2002

New Agricultural Biotechnologies: The Struggle for Democratic Choice

Gerad Middendorf
Kansas State University

Mike Skladany

Elizabeth Ransom
University of Richmond, eransom@richmond.edu

Lawrence Busch
Michigan State University

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In the contemporary global agrifood system, the emergence of a plethora of new agricultural biotechnologies poses a series of far-reaching social, technical and ethical consequences and contradictions. These tools have radically merged questions of design at the molecular level with those of agricultural change. With more possible technological paths than ever before, the new biotechnologies have made technology choice central in the discourse over the future of agriculture. Implicit in the choice of these technologies is a redesigning of nature that could profoundly transform the agrifood system, ecosystems, and the social organization of agriculture. Indeed, global food production and consumption currently stand on the brink of a fundamental alteration in organizational form, which conceivably could surpass the redistributional outcomes of twentieth-century industrialization of farming, agriculture and the food system.

Humans have for millennia been actively modifying nature to provide their sustenance. However, never before have the tools been available to redesign nature with the precision and speed that the new agricultural biotechnologies permit. For example, recombinant DNA techniques for conferring insect resistance in crops are both more precise and much faster than conventional plant breeding techniques, which require repeated selection over many generations of plants. Similarly, DNA probes have been developed to allow for the identification of certain traits in animals, without going through the lengthy process of waiting for the offspring to be born. This will allow farmers to select out undesirable traits and add or enhance desired livestock traits with more speed and precision.

The new biotechnologies also allow the rapid movement of diverse genetic materials across previously insurmountable biological and chemical barriers to create microorganisms, plants, and animals in a manner intentionally desired and designed by humans. In essence, genetic material can now be exchanged among vir-
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...ually all living organisms. This makes all of the world's genetic diversity into raw industrial material to be used in research and development. Moreover, expanded claims to intellectual property rights for genetic resources are privatizing what was once public domain. Likewise, in a global agrifood system the implications of the new biotechnologies are no longer limited by geography. The ability to produce cocoa or vanilla in a laboratory using cell culture techniques, for instance, could virtually decouple the manufacture of these foods from land-based production systems, threatening the livelihoods of populations in developing countries.

This compression of time and space raises problems for directing biotechnology policy. Much of the research and development in this area is being carried out in the private sector with little public input or oversight. Companies are striving to develop novel biotechnology products as quickly as possible, while simultaneously lobbying to reduce as much as possible the public regulatory processes. They hope this will get their products to market ahead of those of competitors. This greatly reduces the opportunities for those with concerns about biotechnology to have a voice in deciding which directions biotechnology should take.

Moreover, the discourse surrounding emerging biotechnologies is often inadequate, in part because of the shortcomings of current thinking concerning the separation of science and politics. It is time to move beyond these limitations by questioning the very boundaries between science and politics. First, let us review some of the current developments in agricultural biotechnology, and their social, technical and ethical consequences and contradictions.

* NEW BIOTECHNOLOGIES IN AGRICULTURE

The biotechnology industry declares itself to be one of the "cornerstone industries of America's future economic growth," and promises new agricultural technologies that will feed the world. In contrast, some critics have warned that the primary fruits of agricultural biotechnology will be "Frankenfoods" and environmental havoc, spawned by technologies over which we will almost surely lose control. Thus far the developments in the field support neither of these claims. Rather, the story is much more complex. What is clear is that agricultural biotechnology, and the debates surrounding it, will be with us for the foreseeable future.

Biological research in agriculture was traditionally in the public domain. However, most investment in biological research in agriculture is now being done by the private sector. Some analysts predict biotechnology crops will be worth $7 billion by 2005. Thus, it is not surprising that industry leaders are betting heavily on agricultural biotechnology's commercial success, and industry is dominating the research agenda.

Before turning to a discussion of specific technologies and their implications there are two general issues which should be addressed. First, biotechnologies can increase market concentration. As with other products in a capitalist market, biotechnology developers rely on being the first to get their product to market so as to capture the largest market share. Thus, only countries in the forefront of biotechnology development are likely to reap the gains of investment in research and development. Also, due to the
increasing scope and complexity of intellectual property rights on life forms, many companies avoid lawsuits by swapping patented material. Companies that do not have many patents or are not connected into this network may be blocked from entering the market. Furthermore, the agricultural biotechnology industry is located primarily in Western industrialized countries. Only about ten developing countries have biotechnology programs. Thus, the inequalities that currently exist between developed and developing countries are further exacerbated.

Second, advocates of biotechnology focus on increasing productivity without questioning its distributional consequences. Typically, the argument that biotechnology will help feed the world is couched in humanitarian rhetoric and the (promised) results are presented as a means to legitimate the investment in research and development. However, these arguments ignore the multiple dimensions of food security. Biotechnology may address concerns such as the amount and quality of food available, but it does not deal with issues of access and distribution. Indeed, given its potential to displace large numbers of people and to deny them access to the means of subsistence, biotechnology could in some instances actually be detrimental to helping the world feed itself. Let us turn now to specific examples of plant, food, and animal biotechnologies and their implications.

Plants

The list of new plant biotechnologies on the market has grown extensively in the past few years (see Table 1 for a partial listing). In the United States alone, the area of transgenic crops planted increased from 8.1 million hectares in 1997 to 20.5 million hectares in 1998. In plant biotechnology, herbicide resistant crops (HRCs) are one example of commercial developments. HRCs allow herbicide application after the crop has emerged from the soil, extending the period in which the chemical may be used. Expectations are that by 2000 the annual value of herbicide tolerant seed will be about $2.1 billion. With the top four chemical companies controlling 53 percent of the market, it is not surprising that 30 to 50 percent of industry research and development spending is presently going towards HRCs.

In 1997, an estimated 3 to 4 million hectares of herbicide-tolerant soybeans were planted—roughly 15 percent of the total soybean acreage in the United States. This area grew substantially in 1998 worldwide, with the result that “more than one-half of the world soybean harvest and about one-third of the corn harvest now comes from plants engineered with genes for herbicide or disease resistance.” One brand of HRC soybeans on the market is Monsanto’s Roundup Ready transgenic soybean, which is resistant to the company’s leading herbicide, Roundup, the largest-selling weed killer in the world. Farmers who use the seed must sign a contract requiring them to use only Roundup and allowing Monsanto to inspect their fields at any time. Roundup accounts for about 17 percent of Monsanto’s total annual sales. For Monsanto, HRCs like Roundup Ready soybeans represent an opportunity for the company to increase its overall share of the agricultural inputs market by introducing genetically engineered seed that is tied to the use of its herbicides.

Today, all major seed companies have been bought by or are tied to chemical companies. The consolidation of the chemical and seed industries has allowed a few companies to gain a large share of the agricultural inputs market. Concentration in the industry has generated considerable criticism of the control that agribusi-
**Table 1: Commercialized Biotechnologies in The U.S.**

**Name of Product (Year Commercialized)—Brief Description**

<table>
<thead>
<tr>
<th>Herbicide Resistant:</th>
<th>Identity Preserved:</th>
<th>Insect Resistant (Bt toxin):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canola (NOM)—resistant to</td>
<td>Laurical (1995)—high lauric acid oil</td>
<td>KnockOut (1995)—corn resistant to corn borer</td>
</tr>
<tr>
<td>herbicide glufosinate</td>
<td>composition in canola</td>
<td></td>
</tr>
<tr>
<td>Roundup Ready Canola (NOM)</td>
<td>FlavrSavr (1994)—delayed ripening tomato</td>
<td>NatureGuard (1995)—corn resistant to corn borer</td>
</tr>
<tr>
<td>(NOM)—resistant to herbicide</td>
<td><em>(taken off market)</em></td>
<td></td>
</tr>
<tr>
<td>glyphosate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BXN Cotton (1995)—resistant</td>
<td>High Oleic Acid Soybeans (NOM)—higher</td>
<td>Bollgard (1995)—resistant to bollworm and budworm</td>
</tr>
<tr>
<td>to herbicide bromoxynil</td>
<td>levels of oleic acid in the oil.</td>
<td></td>
</tr>
<tr>
<td>(1996)—resistant to herbicide glyphosate</td>
<td>seed</td>
<td></td>
</tr>
<tr>
<td>(1995)—resistant to herbicide glyphosate</td>
<td>resistant to two viruses <em>(taken off market)</em></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Food Modified Flavors: High</th>
<th>New Processing Techniques:</th>
<th>Biosensors (1980s)—detects biological activity in food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fructose Corn Syrup (1980s)—corn sweetener</td>
<td>Chymogen (1990)—</td>
<td></td>
</tr>
<tr>
<td>used in soft drinks, etc.</td>
<td>recombinant rennet used in cheese making</td>
<td></td>
</tr>
<tr>
<td>Aspartame (1981)—high-intensity sweetener</td>
<td>Rapid Detection Systems:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DNA probes (1980s)—</td>
<td></td>
</tr>
<tr>
<td></td>
<td>evaluates authenticity of food ingredients</td>
<td></td>
</tr>
</tbody>
</table>

| Animal Growth Hormones: Bovine Somatotropin| DNA probes (1982)—allows for the identification of certain traits | Dolly (NOM)—Lamb cloned using a nonreproductive cell nucleus taken from a ewe’s udder |
| (1994)—growth hormone injected into cow to increase milk production | | |
| Porcine Somatotropin (NOM)—injected growth hormone to increase average daily weight gain and lean tissue, while decreasing back fat in pigs | Embryo splitting (1980s)—produces identical animals. Not cost effective in the U.S., so not widely practiced in the industry. | Transgenic "Pharming": Rabbits that produce an enzyme (NOM)—used to treat a rare human genetic disorder. |
| Reproductive Technologies: Embryo Transfers (1973)—one of first animal biotechnologies used, primarily for farm breeding | Transgenic Animals: Mice (1976)—first transgenic animal | Goats (NOM)—produce a drug called TPA |

*For a more complete list of agricultural biotechnology refer to http://www.bio.org. For plant biotechnologies on the market refer to The Gene Exchange, Fall 1997.*
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ness is gaining over the agrifood system. The concern is that, as fewer input suppli-
ers increasingly dominate the market, the choices that farmers have before them
will actually become more restricted. A few products will be heavily pushed as the
industry standard. This can promote a narrower genetic base for agriculture as well
as restrict the types of farm enterprises and narrow the range of choices available
to farmers.

The commercialization of HRCs raises other long-term environmental issues as
well. Some researchers have shown that herbicide tolerance engineered into crop
plants can spread quite easily into weedy relatives of a crop. Thus, widespread use
of HRCs could lead to hardier weeds. Of course, everyone shares these conse-
quences; they are not experienced solely by direct users of the technology.

The most recent plant biotechnology to create international controversy is the
“Terminator technology.” Co-developed by the USDA and seed company Delta and
Pine Land, the Terminator technology encodes within each seed’s DNA a gene that
kills its own embryos, thereby sterilizing the seed and forcing growers to return to
seed companies on a yearly basis to purchase new seeds. Grassroots organizations,
particularly groups in parts of the world that struggle with food security, have vehe-
mently opposed this technology. As one foundation research director explains,
“engineering seed sterility is a logical goal for the multinational seed industry
because around three-quarters of the world’s farmers routinely save seed from their
harvest for re-planting.”

While users of hybrid seed have long faced this same issue (i.e., having to
return to seed companies annually), the Terminator technology is different in two
fundamental ways. First, hybrids have only been successful with a few crops. In
principle, all crops could be modified with the Terminator gene. In fact, if the gene
works as expected, it will likely be licensed widely to seed companies, making it dif-
cult for farmers to buy seed that does not contain the gene. Thus, farmers might
well find that they have no choice in the matter.

Second, hybrids are relatively easy to produce by conventional breeding, so
although the market is concentrated, there are many companies in the market. The
Terminator technology could eventually allow a few chemical/seed companies to
control all crop seeds worldwide. The serious inherent risk is the assumption of per-
manently stable institutions. If used on a large scale, it will make farmers fully
dependent on seed companies for seed. If the seed is unavailable due to war, civil
disturbance, natural disaster, etc. then farmers will suddenly discover that they
have no seed to plant. This would obviously be catastrophic.

Another group of plant biotechnologies currently in use is identity preserved
(IP) crops, which have been engineered with specific altered traits, such as toma-
toes with delayed ripening (e.g., Flavr Savr), or canola with high lauric acid (an
ingredient in cosmetics), such as Calgene’s Laurical. IP crops are a way of adding
value to a crop because the altered trait commands a premium in the market. Yet,
for the developers to maximize profits they must maintain ownership or control of
the product from seed to market. This encourages, and is certain to promote, con-
tract farming. Contract farming has some advantages for farmers. For instance,
farmers may not have to incur a large debt to finance the crop under contract.
However, farmers entering contracts also lose autonomy as they no longer are per-
mitted to make basic production and marketing decisions. Moreover, contract farm-
ing may also continue the shift toward larger and fewer farms, because the con-
tracting company will face increased transaction costs as the number of contracts
into which it enters increases. For example, if Calgene wishes to contract out one thousand hectares of its antisense tomato, it would likely seek out a larger, more capitalized producer for the full one thousand hectares, rather than enter into ten contracts at one hundred hectares each.

**Food**

Many food biotechnologies have been developed with little public awareness or discussion. In part, this is due to the fact that most consumers know very little about research and development in food processing. For example, researchers have produced chymosin, an enzyme used in cheese making, from genetically engineered organisms. The first commercial product, a recombinant chymosin called Chymogen, can be found in approximately 60 percent of all hard cheeses in the United States.\(^{17}\) Yet, most people in the United States have never heard of this genetically engineered enzyme.

Food biotechnology also includes the use of enzymes in fermentation, as well as in starch processing. Today, the value of the world fermentation market is estimated at between $20 and $40 billion annually, while the market for starch enzymes is approximately $200 million annually.\(^{18}\) One of the first products made with starch enzymes was High Fructose Corn Syrup (HFCS). HFCS is produced by using biologically produced enzymes to convert corn into a sweetener. Corn converted by this method has attained widespread use in major food products such as soft drinks. Other products not yet commercialized include vanilla and cocoa produced in vitro.\(^{19}\) In principle, any commodity that is consumed in a highly processed, undifferentiated form could be produced using these techniques. The result would be large batches of the commodity that are completely aseptic and require far less processing.

If successfully commercialized, in vitro biotechnologies will have an impact well beyond merely the technical aspects of their development. These technologies permit the global displacement of markets. Market displacement has always occurred due to product substitution, but biotechnology accelerates the process and leaves developing country populations in a precarious position. For instance, when HFCS attained widespread use it captured a large share of the cane sugar market from developing countries, threatening the livelihoods of an estimated eight to ten million people in the South.\(^{20}\) Presently, vanilla and cocoa are still cheaper to import than to produce in factories. But, if such factory production can be done economically, people who depend on the export of these crops for their livelihood may see a significant loss of market share.

**Animals**

Unlike food biotechnologies, animal biotechnologies have created significant controversy. The fact that animals are sentient beings creates very different issues for biotechnology development. The issues are further complicated because the information about animal biotechnology research and development is not readily available. Almost all research on animal biotechnologies is funded by private industry. Furthermore, due to the controversy over the use of animals, much research is undisclosed. Often, only after research is completed do the results become public knowledge. Dolly, the lamb cloned in 1997, is a prime example of both the secrecy surrounding the industry and the controversy which animal biotechnology creates.
Early animal biotechnologies involved reproduction, particularly the ability to select certain desired livestock characteristics. Recent research has shifted towards (1) increasing the milk production of cows (i.e., bovine growth hormone), (2) improving or changing meat characteristics (e.g., porcine growth hormone), and (3) using animals to produce pharmaceuticals. Pharmaceutical manufacturing, also called "transgenic pharming," is the leading area of investment in transgenic animal research and development. If successful, "pharming" will allow pharmaceutical companies to use an animal much like they would a laboratory. The animal would be engineered to produce a desired compound that would then be sold to treat various ailments. The first pharmed drug, likely to arrive on the market late in 1999, is an enzyme produced in the milk of transgenic rabbits for individuals who lack this enzyme due to a rare genetic disorder, known as Pompe's disease. A list of other transgenic animals that have successfully produced a desired drug or drug ingredient includes pigs that produce human hemoglobin and sheep that produce an amino acid lacking in some humans. The intention is to eventually commercialize these products.

In addition to the issues noted above, certain concerns are specific to animal biotechnologies. Is it appropriate to treat animals as mere factories for human drugs? Will such animals suffer from their own health problems? Should we treat the patenting of animals in the same manner as we treat the patenting of a drug produced in a lab? Also, how will pharming impact the current structure of agriculture? These questions have received little public discussion.

The plant, food, and animal technologies discussed above and listed in Table 1 are merely the tip of the iceberg. In 1997 one of the largest agriculture biotechnology companies had 17 million hectares of genetically modified crops planted. In addition, in the past three years there has been a dramatic increase in the use of biotechnology in production and processing of foods. Today, foods that are produced or processed using biotechnology include breakfast cereals, taco shells, corn syrup, cooking oil, candy, margarine, milk, and cheeses, to name just a few. Indeed, there are many technologies still a few years from the market that will eventually reach commercialization. These include transgenic fish, such as salmon, tilapia, and catfish, which are being engineered for industrial aquaculture production. Also, there are many more developments in pharming in both plants and transgenic animals. This makes it even more urgent that society begin to grapple with how and who will decide what directions biotechnology takes.

**BIOTECHNOLOGY AS POLITICS BY OTHER MEANS**

Despite the best efforts of advocates to portray biotechnology as the logical, inevitable, and unproblematic direction of agricultural research and development, it is a series of choices being made, each with associated consequences. The consequences of developing new technologies under the direction of corporations are substantial and extend throughout the global agrifood system. Thus, everyone is a participant in a global experiment with this new set of technologies that promises to create new winners and losers around the world, yet only a few have access to decision-making processes. Discussions of critical social, technical and ethical aspects of these technologies are currently suppressed by the view that science and technology are beyond the boundaries of conventional political discourse. The new
biotechnologies are potentially beneficial to society, but not unless the institutional bases for technology choice are democratized. These technical and political dimensions can no longer remain separate if a socially just biotechnology is to emerge.

The rhetoric of neutrality embedded in the science of biotechnology masks a series of social contradictions. When closely examined, technical choices are simultaneously political choices not necessarily congruent with the fuller aspirations of a free, democratic society. The current developments in biotechnology reflect a decision-making process in which commercial interests override societal and environmental concerns. Moreover, while most scientists see themselves as searchers for truth, they remain largely oblivious to the partial character of what they “discover” or create. Similarly, corporate managers have a vested interest in promoting their own agenda even while claiming it serves merely to advance scientific knowledge. Given the increasing influence of corporate funding of and collaboration with university and government scientists, their research agendas are reshaped as well. This fundamental contradiction is at the heart of the politics of the new agricultural biotechnologies.

Biotechnology is one valid and reliable way of knowing, representing and manipulating nature. In principle, there is nothing inherently harmful about this new set of tools. However, within industrial capitalism biotechnology is tied to private profit, short-term control over nature, and neglect of short- and long-term social consequences. In part, this emerges from our society’s faith in technological progress as the sole means to resolve human problems. At the same time, the institutional basis of industrial capitalism reinforces an increasingly illegitimate distinction between the political and technical. The legacy of this distinction can be traced back to the industrialization of agriculture and the industrialization of society.

In many respects, the production-oriented arguments utilized by biotechnology advocates echo sentiments exhibited in the post-Second World War era development of industrial agriculture that produced the “green revolution.” The green revolution focused on rapid production gains as a singular means to solve world food problems while stemming what was perceived as the advance of communism. Indeed, the application of new technological packages, corresponding infrastructure development, and the growth of export markets are all legacies of the green revolution. This approach did lead to significant production gains. However, the contradictions arising from these developments also led to exacerbated social, political and economic inequalities within localities, nation-states and regions of the developing and developed world. Moreover, the debasing of tropical agricultural resources has led to negative long-term environmental consequences resulting in profound ecosystem alteration and, in some cases, severe degradation of the ability of the land to produce food. The green revolution provides an important lesson with respect to the application of the new agricultural biotechnologies: the ideology of inevitable technological progress excludes consideration of the distributional and environmental consequences of such efforts.

Marx was ambivalent about technological choice. On the one hand, he envisioned that new technologies could help achieve human emancipation and lead to a society of abundant production and consumption. On the other hand, Marx realized that technologies could also create routine drudgery that would alienate and demean those who use them. He foresaw the social conditions of industrial capitalism, which currently relate to how the new agricultural biotechnologies have emerged and are taking shape. However, there is nothing that necessitates this outcome.
**Narrow or Strong Objectivity**

Perhaps one of the primary sources of legitimacy for biotechnology is its connection to scientific objectivity—an association frequently highlighted by advocates in an effort to immunize their endeavors politically by attempting to draw a clear distinction between the scientific and the political. It is these very sources of legitimacy that require scrutiny. Acting on behalf of a “concerned public,” proponents appeal to scientific objectivity to advance arguments for the best possible outcomes regarding support for new agricultural biotechnologies. This is not to say that biotechnology is not based on valid and even well-intentioned science. What is problematic, however, is that early decisions about the direction of biotechnology become invisible after research is completed and technologies are produced. When choosing problems, scientists have a range of possibilities before them. For example, they could work on developing crops that more effectively shade out weeds, or intercropping and rotation systems for better weed control, or they could genetically modify plants to be resistant to herbicides.

Yet, after the direction of research and development has already been decided, the initial alternatives tend to disappear as scientists often portray the chosen path as the only viable one. The chosen path then becomes, according to scientists, the only “accepted” objective view of the world. Hence, a narrow objectivity prevails in which a few scientists and corporate executives make early choices (i.e., when there are a number of viable alternative choices) about the direction of research and development, and then later define the chosen path as the standard measure for objectivity. They do so even as research is supported by corporations that have an obvious vested interest. This weaker form of objectivity can only be enhanced by increasing the number of perspectives—and the legitimate representation of those perspectives in decision making—that are included in making the initial choices.

The conventional stripping away of the social context of science facilitates the mystification of biotechnology. But, science and technology are political developments, with real constituencies and real social consequences. Democratizing science and technology policy is a necessary part of the process of addressing these contradictions. This requires developing new institutional mechanisms to promote the participation of those affected by new technologies. As a first step, the very definition of science and technology needs to be broadened to include activities that go on outside the laboratory, but that are fundamental to the scientific enterprise. Public and private funding agencies, instrument manufacturers, biotechnology firms and general farm and commodity organizations, among others, must all be recognized as essential social agents in science and technology development. Only when these intertwined components of science and technology are addressed can we speak of objective, socially responsible and ethically informed decision making.

**The Struggle to Democratize Science and Technology**

Increasing corporate control of the biotechnology research and development agenda raises a host of problems, not the least of which is a restricting of public access to decision making in this arena. While opening the technology policy process to broad participation comes up against considerable structural constraints, a democratization of science and technology should not be seen as merely...
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a utopian illusion. We are now accustomed to considering democracy as limited to party polities. However, there have been continuing struggles to extend it to technology choice. Several countries have made notable progress in this direction. While efforts in the United States have received limited support, in Western Europe the institutional innovations toward a more inclusive technology policy process are taking place. These initiatives should by no means be considered a panacea for dealing with technology development, but they are one approach to challenging corporate and state hegemony over technology choice.

For example, for more than a decade the Danish Board of Technology (DBT) has been running consensus conferences that have provided a forum in which ordinary citizens with diverse backgrounds are involved in technology assessment. The results of these dialogues between citizens and a panel of experts are widely disseminated in the media, and are often acted on by legislative bodies. The DBT has held conferences on industrial and agricultural biotechnology (1987), irradiation of food products (1989), and genetically manipulated animals (1992). It appears that this model is now being more widely adopted in Europe.

In the United States the first promising efforts at proactively involving citizens in technically complex areas of policy are beginning to appear. In 1997 the Loka Institute, along with a number of other collaborating institutions, organized a pilot citizens' panel based on the consensus conference model. This particular panel dealt with issues arising from changes in telecommunications technologies and policy. Judging from the conference reports, the panel demonstrated that lay citizens are capable of meaningful participation in complex technical and public policy issues. Both this approach and the work of the Danish Board of Technology warrant further exploration.

These are just two examples of mechanisms that attempt in some way to extend democracy to technology choice. While our purpose here is not to review the full range of extant examples, it is useful to consider some of their shared principles. In these efforts, the relationship between social priorities and technology choices is made explicit. A key feature of these strategies is that society must democratically define its priorities; only then should it ask how technologies might help to achieve those goals. This challenges the common assumption in science policy of a positive, linear relationship between scientific advance and social progress. Another guiding principle is that since all citizens experience the effects of science and technology, and since citizens in democratic societies ordinarily expect to have a voice in decisions that will affect the way they live their daily lives, they must be involved in deciding the direction of science and technology policy.

These approaches also begin with the assumption that science and technology policymaking is an inherently political process, and that any constructive dialogue will necessarily bring together actors with divergent goals and values that often contradict each other. In the debates over biotechnology some might argue for values such as profitability or freedom from excessive regulation, while others might argue for safety, environmental soundness, or equity. There is no one decision rule with which to rank these competing values in a simple hierarchy. Rather, decisions must be accomplished through a process of debate, negotiation and compromise in which all stakeholders have a voice.

In the United States, we have typically relieved ourselves from responsibility for the consequences of technical change by attributing them to the inevitable effects of technological advance combined with market forces. In this view, if undesirable consequences should result from technical change, we can develop not only new technical fixes, but also new products and additional economic activity. Yet, as the
examples above suggest, it is not necessary to actually employ new technologies in order to determine their consequences. Such an approach leads to the never-ending search for technological fixes, even as it tears at the social fabric. Indeed, many of the negative consequences could be avoided if initial science and technology choices were made with better consideration of social priorities. We currently do not have these kinds of mechanisms in place—technical change has by far outpaced institutional innovation—but we do have the capacity in universities, nongovernmental organizations, companies, and in our citizenry to direct science and technology in more democratic and socially desirable directions.

NOTES

1. Defined broadly to include techniques that use living organisms to improve plants, animals, or products, biotechnology in itself is not new. We use "new" to refer to technologies that use rDNA, cell fusion techniques, new bioprocesses, monoclonal antibodies, plant and animal cell and tissue culture, and embryo transfer, splitting and sexing.


7. Sehgal, "Biotechnology Heralds a Major Restructuring."


10. Ibid.


12. Moffa, "Toting Up the Early Harvest."

13. A transgenic organism is formed by inserting foreign genetic material into the germ line cells of organisms.


17. BIO, 1996.


19. In vitro production is an industrial process in which the cells of a multicellular organism are treated as if they were microorganisms. They are placed in a large vat where the environment (light, temperature, nutrients, etc.) is manipulated such that the cells multiply.


21. Transgenic animals are animals into which foreign DNA is implanted into the fertilized egg.


27. Danish Board of Technology, Technology Assessment in Denmark: A Briefing (Copenhagen: Danish Board of Technology, 1992).

