 farmers who mass-produce 85 to 90 percent of the undifferentiated commodities that are sold as raw materials into the global market. These are the new wave of industrial farmers. We will likely see these farms dramatically increase in size and decrease in number as they become vertically integrated into the food system through contractual relationships. Some anticipate that the number of these farms will decrease to 25,000 in the next decade. That seems like a reasonable projection.

The production paradigm of these industrialized farms is not likely to change. Genetic engineering will increasingly be the "direct external counter force" used to solve farming problems. In the short-term, these technologies will be successful in solving some production problems. Eventually, we will see the technologies become ineffective and increasingly ecologically worrisome.

But even if they question their long-term effectiveness, these farmers will be required to use these technologies because their contractual relationships will mandate it. But industrial farmers should not expect to generate great profits, with or without genetic engineering, unless they can develop some kind of effective collective bargaining to claim a larger share of the food system profits.

Then there are the 1.5 million farmers who make up the balance of the farm sector. Increasingly, these farmers are developing ways of differentiating their product and shortening the distance between farm gate and consumer table. These are farmers who generally fit the description of the new economy described in detail by futurists like Alvin Toffler and Peter Drucker. Instead of mass producing an undifferentiated commodity in ever increasing economies of scale, these farmers will remain smaller, more flexible, and more innovative, using systems to produce a variety of highly differentiated products produced for specific markets. In other words, they will use "mind" instead of "muscle," as Toffler puts it. These farmers will increasingly shift to new production paradigms that internalize costs, and develop self-regulating and nutrient cycling systems. These shifts will take place not only because consumers demand them, but because energy efficiency and the demand to end public subsidies will require them. Most will eventually gravitate toward whole systems management in their production, as well as in their marketing.

These farmers are not likely to benefit much from the present applications of genetic engineering technologies. In fact many, like the Sinners in Casselton, ND, will gear up to fill market niches created by the consumer backlash against genetic engineering (*Jamestown Sun* 1999). The Sinners have long differentiated their production by certifying and selling seed. For them, identity preserving genetically natural crops is simply another way of differentiating a premium product that consumers want. Of course there are some applications of genetic engineering that this generation of "new economy" farmers can use. Genetic engineering, for example, might help us to better understand and implement self-regulating systems. However, since that application of the technology will result in few product sales, its development will have to be undertaken by public research institutions.

The industrialized farms, in my opinion, will fail in the long run. There are three fundamental reasons for their failure:

1. These farms will be highly centralized, routinized, and specialized. That means there will be little room for flexibility, diversity, or innovation. History does not give us many examples of farming systems designed on those principles that have succeeded. Increasingly these production systems will attempt to force the market to change (witness efforts to get Europeans to accept genetically engineered food, and hormone fed beef) rather than adapting to changing markets. That is not likely to succeed. As *Nature* magazine put it recently, "consumer acceptance" must be part of the equation (*Nature* 1999).

2. The routinization of these farms will dictate that the preferred technologies will be those that serve as a direct external counter force to solve problems, rather than those that make systems changes. There is no good reason to believe that molecular biology, used in that paradigm, will be any more successful than chemistry in creating sustainable pest management systems.
3. Genetic engineering will increase the specialization and routinization of these farms and they will therefore continue to dramatically reduce the biodiversity of farms and the ecosystem in which the farms exist. This further reduction of both genetic and species diversity will make these farming systems increasingly vulnerable to new pests and diseases.

Eventually the system will collapse

For farmers who choose to create their future in the new paradigm, there is hope for a brighter tomorrow. There will, however, be many challenges along the way. Precious little research and technology development has been done to support this alternative direction. Market infrastructures have not been developed, and public policies, for the most part, favor the old paradigm. Public policies that put that alternative on a level playing field would help farmers gain a foothold in this "new economy," "new paradigm" future.

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For additional reasons why genetic engineering will not help feed the world, see the 28-page briefing entitled “Food? Health? Hope? Genetic Engineering and World Hunger,” prepared by The Corner House, PO Box 3137, Station Road, Sturminster Newton, Dorset DT10 1YJ, UK.

Why Biotechnology May Not Represent the Future in World Agriculture

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- U.S. environmental groups are suing to end the use of *Bacillus thuringiensis* (Bt) to provide pest resistance in genetically modified crops.
- European public opposition to genetically modified crops increased from 35 percent in 1997 to 51 percent in 1998.
- The Swiss nearly voted to ban biotechnology in food production last year (Gottfried 1998). Important members of the anti-biotechnology coalition were the national organizations representing both Lutheran and Catholic women. Modern agriculture cannot even count on what should be its core audience of homemakers.
- Virtually the only messages that reach today's urban First World[1] public about high-yield agriculture (biotechnology or otherwise) come from such organizations as Greenpeace and the Sierra Club. Agriculture tries to send its messages through journalists who behave as though committed to the environmentalist cause — and thus reject modern farming.

There are two major reasons why biotechnology should be the future in world agriculture: First, the world will need three times as much farm output in the middle of the 21st century as it harvests today. Agriculture has no choice but to provide fully adequate diets for the larger, more affluent human population projected for the year 2050. Parents will not let their children starve. In the 21st century, they will not even allow them to go without high-quality protein (meat, milk, and eggs). Nor will tomorrow's pet-owners accept low-quality diets for perhaps two billion additional cats, dogs, and other companion animals.

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[1] First World here means the developed countries of the world.

Second, humanity wants to preserve the planet's wild lands and wild species — and we cannot do that without achieving still-higher yields from our crops and livestock. We are already using 37 percent of the earth's surface for farming. We cannot preserve wild lands with a peak population of 8.5 billion affluent people unless we produce much higher yields.

Biotechnology is the largest piece of unexploited knowledge available to agriculture as we enter the 21st century. Moreover, biotechnology is already proving that it's likely to become the most powerful tool for advancing the productivity and sustainability of agriculture in all history.

Unfortunately, there is one major reason why biotechnology may not be the future in agriculture: the shortsightedness — or arrogance — of modern agriculture and agribusiness.

Is Self-righteousness Agriculture's Fatal Mistake?

Farmers and agriculturists have a deep and steadfast belief in their own righteousness because they produce food. When the public still suffered periodically from food shortages, they always seemed to concede the importance and virtue of farmers. Today, when the public has real food security for the first time, it no longer reveres farmers. Urbanites have no more sense of gratitude for food than they have for radial tires (which also save lives). They know their food comes from the supermarket. It's available 24 hours per day, seven days per week, and it can be bought for a small and declining share of income.

Farmers are unlikely to ever again get political credit for producing food anywhere this side of Russia. It's too plentiful, too cheap, and too reliable. Hence, it is taken for granted.

Farm subsidies have proven another key public affairs mistake for agriculture. First World farmers asked for subsidies, because there was "too much food," though the world never had a food surplus. Rather, it had a lot of potential customers with no money. Today, another two billion consumers are getting the money to buy — but pervasive trade barriers still prevent export farmers from supplying them. Thus, much of the First World public is still looking at piles of surplus grain and meat. (The import barriers won't be lifted as long as Europe uses export subsidies.)

Farming's final mistake was not talking to city folks. Farmers always felt a little embarrassed about being "country." And when the mass exodus to the cities began about 1946, farmers started talking to their legislators instead. The agricultural committees always listened, and then cut interesting deals with the non-farm legislators.

That worked until the environmental movement emerged — and trumped the farmers' legislative strategy by talking directly to the urban public. What they said was that modern farming was bad for the environment.

The Environmental Campaign Against Modern Farming

Agriculture was initially shocked at the environmental attacks. Farmers and researchers have spent decades attempting to refute what they thought were serious charges about cancer and wildlife losses. However, as the eco-activists have continued to assail modern farming, it has become clear that their charges are not based on science. (Rachel Carson was wrong about even early pesticides causing cancer [Ames and Gold 1992; Ritter 1997], and even about the famous robin deaths being caused by DDT [Klaus and Bolander 1977].) It is clear now that the eco-activists will claim anything that city folks are willing to fear.

- The eco-activists began telling city folks that pesticides cause cancer. Never mind that after 50 years of widespread pesticide use and billions of research dollars, science is still looking for the first case of cancer caused by pesticide residues.
- Wildlife groups have universally claimed that modern farming was poisoning massive amounts of wildlife with chemicals. Never mind that there is never much wildlife in the fields, nor much biodiversity on the good quality land that is generally used for farming. Nor have they given credit for the massive amounts of wildlife, which have not had to be plowed down for low-yield crops. Noble laureate Norman Borlaug has estimated that if American farmers hadn't raised their yields in recent decades, we would have had to clear all of the forest east of the Mississippi to get today's food supply. (Borlaug 1997) How many billions of birds would that have destroyed?
- Eco-activists claim that more food would simply mean more people. Never mind that births per woman in the Third World are down from 6.5 in 1960 to 2.9 today. We are clearly in the first era of human history when more food has not meant more population. Instead, more food security has encouraged smaller families because parents can feel secure that their first two children will live to support them in their old age.
- The activists claim that modern farming is destroying the soil with rampant erosion (Pimental, et al. 1999). Never mind that tripling yields on the best land cuts soil erosion per ton of food by two-thirds. Or that conservation tillage allows us to build topsoil even as we grow high-yielding crops.
- The eco-activists claim that modern seeds are destroying the world's biodiversity — displacing thousands of land race crop varieties with a few dozen modern hybrids that would eventually expose us all to crop epidemics (Tuxill 1999). Never mind that we would have long since starved or destroyed all our wild lands without the higher yields produced by modern seeds. Never mind that much of the biodiversity is already in the world's gene banks and more of it would be if we modestly increased gene bank funding. Never mind that biotechnology can use wild genes to create more biodiversity.

We can document a long list of charges made against modern agriculture by people who claim to be plaintiffs for the environment — but all their charges have proven false or misleading.

Agriculturists must now realize that they are being targeted, not because they are bad for the environment, but because modern farming 1) represents the pinnacle of success for technological abundance; and 2) the environmental movement wants the farmers' land and water. They think they would rather see more bison and prairie dogs and fewer corn plants. They think they'd prefer a farm that looks like a Currier and Ives print than the grain bins and tractors of a modern high-yield farm.

THE NEW GLOBAL CAMPAIGN AGAINST PLANT NUTRIENTS

The latest big eco-effort is a campaign against plant nutrients keyed to water quality. A crisis is being created to renewing the Clean Water Act of 1972 with sweeping new powers. In the public mind, vital plant nutrients, such as nitrogen and phosphorus, are being turned into threats.

Hypoxia — A White House task force has been appointed to resolve the hypoxia problem in the Gulf of Mexico. The hypoxic, or low-oxygen zone, doubled after 1990 from 3,500 square miles to 7,000 square miles. Agriculture, again, is being blamed. The presumed solution is to make Midwest farmers radically cut their use of fertilizer, and to "crack down" on big livestock and poultry farms. Never mind that hypoxic zones are characteristic of rivers that drain fertile regions. Never mind that the size of the hypoxic zone in the Gulf of Mexico shrank back to 4,800 square miles in 1998, linking the size of the hypoxic zone to the Mississippi water volume, not the nitrate levels. Never mind that cutting fertilizer use in the corn belt will mean clearing tropical forest for low-yield crops somewhere else in the world.

Manure as toxic waste — For 50 years, the critics of modern farming have held up organic crops fertilized with animal manure as the global ideal. Now the same critics are saying "organic fertilizer" is "toxic waste"— if the animals are being raised in a big confinement facility. Never mind that the big confinement feeders protect the environment by collecting their wastes and using them to more-sustainably raise the yields of feed crops. Never mind that the little outdoor producers let the wastes wash into the streams. As the world triples the number of hogs in its inventory from one billion to three billion we better hope, for the sake of the environment, that the additional hogs will be raised in confinement.

Volatilized nitrogen — Recently, the activist magazines (and even mainstream *Science*) carried articles about the dangers of "too much fixed nitrogen." They're concerned that too many crops are being fertilized, and too many meat and milk animals are producing too much manure. They say that too much fixed nitrogen might even change the global climate and our ecosystems. Certainly, some of the fixed nitrogen from agriculture is volatilized into the atmosphere, but so far no one has found that to be much of a problem. One researcher complained that the extra nitrogen "aggravates acid rain" (Vitousek 1997). Never mind that a $600 million federal study found that acid rain was a minor problem, confined to a few tree species, such as red spruce, in a few mountain areas lacking limestone or other buffering from the natural acidity of our rainfall. Never mind that nitrogen, from perhaps four million square miles of high-yield crops and intensive livestock, is being spread over 197 million square miles of land, water, mountain and forest around the world — where its major impact is to slightly enrich the food chain. The biggest negative impact is likely to be a slight disadvantage for wild legume plants.

Complaints about wonder wheat — When the International Maize and Wheat Improvement Center (CIMMYT) recently announced a major re-breeding of the wheat plant to raise yields by 50 percent, the initial reaction cited in *Science* was distress that this would encourage high levels of fertilizer use. CIMMYT says its new wheat varieties have yielded up to 18 tons of grain per hectare, far more than any other wheat. An Indian scientist was quoted as being dismayed that this would mean using up to 400 kilograms of fertilizer per hectare of wheat. Never mind that it takes a fixed amount of about 25 kilograms of fertilizer to grow a ton of wheat. So, it takes 400 kilograms of fertilizer to grow 18 tons of wheat why not use it on one optimal, erosion-resistant hectare of farmland rather than clear another 17 hectares of wildlife habitat. The difference is that the high-yield wheat leaves far more room for nature.

Why Modern Agriculture Deserves to Win

High-yield farming is mankind's greatest humanitarian achievement. The whole world is getting true food security for the first time in history. People are no longer pitted against people during food shortages. Parents are no longer forced to choose between feeding themselves and feeding their children, or choosing whether girl babies will starve while boy babies live.

High-yield farming is humanity's greatest conservation achievement. Crops have saved the most — probably about 15 million square miles. Confinement livestock and poultry have saved an additional several million square miles. Food processing allows us to grow the food where the yields are highest, and transport the production to wherever the people choose to live without post-harvest losses. The total wild lands saved by the modern food system is probably close to 20 million square miles — or the total land area of the U.S., Europe, South America, and some major parts of Asia or Africa.

But agriculture hasn't told anyone

Biotechnology in Food is Important — to Wildlife

The world is in the early phases of exploring biotechnology's potential — the "biplane stage" to draw the analogy with airplanes. But already we see enough to know that biotechnology will be enormously important to conservation.

Saving Wild Species with Aluminum-Tolerant Crops

Two researchers from Mexico discovered a way to overcome the aluminum toxicity that cuts crops yields by up to 80 percent on the acid soils characteristic of the tropics (Barinaga 1997). Noting that some of the few plants that succeed on the world's acid savannas secrete citric acid from their roots, they took a gene for citric acid secretion from a bacterium and put it into tobacco and papaya plants. Presto, they had aluminum-tolerant plants. The secreted acid ties up the aluminum ions, and allows the plants to grow virtually unhindered. The Mexican researchers have since gotten the citric acid gene to work in rice plants, and hope that it can be used widely in crop species for the tropics.

Acid-soil crops have enormous potential for wildlife conservation. Acid soils make up 30 to 40 percent of the world's arable land, and about 43 percent of the arable land in the tropics. Thus far, they have been one of the major barriers to providing adequate food in the very regions that are critical to wild lands conservation — the Third World tropics. The very area where the populations are growing most rapidly, where incomes are growing most rapidly, where the food gaps are growing most rapidly — and where most of the world's biodiversity is located.

The world's good cropland typically had large wildlife populations — but only a few wild species. (Argentina's famed Pampas, for example, had virtually nothing but Pampas grass.) Most of the world's biodiversity is found in the tropical forests, the wetlands, the mountain microclimates, and other places where we shouldn't even try to farm. If the world has 30 million species (a reasonable biologist's guesstimate) then 25 to 27 million of them are probably in tropical forests. Researchers have now found more wild species in about five square miles of the Amazon rain forest than we have ever found in all of North America.

In the name of conservation, we must farm the world's good land for all it can produce — so we can leave the tropical forests and fragile lands for the wild species.

Raising Yields with Wild-Relative Genes

Two researchers from Cornell University reasoned that more than a century of inbreeding the world's crop plants had significantly narrowed the genetic base of our crops. They also reasoned that the world's gene banks contained a large number of genes from wild relatives of our crop plants. They selected a number of genes from wild relatives of the tomato family, a crop where yields have been rising by about one percent per year. The wild-relative genes produced a 50 percent gain in yields and a 23 percent gain in solids. The same researchers selected two promising genes from wild relatives of the rice plant — a crop where no yield gains had been achieved since the Chinese pioneered hybrids some 15 years ago. Each of the two genes produced a 17 percent gain in the highest-yielding Chinese hybrids; the genes are thought to be complementary, and capable of raising rice yield potential by 20 to 40 percent (Tanksley and McCouch 1997).

Speeding Progress in Protecting Crop Yields

Recently, a research consortium announced it had succeeded in creating a genetic barrier against a new race of barley stem rust that had been advancing northward in recent years from Colombia. The new barrier was created in less than a decade. With traditional plant-breeding techniques, it might have taken several decades. With farmer-saved land race seeds, overcoming the rust might have taken centuries.

Saving Land for Nature with Biotechnology Trees

The world will not only demand three times as much food in the year 2040, it will demand ten times today's harvest of forest products. We could provide the increased tree production if we planted just five percent of today's wild forests in high-yield tree plantations. Such plantations are good-but-not-great wildlife habitat because they are not "fully natural" — but they could apparently take all of the logging pressures off 95 percent of the natural forests.

Trees have always been difficult to improve through crossbreeding because the time frames are so long. Biotechnology is already helping to provide the higher-yielding trees through cloning and tissue culture — which permit us to rapidly copy the fastest-growing, most pest-resistant trees in a species. When we master the tools of biotechnology more fully, we should be able to increase growth rates, drought tolerance, pest resistance and other important traits more directly, and even more effectively.

Biotechnology is also likely to permit the creation of new crops producing new products that we've never had before. I am ambivalent about new biotechnology crops, however, as I have long been ambivalent about "energy crops." I know that we can produce them, but they take land. Unless we can raise yields even more than three-fold, diverting cropland to non-food products may simply take more land from nature.

Why Did Switzerland Try to Outlaw Biotechnology?

This summer, Swiss activists collected more than 100,000 signatures to ban biotechnology in food production. The signatures put the question on a national referendum ballot.

The good news for agriculture is that the initiative failed, and the ban was defeated. The bad news is that the Swiss ballot initiative is probably a warning of further troubles with public acceptance of high-yield modern farming, and specifically with biotechnology in food production. The worst news is that outspoken female scientists led the opponents of biotechnology food in Switzerland, and the coalition included both the country's largest Protestant women's group and its largest Catholic women's group. In other words, the opponents of biotechnology food in Switzerland included most of modern agriculture's core customers, the people who should be its strongest supporters.

Why did so many Swiss sign the petition? First, the Swiss signed the petition because they already have plenty of low-cost food. That describes a billion people in the world today, but it will describe three billion people in the next decade and five billion people in the decade after that. Agriculture can no longer count on consumers to feel "grateful" for their food. Second, they signed the petition because Europeans see more food as simply leading to global overpopulation. There are only seven million Swiss, but they're crowded into mountain valleys with the same traffic jams and exhaust fumes as New York and London. Third, they signed the petition to protect laboratory animals. The animal rights activists were a key element in the anti-biotechnology coalition. The fact that the Catholic and Lutheran women's groups joined the coalition probably means that First World religious groups no longer feel comfortable with the Judeo-Christian assertion that God gave man "dominion" over the other species on the planet. The Swiss petition defined laboratory animals to mean not only monkeys and lab rats, but also fruit flies and earthworms. Fourth, the Swiss signed the anti-biotechnology petition because they are genuinely nervous about the power of biotechnology. They understand that the power to manipulate genes directly goes well beyond any power scientists have ever had before. They are willing to accept the use of biotechnology in human medicine because they clearly see the benefits.

Unfortunately, agriculture has never given European consumers what they consider a valid reason for putting the power of biotechnology into the hands of big companies and big laboratories whose work they cannot even understand, let alone supervise closely.

From the public's point of view, we started the biotechnology revolution in food with bovine growth hormone for a dairy industry that already produced milk surpluses throughout the First World. Then we moved on to herbicide-resistant soybeans, and the activists said this was just to foist more chemicals onto family farmers to enrich big corporations. To this day, agriculture has never given the urban public that controls its regulatory structure an emotionally valid reason to support it.

Why did the Swiss ultimately vote for biotechnology? The two big reasons were 1) people do want biotechnology for human medical problems; and 2) the Swiss pharmaceutical industry said they'd have to move their research jobs out of the country if the ban passed. In no other country of the world would an appeal for biotechnology jobs carry the day in a public referendum. If the Swiss referendum had been a straight-up vote on whether to allow biotechnology in agriculture, agriculture would have lost big-time.

As a signpost for the future, a top manager for one of the Swiss biotechnology companies says they got a strong positive response to the argument that biotechnology can help us save more room for nature.

Why Do the Activists Push the World into More Risk?

The activists of the world are always unhappy, and always pushing for something different. It is the nature of activists.

In Peru, the activists demanded an end to the chlorination of drinking water because the U.S. Environmental Protection Agency (EPA) found those high levels of chlorine could cause cancer in laboratory rats. Peruvian officials took the chlorine out of the water, and the cities promptly suffered a cholera epidemic that killed 7,000 people.

I don't blame the activists. I blame the people who trusted the activists, and the people who should have represented the other side of the question. I also blame the press, which should have sought out reality.

But the world is on a trend to have more activists, in more countries. Democracy and affluence encourage activists and the free, open debate of public questions. If modern agriculture is to succeed, it must learn to succeed in an activist-rich environment.

The Achilles Heel of Modern Agriculture — Regulation

The desire to preserve nature is so urgent among the world's affluent city-dwellers that the Greens haven't needed to win elections. Environmental concern is so widespread that politicians race each other to embrace key points of environmental strategy. In recent years, Wirthlin Group surveys have found that 75 percent of the public agrees with the statement: "We cannot set our environmental standards too high — regardless of cost." Even motherhood no longer gets ratings that high.

Because of the high public approval for the environment, we have an EPA with virtually no congressional oversight. The bureaucrats who work for the EPA read the newspapers, and they can interpret polling results. They assume that they can regulate "environmentally offending" industries, such as agriculture, in virtually any way they choose.

The draconian new regulations covering animal wastes in this country are a case in point. There is no evidence of a water quality problem in the country, and strong evidence that modern meat and milk production has reduced any water quality problems that may have existed in the past. There is no good reason to expect that the proposed regulations will improve our water quality or our safety in any meaningful way, though they will add billions of dollars per year to farmers' costs without helping public health. There is probably no way to stop the proposals short of suing in the federal courts. The regulators have the bit in their teeth.

The Betrayal of Modern Journalism

It grieves me to criticize the media. I had dual majors in my undergraduate college years: agricultural economics and journalism. No one believes more fervently than I do in the importance of a free press.

Unfortunately, today's mainstream media are not living up to their professional obligations for objectivity and research. Somewhere during the Vietnam era journalists got the idea that refereeing the game of life was not as satisfying as playing on the winning team. Among the causes they adopted as their own in recent decades is the environment. They have decided to side with the Greens. (The *New York Times* is perhaps the most dramatic example of this, but the phenomenon is widespread.) Of necessity, adopting the Greens meant that journalists have disowned modern agriculture.

I have been on a first-name basis with *New York Times* Science Editor, Bill Stevens, for a decade. He cheerfully quotes me on world hunger questions — and just as cheerfully ignores the environmental benefits that I tell him are being delivered by high-yield farming.

In May 1999, we put out a press release noting that data from North Carolina showed the nitrate loading in the Black River had declined during a period when its hog population had quintupled to one of the highest levels in the U.S. A reporter called and asked whether the hog industry had sponsored the study. No, we told her, the data was from a state agency. "But that's not what my readers want to hear," she lamented. That's how far behind the public affairs curve modern agriculture currently finds itself. This is not a problem that can be dealt with by writing press releases, or by hosting community tours of farms and processing plants.

There is virtually no possibility of getting favorable messages about farming into the news and commentary columns of big-city newspapers and even less opportunity on network TV news.

A Public Affairs Strategy for Modern Agriculture — and Biotechnology

On the basis of my experience over the past two decades in speaking to the environmental community, the organic community, and the urban public at-large, I would like to propose a public affairs strategy for modern agriculture. It is a long-term strategy because there are no short-term strategies with any visible success potential.

The key element of the strategy is to tell the urban public about the environmental benefits of high-yield modern farming. We can talk about reducing malnutrition for children, but we cannot leave ourselves open to Paul Ehrlich's charge that more food simply means world overpopulation.

"Saving nature" is the one public policy priority universally accepted throughout the First World today. We must talk about saving wild lands and wild species with better seeds. We must talk about conquering soil erosion with high yields and conservation tillage. We must talk about preventing forest losses to slash-and-burn farming (which has destroyed two-thirds of the tropical forest). We must analyze every eco-activist proposal in terms of its land requirements. If they propose organic farming, we must point out the additional five million square miles of wildlife refuges that will have to be planted to clover and other green manure crops to provide adequate nitrogen sources for crops. If they want free-range chickens, we must point out that it would take wild lands equal to the State of New Jersey for the chicken pasture. If they want to reduce fertilizer usage in the Corn Belt, we must ask how many additional acres of poorer-quality land will have to be cleared in some distant country to make up for the lost yield. If they oppose free trade in farm products and farm inputs, we must ask how much tropical forest will be cleared for food self-sufficiency in Asia.

The environmental movements own organic food is also vulnerable on the grounds of consumer safety. The Centers for Disease Control has been afraid to publicize it, but their own data seem to show that people who eat organic and "natural" foods are eight times as likely to be attacked by the virulent bacteria, E. coli O157:H7. *Consumer Reports* wrote that free-range chickens carried three times as much salmonella contamination. The fact is that organic food is fertilized with animal manure — a major reservoir of bacterial contamination — and composting is neither careful enough nor hot enough to kill all of the dangerous organisms.

Presenting Agriculture's Case with Advertising

How can we present our case if the journalists will not write it, and if U.S. politicians fail to support it?

My model is the advertising of the Weyerhaeuser Company, which has been telling me for decades that it's the tree-growing company. Not the tree-cutting company, not the tree-using company, but the tree-growing company.

The American Plastics Council has largely defused the opposition to plastics with a series of radio and TV ads that simply talk about the ways plastics help us and protect us. (They even have one on food that shows a mother and son walking from the filth of medieval farmers' market into a modern food store.) Now, David Brinkley, the most respected journalist in America today, is presenting the case for modern agriculture on U.S. network TV. Archer Daniels Midland, the big corn and soybean processor, sponsors the Brinkley ads. They are doing a fabulous job.

- Brinkley notes that farmers are still the most indispensable people.
- He shows a cute little girl in Taiwan, and points out that her mother wants her to have meat and milk in her diet so she will grow strong and vigorous. Who could oppose that?

- ADM notes that “the higher yields achieved by modern farmers are providing food — and in some cases even shelter — for families around the world.” (As they show families of deer and pheasant.)

Many of the firms with billions of dollars invested in modern agriculture are already talking to urban America. DuPont and Dow have whole rosters of consumer products and millions of dollars worth of consumer advertising. Why not wrap the whole corporate product line in the golden glow of wild land conservation? Cooperatives like Land-O-Lakes and Countrymark have consumer ad budgets too. Wild land conservation would be a winner with both their customers and their farmer members. Pioneer Hi-bred has used Merlin Olson as a corporate spokesman. Merlin played Grizzly Adams on TV. What a terrific conservation advocate he could make!

If the eco-activists want to argue with the ads, they'll have to deal with substance. And agriculture will win on substance. Plastics are winning on substance.

I know that agriculture has never in the past had to spend money on its consumer image. But agriculture in the past was winning. If they were winning today, I wouldn't be suggesting a new strategy.

Mainstream agriculture has so far been content to feel neglected, abused and sorry for itself. But this attitude is unworthy of a major, vital industry. I have high hopes that agriculture will soon realize the stakes, and its potential for success.

Alternatively, we could wait until the citizens of the world's affluent cities are finally convinced of the need for high-yield farming by their own hunger. By that time, the momentum of agricultural research would have been lost, the wild lands would have been destroyed forever, and this generation of farmers and agribusiness firms would have gone bankrupt.

It is up to agriculture.

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Meeting Food Needs through Sustainable Production Systems and Family Farms

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Thank you for inviting me to speak about how the world's food needs can be met by agricultural systems that strengthen family farms, support strong communities, and protect the environment. It's always difficult to follow Dennis Avery. Dennis is very eloquent. He speaks with great certainty — which is in itself persuasive. And Dennis' message is implicitly appealing to a group of scientists and industry leaders. It is essentially that if we give scientists more money and industry and producers more freedom to do what they do best, the problems will be solved.

I don't believe it's that simple. And so my message, though sincere, may be less appealing.

But nevertheless, join me in exploring with an open mind some of the most vexing problems confronting agriculture and human kind, and probing the question of how agricultural science can achieve its full potential to contribute to the betterment of agriculture, agricultural communities, and the global society.

The question I will address is whether we can meet food needs with a sustainable family farm system of agriculture. I believe that it is just such systems that hold the greatest potential for food security. But ultimately, fulfillment of their potential depends on how we invest our agricultural research dollars.

The agricultural research and education system is not only a part of the solution, it is the most critical element of the solution. But — and this is perhaps the most important point I will make today — it can achieve that potential only if we create agricultural systems that address issues of fairness, opportunities, and justice; that provide genuine opportunity in agriculture and reduce poverty in agricultural communities; that feed hungry people; and that are sustainable, resilient, and environmentally responsible.

I will discuss three principles for meeting those lofty goals.

Principle A: There is no question that we must increase production over the coming decades, as Dr. Pinstrup-Andersen addressed yesterday. There will be many more mouths to feed.

But two caveats are in order. First, increasing production by itself will not solve the problem of hunger. In fact, if we focus on maximizing production at the expense of all other objectives it may in some instances exacerbate the problem. Second, American farmers should not count on a future of unlimited markets and prosperity based on exports to nations with increased numbers of mouths to feed. Productivity growth continues to out pace people's capacity to buy food.

The expectation that a growing middle class in the developing world will create huge markets for meat and feed grains is often oversold. Farmers have been promised that for decades and it has never materialized. The Asian economic crisis demonstrates just how shaky that promise is. And remember that with biotechnology, developing nations will have the potential to gain access to much cheaper meat- and dairy-type products using fermentation technology. I love the real thing. But since they've never acquired our taste for it, they may opt for cheaper substitutes. Don't bet the ranch on a booming export market.

Principle B: We must develop agricultural systems that create genuine economic opportunity in agricultural communities both here and in the developing world.

In the developing world, it is a matter of life and death. The Nobel Prize winning economist Amartya Sen observed that poverty, not absolute food shortage, has been the primary cause of starvation in the world — even during famines. The victims of starvation in the developing world are most often landless laborers or small farmers who have low and uncertain incomes and few assets. Even in famine, food was often available but they had no income to buy it. If we want to address hunger we have to address the ability to purchase food.

The fact is that the greatest hunger exists in the world's most agricultural societies — rural Africa and part of south Asia — where in many cases upwards of 60 percent of the population is rural and the primary source of employment is agriculture. These societies will remain highly dependent on agricultural employment for the foreseeable future.

For agricultural science to contribute to a significant reduction in hunger in these societies, it must create agricultural systems that improve economic opportunity for the rural people and thereby reduce poverty. That will not happen without strategic implementation.

In truth, much agricultural technology has reduced opportunity in farming and farm communities. Certainly, that has been the case in the United States. The most insightful analysis that I've seen on the impact of technological change on U.S. farmers and farm communities is an analysis by Stewart Smith, on behalf of the Joint Economic Committee of the U.S. Congress. (Smith 1992)

Smith analyzed where value is added and to whom profit accrues in the U.S. food system. Not surprisingly, he found that the share of profit captured by the input sector (corporations that sell products to farmers) and the post harvest sectors (the processing, transportation and marketing companies) grew — at the expense of the share received by farmers. Most startling, Smith found that the farm share of the profit in the U.S. food system would fall to zero by about the year 2030 based on extension of the current trend line. That's not to predict it will fall all the way to zero, but it demonstrates how powerful this trend has been.

This is critical. Individual farmer operations have to get a little bit bigger every year to earn the same income. We also have to comprehend this if we want to understand rural poverty. When we consider poverty in agricultural communities the assumption is that it happens only in the developing world or the southeastern United States. But that is not the case.

In 1997, the nation's three lowest income counties were Nebraska farm and ranch counties. The average tax return in Arthur county Nebraska — the nation's lowest income county — reported income of less than $10,000. More than one-third of the nation's 50 lowest income counties are farm and ranch-based counties in Nebraska and the Dakotas. Nebraska counties alone account for 10 of the bottom 50.

The Nebraska Rural Development Commission projects that without fundamental change in public policy the most rural communities in this state could lose 25 percent of their population over the coming decades. They would be reduced to repositories of the poor and aged, plus a few very large farms. This is not only an agricultural issue. Many of the poorest in farm communities are non-farmers. We need rural development programs that address their needs.

But make no mistake. It is also an agricultural issue. These communities are highly dependent on agriculture and their fortunes reflect the declining farm income. Contrary to many generalizations about farm income, in this region the incomes of middle size farms that rely on farming for their livelihood are well below national averages.

Future developments in the seed industry may exacerbate the declining farm share of profit in the food system. Iowa State University Economist Neil Harl recently sketched a potential scenario for evolution of the seed industry and agriculture. (Harl 1998) He foresees the possibilities of a very small number of firms gaining control of elite genetics with superior end use characteristics and then extending their control over markets for both inputs and grain, thus retaining ownership throughout the production and marketing process. Corn and soybean farmers would become like contract poultry growers. They would receive a fee for field operations to grow company-owned grain, using company owned inputs following company instructions.

Under this scenario farmers would add even less of the value to food and receive less of the return. Their role would perhaps involve lower risk, certainly lower management, and correspondingly lower return. Farmers would be reduced to custom machinery operators. They would need to cover ever-larger acreage's to earn middle class incomes. There would not be many farmers left.

This is just one scenario. It is not by any means inevitable. Whether or not it comes to pass, whether Stewart Smith's trend line continues, and whether the agricultural communities of the developing world are centers of starvation depend in large part on us. Today's trends are not inevitable. They are the result of decisions made by people that can be reversed by people. We can exercise choice.

Principle C: If our goal is to prevent hunger, we must develop production systems that are resilient, environmentally responsible, and capable of sustaining production in the face of unforeseen developments. If we develop technologies that maximize production under current or predictable conditions, but leave us with a fragile food system vulnerable to failure in the face of unforeseen circumstances, we will have built a "house of cards."

The world's food system faces profound challenges. In many parts of the world soil is eroding at rates exceeding new soil formation. We continue to threaten the long-term productivity of the world's fisheries due to water pollution, some of it attributable to agriculture.

We will, for all practical purposes, run out of oil during the next century. We face climatic uncertainty. Most scientists believe the globe will warm, extreme weather events will become more common, and rainfall patterns will shift as atmospheric concentration of greenhouse gases increase. Even if you discount the greenhouse effect, that does not eliminate climatic uncertainty. Climatologist recently reported research demonstrating that mega droughts — lasting 20–30 years — regularly swept the American West and Great Plains as recently as 400 years ago and could do so again.

It's not just climate. Nature in all of its aspects is unpredictable. It's true of pestilence and disease, as well. We cannot predict what nature will throw at us.

For that reason, it is risky to create food production systems of great uniformity. Diversity reduces risk. But industrialization of agriculture is all about uniformity. First, we reduced cropping systems and species diversity. Then we narrowed genetic diversity, a trend likely to be accelerated by biotechnology. In the final stages of industrialization, we are adding management uniformity. The classic example is poultry production. Integrators enforce uniform production practices for genetically uniform birds in uniform buildings — a system spreading throughout agriculture.

Uniformity is often cited as the rationale for industrialization — that consumers and end-users demand a uniform quality product that family farmers won't provide. I don't buy that. If packers and food processors want farmers to provide crops and livestock with different traits, there is a proven way to accomplish that in an open market system: pay for it and discount the undesirable. Furthermore, consumers are demanding variety more than uniformity. In my judgment, the driving force behind industrialization is not consumers but rather agribusiness corporations exercising their economic power to reduce risk and uncertainly by gaining control over and locking in place supplies and markets.

The core point is that the ever more uniform food system created by industrialization is an ever more fragile system. Nature is unpredictable. It is foolhardy to put "all of our eggs in one basket."

What To do?

What steps must we take in agricultural research and education to develop secure and resilient food systems that create genuine opportunity in farm communities here and abroad, protect the environment, and meet the world's food needs?

First, we must secure the capacity for public good research. There is a place for profit driven research, but it will never meet all of the world's needs.

It will not meet the needs of the poorest farmers in the developing world for improved varieties, especially those who depend on crops for which there is not a large market like cassava and edible beans. They do not constitute a lucrative seed market.

The developing world needs research centers producing publicly available varieties available at a reasonable cost. It needs education programs responsive to its crops, its needs, and the circumstances of its most vulnerable farmers and rural people. It needs farming systems that increase both productivity and the incomes of rural people, if hunger is to be reduced.

We need a balanced approach that utilizes production-enhancing inputs within the financial reach of small farmers, but places at least equal emphasis on utilizing more of farmer's skills, management, and labor to expand income earning opportunities. As the richest and most powerful nation in the world, I believe we have a moral responsibility to help less fortunate nations develop that capacity. I also believe it is in our long-term interest. As long as the developing world produces a surplus of poor, hungry, desperate people, willing to work at "dirt-cheap" wages, real wage levels and living standards for working people in this country will fall.

That includes family farmers. As long as corporate farms can obtain their labor at poverty-level wages, it will be difficult for family farmers to pay themselves a middle class income for their own labor and to compete.

The profit-driven system will also not meet all research needs in the United States. It will not provide farmers with knowledge and production systems that enable them to reduce capital and input costs and increase their share of the profit in the food system. That does not create a product for sale. It is essential that we provide the necessary public funding to maintain a strong public research and education system to do public-good research.

But it is equally essential that public institutions resist pressures to allow their research agendas to be set by profit opportunities — in pursuit of royalties and private contracts. Public institutions must serve the public good. If they fail that mission, they will ultimately undermine their reason for existence and threaten their tax support and their very survival.

To more effectively pursue public goods, we must change the focus of much of our public agricultural research. To create the economic opportunity that will allow the rural poor in the developing world to feed themselves and family farmers and farm communities in the U.S. to prosper, public research institutions must help change Stewart Smith's trend line. We can do that.

The trend of farmers and farm communities receiving an ever declining share of the profit in the food system reflects, in part, choices we have made about how to pursue efficiency through agricultural research. To a great extent, we have focused on developing expensive new products for the input sector to sell to farmers — to enable fewer people to produce the nation's food — and shift farm profits to the input sector. That is not the only option.

The alternative is pursuing greater efficiency in the food system while enhancing opportunity in agricultural communities. This can occur by developing the knowledge and production systems that enable farmers to more effectively use their management, skilled labor, and, perhaps in the developing world, unskilled labor to enhance the volume and value of their output and/or reduce their capital and input costs.

I am not suggesting low-tech agriculture or even low-input agriculture. Rather, I am suggesting a knowledge and management intensive system of agriculture that makes greater use of human input to both increase production and moderate capital and input costs. One participant at this meeting made a most insightful comment when he said that farmers are well paid only when they have leverage.

Research focused on developing new products for farmers to buy increases the leverage of the input sector. Research that focuses on enhancing farmers' management increases farmers' leverage and returns.

The hoop-house for hog production provides an excellent example of how agricultural research can enhance farmers leverage and returns. The hoop-house is a low-cost technology developed in Canada. It has a four- or five-foot wooden wall on which rests a half circle steel hoop, covered by a durable plastic tarp. Hoop houses are deep bedded typically with straw or corn stalks.

Hoop-houses require about one third of the capital of total-confinement hog-finishing systems. They require more management and more skilled labor. Because they do not provide a controlled environment, they require the daily presence of a highly knowledgeable and motivated manager who understands hogs and is able to exercise judgment. That is the strength of the family farm.

Although we have spent hundreds of millions of public dollars to refine and perfect total-confinement systems, and virtually nothing on hoop-house type systems, it is most remarkable that they are roughly comparable in total-cost of production.

But there are two key differences. First, the hoop house is most cost effectively applied at a very modest scale of about 200 head. Second, when a farmer sells a hog out of a hoop house more of the check remains in his/her pocket to compensate for his/her skills and management; and less goes to pay off a note on a confinement building.

If we had invested the same research resources in these types of systems that we invested in total confinement, family farmers would be beating the corporate giants and the industry would look very different.

In crop production today, our first impulse is to seek a solution to every problem utilizing new genetics thereby reducing the need to address the problem by managing the farm as a system.

Assuming that an approach using new genetics succeeds, the new genetics is probably privately owned by, for example, a seed company that will capture the associated profit, not the farmer. To the extent privately held genetics provide a substitute for farm management and skilled labor, they shift profit and opportunity from the farm sector and reduce family farm opportunities. Farmers' leverage is reduced.

In my judgment, we have over emphasized genetics and under emphasized systems science in agriculture research. We have severely under invested in basic research on agroecology — to gain under-standing of the interactions between living-organisms in agricultural ecosystems — and how they are affected by farm management.

It is that kind of systems research that can provide farmers the new knowledge to manage their farms in ways that minimize pests, nutrient shortages, and other stresses that limit yield or require use of expensive inputs.

If our goals are to enhance production, increase farm opportunity, and create resilient farming systems, we should start first with research on diverse, management-intensive, environmentally-sound farming systems that enhance farmer's share of food system profit and then determine how traditional and transgenic plant breeding can strengthen those systems.

There is a great need for improved varieties of cover crops, rotation crops, crops better suited to cultural weed-control — for example faster germinating and emerging crop varieties. All could improve farm resiliency, productivity and profitability, but they have largely not been addressed.

The research and education system can also provide a great service by helping family farmers develop the knowledge, skills, and markets to respond to new consumer demands for value-added products. Markets are becoming segmented. Consumers are willing to pay a premium for food with unique attributes including food produced in ways that they support.

A recent nationwide consumer survey found that half of consumers are willing to pay some premium for food produced in an environmentally responsible manner.

Let me share an example. Networks of family farmers in Iowa are earning substantial premiums on hogs delivered to Nimon Ranch, a California food company. By meeting taste standards, producing out of confinement, and following guidelines for humane treatment of their animals, they earn substantial premiums and are protected by a price floor many times higher than the cash market prices for hogs at its lowest level last winter.

They are changing our paradigm of value-added. Value-added is no longer something that necessarily happens in a factory after the product leaves the farm. Farmers on the farm can add value by producing in ways that make their products worth more to consumers. That is leverage.

How we respond to the opportunities presented by these emerging markets will to a great degree determine whether we have family farmers in future generations. Returns for production of undifferentiated commodities are low. They are especially low for family size farmers, because they don't operate on a level playing field.

A large corporate hog farm, for example, receives more for the same quality hog than a family farmer does because it has the power to command a premium. We need to address this inequity through state and federal laws designed to ensure fair market access, such as those passed by state legislatures in Minnesota, Missouri, Nebraska, and South Dakota this spring. But we also need to develop higher-value markets and capture them for family farms.

The questions of how we produce food, who produces its, and who owns the land are fundamental social issues. For much of the developing world it is an issue of life and death. The concentration of land ownership and wealth in the U.S. present fundamental social issues that we ignore at our peril.

The share of our nation's wealth held by the richest one percent of Americans is approaching 50 percent, more than double that in 1976. In agriculture, farm communities are sinking into poverty, corporations are consolidating control over animal agriculture, and we teeter on the edge of the greatest period of land consolidation in the history of America.

These things matter. Historians Will and Aries Durant describe a recurring historical process in their book, The Lessons of History. A civilization arises, wealth concentrates, and if left unaddressed, the civilization collapses as too few people retain a stake in the society to sustain it.

The Durants wrote that when the invading armies that toppled the Roman Empire entered its hinterlands, they were surprised. They expected to be met by resistance. But they were met not by resistance, but by slaves listlessly tilling the soil.

My point is not that this is a critical military issue, but rather that no society can sustain itself and thrive if its people do not have a stake it. People who feel a stake in society contribute to society, build communities, give back, and take responsibility for the society. We are producing a society with many people who don't have much stake in it — and it shows.

For those who say that this is not the concern of the land grant college system, I say read your history. The grant system was a great social experiment with a great social mission. Yes, the system was to make two blades of grass grow where one grew before. But also as recorded in the congressional debate over its origin — it was created to improve the lives of rural people — especially small farmers and the disadvantaged. It was to make education available — not just to the elite — but to the sons and daughters of farmers, mechanics, and ordinary people.

We must regain our sense of a social mission. We must aim at nothing less than providing society with the knowledge and resilient food systems that meet the food needs of a growing population. We must develop systems that protect our environment, that reduce hunger and increase opportunity, and that revitalize rural communities.

Let's accept that as our mission, let's embrace it, and create the nation's best institutions in meeting this challenge.

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Biotechnology and Mature Capitalism

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Introduction

Most of the biotechnology products on the market today are pharmaceuticals. They have been introduced with relatively little opposition or public debate. However, agricultural products produced from biotechnology seem to have been surrounded with controversy from the outset. It is this segment that I wish to address.

The recent ban on some of these food products by countries that are major purchasers of food commodities from the United States has created major confusion in farming communities. Farmers were promised that products containing new genetically modified organisms (GMOs) would provide new opportunities for them and would increase profits for farmers willing to embrace them (*Doane's Agricultural Report* 1999). However, between the time farmers purchased their seed and the time they had it planted in the spring of 1999, some learned that certain processing firms would pay a premium for non-GMO products. Others discovered that in receiving certain GMO seed, they had to sign a contract stating that they were responsible for guaranteeing that the products of this seed would not get into the stream of products (or by-products) heading to Europe. All this happened at a time when the world seemed to be awash in grain and oil crops as reflected in commodity prices below the cost of production. These issues were added to the farmers list of negative reactions to the $6.50 technology fee added to each bag of seed purchased, and to Monsanto's hiring of a detective firm to enter farmers' fields (as allowed by the contract a farmer had signed) to take a tissue sample to ensure the company that the farmer had not planted in the current year seed saved from the previous year. By the summer of 1999, some of the early adopters were wishing they had never heard of these new products.

Those individuals and organizations with research interests in biotechnology and firms that see the opportunity to obtain economic profits from their involvement in biotechnology defend their interests by suggesting that the technology will help to feed the earth's growing population. Although this provides strong moral legitimization, it overlooks a major principle of a capitalist system, namely that a firm's primary motivation is to generate returns for those who provide its capital. Profit is the goal that guides their decision-making. This goal is not necessarily compatible with feeding all people of the world. These firms will focus on feeding that portion of the population that can pay a price that allows a good profit. However, as Per Pinstrup-Andersen noted, about one-fifth of the people of the world are members of families that earn less than a dollar a day. These people are not getting their food from firms that comprise the globalized food system — the same firms that make the major decisions regarding how biotechnology is used — and they are not able to purchase the increasingly expensive inputs to produce such crops.

Today, there are many that argue that we have adequate global food production now and that the real issue is a distribution problem. Some argue against the need for biotechnology and suggest that producing food for the growing population is not the problem. Others defend biotechnology, but do suggest that someone should address the distribution problem. My major concern is that biotechnology is increasing, rather than decreasing, the problem of whom is able to get food versus who needs food. My purpose is to show that under the current form of capitalism evolving in the world, biotechnology is becoming one of the major drivers of change in the global food system resulting in more, not less, inequality in the distribution of food.

There is little doubt that biotechnology is a very powerful scientific technology, but like the development of another powerful technology, nuclear energy, the products of this scientific discovery have the potential to be used for both major societal good and harm. The technology is neither good nor bad. The key question must focus on who will make the decisions about how biotechnology will be used and who will reap the benefits from the technology. To understand this, we must understand how the social system operates, especially political/economic institutions.

Recent documentaries have reminded us of the race between nations to develop the atomic bomb that helped speed the end of World War II. The United States and its allies won that race and were the "benefactors." The conclusions we have drawn about whether that technology was good or bad might have been quite different if Hitler had been the first to develop the bomb. History has shown that even the peace time benefits of nuclear energy have been accompanied by some major costs. In fact, many of the costs have been so great and will be with us for so long that it has not lived up to the expectations many had for it. Nuclear energy has certainly not been the solution to the world's growing energy needs.

In the development of biotechnology, the race is between a few global food firms. I wonder if the same comparisons and observations about societal benefits and costs will someday be said about biotechnology and food. Events in the past year have certainly begun to identify some of the possible costs. My purpose is to examine the globalized, industrialized food system into which food biotechnology is being introduced, and suggest some of the implications the system has for feeding the people of the world and other potential public benefits often listed by supporters of biotechnology.

The Diminished Decision-Making Role of Farmers

The movement toward industrialized agriculture with its heavy dependence upon scientific discoveries can be traced back to the beginning of the 20th century, but it was not until mid-century that major structural changes in the food system became obvious. This was the time when hybrid seeds, commercial fertilizer and, soon thereafter, agrichemicals became common inputs on farms. About this time farm equipment also was becoming much larger than that used when horsepower was the major source of energy. Farm families could now farm a much larger acreage than ever before.

This was also the time when the confinement production of large numbers of animals began to emerge. With the movement of animals into confinement came a major structural change in the food production system. Many of the decision-making responsibilities regarding the production of animals moved from the farm family to integrating firms that would provide some of the production inputs, the market for the products, or both. In the case of broiler production (the first major sector to change), the integrating firms provided the birds and feed and made all of the major decisions regarding production, such as the building and equipment designs used, the genetics of the birds, the ration fed, the schedule for when the chicks were delivered to the grower, and when the broilers were taken for processing (Heffernan 1984). The growers provided the land, the capital for the buildings and equipment, and the labor. The growers were no longer involved in marketing because they did not have title to the birds. They received compensation from the integrating firm rather than from the sale of broilers. Payment to the growers was based on a piece rate. Today, growers are paid between three and four cents a pound for the number of pounds produced.

The movement from the family farm system in which the farm family provided the majority of the management, labor, and capital, to an industrialized type of organization in which some of the capital and all of the major management decisions were made by the integrating firms, had begun by the mid 20th century. Eventually, most other animal productions systems would follow a similar reorganization. On crop farms, a structure was emerging in which a larger proportion of the labor on the farm was non-family labor. This too was a change from the family farm and was more similar to industrialized production systems that hire workers based on an hourly payment or a wage.

As the 20th century comes to a close, we hear more and more about needing only 20,000 to 30,000 farms in the U.S. producing feed grain, oil crops, and animals for the globalized, industrialized food system. These farms will be operating under a system that includes characteristics of production contracts like those used in the broiler sector, a hired labor system (industrialized system), or most likely a combination of both. None of these alternatives resembles the decentralized decision-making system of the past (i.e., the family farm system). I hear “rumors” that we will be seeing production contracts for non-identity preserved corn, soybeans, and wheat by the next cropping season. Whatever the exact form of the relationships between the farmer and the firms that provide the farmer’s inputs and markets for the farm products, it appears that the relationships will be different from those a half century ago. Then no firm could set the price or conditions of sale for either the inputs or the products grown on the farm since there were many providers of the inputs farmers needed and sufficient markets (processors) available to the farmers. As a major decision-maker in the globalized food system, the management of a few large global food firms or food clusters is rapidly replacing the “farmer.”

Concentration of the Markets

For more than a decade, some of us at the University of Missouri have been documenting the growing concentration of ownership and control by a few firms of the processing stages of the major farm commodities produced in the Midwest. Increasingly the food system began to resemble an hourglass, with thousands of farmers producing the farm products that had to pass through a relatively few processing firms before becoming available to the millions of consumers in this and other countries.

The extent of horizontal integration, that is the concentration of ownership and control in the processing stage of selected crop and meat commodities, is shown in Table 1. In the meat sectors, about 80 percent of the beef cattle and 57 percent of hogs are slaughtered by the four largest firms. About one-half of the broilers (chickens produced for meat) are produced and processed by the four largest firms with Tyson Foods now producing and processing almost one-third of the broilers in the United States. In the crop sectors, the four largest firms process from 57 to 76 percent of the corn, wheat, and soybeans in the United States.

Although debate continues as to what constitutes an oligopolistic or near monopolistic market, much of the literature suggests that when four firms control 40 percent or more of any market, these few firms are able to exert influence on the market unlike in a competitive system. Just as the narrow opening of an hourglass controls the flow of sand from top to bottom, the processing firms are able to exert considerable influence on the quantity, type, and quality of the product, the location of production, and the price of the product at the production stage and throughout the entire food system. The

TABLE I

The Four largest Commodity Processing Firms and Percent of U. S. Market Share They Control	
Broilers (meat chickens):	49% of production
Tyson-Foods, Gold Kist. Perdue Farms, Pilgrim's Pride	
Beef:	79% of slaughter
IBP, ConAgra (Armour, Swift, Monfort, Miller), Cargill (Excel), Farmland National Beef Pkg.	
Pork:	57% of slaughter
Smithfield (Gwaltney, Cudahy, Morrell, Lykes), IBP, ConAgra, Cargill	
Sheep:	73% of slaughter
ConAgra, Superior Packing, High Country, Denver Lamb	
Turkey:	42% of production
Hormel (Jennie-O) ConAgra (Butterball), Wampler Turkeys, Cargill Turkeys	
Flour Milling:	62% of milling
Archer Daniels Midland, ConAgra, Cargill, Cereal Food Processors	
Soybean Crushing:	80% of processing
Archers Daniels Midland, Cargill, Bunge, Ag Processors	
Dry Corn Milling:	57% of milling
Bunge, Cargill (Illinois Cereal Mills), Archer Daniels Midland (Krause Milling), ConAgra (Lincoln Grain)	
Wet Corn Milling:	74% of milling
Archer Daniels Midland, Cargill, A. E. Staley (Tate and Lyle), CPC	

Source: W. D. Heffernan, "Concentration of Agricultural Markets," Unpublished paper, Department of Rural Sociology, University of Missouri–Columbia, (January, 1999) only stages remaining in the food system where there is competition between firms of equal economic power is between processing and retailing stages. In the past year, the retail stores have become much more concentrated, with the 10 largest firms now controlling half of the retail trade.

A quick review of the names of the four largest firms in the processing stage of farm commodities from Table 1 suggests that the same names appear on the list of processors of more than one commodity. Names such as Cargill, ADM (Archer Daniels Midland), ConAgra, Bunge, and IBP (Iowa Beef Processor) appear more than once. ConAgra ranks in the top four processing firms for beef, pork, sheep, turkeys, and seafood, which is not listed. Until 1998, they were in the top four in broiler production and processing. They have now dropped into fifth place.

A second means to concentrate the food system is referred to as vertical integration, which is joining two or more stages in the food system — the process of concentrating ownership and control. ConAgra notes in its 1997 Annual Report that it is the leading distributor of crop chemicals, fertilizer products, and seed in the U.S., Canada, Mexico, UK, and Chile. They own and operate 100 elevators (both local and terminal), 1000 barges, and 2000 railroad cars. They manufacture animal feed, and produce and process their own broilers. The broilers can be purchased as whole fryers, or as further processed foods such as Banquet TV dinners. ConAgra is the second largest processor of food in the U.S., behind Philip Morris.

A third way to concentrate the food system is to expand beyond national borders and become part of the globalized industrialized food system. Slogans like "supermarket to the world" and "world without borders" indicates the global reach of a relatively small number of food firms. Cargill has operations in 70 countries, but its economic transactions extend to many other countries. In fact, the food systems of the world are becoming so integrated by the transnational corporations (TNCs) that it often makes little sense to speak of the food system of a single country.

With the passage of the North American Free Trade Agreement (NAFTA), beef cattle easily travel back and forth across the borders. IBP, Cargill, and ConAgra, which slaughter three-fourths of the beef in U.S., all have feedlots and processing facilities in Canada and about the same market dominance there. It is possible for them to purchase a feeder calf in one country move it across the border as a stocker animal, send it back across the border to their feedlot, and back across the border one more time to have it processed. In fact, one of the firms could purchase the feeder calf in Mexico, feed it in their feedlot in U.S., and slaughter it in Canada. The question then is — in what country was it produced? This question has taken on great significance given the efforts of many cattle producers and their organizations to legislate "country of origin labeling" for red meat. The firms identified above also have production and slaughtering facilities in many countries of the world, including Australia, Brazil, and Argentina.

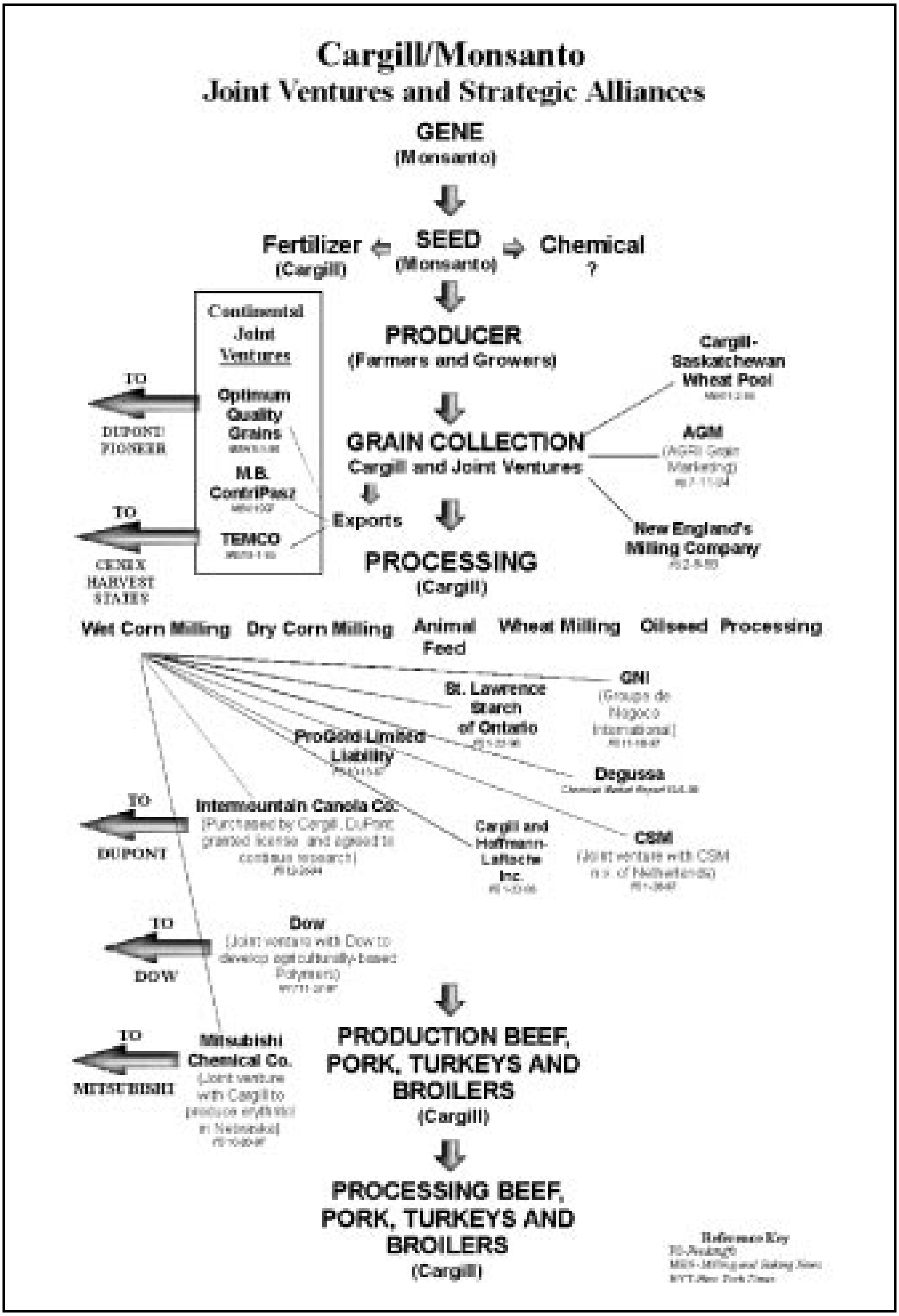
The Emerging Global Food System

In the past, most of the global grain firms were family-held operations that tried to maintain low visibility and were quite secretive about their transactions. These firms operated in one or two stages of the food system and in a very few commodities. Today, that system is breaking down as the three processes of horizontal integration, vertical integration, and globalization are combining to develop the globalized, industrialized food system. The emerging global food system is characterized by a few dominant firms that have developed a variety of different alliances with other firms in the system. Acquisition is still a common method of combining two or more firms; but mergers, joint ventures, partnerships, contracts, and less formalized relationships and side agreements are also utilized. We have used the concept of "food system clusters" to represent these new economic arrangements into which the emerging biotechnology will be located (Heffernan et al. 1999). These clusters will make the decisions as to how biotechnology will be used and who will benefit.

Figures 1, 2, and 3 suggest three food system clusters that appear to be emerging. We speculate that one to three more such clusters might develop in the globalized food system, because some of the major life science, chemical, and processing firms are not yet included in the clusters we have identified. Firms like AstraZeneca and Aventis, which is a new joint venture of existing alliances of former European life science and chemical firms, will clearly be major firms along with firms like Dow and DuPont, which now owns Pioneer. Other processing firms like Tyson Foods, Smithfield, and Farmland Industries, a farmer cooperative, and some of the others listed in Table 1 are not included in the diagramed three food system clusters. We keep watching for other firms from countries other than the U.S. to emerge. (Note that Novartis is based in Switzerland.) The extremely high capital cost of biotechnology research, combined with the U.S. allowing firms to patent their technology to protect their intellectual property rights, has set up the basis for an oligopoly (near monopoly) at the global level.

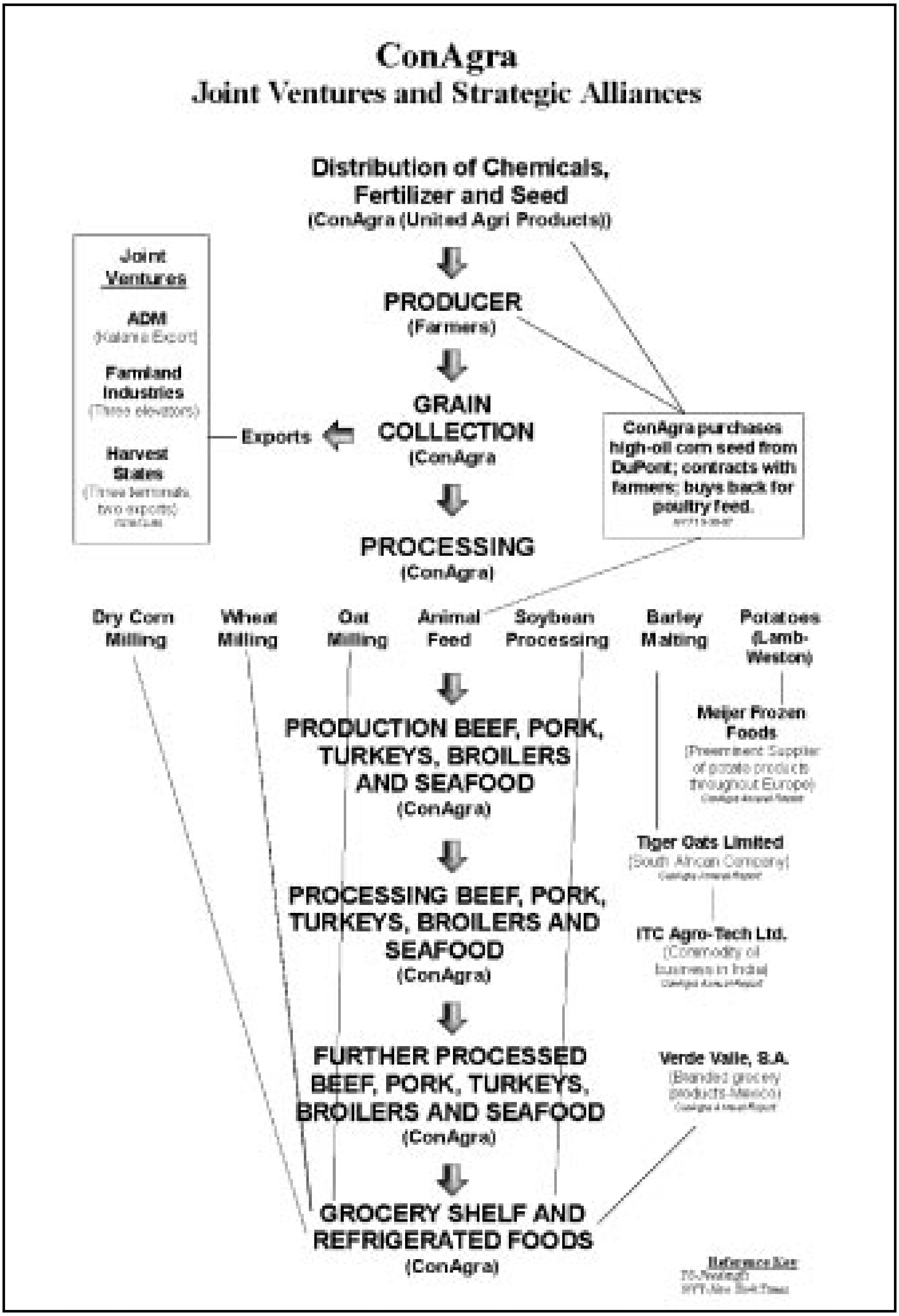
The introduction of biotechnology and the patent rights the firms have been given is reshaping the hour glass analogy. Increasingly we see the constraining of competition in the food system on the input side of agricultural production to be at least as great and quite possibly greater than the constraints of a few dominant firms at the processing stage (Hayenga 1998). I often have interesting discussions with my agricultural economist colleagues about whether the lack of competition in the system is the result of economic (and political) power acquired by the dominant firms or whether it is the result of "economies of size." In the case of biotechnology, government-granted patent rights may reduce competition. We feel that each of our food system clusters will include a firm that has access to biotechnology. Those firms, because of exclusive patent rights, will be a dominant firm in the food system cluster. We are not aware of any formal alliance that has ConAgra a dominant firm with a biotechnology

Figure 1



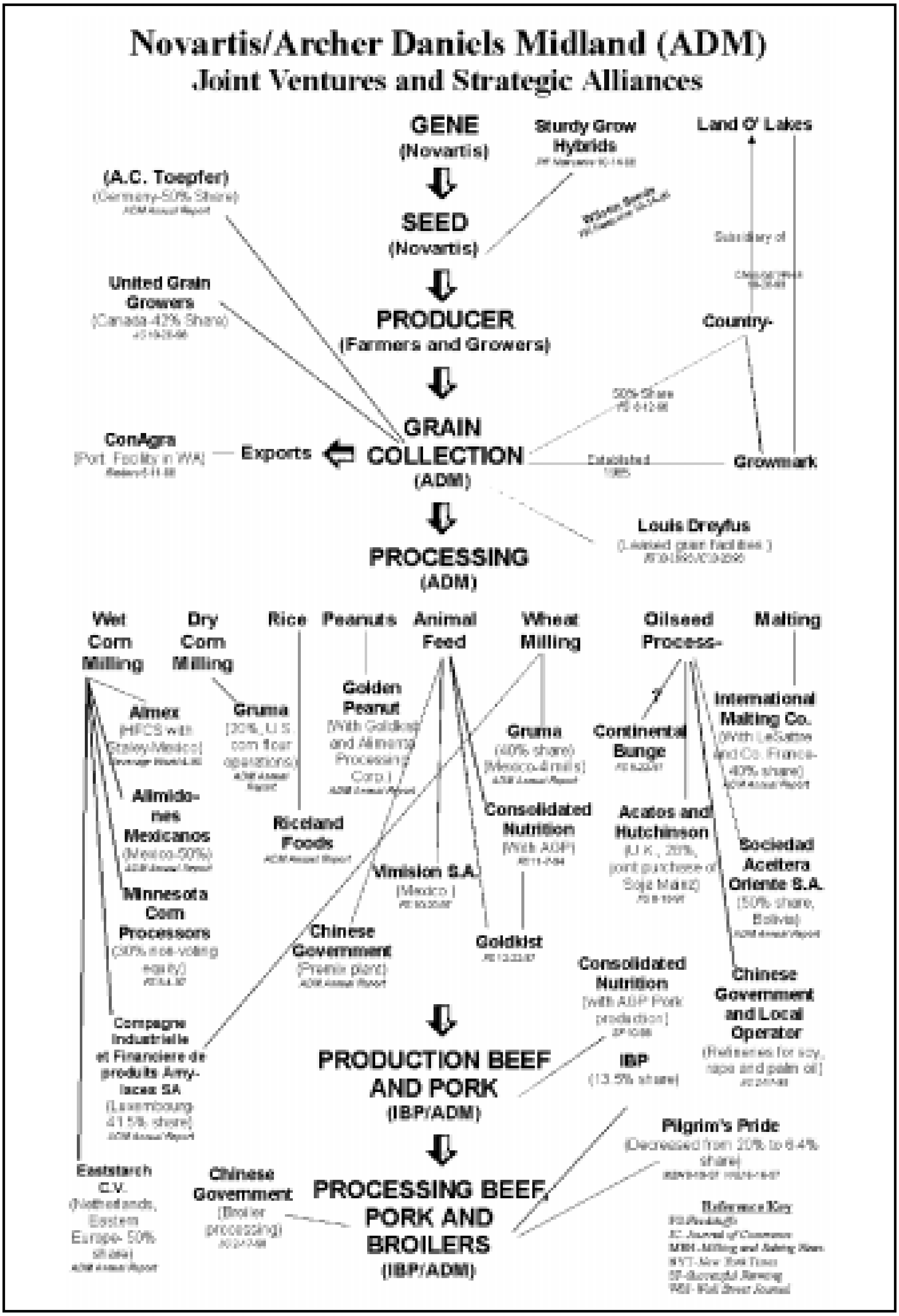
Cargill/Monsanto
Joint Ventures and Strategic Alliances
GENE
(Monsanto)
Fertilizer
(Cargill)
SEED
(Monsanto)
Chemical
?
Continental
Joint
Ventures
PRODUCER
(Farmers and Growers)
Cargill-
Saskatchewan
Wheat Pool
TO
DUPONT
PIONEER
Optimum
Quality
Grains
M.B.
ContriPasz
TEMCO
GRAIN COLLECTION
Cargill and Joint Ventures
AGM
(AGRI Grain
Marketing)
TO
CENEX
HARVEST
STATES
Exports
New England's
Milling Company
PROCESSING
(Cargill)
Wet Corn Milling
Dry Corn Milling
Animal
Feed
Wheat Milling
Oilseed Processing
GNI
(Groupe de
Negoce
International)
St. Lawrence
Starch
of Ontario
ProGold Limited
Liability
Degussa
TO
DUPONT
Intermountain Canola Co.
(Purchased by Cargill, DuPont
granted license and agreed to
continue research)
Cargill and
Hoffmann-
LaRoche
Inc.
CSM
(Joint venture with CSM
n.v. of Netherlands)
TO
DOW
Dow
(Joint venture with Dow to
develop agriculturally-based
Polymers)
TO
MITSUBISHI
Mitsubishi
Chemical Co.
(Joint venture
with Cargill to
produce erythritol
in Nebraska)
PRODUCTION BEEF,
PORK, TURKEYS AND
BROILERS
(Cargill)
PROCESSING BEEF,
PORK, TURKEYS AND
BROILERS
(Cargill)
Reference Key

Figure 2



ConAgra
Joint Ventures and Strategic Alliances
Distribution of Chemicals, Fertilizer and Seed
(ConAgra (United Agri Products))
PRODUCER
(Farmers)
GRAIN COLLECTION
(ConAgra
Exports
Joint Ventures
ADM
Farmland Industries
Harvest States
ConAgra purchases high-oil corn seed from DuPont; contracts with farmers; buys back for poultry feed.
PROCESSING
(ConAgra)
Dry Corn Milling
Wheat Milling
Oat Milling
Animal Feed
Soybean Processing
Barley Malting
Potatoes (Lamb-Weston)
PRODUCTION BEEF, PORK, TURKEYS, BROILERS AND SEAFOOD
(ConAgra)
Meijer Frozen Foods
(Preeminent Supplier of potato products throughout Europe)
Tiger Oats Limited
(South African Company)
PROCESSING BEEF, PORK, TURKEYS, BROILERS AND SEAFOOD
(ConAgra)
ITC Agro-Tech Ltd.
FURTHER PROCESSED BEEF, PORK, TURKEYS, BROILERS AND SEAFOOD
(ConAgra)
Verde Valle, S.A.
GROCERY SHELF AND REFRIGERATED FOODS
(ConAgra)
Reference Key

Figure 3


Novartis/Archer Daniels Midland (ADM)
Joint Ventures and Strategic Alliances
GENE
(Novartis)
SEED
(Novartis)
PRODUCER
(Farmers and Growers)
GRAIN
COLLECTION
(ADM)
PROCESSING
(ADM)
PRODUCTION BEEF
AND PORK
(IBP/ADM)
PROCESSING BEEF,
PORK AND
BROILERS
(IBP/ADM)
Sturdy Grow
Hybrids
Land O' Lakes
(A.C. Toepfer)
(Germany-50% Share)
United Grain
Growers
(Canada-42% Share)
Country-
Growmark
50% Share
Established
1985
ConAgra
(Port. Facility in WA)
Exports
Louis Dreyfus
(Leased grain facilities.)
Wet
Corn
Milling
Dry
Corn
Milling
Rice
Peanuts
Animal
Feed
Wheat
Milling
Oilseed
Process-
Malting
Almex
(HFCS with
Staley-Mexico)
Gruma
(20% U.S.
corn flour
operations)
Golden
Peanut
Gruma
(40% share)
Continental
Bunge
International
Malting Co.
Almidones
Mexicanos
(Mexico-50%)
Riceland
Foods
Consolidated
Nutrition
(With AGP)
Acatos and
Hutchinson
Sociedad
Aceitera
Oriente S.A.
(50% share,
Bolivia)
Minnesota
Corn
Processors
Minsa S.A.
(Mexico)
Chinese
Government
(Premix plant)
Goldkist
Compagnie
Industrielle
et Financiere de
produits Amylaces SA
(Luxembourg-
41.5% share)
Consolidated
Nutrition
(with AGP Pork
production)
IBP
(13.5% share)
Chinese
Government
and Local
Operator
(Refineries for soy,
rape and palm oil)
Eaststarch
C.V.
(Netherlands,
Eastern
Europe- 50%
share)
Chinese
Government
(Broiler
processing)
Pilgrim's Pride
(Decreased from 20% to 6.4%
share)
Reference Key

firm (Figure 2). ConAgra does purchase high-oil corn seed from DuPont. This helps to make the point that this system is still very dynamic and still evolving. But the direction or trend seems quite clear — at least in the short term.

The numerous "alliances" in each cluster lead to what is often called a "seamless system," which describes the emerging, fully integrated food system from the gene to the supermarket shelf. Within this emerging system there will be no markets and thus no "price discovery" from the gene to the shelf. The first time the price of any input in the food system will be public information will be at the supermarket. As this system evolves, the public will not know the price of animal feed and its ingredients, such as the corn, because like today's broilers the product will not be sold. The firm owns the chick and sends it to its processing facility from which it emerges, perhaps as a TV dinner. In a food system cluster, the food product is passed along from stage to stage. Technically ownership may change, but the location of the key decision-makers does not change. Starting with the intellectual property rights that governments give to the biotechnology firms, the food product always remains the property of a firm or cluster of firms with close working relationships. The farmer becomes a grower, providing the labor and often some of the capital, but never having clear title to the product as it moves through the food system and never making the major decisions.

Biotechnology and Capitalism

The food system is not becoming different from other economic systems of the global economy. In fact, it is becoming more like the banking, computer, automobile, and mass media economic systems. One of the interesting topics some of my fellow sociologists have explored is why the food system, especially the agricultural portion of it, was so slow to follow the industrialized model. Because food is a necessity of human life and is needed on a regular basis, unlike other goods and services exchanged in the global market, the changing structure of the food system may attract more attention than changes in other economic systems.

The concept "capitalism" is often used to describe different types of economic systems. Often the concept capitalism is used to suggest an economic system with limited government intervention and a market system characterized by competition. The characterization of the agriculture/food system in which 1) no firm providing inputs into agriculture or markets for agricultural products had enough market share to influence the price; 2) there existed relative freedom of entry into the input sectors, production sectors, and market sectors; and 3) reasonable public knowledge of local markets prices and conditions existed, was correct until about the middle of the 20th century. This type of capitalism is sometimes referred to as "early capitalism."

Without strong government intervention to "keep the playing field level," it is inevitable that certain firms will begin to develop economic, (and possibly political) power, such that they can begin to squeeze out their competition. The literature on industrial organizations lists many means that firms in the competitive phase can use to gain the edge over their competitors. Two of the most common means used are 1) increasing size to take advantage of economies of size, and 2) becoming one of the earliest adopters of new technology. As an economic system matures, competition becomes greatly reduced. A firm that operates in many commodities, in many stages of the production sector for that commodity, and in numerous countries in the world, can make very difficult the survival of a firm operating in one commodity, in one stage of the production system, and in one country. If small firms hope to survive, they must find a niche where the large diversified firm does not wish to operate.

Because biotechnology is such a capital intensive research enterprise, most small firms soon become marginalized. They cannot generate the capital needed to compete in the research arena. The larger and more powerful firms then receive patents on their technologies, further eliminating competition. One only needs to examine the number of established seed firms that Monsanto has acquired in the past year or so to see the restructuring of the seed input stage of the food system as a result of the dominance of biotechnology. Even a firm as large as Cargill felt it was better to sell the global seed business to Monsanto and form a joint venture with them than it was to try enter the biotechnology field on its own.

Finally, I would return to the goal of corporations — the corporations that are making the major decisions and basically controlling how biotechnology will be used in the food system (Kloppenburg and Burrows 1996). The firms are very honest about their goals. One of the dominant firms suggests that their major mission is to enhance the wealth of their stockholders. In the past several years, the pharmaceutical firms have had the highest rates of return on equity of all firms in the manufacturing sector. In most years, food firms ranked second. The dominant food firms expect to achieve a 20 percent return on stockholder equity by traveling around the world and “sourcing” their products wherever they can get them produced the cheapest. In the globalized system, both capital and technology are very mobile and can be moved anywhere in the world very rapidly.

Food firms are not charitable organizations. They are not concerned with feeding all the people of the world. They are concerned with feeding people who can purchase food products, even those shipped halfway around the world under refrigeration. Poor people in this country and other countries of the world cannot be consumers in such a system. Neither can the farmers (peasants) in poor countries be purchasers of the high-priced inputs that accompany producing agricultural products with biotechnology. Poor people can provide some of the labor needed in food production, but the food they produce may never belong to them or their families. That food may very likely be sent to more affluent countries, where labor costs and the cost of selected health and environmental regulations result in higher food production costs, and thus higher priced food. This is already happening, but biotechnology will exacerbate it.

Many of us have pension plans and/or personal investments in a variety of for-profit firms. We have come to expect high rates of return from our investments (unless that investment is in farmland or a farm operation). In fact, if we receive only an annual rate of five or six percent return on our investments for a short period of time, we think that it is time for a new CEO. This attitude forces these firms to become very shortsighted. The CEO must be concerned about the firm's financial performance in the next few months if he/she expects to be in that position for the next few years. We are a part of the economic system that has become obsessed with profit and consumerism. Perhaps I have slightly over-dramatized the importance of short-term profits in guiding the global, industrialized food system, but put yourself in the shoes of a CEO of one of the dominant food firms. Ask what criteria you would use in making the many relatively small, daily decisions within the organization that has a major cumulative effect? Would the criteria be different than that used for making major decisions such as involvement in a merger or joint venture? These decisions made in the dominant firms help to shape the globalized system.

Creating a secure and sustainable world food supply is seen by many of those managing the food firms as a concern, but it is not seen as the responsibility of the private sector. It is seen as the responsibility of the society as represented by the government. The irony is that as trade liberalization is extended around the world, it simply means that governments, which are supposed to be responsible for the common good, turn more and more of the decision-making in the economy over to the transnational corporations.

The economic institution has become so strong that it is having a major impact on our entire culture and the institutions that it encompasses. The power of the global economic institution is so strong today that many neo-classical agricultural economists suggest that the growing concentration and power imbalance is part of a "natural system." The implication is that we cannot change the direction of the economic system and must adjust to it.
As a sociologist, I disagree that the economic system cannot be changed. The economic system has been created by humans and can be willfully changed, but it will not be done overnight. Not all people have been involved in determining the economic system that clearly serves some better than others. If we want to feed all the people of the world, we will need to take a serious look at the economic system and its relationship with the political system.

Many find it is easy to suggest that the major food problem is "just a problem of distribution." Others recognize there is a distribution problem, but simply suggest that the government needs to take some action. They then move on, fully supporting the development of more technology and hoping that somehow the new technology will help feed the growing populations. I see very little research funded to help us better deal with the issues of food (or even income) distribution that are the real issues in feeding all the people of the world now and in the future. These issues are probably more difficult to solve than generating more technology. Until we seriously deal with the distribution problem other than in the *de facto* way of allowing it to continue, I do not think biotechnology will make much progress in feeding the people of the world whom now have inadequate diets. I am even suspicious about the voiced concern for feeding the growing population. While it may be one concern of the food system clusters including the biotechnology firms, it doesn't rise to a level of commitment.

My sense is that biotechnology has been introduced much too rapidly into society. The political institutions, as well as the religious and other social institutions, are simply not able to evolve fast enough to deal with the rapid introduction of such a powerful technology. Returning to my comparison with nuclear technology, I ask — what is the purpose of the "race" for biotechnology at a time when we are awash in commodities and show no signs of solving the distribution problem? There are probably two races going on. The first is between a few major firms to see who can make the most profit in the shortest period of time, and the second is between research institutions to see who can garner the most research funding and academic status.

In allowing firms to patent intellectual property, the U.S. government set in place a structure that would greatly reduce competition in the food system. The explanation for this was that it would encourage firms to invest huge sums of capital into biotechnology and bring it to the market in a short period of time. What was the big rush? Would it not have been better to keep this life science technology in the public domain so that there could have been public debate and democratic decision-making involved during the research process? Privatizing the research led to secrecy both in the research and in the development of products. This often increases public suspicion and makes it difficult for other institutions to prepare for such a new technology. At this point in time, it appears societies feel their only choice is that of accepting or rejecting all of biotechnology in the food system. The question is whether there is room for any compromise?

In closing — is it too much to ask that we slow the development of this technology, engage the public in a debate as to its costs and benefits following our democratic tradition, and slow the process until we can determine how to properly engage the other institutions in our society?

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The Federal Role of University Sponsored Agricultural Research and Resolving Conflicts Arising Out of the Implementation of New Technologies

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Often in my work outside of the U.S. Department of Agriculture (USDA), I need to remind respected scientists and policy-makers that the federal government's sustained commitment to universities did not start 50 years ago with the release of Vannevar Bush's report "Science: The Endless Frontier" and the subsequent creation of the National Science Foundation. There is a rich history of federal support for university-based agricultural research. Starting with the enactment of the Morrill Act and the establishment of the land grant colleges in 1862, through the recent passage of the Agricultural Research, Extension, and Education Reform Act of 1998, the relationship between the federal government and the land grant universities has evolved into a partnership that is vital to the nation's economy and to its ability to produce an affordable, safe, nutritious, and sustainable supply of food and fiber.

While the distinction between the land grants and other public and private research universities is blurring, the land grants, especially through their commitment to public outreach and science associated the management of natural resources, make an invaluable contribution to the nation. However, before I address the role of the federal government in supporting agricultural research at universities, I would like to present some of the results of a recently released Presidential Review Directive that makes recommendations on how the broader federal government-university partnership might be strengthened.

First and foremost, the federal agencies participating in the review called for the development of a clear set of principles or expectations on which future policies can be based and past policies can be judged. While the partnership is often referred to, it has never been clearly articulated and usually is subject to multiple interpretations. For example, one of the hallmarks of the U.S. system of research universities is the integration of research and education. What is the federal government's responsibility in promoting and supporting the dual role of scientist-teacher? Are agencies interested only in procuring research or are they also committed to the production of the next generation of scientists and engineers? Do federal policies support our expectation or do they work at cross-purposes with them?

Principles of the Partnership

When President Bill Clinton released the National Science and Technology Council (NSTC) report "Renewing the Federal Government-University Partnership for the 21st Century" during the May 1999 Medal of Science and Medal of Technology ceremony, he stated that "we must move past today's patchwork of rules and regulations and develop a new vision of the university-federal government partnership." The President asked the university community to work with the federal government to develop a set of principles that clearly articulates the shared expectations of the partnership. The following draft set of principles is extracted from the NSTC report:

Research Is an Investment in the Future. Government sponsorship of university research — including the capacity to perform research and the training of the next generation of scientists and engineers — is an investment in the future of the nation, helping to assure the health, security, and quality of life of our citizens. Government investments recognize that the expected benefits of research often accrue beyond the investment horizons of corporations or other private sponsors. Investments in research are managed as a portfolio, with a focus on aggregate returns; investments in individual research efforts that make up the portfolio are based on the prospects for their technical success, though not on a presumption that those outcomes can be predicted precisely.

The Linkage Between Research and Education Is Vital. The integration of research and education is the hallmark and strength of our nation's universities. Students (undergraduates and graduates) who participate in federally sponsored research grow intellectually even as they contribute to the research enterprise. Upon graduation, they are prepared to contribute to the advancement of national goals and to educate subsequent generations of scientists and engineers. Their intellectual development and scientific contributions are among the important benefits to the nation of federal support for research conducted at universities. There should be compelling policy reasons for creating or perpetuating financial or operational distinctions between research and education. Our scientific and engineering enterprise is further enhanced by the intellectual stimulation brought to campus by students from varying cultural, ethnic, and socioeconomic origins. Excellence is promoted when investments are guided by merit review. Excellence in science and engineering is promoted by making awards on the basis of merit. Merit review assesses the quality of the proposed research or project and is often used in combination with a competitive process to determine the allocation of funds for research. Merit review relies on the informed advice of qualified individuals who are independent of those individuals proposing the research. A well-designed merit review system rewards quality and productivity in research, and can accommodate endeavors that are high-risk and have potential for high-gain.

Research Must Be Conducted with Integrity. The ethical obligations entailed in accepting public funds and in the conduct of research are of the highest order, and recipients must consider the use of these funds as a trust. Great care must be taken to "do no harm" and to act with integrity. The credibility of the entire enterprise relies on the integrity of each of its participants.

These draft principles are designed to capture the entire scope of the research university partnership with the federal government. Perhaps this is something the state agricultural experiment stations and colleges of agriculture should consider doing with the USDA or with the federal government more generally. To a large degree, this is done for you each time the Congress and the Administration pass a new research title of the Farm Bill. But I would argue that many of the provisions contained in these bills and the subsequent appropriations bills should be better grounded in a mutual understanding of the shared expectations of the partnership that exits between the government and the experiment stations and colleges of agriculture. Issues such as merit review; formula funds versus competitive grants; the extent of support for research targeted to local, regional, or national needs; technology transfer; and integration of extension, education, and research, could be addressed and expectations clearly articulated.

Federal Funding for Agricultural Research

One of the strengths of the federal research portfolio is its diversity — diversity of supporting agencies, as well as diversity of funding mechanisms. The tight link that exists between the research and agency mission allows for support of mission-relevant research that otherwise might not be supported. In theory, the diversity of funding mechanisms, i.e., intramural, extramural, formula, competitive, and special grants, should allow policy makers to direct research and related support activities to the best performer for a given purpose.The intramural programs should support long-term research or research support activities that are of regional or national significance, such as food safety and nutrition research, and germplasm conservation. Competitive grants are best suited for stimulating high quality creative science of national significance in research programs that do not necessarily require a long-term commitment on the part of the agency. Formula funds represent the federal commitment to supporting research in areas deemed important locally or regionally. Special grants support highly targeted areas of research that are unlikely to be funded through other means.

The administration views federal support for agricultural research as a core piece of the federal research and development (R&D) budget. It is included in the President's 21st Century Research Fund. When developing the President's budget and allocating resources among these programs, we attempt to balance these funding mechanisms. Both the Clinton and (George) Bush administrations have been seeking to increase significantly the size of competitive grants program in the USDA. In our view, competitive grants continue to be underrepresented in the USDA research portfolio.

Priority Setting

How do you determine what the proper balance is among these programs? Under times of growing budgets, this is much easier. When budgets are tight or actually shrinking, this becomes much more difficult as the tradeoff between programs needs to be carefully considered. You need to determine which programs will deliver the highest quality science with the most relevance to the highest priority research areas. Each year, the Office of Science and Technology Policy (OSTP) and the Office of Management and Budget (OMB) develop a R&D priorities memo that reflects current initiatives managed by the NSTC. In addition to stressing the NSTC's support for peer reviewed competitive research and other program attributes, the memo lists several special areas of emphasis that will receive favorable treatment during this year's budget cycle.

Program Attributes

- Favor investments that focus on long-term, potentially high-payoff activities and outcomes that would not occur without federal support, such as activities in the 21st Century Research Fund.
- Ensure that the government-wide portfolio of R&D investments establishes a desirable balance among fields of science.
- Maximize the efficiency and effectiveness of federal R&D investments, by, for example, favoring activities that employ competitive, peer-reviewed processes; encouraging collaboration among agencies, industry, academia, and the states when such efforts further the goals of the research; encouraging strategic collaboration with key international counterparts that will address fundamental science priorities as well as global energy, environment, security, and health challenges; and improving, phasing down, or eliminating programs that are not resulting in substantial benefits or are not important to an agency's mission.

Interagency Priorities for Agricultural R&D Budgets

Plant Genome: Promote the coordinated development of plant genomic information, new technologies, and resources that will improve our understanding of plant biology and be applied to the enhancement of economically important plants.

Climate Change Technology: Promote and coordinate research aimed at technologies capable of achieving reductions in U.S. carbon emissions at the lowest possible cost. Technologies include products and production methods that reduce greenhouse gas emissions and increase the efficiency of energy and materials used in transportation, buildings, and manufacturing while lowering the cost and improving the quality of the goods and services delivered and technologies which provide cost-effective renewable alternatives to fossil fuels.

Food Safety: Promote food safety research that provides a scientific foundation for sound food safety policy and regulation, innovations in food production to increase safety, consumer education to improve food safety practices, and global monitoring (surveillance) and response to outbreaks of food-borne illnesses.

Integrated Science for Ecosystems Challenges: Develop the knowledge base, information infrastructure, and modeling framework to help resource managers predict/assess environmental and economic impacts of stress on vulnerable ecosystems, with particular focus on invasive species, water and air pollution, changes in weather and climate, and land and resource use.

An overarching consideration in our priority setting process is the Government Performance and Results Act or GPRA. GPRA requires a new level of accountability to Congress and to the taxpayer. Increasingly, Congress and OMB are demanding an accounting of what the taxpayer will get for an increased investment in a program. OMB is required to ask agencies for this information when preparing the President's annual budget request to Congress. Inherent in the GPRA process is stakeholder input to identify high priority national needs.

With GPRA, there is a juggling act between qualitative and quantitative performance measures. There is a real danger in employing quantitative performance measures inappropriately. Agencies, OMB, and Congress need to understand when the use of more qualitative measures is better suited to gauge a program's performance. For example, the use of peer review by a committee of visitors rather than an accounting of published papers or patents.

One fundamental consideration in establishing programmatic priorities is industry's role in advancing research in any given area. This isn't always straightforward. For example, in the area of plant genomics, industry has a large investment that dwarfs anything we could hope to do in the public sector. However, access to industry generated information is limited and generally comes with strings attached. The question we need to ask is how important is this information to the future of publicly supported biological research and to agriculture? We believe the answer is very important. Unfortunately, until we are able to establish mutually acceptable data access provisions in this field of study, the limited public sector investment will almost certainly duplicate work conducted by the private sector. Plant scientists in the public sector need ready access to plant genomics information if they are going to capitalize on this technology to advance the scientific frontiers.

Technology Conflict Resolution: What is the Federal Role?

One of the issues the organizers of this conference asked me to address is the role the federal government plays in resolving conflicts created by conflicting technologies. In my experience, the federal government is not particularly good at this and in cases that don't have environmental or human health implications market forces have largely driven resolution. In cases with environmental or human health implications, the federal government resolves conflicts through legislation and regulation. In cases where there are conflicting technologies, special programs can be established to shelter one technology over another, but the marketplace is usually where these get sorted out.

Three examples of conflicts that are in the process of sorting themselves out include the following: Organic versus biotechnology, human and environmental health versus chemical pesticides, and labeling based on risk versus the consumer's right to know.

Organic and biotechnology: This conflict clearly surfaced when the USDA issued proposed guidelines on what could be considered compatible with organic farming and what wasn't for the purposes of labeling. Several issues raised in the USDA proposal generated much controversy with the USDA receiving over 200,000 comments. Much of this was targeted toward the suggestion that under some circumstances biotechnology products might be compatible with organic production. All the proposed rule did was ask for guidance on this issue; it didn't propose to allow biotechnology products in organic production. Even so, the comments poured in to such a degree that Dan Glickman, Secretary of Agriculture, decided to take biotechnology off the table. In this case, the Secretary decided the organic industry didn't want it, and therefore, he acted accordingly. This was not a decision based on science or risk.

In another instance, the organic community and others have presented valid concerns about the use of transgenic crops expressing Bt toxins. Concerns are not focused on safety, but rather on the development of resistance. Here, the Environmental Protection Agency (EPA) and the USDA are working with the various stakeholders to develop resistance management plans.

Human and environmental health and chemical pesticides: We have been resolving this issue since the publication of Rachel Carson's *Silent Spring* in 1962. The latest manifestation of this was the enactment of the Food Quality and Protection Act of 1996 or FQPA. This law came about because of deep concerns on many fronts that our existing pesticide legislation was not adequate to protect the public's health, especially the health of more vulnerable populations like children. The requirements of FQPA are presenting a challenge to the EPA. Not only will the deadlines be difficult to meet, but the demands FQPA places on our ability to conduct risk assessments are also great. For example, FQPA requires an assessment of aggregate exposures of pesticides for multiple crops and also requires the consideration of exposures from pesticides with similar modes of action when setting tolerances. These new requirements have caused us to question the adequacy of our databases and risk assessment models.

Labeling for health and safety reasons and consumer's right to know: Traditionally, the federal government has mandated food labeling when there is important health or safety information that needs to be conveyed to the consumer. Therefore, I believe that government mandated labels that do not convey facts on the nutritional or safety aspects of the food, as supported by sound science, should be discouraged. I believe the government should stay away from mandated labels that relate simply to how a product was made or where it was made. Exceptions to this have occurred; for example, the current effort to develop standards for organic foods and mandated country of origin requirements for some foods.

When it comes to labeling biotechnology derived food products, there is a growing consumer demand in many parts of the world for mandatory labeling. In numerous fora, such as the biosafety protocol negotiations under the Convention on Biological Diversity and the Codex Alimentarius, NGOs (Non-Government Organization) and many national governments are pushing for mandatory labeling requirements of genetically engineered food products. The United States is in the unique position of having a citizenry that has a great deal of trust in its food safety regulatory agencies and having the most advanced biotechnology product line. Our position is that these products don't need labels unless they are significantly different from products with which consumers are already familiar. For example, if a product has altered antigenic or nutritional properties, Food and Drug Administration (FDA) would require labeling. However, there is a serious disconnect between the U.S. government's approach to labeling than that of the European Union and many others countries. In order to avoid major losses in trade, we need to resolve this issue quickly.

Conclusion

The federal government has had and will continue to play a major role in promoting sustainable agriculture though its support for research at land grant universities and elsewhere. Key to the future success of federal efforts will be improved mechanisms of accountability as determined by both qualitative and quantitative performance measurements as mandated by GPRA. We need to apply the very best science to problems associated with the future of agriculture and peer review will be used increasingly to determine the quality of work supported by the USDA as it is with support from other government R&D agencies. We need to do a better job listening to stakeholders. We need to make sure that the nature of the partnership that exists between our universities and federal government is clear and that our policies that shape the partnership are not working at cross-purposes.We need to look carefully at our underlying national goals for a robust economy and excellent public and environmental health and make sure that our diverse agricultural sector is contributing to achieving these goals in positive ways. As we continue to develop and adopt new technologies, conflicts will arise. It is not the government's role to determine which technologies succeed and which will not. It is the government's role to help pave the way for or enable technological developments in a manner that is consistent with our underlying national goals.

Changing Consumer Demands Can Drive Biotechnology Adoption

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Appreciating the role of the consumer in shaping the agricultural and food system is key to understanding its structure and evolution. Emerging patterns in food demand help explain the transformation of agriculture from a commodity business, in which competition to sell homogenous goods is based solely on price, to one that delivers a broadening range of quality-differentiated products.

One of the immutable relationships in economics is known as Engel's law, which holds that as consumer incomes increase, the proportion of income spent on food decreases (Tomek and Robinson 1981). At lower income levels, spending on food may increase in proportion with income growth to ensure a sufficient quantity of food is purchased. As income continues to grow, food spending will continue to expand as individuals or households seek better quality food or buy food with more "built-in" services (as with food consumed in restaurants, for example). Eventually, food spending in the absolute may level off, so that it accounts for an ever-smaller proportion of growing income. At this stage, the demand is not so much for larger quantity but better and more diverse food quality. Although Engel's law technically pertains to food spending by individuals or households, the concept can be used to characterize differences in national spending patterns and to illuminate different demands being placed on food systems.

To begin close to home, consider the United State's food market. In the U.S., food quantity consumed in the aggregate essentially increases only with population growth. The proportion of income spent on food has fallen steadily over the past century. In a mature food market such as this, growth in demand for one food product likely only comes at the expense of another product. Consumers may switch from one product to another based on a desire for a different quality characteristic, as from one kind of breakfast cereal to another. No more cereal is consumed, so growth in one cereal's market share comes at the expense of another's.

The proliferation of many types or varieties of foods is called product differentiation, and there are many examples outside of food and agriculture. The automobile industry evolved from one where any color of Model A could be had as long as it was black, to one in which new models appeared that were differentiated along many quality dimensions, including safety and styling, as well as performance. Much U.S. spending on clothing is predicated on the imperative of product differentiation, that is, the demand for clothes for different occasions, seasons, and other quality dimensions. In the food business, the past 10 or 15 years has seen an explosion in the number of new product introductions. Retail food stores offer choices that provide novelty or variety or convenience. Examples include organic produce, exotic fruits, marinated cuts of meat, and brands of bottled water. At the same time, spending on food consumed away from home continues to rise, reflecting the purchase of food with more built-in services.

How does the agro-food industry organize to meet food demand in this kind of mature market? One response, similar to that adopted in other sectors, is to coordinate the different parts of the supply chain more closely in order to assure that signals from consumers are translated swiftly and effectively. Food retailers, for example, may seek direct ties to growers in order to contract for products with specific qualities for delivery at specific times. Vertical integration in the hog industry appears to have helped develop the market for pork, including the introduction of convenience products, such as pre-trimmed and marinated tenderloins of uniform size and meat quality. Another response may involve focus on niche markets, which can exist side-by-side with mass retailing. Here, a good example is found in the wine industry where premium vintners thrive along with large volume distributors.

So far, explanation of structural change in the US agro-food sector has not included discussion of the use of biotechnology in food production or processing. But the question can now be posed: how will consumer demand pull biotechnology through the system? One possibility is expansion of the already-observed demand for "functional foods," which are products differentiated by nutritional content in ways that appeal to consumers' concerns about diet and health. New margarines or potato chips that have desirable types of fat are but two examples of new products that receive premium prices. The bottom line is that if biotechnology can be used to create products with characteristics that consumers value, then they will be used in production and processing. This is the promise of the so-called "second generation" of biotechnology products, as distinguished from the "first generation," which were innovations largely applied to reduce the costs of commodity production or boost yields but which imparted no changes to commodity quality.

In the United States, Canada, Western Europe, and a few other places, it is fair to characterize food markets as mature, with product quality differentiation explaining much of the dynamics of change. But in other parts of the world, the motivations underlying expansion of food demand and markets still have to do with desires to attain caloric sufficiency and key diet quality improvements. Some 800 million people, according to United Nations estimates, are malnourished, and many of them live in sub-Saharan Africa, as Per Pinstrup-Andersen explained. For these people and many others around the world, markets are a less important source of food than their own subsistence farms. First-generation biotechnologies matter here, where reliable growing is the main concern. But there are billions more people in Asia and Latin America, for example, who do have the wherewithal to demand more in food markets, seeking better diet quality, largely in the form of animal protein. Indeed, one of the most striking aspects of U.S. agricultural export growth over the past 15 years has been acceleration in meat exports. Indeed, the Governor of Nebraska told of his recent trip to Taiwan and Japan, where there are important consumers of key state products such as beef. It is true that economic growth in Asia is significantly off the pace of earlier projections. However, with well-educated and motivated labor forces these Asian nations still possess the fundamental determinants of food demand growth. Biotechnologies for these consumers may mean first- generation applications but increasingly could mean second-generation uses as diet quality becomes central.

In conclusion, it is worth emphasizing the importance of understanding causality — why events happen — in trying to assess the role of biotechnology in the food and agriculture systems of both developed and developing nations. There is currently much change in these sectors, and so care must be taken neither to demonize or lionize any one factor — whether it be biotechnology or industrialization or consolidation — as responsible for all that occurs. In particular, the role that consumers play in driving change deserves more attention. Competition for the food dollar will lead retailers and others who sell directly to consumers to look for ways to provide quality-differentiated products in the form and at the times that the market demands. Forging new supply chains and adopting new production and processing technologies will likely be parts of the adjustment to consumer-driven agriculture. Ultimately, it is only by understanding causality that there is any serious prospect of affecting outcomes, which is the real reason to be thoughtful in sorting through the complexity and ambiguity of change.

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Where Do We Go From Here? The View From Times Square.

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I am a product of the city and the suburbs. My only contact with farms as a boy was to lean my head out of the car window and try to communicate with cows when we drove through the country. My first contact with agriculture as a reporter came in 1988, when I went to an Agricultural Research Conference in Beltsville, Maryland. There I heard ominous phrases I hadn't heard before — talk of "genetic erosion" and "seed morgues." The conference was on the subject of germplasm preservation. One speaker after another stood at the podium proclaiming a crisis in the national germplasm preservation system.

As an environmental writer, I was interested in biological diversity, but at that conference I learned about an example of biological diversity that I had not heard of before. If I asked what place on Earth contained the most biological diversity, you might answer that it must be somewhere in the tropical rainforest. But I'm not sure that's right. I know a place where I can identify 500,000 genetically distinct organisms in the space of a few thousand square feet — an example of diversity that transcends even the incredible natural diversity of tropical rainforests. The place I have in mind is the National Seed Storage Laboratory in Fort Collins, CO. It's a fantastic repository of genetic diversity, containing thousands of varieties of corn and beans and wheat — and virtually every other crop you might name.

I mention it partly because it hasn't been mentioned during the conference, and, from the perspective of scientific research, I think it is important. The National Seed Storage Laboratory is one of the foundations on which biotechnology is built. We often think of biotechnology as almost a magical thing, capable of creating any kind of crop we can imagine. But biotechnology is actually a very limited thing: it can move genes around and manipulate them, take them from one species and put them into any other species. But, at present, it is utterly unable to create entirely new genes that do entirely new things. From a scientific point of view, it is important to remember that without a treasure chest of genetic diversity, biotechnology isn't much good. There are many genes in that treasure trove that could produce crops that might solve some of the problems we've been discussing during the past few days. But there are two problems: One is that the seed storage laboratories are not getting enough money to preserve their collections. Seeds are living things, and they don't live forever. From time to time, they have to be taken out and planted, and then the fresh seeds can be harvested and put back into storage. That is not being done, and some of the sample envelopes in the seed storage laboratory now contain nothing but lifeless dust.

A second problem is that biotechnology companies are motivated by short-term financial considerations. They cannot choose genes to produce crops that might help solve some of the social and financial problems we've been discussing at this conference. If we want to use biotechnology to help feed the world's starving poor or serve other social aims that may not be profitable, we have two options: We can persuade government to do it, or we can mobilize public opinion to persuade biotechnology companies to donate technology to those who will never be able to afford to buy it.

Another thing I would like to mention is a word that comes up all the time in discussions at *Business Week* about economic trends. It's a bit of a surprise to me that it didn't figure more into discussions here. The word is: Internet. The Internet is transforming American business of all kinds, and it's happening extremely rapidly. To give you a New York example, the stock broker Merrill Lynch has long said that it wasn't interested in online trading on the Internet. Merrill Lynch felt that it offered superior products and services, that its knowledgeable brokers and researchers offered information that stock traders would be happy to pay a premium for. A couple of weeks ago, Merrill Lynch reversed course and said it would begin offering trading online. The economics of the Internet were simply overwhelming. Trading on the Internet was so much easier and cheaper than trading through a broker that Merrill Lynch was losing customers. It had no choice but to join the trend.

So my question to you is: What opportunities does the Internet offer to agriculture? How does it intersect with biotechnology? What, if anything, can it do to help make this technology available to those who cannot now afford it? One of the buzz words connected with the Internet is this mouthful: disintermediation. It is a complex bit of jargon for a simple idea: The Internet is, in many circumstances, removing the middle man in business transactions. People who want to buy stock don't need a broker. They can deal directly with the market. People can look at schedules and fares in airline computers without needing to consult a travel agent. Increasingly, it is possible to deal with wholesalers directly, avoiding retail markup. At this conference, many speakers have talked about the long chain between farmers and end-users. What can the

Internet do to shorten those long lines? I'm not talking about using the Internet as a research tool, or a communications tool. Those are important, but that is already happening. I'm talking about using the Internet as a marketing tool. What are the opportunities for E-commerce in agriculture? There might be a thousand reasons why I cannot sit in New York and order beef directly from a Nebraska farmer on the Internet. But maybe not. It's a question worth exploring.

And while we are on the subject of the long lines between farmers and end users, I think it is important to remind you how little we know from our perch in New York. This is the view from Times Square. Given the extremely rapid adoption of genetically modified crops in Nebraska and elsewhere in the Midwest, I assume I am now eating meat in New York that has been fed with genetically modified feed. Is that a reason for concern? It's hard to say. During the past few days, we have heard a lot of questions raised about the safety of genetically engineered crops. And we have heard just as many assurances that there is nothing to worry about. It will be a difficult issue to resolve. But one thing is very clear: many people are concerned about the potential health dangers of genetically modified crops, and that is an important thing to think about — whether they are right or wrong to be concerned. The point is that, in New York, we don't know, when we shop at the supermarket, whether we are buying food that ultimately comes from genetically engineered crops. The issue has been widely discussed in Nebraska by farmers, by researchers, and by those in the biotechnology industry. But it hasn't yet been widely discussed in New York, or in Washington, or in the press. Those discussions need to take place if people are to become informed about genetically engineered crops and make intelligent decisions about them.

As people discover that this revolution in agriculture took place without any national debate, they might decide they have been hoodwinked — and that could lead to a backlash in which many would decide to reject these foods out of hand. Many people might be perfectly happy to eat genetically modified foods, but nobody likes to be fooled. The monarch butterfly has been mentioned repeatedly during the conference. In the coming months, we might all forget about the monarch butterfly study. We really don't know whether monarchs are exposed to Bt pollen, and this concern might completely disappear.

Or it might not. Rachel Carson's cause got huge visibility in part because of her eloquent advocacy but also because the animal that was in danger was the bald eagle — the symbol of the country. Trying to predict the fate of genetically engineered foods is, at this point, a little like trying to predict what the stock market will do in the coming months. It could soar. The Dow Jones index could hit 12,000, or 15,000. But you would be prudent not to bet on it. Prices could just as easily turn sharply down. I don't know what the American public will think about the monarch butterfly research a year from now, but it would be prudent to prepare for a public backlash. The monarch butterfly could turn out to be the bald eagle of biotechnology. I happen to think biotechnology is an important and useful tool. I don't necessarily see a conflict between biotechnology and alternative agriculture, or organic farming. I like to think of alternative agriculture and organic farming as the "soft paths" in agriculture. Biotechnology is the hard path. Both can help us get to a healthier, more profitable, more environmentally sustainable kind of agriculture. Both can be used for the good of consumers and for the good of farmers. Biotechnology can be used to produce improved crop varieties for organic farmers, allowing them to produce tastier foods and a wider variety of foods without using chemicals — and the opportunity to use fewer pesticides and other chemicals could help win consumer acceptance. Whether that happens will depend upon how this new technology is used. Using it to sell more herbicide offers nothing to consumers, and it isn't going to earn their acceptance of crop biotechnology.

PART V

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