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Of Frankenfoods and Golden Rice

Risks, Rewards, and Realities of Genetically Modified Foods

TRANSACTIONS Volume 89, 2001

Edited by Frederick H. Buttel and Robert M. Goodman

Wisconsin Academy of Sciences, Arts and Letters
Since 1870, supporting thought, culture, and the exchange of ideas

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Edited by

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About the Wisconsin Academy

The Wisconsin Academy of Sciences, Arts and Letters is an independent, nonprofit membership organization founded in 1870 to gather, share, and act upon knowledge in the sciences, arts, and letters for the benefit of the people of Wisconsin. Everyone is welcome to join. Programs include an art gallery featuring a different Wisconsin artist every month; a quarterly magazine about Wisconsin thought and culture (the *Wisconsin Academy Review*); the Wisconsin Idea at the Academy, which brings together people from diverse fields to examine public policy issues; and public forums on topics of current interest. Our annual journal *Transactions,* which has been published since 1872, this year reflects content of our Fall Forum 2000 on genetically modified foods.

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From the Wisconsin Academy

Michael Goodman
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"No one in biotech will want to speak at a public forum. They're hoping that the whole issue will just go away." I heard this sentiment often in the early days of planning for the Wisconsin Academy's Fall Forum 2000, "Genetically Modified Food: Risks, Rewards, & Realities," which was held in Madison in November of that year. As it turned out, that sentiment was stating things far too simply.

When I met with scientists and others working in the biotechnology realm, I learned that many indeed were interested in letting others know their thoughts and motivations. Among those standing on the "other side" of the issue—people who oppose production of genetically modified foods—there were some who wanted to denounce the entire science, but many more who were interested in searching for common ground. And then there were those people—specifically, farmers—who felt they were being left out of the discussion altogether. It became clear that there was a tremendous opportunity to initiate an open discussion on this very contentious issue.

The Wisconsin Academy's mission to further knowledge required us to bring in as many points of view as possible (and believe me, there are many more than the ones I portrayed above). Our goal was to craft a discussion that would allow those involved and those in attendance not only to learn some basics and hear the disagreements, but also to hear where those in opposition could find common ground. Forum planners and advisors—a diverse group that included scientists, educators, farmers, historians, writers, and ethicists—came up with a structure that brought a wide range of experts, views, and content to the one-day discussion (see appendix for the forum agenda). You can see the basics of the format we chose in the content of this volume of *Transactions*. Much of the content for this book came from the forum. Presenters generously rewrote, adapted, and updated their talks for this collection.

These articles represent a wide range of thoughts on the subject of biotechnology and agriculture. Topics touch upon economics and international trade, farming and storage, world hunger, history, and ethics. The introduction to this book by our guest editors Frederick Buttel and Robert Goodman, who also served as forum planners, does a wonderful job giving the reader a thorough background on the subject of genetically modified food as well as outlining the range of authors and subjects in this volume. Our special thanks to them for their expertise and hard work in putting together this volume of *Transactions.*

I believe that this mix of topics and viewpoints is greater than the sum of its parts. Forum attendees were given the opportunity to have some of their opinions questioned and to discover the many shades of gray that exist when talking about such complicated issues. I am sure that some people left with the same opinions they had on arrival. But I know that many others changed their views, maybe not enough to make them join the "other side," but enough to leave them thinking about these issues with new insights and more information at their disposal. I am certain this collection of essays will offer readers that same opportunity. And that is the Wisconsin Academy at its best.

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Introduction to the Scientific, Political, and Ethical Dialogue on Genetically Modified Organisms

Frederick H. Buttel and Robert M. Goodman

The genetically modified organism (GMO) controversy in the United States is in one sense a very particular phenomenon; yet in another sense it is an entirely predictable occurrence in the early twenty-first-century development of the agricultural and food system.[1] In the latter sense, it is deeply rooted in U.S. regulatory politics of the 1980s and corporate decisions of the early 1990s. In the 1980s, a laissez-faire regulatory environment coincided with new technologies and new investment emerging from the private sector that resulted in prototype GMO and GM food products (Flavr Savr tomatoes and virus-, herbicide-, and insect-resistant crops). These new products were "shoehorned" into existing regulations at the EPA, the USDA, or both, with only grudging overview from the FDA. Ironically, what regulatory oversight these early products received was demanded by industry.

[1]Accordingly, genetically modified (GM) foods are those that contain ingredients from GMO crop varieties, though there remains debate as to whether there should or should not be a statistical definition (regarding "tolerance" of the maximum permissible amounts of one or another GM ingredient) in defining what are and are not GM foods. Also, as we will note, the definition—even the usage—of GMO is subject to debate. We actually prefer the terminology "genetically engineered crop."

In the 1980s and 1990s, several major chemical companies experimented with their reinvention as "life sciences" companies. These companies, which emerged as the commercial proponents of GMO crops, made a fateful decision—to reject labeling of their products and largely withdraw from early initiatives to educate a public whose nascent skepticism had failed to ignite in response to Jeremy Rifkin and various environmental groups. They also ignored the early signs from Europe of a controversy in the making.

By early 1999, agricultural biotechnology in the United States was clearly on a roll with considerable momentum. As of the 1998 growing season about 36 percent of U.S. soybean acreage, 20 percent of U.S. cotton acreage, and 22 percent of U.S. corn acreage was devoted to genetically engineered varieties, and about 60 percent of Canadian canola acreage was devoted to genetically engineered varieties (James 1998). The adoption rates for U.S. GMO soybeans, corn, and cotton from 1995 to 1998 and for Canadian canola arguably represented the most rapid adoption curve of any new agricultural technology in world history. The controversy over recombinant bovine somatotropin (rBST; also known as recombinant bovine growth hormone, or rBGH), which had heretofore been the United States's most contested new biotechnology product, had largely blown over by early 1999, and in retrospect nothing that might have been learned about corporate approaches to public concerns over technologies provided to farmers was in fact learned.

By April 1999, the European Union (EU) had approved three *Bacillus thuringiensis* (Bt) corn varieties and one herbicide-tolerant corn variety, and at least six additional Bt and herbicide-resistant crop varieties (and two "stacked" [both Bt and herbicide-resistant] varieties) were under EU regulatory review. In early 1999, the World Trade Organization (WTO), which included a number of provisions on intellectual property, nontariff barriers to trade, and the harmonization of national standards of food regulations that were favorable to commercial biotechnology, had been in effect for nearly four years and appeared to be becoming increasingly well institutionalized. WTO rules seemed to obligate the EU countries to not only approve these new agricultural input products but also to accept imports of GM grains and oilseeds product.

By the summer of 1999, however, there was a transnational eruption of social conflict over GMOs. The EU began to restrict imports of GM corn and soybeans and initiated what at this writing remains a de facto moratorium on approval of new GM input products. The Seattle protests at the 1999 WTO ministerial meeting were galvanized to a significant degree around consensus among environmental, labor, consumer, sustainable agriculture, development-assistance, and human rights groups that there should be resistance against GM foods and, most importantly, against WTO rules that limit the ability of nations and consumers to choose not to consume GM food ingredients. In 2000, the resistance to GM foods spread to a number of other nations and regions, including especially Japan, Korea, Thailand, Australia, and India. In early 2000 there was so much uncertainty about securing markets for GM corn and soybean products that many U.S. farmers stopped using them, or continued to do so with great apprehension. Bt corn use in the U.S., for example, has declined during each of the past two growing seasons.

One of the points that came out at the Wisconsin Academy conference "Genetically Modified Food: Risks, Rewards, and Realities" is that there is little agreement on what the notion of "GMO" (and thus of "GM food") means. Before proceeding further we want to be clear about what we mean by GMOs. Some observers—including, interestingly enough, many of the most active proponents and opponents of molecular biological technologies used in agriculture—tend to see GMOs as being synonymous with "agricultural biotechnology." Biotechnology is a very broad term that encompasses a suite of conventional methods—including tissue culture—as well as newer techniques based on molecular biology used for enhanced management of plant-breeding programs and in diagnosis of diseases and stresses that reduce crop production. These biotechnology methods are not what the GMO controversy is about. Rather, the focus of the controversy is on crop varieties and the foods derived therefrom that have been developed with the use of genetic engineering. By genetic engineering is meant the construction of genes engineered from recombinant DNA made in the laboratory and introduced into the chromosomes of a crop plant. Such genes, collectively called transgenes, when expressed in the recipient plant impart a new trait or property on the plant.

Today, GMO crop plants contain single-gene (or a small number of) transgenes that impart two major types of traits: There are the Bt crops (chiefly corn, cotton, and potatoes) that as a result of expression of a gene taken from the soil bacterium *Bacillus thuringiensis* are resistant to insect pests, and herbicide-resistant (HR) crops (chiefly soybeans, corn, and canola) engineered using bacterial or modified plant genes. Virus-resistant crops also fall within our definition of GMOs, since they involve one or a few transgenes that code for proteins that affect input traits. Interestingly, virus-resistant crops have not been particularly controversial. In part, this is because virus-resistant crops were not adopted rapidly and have not been the commercial blockbuster products that Bt cotton and corn and HR soybeans have been. It is also the case that most environmental and related organizations see virus-resistant crops as being environmentally benign, if not somewhat positive.

The fact that during mid- to late 1999 there emerged very rapidly a considerable controversy over GMOs was in some sense not surprising. This controversy is in many respects a fairly typical aspect of agricultural research and development in the United States and elsewhere. Agricultural science is no longer undertaken in a relative vacuum of interest and concern by most farmers, consumers, and citizens groups, as was the case until about the early 1970s. The dominant institutions of agricultural research and development—especially the land-grant universities and affiliated system of agricultural experiment stations, the Agricultural Research Service of the U.S. Department of Agriculture, and multinational seed-chemical-biotechnology companies—have quite definite sets of supporters and detractors among the American public. Though the reasons for this support and dissent vary, the system's supporters believe that the research and development trajectories that are under way are either clearly proven or highly promising and portend a more sound future of expanded productivity and output, increased food quality, and greater food security. Detractors worry that the agro-food system is being shaped according to a corporate agribusiness agenda, that the new technologies that are being developed are environmentally unsustainable and detrimental to the future of family farming, and that GMOs are likely to contribute little to global food security. The relative lull in what had become a fairly standard 1980s and 1990s debate over a range of agro-science issues was more the exception than the rule. Since that time, however, there has been a steady—if not always newsworthy or publicly visible—struggle within and between countries over GMOs.

But while it has become commonplace that agricultural research and new agricultural technologies are subject to debate and controversy, in certain ways the GMO controversy differs from those of previous decades (such as the controversies over Alar use on apples, antibiotic use in livestock, and factory methods of livestock farming). First, the GMO controversy was unique in that it was essentially induced by international trade and by the WTO's rules governing trade. European resistance to GMOs was spearheaded by the realization by European people, European nations, and the EU that adherence to WTO rules would result in a widespread presence of GM foods in the European food supply. Thus, the GMO controversy was set in motion by WTO rules and European reactions to these trade rules. Not surprisingly, concern about GMOs would ultimately prove to be one of the major factors that catalyzed the ongoing antiglobalization movement (though GMO concerns now play a very minor role in this movement).

A second distinctive aspect of the GMO controversy is closely related to the first: this controversy is a global one. Clearly, every Organization for Economic Cooperation and Development (OECD) country must deal with a range of GMO policy issues—regulatory issues, intellectual property issues, agro-food trade policy, and so on. But the GMO controversy does not end there. The GMO controversy has become a North-South and international development controversy. As Borlaug and Ruttan suggest in their articles on biotechnology and the prospects for food-production increases in the developing world, the voices of the contending parties are perhaps most shrill when they discuss whether GMOs—or biotechnology more generally—will be positive for the developing world.

Much of the North-South GMO debate has centered on the "golden rice" issue. GMO proponents tout the potentials of golden rice—a transgenic rice containing one daffodil gene and two bacterial genes that together code for an increased level of provitamin A—for its being able to reduce the incidence of night blindness and other disorders that lead vitamin A deficiency to be associated with elevated rates of mortality, especially childhood mortality. GMO opponents, however, suggest that golden rice is little more than a "rhetorical technology."[2] Golden rice, they say, will probably never

[2]The term "rhetorical technology" was used by Michael Pollan in his widely circulated March 4, 2001, *New York Times Magazine* article on the golden rice debate entitled "The Great Yellow Hype."

be deployed in a widespread manner, since it is covered by dozens of patents, many of which are likely to involve claims on new rice varietal products that will make them impractical to commercialize. Further, they suggest that golden rice is a wrongheaded solution to the problem of poverty and homogenization of the food supply. Poor rural people do not need golden rice as much as they need social arrangements that enable them to diversify their production systems and to have access to balanced diets containing sufficient vitamin A. There is also legitimate concern about acceptance of this odd-looking rice by the world's poorest.

A final way in which the GMO controversy has been distinctive is in the degree to which agricultural scientists have been mobilized to support one or the other side of the issue. A good many molecular biology researchers in the agricultural sciences have banded together under the organizational banner of the AgBioWorld Web site (http://www.agbioworld.org/) created by Tuskegee University molecular biology researcher C. K. Prakash. AgBioWorld has obtained the endorsement of more than 3,000 agricultural scientists around the world and is the leading nonprofit group supporting the use of biotechnology and molecular biology in agriculture. Importantly, AgBioWorld's home page touts golden rice technology. AgBioWorld's mobilization of agricultural scientists against those who criticize the technology (e.g., Pat Roy Mooney, who is also mentioned on the home page of this Web site) is one of the largest and most impressive instances of agricultural researchers banding together to defend this cluster of new technologies. Note, though, that while the cadre of agricultural scientists who support GMOs is very substantial and represents the majority of researchers, a smaller but still impressive-sized group of agricultural scientists and other biologists (especially ecologists) has expressed significant concerns about GMO technology. The skeptical minority of agricultural and ecological scientists is concerned that the methods and regulatory procedures for determining the environmental risks of these technologies are inadequate, and that these technologies may already be exhibiting major environmental (as well as socioeconomic) problems such as weed resistance to herbicides, genetic drift to wild and weedy relatives, and insect resistance to Bt. In addition, there are a good many other scientists whose views about GMOs are ambivalent; they recognize the importance of molecular tools in agricultural research and see some advantages to GMOs, but they also recognize that the current generation of GMO products has shortcomings and that public opposition to GMOs carries the risk of souring the public on agricultural research as a whole. In general, then, there has never before been a sociotechnical issue in agriculture that has so divided citizens, agricultural scientists, and countries as this one.

The Conference Papers and the Key Issues Regarding GMOs and GM Foods

The papers in this special issue of *Transactions* represent a variety of views and touch on a wide-ranging set of issues relating to GMOs. The first paper, by Dan Charles, is based on Charles's research and writing of *Lords of the Harvest: Biotech, Big Money, and the Future of Food* (Perseus, 2001). In his book, Charles provides an overview of the development of the agricultural biotechnology industry and of the GMO controversy. Charles, a former reporter for National Public Radio, is not a biologist, historian, or social scientist but rather a storyteller. In his contribution to this volume, he draws on his upbringing and subsequent family experiences in agriculture to capture in stories the disconnect that often is found between the thinking and actions of corporate scientists and their leaders on the one hand and the realities of agriculture on the other. He also raises the specter of a "double standard" of society's interest in agriculture. To go along with the question "Where do the realities of GMO crops end and the myths begin?", Charles also asks, "Where do the myths of traditional agriculture end and the realities begin?"

The next two papers illustrate the main dimensions of the GMO debate. One of these papers, by the renowned plant breeder and geneticist Norman Borlaug and reprinted from *Plant Physiology*, is a spirited advocacy of biotechnology in general and contemporary GMO products in particular. Norman Borlaug was for about two decades the principal wheat breeder at CIMMYT (the Spanish acronym for International Center for the Improvement of Maize and Wheat, located outside Mexico City), and for his efforts in introducing Green Revolution wheat to South Asia he received the Nobel Peace Prize in 1970. The wheat Green Revolution in India, Bangladesh, and Pakistan, along with the introduction of Green Revolution rice varieties from the International Rice Research Institute into the region in the 1970s, is credited with saving millions of lives of persons who would otherwise have perished due to the direct and indirect results of malnutrition. Borlaug's scientific and political stature has provided him with a unique vantage point and platform from which to assess the new trajectory of agro-food research and development.

Borlaug stresses that ultimately the focal issues in evaluating the matter of biotechnology and the future of world agriculture are the relative safety of GM crops for humans and the environment, and the fact that the future food security status of the majority of the world—the peasants and urban dwellers of low-income countries—depend on pursuing biotechnological research with dispatch. Borlaug stresses that GM crop varieties do not differ in any significant ways from conventional or nontransgenic ones, and that the new GMOs are as safe as—and in some ways superior to—conventional varieties on human health and ecological grounds. But Borlaug's most direct comments come on the topic of the role that biotechnological research and GMO technology will need to play in winning the race against population in the developing world, and on the related topic of the environmental and other activist groups that he sees as impeding the pursuit of food production innovations needed by the poor.

In contrast to Borlaug's confidence in biotechnology and his conviction that the future well-being of billions of the world's poorest depend on aggressive development of these new technologies, Frederick Kirschenmann, director of the Leopold Center for Sustainable Agriculture at Iowa State University, raises a number of pointed concerns about GMOs and biotechnology. GMO technology, according to Kirschenmann, is rooted in an ideology of biological determinism, which sees agricultural problems and their necessary solutions primarily in genetic terms, and in terms of "quick fixes." Not only does this ideology tend to lead to de-emphasis on ecological and social risks; in addition, Kirschenmann argues, biological determinism tends to crowd out promising alternatives such as agroecological approaches that employ, rather than suppress, biological and habitat diversity.

Jeffrey Burkhardt, a professor of agriculture and natural resource ethics in the

Institute of Food and Agricultural Sciences at the University of Florida, begins his article by noting that as important and widely discussed as the scientific and legal-political dimensions of GMOs have become, the GMO issue should ultimately be seen as being an ethical one—whether GMOs and GM foods are ultimately morally and ethically acceptable. Burkhardt stresses, however, that the matter of ethical acceptability of GMOs and GM crops is a complex matter in that there are several extant "ethical paradigms"—consequentialist ethics, the ethics of autonomy and consent, and the ethics of virtue and tradition—that bring very different ethical considerations to bear on GMO issues. In addition, ethical acceptability of GM inputs and food products depends on the kind of GM product being considered. Various GM products, for example, involve major variations in environmental, social-distributional, and productivity consequences.

Borlaug, Kirschenmann, and Burkhardt all make frequent reference to the issue of whether GMOs and GM foods are critical to economic development and food security in the low-income countries of the South. Vernon Ruttan, Regents Professor Emeritus of Economics and Agricultural and Applied Economics at the University of Minnesota and the former head of agricultural economics at the International Rice Research Institute during the early years of the Green Revolution, addresses this issue in a provocative and somewhat unexpected way. As amply illustrated by Borlaug's article, it has become fairly typical that those persons who were involved in the early stages of the Green Revolution tend to support GMOs, and biotechnology research and development more generally, because of biotechnology's promise in generating sustained agricultural productivity improvement in developing countries. Ruttan states how important it will be to achieve new trajectories of productivity and output improvement in agriculture in the South. He suggests, however, that it remains an open question as to whether GMO-type technology will have sufficient potential to remove the current physiological constraints to yield increase that are now becoming manifest in crop agriculture across the developing world.

International aspects of the GMO food controversy receive two further treatments from very different perspectives. Lori P. Knowles brings the perspective of one who has studied contemporary trade negotiations and the related international political issues; she places the GMO issues in this context and in particular focuses on their relationship to the politics of biodiversity issues. Agriculture's history is one of international exchange of biological materials; no country in the world, in the North or the South, depends for its agriculture primarily on its native species but instead relies on species introduced over centuries of international trade, and more recently through intentional collection and distribution of germ plasm. Richard Manning has traveled the world in recent years reporting on crop improvement research being carried out in developing countries, from Brazil, Chile, China, and India to Ethiopia, Uganda, and Zimbabwe. In an article based on his recent book, *Food's Frontier: The Next Green Revolution* (North Point Press, 2000), Manning contrasts the debate over GMO technologies in the developed countries to the issues of local empowerment of developing-country citizens to make their own decisions about appropriate technologies as they strive to address the critical need, for example, for improved pest resistance in a grain legume, chickpea, which is an important source of protein in the diets of many of the poor in India.

While the implications of GMOs and GM foods for international development are among the most potent social and ethical issues in evaluating these new technologies, the articles by Bradford Barham, Lydia Zepeda, John Petty, and Carl Gulbrandsen and Howard Bremer suggest that there are crucial domestic policy dimensions of GMOs. Barham argues that in some respects GMO technology has similarities to that of rBST in the dairy sector. Both technologies are seemingly scale neutral because the input product can be purchased in either small or large lots and can be used on farms ranging from very small to very large. At the same time, available data on both technologies suggest that they are much more applicable to large-farm operations, suggesting the likelihood that GMOs as well as other agricultural biotechnology products will benefit larger farmers over smaller ones.

Zepeda examines the second crucial domestic policy issue relating to GMOs, that of labeling for international—and possibly domestic—markets. Zepeda suggests that strong rationales exist for GMO labeling for both domestic and international markets. Survey data from American consumers show very strong public support for labeling, and GMO labeling for international markets would serve to help maintain

U.S. market access in Europe and Asia and to diffuse trade conflicts between the United States and its major trading partners. These factors, plus the reality that labeling is already widespread in many other countries, suggest that GMO labeling is the appropriate direction to follow. The fact that GMO labeling is not actively being considered in the United States indicates the range of powerful interests that are opposed to labeling.

John Petty's paper illustrates one of the reasons that GM food labeling has its critics and opponents. Petty, Executive Director of the Wisconsin Agri-Service Association, a trade association of the state's feed, grain, and seed managers and owners, notes that GM food labeling would entail a number of costs for consumers and farmers as well as the grain and food-manufacturing industries. In addition to the costs of labeling, Petty stresses that it will be impossible to ensure that there will be no "adventitious presence" of GMO grain; tolerances for GMO-free grains will need to be established, and the smaller the tolerance, the more expense will be incurred in labeling.

A significant subtext in the broader consideration of biotechnologies in agriculture has been the issue of ownership of intellectual property. In 1980 in its landmark 5–4 *Diamond v. Chakrabarty* decision, the U.S. Supreme Court made it possible to lay claim to patents covering living things, including genes. Subsequent interpretations of this ruling have extended to patenting of crop varieties, particularly in the United States. A further development in this recent history has been the growth of patent seeking by public institutions, such as universities and agencies of the U.S. government itself. Carl Gulbrandsen and Howard Bremer describe some of the history behind these trends, with particular focus on the Bayh-Dole Act of 1980 as subsequently amended. Their article places the history of Bayh-Dole in the context of the much longer history of the Wisconsin Alumni Research Foundation, one of the pioneering institutions for protecting intellectual property arising from publicly funded research.

Conclusion

The Wisconsin Academy conference, entitled "Genetically Modified Food: Risks, Rewards, and Realities," was extraordinarily exciting and informative. A good many people came to the conference with fairly definite ideas about genetically engineered crop varieties and GM foods, but regardless of their previous commitments on the issues at hand, most of the approximately 250 people in attendance found they learned a great deal. The articles in this special issue include several of the major addresses given at the conference, but dozens of other contributions were lively, informative, and well received.

It is telling that despite the particular points of view expressed in the articles on GM food issues, three aspects of these issues—ethical responsibilities, the emergence of new paradigms, and global relevance and impacts—were repeatedly touched on by the authors. All of our authors see that the GMO/GM foods issue must ultimately be addressed or resolved on ethical grounds, or on grounds of the public good, even though the authors have varying views about how ethical and public good considerations should be weighed. The authors also see the GMO/GM foods issue in paradigmatic terms—that the way we debate, address, and resolve these issues will cast the die for decades to come in terms of how we approach food and agriculture. Finally, while the U.S. government and its social groups will address GMO/GM foods policy issues in terms of domestic considerations, these issues are by their nature global. What we do here in the United States and how we do so will shape the future of food security across most of the nations of the world. The nature of GMO/GM foods issues is that we cannot approach them solely in terms of group or national interests, since the welfare of much of the rest of the world depends on the quality of the judgments we will make during the first decade of this new millennium.

Frederick H. Buttel (Guest Editor, Transactions*) is professor and chair, Department of Rural Sociology, and professor of Environmental Studies at the University of Wisconsin–Madison. He is also associate director of the Program on Agricultural Technology Studies at UW–Madison after having served as its director from 1992-1998, and an affiliated professor in the Development Studies Program and a senior fellow at the Center on World Affairs and the Global Economy (WAGE). Buttel has had a longstanding interest in environmental sociology, rural sociology, and the sociology of the environmental and agricultural sciences. He was elected a fellow of the American Association for the Advancement of Science (AAAS) in 1987, and is past president of the Rural Sociological Society, past president of the Agriculture,*

Food, and Human Values Society, and a former chair of the Section on Environment and Technology of the American Sociological Association. He is currently president of the Environment and Society Research Committee (RC 24) of the International Sociological Association (1998-2002).

Robert M. Goodman (Guest Editor, Transactions*) is a professor in the departments of Plant Pathology and Environmental Studies, and chair of the Undergraduate Program in Molecular Biology, at the University of Wisconsin–Madison. He chairs the oversight committee for the McKnight Foundation's Collaborative Crop Research Program and is a member of the Board of Trustees of the Centro Internacional de Meijoramiento de Maiz y Trigo (CIMMYT). He serves on the Boards of Directors of two genomics companies and of the Cornell Research Foundation, and was formerly executive vice president for research and development at Calgene, Inc. Prior to his years at Calgene, Goodman was on the faculty of the Department of Plant Pathology and the International Soybean Program (INTSOY) at the University of Illinois at Urbana–Champaign. Goodman was the first to prove the viral cause of a widespread group of devastating tropical plant diseases and to show that the genomes of the viruses involved were tiny circular molecules of DNA, which are still among the smallest known viruses. Since moving to Wisconsin in 1991, Goodman's research has turned to basic studies on microbial diversity in natural environments. He is currently writing a book and developing a new course on microbial symbiosis.*

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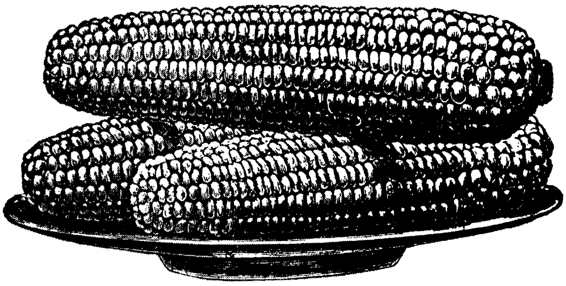
Telling the Story

Daniel Charles



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I am a storyteller by profession and with conviction. I'm convinced that stories stay with us longer than any collection of miscellaneous facts. They help us make some sense of the world. When I began working on a book about genetically engineered crops, I imagined that storytellers got a special exemption from being drafted into the battles raging over them. I thought I could stroll unimpeded among the bristling barricades, and I tried to persuade everyone I met that I posed no threat to anyone. *I just want to tell this story.*

They still didn't trust me. Below the surface of almost every conversation, evident in opaque expressions, in hesitations and vague answers, lurked uncertainty. *Friend or foe?* Later, as I struggled to carve a narrative out of masses of information, I decided that the people I'd been interviewing had been right all along. Storytellers were not onlookers in this battle; we were, if anything, its grand strategists. The dispute over genetic engineering involves facts, to be sure. But its parties disagree far more passionately over the *story.* They quarrel over the nature of the characters, over the plot, and over the editing. They also feud over the unknowable: the ending.

Among the anecdotes and tales that occupy our minds, a few are embedded so deeply that they shape the way we perceive the world. Those stories—sometimes we call them myths—create cavities within our brains, shaped to accept any similar narratives. Facts and experiences stick with us—they strike a chord, to use a common phrase—if they slip into these preformed contours. And as it happens, the tale of genetically engineered plants fits some of the most cherished spaces that our minds possess.

It is, for instance, a tale of progress, of discovery and creativity, solving problems and expanding the boundaries of human possibility. It follows outlines carved out by the Wright brothers, and Alexander Graham Bell, and Jonas Salk with his vaccine for polio. It's Gregor Mendel, planting peas in the garden of his monastery more than a century ago and discovering the patterns of human inheritance. These stories form part of the professional ideology of scientists, each of whom dreams of finding his or her role in this grand tale. And it is a powerful myth that shapes many people's understanding of genetically engineered food. (When I interviewed people recently at Cereon, Monsanto's genomics subsidiary, I met them in a small room with a revealing name: the Copernicus Room.)

Others think of the story of Bill Gates, or the Internet. It's a tale of new technology that will destroy old businesses and build new ones; it's also a dream of great wealth. I was talking to a financial analyst the other day about agricultural biotechnology. He said, "It's like—and this sound crazy—but it's like if you got plunked down fifty years ago in the orchards of places like Sunnyvale, and Palo Alto." This, of course, is the place known today as Silicon Valley.

A countervailing myth flows like an undertow beneath the triumphal story of progress, undermining it. It's the story of unpredictable, threatening technology unleashed upon an unsuspecting world through human folly: Pandora opening her box; Rachel Carson's account of DDT in *Silent Spring*; nuclear power and Chernobyl. In the words of a passionate opponent of biotechnology in New Zealand: "Today, the smug status of genetic engineering eerily recalls that period in the early 1960s when nuclear reactors were 'commercialized' on the basis of enthusiasts' claims of understanding and control. . . . Alongside airy dismissals of the dangers, the promised benefits are wildly exaggerated."

Several layers deeper, almost buried in our collective unconscious, lie other stories, ancient ones from the Mediterranean cradle of civilization, warning against the temptation to overstep humanity's rightful bounds. In the Garden of Eden, the serpent tempts Eve: You can eat the fruit of this tree. *You will be like God.* Just a few pages further on, God contemplates humanity's attempts to build a tower that will reach to heaven, and confounds its hubris in a confusion of languages. Centuries later, Mary Shelley repeats the warning in her story of Dr. Frankenstein and his fateful, doomed monster. Echoes of these tales resound in the anti-biotechnology proclamation of Charles, Prince of Wales, from the summer of 1998: "This kind of genetic modification takes mankind into realms that belong to God, and to God alone."

It's pointless to argue over which one of these versions of the agricultural biotechnology story is true. They all hold some truth. They all are, in the same measure, false, because they aren't really about agricultural biotechnology at all. They are, literally, preconceptions. They allow us to recognize important things about the world, but they also blind us to reality, when that reality doesn't fit such preset patterns.

I'd like to tell a few stories as well. These aren't grand, mythic stories like the ones I just mentioned. Those you might call stories with a capital S. These are small stories, the kind you might tell about your slightly crazy uncle. The good thing about them is that they really are about genetically engineered food, as opposed to something else. And they do, I think, offer some food for thought. So we'll just see if these stories are powerful enough to stick in your minds.

Twenty years ago a man named David Padwa went to see the famous financier George Soros. Padwa was one of the earliest visionaries of agricultural biotechnology. He was a precocious child of New York City; he'd made a fortune in the computer business, then he'd wandered the world and ended up in Santa Fe. He'd also acquired some small seed companies. And when he heard about the first breakthroughs in gene splicing, a light bulb turned on in his head. My seeds, he said to himself, are really packages of DNA. We now can manipulate that DNA, create new genetic packages, and sell them for lots of money.

This was 1981; biotechnology was hot in the investment community. And Padwa tried to tap some of that money. He went to see Soros and presented his vision for a revolution in agriculture.

When Padwa was done, Soros said, "I'm not going to give you any money. Two reasons. I don't like businesses where you only get to sell your product once a year, and I don't like businesses in which anything you could possibly do can be overwhelmed by the weather."

When David Padwa told me this story he laughed and said, "Two very good reasons!" The point of this story is: Agriculture is different. Selling genetically altered plants is different from selling chemicals, and it's different from selling pharmaceuticals. And from the point of view of biotech companies, agriculture is different in extremely annoying ways.

I'll quote one former executive from the company Calgene: "I love agricultural biotechnology . . . except for the fact that it involves agriculture." This, in fact, could be the epitaph on Calgene's tomb.

Some of you may remember Calgene. In the early 1990s, it was the first company to sell a genetically engineered plant: the Flavr Savr™ tomato. Calgene's scientists had figured out how to shut down a particular gene within the plant. As a result, the tomato didn't go soft as fast as a conventional tomato; it had a longer shelf life. And Calgene told the world that this genetic alteration was so powerful, it would allow the company to take over a big chunk of the fresh tomato business. They were going to sell a billion dollars' worth of tomatoes each year.

Then Calgene ran into agriculture. The first problem was that somehow they didn't quite get around to breeding their new gene into all the different varieties of tomatoes that might grow well in different parts of California, Florida, and Mexico. When they finally got some tomato breeders working on the problem, there was almost no time left.

This is my favorite part of the story. One of the company's young executives went to see the tomato breeder and told her that she needed to have the breeding done in a year. The breeder was doing her work as fast as she possibly could, but a tomato plant will grow only so fast. "It's not possible," she said.

"But you've *got to,*" said the man from the business side of the company. "Listen! Money is no object! Anything you need to speed it up, we can get it!"

The plant breeder, getting exasperated, replied, "It can't be done! There are biological limits!"

The division of Calgene that was producing the Flavr Savr™ was seriously devoted to new ideas in management. People there talked a lot about teamwork and communication and synergy. "Come on!" said the man from Calgene to the breeder. "Think outside the box!"

To make a short story even shorter, the tomato flopped in the field. Yields were terrible. Disease claimed much of the crop in Florida. And many of the tomatoes weren't hard enough to withstand shipping and handling; they turned into tomato puree en route.

With a bit of time, Calgene managed to iron out many of those problems, but they still were losing money. And then came the final, fatal insult. Calgene's products were buried in a flood of tomatoes from Mexico—a product of traditional breeding called the Long Shelf Life tomato. It was a beautifully ripe-looking, red, hard tomato; it didn't taste that great, but at least visually, it *delivered* what Calgene had promised. Tomato prices fell through the floor, and Calgene's project was finally dead. It was a triumph of old technology over new technology.

A few years later, Monsanto came along, with a couple of genes that really did make a big enough difference that farmers would be willing to pay extra for them: *Bacillus thuringiensis* (Bt), and Roundup resistance genes. Monsanto's leaders really did believe the Silicon Valley story. Their company, they said, would be the Microsoft of agriculture. It would deliver the software, in this case the genes. It would license those genes to seed companies, which owned the hardware—the seed.

But once again, *agriculture is different*. Monsanto ran into the complexity of the seed business. Seed lives in this twilight zone of capitalism—somewhere between a real product, like a car, and a free gift of nature, like the air. (Hybrid corn is a special case: it's more like a product, because it's complicated to create hybrid seed, and farmers can't usually do that on their own.) Companies in the soybean or wheat seed business were selling something that they couldn't really control. Farmers could take part of the harvest and use it for seed the next year. Other seed companies could take any new variety and start using it as breeding material. As a result, seed companies had never been able to charge a huge amount for an improved product. But Monsanto wanted huge amounts of money for its genes— huge amounts at least by the standards of the seed industry.

This led to two things: Monsanto came up with ways to impose new rules on the seed trade; it used patents and contracts to ban the saving of seed and to set the prices that farmers were charged for the use of Monsanto's genes. And as time went on, Monsanto became convinced that the only way to earn what it wanted was to own substantial chunks of the seed industry. So Monsanto went out and spent $8 billion to buy seed companies. (One of the acquisitions was blocked, so the final total was closer to $5 billion.)

It was a more fateful decision, I think, than anyone inside the company realized at the time. Some risks the company's executives had considered. They understood the financial impact. They thought about potential antitrust problems. But they did not comprehend the emotional impact of those decisions on a community of people who object to turning biology into commodities.

Seeds are different. They are products, but they represent the bounty of the earth and the mysterious nature of life. For twenty years, a committed band of activists had been predicting that patents on life would bring forth monopolists of life. Monsanto, because of the manner in which it had entered the seed business, had become exactly the corporate monster that these activists had long predicted. And one of the most gifted of these activists, Pat Mooney, stood at a pay phone on a chilly streetcorner in Victoria, British Columbia, listening to one of his colleagues describe a new technology that would render the offspring of a harvest sterile. It was a biological tool that would prevent the saving and replanting of a farmer's harvest. Monsanto was about to buy the seed company that owned this technology. And Pat Mooney said, "Let's call it Terminator!" The Terminator gene, as millions of people around the world came to call it, symbolized everything that people felt was wrong and perverse about biotechnology in agriculture.

There is a moral to these stories. It's the second point I'm trying to make. People who are trying to introduce products of biotechnology into agriculture would do well to remember some old-fashioned virtues: modesty and patience. Modesty in one's claims regarding the technology, and patience when it comes to trying to extract profits from it. Calgene couldn't afford to be modest and patient with its tomato and was punished by the market. Monsanto wasn't willing to be modest and patient and reaped a whirlwind of public opposition. If a company can't afford to be modest and patient in this business, well, maybe it shouldn't be in the business in the first place.

The tale of agricultural biotechnology is one of new wine in old wineskins, of new technology emerging within a traditional industry unwilling to change its practices. It is a story of double standards, as the public demanded strict assurances from genetic engineering while taking a relatively laissez-faire approach to traditional agriculture. Indeed, if the standards governing genetic engineering were applied to the rest of agriculture, much food production would have to be shut down.

Forget chemical factories and toxic waste dumps—the single most environmentally destructive human activity on the planet is agriculture. Clearing and plowing land in order to grow crops (even following organic methods) amounts to an ecological disaster visited annually upon at least a quarter of the planet's land surface.

Nor are the products of traditional agriculture uniformly safe to eat. Food from some plants, such as peanuts, causes allergic reactions among hundreds of thousands of people. Other grains, including wheat and corn, contain small amounts of extremely toxic and carcinogenic compounds that result from certain plant diseases. Yet the public, for the most part, smiles indulgently. As the hapless George Banks says of fox hunting in *Mary Poppins*, "Well, I don't mind *that* so much. It's tradition!"

Except for the use of technology invented since World War II—primarily pesticides—agriculture is largely unregulated. Farmers can plant what they want on their land. They can plow right up to the edges of creeks, causing soil erosion; they can overdose their land with fertilizer or agricultural chemicals, placing nearby streams or groundwater at risk. They can plant the same crops year after year, depleting the soil of nutrients and risking infestations of destructive pests or epidemics of plant disease. Farmers *shouldn't* do any of this; it's not in their economic self-interest, and most don't. But none of it is illegal.

Plant breeders, for their part, are free to introduce genes into crops from any of the plant's closely related species without worrying about reactions from either government regulators or consumers. Some years ago, a soybean breeder located wild relatives of the soybean in Australia that appeared to be immune to one of the major pests afflicting soybeans in the United States, a worm called the cyst nematode. He took pollen from these plants, fertilized conventional soybeans, and managed to recover fertile offspring of this union that also were immune to the pest. The trait was then bred into standard soybean varieties, ready for planting by any American farmer. These varieties were products of the laboratory, not of nature. No one, in this case, even knows what genes make the plant immune to the cyst nematode, or why. No one needs to know. They are subject to no regulatory review.

Neither are so-called STS soybeans, which can tolerate sprays of an herbicide called Synchrony. These plants were created by soaking soybeans in chemicals, inducing random mutations in soybean DNA. Because the mutation was created *within* the cell, and not spliced in from an outside source, it faced no government review.

The supporters of biotechnology speak constantly and with great irritation about the higher standards applied to genetically engineered crops. It would be more logical (and therefore more correct, they believe) to apply the same standard across all crops.

But *which* standard? Consider the unspeakable: that all of agriculture deserves the same scrutiny applied to genetically engineered crops. Perhaps, when plant breeders create STS soybeans, or a variety of wheat that resists the predations of the Hessian fly, they shouldn't simply be allowed to start selling such seeds to farmers. Perhaps they should be required to find out what genes produce this trait and whether these varieties might cause any unwanted effects either to the ecosystem or to human health.

If farmers are required to limit their plantings of Bt corn or cotton for the good of the ecosystem (as indeed they should be), why not go further? Why not compel (or induce, through cash incentives) farmers to do other things that would produce even more substantial environmental benefits, such as allow more of their land to revert to grasslands or wooded areas?

Plant breeders, and most farmers, will be outraged at such suggestions. They will point out that the burden of such initiatives will fall most heavily on the smallest seed companies and on farmers already teetering on the edge of financial oblivion. Others will point out that efforts to subsidize better (but less efficient) agricultural practices might be incompatible with free trade in agricultural products.

That's all true. Those are good reasons for proceeding cautiously and patiently, alert to the social and economic consequences of our actions. But they aren't reasons for turning a blind eye toward the environmental effects of traditional agriculture.

Finally, there is the most pernicious aspect of the double standard affecting agriculture and biotechnology: the double standard of knowledge and passion. This double standard needs to be abolished first. If genetic engineering is fascinating, or even ominous, then plowing, sowing, reaping, or breeding cannot be mundane.

So let genetic engineering be a window into things that ultimately are more important. Let us begin to learn where the myth of agriculture ends and reality begins. Let's try to understand why farmers do what they do to so much of Earth's surface. And if we care about the health of the planet, particularly the part of it devoted to agriculture, perhaps we'll be willing to pay for what we value, either through direct purchases of food or through taxes. In the best of worlds, we might be able to create forms of agriculture that are good for all of the world's inhabitants.

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Ending World Hunger: The Promise of Biotechnology and the Threat of Antiscience Zealotry

Norman E. Borlaug

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During the twentieth century, conventional breeding produced a vast number of varieties and hybrids that contributed immensely to higher grain yield, stability of harvests, and farm income. Despite the successes of the Green Revolution, the battle to ensure food security for hundreds of millions of miserably poor people is far from won. Mushrooming populations, changing demographics, and inadequate poverty-intervention programs have eroded many of the gains of the Green Revolution. This is not to say that the Green Revolution is over. Increases in crop management productivity can be made all along the line: in tillage, water use, fertilization, weed and pest control, and harvesting. However, for the genetic improvement of food crops to continue at a pace sufficient to meet the needs of the 8.3 billion people projected to be on this planet at the end of the quarter century, both conventional technology and biotechnology are needed.

What Can We Expect from Biotechnology?

The majority of agricultural scientists, including myself, anticipate great benefits from biotechnology in the coming decades to help meet our future needs for food and fiber. The commercial adoption by farmers of transgenic crops has been one of the most rapid cases of technology diffusion in the history of agriculture. Between 1996 and 1999, the area planted commercially with transgenic crops has increased from 1.7 to 39.9 million hectares (James 1999). In the last twenty years, biotechnology has developed invaluable new scientific methodologies and products, which need active financial and organizational support to bring them to fruition. So far, biotechnology has had the greatest impact in medicine and public health. However, a number of fascinating developments are approaching commercial applications in agriculture.

Transgenic varieties and hybrids of cotton, maize, and potatoes, containing genes from *Bacillus thuringiensis* that effectively control a number of serious insect pests, are now being successfully introduced commercially in the United States. The use of such varieties will greatly reduce the need for insecticides. Considerable progress also has been made in the development of transgenic plants of cotton, maize, oilseed rape, soybeans, sugar beet, and wheat, with tolerance to a number of herbicides. The development of these plants could lead to a reduction in overall herbicide use through more specific interventions and dosages. Not only will this development lower production costs, but it also has important environmental advantages.

Good progress has been made in developing cereal varieties with greater tolerance for soil alkalinity, free aluminum, and iron toxicities. These varieties will help to ameliorate the soil degradation problems that have developed in many existing irrigation systems. These varieties will also allow agriculture to succeed in acidic soil areas, thus adding more arable land to the global production base. Greater tolerance of abiotic extremes, such as drought, heat, and cold, will benefit irrigated areas in several ways. We will be able to achieve more crop per drop by designing plants with reduced water requirements and adopting between-crop/water-management systems. Recombinant DNA techniques can speed up the development process.

There are also hopeful signs that we will be able to improve fertilizer-use efficiency by genetically engineering wheat and other crops to have high levels of Glu (glutamine) dehydrogenase. Transgenic wheats with high Glu dehydrogenase, for example, yielded up to 29 percent more crop with the same amount of fertilizer than did the normal crop (Smil 1999).

Transgenic plants that can control viral and fungal diseases are not nearly as developed. Nevertheless, there are some promising examples of specific virus coat genes in transgenic varieties of potatoes and rice that confer considerable protection. Other promising genes for disease resistance are being incorporated into other crop species through transgenic manipulations.

I would like to share one dream that I hope scientists will achieve in the not-too-distant future. Rice is the only cereal that has immunity to the *Puccinia sp.* of rust. Imagine the benefits if the genes for rust immunity in rice could be transferred into wheat, barley, oats, maize, millet, and sorghum. The world could finally be free of the scourge of the rusts, which have led to so many famines over human history.

The power of genetic engineering to improve the nutritional quality of our food crop species is also immense. Scientists have long had an interest in improving maize protein quality. More than seventy years ago, researchers determined the importance of certain amino acids for nutrition. More than fifty years ago, scientists began a search for a maize kernel that had higher levels of Lys (lysine) and Trp (tryptophan), two essential amino acids that are normally deficient in maize. Thirty-six years ago, scientists at Purdue University (West Lafayette, Ind.) discovered a floury maize grain from the South American Andean highlands carrying the opaque-2 gene that had much higher levels of Lys and Trp. But as is all too often the case in plant breeding, a highly desirable trait turned out to be closely associated with several undesirable ones. The dull, chalky, soft opaque-2 maize kernels yielded 15 to 20 percent less grain weight than normal maize grain. However, scientists from the International Maize and Wheat Improvement Center (near Mexico City) who were working with opaque-2 maize observed little islands of translucent starch in some opaque-2 endosperms. Using conventional breeding methodologies supported by rapid chemical analysis of large numbers of samples, the scientists were able to slowly accumulate modifier genes to convert the original soft opaque-2 endosperm into vitreous, hard-endosperm types. This conversion took nearly twenty years. Had genetic engineering techniques been available then, the genes that controlled high Lys and Trp could have been inserted into high-yielding hard-endosperm phenotypes. Thus, through the use of genetic engineering tools, instead of a thirty-five-year gestation period, quality protein maize could have been available to improve human and animal nutrition twenty years earlier. This is the power of the new science.

Scientists from the Swiss Federal Institute of Technology (Zurich) and the International Rice Research Institute (Los Baños, the Philippines) have recently succeeded in transferring genes into "golden rice" to increase the quantities of vitamin A, iron, and other micronutrients. This work could eventually have profound impact for millions of people with deficiencies of vitamin A and iron, causes of blindness and anemia, respectively.

Because most of the genetic engineering research is being done by the private sector, which patents its inventions, agricultural policy makers must face a potentially serious problem. How will these resource-poor farmers of the world be able to gain access to the products of biotechnology research? How long, and under what terms, should patents be granted for bioengineered products? Furthermore, the high cost of biotechnology research is leading to a rapid consolidation in the ownership of agricultural life science companies. Is this consolidation desirable? These issues are matters for serious consideration by national, regional, and global governmental organizations.

National governments need to be prepared to work with and benefit from the new breakthroughs in biotechnology. First and foremost, governments must establish regulatory frameworks to guide the testing and use of genetically modified crops. These rules and regulations should be reasonable in terms of risk aversion and implementation costs. Science must not be hobbled by excessively restrictive regulations. Because much of the biotechnology research is under way in the private sector, the issue of intellectual property rights must be addressed and accorded adequate safeguards by national governments.

Standing Up to the Antiscience Crowd

The world has or will soon have the agricultural technology available to feed the 8.3 billion people anticipated in the next quarter of a century. The more pertinent question today is whether farmers and ranchers will be permitted to use that technology. Extremists in the environmental movement, largely from rich nations or the privileged strata of society in poor nations, seem to be doing everything they can to stop scientific progress in its tracks. It is sad that some scientists, many of whom should or do know better, have also jumped on the extremist environmental bandwagon in search of research funds. When scientists align themselves with antiscience political movements or lend their names to unscientific propositions, what are we to think? Is it any wonder that science is losing its constituency? We must be on guard against politically opportunistic pseudoscientists like the late Trofim D. Lysenko, whose bizarre ideas and vicious persecution of his detractors contributed greatly to the collapse of the former USSR.

We all owe a debt of gratitude to the environmental movement that has taken place over the past forty years. This movement has led to legislation to improve air and water quality, protect wildlife, control the disposal of toxic wastes, protect the soils, and reduce the loss of biodiversity. It is ironic, therefore, that the platform of the antibiotechnology extremists, if it were to be adopted, would have grievous consequences for both the environment and humanity. I often ask the critics of modern agricultural technology: What would the world have been like without the technological advances that have occurred? For those who profess a concern for protecting the environment, consider the positive impact resulting from the application of science-based technology. Had 1961 average world cereal yields (1,531 kilograms per hectare) still prevailed, nearly 850 million hectares of additional land of the same quality would have been needed to equal the 1999 cereal harvest (2.06 billion gross metric tons). It is obvious that such a surplus of land was not available, and certainly not in populous Asia. Moreover, even if it were available, think of the soil erosion and the loss of forests, grasslands, and wildlife that would have resulted had we tried to produce these larger harvests with the older, low-input technology! Nevertheless, the antibiotechnology zealots continue to wage their campaigns of propaganda and vandalism.

One particularly egregious example of antibiotechnology propaganda came to my attention during a recent field tour to Africa. An article in the *Independent* newspaper from London, entitled "America Finds Ready Market for Genetically Modified

Food: The Hungry" (Walsh 2000), is accompanied by a ghastly photograph depicting a man near death from starvation, lying next to food sacks. The caption below reads, "Sudanese man collapsing as he waits for food from the UN World Food Program."

The article's author, Declan Walsh, writing from Nairobi, implies that there is a conspiracy between the U.S. government and the World Food Program (WFP) to dump unsafe, genetically modified American crops into the one remaining unquestioning market: emergency aid for the world's starving and displaced. I, for one, take heartfelt umbrage against this insult to the WFP, whose workers and collaborators helped feed 86 million people in eighty-two countries in 1999. The employees of the WFP are among the world's unsung heroes, who struggle against the clock and under exceedingly difficult conditions to save people from famine. Their achievements, dedication, and bravery deserve our highest respect and praise.

In his article, Walsh quotes several critics of the use of genetically modified food in Africa. Elfrieda Pschorn-Strauss, from the South African organization Biowatch, says, "The US does not need to grow nor donate genetically modified crops. To donate untested food and seed to Africa is not an act of kindness but an attempt to lure Africa into further dependence on foreign aid." Dr. Tewolde Gebre Egziabher of Ethiopia states, "Countries in the grip of a crisis are unlikely to have leverage to say, 'This crop is contaminated; we're not taking it.' They should not be faced with a dilemma between allowing a million people to starve to death and allowing their genetic pool to be polluted." Neither of these individuals offers any credible scientific evidence to back their false assertions concerning the safety of genetically modified foods. The WFP accepts only food donations that fully meet the safety standards in the donor country. In the United States, genetically modified foods are judged to be safe by the Department of Agriculture, the Food and Drug Administration, and the Environmental Protection Agency and thus they are acceptable to the WFP. That the EU has placed a two-year moratorium on genetically modified imports says little per se about food safety, but rather it says more about consumer concerns, largely the result of unsubstantiated scare mongering done by opponents of genetic engineering.

Let's consider the underlying thrust of Walsh's article that genetically modified food is unnatural and unsafe. Genetically modified organisms and genetically modified foods are imprecise terms that refer to the use of transgenic crops (i.e., those grown from seeds that contain the genes of different species). The fact is that genetic modification started long before humankind began altering crops by artificial selection. Mother Nature did it, and often in a big way. For example, the wheat groups we rely on for much of our food supply are the result of unusual (but natural) crosses between different species of grasses. Today's bread wheat is the result of the hybridization of three different plant genomes, each containing a set of seven chromosomes, and thus could easily be classified as transgenic. Maize is another crop that is the product of transgenic hybridization (probably of teosinte and Tripsacum). Neolithic humans domesticated virtually all of our food and livestock species over a relatively short period 10,000 to 15,000 years ago. Several hundred generations of farmer descendents were subsequently responsible for making enormous genetic modifications in all of our major crop and animal species. To see how far the evolutionary changes have come, one needs only to look at the 5,000-year-old fossilized corn cobs found in the caves of Tehuacan in Mexico, which are about one-tenth the size of modern maize varieties. Thanks to the development of science over the past 150 years, we now have the insights into plant genetics and breeding to do purposefully what Mother Nature did herself in the past by chance.

Genetic modification of crops is not some kind of witchcraft; rather, it is the progressive harnessing of the forces of nature to the benefit of feeding the human race. The genetic engineering of plants at the molecular level is just another step in humankind's deepening scientific journey into living genomes. Genetic engineering is not a replacement of conventional breeding but rather a complementary research tool to identify desirable genes from remotely related taxonomic groups and transfer these genes more quickly and precisely into high-yield, high-quality crop varieties. To date, there has been no credible scientific evidence to suggest that the ingestion of transgenic products is injurious to human health or the environment. Scientists have debated the possible benefits of transgenic products versus the risks society is willing to take. Certainly, zero risk is unrealistic and probably unattainable. Scientific advances always involve some risk that unintended outcomes could occur. So far, the most prestigious national academies of science, and now even the Vatican, have come out in support of genetic engineering to improve the quantity, quality, and availability of food supplies. The more important matters of concern by civil societies should be equity issues related to genetic ownership, control, and access to transgenic agricultural products.

One of the great challenges facing society in the twenty-first century will be a renewal and broadening of scientific education at all age levels that keeps pace with the times. Nowhere is it more important for knowledge to confront fear born of ignorance than in the production of food, still the basic human activity. In particular, we need to close the biological science knowledge gap in the affluent societies now thoroughly urban and removed from any tangible relationship to the land. The needless confrontation of consumers against the use of transgenic crop technology in Europe and elsewhere might have been avoided had more people received a better education about genetic diversity and variation. Privileged societies have the luxury of adopting a very low risk position on the genetically modified crop issue, even if this action later turns out to be unnecessary. But the vast majority of humankind, including the hungry victims of wars, natural disasters, and economic crises who are served by the WFP, does not have such a luxury. I agree with Mr. Walsh when he speculates that esoteric arguments about the genetic makeup of a bag of grain mean little to those for whom food aid is a matter of life or death. He should take this thought more deeply to heart.

We cannot turn back the clock on agriculture and use only methods that were developed to feed a much smaller population. It took some 10,000 years to expand food production to the current level of about five billion tons per year. By 2025, we will have to nearly double current production again. This increase cannot be accomplished unless farmers across the world have access to current high-yielding crop production methods as well as new biotechnological breakthroughs that can increase the yields, dependability, and nutritional quality of our basic food crops. We need to bring common sense into the debate on agricultural science and technology, and the sooner the better!

Conclusion

Thirty years ago, in my acceptance speech for the Nobel Peace Prize, I said that the Green Revolution had won a temporary success in man's war against hunger, which if fully implemented could provide sufficient food for humankind through the end of the twentieth century. But I warned that unless the frightening power of human reproduction was curbed, the success of the Green Revolution would be only ephemeral.

I now say that the world has the technology that is either available or well advanced in the research pipeline to feed a population of ten billion people. The more pertinent question today is: Will farmers and ranchers will be permitted to use this new technology?

Extreme environmental elitists seem to be doing everything they can to derail scientific progress. Small, well-financed, vociferous, and antiscience groups are threatening the development and application of new technology, whether it is developed from biotechnology or more conventional methods of agricultural science.

I agree fully with a petition written by Professor C. S. Prakash of Tuskegee University, and now signed by several thousand scientists worldwide, in support of agricultural biotechnology, which states that no food products, whether produced with recombinant DNA techniques or more traditional methods, are totally without risk. The risks posed by foods are a function of the biological characteristics of those foods and the specific genes that have been used, not of the processes employed in their development.

The affluent nations can afford to adopt elitist positions and pay more for food produced by the so-called natural methods; the one billion chronically poor and hungry people of this world cannot. New technology will be their salvation, freeing them from obsolete, low-yielding, and more costly production technology.

Most certainly, agricultural scientists and leaders have a moral obligation to warn the political, educational, and religious leaders about the magnitude and seriousness of the arable land, food, and population problems that lie ahead, even with breakthroughs in biotechnology. If we fail to do so, then we will be negligent in our duty and inadvertently may be contributing to the pending chaos of incalculable millions of deaths by starvation. But we must also speak unequivocally and convincingly to policy makers that global food insecurity will not disappear without new technol-ogy; to ignore this reality will make future solutions all the more difficult to achieve.

Norman E. Borlaug was awarded the Nobel Peace Prize in 1970 for launching the "Green Revolution," which helped Pakistan, India, and a number of other countries

improve their food production, and for his lifelong work in helping feed the hungry. Borlaug, who grew up on his family's farm in rural Iowa and attended a one-room schoolhouse, was awarded his doctorate in plant pathology in 1942 by the University of Minnesota. He served at the Rockefeller Foundation as the scientist in charge of wheat improvement under the Cooperative Mexican Agricultural Program. With the establishment of the International Maize and Wheat Improvement Center (CIMMYT) in Mexico in 1964, he assumed leadership of the Wheat Program, a position he held until his official retirement in 1979. He now leads the Sasakawa–Global 2000 agriculture program (SG 2000), a joint venture between the Sasakawa Africa Association and The Carter Center's Global 2000 program. SG 2000 works with more than 600,000 small-scale farmers in eleven sub-Saharan African countries. For more information, see the Norman Borlaug Heritage Foundation at www.normanborlaug.org

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Questioning Biotechnology's Claims and Imagining Alternatives

Frederick Kirschenmann

. . . [humans] are only fellow-voyagers with other creatures in the odyssey of evolution. This . . . should have given us, by this time, a sense of kinship with fellow-creatures; a wish to live and let live; a sense of wonder over the magnitude and duration of the biotic enterprise.

—Aldo Leopold

The controversy surrounding the use of transgenic technology appears to be based largely on different assessments of the merits of that technology. Proponents argue that genetic manipulation will help us feed the world, cure diseases, and solve many other problems facing the human species. Opponents argue that the projected benefits are overblown and that the technology poses many risks that have not been adequately assessed.

But these quarrels inevitably lead us into circular arguments. We won't know, *for sure*, whether genetic engineering will feed the world until we try it, and if it doesn't, it will be too late—developing other options for enabling the world to feed itself will have been ignored. We won't know, *for sure*, if transgenic organisms will create ecological havoc until we release them, and if they do, it will be too late—we won't be able to put the genie back into the bottle. In the meantime, we continue to limit our debate to our assessment of the technology's potential risks or benefits, relying on our personal or collective judgments about the technology's efficacy or on our biases about the technology's capabilities.

It seems more fruitful to look at some of the underlying assumptions that lead us to our conclusions about the technology's promises and problems. If the assumptions are faulty, a strong likelihood exists that the conclusions may be unreliable as well. The fact that many of these assumptions are found wanting leads us to the second topic of this paper: an examination of alternatives to biotechnology.

Prevailing Ideology

The first questions we might consider are these: What is the ideology that informs modern science, and is that ideology sound? Richard Lewontin, the prominent geneticist at Harvard University, argues persuasively that our modern optimism regarding the ability to solve many of our social, medical, and agricultural problems with transgenic technologies is based on an ideology that he calls "biological determinism." This is an ideology that, he says,

> ... makes the atom or individual the causal source of all the properties of larger collections. It prescribes a way of studying the world, which is to cut it up into the individual bits. It breaks the world down into independent autonomous domains, the internal and the external. Causes are either internal or external, and there is no mutual dependency between them.
>
> For biology, this world-view has resulted in a particular picture of organisms and their total life activity. Living beings are seen as being determined by internal factors, the genes. (Lewontin 1991, 13)

But Lewontin (1991) argues that this ideology completely ignores the actual relationship that exists between organisms and their environments. He suggests that there are actually four rules of "the real relationship between organisms and their environment" (87):

1. "Environments do not exist in the absence of organisms, but are constructed by them out of bits and pieces of the external world" (87).
2. "The environment of organisms is constantly being remade during the life of those living beings" (87).
3. "Fluctuations in the world matter only as organisms transform them" (90).
4. "The very physical nature of the environment as it is relevant to organisms is determined by the organisms themselves" (91).

Lewontin's rules of biology remind us that organisms are not the isolated entities that we assume they are when we fantasize about feeding the world by manipulating a few genes in a few plants or animals, or healing debilitating diseases by adjusting a few defective genes. Each individual within a species is a "unique consequence of both genes and the developmental environment in a constant interaction" (Lewontin 1991, 26). Such interactions remind us that all problems and threats to our well-being are finally a combination of molecular specification and the unique interactions among genes, organisms, and environment. "It is a fundamental principle of developmental genetics," writes Lewontin, "that every organism is the outcome of a unique interaction between genes and environmental sequences modulated by random chances of cell growth and division, and that all these together finally produce an organism. Moreover, an organism changes throughout its life" (27).

The notion that gene technology can, by itself, solve problems when those problems are, at least in part, derived from social and environmental interactions illustrates a faith in technological fixes that is not corroborated by experience. For example, it has always been something of a mystery to me how we can claim that we will be able to "feed the world" of expanding future populations by producing more food with biotechnology when we are presently failing to feed more than 800 million malnourished people in an era of overproduction (Sen, 1981, 1984; Leisinger, 2000).

Molecular World as Ecosystem

A second underlying question we might ask is this: Is it possible to do "just one thing" at the molecular level? Ecologists have demonstrated that it is *not* possible to do "just one thing" in the ecosystems in which we live. Even when we have made good-faith efforts to improve the resilience of our ecological homes, we have often miscalculated the extent to which, and the manner in which, species within ecosystems are interdependent.

Ecologist Yvonne Baskin provides a chilling example. In an effort to boost the numbers of salmon that swim upstream from Montana's Flathead Lake to spawn in Glacier National Park's McDonald Creek, state fisheries officials stocked the upstream portions of the watershed with exotic opossum shrimp to provide extra food for the salmon. Extra salmon, they believed, would, in turn, provide more food for eagles, bears, gulls, mallards, goldeneyes, coyotes, minks, otters, and many other species that feed on the salmon and their eggs.

But, as Baskin (1997) notes, "The plan overlooked an important bit of natural history of both shrimp and fish" (41). The salmon, it seems, feed on zooplankton near the surface during the day while the shrimp spend the day near the bottom, pretty much out of reach of the fish. "At night the shrimp migrate upwards to feed on zooplankton themselves—the same zooplankton, unfortunately, that serve as the chief food for [the salmon]" (41). Consequently, "Rather than supplying a new food resource for the [salmon], humans had unwittingly introduced a competitor" (41). As a result, writes Baskin,

> . . . zooplankton quickly declined, especially populations of daphnia, or water fleas, which are a favored food of both the [salmon] and the shrimp. Within just a few years, the [salmon] population in the lake had collapsed, too. One hundred kilometers upstream in McDonald Creek, the disappearance of the spawning [salmon] eliminated a food resource that had once fortified eagles for their winter migration and fattened bears for hibernation. It also brought to an end a wildlife spectacle that had boosted off-season tourism revenues for the park and neighboring communities. (Baskin 1997, 42)

In less than nine years, the population of 100,000 salmon was reduced to 50. If our judgment is this bad, are we really ready to begin modifying the genome?

There is every reason to believe that the same ecosystems dynamics that are at work on the organism level are also at work on the molecular level. In fact, Robert Service revealed in a 1997 *Science* magazine article that the use of "gene-typing techniques that directly sample and compare gene sequences from different organisms" (1740) for the first time reveals just how diverse and interconnected the world of single-celled microbes is. He reports that "a pinch of soil can contain 1 billion microbes or more" and describes the world of microbes as a "thimble-sized rainforest" (1740). Moreover, he concedes that describing the "ecological structure" of this biodiversity is "virtually impossible" (1740).

Such observations, made possible by sophisticated analyses of DNA, would tend to confirm Richard Lewontin's suggestion that the *ecosystem* metaphor is much more appropriate for biotechnology than the software "operating systems" metaphor that the biotech industry prefers.[1] "You can always intervene and change something in it," says Lewontin, "but there's no way of knowing what all the downstream effects will be or how it might affect the environment. We have such a miserably poor understanding of how the organism develops from its DNA that I would be surprised if we *don't* get one rude shock after another" (quoted in Pollan 1998, 49).

This is not to suggest that all genetic engineering should be banned. All species, after all, do modify their environments. In fact, as we have seen, Lewontin argues that the environment is constructed by living organisms out of the bits and pieces of the external world available to them. In other words, the environment wouldn't even exist if it were not for organisms modifying it. But it does suggest that if we continue to ignore the ecological dimensions of our modifications, as we seem to regularly do with genetic engineering, we are likely to experience many unpleasant surprises.

The awareness that ecosystems dynamics are at work at the molecular level suggests that we need to proceed more cautiously than most molecular biologists have

[1]Evelyn Fox Keller in *The Century of the Gene* (Cambridge, Mass.: Harvard University Press, 2000) argues that given the dynamic, ecosystem nature of the genetic world, the major lesson we are likely to learn from our further research in genetics is "humility."

done thus far. And it means that we need to pay attention to fundamental ecological principles in the process of our modifications. We can no longer blithely continue to assume that our proposed modifications are "safe" simply because we have convinced ourselves that

- genetic engineering is no different from ordinary sexual reproduction,
- nature will always keep all populations in balance,
- transgenic organisms will always be ecologically competent, or
- because the host has been domesticated, it is so genetically debilitated that the transgenic organism will not pose an ecological problem.

None of these assumptions will serve us well.

It is prudent to remember here that not all of our natural selection modifications have been problem-free. For example, Phil Regal, professor in the college of biological sciences at the University of Minnesota, reminds us that domesticated bees "became a spreading menace when the genes of African bees were added to their populations" (Regal 1994, 12). Regal has provided us with a good set of ecological principles for assessing the risk of releasing transgenic organisms based on his extensive studies of patterns and mechanisms of adaptation to natural environments in plants and animals.

The Basis for Assessing Risk

There is a third underlying question we might ask ourselves: What is an appropriate basis for evaluating a decision to release a transgenic organism into the environment?

In a cogent essay published in the November 1994 issue of *BioScience* magazine, Mario Giampietro, at that time a visiting associate professor at Cornell University, evaluated the bases on which we might determine whether or not it is "good" to release a transgenic organism into the environment. He suggested that such a decision must be analyzed on at least three different levels—the individual, the social, and the biospherical (Giampietro 1994).

At the individual level we would ask whether a transgenic organism would be beneficial to individuals—to the company that develops it, to the individual who will use it, to the organism that has been altered. At this level it is relatively easy to quantify risks and benefits. It is also the level at which most industries want to make decisions.

At the social level things begin to get more complicated. Here we need to determine if the release of the transgenic organism will contribute to the overall well-being and stability of society. At this level we need to ascertain if the release of a particular organism will contribute to the economic welfare of the community in which it is released and whether it poses unacceptable health risks to human populations.

At the biospheric level we begin to encounter a wide range of issues that are extremely difficult to assess through conventional risk/benefit analysis. The overarching complexity of ecological systems makes it impossible to quantify outcomes, but we should at least acknowledge the complexity and the questions it raises.

> Since every organism is part of a very complex, well-orchestrated ecosystem that has evolved over several millennia it is virtually impossible to assess, in advance, how changes in an organism may change the ecology in which that organism exists. How do these changes affect energy flows? How do they affect oscillations in predator-prey relationships over many life cycles? Do they increase the possibility of one species taking over, as non-native species have done when introduced into new ecologies? (Kirschenmann and Raffensperger 1995, 6)

Giampietro suggests that our decisions regarding transgenic organisms are made mostly at the individual level, with occasional passing reference to the social level. We rarely make them on the biospheric level. He reminds us that if we are interested in sustainability, then we need to give primary attention to the biospheric level.

Giampietro's analysis implores us to be clear about which problems we are trying to solve with transgenic organisms. For example, if we are concerned only about making more food immediately available to help feed a growing population, we might well decide to support the development of genetically engineered organisms that promise to improve yield (the individual level). If, on the other hand, we are concerned about the social inequities and the political structures that prevent people from gaining access to food despite adequate production (the social level), or if we are concerned about the size of the ecological footprint that increased populations of overconsuming humans leave on the planet, causing a degradation of the environment and loss of the ecosystem services on which food production depends (the biospheric level), then we might be led to approach the problem of hunger from a different perspective.

If Giampietro's analysis helps us to be clearer about the problem we are actually trying to solve, his proposal might help us realize, for example, that current applications of biotechnology in agriculture are primarily designed to solve the problems of monoculture farming—specializing production systems by reducing them to one or two species of crops or animals within a bioregion.

Most biotechnology applications in crop production seem to be designed to prop up monocultures and the industrial food system they serve. But as every biologist and every farmer surely knows by now, monocultures are inherently unstable and fraught with pest problems. This is because monocultures are fundamentally at odds with nature. Nature is diverse and complex. All organisms in nature have learned to adapt to biodiversity. Nature, accordingly, will always find ways to overcome the specialization and simplification of monocultures. A recent study on the benefits of biodiversity published by the Council for Agricultural Science and Technology concludes that "the development and increased use of high-diversity cropping systems, which currently are greatly underutilized, could substantially contribute to agricultural productivity, sustainability, and stability" (Council for Agricultural Science and Technology 1999, 1). On what basis do we convince ourselves that molecular biology will be any more successful at solving monoculture's inherent weaknesses than toxic chemicals have been?

Ethical Issues

The aforementioned issues, of course, force us to ask yet another question: What is the ethical basis for making decisions with respect to transgenic organisms? This is a particularly difficult question to answer in that our culture, going all the way back to the seventeenth century, has insisted on separating facts from values. Values, accordingly, have been relegated to the realm of personal opinion and private faith. Ethics and values have nothing to do with science and facts. That perspective has left us with few disciplined tools for making ethical decisions as a society. The technologies of our new generation, however, are rapidly propelling us into a world in which we no longer have the luxury of relegating ethics to the arena of private and personal choice.

In his thought-provoking paper published in the April 2000 issue of *Wired* magazine, Bill Joy, cofounder and chief scientist of Sun Microsystems, helps us to understand why this is so. Our new-generation technologies—robotics, genetic engineering, and nanotechnology—not only are self-replicating, but they also have the power to radically change the physical world and run the risk of doing "substantial damage in the physical world" (Joy 2000, 240). Moreover, while they have the potential to "significantly extend our average life span and improve the quality of our lives," they lead "to an accumulation of great power and, concomitantly, great danger" (242).

Joy proceeds to spell out what is different about the dangers of twenty-first-century technologies compared with the dangers of those of the twentieth century.

> Certainly the technologies underlying the weapons of mass destruction ... —nuclear, biological, and chemical . . . —were powerful, and the weapons an enormous threat. But building nuclear weapons required, at least for a time, access to both rare—indeed, effectively unavailable—raw material and highly protected information: biological and chemical weapons programs also tended to require large-scale activities.
>
> The 21st century technologies—genetics, nanotechnology, and robotics . . . —are so powerful that they can spawn whole new classes of accidents and abuses. Most dangerously, for the first time, these accidents and abuses are widely within the reach of individuals or small groups. They will not require large facilities or rare raw materials. Knowledge alone will enable the use of them. Thus we have the possibility not just of weapons of mass destruction but of knowledge-enabled mass destruction . . . , this destructiveness hugely amplified by the power of self-replication.
>
> I think it is no exaggeration to say we are on the cusp of the further perfection of extreme evil . . . (Joy 2000, 242)

It may be important to remind ourselves that this is not the ranting of an end-of-the-world fanatic who foresees Armageddon at every turn. This is someone who has been at the forefront of developing the very technologies that he feels now put us in a situation where we simply no longer have the luxury of ignoring difficult ethical issues.

In the December 1997 issue of *Harper's* magazine, David Shenk reaches similar conclusions about the decisions that society will impose as a result of the new choices that will be available to us. He describes these choices as "the burden of knowing, the burden of choosing" (Shenk 1997, 39). He imagines his daughter, twenty years from now, pregnant with her first child. Her doctor informs her that the karyotype and the computer analysis indicate that the fetus is carrying a genetic marker for severe manic depression. Will she abort?

According to Shenk, that question is only the beginning of a long list of ethical decisions we will be forced to make, including what kind of children we will decide to bring forth into the world. And what happens if a "pop-genetics culture" emerges that leads millions of people to choose identical offspring—another monoculture with all of its attendant deficiencies?

Shenk, like Joy, ultimately finds us wrestling with the issues of control and freedom. Are we going to allow these powerful technologies to be available to anyone who wants them, or are we going to control who uses them and for what purpose—and if so, who will be the ones to control them? If we allow them to be freely available, Joy argues, they will inevitably fall into the hands of people who will use them for evil, evil that can destroy the world as we know it. Likewise, Shenk argues that free markets and consumer choice would become even more dominant forces in society than they already are, and the prospect of individuals or elite groups of individuals buying genetic advantages for themselves "might well spell the end" to "egalitarian harmony" (Shenk 1997, 45). The faith we have had in the notion that we *all* have to be considered equal at some fundamental level in order to sustain a peaceful, just, and functional society may evaporate.

For farmers who have worked hard to develop and supply markets for crops that do not contain genetically modified organisms (GMO), there is another, more immediate ethical problem. As transgenic crops spread throughout the landscape, it is becoming increasingly difficult for farmers to produce GMO-free crops.

Mary-Howell Martens recently completed research that explores the difficulty farmers are having with the production of non-GMO crops. She discovered that virtually all of the 2000 non-GMO corn crop produced in the Midwest that has been tested revealed GMO contamination at an average level of 0.25 percent (Martens 2001).

David Vetter, a veteran organic grower and processor near Marquette, Nebraska, had managed to keep his open-pollinated organic corn free of GMO contamination since he started developing the variety twelve years ago. But when he finished harvest in November he had his 2000 crop tested and found GMO contamination. Careful management and selective breeding enabled Vetter to develop an open-pollinated variety of corn that produces a quality comparable to that of standard hybrid varieties—making it a valuable product. Quality open-pollinated varieties not only save on input costs, but Vetter's customers prefer them as well. In addition to the extra costs involved in managing his corn to prevent pollen drift, Vetter now also has to absorb the additional cost of testing all of his corn. Further, now that the corn has traces of GMO contamination, Dave will label his corn to reflect the contamination—something he feels he must ethically do, but also something he is certain will cost him some of his customers (Vetter 2000, personal communication).

Seed companies that sell GMO-free seed are now pushing for higher GMO residue tolerances of GMO contamination so they can still market their seed as GMO-free. Vetter believes this is an indication that the more often such seed is planted, the higher the contamination levels will climb. That prospect, plus the expectation that many additional GMO crop varieties will be introduced into the environment, suggests that farmers in the United States will soon be unable to produce any GMO-free, and therefore any "organic," crops at all.

Small farms everywhere are finding that the development of specialty markets is critical to their survival. The market Vetter has developed for his corn is a very high value specialty market that took him twenty years to develop. If he must finally sell his certified organic corn on the conventional market because his customers reject it, the price differential will be equal to his annual farm income, approximately $17,000 on forty acres.

Who pays for David Vetter's loss?

Imagining Alternatives to Biotechnology

Most proponents of agricultural biotechnology argue that although some risks may be involved in using this technology, we have no alternative but to forge ahead. Given the exploding growth of the world's human population, it is the only way to avoid calamity. A recent essay by Klaus Leisinger (Leisinger 2000), executive director of the Novartis Foundation for Sustainable Development and professor of sociology at the University of Basel, serves as a good example of this position. Leisenger paints the usual picture. The global population will grow another 50 percent by the year 2050—three billion additional people. Most of that population growth will take place in the developing world. And much of it will take place in urban centers since urbanization will soar. By 2030, 57 percent of the population of developing countries will live in cities. And, he says, "People living in cities are not able to feed themselves through subsistence food production in the same way that people living in rural areas do" (2).

This will have a cascadelike effect. Exploding populations living in urban areas of poor nations where the people do not have the opportunity to feed themselves (urban gardens and urban fringe farms notwithstanding) will require that we begin producing higher yields. Because the eating patterns of urban people are substantially different from those of rural people, we will also have to produce different food. Urban people eat more high-value foods, more animal proteins, and more vegetables. That means that there will be a diversion of cereals from food to feed and the need to produce even more grain because of the loss of protein involved in the conversion of plant food to meat. Leisinger doesn't tell us why this shift from rural to urban must *necessarily* take place. We do know that the industrialization of agriculture in the industrial world has had the related social cost of pushing farmers off their land by increasing farm size. But the necessity of doing this to achieve production goals is not self-evident. In fact, many studies show that midsized farms are more efficient producers than megafarms (Peterson 1997; Strange 1988).

Leisinger goes on to argue that this higher productivity (which, in his view, can be achieved only with biotechnology) will also have positive ecological effects. "If average annual per hectare productivity increases just 1 percent, the world will have to bring more than 300 million hectares of new land into agriculture by 2050 to meet expected demand. But a productivity increase of 1.5 percent could double output without using any additional cropland" (Leisinger 2000, 2–3). Failure to achieve that productivity through biotechnology will necessitate bringing fragile lands and wilderness areas into agricultural production, with all of the attendant ecological devastation. There is no mention of the land that will be taken out of production due to urban sprawl if Leisinger's scenario comes to pass, or the potential for increased production through successful urban farming ventures such as the urban gardens in Cuba, where 50,000 tons of food are now produced annually inside the city of Havana—without the aid of genetic engineering.

Nor does Leisinger mention the potential for increasing food availability by decreasing waste. In the United States it is estimated that 25 to 40 percent of the food produced in agricultural fields is lost due to waste and spoilage between field and table. Nor does he mention the potential of increasing yields by improving soil quality—the most effective way to further increase yields, according to the National Academy of Sciences (National Research Council 1993). Nor does Leisinger tell us how people crammed into urban centers, living on annual incomes of less than $400, are going to be able to buy the food produced with biotechnology. He suggests that as the economies of developing nations grow, people will eat higher on the food chain. But he fails to mention the fact that as economies grow, the "absolute gap between rich and poor … increase[s]" (Korten 1995, 48).

To his credit, Leisinger *does* call attention to the additional problems associated with maintaining current levels of productivity, such as declining water resources, declining soil quality, unforeseen climate changes, and poor governance—issues that biotechnology proponents often overlook. He fails to mention, however, that most of these problems were caused by the industrial farming methods that he wants to perpetuate. He also fails to acknowledge that food security is often most radically affected by two consequences of modern industrial agriculture: the pest infestations that occur because of the lack of biodiversity and genetic variability that is integral to modern industrial farming practices, and the failure to initiate land reforms that could put land into the hands of local farmers who can produce food for local populations.

Nevertheless, Leisinger believes that agricultural biotechnology is the linchpin to solving the food security problem associated with global population explosion. His contention, however, is rarely based on concrete field data. Mostly it is based on conjecture and analogy. He cites a World Bank panel's *prediction* that rice yields in Asia could increase by 10 or 20 percent with biotechnology. He compares the *future* potential of biotechnology with the past yield increases achieved with Green Revolution technologies.

Yet he does not mention the downsides of the Green Revolution technologies—the same waterlogging and salinization of soils, depletion of water resources, and environmental contamination that he feels we must now address with biotechnology in order to achieve adequate yields. He also fails to report that while rice yields increased with Green Revolution technologies, other food sources were depleted, such as the fruit previously grown on trees surrounding rice paddies and the fish previously produced within rice paddies. Both were destroyed by the pesticide inputs required to make the Green Revolution technologies perform. Neither does he mention that in many developing countries farmers are abandoning the Green Revolution technologies in favor of integrated pest management (IPM) and other less invasive agroecological practices, and in many instances they are now experiencing higher yields with less costly inputs.

To his credit, Leisinger acknowledges that we should judge genetic engineering "in the context of a wider technological pluralism" (Leisinger 2000, 11). Biotechnology, he argues, should be used only if it proves "superior to other technologies with regard to cost-effectiveness" (11).

Fair enough. But cost-effectiveness has to include the potential ecological and social costs. And here, I think, is where Leisinger's analysis, as well as the analyses of many other proponents of agricultural biotechnology, fails to give us a sufficiently thorough perspective. Above all, it does not give adequate attention to alternatives for achieving the goals of providing adequate food and fiber within a robust economy, a healthy ecology, and vibrant communities.

Assessing Risk

If we include the social and ecological costs in our assessment of the cost-effectiveness of agricultural biotechnology, we have to begin with the question of risk. Most proponents (and Leisinger is no exception) want to dismiss the problem of risk by claiming that "sound science" has already settled the matter. Leisinger argues, for example, that "there is a scientific consensus" establishing that there is "no conceptual distinction" between biotechnology and classical methods, and that the same laws govern both methods (Leisinger 2000, 11). That presumably provides prima facie evidence that there is no significant risk.

That assumption leads him to the conclusion that anyone who introduces the specter of "speculative risks" into the debate is doing so *deliberately* in an "attempt to stir up controversy" (12). He goes on to imply that the debate over risk finally boils down to uninformed "laypersons" on one side, who operate out of "*Angst*" and "feelings," and Nobel laureates in biochemistry and molecular biology on the other, who have the "irrefutable facts presented by scientists" (17).

One almost doesn't know where to begin here. One would have thought that the discoveries of quantum mechanics had laid to rest, once and for all, the flawed notion that science can establish anything as an "irrefutable fact." Quantum physicists demonstrated that the world is a world of *probability*, not *predictability* (Pagels 1982). Risks, therefore, can never be assessed with any kind of certainty.

Furthermore, science doesn't operate on the basis of "irrefutable facts." It operates on the basis of a consensus of the scientific community. That consensus is arrived at as a result of the peer review of data over long periods of time. And the consensus is *always* subject to review. Whenever scientists discover new data, or look at old data from a new perspective, old conclusions can give way to radical new ones, establishing a new consensus—and therefore a new "objective" truth. It is the scientific community's own failure, from time to time, to honor this reality, and therefore the necessary tentativeness of its conclusions, that gives rise to public distrust of science. Jim Davidson, research dean at the University of Florida, stated the matter with poignant clarity, with respect to agricultural science, as early as 1989.

> The distrust on the part of non-agricultural groups is well justified. With the publication of Rachel Carson's book entitled *Silent Spring*, we, in agriculture, loudly and in unison stated that pesticides did not contaminate the environment—we now admit that they do. When confronted with the pres-

> ence of nitrates in groundwater we responded that it was not possible for nitrates from commercial fertilizer to reach groundwater in excess of 10 parts per million under normal productive agricultural systems—we now admit they do. When questioned about the presence of pesticides in food and food quality, we assured the public that if a pesticide was applied in compliance with the label, agricultural products would be free of pesticides—we now admit they're not. (Quoted in Pesek 1990)

To this list, one can add scientists' assurances that there was no link between mad cow disease and Creutzfeldt-Jakob disease, between organophosphates and pesticide poisoning, and between the release of chlorofluorocarbons (CFCs) and the hole in the ozone. One can also add the assurances of scientists that nuclear energy was safe and would be "too cheap to meter" and that thalidomide was a safe drug. Proponents of biotechnology always seem to leave these examples out when they compare opponents of biotechnology to the technophobes who were opposed to railroads and the Model T (Anderson 2000; Leisinger 2000).

The problem here is not with the intelligence of scientists. If that were the case, the solution would be simple—just get smarter scientists. The problem is that scientists sometimes fall into the trap of making universal claims based on insular data. We simply cannot make accurate predictions about how a technology will perform in the world of interconnected and interdependent relationships of living systems based on isolated data collected in laboratories. In the world of social and ecological relationships there will simply always be surprises—and the surprises will be vastly magnified when we introduce technologies into ecosystems with which they did not evolve. And finding out the "truth" about how these technologies will behave in that complex, interdependent world usually takes a lot of time and careful monitoring. It took us forty years to discover that CFCs were blowing a hole in the ozone.

Thoughtful scientists and conservationists have, in fact, suggested some "laws of technology" based on these ecological observations. Stephen Schneider suggests, "The bigger the technological solution, the greater the chance of extensive, unforeseen side effects and, thus, the greater the number of lives ultimately at risk" (Schneider

1976, 14). And Aldo Leopold proclaimed, "The greater the rapidity of human-induced changes, the more likely they are to destabilize the complex systems of nature" (Leopold 1949, 220).

So when Professor Leisinger wants to assure us that agricultural biotechnology does not pose any significant risk, that it is "not very different" from what we have done in the past, and that the only reason there is so much opposition is that "highly sophisticated activists are easily able to mislead a scientifically uneducated public" (Leisinger 2000, 15), we can perhaps be forgiven if we simply disagree.

Bill Joy, cofounder and chief scientist of Sun Microsystems, also disagrees. Joy suggests that our new generation of technologies—robotics, genetic engineering, and nanotechnology—do "pose a different threat than the technologies that have come before" since they "share a dangerous amplifying factor: They can self-replicate" (Joy 2000, 240). Joy, who has been at the forefront of developing these technologies and is a consummate student of the science of those technologies, hardly fits Leisinger's description of a "sophisticated activist" intent on misleading an "uneducated public."

I believe we will be better served if we follow the advice of ecologists who have carefully observed the workings of nature rather than the advice of Leisinger, who seems to have observed only the tantalizing promises of a largely untested technology. Ecologists warn that "the level of uncertainty in our understanding of ecological processes suggests that it would be prudent to avoid courses of action that involve possibly dramatic and irreversible consequences and, instead, to wait for better information" (Daily et al. 2000, 395).

The Wrong Paradigm

But concerns about the potential risks embedded in this technology are not the only reason that we should look for alternatives. Perhaps the more basic reason to search for alternatives is that the present application of biotechnology in agriculture conforms to the same paradigm that has failed us in chemical technology.

The central problem is brilliantly articulated by Joe Lewis and his colleagues in a brief perspective paper published by the National Academy of Sciences (Lewis et al. 1997). Lewis is a researcher with the Agricultural Research Service's Insect Biology and

Population Management Research Laboratory in Tifton, Georgia. His research has focused on pest-management problems in agriculture. Lewis argues that the principal problem with industrial pest management is that we are operating out of a paradigm that he calls "therapeutic intervention." That approach attempts to solve pest problems by applying a "direct external counterforce" against the problem. In other words, we attack the problem of a pest within a complicated, interconnected system by intervening in that system with an external force geared simply to eradicate the pest. Though that approach has succeeded in killing some target pests, it has not solved the problem of crop losses due to pests. Some studies, in fact, indicate that crop losses have actually *increased* with the continued intensification of pesticide applications (Lewis et al. 1997).

This therapeutic intervention approach is now being widely questioned, not only in agriculture but also in medicine, social systems, and business management. The reason this approach is being abandoned is that we now generally recognize that using a counterforce from outside the system to solve a problem that is intrinsic to the system exacerbates rather than solves the problem.

In his work on systems dynamics, Peter Senge helps us understand why this is so. He warns that applying externally imposed solutions at the expense of analyzing and understanding the functions of the system usually leads to *creating* the problem we are trying to solve. The reason, he suggests, is that "the long-term, most insidious consequences of applying non-systemic solutions is increased need for more and more of the solution" (Senge 1990, 61).

Industrial pest management is simply a classic example of this principle at work. Trying to solve a pest problem by applying a pesticide kills not only some of the target pest but also nontarget predators that previously kept other pests in check. In addition, it creates resistant varieties of the target pest, making the original pest even more difficult to manage.

To date, the application of biotechnology has largely followed this same interventionist paradigm and therefore is likely to experience the same problems. Instead of using the technology to better understand how systems work and perhaps using it as one tool within a whole-systems approach, we use the technology to intervene in the system to "fix" the problem. Genetically inserting *Bacillus thuringiensis* (Bt) into the corn plant to control the corn borer is a poignant example. Virtually all entomologists agree that the corn borer will develop resistance to Bt; it is simply a question of when. And if the study reported in *Science* magazine is correct in its assessment that genes encoding resistance to Bt in the European corn borer are *dominant* rather than *recessive* as previously thought, then the high dose/refuge strategy[2] that farmers have been told to use to postpone resistance is likely to have little effect (Huang et al. 1999).

Furthermore, if we apply Professor Leisinger's cost-effectiveness screen, then planting Bt corn to control corn borer turns out *not* to be a very good choice. Peer-reviewed data now suggest that yield losses due to corn borer infestations have to exceed 10 to 15 bushels an acre before Bt corn becomes less costly than other options. And that does not take into account the yield loss the farmer will experience from planting the 20 percent of his crop to conventional corn not *protected with insecticides*, which farmers are supposed to plant to slow down resistance (Sears and Schaafsma 1999).

The Alternatives

As it turns out, alternatives often exist to the "quick-fix" applications of biotechnology. Managing corn rootworm serves as an example. Corn rootworm has become one of the most difficult pests for corn farmers to manage. The University of Illinois's Michael Gray, one of the leading entomologists in the country studying this pest, reports that Western corn rootworm has not only become resistant to most of the insecticides used against it, but it also has evolved resistance to cultural practices such as crop rotation. So here it would seem we have a perfect candidate for a transgenic Bt variety to control a problem for which there are no alternatives (Gray 2000).

But Gray is not so sure. First, from the cost-effectiveness perspective, he calculates that farmers will invest more than $400 million annually in technology fees alone to prevent an economic loss estimated at $650 million annually. So at best, farmers can

[2]The high dose/refuge strategy is the practice of inserting high doses of Bt into the transgenic plants to obtain maximum kill and simultaneously requiring that farmers plant at least 20 percent of their crop to conventional, non-transgenic varieties on which no pesticides at all are used to serve as a breeding ground for insects unaffected by Bt.

expect less than a one-dollar return for each dollar invested, and that assumes that losses due to pest infestation in the refuge acres will be minimized.

But there are other problems. The long-term cost to the environment, and eventually to the farmer, could be significant. Some scientists believe a strong likelihood exists that Bt corn for rootworm control could harm beneficial insects, such as the pest-eating ladybird beetle. They also worry that the toxins may not break down in the soil and therefore may harm vital soil organisms, which could affect yields. There is also concern that this technology may quickly lead to the development and spread of Bt-resistant rootworms because the rootworms will feed on the endotoxins of the transgenic plants twice during a growing season, first as larvae on the roots and then as adults on the pollen and foliage. Gray believes that apart from careful IPM monitoring and careful selection of fields in which the transgenic varieties would be planted, resistance is assured (Ferber 2000).

But even in this case there may be an alternative scenario. A trio of researchers with the Agricultural Research Service at the University of Missouri have developed corn lines with *native-plant* resistance to corn rootworms. The selection process used to develop new varieties from these native plant sources produces resistance with multiple proteins. Transgenic varieties, on the other hand, depend on only one protein. Rootworms, accordingly, will likely develop resistance to the transgenic varieties rather quickly, while the multiple-protein varieties could be effective much longer. Interestingly, Bruce Hibbard, one of the researchers working with the native plant varieties, says that they "aren't necessarily trying to eradicate corn rootworms completely" but desire simply to hold "rootworm damage below the economic threshold" (Ritchie 2000, 14). Hibbard's comment suggests an effort to understand why the rootworm is a pest and find ways to alter the system so that it will no longer be a pest rather than introducing an external counterforce to eradicate it.

This raises an important question. If we were to put as much effort and research funding into ecological approaches for solving production problems as we are currently expending in the engineering approach, what solutions would we find? Conversely, if we begin by telling ourselves that there are no alternatives to engineering external controls, we guarantee that the ecological approaches won't be explored.

Leisinger suggests the possibility of increasing rice yields by 10 or 20 percent with biotechnology. But *Science* magazine reported on a research project conducted in China recently in which two varieties of traditional rice that are locally adapted were companion planted. Farmers experienced an 18 percent overall yield increase and did not need to use a fungicide ("Variety Spices Up Chinese Rice Yields," 2000). Mae-Wan Ho, head of the bioelectrodynamics laboratory at Open University in the United Kingdom, reports that a Japanese farmer has developed a method of producing rice, which he calls the Aigamo method, that increases rice yields 20 to 50 percent in the first year. The method involves putting about 200 ducklings into each hectare of rice paddy. The ducks, it seems, eat insects and snails that attack rice plants; eat weed seeds and seedlings; and oxygenate the water, which encourages the roots of rice plants to grow. And the mechanical stimulation of their paddling makes for sturdier rice plants. Using this method, the farmer's two-hectare farm annually produces "seven tonnes of rice, 300 ducks, 4,000 ducklings and enough vegetables to supply 100 people" (Ho 1999, 339). Observers believe that the Aigamo method, which is now being adopted in many developing countries, has the potential to make Japan—which currently imports 80 percent of its food—food self-sufficient again.[3]

The type of agriculture the Aigamo method represents has the potential to bring about other positive effects. Agriculture that is based on such wonderful complexities cannot be readily managed in large-scale monocultures. And because the method promises to be extremely productive, it suggests the possibility of supporting more people on the land with smaller-scale, highly productive farms. That poses the possibility of a different kind of future. A system that supports more people on the land may slow down, or even reverse, the migration to megacities. Could it therefore be possible that the rest of the scenario Leisinger predicts, which follows from the continued trend toward urbanization, might also not come to pass?

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[3]Brian Halweil (2001) provides another example of an alternative to transgenic crops. He reports that farmers in East Africa have managed to successfully control the Striga weed by planting leguminous trees prior to planting corn. He argues this may be a more useful technology than herbicide-resistant corn because the corn and the herbicide would be too expensive for African farmers. "Biotech, African Corn and the Vampire Weed," *World Watch* magazine, September/October 2001. Volume 14, Number 5 (pp. 26-31).

There are other examples of alternative approaches to food security that do not include the use of biotechnology. The Land Institute in Salina, Kansas, has been developing perennial polycultures from wild grasses that could reduce soil erosion, use water more efficiently, and reduce planting and tillage costs (Land Institute 2000). John Jevons, world renowned for his "double digging"[4] method, has experienced phenomenal yield increases in vegetable production (Madden and Chaplowe 1997). Richard Manning, after studying the various sites where the McKnight Foundation is conducting pioneering research in developing countries, concludes that we will never be successful in our efforts to feed the world if we do not take the complexity and diversity of local cultures and local ecologies into consideration (Manning 2000). After careful observation, Manning concludes that genetic engineering may be a limited tool that can be used effectively in these whole-systems approaches to food production in an expanding human population, but it will not be the solution.

Manning's concluding remarks are instructive for us.

> The genetic engineering business is going to get all the headlines, but these simple matters [attending to the needs of local cultures and local ecologies] are potentially far more earth-shaking. What must happen, and to a degree is happening, in agriculture is also an information revolution. If there was a key mistake of the Green Revolution, it was in simplifying a system that is by its very nature complex.
>
> Farming is not just growing food. It is not simply a tool we use to feed however many beings our social structure generates. The way we grow food determines our structure, makes our megacities, makes us who we are. Agriculture is culture, at bottom about the integrity of individual lives. Those lives gain their integrity and value when they are deeply embedded in a rich environment of information. This is about growing good food, but more important, it is about making good lives. We will fail if we attend to the former without considering the latter. (Manning 2000, 218)

[4]Double digging is a method of cultivation that loosens the soil at both the topsoil and subsoil levels.

Conclusion

What is our prevailing scientific ideology, and how does it affect the assessment of these new technologies? Do we recognize ecosystems dynamics at the molecular level, and will we incorporate the potential consequences of ecosystems functions in our assessment of the potential ramifications of the release of transgenic organisms? Will we be clear about the level at which we are attempting to solve a problem and properly assess the risk at the individual, the societal, and the biospheric levels? What are the ethical implications of the new technologies, and how do we begin making sound ethical choices in the wake of an ethically challenged society? These are all questions we need to ponder if we are going to make sound decisions as we enter the new era of our new-generation technologies.

Our current fascination with new-generation technologies may be distracting us from recognizing at least two important human failures. The first is our tendency to believe that we can solve all our problems without nature. In Iowa we now have a cow named Bessie that will shortly give birth to a gaur, an oxlike Asian bovine mammal. It will be the world's first cloned endangered species, and the experiment is being executed to help save the species from extinction.

Columnist Ellen Goodman suggests that this may be a necessary thing to do, but it raises a number of questions when one looks at the problem from a whole-systems perspective. How is it that we are willing to expend this extraordinary effort to save one species while we seem oblivious to the fact that we continue to destroy the habitat of hundreds of others? What does it mean to save a species from extinction when its habitat has been destroyed? Do we think that the baby guar can live on an Iowa farm, raised by an Iowa cow, and still be a gaur (Goodman 2000)?[5]

Proponents of biotechnology often seem to be oblivious to the context in which the technology is released—all the complex, interdependent relationships of organisms within a species and of species within their environments. Biotechnology is never simply a matter of "just adding another gene to what we have already been doing," as Monsanto Science Fellow and Agronomist John Kaufmann put it recently at a biotech

[5]The gaur was born on January 8, 2001, and died eighteen hours after birth.

conference.[6] Stuart Newman, professor of cell biology and anatomy at New York Medical College, says, "There is an incorrect, but prevalent notion, that genes are modular entities with a one-to-one correspondence between function and a gene" (Newman 2000, 27).

An article that appeared in the *New York Times* science section in July 1994 provides one example of the complex relationships that have evolved in nature. The article points out that researchers have discovered "a chemical laxative in the cherry-sized fruit of a Costa Rican shrub. The drug appears to act on the bowels of the birds, to the plants' and not the birds' advantage" (Yoon 1994, 1). Though we have known that fruits contain laxatives, this is the first evidence that "the biological effect of these tasty treats is the result of chemical manipulation in which animals are drugged into transporting and dropping the precious seeds quickly" (1). In other words, plants have evolved a complex mechanism that enables them to control the rate of passage of a seed through birds to give the plants the best opportunity to propagate themselves. We simply have to take such contexts into account as we contemplate changing the world with powerful, self-replicating technologies.

Everyone agrees that biotechnology has the ability to make dramatic changes in nature. If that were not true, then the argument that it has the potential to dramatically increase productivity would be hollow. But if powerful technologies have the potential to radically change components of such complex relationships, thereby potentially upsetting delicate interactions that have evolved over millennia, shouldn't it inspire caution?

Bill Joy reminds us of a second human failure that we also must ponder as we develop new technologies. He writes that we almost never pause to try to "understand the consequences of our innovations while we are in the rapture of discovery and innovation" (Joy 2000, 243).

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[6]Comment made by Dr. Kaufmann during a panel presentation at the Wisconsin Academy of Sciences, Arts and Letters conference on genetically modified foods in Madison, Wisc., November 3–4, 2000.

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The Genetically Modified Organism and Genetically Modified Foods Debates: Why Ethics Matters

Jeffrey Burkhardt

Genetically modified organisms (GMOs) and genetically modified (GM) foods have become subjects of considerable public debate. The controversies are the result of differing views concerning the products of "the new biotechnology"—recombinant DNA (rDNA) technology, to be precise. rDNA technology has allowed scientists to move genes across species' boundaries, to create traits in plants, animals, and microorganisms that could never be accomplished using traditional crossbreeding techniques. For example, genes from cold-water fish can be inserted into tomato plants to make them more tolerant to colder weather. The reality of transgenic technology has caused some people to raise questions about the nature and consequences of GMOs. For example, do GM foods differ in any relevant ways from non-GM foods? Are any differences significant as to how they will affect human health or the environment? How strictly are GMOs being tested? Who oversees the regulation and registration process? These are scientific and legal-political issues, and they are being discussed everywhere from grocery stores to the halls of Congress.

As important as these kinds of issues are in the GMOs/GM foods debates, other controversies have arisen regarding the *ethics* of GMOs and GM foods. People differ in their judgments about whether producing and using GMOs are morally correct things to do. The issue is whether GMOs and GM foods are morally and ethically acceptable. If they are ethically acceptable, then there is nothing wrong about producing, using, or consuming them. If they are not acceptable, people should stop producing them; or at least those people who find them unacceptable should be able to avoid them. Clearly, some people think GMOs and GM foods are ethically acceptable, whereas others do not. The point of this essay is to explain why the deeper ethical-philosophical reasons underlying the GMO debates are so important. If we are to resolve ethical (as opposed to scientific) controversies associated with GMOs and GM foods, a key step is to acknowledge differences in basic values and then debate the matter in terms of these deeper commitments and concerns.

Components of Acceptability

Judgments about ethical acceptability depend on answering several preliminary questions. Although there are people who for philosophical or religious reasons reject transgenic technology whatever its applications, it is still important to recognize that differences exist among the products of biotechnology. The first question regarding acceptability should be, "What GMO are we talking about?"

What Product?

Different products have different ethical dimensions. For example, bovine growth hormone (recombinant bovine somatotropin, or rBST), an early GM product, was designed to increase the efficiency of milk production by getting cows to produce more milk without increasing their feed intake. People who have written on the ethical acceptability of rBST have called attention to its possible negative effects on cows, potential impact on human health, and economic effects on small-scale dairy operations (see, e.g., Comstock 1989). In contrast, Roundup-Ready® crops, such as soybeans and cotton, were designed to permit a farmer to spray a herbicide on his or her field, killing weeds but not affecting the Roundup-Ready® crops at all. Analysts have written on the potential cost savings resulting from farmers not having to till weeds or use numerous herbicides to kill the different sorts of weeds that invade the field. Others have pointed out the potential human health risks and, again, economic effects on small farms (Lappé and Bailey 1998). *Bacillus thuringiensis* (Bt) corn is yet another example. Bt corn was engineered to produce a substance in the plant that is toxic to insect pests. The product was designed to reduce the need for spraying insecticides; however, people have claimed—in fact, it was a major controversy in the Corn Belt—that the pollen from Bt crops kills monarch butterfly larvae that consume it, a significant environmental impact (Environmental News Service 1999). Finally (though the list of GMOs and GM foods is much longer than provided in these examples), so-called "golden rice" is a transgenic product with greatly enhanced beta carotene (vitamin A–producing) content, intended to provide a more nutritious food staple for people in Third World rice-consuming countries where vitamin A deficiency is a serious problem—a cause of blindness in children. Although this GM product is several years away from the market, it has been discussed in terms of both its major health benefits as well as its potentially prohibitive cost to poor people (Burkhardt 2001).

The point concerning each of these examples is that, in part, the ethical acceptability or lack of it depends on the kind of GMO or GM food we are addressing: What are its features? What are its intended consequences?

What Context?

A second set of concerns that bear on ethical acceptability is the context in which the analysis or argument is set. Part of what has made the GMO and GM foods debates difficult for some people to understand is that individuals frequently talk past each other, as one party focuses on a set of issues in one context that are different from the issues and context that concern another party. For instance, much of the scientific community has tended to focus on the role of the new biotechnology in contributing to food quantity, quality, and affordability, whereas others have focused on contexts such as human (animal) health, environmental safety, issues concerning social justice or fairness, or different implications of GM technology for the developed versus the developing world. Certainly, each of these general areas of concern is important in the ethical appraisal of GMOs and GM foods. By focusing primarily or even exclusively on one area, however, parties involved in the debates or controversies tend to ignore other relevant issues or considerations that appear in a different context. For example, when scientists limit the context of their ethical appraisal of GMOs and GM foods to the context of producing enough affordable food ("feeding the world"), they bypass other legitimate issues such as whether peasant farmers in a developing nation may be put at a disadvantage because they are unable to afford to employ the newest bioengineered crop variety. Similarly, those who limit their vision regarding rBST to effects on animals may have missed important points about the need for increased dairy productivity in poor areas of the world. Attention needs to be paid to all of the relevant contexts in which a judgment about the ethical acceptability of GMOs and GM foods can (and should) be made.

What Ethical Paradigm?

Focusing on particular products and their contexts provides the target for judging ethical acceptability. An ethical paradigm provides the criteria for making judgments. An ethical paradigm is a basic, general philosophy about what things count as right or wrong, and why. The paradigm contains basic value judgments about what is most important for people to do, or how they should be treated, or overall how we should live. In essence, the paradigm establishes the lens through which people view the world, providing a substantive standard for unequivocally deciding whether actions, policies, or, in this case, a set of products and processes are ethically correct. In the following section the three major paradigms identified by philosophers of ethics are discussed. These are (1) consequentialism, (2) autonomy/consent ethics, and (3) virtue/tradition ethics. Each of these implies a set of ethical judgments about food and agriculture generally, which in turn entails a judgment about the ethical acceptability of GMOs and GM foods.

In our daily lives, we seem to make ethical judgments on the basis of all three paradigms. Sometimes we decide as if we are consequentialists, sometimes as if we hold to autonomy/consent ethics, and sometimes as if we are virtue/tradition based. However, in our public acts—voting, expressing opinions in community forums, talking with friends or colleagues—we tend to fall into one of the camps. We become *more* consequentialist, *more* autonomy/consent oriented, or *more* virtue/tradition focused. Regardless of an individual's own moral or ethical code, these ethical paradigms provide criteria for judging how we collectively ought to act, how we societally ought to judge right and wrong, and how we ought to direct public policy. In the public debates over GMOs and GM foods, the three ethical paradigms discussed here are routinely invoked as reasons why we should do something regarding GMOs. Scientists, farmers, consumer activists, environmentalists, animal welfarists, concerned citizens, and so on—the parties to the debate—express these ethical perspectives in clear and forceful ways. Just as it is worth paying attention to differences among products and contexts, it is worth attending to differences among ethical paradigms or basic ethical philosophy. It may not make the disagreements go away, but we will be clearer about where we all stand.

Three Ethical Paradigms

Consequentialist Ethics

For many people, the question "Is X ethically right?," where X stands for an action, policy, or, in the present case, the production and use of a technology, is best answered by answering a different question: "Does (will) X produce good consequences (outcomes, effects, etc.)?" If the answer to this latter question is yes, then we have an obligation to do X, or at least it is permissible (acceptable) to do X. If the answer is no, then it is ethically or morally wrong to do or allow X. The question here is, what counts as a *good* consequence?

Despite general agreement among consequentialists that we ought to promote good consequences or outcomes, there is no universal assent as to what those might be. Numerous candidates have been offered: we ought to satisfy the wants and needs of the greatest number of people; we ought to promote the greatest amount of material, spiritual, intellectual, and emotional happiness as possible; we ought to maximize material benefits and minimize costs; and so forth. Some have placed an economic value on the definition of "good," yielding what we commonly call the benefit-cost approach: try to achieve the greatest net financial benefit as a result of our actions or policies. Not everyone agrees with the financial interpretation of consequentialist ethics, but some version of a "satisfied wants and preferences" criterion has come to dominate the consequentialist paradigm's calculus of right and wrong. Indeed, the long-standing slogan of consequentialist ethics, that "the greatest good of the greatest number" is what determines ethical acceptability or ethical obligations, has come to be understood as what satisfies most people's preferences and desires. Personal health and security (and hence financial stability) are undoubtedly part of what most people want, so that consequentialist ethics also requires actions or policies that help achieve those goods. Most who subscribe to the consquentialist ethical paradigm believe that with enough foresight and care in reasoning, we can find the ethically right solution to any problem we may face (see Slote 1985).

Ethics of Autonomy/Consent

Those who subscribe to the ethics of autonomy/consent approach the matter of right and wrong in a very different fashion. Ethical rightness or acceptability depends on whether an action, practice, or policy respects or protects the individual person as he or she acts on his or her judgments about morality. The assumption, initially, is that people are generally rational and are mature enough to make judgments about what is right and wrong. People are *entitled* to make their own judgments. This is what autonomy means—self-determination. There is a long history, within the paradigm, of discussion about what it is that makes individual human beings deserving of personal sovereignty or autonomy, and how respecting and protecting autonomy should be translated into practical ethical rules or duties. One line of thought views this as a matter of respecting people's *rights*, that is, legitimate claims people have that others do or do not act toward them in particular ways. For many contemporary autonomy/consent ethicists, the idea of individual rights is further refined: anything anyone might do that affects other people, potentially infringing on rights or limiting self-determination, requires the consent of those affected. Without prior consent, actions that affect people are ethically unacceptable, indeed, ethically wrong.

It is instructive to note here that those who subscribe to the ethics of autonomy/consent demand that actions be consented to, even if, on some consequentialist calculation, those actions would benefit people. For example, it might be shown that putting chemicals in the public water supply kills bacteria that could harm people; hence, adding the chemical achieves a public good. Even so, the autonomy/consent paradigm requires that people be given the opportunity to agree with or object to the action and, at the extreme, be provided with an alternative water source if they disagree. For those accustomed to the consequentialist or benefit-cost approach, this demand may seem stubborn or unreasonable. Nevertheless, it is based on the principle that each individual person is entitled to decide how to live his or her life; others may not interfere without each individual's prior agreement (see Rippe 2000).

Ethics of Virtue/Tradition

A third basic ethical paradigm defines ethical rightness in terms of whether an action, practice, or policy promotes or is consistent with a set of virtues, usually set by a particular ethical or moral tradition. Virtues are ideal character traits or states of being that are thought to be definitive of the ethical life. For example, honesty, integrity, piety, and fairness are virtues under this definition. So are self-actualization, harmony with human nature, and life in accordance with Nature. These are in turn defined by the community within which one lives or by which he or she defines himself or herself. Honesty may mean complete openness and candor ("tell all") in one community's view; it may be simple truthfulness ("don't lie") in another's. Life in accordance with Nature may mean not killing animals in one community, and humane killing for consumption in another. The key is that the community and its tradition define what it understands to be the "excellences of character" that constitute the good life, the ethical life. It is incumbent on others not to endanger the so-defined way of life or act in ways that prevent people from virtuous actions (Crisp and Slote 1997).

An important aspect of this is that there may be certain elements of a community's tradition that seem at odds with what the majority believe, or even what is in the majority's best interests. Indeed, there may be occasions where the greatest good for the greatest number appears to require violation of a tradition or limitation on the practice of particular virtues. For example, the demands of an ethically justifiable war require drafting religious pacifists into military service. All this attests to is the fact that the virtue/tradition paradigm, like the autonomy/consent paradigm, can stand in decided opposition to what consequentialist ethics deems ethically acceptable or even obligatory. There may also be cases where preservation of a community's way of life seems to require violation of a person's autonomy. Literature and films are filled with examples of people torn between self-determination and the demands of their religious or cultural tradition.

The preceding discussion of ethical paradigms is far too brief to do justice to the complexity of these positions. I refer the interested reader to Blackburn (2001) for a more thorough discussion of the major differences among, and subtle nuances within, each of the paradigms or ethical orientations. The point is to recognize, in advance of any discussion of food and agricultural GMOs, that these are long-standing ethical perspectives that have informed ethical debate on matters from slavery to abortion. How they apply to the GMO and GM foods controversies remains an interesting and critical aspect of these disagreements.

Ethics and Agricultural Biotechnology

The ethical acceptability of agricultural GMOs, whatever paradigm the issue is approached from, in part depends on judgments about the ethical acceptability of major features of the food and agricultural system. For example, the judgment that pesticide-reducing GMOs are ethically acceptable depends on a more basic judgment about the unacceptability of pesticide use. In fact, debates about the ethics of certain agricultural practices predate current controversies about GMOs and GM foods. Each of the paradigms entails judgments about agriculture and the food system, and arguments or positions regarding biotechnology are based on those judgments.

The Consequentialist Perspective on Agricultural Biotech

Consequentialists subscribe to the view that actions, policies, practices, and technologies ought to promote people's happiness, defined as satisfied wants or preferences. The question is whether agriculture does this, and the answer is usually that it does. Historically, agricultural policy in the United States has been guided by a set of clearly consequentialist goals: (1) produce enough food to feed a growing and nonrural population (sufficient *quantity*), (2) produce food that is safe and nutritionally adequate (good *quality*), and (3) ensure that food is generally affordable for consumers while also ensuring that farmers receive profits from their work sufficient to keep them in business (adequate *price*). I refer to these goals collectively as the *QQP* formula, which in turn provides a consequentialist justification for actions or technologies needed to maintain QQP. Those actions and technologies help to guarantee as far as possible that the greatest good of the greatest number is achieved. People's wants and preferences for available, safe, and affordable food are satisfied.

Most observers agree that the key to achieving QQP is *efficiency* in agricultural production. This means getting the most output from the least inputs, or in standard farming terms, productivity and yields. Growers want to keep costs down while maintaining high quality and high quantity. Historically, most successful farm technology, from hybrid seed to chemicals to high-tech machines, has been adopted with productivity and yield in mind. It is not surprising, then, that farmers and policy makers concerned with efficiency, and ultimately with QQP, should want technologies continually improved so as to achieve even greater productivity and yield—all the time maintaining safe, affordable food. This is where agricultural biotechnology enters the picture.

The so-called "first generation"[1] of GM technology was designed to help farmers achieve greater degrees of efficiency. Roundup-Ready® crops were intended to reduce the need for costly herbicides while maintaining or improving yield. Bt crops were designed to reduce the need to spray pesticides, and rBST's purpose was to increase milk yields without increased feed costs. To the extent that each of these GM products and any others intended for increased efficiency achieve their desired results, they logically must receive a judgment of approval in terms of QQP. Generally speaking, a consequentialist appraisal of the ethical acceptability of these GM products results in a straightforward endorsement. If GMOs and GM foods contribute to the satisfaction of people's wants and preferences, they are ethically justifiable—perhaps even ethically required (Burkhardt 2001).

Currently, most ethical discourse about GMOs has been couched in consquentialist terms. At issue have been questions about whether current or foreseeable GM

[1] Please refer to end notes for all notes in this article.

products will satisfy the "greatest good for the greatest number" criterion. Though the answer is usually yes, occasionally there have been concerns that some things that people want other than QQP, for example, environmental protection, are not being provided by GMO and GM food technology, and in fact, GMOs may endanger these "other goods." The controversy over Bt corn and monarch butterflies is a case in point. People want butterflies protected at the same time they want inexpensively produced, available, safe food. Similarly, some consequentialists have raised issues about long-term consequences of GMOs: Will our children's health be placed at risk by the use of GM technology? What about future people's wants and preferences? Are they being placed at risk?

Despite these kinds of questions, by and large the consequentialist position has been that with enough foresight and a careful calculation of benefits and costs, we can find the ethically correct solution to any problem we may face. This implies vigilance in risk assessments and inclusion of food and environmental safety concerns in appraisals of acceptability. Once we commit to satisfying wants and preferences, however, we have to at least implicitly endorse those technologies that help us achieve that end. For the vast majority of consequentialists, GM technology, in agriculture as in medicine, in principle and nearly always in practice is ethically acceptable.

Autonomy/Consent and Food/Agricultural Biotech

The autonomy/consent paradigm begins with the axiom that self-determination implies that people have inviolable rights, which establishes the ethical demand that people be given a choice concerning how they want to act and be treated. Foremost among these rights is the right not to be harmed or placed at risk against one's will. Certainly, an individual can choose to accept some risks: people freely choose to drive cars, fly in airplanes, engage in sports such as football, invest in the stock market—all activities with some degree of risk associated with them. As long as a person's choice to engage in one of these activities is not coerced and does not harm others or place other people at risk, these are ethically acceptable acts. When a person drives drunk, plays sports recklessly, or puts all the family savings into a stock of questionable value, acceptability starts to evaporate: the individual is risking or harming others. This is ethically wrong.

Autonomy/consent ethicists may not concern themselves with the overall goals of the agricultural/food system, as do consequentialists, but proponents of free choice and the right not to be harmed occasionally agree with some consequentialists in posing this question: Is our food safe? The food system, they maintain, is far from transparent. Most consumers know nothing of farm production techniques, transportation and processing systems, even packaging and marketing activities. Yet most consumers want to know that when they purchase foods from the grocery store or at a restaurant, the food will not harm them. In fact, under this ethical orientation, people have a right to purchase items that will not place them unknowingly at risk. This puts the ethical burden on everyone in the chain from farm gate to food store to ensure that food is free from harmful contaminants and as safe as can reasonably be expected. And it is also part of the legal (and I would add ethical) mandate of certain agencies of the U.S. Department of Agriculture and the Environmental Protection Agency, the U.S. Food and Drug Administration, and state and local public health agencies. Autonomy/consent demands that people not be placed at risk against their wills; lack of transparency in the food system makes the obligation of government agencies to ensure safety a strong one.

For the autonomy/consent perspective, the issue of GM foods arises in part because of the lack of transparency of the food system to consumers, but also because at least in the United States, the regulatory agencies made a decision that, in effect, exempted most GM foodstuffs from any special testing regarding safety. USDA, EPA, and FDA agreed that the process of modifying soybeans, for example, was irrelevant to the safety of the soybeans themselves. That is, if a soybean is submitted for approval by EPA or FDA, it does not matter if it was modified through conventional plant-breeding techniques or with the use of rDNA technology (FDA 2000). Some consumer activist groups saw this as an attempt to smuggle GM crops into the food supply, even though, they argued, there had not been any long-term studies concerning the safety (particularly regarding allergenicity) of GM-derived crops. Even if GM foods are safe under current government guidelines, over the long term, consumers may be being placed at risk against their wills.

An even more fundamental point of the autonomy/consent proponents is this: whatever reasons a person might have to want to avoid GMOs and GM foods, he or she has the right to be able to avoid them. Some people may have reservations about government and industry claims regarding the safety of GM foods. Some may object to the specific kinds of commodities that are being genetically engineered, for example, corn and rice, staples in poor nations. And some may have deeper religious objections to GMOs and GM foods—concerns about scientists "playing God." Whatever the reason, autonomy/consent ethics demands that people have the choice to avoid these products. Hence, autonomy/consent proponents have been the strongest supporters of some form of labeling of GM foods. Mandatory labeling is now the rule in other parts of the world, notably, the European Union (EU), and various pieces of legislation have been put forth in the U.S. Congress and in state legislatures requiring some form of labeling. How this will play out in the United States remains to be seen. The point is that labeling receives its strongest philosophical and ethical justification in terms of the ethics of autonomy/consent.

One further dimension of the autonomy/consent perspective on GMOs deserves attention. This has to do with farmers' choices. Even before the enactment of the EU labeling legislation, there were concerns among some farm groups that non-GM crop seed would become less and less available. Because farmers make their planting decisions on the basis of expected markets (among other things), and with the possibility that markets for GM grains would shrink significantly (boycotts in the EU), some farmers desired to plant non-GM varieties. The way the seed industry is structured, however—with a very small number of large corporations, all heavily invested in GM crop technology, controlling a large portion of the seed market—questions have been raised as to whether corporations will continue to supply non-GM seed.

For affected farmers, this is also a matter of autonomy/consent. Some small-farm activists maintain that the actions of the commercial seed industry giants deliberately harm smaller operations, especially those in developing nations (Rural Advancement Foundation International 1999). Whether or not that is true, it has primarily been larger commercial farm operations in the United States (and commodity associations such as the American Corn Growers Association [ACGA]) who have voiced concern about choices and alternatives. Despite costs and other practical constraints, government agencies and seed industry giants are exploring ways to "segregate" and "identity preserve" GM and non-GM seed as a way of accommodating farmers' needs and the demands of the global market.

Many people who take a consequentialist view on these matters believe that the autonomy/consent issues that are raised are not so much a matter of biotechnology as a matter of power and control: consumers and farmers want greater control over the choices available to them in their respective arenas. Consequentialists liken the GMO controversy to the issue of organic foods: organics tended to be produced for local markets by smaller-sized producers, so that a choice for organic was really a rejection of large-scale corporate agriculture and the multinational seed/chemical inputs corporations. Though there may be some truth in these claims, they do not undermine the essential claims of the autonomy/consent approach to the ethical acceptability of GMOs, GM foods, and GM crop seed. People have the ethical right to choose what they consume and purchase, which implies that they be allowed both to *know* what they are consuming and to avoid or reject it if they so desire.

Ethics of Virtue/Tradition and Food/Agricultural Biotech

Several versions of virtue/tradition ethics have been offered in connection with the appraisal of agriculture generally and food/agricultural biotechnology in particular. These include the positions taken by Roman Catholics and some fundamentalist Protestant denominations in the United States (see Warner 2000), and rural and farm groups in other nations, again notably the EU. Though each position has its unique features, these usually negative appraisals of GMOs and GM foods tend to reflect more general traditions within virtue/tradition ethics, *agrarian* ethical philosophy, and, for lack of a better term, what I call *naturism*. These are somewhat different approaches to assessing ethical acceptability in general, so they will be discussed separately.

Agrarianism is the philosophy that views agriculture as more than a business or economic sector in society: agriculture is a "way of life." What this means is that agriculture has a unique and ethically special set of contexts, practices, and virtues that are inherent in its nature. The practice of bringing forth sustenance from the soil in the face of nature's unpredictability requires that the farmer be patient, strong, and self-reliant and respectful of natural processes. It also requires that the farmer work in harmony with others in the community, since only through mutual respect and reciprocity can many of the tasks of farming, or living in a rural community, be accomplished. Agrarianism sees the traditional family farm as a place where real human values and virtues can be practiced, instilled in the next generation, and hence preserved. Participation in and psychological and ethical "ownership" of an *agricultural* community is among the most important virtues or values people can embrace (Berry 1977).

Whatever challenges or threatens traditional farm virtues and rural communities is regarded as ethically suspect if not plain unacceptable. For this reason, agrarians have long been critics of government policies, business decisions, and technology-development agendas that have tended to undermine farming as a way of life. For example, agrarians claim that U.S. government policies have tended to favor larger, corporate, heavily "industrialized" farms that are (assumed to be) better able to deliver QQP to a predominantly urban/suburban population. Nonfarm interests (e.g., multinational petrochemical corporations) have increasingly purchased large blocks of farmland and have destroyed many rural communities as farming transformed from a family-based, labor-intensive, community-oriented enterprise to a mechanical/chemical production system. Researchers in both industry and in agricultural colleges and universities have limited their attention to efficiency and productivity in the development of technologies for agriculture. With the exception of farm protest groups and some academics, respect for traditional family farms and rural communities is rarely found outside those rural communities that have managed to hang on despite the accelerating trends toward large agri*business*.

Given the basic ethical position of agrarians toward modern agriculture, it should come as no surprise that most agrarians find GM technology to be ethically unacceptable. As noted earlier, food/agricultural GMOs are usually designed and intended for businesslike efficient production. They are not designed to enhance the quality of life for farm families or their communities. In this regard, agrarians echo many of the concerns voiced by proponents of autonomy/consent ethics: farmers are systematically being robbed of the ability to choose. In this case, however, it is not only that they may not be able to resist the technology—they may not be able to preserve their values and ways of life (Burkhardt 2000).

By far the strongest expression of the agrarian rejection of modern agriculture and GM technology has come from smaller-sized, traditional farm communities in Europe and from peasant farm activists in developing nations in Africa, Latin America, East Asia, and India. In Europe, the concern is that GM technology will favor larger farms, make traditional agriculture less competitive, and drive small farms out of business. Alternatively, GM technology may make foodstuffs cheaper, allowing foreign- (read: U.S.-) produced foods to replace domestic products, again, forcing traditional farmers out of business. In either case, a valued way of life is threatened.

In the developing world, the agrarian critique of GMOs reflects a view that even if traditional family-style agriculture is not threatened initially, decreased availability of non-GM crop seed (again as a result of the concentration of ownership in the seed industry) may mean peasant farmers would be forced to use GM seed. This may be costly, and it may force farmers to get big or get out. More importantly, it threatens traditional ways of life, including the use of indigenous crops and growing practices.

In the United States and Canada, where most people are so far removed (physically and psychologically) from agriculture, the agrarian position and critique of the ethical acceptability of GMOs and GM foods has not received much attention. In the late 1980s and early 1990s the agrarian critique of bovine growth hormone (rBST) did surface in Wisconsin, Minnesota, Missouri, and a few dairy farm–rich areas in New England. After that controversy faded from public awareness, agrarianism itself faded from public view.

The second version of a virtue/tradition ethics to be considered here is what I call naturism. This view has also been endorsed in part by members of religious denominations in their exhortations that scientists engaged in GM research and development should not be "playing God." In its more general and secular interpretation, this view simply argues that we should not be engaging in *transgenic* technology—crossing species boundaries. *Nature,* understood as an integrated system of beings and processes, should not be treated this way: GM technology is ethically unacceptable.

Appealing to nature in this way can occasionally seem fuzzy-headed or mystical, but there is actually a rational basis for this perspective. The term nature is a placeholder for a complex set of relationships among species of plants and animals, what we call an ecosystem. Though ecosystemic interactions are not all beneficial to every participant in the system—some things die, some things prey on others, some things mutate into others—the process of evolution produces, at any given point in time, an equilibrium. This is not to say that the system becomes static, rather, that each species functions in such a way that makes the system work as it does. In effect, each species contributes to the ecosystem's operations.

The problem with GM technology is that by transferring genetic material across species boundaries, one transfers physical traits from the donor to the recipient. These are not always (nor are they usually intended to be) traits that would appear in the recipient species through natural evolutionary processes or even through deliberate intraspecies crossbreeding. According to naturism, trans-species transfers of genetic material can upset the operation of ecosystems. At the very least, we do not know enough about, nor can we control enough of, complex ecosystems to be sure that the GMO will not cause irreparable damage. Perhaps even life as we know it—including human life—may be threatened.

For naturists, once we recognize the delicate balancing processes that constitute ecosystems or nature, we must see that human beings have no right to manipulate species or processes in this way. At root, people have an ethical responsibility to try to avoid disruption of deep ecological processes. Obviously, nearly everything people do "interferes with nature," and much of this is necessary for people to live their lives. However, the position taken by naturists is that GM technology is an arbitrary and capricious attempt to manipulate life at the deepest level.

The specific virtues and tradition implied by the naturist perspective are not as well defined as within agrarianism and some other virtue/tradition ethical orientations. Considerable philosophical work is under way to try to articulate what naturism practically implies (Callicott 1999). One thing naturists agree on is that genetic engineering is ethically unacceptable.

In sum, then, virtue/tradition ethics defines ethical acceptability in terms of consistency with some deeply held values and virtues, whether they relate to farming as a way of life, to life in accord with nature, or to following God's plan and will. Not all virtue/tradition ethical perspectives will necessarily reject GMOs or biotechnology overall. However, both in the United States and around the world, variations on this ethical paradigm have generally rejected GMOs and GM food. The depth of convictions among adherents to virtue/tradition ethics, as well as the force of reasoned arguments stemming from these convictions, have contributed to the seriousness and intensity of public debates and have occasionally fueled violent political action against GMOs and GM foods.

Concluding Remarks

It has not been the intention here to argue in favor of any of the ethical paradigms or approaches to evaluating the ethical acceptability of GMOs and GM foods. Rather, the point has been to illustrate the importance of each of these three ethical paradigms in the GMO debates. In many respects, both autonomy/consent and virtue/tradition ethics have been marginal to public debate, though perhaps autonomy/consent less so than virtue/tradition ethics. While somewhat marginal, these orientations should not be marginal*ized.*

Indeed, public debate about GMOs and GM foods over the past decade-plus has been dominated by considerations of risk, costs, and benefits of these products of the new biotechnology. Because these products and technologies are logically and institutionally linked to an important social and economic force in the global community—agriculture—it is hardly surprising and initially justifiable that the economic dimensions be primary. Potential implications for the environment and for people's health demanded that environmental and food safety be factored into the assessment of ethical acceptability. Still, these concerns were defined in terms of economic costs and benefits.

In the 1990s, however, consumer activist groups began to push an agenda of autonomy/consent regarding GM foods. In some cases this opened the debate to a different set of ethical concerns, indeed, a different way to think about the ethics of GMOs. So-called "civil society organizations" (CSOs) such as the Rural Advancement Foundation International and Farm Aid began to push agendas stressing protections for small farms and the rural way of life. Environmentalist groups encouraged considerations of intrinsic value in natural systems and places. Each perspective introduced ethical considerations that had been absent from the public arena.

Whatever one may believe about the soundness of the arguments presented by political actors opposed to GMOs, these critics have provided a valuable service to all of us concerned about agriculture and food as well as technology. The three ethical paradigms presented here predate and are independent of any critics' (or proponents') use of them in public discourse and debate. Professional philosophers and ethicists wrote about issues in agriculture and agricultural biotechnology years before these issues became matters of widespread public controversy.[2] Nevertheless, the fact is that autonomy/consent and virtue/tradition ethics were forced into the public consciousness by activist critics. Activists have refused to limit ethical discussion to consequentialist issues—costs, benefits, risks. In so doing, they have forced policy makers and concerned citizens to recognize that we differ in what we believe is right or wrong about GMOs, but more importantly, why we differ.

As is true regarding many public issues with ethical dimensions or with deep, conflicting underlying ethical judgments, the solution to the GMO controversies may ultimately come down to political-economic decisions. Lawmakers may decide in favor of labeling as a way of appeasing constituents. Policy makers in USDA, EPA, or FDA may decide that any additional or different kinds of tests for GMOs would be too costly and establish inefficient barriers to marketing these products. The president of the United States may direct the secretary of the Department of Agriculture to press ahead with a "more biotech is better" research agenda to try to capture the world market for GMOs, GM foods, and GM crops. Regardless of the reasons that laws and policies ultimately are made, ethics still matters. Recognizing—and respecting—the rationality of opposing basic ethical beliefs and a different ethical paradigm is an important step in understanding the debates. Those who disagree with us are not always uninformed or irrational; sometimes they just subscribe to a different ethical paradigm.

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Notes

1. Observers have characterized the products of GM technology in terms of the general kinds of goals or properties associated with them. The so-called "first generation" has been targeted at agronomic goals—productivity and yield, reduced chemical inputs, and the like. The "second generation" is supposed to provide benefits more directly to consumers, such as better flavor, longer shelf life, improved nutrition content, and so forth. The "third generation," still a long way from reality, would include novel uses of agricultural products, for example, building materials from plant fibers (not wood) and oils, alternative energy sources, and single foods (e.g., corn) with all the vitamins, minerals, and proteins necessary for a wholly nutritious diet.

2. Berry (1977) alluded to the development of agricultural biotechnology and offered an agrarian critique as early as 1977, although the agricultural biotechnology research and development effort was still in a prenatal stage at the time. It was not until after the 1980 *Diamond v. Chakrabarty* U.S. Supreme Court decision, allowing patents on "novel life forms" produced through rDNA techniques, that the agricultural biotechnology industry began in earnest. Among the earliest ethical treatments of food and agricultural biotechnology are Thompson (1984), Doyle (1985), and Burkhardt (1986). There is now a considerable ethical/philosophical literature on GMOs and GM foods; I refer the reader to the extensive bibliography in Thompson (1998).

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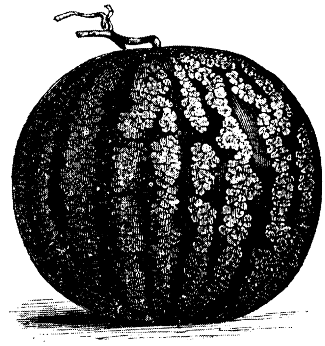

Biotechnology and Agriculture: A Skeptical Perspective

Vernon W. Ruttan

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A combination of population and income growth will almost double the demand for food and other agricultural commodities over the next half century. Advances in crop productivity during the twentieth century have largely been based on the application of Mendelian genetics. If farmers are to respond effectively to the demands that will be placed on them over the next half century, research in molecular biology and biotechnology will have to be directed to removing the physiological constraints that are the source of present crop yield ceilings.

Since the beginning of the industrial revolution, a series of strategic or general-purpose technologies have served as the primary vehicles for technical change across broad industrial sectors. In the nineteenth century the steam engine was the dominant general-purpose technology. In the early twentieth century the electric generator and the internal combustion engine became pervasive sources of technical change. By the third quarter of the twentieth century, the computer and the semiconductor had assumed that role across both the manufacturing and service industries. It is not an exaggeration to suggest that biotechnology is poised to become the most important new general-purpose technology of the first half of the twenty-first century.

A consistent feature of these general-purpose technologies has been a long period between their initial emergence and their measurable impact (David 1990). The steam engine underwent a century of modification and improvement before its widespread adoption in industry and transport. It was half a century from the time electric power was first introduced until it became a measurable source of growth in industrial productivity. Controversy about the impact of computers on productivity continued into the 1990s. It is not yet possible to demonstrate measurable impact of biotechnology on either human health or agriculture in terms of broad indicators for health (such as infant mortality or life expectancy) or agriculture (such as output per hectare or per worker).

The argument I make in this paper is that the advances in crop productivity experienced during the twentieth century were made possible primarily by the application of the principles of Mendelian genetics to crop improvement. Biotechnology is poised to become an important source of productivity growth in agriculture during the first half of the twenty-first century. But the advances in the new biotechnology achieved thus far have not yet raised yield ceilings beyond the levels achieved using the older methods. Nor do they promise to do so in the near future.

The Mendelian Revolution

Before the beginning of the twentieth century almost all increases in crop production were achieved by expanding the area cultivated. Selection by farmers led to the development of landraces suited to particular agroclimatic environments. But grain yields, even in favorable environments, rarely averaged above 2.0 metric tons per hectare (30 bushels per acre). Efforts to improve yields through farmers' seed selection and improved cultivation practices had relatively modest impact on yield prior to the application of the principles of Mendelian genetics to crop improvement. In the United States, for example, maize yields remained essentially unchanged, at below 30 bushels per acre, until the 1930s. Not until the introduction of hybrids was the corn yield ceiling broken (Duvick 1996; Mosher 1962).

Similar yield increases have occurred in other crops. These increases occurred first in the United States, Western Europe, and Japan. Since the early 1970s, dramatic yield increases, heralded as the Green Revolution, have occurred in many developing countries, primarily in Asia and Latin America. By the 1990s, several countries in Africa were beginning to experience substantial gains in maize and rice yields (Eicher 1995).

Yield Constraints

By the early 1990s, however, concern was growing that yields of a number of important cereal crops, such as maize and rice, might again be approaching yield ceilings. In the Philippines, rice yields in maximum yield trials at the International Rice Research Institute had not risen since the early 1980s (Pingali, Moya, and Velasco 1990). In the United States, maize yields that had been rising at an arithmetically linear rate of approximately 2.0 bushels per year appeared to be following a logarithmic path. Two bushels per year is a much lower percentage rate of increase when maize yield stands at 130 bushels per acre than when it was 30 bushels per acre.

The issue of whether crop yields are approaching a yield plateau has become increasingly controversial. In an exceedingly careful review and assessment of yield trends for eleven crops in the United States, Reilly and Fuglie found that an arithmetically linear trend model provided the best fit for five crops while an exponential model provided the best fit for another five—"but none of the differences between the two models are statistically significant" (Reilly and Fuglie 1998, 280).

Efforts have been made to partition the sources of yield increases among genetic improvements, technical inputs (fertilizer, pesticides, irrigation), and management. I find many of these approaches conceptually flawed.[1] Genetic improvements have been specifically directed to enabling yield response to technical inputs and management. For example, changes in plant architecture such as short stature and more erect leaves have been designed to increase plant populations per unit area and to enhance fertilizer response. The combined effect has been to substantially raise yield per acre or per hectare.

It is hard to escape a conclusion, drawing on the basic crop science literature,

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[1]In the mid-1990s, Donald N. Duvick of Pioneer Hybrid International conducted a series of very careful experiments to determine the relative contribution of increases in maize yields due to breeding. His results suggest that plant breeding contributed about 60 percent of the yield increases between 1935 and 1975. Duvick has also suggested in correspondence (February 13, 1999) that by the mid-1990s in the United States and other developed countries, the relative contribution of plant breeding is probably higher than in the period he studied because there are fewer increments to yield being realized from more effective weed control or higher levels of nitrogen fertilizer application. Duvick also reminded me that advances in crop yield from plant breeding has been due at least as much to the tacit knowledge of experienced breeders as from the application of the principles of Mendelian genetics.

that advances in the yields of the major food and feed grains are approaching physiological limits that are not very far above the yields obtained by the better farmers in favorable areas, or at experiment station maximum yield trials (Cassman 1998; Sinclair 1998). If present yield ceilings are to be broken, it seems apparent that improvements in photosynthetic efficiency, particularly the capture of solar radiation and reduction of water loss through transpiration, will be required. Even researchers working at the frontiers of plant physiology are not optimistic about the rate of progress that will be realized in enhancing crop metabolism (Cassman 1998; Mann 1999; Sinclair 1998).

The Biotechnology Revolution

The impact of advances in biotechnology on crop yields has come much more slowly than the authors of press releases announcing the biotechnology breakthrough of the week anticipated in the early 1980s (Ruttan 2001). The development of in vitro tissue and cell culture techniques, which were occurring in parallel with monoclonal antibody and rDNA techniques, would make possible the regeneration of whole plants from a single cell or a small piece of tissue. It was anticipated that the next series of advances would be in plant protection through introduction or manipulation of genes that confer resistance to pests and pathogens. Many leading participants in the development of the new biotechnologies expected that these advances would lead to measurable increases in crop yields by the early 1990s (Sundquist, Menz, and Neumeyer 1982).

Though the early projections were overly enthusiastic, significant applications were beginning to occur by the mid-1990s. The first commercially successful virus-resistant crop, a virus-resistant tobacco, was introduced in China in the early 1990s. The Calgene Flavr Savr™ tomato, the first genetically altered whole food product to be commercially marketed, was introduced (unsuccessfully) in 1994. Important progress was made in transgenic approaches to the development of herbicide resistance, insect resistance, and pest and pathogen resistance in a number of crops. DNA marker technology was being employed to locate important chromosomal regions affecting a given trait in order to track and manipulate desirable gene linkages with greater speed and precision. By the 1998 crop year, almost 110 million acres (44 million hectares) had been planted worldwide to transgenic crops, primarily herbicide or virus-resistant soybeans, maize, tobacco, and cotton (table 1).

Table 1. Global Area of Transgenic Crops in 1999 and 2000 by Crop and by Trait

	1999		2000		1999–2000	
	Hectares planted (in millions)	Area planted (%)	Hectares planted (in millions)	Area planted (%)	Hectares increase (in millions)	Percent increase (1999/2000)
Crop						
Soybean	21.6	54	25.8	58	+4.2	19
Corn	11.1	28	10.3	23	-0.8	-7
Cotton	3.7	9	5.3	12	+1.6	43
Canola	3.4	9	2.8	7	-0.6	-18
Potato	<0.1	<1	<0.1	<1	<0.1	N/A
Total	39.9	100	44.2	100	4.3	+11
Trait						
Herbicide tolerance	28.1	71	32.7	74	+4.6	+16
Insect resistance	8.9	22	8.3	19	-0.6	-2
Bt/Herbicide tolerance	2.9	7	3.2	7	+0.3	+10
Other traits	<0.1	<1	<0.1	<1	<0.1	N/A
Total	39.9	100	44.2	100	+4.3	11

Source: Review: *Global Review of Commercialized Transgenetic Crops* (ISAAA Briefs No. 21-2000) by Clive James, 2000.

The important point that needs to be made, however, is that the biotechnology products presently on the market are almost entirely designed to enable producers to achieve yields that are closer to present yield ceilings rather than to lift yield ceilings.[2] When I

[2]Control of insect pests of cotton, primarily tobacco budworm, cotton bollworm, and pink bollworm, represents one of the most dramatic, and clearly positive, results of the introduction of a transgenic crop. The introduction of the *Bacillus* microorganism into cotton has resulted in a dramatic reduction in the use of insecticides while substantially enhancing cotton yields (Flack-Zepeda, Traxler, and Nelson 2000). The effect was, however, not to enhance the genetic potential of the cotton plant but rather to enable the plant to come closer to realizing its genetic potential in the field.

asked the research director of a major commercial seed company when he might expect to see a line in table 1 for higher biological potential, his response was, "I don't know. There is a lot of hype out there." One reason for the cautious response is that attention is shifting away from yield to a second-generation emphasis on quality traits.

More Generations

Even as we move into the initial years of the first generation of agricultural biotechnologies, second- and third-generation technologies are being enthusiastically heralded (Kishore and Shewmaker 1998). The objective of the second generation, now being explored at the laboratory level, is to create value downstream from production. A high-oil maize, recently introduced by DuPont, though not strictly a biotechnology product, is often referred to as an example. Efforts are being directed to develop cereals fortified with the critical essential amino acids such as lysine, methionine, threonine, and tryptophan for use in animal feed rations and in consumer products. It is also anticipated that oilseeds will be modified to enhance protein quality and their content of fat that is free of trans fatty acids (Kalaitzandonakes 1998).

A third generation of biotechnologies, directed to the development of plants as nutrient factories to supply food, feed, and fiber, is also anticipated. High-carotene fruits, vegetables, and oils designed to reduce vitamin A deficiency is one example. In the longer run it is anticipated that biotechnology will revolutionize crop production and utilization technology. Processed feed and food will be grown in fermentation vats using biotechnology-engineered microorganisms and generic biomass feedstocks (J. Reilly, personal communication, January 25, 1999; Rogoff and Rawlins 1987).

In a fit of what can only be characterized as irrational exuberance, some biotechnology publicists have proclaimed that the benefits of new value-added grain production systems will be shared equitably among producers, the biotechnology and food industries, and consumers. In addition, these systems will eliminate the historic cycles of price and profit instability associated with traditional commodity market instability (Freiberg 1998). It is not too difficult to hear echoes of the hype of the early 1980s when the first-generation biotechnologies were still in the laboratory.

Some Concerns

I am concerned that more intensive research efforts are not being devoted to attempts to break the physiological constraints that will limit future increases in crop yields. These constraints will impinge most severely on yield gains in those areas that have already achieved the highest yields. It is possible that advances in fundamental knowledge in areas such as functional genomics, for example, might provide a scientific foundation for a new round of rapid yield increases. This would, in turn, enhance the profitability of private-sector allocation of research resources to yield improvement. But it would appear exceedingly rash to predict that these advances will leave any measurable impact on production within the next several decades (Duvick 1996).

I am concerned that many developing countries have not yet acquired the research and development capacity necessary to enable their farmers to realize the potential yield gains from crop-improvement efforts. In most developing countries, yields are still so far below existing biological ceilings that substantial gains can be realized from a strategy emphasizing traditional crop breeding combined with higher levels of technical inputs, better soil and crop management, and first-generation biotechnology crop-protection technology. Because the fastest rates of growth in demand, arising out of population and income growth, will occur in the poorest countries, it is doubly important that these countries acquire the capacity to sustain substantial agricultural research efforts.

I am also concerned about the economic and scientific viability of public-sector agriculturally oriented research in developed countries. Since 1980, the resources available to the federal government (USDA) agricultural research system have remained essentially unchanged in real terms. Public support for the state agricultural experiment stations (from federal and state sources) has barely kept up with inflation.[3] The eco-

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[3]The Department of Plant and Microbial Biology at the University of California–Berkeley has recently entered into an arrangement to sell its "research product" to Novartis (Wein 1999). A number of similar relationships had been developed between private universities (Harvard, Massachusetts Institute of Technology, and Washington University) and large pharmaceutical companies in the early 1980s. The Berkeley arrangement is controversial, primarily because it is the first time a major public university has entered into such a close arrangement.

nomic viability of private-sector research requires that it be directed to the development of proprietary products. It is important for the scientific and technical viability of private-sector agricultural research that the capacity of public-sector institutions to conduct basic and generic research be not only maintained but enhanced as well.

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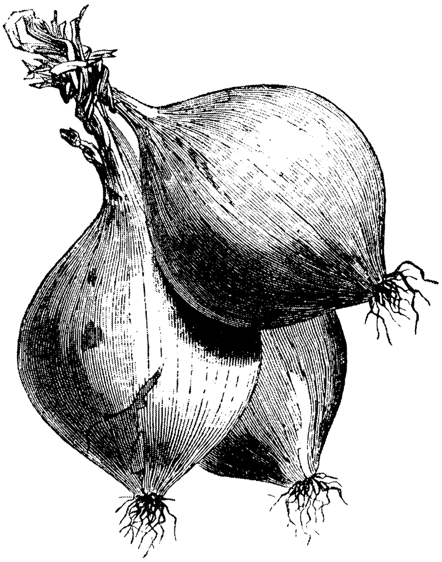
Biodiversity and Bioprospecting: Conflicting Worldviews



Lori P. Knowles

Much of the debate over the ethical use of agricultural biotechnology focuses on domestic perception and regulation of genetically modified foods. Commentators often neglect the importance of situating this technology within the international political and legal context. The value of agricultural biotechnology to the United States is dependent on the acceptance of its products by overseas markets. Genetically modified (GM) food and crop exports are, therefore, affected by trade negotiations regarding the importation of these goods. In addition, approximately 90 percent of the world's biological resources are found in developing countries. From these biological resources, medicines, pesticides, and other profitable products may be extracted. Exploring agreements affecting international trade will show that conflicting worldviews are embodied in international instruments with respect to the use and protection of the world's biological resources. The primacy of economic value and intellectual property right protections over social, cultural, and ethical values in international agreements has profound implications for both bioprospecting and biodiversity.

Challenging the International Commonwealth

At this time in history we are seeing a shift in global political and legal ideology. Until recently, the international legal system has been based on a commonwealth model.[1] This model has strengths and weaknesses. The commonwealth model is predicated on multiparty diplomacy, global representation, and respect for national sovereignty. In theory, the entire human community is represented by their governments and by non-governmental organizations in organs such as the United Nations. Work generated by parties to the international legal system is largely embodied in agreements, treaties, covenants, and conventions.

Despite the politics of power that exist in any international legal system, many believe that a cooperative model of dispute resolution will best respect and serve the interests of each party as well as the interests of the international community. This method of problem solving has developed tremendously positive and authoritative agreements, not the least of which are the agreements forming the International Bill of Human Rights.[2] The strengths of the commonwealth model are accompanied by some weaknesses; a system based on multiparty diplomacy is complex, somewhat cumbersome, and resistant to change. It also requires a commitment of time and respect for cultural differences by all parties. These characteristics have proven to be impediments in the search for effective responses to international emergencies.

The traditional multiparty diplomacy model of international law is being challenged. Its importance is being rapidly superseded by the emergence of a new international political order resulting from the rise of global capitalism. The World Trade Organization (WTO) best exemplifies the values and workings of this new order. International decision making on a wide range of activities is now to a large extent circumscribed by WTO dispute mechanisms. Accordingly, the economic might of dominant parties in the WTO, such as the United States, plays a tremendous role in the outcomes of various disputes.

Issues adjudicated before the WTO often have more than simple "trade" implications. The WTO's decision-making power is far-reaching; it does not, however, adequately recognize legitimate concerns of a nontrade orientation that are intimately con-

[1] Please refer to end notes for all notes in this article.

nected to the trade aspects under consideration. There is disagreement about which criteria are relevant and what values are at stake in trade disputes. Americans argue that only economic concerns are relevant in trade negotiations, with very limited exceptions. For example, with respect to agricultural trade, Americans consider European concerns about animal welfare to be an illegitimate concern in trade negotiations. Several American commentators have even accused the Europeans of raising such concerns as a way to introduce nontrade tariff barriers into international negotiations.[3]

With respect to GM food and bioprospecting (mining biological resources for profitable properties), concerns about corporate ownership of the world's future food supply, benefit sharing, and irreversible environmental degradation cannot be adequately addressed through WTO negotiations.[4] The WTO represents the emergence of an openly competitive and adversarial model of international dispute resolution. It is competitive rather than cooperative and promotes the primacy of economic value in making decisions to order world affairs. Understanding this background helps illuminate the motivations behind recent antiglobalization demonstrations in Seattle and Sweden and the popular backlash against American multinational corporations involved in agricultural biotechnology. Alongside concerns about risks to human health, the environment, and global justice, there appears to be deep concern about the imposition of "capitalist values" on an agrarian tradition that incorporates other frames of valuation: spiritual, cultural, social, *and* economic. The impact of this on the conservation of biological diversity is apparent when one looks at the conflict of worldviews between the commonwealth approach and the trade approach to conservation and use of the world's biological resources.[5]

Intellectual Property Rights

One of the building blocks of global capitalism is the international protection of intellectual property rights (IPRs). IPRs include copyright, trade secrets, patents, industrial design, and trademarks, among other things. Of particular interest with respect to genetically modified organisms (GMOs) are patents. A patent represents a bargain with an inventor that is based on the endowment of a time-limited monopoly (usually 20 years) in exchange for public disclosure of the inventor's creation. In this way patents are thought to stimulate research and development, although in the age of biotechnology this has become a more controversial claim.[6]

Until recently there has been a long tradition of not permitting the patenting of "products of nature"; therefore, animals and plants were not patentable. To provide for the protection of new plant varieties developed by traditional techniques of cross-breeding, plant breeders' rights were introduced. In 1980 in the United States, the Supreme Court of that country opened the gates to the patenting of "non–naturally occurring" living substances.[7] As a result virtually any living thing that can be reproduced by human intervention has become patentable. The ability to patent living products of biotechnology has been controversial for many years. At the same time, this ability forms the backbone of American biotechnology dominance and investment by multinational corporations in exploiting the world's biological resources. European experience with patenting of life forms has been markedly different. Political ambivalence in Europe on this issue for many years resulted in the passage of a moratorium on the patenting of life forms.[8] Recently, in the face of American dominance in global biotechnology that moratorium was lifted, although the change in policy continues to be controversial.

Trade-Related Aspects of Intellectual Property Rights and the Convention on Biological Diversity

It is telling to engage in an examination of the conflicting approaches to the treatment of the world's biological diversity and biological resources as articulated under the Trade-Related Aspects of Intellectual Property Rights (TRIPs) agreement, a product of the WTO; and the Convention on Biological Diversity (CBD), a product of the commonwealth model to international agreement.[9] A cursory examination of the values that motivate these international agreements illustrates the conflicts that exist between them. The TRIPS agreement is based on the protection of economic value, the pursuit of capitalism and profit, and the safeguarding of individual property rights. By contrast, the CBD emphasizes the value of conservation, fair and equitable sharing of benefits, and the value of communities of people.

The TRIPs agreement is a WTO agreement based on the promotion of effective and adequate protection of IPRs. It is also based on the extension of patentability to pharmaceuticals and to the microorganisms and processes for creating plants and animals. All signatories must have an effective plant-protection system in place. Exceptions to the intellectual property protections required by the agreement are permitted if they are based on measures for public health and interest. Permitted exceptions must, however, be consistent with the provisions of the TRIPs agreement. Consequently, whether such measures could be instituted to protect cultural and social welfare in a given country seems unlikely. Valuation of biological diversity, under TRIPs, therefore, is clearly instrumental to the desires and needs of parties wishing to exploit biological resources found around the world or, in other words, those companies and governments engaging in bioprospecting.[10]

The CBD resulted from the Earth Summit in Rio de Janeiro in 1992. It is a product of the commonwealth approach to formulation of international policy. Where the TRIPs agreement is based on economic exploitation of existing biological diversity, the CBD is committed to the conservation of the world's biological diversity. In addition, the CBD is premised on the principle of fair and equitable sharing, not only of the profits from exploiting those resources, but also of the medical benefits derived from them. Furthermore, provisions for transfer of technologies is included. The CBD explicitly provides for the recognition of and compensation for the contributions of indigenous peoples in cultivating and caring for plants that yield patentable properties. In stark contrast to the TRIPs agreement, the CBD states that intellectual property regimes must be consistent with and not detract from the provisions of the CBD. It is clear, therefore, that the values of conservation, stewardship, sharing, and inclusion are paramount values in the vision articulated by the CBD.

Commodification, Exploitation, and the Property Paradigm

The contrasting approaches to biological diversity embodied in the TRIPs and CBD raise a number of other ethical issues. For example, the imposition of property rights on living material raises concerns about the commodification and commercialization of life forms. In addition, introducing Anglo American property schemes into agrarian traditions customarily ordered by other norms may disrupt cultural and societal traditions as well as biological diversity. Finally, the appropriateness of choosing the legal tool of private property to govern our use of biological resources rather than other legal property concepts is at issue.

The application of IPRs to plants, animals, and other living matter has created a significant amount of debate about the commodification and commercialization of life. This concern is popularly articulated as concerns about the appropriateness of "owning life." Although IPRs do not confer ownership in the legal sense, concerns about "owning life" respond more generally to the commodification of living things.

The sentiment is widely shared that living things are sacred or different from nonliving things in a morally relevant way. For many, this special character mandates that living matter not be subject to the rules that govern private property. Many people believe that applying private property rights to living organisms serves to devalue that life by changing it into a commodity that can be transferred in the marketplace much like any other thing. This concern can be seen with respect to the whole spectrum of living matter, be it property rights in the human body, animals, plant life, or embryonic stem cells.[11] Regardless of one's views about the character of living matter, it is true that much living matter does not correspond to our notions of what constitutes fungible property that can be bought, sold, traded, or destroyed according to an individual's whim.[12] This is particularly true when we consider the nature of property in the human body, animals, frozen embryos, and plants that are used as food or for medicine by whole communities of people.[13]

Awarding IPRs to corporations in the industrialized world in products derived from biological resources found in developing nations raises concerns about exploitation. That exploitation concerns the contribution of indigenous peoples who for centuries have cultivated and used plants for their properties that are now patentable. Approximately 90 percent of the world's biological resources can be found in underdeveloped regions of Asia and Africa. Despite this, multinational corporations hold 97 percent of all patents worldwide.[14] Granting IPRs in these biological resources overlooks indigenous contributions that have led to the discovery of the valuable properties in the first instance. In addition, few corporations provide for sharing the financial or medicinal benefits derived from the biological resource with indigenous peoples. Perhaps the most notorious example is the European patent that was granted to the United States Department of Agriculture and the multinational agricultural company WR Grace on fungicidal properties of the neem tree.[15] In India the neem tree is revered. It has been carefully cultivated, and its fungicidal, pesticide, and medicinal properties have been used for centuries. The privatization of those properties for profit in industrialized nations has been widely condemned as a textbook case of biopiracy.[16] Recently that patent was overturned; however, hundreds of other patents on neem are still under consideration.[17]

IPRs can be disruptive and disrespectful of agrarian traditions in countries in which the sharing of crops and seeds is part of the culture. Private property traditions emphasize the dominion of an individual over a good, and in particular the right of that individual to exclude others from using that good. Although many argue that no form of property rights should be used with respect to living matter, in truth property rights have extended to land, plants, and animals for many years. The question, therefore, is whether intellectual property is the best legal tool to describe humankind's relationship to biological resources or whether some other property relationship better describes our relationship and serves our interests.

The ability to protect a resource for the use of many is part of our legal property traditions. Notions of "the commons" reflect the idea that there are some resources, formerly common lands, that should be open to all and cannot be subject to exclusive dominion or exploitation. It is this notion of common property that has been used to protect the integrity and sharing of the deep-sea beds. In addition, notions of common property apply to heritage and cultural property.[18] As with objects of cultural significance to the people of a particular region or heritage, our biological diversity is more than simply a tangible thing to be exploited and used up at the owners' whim. Notions of intrinsic value aside, the world's genetic resources often represent the cumulative efforts of generations of care and cultivation. Consequently, the benefits of those generations of stewardship should be protected and accrue to all people as well as future generations. The interests of all humankind would be better served if the world's biological resources were considered common property to be preserved and shared rather than individual property to be exploited.

Conclusion

Agricultural biotechnology is part of the larger biotechnology industry, which relies on exploiting useful properties from the world's rich biological diversity. Understanding ethical issues associated with this technology requires an examination of the international legal and political context as well as domestic perceptions and regulatory concerns. The rise of global capitalism has created new political and legal norms. A shift from a commonwealth model of international negotiation based on cooperation and equality to a trade-oriented model that is adversarial and favors the economically powerful is taking place. This shift places conflicting worldviews about the value and stewardship of the world's biological resources in stark contrast. Trade agreements involving biological products are intimately connected with intellectual property protections. The extension of intellectual property to life forms has paved the way for industrial countries and corporations to lay claim to biological resources in developing countries with medicinal and other useful properties. With privatization of these resources, social, historical, and cultural traditions are disrupted and the contributions of indigenous peoples are ignored. Not all property notions need lead to this result. The world's biological resources should be conserved and shared. Rather than awarding private property rights to their bounty, we should consider the wisdom of regarding biological diversity as our cultural and environmental heritage and common property for all people.

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Notes

1. I take this notion of the international commonwealth from Peter G. Brown, *Ethics, Economics and International Relations: Transparent Sovereignty in the Commonwealth of Life* (Edinburgh University Press, 2000).

2. *Universal Declaration of Human Rights*, adopted and proclaimed by UN General Assembly Resolution 217A(III) (December 10, 1948). International Covenant on Civil and Political Rights, G.A. Res. 2200(XXI), 21 U.N. GAOR, Supp (No. 16) 52, U.N. Doc. A/6316 (1966). International Covenant on Economic, Social and Cultural Rights, G.A. Res. 2200 (XXI), U.N. GAOR, Supp. (No. 16) 49, U.N. Doc. A(6316) 1966.

3. John Micklethwait, "Europe's Profound Fear of Food," *New York Times*, 7 June 1999, p. A21; Rick Weiss, "In Europe, Cuisine de Gene Gets a Vehement Thumbs Down," *Washington Post*, 24 April 1999, p. A1.

4. Editorial, "The Name of the Game: The Battle over Genetically Modified Foods Is Not What It Seems," *New Scientist*, 22 May 1999, p. 3.

5. See Lori Wallach and Michelle Sforza, *Whose Trade Organization? Corporate Globalization and The Erosion of Democracy* (Washington, D.C.: Public Citizen, 1999).

6. See Robert Mullan Cook-Deegan and Stephen J. McCormack, "Patents, Secrecy, and DNA," *Science*, 13 July 2001, 217.

7. *Diamond v. Chakrabarty,* 447 U.S. 303 (1980).

8. See http://www.European-patent-office.org; Quirin Schiermeirer, "European Union Move to Curb Moratorium on Transgenic Plants," *Nature* 409 (22 February 2001): 967.

9. The TRIPS agreement can be found at http://www.wto.org/english/tratop_e/trips_e/intel2_e.htm. Convention on Biological Diversity, Decreto No. 2519, de 16 de marco de 1998, DO de 17/03/98.

10. See Panos Kanavos, "The WTO-TRIPS Agreement: Areas of Dispute and Implications," *EuroHealth* 6 (Autumn 2000): 21.

11. *Biotechnology, Patents and Morality*, edited by Sigrid Sterckx (England: Ashgate Publishing Ltd., 1997); editorial, "Who Owns Plant Genetics?" *Nature Genetics* 26 (4 December 2000): 385.

12. The body of property law is, of course, more complex than I present it. In a number of circumstances there are restrictions on the uses that an owner can make of his or her property. Those restrictions may take the form of zoning bylaws, or restrictions on the treatment of one's own body or one's pets.

13. See, for example, Andrew Kimbrell, *The Human Body Shop: The Cloning, Engineering, and Marketing of Life*, 2d ed. (Washington, D.C.: Regnery, 1997).

14. "India: New IPR Regime: Protection for Indian Patents," *Financial Times Information*, 24 April 2001.

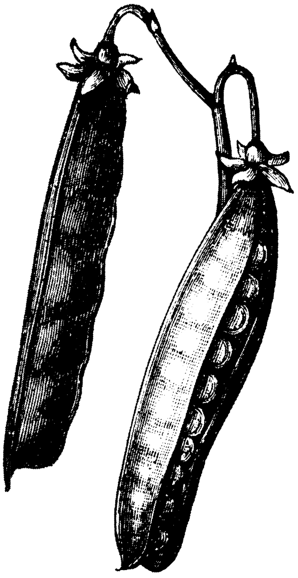
15. Patent 0436257 B1. See also Paul Hoversten, "Legal Battle Takes Root Over 'Miracle Tree,'" *USA Today*, 18 October 1995.

16. Vandana Shiva, "Free Tree," *Hindustan Times*, 9 June 2000, http://www1.hindustantimes.com/nonfram/090600/detOPI01.htm.

17. Karen Hogan, "Neem Tree Patent Revoked," *BBC News*, http://news.bbc.co.uk/hi/english/sci/tech.

18. Joseph L. Sax, "Heritage Preservation as a Public Duty: The Abbe Gregoire and the Origins of an Idea," *Michigan Law Review* 88 (1990): 1142, 1152.

Biotechnology and Genetically Modified Foods: The Role of Environmental Journalists



Richard Manning

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The controversy about genetically modified foods looks so very different when laid out not in the way we who work in environmental journalism usually cover it, in a confrontation between a corporation and food activists, but by three middle-aged women in saris in a spartan lab in Pune, India. The three, each with a Ph.D. and full careers in biological research, are tinkering with the genes of chick-peas but begin the conversation by speaking of suicides.

Their target is an insidious little worm called a pod borer, which makes its way into the ripening chickpea pods and, unseen, eats the peas inside. Subsistence farmers expecting a bumper crop find the fat pods hollow at harvest. Then—and this happens most every year—a few hundred suicides preface a hungry season for entire villages.

Three years ago I began profiling nine agricultural research projects in the developing world. The idea was that these projects, culled from a list of 450 applica-tions for grants from the McKnight Foundation, would distill cutting-edge ag research to its essence and give a mosaic picture of the future of the human enterprise with the greatest environmental footprint on the planet.

There is some urgency to this. In the late 1960s Paul Ehrlich warned of worldwide famine in *The Population Bomb* (Sierra Club–Ballantine, 1968). Population doubled in the past generation to six billion, but doom did not occur, mostly because of the massive increase in yields of grain brought on by the Green Revolution. Now, though, even most unrepentant "Green Revolutionaries" agree those technologies have almost reached their limits for increasing yields. More important, the environmental damage from the Green Revolution's dependence on pesticides and chemical fertilizers, and the consequences—soil and water depletion, and habitat loss—are simply unsustainable at present levels, never mind future increases. Meanwhile, 800 million people are underfed in the developing world. The expected population increase from 6 to 9 billion by 2050 likely all will accrue in the poorest parts of the globe. This is one of the biggest environmental stories of our time, and we're missing it. Worse, our focus on safety and genetically modified foods hypes a developed-world debate that is damaging biotechnology, an important tool to address the bigger problems in the developing world. We are feeding a sort of agricultural NIMBYism.

I went into my piece of this story expecting to write about warm and fuzzy sustainable ag techniques such as crop rotation, intercropping, neglected crops, and integrated pest management. In fact, that's what I found in most of the projects, but what blindsided me was the degree to which each is dependent on some form of biotechnology, even in some of the world's most primitive places. I was in a lab in Uganda that could not regularly flush its toilets because of a lack of running water, but its work relied on biotech.

This, of course, raises the specter of genetic engineering. Because I write books, I don't have to hide my judgments and opinions, but I went into the story almost without an opinion; if anything, I was biased against genetically engineered crops. I remain ambivalent, opposed to some cheap parlor tricks like *Bacillus thuringiensis* (Bt) corn that has gotten all the press in the United States. When all is said and done, Bt corn is simply a passive way of applying insecticide; it doesn't matter a bit that the insecticide is "natural."

Still, I think badly needed biotechnology is being suppressed by overblown fears about genetic engineering. The way the debate is structured—and this is mostly journalists' fault in that we are paid to guide debate—causes us to miss some big pieces of this story.

First, genetic engineering is a subset of biotechnology. We often err by treating it as if it were the whole, and that is dangerous. For more than twenty years, scientists have been able to splice genes from one organism to another and have done so again and again. That technique is controversial. Three of the nine projects relied on genetic engineering, but all relied on what I call biotechnology.

Sequencing, reading, and marking genes does not necessarily imply their manipulation. Traditional plant breeders, for instance, now routinely rely on genetic markers to guide their work. We are entering an exceedingly sophisticated era of science of which the human genome project is a part. A little-noticed parallel to the human genome project has taken place in Brazil, where scientists have mapped the gene of a bacterium that destroys citrus crops. This area of genomics has enormous promise to refine our basic understanding of host-parasite relationships. At the genetic level, those relationships are guided by a series of locks and keys. A firm understanding of them will allow us to gently lock out one burglar—likely without genetic engineering—instead of using the neutron bomb of pesticides to poison every being in the vicinity.

My biggest concern here is that the controversy about genetic engineering will hamper all of biotechnology, and this set of tools will never reach its potential, or, more darkly, that the controversy will leave the corporations, over which we have very little control, operating largely unaffected and tie the hands of public-sector scientists. This is especially important in the developing world, where most crop science is public. Many countries such as India, Brazil, Cuba, China, and Chile are already effectively using these tools, and many more, such as Uganda and Ethiopia, have begun to. The very act of exercising these skills gives them a big leg up in building the infrastructure they need to gain some independence in charting their own agricultural destiny.

The distinction between public and corporate science is key in all of this. We have already seen how corporate science gave us Bt corn, a technology now considered primitive by many working in the field. Corporations such as Monsanto and

Novartis go ahead with these blunt instruments only because a decade or so of research and development money has to be recovered. They are in a time warp, and attaching the discussion to their actions leaves all of us in the same warp. Recovering investment is also why they mercilessly pursue any farmers who break licensing agreements and save seeds. (With the earlier generation of improved crop plants, this was not an issue, because the gains came largely from development of hybrid varieties, and hybrid vigor does not carry to the next generation, so seeds must be bought each year. Many of the transgenics are not hybrids, so the gain is permanent.)

In my mind, I contrast all of this with the case of chickpeas cited earlier. India's protein consumption is about half what it should be, mostly because of losses to this one neglected crop, a situation that has to be corrected if a billion people are to maintain an efficient vegetarian diet. The scientists are getting the genes for resistance to the pod borer from Asian wing bean and peanuts, already food crops. It will cause chickpeas to express not an insecticide, but a protease inhibitor, a common protein that disables the pod borers' digestive enzymes. Humans can and already do digest this same protein in beans and peanuts. The pod borer is now controlled in India with insecticides, which, environmental and health problems aside, most farmers can't afford. Yet if the government gives them this new seed, they need only save seed to keep this resistance on their fields.

And, yes, there are drawbacks, chief among them that the pod borer can and will build resistance to the protease inhibitor, but that's agriculture and has been for 10,000 years. We need to do all the running we can to hold our place. Or at least buy us time to gain the wisdom and will to pursue longer-term solutions.

Genetic modification and even biotech need to be looked at in the context of conventional plant breeding. For all 10,000 years of the history of this enterprise, most gains in agricultural productivity have come through breeding, especially in the time since Gregor Mendel. Breeding haphazardly alters genes through human selection and carries with it many of the same problems now ascribed to genetic modification. Further, breeding has become sophisticated enough to force matings that never would occur naturally, many of them across species lines, some across genera.

In turning all this over in my mind for the past few years, it finally snapped into focus when I heard someone worry that genetic modification could provoke an environmental catastrophe. Maybe, but in a very real and demonstrable sense, all of agriculture already is an environmental catastrophe, in fact, our biggest. News of this has not been in all the papers, but this is journalists' fault.

Aldo Leopold said even a generation ago: "As for diversity, what remains of our native fauna and flora remains only because agriculture has not got around to destroying it."

A century before Leopold, George Perkins Marsh said, "With the pastoral state, man at once commences an almost indiscriminate warfare upon all the forms of animal and vegetable existence around him, and as he advances in civilization, he gradually eradicates or transforms every spontaneous product of the soil he occupies."

That is no less true in our time, and our coverage needs that perspective.

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Adoption of Agricultural Biotechnology by Wisconsin Farmers: Recent Evidence

Bradford L. Barham

Two major types of agricultural biotechnology are currently available to Wisconsin farmers, recombinant bovine somatotropin (rBST) (otherwise known as bovine growth hormone [BGH]) and genetically modified organism (GMO) crops, particularly herbicide-tolerant soybeans and corn and *Bacillus thuringiensis* (Bt) corn. This paper examines the adoption patterns of these two types of agricultural biotechnologies to see what lessons might be drawn from their experiences that might be of relevance to the controversy surrounding genetically modified foods.

Wisconsin agriculture provides a fascinating backdrop for such a study. First, Wisconsin agriculture remains to this day dominated by moderate-scale family farms in both the dairy and grain sectors. For example, 96 percent of Wisconsin dairy farms have less than 200 cows, and more than 85 percent have less than 100 cows (Jackson-Smith and Barham 2000). Similarly, Wisconsin has very few large-scale grain farms. Indeed, most grain production occurs on dairy farms, and most of the rest is on what were once dairy farms. Second, dairy farming remains the dominant sector of Wisconsin agriculture (accounting for 30 percent of the farms and more than 60 percent of the agricultural output), so what happens on dairy farms is crucial to the outcome of agricultural biotechnology adoption in Wisconsin. Third, unlike many other states, the articulation between Wisconsin consumers and Wisconsin's farmers and agricultural sector, overall, remains quite strong. Even though less than 2 percent of Wisconsin's population works as farmers, I would not be surprised if a third to a half of Wisconsin's population knows either through family connections or close friends people who are currently or were recently farmers. This connection is reinforced through farmers' markets, community-supported agriculture schemes, county dairy breakfasts, and all kinds of less formal events that bring consumers and farmers together. Fourth, Wisconsin was very much at the heart of the international debate that preceded the commercial approval of rBST in the United States in the late 1980s and early 1990s, and as such the politicization of these technologies was quite extensive here in Wisconsin, among both farmers and consumers.

One of the major institutional outcomes of the political debate over rBST in Wisconsin was the State Legislature's 1990 decision to create the Agricultural Technology and Family Farm Institute (ATFFI) as an independent research and extension unit at the university dedicated to studying the impacts of new technologies and public policies on family farming in Wisconsin. From its inception in 1992, ATFFI, now known as the Program on Agricultural Technology Studies (PATS), has monitored the commercialization and adoption of rBST and other emerging technologies in Wisconsin. The first survey undertaken by ATFFI in 1993 asked a random sample of 1,000 dairy farmers about their intentions to adopt rBST (BGH) under two potential scenarios of marketing conditions being debated at that time (no labeling of products versus mandatory labeling for all dairy products using milk from cows treated with rBST). Since that time, ATFFI, and later PATS, has surveyed dairy farmers again in 1994, 1995, 1996 (only recent entrants), 1997, and 1999. In 2001, PATS completed two more surveys, a statewide random sample and a statewide panel data sample (including farmers who were interviewed previously in 1994, 1995, and 1997), to examine the dynamics of technology adoption change among dairy farmers over the relevant time period. In the case of GMO crops, PATS has done surveys in 1999 (asking about 1998) and in 2000 (to the same farmers as in 1999, asking about 1999 and looking forward to 2000). This panel has also been recently extended to the year 2001.

Before we pursue the main task of this paper, which is to examine the adoption patterns of rBST and GMO crops among Wisconsin farmers, it is worth briefly contrasting the two technologies to identify some important differences between them. To begin, while rBST works in combination with a suite of other technologies and management practices to augment the productivity of cows, GMO crop varieties are essentially input-reducing technologies aimed at allowing farmers to spend less time in the fields with their machinery and chemicals fighting weeds and other pests. In addition, rBST has a longer commercial history (released in February 1994 vs. 1996 to 1998 for most of the GMO crops) and was much more controversial among both farmers and consumers, especially in their involvement in the protracted political struggle that surrounded its commercial approval and initial introduction. As a result, voluntary labeling of fluid milk and some other dairy products began immediately after the commercial release of rBST in 1994, whereas the push to label products according to their use of GMO crops is still unfolding, several years after the release of these technologies and the ongoing commercialization of processed foods using these crops. Finally, GMO crops in Wisconsin are largely used as inputs to livestock (especially on dairy farms), and because unlike rBST they are essentially input-reducing rather than output-enhancing technologies, they are not as likely to be viewed by farmers (both adopters and nonadopters) as likely to lower prices and revenues.

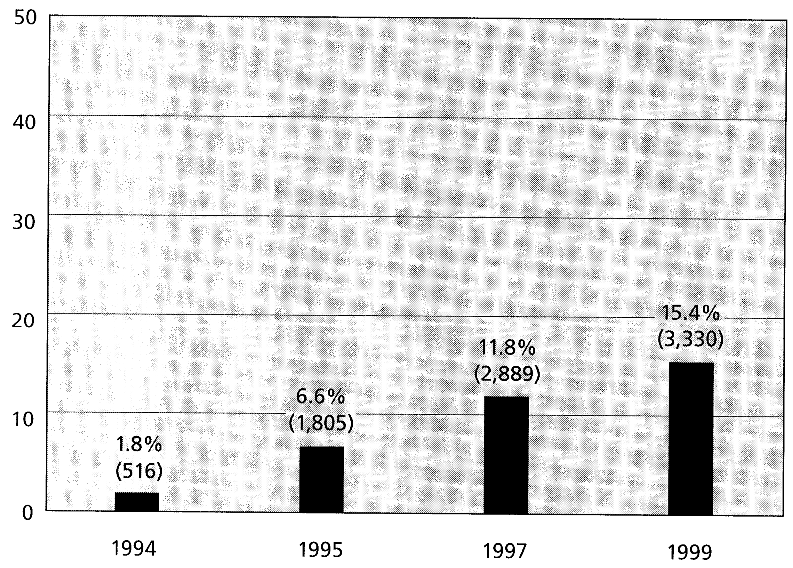
The rBST Experience in Wisconsin

Adoption of rBST in Wisconsin has been quite moderate, especially when compared with most precommercialization predictions of rapid adoption.[1] In 1999, five years after the commercial release of the technology, rBST was being used on 15.4 percent of Wisconsin dairy farms. As figure 1 demonstrates, the rate of adoption increased by more than 1,000 users between 1994 and 1995 and again between 1995 and 1997. However, between 1997 and 1999, the estimated number of new users increased by less than 450. Thus, while figure 1 shows a pattern of increasing adoption, the rate of adoption growth appears to be flattening out. Indeed, as this article goes to press,

[1]The figures and data for this section are from Barham, Jackson-Smith, and Moon 2000.

Figure 1

Percent (estimated number of farmers) of Wisconsin Dairy Farms using rBST



Wisconsin survey data for 2001 show that rBST adoption is 16.5 percent, having grown only slightly in the past two years.

Several factors limited the adoption of rBST among Wisconsin dairy farmers. Certainly, following its commercial release, consumer and farmer resistance to the technology prompted processors and retailers to pursue a voluntary labeling scheme especially for fluid milk, which in most grocery stores led retailers to advertise quite explicitly that their milk came from cows not treated with rBST. In addition, the survey data collected by ATFFI and PATS in those years revealed a surprising percentage of farmers who claimed to refuse to use the technology for essentially political reasons (Barham et al. 1995). Recent studies of rBST adoption (Stefanides and Tauer 1999; Foltz and Chang 2000) and its impacts on profitability suggest another reason that many farmers may not be using the technology, namely that, on average, it does not appear to enhance profitability. If these results are valid, perhaps it should not be such a surprising outcome given that sales of the technology are monopolized by a single company. Finally, there is the fact that for many dairy farmers rBST may not fit with the other production system decisions they are making and the ways in which they are organizing management and labor on their farms.

What types of farms are adopting rBST? As table 1 reveals, there is definitely a strong size bias in the adoption patterns in Wisconsin. Only 5 percent of farms under 50 cows use it. About 15 percent of farms in the 50 to 99 herd size category use it, but over 75 percent of the farms in the over 200 herd size category are rBST adopters. There is no other technology in dairy farming, other than parlors and free stalls that are built *explicitly* for large herds, that demonstrates a similar scale bias.

Table 1

Percent of Farms Using rBST in Wisconsin, by Size of Milking Herd (%, 1999)

Size Categories	1995	1997	1999
1–49 cows	2.2	3.3	5.3
50–99 cows	10.4	13.9	15.3
100–199 cows	20.8	30.1	34.9
200+ cows	46.7	48.3	75.0
All dairy farmers	6.6	11.8	15.4

The interesting puzzle about this size bias in rBST adoption is that, prima facie, the actual application of the technology offers no compelling reason that adoption should be so size biased. Basically, applying it to 200 cows should take a farmer four times as long as applying it to 50 cows would. Of course, applying the technology says nothing about its efficacy, and that is where issues of management and complementary technologies come into play. In fact, effective rBST use depends on careful feed and herd management to insure that the cows can make efficient use of the stimulus to milk production provided by the hormone. As a result, it should not be surprising that rBST adoption, as shown in table 2, is much higher on farms using other productivity-enhancing practices, such as total mixed ration (TMR) equipment, regular feed balancing, herd production record keeping, and regular veterinary services. As shown, rBST adopters in all herd size categories are much more likely than nonadopters to use these other productivity-oriented management practices.

The association of rBST with other productivity-enhancing technology use helps to explain the size bias in rBST adoption, at least in Wisconsin. Adopters of rBST appear to have a certain production system orientation that gives rise to the use of a whole package of technologies, facilities, and management practices, most of which reward rBST use. Because many of these in turn have strong technical, investment, or labor-scale biases, their differential adoption profiles and their association with rBST use affect the scale neutrality of rBST adoption.

Table 2
Adoption (A) and Nonadoption (NA) of Various Milk Production Practices, by rBST Use Status and Herd Size in Wisconsin (%,1999)

	TMR		Vet Service		Herd Prod. Record		Bal Feed Rations	
rBST Adoption	A	NA	A	NA	A	NA	A	NA
1–49 cows	35.3	6.6	70.6	50.2	88.2	36.6	58.8	41.3
50–99 cows	70.0	27.1	90.2	71.6	92.0	60.5	98.0	74.8
100–199 cows	93.1	50.0	93.1	79.6	93.1	58.5	100.0	90.7
200+ cows	95.2	57.1	93.1	58.5	95.2	42.9	100.0	85.7
All	75.2	19.7	89.8	62.2	92.3	48.9	93.2	60.5

GMO Corn and Soybeans

Nationally, many analysts viewed the 2000 growing season as a potential turning point in terms of the adoption of two of the major GMO crop varieties, Bt corn and herbicide-tolerant (HT) soybeans.[2] From 1996 to 1999, the pace of adoption of these two

[2]The figures and data for this section are from Chen, Barham, and Buttel 2000.

GMO varieties had been precedent setting; no other major agricultural technologies in the United States had been adopted as rapidly as Bt corn (and cotton) and HT soybeans. From minuscule levels of adoption in the first marketing season of 1996, by 1999 about 25 percent of U.S. corn acreage had been planted in Bt corn, and about 57 percent of U.S. soybean acres were in HT soybean varieties.

Then, the European storm clouds of consumer opposition to GMO crops began to roll across the oceans toward the United States. Would the adoption decisions of 2000 be substantially different, as U.S. farmers found themselves facing a more uncertain marketing environment for GMO crops than they had in the first three years of the technology's commercial availability? PATS survey work allows a careful look at that issue for Bt corn and HT soybeans.

As shown in figures 2 and 3, there was essentially no growth between 1999 and 2000 in farmer adoption of Bt corn and HT soybeans, but acreage of soybeans expand-

Figure 2
The Adoption of Bt Corn among Wisconsin Corn Producers

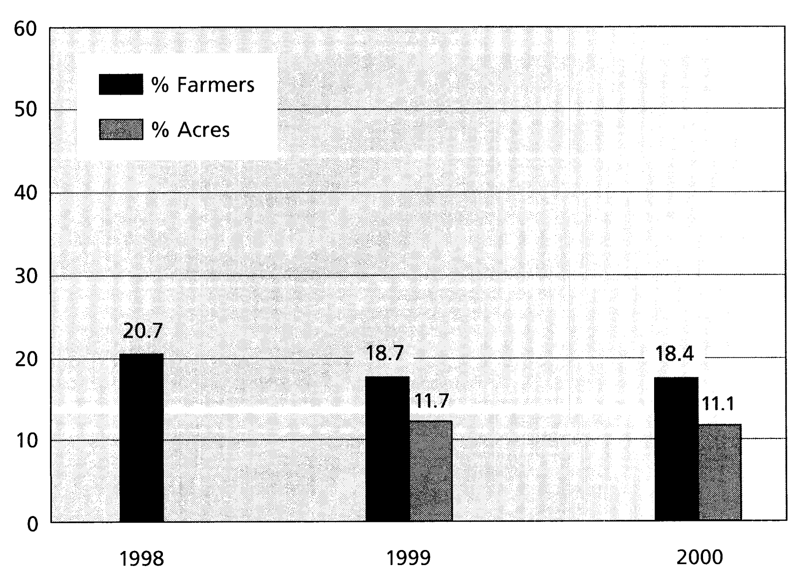
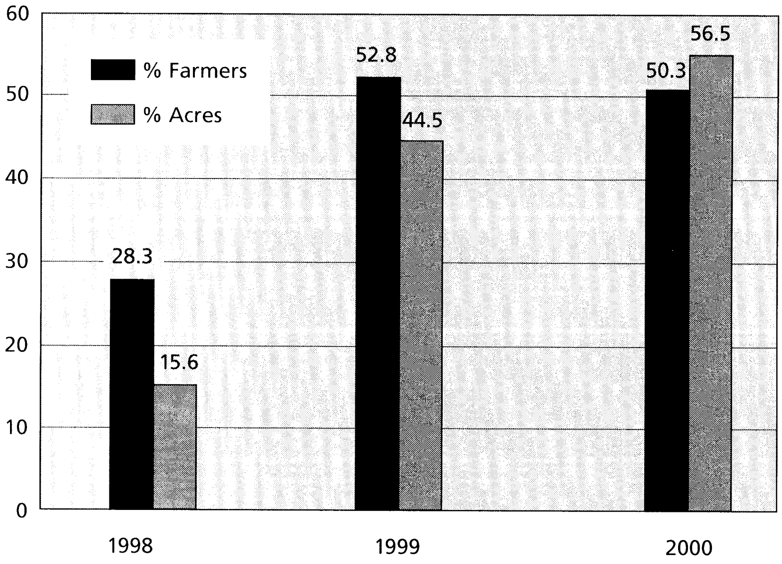


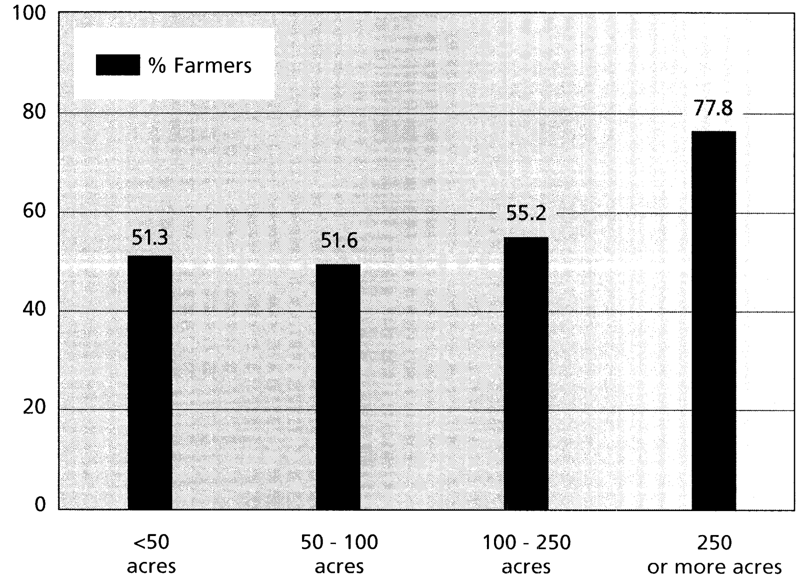
Figure 3
The Adoption of HT Soybeans among Wisconsin Soybean Producers



ed significantly. In particular, Bt corn adoption remained at around 18 percent of farms raising corn and 11 percent of corn acres. Meanwhile, HT soybean adoption fell slightly from 53 percent of farms raising soybeans to 50 percent, while the share of soybean acres accounted for by HT soybean varieties increased from 44.5 percent to 56.5 percent. This rather notable increase in acreage also underscores the size bias in HT soybean adoption illustrated in figure 4. Note that in 1999, whereas HT soybean adoption was around 50 percent on farms with less than 250 acres of soybeans planted, HT soybean adoption was about 78 percent on farms with more than 250 acres of soybeans planted. This size bias is notable but not nearly as strong as the case of rBST.

On the whole, then, 2000 did not give rise to a significant downturn in adoption or de-adoption of GMO crops as some had anticipated it might. That said, there is considerable turnover in adoption from one year to the next. Tables 3 and 4 provide transition data on farmers' decisions across two time periods. It is noteworthy that about

Figure 4
The Adoption of HT Soybeans by Size of Farm in 1999



20 to 25 percent of farmers who adopted one of these GMO crop varieties in 1999 did not use the variety again in 2000 and were replaced by new adopters. While the basis for this turnover is still being investigated, initial analyses suggest that those continuing with the crop report having had higher per-acre yields and profits and less labor effort than those who de-adopted. Relatedly, marketing concerns and uncertainties appear to be considerably less important to the de-adoption decisions than were crop performance variables. In 2001, as this article goes to press, marketing issues continue to appear to be secondary to farmers' adoption decisions relative to production experiences, though there is some evidence of those who choose not to adopt GMOs again being more concerned about marketing problems in the future. The fact that the majority of Wisconsin's GMO crops are destined for animal feed may help to explain what appear to be the rather small impacts so far of marketing concerns on producer GMO adoption decisions.

Table 3
Number and Percent of Bt Corn Adopters and Nonadopters in Wisconsin: 1999–2000

	Bt Corn in 1999 Yes	No
Bt Corn in 2000		
Yes	46	16
(Column %)	(76.7)	(6.3)
No	14	238
(Column %)	(23.3)	(93.7)
(Total %)	(100.0)	(100.0)

Lessons from Wisconsin and Looking Ahead

The experiences with rBST and GMO adoption in Wisconsin offer several important lessons to help guide public policy discussions regarding agricultural biotechnology. First is the fact that adoption patterns of agricultural biotechnology vary substantially. Only HT soybeans appear to be a "juggernaut" technology, where widespread adoption is occurring and perhaps transforming the performance of the sector. In the case of dairy farming, more than five years after the release of rBST, adoption is rather moderate and is having only small impacts on the sector's performance. Similarly, Bt corn appears to be on more of a rBST adoption track, stalling out at a relatively moderate level of adoption rather than becoming widely used and accepted.

Though consumer resistance may have played a decisive role in the early years of the rBST experience (giving rise as it did to a voluntary labeling scheme for fluid milk products), more recent evidence suggests that farm-level characteristics are also playing a crucial role in determining adoption outcomes. In particular, the potential importance of distinctive production systems should not be underestimated and may give rise to considerable heterogeneity in adoption patterns of technologies across similar types of agricultural enterprises. Again, in the case of dairy farming, rBST use is much higher on farms where a suite of other productivity-enhancing technologies are used and is lower where grazing-oriented production systems are in place.

Table 4
Number and Percent of HT Soybean Adopters and Nonadopters in Wisconsin: 1999–2000

	HT Soybean in 1999 Yes	No
HT Soybean in 2000		
Yes	57	15
(Column %)	(78.1)	(22.7)
No	16	51
(Column %)	(21.9)	(77.3)
(Total %)	(100.0)	(100.0)

Considerable size bias is evident in the adoption of these three agricultural biotechnologies, especially in the case of rBST. However, the reasons for this size bias may be related more to the overall management orientation and production system being used on the farm than to the inherent properties of the technologies themselves. Nonetheless, to those who argue that these technologies are scale neutral, the evidence from adoption patterns in Wisconsin does not support that contention at all.

The rapid pace of HT soybean adoption illustrates that future agbiotech innovations could sweep rapidly through the system. This experience suggests that a little more attention to up-front review and evaluation will probably not slow down greatly the realization of gains from highly productive new varieties and may save a lot of potential costs and risks for this type of technology in general. Although companies in a hurry to market their new agricultural biotechnologies may not like that advice, except as it applies to their competitors, it may well be that the old maxim holds true here in slightly modified form, that an ounce of precaution might be worth many bushels of returned grains.

Finally, the kind of regular, random-sample-based survey work that PATS undertakes to document the details of adoption patterns can reveal a lot about emerging technologies, the decisions being made by farmers, and hence the likely impacts of the agricultural biotechnology revolution on the economy and society. It would be especially useful if there were other similar programs or centers doing comparable studies in other states. Integrating the findings across different states would allow policy makers a much better picture of the agricultural biotechnology adoption story than current evidence provides. ▼▲▼

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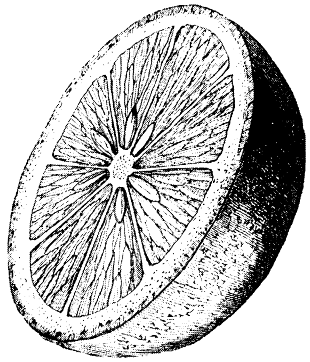
Don't Ask, Don't Tell: U.S. Policy on Labeling of Genetically Engineered Foods



Lydia Zepeda[1]

This paper was presented at the American Association for the Advancement of Science, San Francisco, California, 18 February 2001. It was subsequently presented at the Wisconsin Dietetic Association, Appleton, Wisconsin, 20 April 2001.

Many people assume that the U.S. Food and Drug Administration (FDA) says that *all* genetically engineered (GE) food is safe because it does not require premarket approval. However, the FDA's 1992 policy document identifies specific GE applications that pose potential human and animal health risks.[2] The document indicates that the burden of identifying and reporting potential problems is placed on the companies manufacturing GE products. The policy statement further recommends that manufacturers label foods with any of these potential risks.

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[1]The author notes that this paper does not reflect the views of the University of Wisconsin, where Lydia Zepeda is a professor in the Department of Consumer Science and director of the Center for Integrated Agricultural Systems. Dr. Zepeda would like to express gratitude to Colleen Curran for feedback on a draft of this paper. Any errors are entirely the responsibility of Dr. Zepeda.

[2]Among those cited by FDA scientists (Department of Health and Human Services, Food and Drug Administration 1992) were the transfer of genes from common allergens (milk, eggs, fish, crustacea, mollusks, tree nuts, wheat, and legumes), known toxicants (protease inhibitors, lectins, and cyanogenic glycosides), antibiotic resistance selectable markers (kanamycin resistance gene), and any change in nutrient or toxicant composition of plants that constitute a significant portion of domestic animals' diet (e.g., field corn).

Subsequent investigations by the Environmental Protection Agency (EPA) (Anderson and Milewski 1999), Health Canada, the European Commission, and others have confirmed or broadened the specific health risks identified in the FDA policy statement. This, along with such controversies as human consumption of Starlink corn, has led to criticism of self-enforcement. In response, the FDA has proposed a revision in its policy that will require premarket review 120 days prior to release of all new GE food and animal feeds.

In contrast to the United States, the European Community (EC) has had a moratorium, recently lifted, on approval of GE food. The proposed legislation had strict labeling and tracing requirements for *all* food with GE ingredients. Individual countries such as Japan, Korea, Australia, and New Zealand have also enacted legislation requiring labels for GE food. Thailand has temporarily banned imports of GE seed. These countries have been buying about 43 percent of U.S. agricultural exports. It is estimated that U.S. farmers lost $300 million in overseas sales in 1999 due to GE corn alone.

Given that some health risks are associated with specific GE applications; that a growing number of major trade partners and competitors, as well as a United Nations agreement, require labeling; and that most U.S. consumers favor labeling, the big policy issue in the United States is not whether labeling will take place. The real questions are how and when, and whether labeling will apply only to the export market.

Consumers Want Labels

Most surveys indicate a high proportion (82 to 93 percent) of U.S. consumers want GE food labeled.[3] Support for labeling is so overwhelming that the Secretary of Agriculture has hinted at being more open to the idea. Outside the United States, support for labeling is high as well: 74 percent in the EC, 80 percent in Australia, 92 percent in the United Kingdom, and 98 percent in Canada (Consumers Union 1999).

That most consumers would use labels to make purchase decisions, whether ver-

[3]In a very long question regarding FDA policy, a 1999 International Food Information Council survey found that 58 percent of those surveyed favored the FDA labeling policy. The question is somewhat confusing since it seems to imply that the FDA does not support labeling under any circumstances, which contradicts the FDA's policy document (Consumers Union 1999).

ifiable or not, is probably unlikely.[4] This does not mean that labels would not have an impact. Apart from making it possible to trace any potential problems, labels by themselves serve to reduce the perception of risks associated with GE food. Consumers can choose to incorporate the label information in their buying decision, or not. More importantly, it permits informed consent, that is, it transforms risk perceptions from being "involuntary" to "voluntary" (Thompson 1996). Theoretically and empirically, this reduces the perception of risk. A recent study demonstrated that availability of labels reduces risk perceptions toward GE food (Zepeda, Douthitt, and You, in press), irrespective of whether people act on the information.

Voluntary Labeling: Consumers with Money Will Get What They Want

Voluntary labeling in the United States permits access to GE-free food for some products, generally at a higher price. Voluntary labeling has been exclusively linked to "GE-free" labels. Individual manufacturers of foods with GE ingredients have no incentive to label their products voluntarily given public perceptions about GE food. Collectively, if all manufacturers labeled their products, risk perceptions would decline because involuntary risk exposure would be eliminated.

Agriculture has had a notoriously difficult time finding ways for farmers to capture value-added or to differentiate products. GE-free food is a case where a niche has been created not only at the retail level but also at the farm level. Farmers producing for the export market have already felt the downside of producing unwanted products. The cost savings of pesticide applications due to using *Bacillus thuringiensis* (Bt) corn are estimated to be between $2.80 and $14.50 per acre (Carlson, Marra, and Hubbell 1997). However, given the acres planted to Bt corn in 1999 this was more than offset by the estimated loss to farmers of $300 million in overseas sales attributed to unwanted GE corn. Farmers themselves, concerned about loss of markets at home and abroad, have reduced their use of GE crops. In 1999 about 33 percent of all corn acreage was GE; in 2000 it dropped to 19.5 percent.

[4]While for some GE foods labels might be difficult to verify, cheap tests ($5.75) are available for some foods (Bett 1999). The demand for developing such tests has spurred a growing industry.

In the United States, the definition of organic excludes GE ingredients. Organic sales have climbed, driven in large part by the demand for GE-free food. For example, organic milk sales were up 72 percent in 2000. The demand for organic soybeans in the United States is so high that we are importing them from China, one of our largest export markets for commodity soybeans. The net returns per acre of organic soybeans run about a third higher than for commodity soybeans. A study of Midwestern grain and soybean production found that many organic crops were profitable without any price premiums and for those that were not, the current price premiums exceeded break-even premiums (Welsh 1999). Organic prices are running about 75 percent above commodity prices for soybeans and corn.

U.S. food manufacturers are using voluntary GE-free labels to increase sales or prevent loss of sales due to consumer concerns about GE foods. Individual companies (Nestle, Gerber, Heinz, FritoLay, McDonald's, and Iams) have banned all GE ingredients in some food lines, particularly those consumed by babies, children, and pets (Bett 1999).

That voluntary labeling is concentrated in baby and pet foods is entirely consistent with risk theory. Involuntary risk exposure has been shown to increase the perception of risk (Starr 1969; Fischoff et al. 1978). Thus, adult caregivers are more cautious about exposing others to risks, particularly those who cannot make a choice for themselves, such as children and pets.

Mandatory Labeling: Wording Affects Who Pays and How Much

Effective labeling hinges on the existence of four factors: standards, testing, certification, and enforcement. If all four factors are not in place, it leads to confusion and expense. StarLink corn is an example of such an outcome. Bags of the seed were labeled "not for human consumption." However, there was no testing, certification, or enforcement, which led to the corn being mingled with corn directed to products for human consumption. The estimated value of the StarLink crop was only $68 million; however, its manufacturer, Aventis, set aside $92 million to buy the corn, and it is likely the cost will eventually be much higher. Three separate class-action suits in Nebraska, Iowa, and Illinois have been filed by farmers who claim they incurred losses due to their corn being contaminated or commingled with StarLink corn.

Existing labeling laws abroad and those proposed at both state and federal levels in the United States vary in label wording and implementation. In some cases, animal feeds and products in which it is difficult to verify genetic material, such as oil, are exempt. Because corn and soybeans are largely used for animal feed or oil and are also the primary GE crops, such exemptions imply that the legislation would have little impact.

The two phrases "contains GE ingredients" and "may contain GE ingredients" seem only subtly different, but these differences affect monitoring costs as well as who pays them. The first implies that ingredients are tracked or tested, processes that result in additional costs for anyone involved in growing, selling, or using GE crops. Use of the label "may contain GE ingredients" could eliminate monitoring costs for this group. The presumption would be that some ingredients probably are genetically modified, but if using such a label, one would not need to track, and indeed in some cases all of the ingredients might be GE-free. Because it would require no verification, the only additional cost is the trivial cost of the label itself.

Such subtle differences in wording shift the burden of the cost. In the former case, the direct cost of separation and monitoring is placed on producers, exporters, and processors of GE crops. In the latter case, the burden of separation and monitoring is placed on producers, exporters, and processors of GE-free crops. This cost would be recouped through charging a premium for GE-free food, or perhaps by increasing market share, or both. Clearly under mandatory "may contain GE ingredients" legislation no one would voluntarily label their product "GE-free" unless they expected to recover the cost of verifying that it is free of GE ingredients.

While commodity prices have remained low, the demand and premium for organic products (the best approximation for GE-free) have remained strong. Presumably this would provide incentives to shift to GE-free production and price convergence. How fast prices converge depends ultimately on demand and supply response. However, some farmers may not be able to obtain a premium for GE-free crops if there is no local buyer.

The imposition of mandatory labeling in much of the rest of the developed world and in a recent UN proposal (Codex Committee on Food Labelling, 2001) indicate that labeling of U.S. food exports is inevitable to maintain markets. What is unclear is whether it will extend to the entire domestic market and the form the wording of the label will take. Also, will there be a threshold level of GE content, and what might it be? What products might be exempt? Would labels such as organic, biologique, parve, kosher, and vegan be excluded from a GE label? Given the important role exports play in U.S. agriculture, these details are extremely important. Developing a coordinated set of international standards is vital to reduce information costs and send clear signals to farmers. Even if mandatory labeling is not implemented in the domestic market, the United States has an interest in coordinating international standards to ensure overseas markets for U.S. goods.

Opposition to Labeling: Follow the Money

Consumers clearly state they want labels. The proliferation of voluntary GE-free labels indicates that there is a market for such goods. So why is there opposition to labeling? Manufacturers of GE foods are not necessarily acting solely to avoid the direct cost of labeling, but they wish to avoid the potentially greater cost of liability. Under mandatory labeling, because all companies would bear the direct cost of labeling, they could pass it on to the consumers (which consumers bear that cost depends on the type of label, as discussed earlier). Liability costs, on the other hand, generally affect a single company, making it difficult for them to pass the costs on to consumers without becoming uncompetitive.

Fueling these liability concerns are insurance underwriters who either want compensation for underwriting the risk of GE food or wish to shift liability. In Latin America, insurers exclude GE crops from basic insurance policies, charging a special premium to cover them. Indeed, some insurance underwriters refuse to insure biotech firms against potential risks of GE food *at any cost*. Zurich-based Swiss Re, one of the largest international reinsurance companies, refuses to insure *any* risks associated with GE food.

Clearly, liability exposure would be reduced without mandatory labeling. A plaintiff would have a difficult time demonstrating that he had consumed GE food.

Indeed, the British Medical Association, representing over 80 percent of all British physicians, advocates mandatory labeling for the sole reason that it would be easier to identify, trace, and verify problems should they occur (Weiss 1999). Even the wording of the label ("may contain" versus "contains" GE foods) might make it difficult for the plaintiff to prove exposure to GE foods. This is quite apart from demonstrating that exposure to the particular GE ingredient caused harm. In other words, a plaintiff could convince a jury that the substance causes harm but still could lose the case because she is unable to demonstrate that she was exposed to it.

Minimizing liability exposure would explain why efforts to block labeling are concentrated in the litigious United States as opposed to Europe and Asia. Personal injury lawsuits in Europe and Asia are infrequent compared to those in the United States because they are costlier, drag on longer, and rarely result in the level of damages that occur in this country.

Another factor influencing the incentives to label is the distribution of where GE crops are grown. They are predominantly grown in the United States. Worldwide, the United States represents about 74 percent of all GE acreage. Argentina represents about 15 percent, Canada 10 percent, and the rest of the world 1 percent (*Biodemocracy News 2000*).

Conclusions

Human and animal health risks have been identified for only some specific applications of GE crops and are recognized in the 1992 FDA policy document on GE food. Despite this, the policy debate, analysis, legislation, and consumer opinion tend to treat all GE food the same. Indeed, some of our major trading partners and competitors have implemented mandatory labeling of GE food, resulting in lost export sales of U.S. agricultural products. The implication in the United States is that some form of labeling will be necessary for at least some export crops to avoid jeopardizing further sales.

The details of any labeling policy or legislation remain to be worked out, such as threshold levels, overlap or mutual exclusivity regarding other label names, and, most importantly, compatible international standards for labels. The wording and the implementation of any label will greatly affect how much it will cost and who pays for it. Mandatory "may contain GE ingredients" would be much less costly than mandatory "contains GE ingredients" because the latter would require monitoring, testing, or tracking of ingredients whereas the former would not. However, there is already a small and growing market in the United States for voluntarily labeled GE-free products. The purchasers of these products currently bear the costs.

Biotech firms have a strong incentive to oppose any kind of labeling in the litigious United States to minimize their liability exposure. Insurers have increased this incentive by charging extra premiums or refusing to insure at any price. Absence of labels reduces the ability of a potential plaintiff to easily trace consumption of GE food.

Currently, three policy alternatives for GE food labels are being pursued in the US:

1. *Laissez-faire*. Let the market for voluntarily labeled GE-free products evolve.
2. *Build on the 1992 FDA policy recommendations*. Develop explicit procedures and requirements for testing, reporting, and labeling of risky applications.
3. *Labeling legislation*. This is currently proposed in Congress and various state legislatures.

Voluntary GE-free labels are likely to continue even if labeling legislation passes in the United States because such legislation is directed at foods containing GE ingredients. Relatively cheap tests exist to verify the presence of many GE ingredients, and currently the market for GE-free food is profitable.

Domestically, if the laissez-faire policy is the only policy option pursued, it is likely to be criticized as elitist, since it provides choice only to those with money. Particularly if the price differential continues to be large for GE-free food, the poor would be unable to avoid GE foods even if they wished to. Given income distribution in the United States, it would not be long before such a policy would be criticized as one that disadvantages people of color. Not only do they earn less than Caucasians, but they also have a higher prevalence of food-related illnesses and allergies, and tend to have diets heavy in foods that happen to be GE crops.

The second and third options are being proposed in the United States. The FDA has proposed modifications in its GE food policy that would require premarket approval of any new GE food. It affirmed its opposition to mandatory labeling; however, it has provided some guidelines on voluntary labeling. Mandatory labeling legislation has been proposed in Congress and in several state legislatures. For both the second and third options, the details of the wording and implementation will determine who pays and how much they pay. However, the second option does not address the need to develop internationally recognized label standards to facilitate export sales.

Given that labeling legislation already exists outside the United States, it appears to be in our economic interest to have internationally uniform and clear standards. Without them, U.S. farmers will not have clear demand signals and will continue to lose export markets. The current policy disadvantages U.S. farmers and does not serve U.S. economic interests to maintain export markets for U.S. agricultural products. This would argue for having a uniform domestic labeling policy that coincides with internationally accepted standards, even if it applies only to our export products. ▼▲▼

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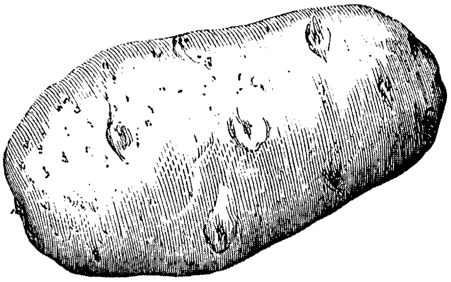
Off the Farm: Transportation, Storage, and Handling Issues



John Petty

I recently heard a radio commentator state, when questioned as to what to do regarding genetically modified organisms (GMOs), "The simplest answer is to label everything." This statement assumes a great deal of infrastructure and procedures in grain handling that currently, by and large, don't exist. To the uninformed, "label everything" may seem like a quick fix—that is, until we think about the changes such a policy would require.

First, a little history. The current grain-handling system was developed over many years as the most efficient and economical system to gather, store, and transport a fungible commodity. Most grain handlers dealt with two or three different commodities at most. Why? Because it was the most efficient method for them. They had less need for the separate storage bins that would be necessary for multiple commodities, and existing space could be used to maximum efficiency. To paraphrase Gertrude Stein, corn was corn was corn.

If GMO crops were to be labeled, what type of grain-handling system would be necessary? Within the United States there exist two parallel handling systems—one for handling human food grade commodities, and the other for handling animal feed or industrial-use commodities. These parallel systems are not perfectly segregated, and latitude exists in the segregation based on the type of human usage for which the commodity will be processed. For example, corn that is going into cornflake production for breakfast cereal is graded much more stringently than corn going into high-fructose corn syrup (HFCS). Obviously, corn destined for HFCS will be processed much more heavily than corn for cornflakes. Both are perfectly safe for human consumption, but eliminating broken kernels and moisture content is not as critical to HFCS production as it is to cornflake production.

That said, if labeling is mandated, identity preservation is required. And identity preservation means segregation of GMO crops from non-GMO crops in the storage, handling, and transportation of the commodities. This means that every grain handler in the country might have to instantly double the number of commodities they currently handle—that is, they would handle a GMO and a non-GMO version of each commodity. Because of identity preservation, these two versions are viewed (and handled) as separate, distinct commodities. Before GMO, the worst thing that a grain dealer could do was mix two commodities, typically corn and soybeans. The commodity mistakenly put in the wrong storage bin instantly becomes what is known in the trade as *foreign material*. And because there is no economical method of separating the two commodities, the commodity that now contains foreign material has its percentage weight, as determined by sample testing, deducted from the volume of the whole. The net effect is that the grain handler or producer loses the value of the commodity that was dumped into the other commodity's storage bin. Under identity preservation, you wouldn't simply have a commingled commodity—you'd now have a different commodity. And that commodity would have the value of the GMO-grade commodity.

Simple segregation is not as simple as keeping each commodity in its proper bin. Seed companies concede that their non-GMO-labeled seed may contain GMO germ plasm. Cross-pollination can occur in corn when pollen is moved by insects or the wind. Most pollen will fall within 50 feet of its source, and USDA guidelines require buffers of 660 feet around GMO-planted fields to keep pollen drift to a minimum. However, I know of reports here in Wisconsin of corn pollen traveling over a mile and a half. Even if the producer gets a GMO-free seed and experiences no pollen drift, commingling can occur at every step in which the commodity is handled. Planters, harvesting equipment, storage bins, and transportation equipment may have been used to handle a GMO product and were not thoroughly cleaned. A single kernel is enough to change a labeled non-GMO quantity to GMO-positive.

Because so many chances for commingling exist, testing should and will have to be done at every step where the commodity changes hands. But there are problems with testing, too. Currently, there is no quick, inexpensive spot test available to test for any and all GMOs. There do exist "quick tests" that take about five minutes and test for *one* single type of GMO. In this case, if you don't have the right test for the right GMO, your test comes up negative. In order to test a sample for most GMOs, a test costing about $350 that takes two to three days for results to be reported is available. Obviously, use of this test is problematic when a grain handler is faced with truckloads of producer grain waiting to unload at a facility. Also, not all GMO crops express their trait in the seed. Some have the trait *only* in the vegetative parts of the plant, so testing the harvested kernels would yield a negative test even though the plant is definitely GMO.

Another problem with any test is the quality of the sample. If a sample isn't representative of the whole, the best test methodology and equipment are worthless and the test itself is called into question. Also, there is currently no available nondestructive test; it is impossible to give complete assurance that a particular quantity is 100 percent non-GMO because by definition, one cannot test every single kernel.

Given the problems and uncertainties of testing, the industry will likely impose a system of warranty conditions on each seller in the line of transactions. This means each seller will be liable for the product they sell if it proves not to match their provided product description. If you wish to see a vision of the future, I ask you only to monitor the news stories concerning the legal battles resulting from the StarLink™ fiasco. In that situation, the StarLink™ hybrid was the only GMO corn not approved for both human and animal consumption. StarLink™ corn eventually was found in several brands of taco shells and resulted in nationwide recalls of the products. All of the affected corn flour was traced to one mill in Texas. In order to keep StarLink™ out of human food channels, Aventis, the company that registered StarLink™, and the U.S. Department of Agriculture agreed to develop plans under which the Commodity Credit Corporation would purchase StarLink™ corn at a cost into the multimillions of dollars. In addition, various food companies that were affected by the recalls sued Aventis. The only definite point that we know now is the USDA's statement that a single market approval of a GMO variety will *never* be allowed again.

So this is where we came in. "Label everything" is not the simplest solution. Labeling advocates must first understand a couple of concepts before we are able to move forward. First, realistic, allowable tolerances must be set to account for adventitious presence of GMO. As an example, the U.S. Food and Drug Administration (FDA) currently allows labels to read "fat-free" or "sodium-free." Does this mean there is 0.0 percent fat or sodium in those products? No, it does not. The FDA allows for a minimal tolerance level while still maintaining the "-free" label. Second, there will be costs involved in expanding the grain-handling infrastructure. These costs will be borne by people at one end or the other of the production/consumption chain. If consumers are willing to pay a premium for non-GMO products over the long term, identity preservation procedures and infrastructure plans will begin developing tomorrow morning. If consumers are not willing to pay a premium for non-GMO products and labeling is required, the costs will be shifted to producers. Given the current state of low prices and a weak agricultural economy, will this alternative be palatable? Either way, "label everything" is not the simple answer some would like to believe it is.

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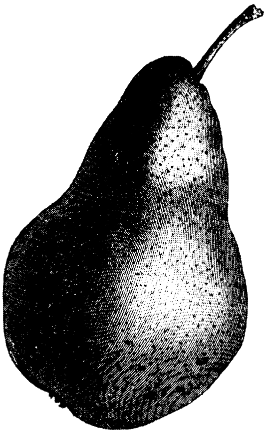
University Ownership of Patents: The Bayh-Dole Act and Using Patents for the Public Good



Carl E. Gulbrandsen and Howard W. Bremer

In the university community there has long been a dichotomy with regard to whether universities should own patents and engage in licensing (technology transfer in today's parlance). Pertinent to the opposing views in that dichotomy are three questions:

1. Does patent ownership positively serve or subvert the university's mission?
2. Does patent ownership frustrate or encourage creativity in the university setting?
3. Does patent ownership by the university serve the public good?

An additional, broader question might also be posed:

4. Do the results of university research benefit national industries?

What Is the Bayh-Dole Act?

The Bayh-Dole Act was a seminal piece of legislation that is as pertinent and viable today as when it was signed into law in 1980. Its terms and provisions indicated, after many years of advocacy, that Congress had finally recognized that

1. imagination and creativity are truly a national resource;
2. the patent system is the vehicle that permits the delivery of that resource to the public for its use and benefit;
3. placing the stewardship of the results of basic research in the hands of universities and small businesses is in the public interest; and most significantly,
4. the pre-existing nonuniform federal patent policy was placing the United States's role as a technological and economic leader in peril at a time when invention and innovation were becoming the preferred currency in foreign affairs.

This recognition is clearly enunciated in the policy and objective section of the statute itself.

> **35 U.S.C. 200 Policy and Objective**
>
> It is the policy and objective of the Congress to use the patent system to promote the utilization of inventions arising from federally supported research or development; to encourage maximum participation of small business firms in federally supported research and development efforts; to promote collaboration between commercial concerns and nonprofit organizations, including universities; to ensure the inventions made by nonprofit organizations and small business firms are used in a manner to promote free competition and enterprise; to promote the commercialization and public availability of inventions made in the United States by United States industry and labor; to ensure that the Government obtains sufficient rights in federally supported inventions to meet the needs of the Government and protect the public against nonuse or unreasonable use of inventions; and to minimize the costs of administering policies in this area.

Of great significance to the universities and other nonprofit institutions as well as small businesses, to which the statute is directed, it changed the presumption of ownership of any invention made by those entities utilizing federally supplied funds from the government to those entities. That change presaged a new and expanding relationship between the universities and industry because it assured industry that certainty of title to the invention lay with the universities.

The original Bayh-Dole Act, enacted as Public Law 96-517, was later amended by Public Law 98-620 in 1984, which removed many of the politically expedient restrictions that were in the original act. The amended act is now part of the *United States Code* and may be found at 35 U.S.C. 200-212. Its implementing regulations are found in the *Code of Federal Regulations* at 37C.F.R. part 401.

The codified act still contains a preference for U.S. industry as well as a preference for small business, with the latter preference undoubtedly arising from the recognition that small businesses create the bulk of new jobs. As for the nonprofit sector, there is a prohibition against assigning rights to an invention created in whole or in part with federally supplied funds without the permission of the government (except that such assignment may be made to an entity that has, as one of its primary functions, the management of inventions). There is also a requirement to share royalties generated on an invention with the inventor and to use the balance of royalties, after expenses, for support of scientific research or education.

In all cases the government retains a royalty-free, nonexclusive license to practice the inventions for governmental purposes and also reserves march-in rights in the event of abuse or when the contractor (university or small business) has not taken effective steps toward practical application of the invention, or the invention is necessary to alleviate health or safety needs not satisfied by the contractor or its license.

The passage of the Bayh-Dole Act may be viewed as the ultimate culmination of a Wisconsin Idea that began with Professor Harry Steenbock and the formation of the Wisconsin Alumni Research Foundation (WARF) in 1925. Professor Steenbock's vision was to develop a plan to make use of patentable inventions generated by the faculty that would

1. protect the individual taking out the patent,
2. insure proper use of the patents, and at the same time
3. bring financial help to the university to further its research effort.

Subsequent efforts by and on behalf of the University of Wisconsin and WARF led to the first breakthrough on reversal of the policy that most government agencies had adopted, which was to take title to all inventions made in whole or in part with federal funds. Under that title policy, the government held title to some 30,000 patents, fewer than 5 percent of which were even licensed for commercialization, and fewer than 1 percent of which found their way into the marketplace.

The breakthroughs represented by the first new institutional patent agreement with the Department of Health, Education and Welfare in 1968 and an agreement with the National Science Foundation in 1973 (the first such agreement issued by that foundation) were highly significant milestones on the road to ultimate negotiation and passage of the Bayh-Dole Act. One might, in fact, view the act as a codification of the terms and provisions of the institutional patent agreements.

Benefits of the Bayh-Dole Act

The benefits the university sector derived from the Bayh-Dole Act are numerous and far-reaching. The number of patents issued to universities has increased dramatically so that of all U.S. patents, the university sector now receives about 3 percent. Moreover, those patents, since they arise primarily from the results of basic research, can often afford the basis for whole new products or even industries, as in, for example, the biotechnology industry. The certainty of title in the universities has permitted a closer relationship with industry. That certainty of title also provides the assurance that the underlying research cannot be frustrated because the rights are given away to industry. There is an opportunity to share in the commercial success of a licensed invention, and in particular an opportunity and basis for start-up companies based on basic research observations and results are provided.

At the same time, university-owned patents protect academic freedom to conduct research. Incentive is provided inventors in that they share in any royalties generated. Any excess over the inventor's share and expenses are utilized to support further research or education. Patents, when issued (or, now, when published as applications), comprise a form of scientific publication for the inventor and therefore contribute to an inventor's scientific recognition in the university community. Through responsible licensing arrangements, university-owned patents serve the public interest by guarding against abuse.

With regard to serving the public interest, in 1980, the same year in which the Bayh-Dole Act was passed, a Supreme Court decision had far-reaching consequences and effect on the patent system as well as on the patenting of "living" things (*Diamond, Commissioner of Patents and Trademarks v. Chakrabarty,* 206 USPQ 193). The essence of the decision was that merely because something was alive (in this case, a bacterium) it was not disqualified from being patentable subject matter—to paraphrase the court's ruling, it considered that "anything under the sun in which the hand of man had intervened" was patentable. This opened the door to the patenting of many life forms and provided the fundamental basis for the biotechnology industry. It also ultimately led to the ability to obtain a utility-type patent on genetically modified organism (GMO) plant products as well as other genetically modified life forms, with the exception of humans.

Patents Serve the Public Good

University-owned patents serve the public good by offering a means to control the irresponsible application of the patented technology. One should not, however, equate such type of control with monopoly. A patent gives the right to exclude others from practicing the invention claimed in the patent document itself. It does not convey an absolute right to practice the invention claimed. There may be other extant patents that may dominate the claimed invention. Thus to practice the claimed invention, a license under the dominant patents would also be required.

Further, the right to exclude others from practicing the invention of a patent extends for a limited time, after which anyone having a desire to practice the invention is free to do so. This was the compromise reached in establishing the constitutional authority for the U.S. patent system. Thus, after patent expiration the invention becomes part of the pool of scientific knowledge available for others to use.

In addition, the protection patents offer, namely, the right to exclude others from practicing the claimed invention, is a strong inducement for the patent holder or its licensee to expend the risk money necessary to develop a given invention for the marketplace. Because the bulk of university-generated inventions arise during the course of basic research, they tend to be embryonic in nature, requiring substantial investment in technical development for commercial application. Also, market development needs to be addressed after technical development has been achieved. The latter two activities, technical development and market development, are generally recognized as requiring substantially more money than the making of the invention itself (although the cost assessment of an invention generally ignores the cost of bringing the inventor to the state of mental preparedness for making the invention).

Before Professor Steenbock's formation of WARF, others at the University of Wisconsin had experienced the pitfalls of not protecting the public through the patent systems. Around 1890, Professor Stephen Babcock at the University of Wisconsin had developed a test and centrifugal machine for determining the butterfat content of milk. He did not seek a patent but merely published his invention, in effect abandoning it to commercial interests. The result was that without the university's ability to exercise control of commercial development for widespread use, commercial development efforts were at best uneven and lacked standardization. In fact, some of the centrifugal machines marketed for conducting the test were so shoddily constructed that they posed a hazard to users. These facts supported the proposition that a patent on an invention that gave the inventor some control over its commercialization seemed appropriate and in the public interest.

University-owned patents in the rapidly expanding field of GMO products may be highly beneficial for the public good. The university researcher has the opportunity to seek the answer to open-ended basic questions, and university-owned patents can help assure that that opportunity remains available. In contrast, industry may not have that luxury, being driven primarily by a product orientation—despite government requirements to test GMO products before their introduction into the marketplace.

These considerations were of vital importance with regard to a particular discovery at the University of Wisconsin–Madison (technology developed by Jerry Kermicle in 1999), and the kind of protection, if any, that should be sought on it. The discovery involved a traditionally bred cross-pollination barrier for corn. With mere publication of the discovery and release of the germ plasm, it could be used by anyone for any purpose, including the preparation of GMO products, in which case the projected special utility of the invention—the value of the technology—would likely be destroyed. If the plant variety protection (PVP), without more, had been sought, again the special utility of the discovery may have been lost because PVP allows free breeding. Seeking utility patents on the discovery was chosen as the mode of protection. This type of patent permitted prohibition of the germ plasm's use in GMO corn while promoting its use as a barrier against convection pollination from GMO cornfields to non-GMO cornfields, since the barrier would prevent pollination by GMO corn pollen. Thus, the patent system gave the means by which both GMO growers and non-GMO growers could be accommodated while permitting the public interest in both kinds of crops to be served.

The University of Wisconsin-Madison and the Wisconsin Alumni Research Foundation

The mission of the university is to discover and transmit knowledge and provide service to the public. WARF enhances those endeavors of and by the university through the management of the intellectual property discovered or developed at the university to support research at the university, and by moving inventions and discoveries resulting from university research to the marketplace for the benefit of the university, the inventor or discoverer, and society as a whole.

WARF was established in 1925 based upon the vision of Professor Harry Steenbock, who had discovered and filed patent applications on a method for producing vitamin D in food and drugs by exposing them to ultraviolet radiation. Professor Steenbock offered his patents to the university but the university declined to accept them. He then envisioned, as opposed to selling his right to a commercial entity, that whatever patents might issue from his applications should be administered and regulated in the public interest by an entity independent of and separate from the university. The fruition of his vision was the formation of WARF as a tax-exempt, not-for-profit corporation to administer inventions made at the university and voluntarily brought to WARF by the inventors. Even today, submission of inventions to WARF by university employees (faculty, staff, and students) is voluntary, since the university does not assert any right to title of inventions made on or in association with its campus. The exception to this position is that for any inventions made in whole or in part with federal funds, the university as the contractor may in the first instance elect to retain title in accord with the terms and provisions of the Bayh-Dole Act. The university has officially designated WARF as its intellectual property manager under that act.

In the year 2000, WARF celebrated its seventy-fifth year in its role as manager of intellectual property on behalf of the university through the patenting and licensing of technology generated at the university to the private sector. That WARF has been an unqualified success in that activity is clear from WARF's consistent position among the top five or ten universities engaged in technology transfer in the United States as measured by its royalty income. With regard to the number of life-saving and other inventions that have contributed to the betterment of the health, welfare, and safety of the public, it is firmly believed that WARF has no peer. Many such inventions generated at the university are still being practiced today, long after the royalty flow from them has ceased, and therefore are still contributing immeasurably to the public benefit.

As a result of WARF's technology-transfer activities and because of the foresight, policies, and management of its trustees, WARF's contributions to the university have been highly significant and have been instrumental in establishing and maintaining the University of Wisconsin as one of the world's premier universities.

Conclusion

Federal support for research in the university sector is essential to the technological leadership of the United States in a global economy. Every indication exists that this

WARF's total grants and commitment to the university since its first grant of $1,200 was made in 1928 through June 30, 2001, are as follows:

General research grants	$400,000,000
Buildings, land, major equipment	60,000,000
BioStar building initiative	80,000,000
Other	80,000,000
	$620,000,000

is a recognized fact, evidenced by that sector's leadership in performing the bulk of basic research in the country. Protection of the intellectual property generated during the course of that research and transfer of the technology that it represents for public use and benefit is viewed as an obligation under the Bayh-Dole Act. The university sector has responded to both the opportunities and the obligations presented by the act, and its performance has reinforced the following perceptions:

1. University-owned patents encourage innovation by providing an incentive to inventors and facilitating publication.
2. University-owned patents support the research function in the university sector by protecting academic freedom to conduct the research; generating royalty income; providing further support for research; and providing an incentive to the researchers.
3. University-owned patents serve the public good by guarding against abuse by irresponsible parties and insuring the opportunity to maximize the transfer of technology that is developed during the course of research conducted at the university in the interests of the health, safety, and welfare of the public.

Howard W. Bremer is currently affiliated with the Wisconsin Alumni Research Foundation (WARF) in a consulting capacity. He served as patent counsel to WARF from 1960-1988. He holds degrees in chemical engineering and law from the University of Wisconsin–Madison.

Carl E. Gulbrandsen has been the managing director of the Wisconsin Alumni Research Foundation (WARF) since January 2000. Prior to that he was the director of patents and licensing and in private law practice. Gulbrandsen received his B.A. from St. Olaf College, Northfield, Minnesota; his PhD degree in physiology from the University of Wisconsin–Madison; and his J.D. degree from the University of Wisconsin Law School.

Appendix

Fall Forum 2000 Agenda

8:30 Welcome Address

Mary Lynne Donohue—Wisconsin Academy Council President

Ben Brancel—Secretary of the Wisconsin Department of Agriculture, Trade and Consumer Protection

Morning Plenary: Overview and Perspective

Philipp Simon—Professor of Horticulture,
University of Wisconsin–Madison
Genetic Modification of Plants: Progress, Processes, and Products

Jeffrey Burkhardt—Professor of Ethics and Policy,
Institute of Food and Agricultural Sciences, University of Florida
The Roles of Differing Ethical Paradigms in Determining the Acceptability of GMOs/GM Foods

10:00 Concurrent Discussion Sessions

I. Farming: Conventional to Organic

Bradford L. Barham—Professor,
Agriculture and Applied Economics, UW–Madison
Adoption Patterns of Agricultural Biotechnology by Wisconsin Farmers: Recent Evidence

Gary Goldberg—CEO, American Corn Growers Foundation
Genetically Modified Crops and the American Farmer: Matching the Rhetoric With the Realities

Steve Pincus—Organic Farmer, Tipi Organic Produce, Fitchburg
Risks, Rewards, & Realities: An Organic Farmer's Perspective

Facilitated by Bradford L. Barham

II. International Dimension: Trade, Technology, World Needs

Lori P. Knowles—Associate for Law and Bioethics,
The Hastings Center, Garrison, New York
Patenting Life: Preserving Biodiversity and Justice in International Trade

Richard Manning—Environmental Writer
Food's Frontier: The Next Green Revolution

Mark Ritchie—President,
Institute for Agriculture and Trade Policy, Minneapolis
International Trade Issues

Facilitated by Karl Nichols, Research Scientist,
Third Wave Technologies, Madison

III. Environmental Benefits/Concerns

Bob Giblin—Morgan & Myers, Public Relations Firm in Jefferson
Biotech Public Relations: Art and Science

John Kaufmann—Science Fellow and Agronomist,
Monsanto Company, Middleton
Ecological Assessment of Biotech Crops

Frederick Kirschenmann—Director,
Leopold Center for Sustainable Agriculture, Iowa State University
Genetic Engineering in Agriculture: Some Underlying Questions

Michelle Miller—Pesticide Use and Risk Reduction Project,
UW Center for Integrated Ag Systems
GE Food, Pesticides, and the Environment: Issues for Developing Public Policy

Facilitated by Craig Trumbo, Professor,
Life Sciences Communication, UW–Madison

IV. Seed to Store

M. Troy Flanagan—Grocery Manufacturers of America
Biotechnology in the Real World

Hemanth Shenoi—Product Manager in Molecular Diagnostics,
Promega Corporation
Methods for GMO Detection: How Do We Determine What's In What We Eat?

John Petty—Executive Director, Wisconsin Agri-Service Association:
Off the Farm: Transportation, Storage and Handling Issues

Facilitated by Frederick H. Buttel, Chair, Rural Sociology, UW–Madison

V. Corporate vs. Public Ownership of Technology and Crops

Kristin Dawkins—VP for International Programs,
Institute for Agriculture and Trade Policy
Ownership of Life: When Patents and Values Clash

Carl E. Gulbrandsen—Managing Director, Wisconsin Alumni Research Foundation
University Ownership of Patents: The Bayh-Dole Act and Using Patents for the Public Good

Charles Sara—Partner and Chair of the Intellectual Property Practice Group, DeWitt Ross & Stevens, S.C.
The Private Side of Patent Ownership: The Risks, Rewards and Realities of Intellectual Property Ownership from a Private Business Perspective

Facilitated by Elizabeth Bird, Outreach Specialist, UW Center for Integrated Ag Systems

12:00 Luncheon

Daniel Charles—Science Writer
The Story Is Mightier Than the Data: Instructive Tales From the Brief History of Genetically Modified Crops

1:30 Afternoon Plenary: Risks, Rewards, and Realities: Searching for Common Ground

John Kaufmann—Science Fellow and Agronomist,
Monsanto Company, Middleton

Richard de Wilde—Organic Farmer, Harmony Valley Farm

Kristin Dawkins—VP for International Programs,
Institute for Agriculture and Trade Policy

Richard Manning—Environmental Writer

Facilitated by Jeffrey Burkhardt, Professor of Ethics and Policy,
Institute of Food and Agricultural Sciences, University of Florida

4:00 Closing

Robert M. Goodman—Professor of Plant Pathology, UW–Madison

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Brad Barham
Norman Borlaug
Jeffrey Burkhardt
Dan Charles
Carl Gulbrandsen
Fred Kirshenmann
Lori Knowles
Richard Manning
John Petty
Vernon Ruttan
Lydia Zepeda

What is the promise and what are the dangers of genetically modified foods? Like it or not, such foods are already in our lives. More than half of all foods produced in the United States now contain genetically modified ingredients. Whether you see such foods as a godsend that could end world hunger or a "Frankenfood" leading to disastrous outcomes, it is vital for all members of the public to be informed about genetically modified foods: their risks, rewards, and realities.

This book arose out of a public forum on genetically modified foods that brought together a wide range of leading thinkers from across the nation—scientists, policymakers, conservationists, industry and agriculture representatives, educators, and more—to share their perspectives on the subject. Their diverse viewpoints are reflected in this volume, which provides a sophisticated yet accessible presentation of one of the most complex issues of our time.

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