The Cultural and Symbolic Dimensions of Agricultural Biotechnology

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The application of biotechnology to agriculture is beginning to affect the deep symbolism we associate with contemporary agrarian culture. In the political discourse emanating from the "public wars over biotechnology," several key ideas are being debated: the notions of what the farm is and what it ought to be, what food is, and what livestock are.[1] Combatants in these struggles include small-farm advocacy organizations, start-up companies, international Green organizations, traditional environmental groups, multinational corporations, natural food associations, and animal rights supporters. The issues are also diverse: a tomato with an inverted gene to slow the ripening process, a microorganism that inhibits frost formation on crops, herbicide-resistant crops, microbially produced animal growth hormones, animals that excrete pharmaceuticals in milk, and transgenic animals that yield leaner or breastier meat. The common thread linking these product controversies is a set of genetic technologies that offer highly characterized genetic modifications of bacteria, plants, and animals.

The controversies over individual biotechnological products represent what might be called the *surficial* phenomena of a deeper set of issues that reach beyond the biotechnology industry and tap into a cultural immune system that responds to new product technologies. On a superficial level the global debates over biotechnological products are about controlling the system of regulation, the conditions of technology transfer, and the criteria used to approve technology for commercial application. At the deeper level, the struggle occurs among forces that seek to control the symbolism of agricultural biotechnology and seek to promote a techno-mythology based almost exclusively on the power of genes. Those who eventually gain control over the bio-mythology will affect the pathways of innovation for future generations.

This essay is about the struggle for control over the symbolic meaning of biotechnology. It is also about the process of mythmaking for this class of technologies. I use the term *myth* judiciously, not to denigrate one side or another in the battles that have erupted over biotechnology. Rather, the term signifies a cultural story that embodies hope, expectations, moral attitudes, fears, or positive visions of modernity. Myths are constructions out of reality that transcend the real into a virtual world of expectations. I will examine the following myths and anti-myths in their socioscientific context:

- Biotechnology gives us natural (unnatural) products.
- Biotechnology offers us more (less) control over nature.
- Biotechnology will contribute to more (less) biodiversity.
- Biotechnology will be friendly (unfriendly) to the environment.

These propositions are not necessarily independent of one another (e.g., being friendly to the environment should be consistent with increased biodiversity) but are useful as organizing schemas for the analysis of debates. I examine the first three propositions seriatim in the next three sections, discussing the fourth in the context of the first three. I then discuss the shifting conceptual boundaries of agricultural and industrial production and conclude by examining the form and function of "power myths" in relation to genetic technology. My organizing thesis is that political debates in biotechnology are essentially about control over techno-mythmaking, which I define as the shaping of social expectations through the association with technology of symbolic powers and simple moral virtues. I am less concerned about the truth or falsity of these techno-myths than I am about how they are used to construct an image of biotechnology.[2]

Biotechnology and the State of Nature

Former U.S. President Ronald Reagan once commented that trees emit pollutants.[3] As an anti-regulator, Reagan meant not to imply that trees must be controlled, but rather to call into question the distinction between the natural and the unnatural, and the uncritical association between the natural and the good. Despite Reagan's ploy, most people today feel comfortable with the natural-unnatural dichotomy and hold a deeper skepticism about the unnatural. It is not surprising, therefore, that representatives of the biotechnology industry have described the techniques associated with genetic modification and the resulting pesticides as offering a natural alternative to agrichemical products. By advancing the thesis that biotechnology uses nature's own methods of pest control, plant fertilization, or toxic waste degradation, its advocates hope to give biotechnology a more favorable image while disassociating biological agents from the negative image often ascribed to chemicals.

Not all representatives of the industrial community (e.g., large chemical companies) find it in their interest to pit biological agents against synthetic chemical agents. But the small venture capital companies advance this theme in part to win public confidence in genetic technologies and also to create receptive market alternatives to the chemical inputs produced by a few leading corporations.

Efforts to gain control over the term *natural* can be observed in other policy debates. Public anxiety over synthetic additives to food has been met with studies indicating that "natural carcinogens" in food are more hazardous to the consumer than traces of food additives and pesticides.[4] If this argument were taken to its logical conclusion, food products would not be regulated differently whether ingredients were indigenous to the plant, taken up in the roots, sprayed on, or added in processing. All products, whether naturally found or synthetically produced, would be on an equal footing. Only demonstrated risk, not methods or generic materials of production, would be subject to regulation.

The U.S. Food and Drug Administration (FDA) also grappled with the natural-unnatural debate when it issued draft guidelines for regulating transgenic food which stated that inserting a foreign gene into a crop did not make the crop unnatural. The agency decided not to regulate genetically engineered food in the same way as it would food to which synthetic chemicals had been added. Under the FDA's proposal a transgenic plant is considered no less natural than a plant that has been selectively bred: the difference is that a bred plant has many undefined genes making up its phenotype while a transgenic plant usually has a well-characterized genetic modification.[5]

The critical discourse of biotechnology encompasses efforts to stigmatize genetic engineering as unnatural as well as efforts to classify it as a natural process. Critics of the FDA approach, who maintain that transgenic plants are not simple extensions of selective breeding, emphasize that genetic engineering makes it possible to exchange foreign genes (a gene from a peanut transferred to a tomato) that would otherwise not be introduced by selective breeding or hybridization. But what makes hybridization natural? Could a hybrid seed arise from natural processes not subject to human intervention? The U.S.-based Foundation on Economic Trends has organized a Pure Food Campaign that opposes all genetic manipulation of plants. At least one argument of the campaign is based on the unnaturalness of transgenic food.

Another struggle for control over the symbol "natural" can be found in the controversy over agricultural pesticides. In agriculture the term *natural*, which is synonymous with "organic," has been identified by the term *chemically free*. Despite efforts by certain sectors in society to break the link between *natural* and *safe*, these concepts are still strongly associated. Food produced on chemically free farms may contain fungi, insect viruses, and natural carcinogens. Nonetheless, in the public mind organically grown food has a strikingly powerful grip over the terms *natural* and *safe.*

Among the boldest promises of biotechnology—and one that is repeatedly emphasized in the popular scientific press—is that its products will replace synthetic chemical pesticides and fertilizers with biological controls.[6] For the antichemical pesticide lobby, fulfilling this promise would place biotechnology on the side of the angels. Evidence for these claims comes directly from laboratory experiments on pest resistance, nitrogen fixation, and viral resistance in plants. The mythmaking behind this view is that enough power exists in biotechnology to displace a system of chemically intensive agriculture that has evolved for over a hundred years. The idea that biotechnology will wean agriculture from its chemical dependence is widely accepted and cautiously promoted despite four major constraints on the realization of this goal: technology, economics, education, and politics.[7] The products replacing chemical pest controls will have to match or exceed existing efficacy criteria. In addition, the economic benefits must equal or outweigh the costs of using chemical controls. Farmers need to know how to use alternative products and practices effectively. And finally, a powerful chemical lobby must be overcome as biological methods and a softer path to pest control are introduced.

While the FDA has sought to treat genetically modified food as it would conventionally bred crops, the U.S. Environmental Protection Agency (EPA) has a policy that distinguishes transgenic organisms from natural substances. Under current EPA practices, transgenic organisms other than pesticides would be regulated under the Toxic Substances Control Act (TOSCA), a major piece of gap-filling legislation passed in 1976. TOSCA's requirement of pre-manufacture notices for all new chemicals has been interpreted to include genetically modified microorganisms. The EPA commitment to regulating transgenic organisms as chemical substances further blurs the distinction that some proponents of biotechnology have made between nature's "biological friends" and its "chemical enemies."

The importance of the symbol of nature's biological friends is exemplified in the bioremediation industry. Conventional microorganisms have been used successfully in sewage treatment plants and with less success in degrading toxic chemicals in situ. The industry is composed mainly of companies that use natural strains of microorganisms screened for their efficiency to degrade a selected substrate. Few companies in the U.S. bioremediation industry have shown an interest in developing genetically engineered strains. Many are concerned that the biotechnological methods may tarnish the image of an industry that exploits the earth's natural recyclers, namely, microorganisms that break down chemicals into simpler elemental forms. Unless the biotechnology industry can remove the stigma of genetically engineered microorganisms as a product of a new and untested technology, the field of bioremediation will move with extreme caution into genetically engineered strains.

Industrialists are also seeking to exploit the so-called natural qualities of microorganisms in the area of food additives. The public is strongly apprehensive of artificial chemical additives. Susan Harlander notes: "Consumer concern regarding chemical additives in foods and consumer demand for 'natural' products have resulted in demand for microbial metabolites which can be used as natural ingredients in foods."[8] Currently, microbially produced additives such as xanthan gum and monosodium glutamate come from natural isolates. If the food industry seeks to expand the manufacture of microbially produced additives, it will have to persuade the public that genetically engineered "food-grade" microorganisms will also yield natural ingredients to ensure that these products are received more favorably than synthetic chemical additives. The pharmaceutical industry has used an analogous strategy when advertising microbially produced human insulin as a natural alternative to porcine or bovine insulin.

The debate over biotechnology as natural or unnatural will not be resolved by empirical study any more than will the debate over hybrid corn. The symbolic importance of *natural*, however, has more to do with risk than with the word's essential meaning. Once the issue of risk is managed, the question of naturalness will slowly disappear. Considerable effort has gone into communicating to the public the idea that bioengineered products inherently have no greater risk than non-bioengineered products. A report of the National Academy of Sciences (NAS) in the United States addressed the issue of unique hazards of recombinant DNA research but finessed the question whether scientists could create something totally unique to nature. An inferred connection certainly exists between unique risks and the unnatural. If we had a technology that was safe by universal criteria (e.g., passive solar energy), the issue of whether it was natural or unnatural is not likely to be of concern. In the struggle over symbols the NAS report represented a major victory for the biotechnology sector. Although the report was somewhat tentative, it contained enough language to serve the interests of a war-torn industry that had often been forced into a defensive posture to justify its existence. "There is no evidence that unique hazards exist either in the use of R-DNA techniques or in the movement of genes between unrelated organisms."[9] I have argued elsewhere that the NAS conclusion about unique hazards has less to do with good science than it does with political correctness within the scientific fraternity.[10]

Greater Control over Nature

One traditional measure of human progress is the degree to which we can control, accommodate to, or survive the forces of nature. Humans have overcome the gravitational force field of the earth, exercised some control over swelling rivers, redefined the landscape by making artificial lakes, rerouted natural water flows, drained wetlands, and irrigated deserts. Yet a growing number of people argue that progress is not made by subduing or dominating nature. They reject the premise that humanity's goal is to make nature more rational—that is, more predictable and more controllable.

Many others believe that the new science of molecular genetics offers qualitatively greater degrees of human control over natural processes while releasing a new bounty of benefits to civilization. How much can we extract from nature without paying a price? Does genetic engineering give us more control, or is that an illusion? And if biotechnology does offer more control, is it desirable to exercise that control?

In agriculture the targets for increased control are weeds, insects, temperature fluctuations, and instability of water supply. For biotechnology to offer greater control over agricultural production, it must help to reduce the erratic effects of these external impediments while sustaining high productivity. Herbicide-resistant crops (HRCs) may illustrate this point. In theory at least, HRCs can improve weed control by enabling farmers to exercise postemergent herbicide treatment that does not harm the crop. HRCs also allow farmers to rotate crops with different herbicide tolerances. Proponents of HRCs maintain that they offer a more predictable and dependable regime of weed control that is friendlier to the environment since they allow industry to shift from higher-toxicity herbicides (e.g., triazines) to lower-toxicity herbicides (e.g., glyphosates and sulfonylureas).

The battle lines over HRCs were taken up early, while companies were still seeking permits to field-test transgenic plants. Leading the cause against HRCs in the United States was the Biotechnology Working Group, a coalition of influential environmental public interest organizations. Their publication of a widely circulated report titled *Biotechnology's Bitter Harvest* set the parameters of the environmental offensive. The report excoriated the biotechnology-chemical industry for initiating a vigorous research and development effort to create new herbicide-resistant plant species. In effect, the report argued, herbicide-tolerant crops would lead farmers to depend more on all types of herbicides, help spread herbicide-resistant weeds, increase ground and surface water contamination, expose applicators and farm workers to more toxic chemicals, increase herbicide residues in food, and contaminate ecosystems. Overall, the report condemned the industry initiative, accusing its proponents of a cynical disdain for the goals of a sustainable agriculture.

> It is inescapable that the widespread use of herbicide-tolerant crops and trees will prolong the use of chemical herbicides for weed control. . . . From a social and economic standpoint, the introduction of herbicide-tolerant crops could exacerbate trends toward economic concentration in agriculture, the decrease in farm numbers, and the deterioration of rural communities. Applied in the Third World, such

plants could have unwelcome impacts on human and environmental health and genetic diversity, as well as increasing petrochemical dependence.[11]

Predictably, the reaction from industry was combative. Significant efforts were being made to craft an image of biotechnology as nature's alternative to chemical pesticides. Corporate CEOs spoke optimistically of the new synthesis of environmentalism and agriculture.[12] The critics of HRCs exploited the difficulty of fitting these products into the newly constructed image, thus undermining industry efforts to control the symbols of biotechnology as environmentally and economically friendly. In response, supporters of HRCs dismissed the arguments of environmentalists as "unscientific" and ideological. The high-profile environmental magazines carried the message that the biotechnology industry had hoped to avoid, namely that companies were engineering herbicide resistance into all major crops with the upshot of more chemical dependence.[13]

The subtle details of the controversy over the environmental impact of HRCs are linked to the broader struggle over the importance of herbicide resistance in the future of agriculture. Two distinct images of the farm portray herbicide-resistant crops as having either a rich or a dim future in food production. Rooted in the texts of Judeo-Christianity and later reinforced in the post-Baconian scientific Enlightenment, the dominant view of nature is that humans must control the wild and irrational forces of their environment. Not only is such control obligatory if we are to exploit nature's largess at highest efficiency, but there are aesthetic, moral, and religious justifications for exacting it. In brief, when nature is rationalized, it looks more pleasing, it better serves social interests, and according to Western religious doctrine it rewards the Creator who has implored humans to harness nature's secrets and to subdue its irrational impulses.

An alternative vision of the farm is that of an organic and dynamic ecosystem that cannot function under the type of mechanistic control found in industrial manufacture. In the agricultural system humans must still understand their role as one among other species living in balance. Pests are an inevitable part of the farm landscape. Farmers must learn to cohabit the land while reaping a generous but not overly selfish yield. Efforts to eradicate unwanted intruders totally in the growing area have generally failed. Once the mindset is changed from eradication to management, a more ecocentric approach to agriculture is possible. John H. Perkins distinguishes between the Total Population Management and the Integrated Pest Management paradigms, both developed in the 1950s.[14] The former held that annihilation of certain pests was within technological capability; the latter was content to maintain pest populations below certain economic thresholds. These two visions of the farm portray vastly different roles for HRCs.

Among the current justifications for greater weed control are fears over food security. Since the world population increases by 90 to 100 million people per year, Malthusian logic tells us that if we do not increase agricultural yields, there will be greater political instability due to scarcity of basic food.[15] Les Levidow argues that industry has embraced food security as the raison d'être for "total systemic control which chemical-intensive methods failed to achieve."[16] The failure of chemical control methods has been documented by David Pimentel and his coauthors: "Despite the widespread use of pesticides in the United States, pests (principally insects, plant pathogens, and weeds) destroy 37% of all potential food and fiber crops. . . . Although pesticides are generally profitable, their use does not always decrease crop losses. For example, even with the tenfold increase in insecticide use in the United States from 1945 to 1989, total crop losses from insect damage have nearly doubled from 7% to 13%."[17]

And why should biotechnology offer the prospect of eradicating pests or improving the efficiency of pest control that has eluded the chemical industry? The distinction made between internal and external controls has instilled in humans a new arrogance that nature can be brought under our control. To control nature externally is to apply physical force, chemical modifications, or energy supplements on the existing agricultural system. In contrast, internal controls involve modifying the genetics of plants to establish a more efficient system of food production with greater accommodation to external variations; for example, producing virus- or insect-resistant plants by introducing genes that immunize the plant or emit a protein toxic to the insect. Since HRCs are used in conjunction with synthetic chemicals, they exemplify applying internal and external controls simultaneously.[18]

The prospect of controlling agricultural yield through the genome of plants evokes among scientists a greater power over nature than that of manipulating external factors. Part of the reason for this attitude is the success of scientific reductionism. Explaining a phenomenon by reducing it to its smallest components remains the ultimate objective of contemporary science. Elementary particle physics, which for all practical purposes has no commercial utility, is among the most revered of the scientific enterprises, garnering billions of dollars to explore the smallest particles of nature. It is perhaps part of the general scientific ethos inherited from the philosophy of physics that prediction and control are linked, and that the power of prediction is heightened as one moves to smaller and smaller units of analysis.

Does biotechnology offer the possibility of greater control over insect resistance than is achievable with chemical pesticides? That insect populations are highly adaptable to chemical pesticides is well recognized. George Georghiou notes that at least 504 insect species have developed resistance to one or more chemicals.[19] On the basis of what is known about insect ecology, Fred Gould concludes that "there is no reason to expect that insects will not be able to adapt to these biopesticides."[20]

Ironically (as Harlander notes) a radically different system of agriculture may offer the solution to the pesticide dilemma, for example, massive tissue culture factories where there are no pests and therefore no need for chemical pesticides. "Plant cell culture used for the production of natural food ingredients offers several distinct advantages over extraction of these components from plants. Seasonal variations, unfavorable weather conditions, and epidemic diseases are not problems when plant tissue is grown under well-defined and controlling laboratory conditions.[21]

Critics of the hypothesis that biotechnology will offer greater control over nature point out that the concept of control is deceptive. One may succeed at controlling a single variable while losing control over other variables. Nevertheless, an appealing if not fanciful notion is that by manipulating a few choice genes, we will gain greater dominance over complex interactions among plants, insects, and environmental factors. (This idea is discussed further below, the section on "Genetic Power and Techno-Mythmaking.")

Biotechnology and the Diversity of Nature

The United Nations Conference on Environment and Development, held in Brazil in 1992, brought considerable attention to the question of biological diversity. The Convention on Biological Diversity was adopted by ninety-eight countries. Noticeably absent as a signatory nation was the United States. The Bush administration opposed the convention on the grounds that it would undermine U.S. patent protection for the biotechnology industry. A specifically targeted concern of the treaty was that "the original possessor of naturally occurring materials can assert an interest in derivative materials after allowing them to leave their possession."[22] Although the controversy was over intellectual property rights and the ownership of genetic resources, its outcome was that biotechnology and biodiversity were opposed.

Concerns about the connection between patent rights and the loss of biodiversity were first raised in the mid-1980s when it was noted that small seed companies were being bought out by multinational corporations like Monsanto and Ciba-Geigy that were engaged in developing both seeds and agrichemicals.[23] Opponents argued that patenting genetic resources results in fewer plant varieties and in the control over those varieties by a group of oligopolistic enterprises. Michael Fox is among those voicing skepticism that biodiversity is compatible with large-scale industrial interests in biotechnology: "There is an accelerating loss of biodiversity caused by agribusiness's overreliance on a few utility strains and varieties of seed stock and livestock."[24] And in Henk Hobbelink's view the outcome of patent rights for germ plasm would mean "the total loss of genetic diversity that is maintained in the field by farmers through the selection and use of their own seed."[25]

Ironically, representatives of the biotechnology industry have actively promoted the new industry as inherently compatible with biological diversity, particularly since the symbolism of biodiversity has gained a prominent place in public consciousness. Environmentalists have invoked biodiversity as a standard to which agricultural biotechnology must measure up. The battle over control of the symbolism has been particularly complex because so many different aspects of biodiversity are involved. The message emanating from the community of international development nongovernmental organizations (NGOs) is that biodiversity is a political and not a technical problem and therefore could never be solved by biotechnology. The practice of biological diversity can only be ensured through decentralization. Centralized systems of research, production, or conservation force the spread of genetic uniformity and genetic erosion.[26]

Another concern linking threats to biodiversity with the release of genetically engineered plants is that the latter could run amok in the environment, overtaking other plant species, particularly those already on the endangered species list. Faced with a potential displacement of species, worldwide attention has focused on the risks of releasing transgenic plants into the environment.[27]

Industrial interests have vigorously promoted biotechnology as compatible with and nurturing of biodiversity. Some of their arguments have persuaded mainstream environmentalists.[28] One argument is that improving agricultural productivity through biotechnology will enable more food to be grown on less land, releasing more land for other purposes.[29] This all-purpose argument could apply to any technology that improved productivity, even chemical technology or innovations in high-yield seeds. Increases in the world population could wipe out any biodiversity benefits derived from higher productivity. The argument also assumes that by improving productivity and narrowing diversity in agricultural land we increase or maintain biological diversity in the fields left fallow.[30] The argument would be more credible if there were evidence that the improvements in production per hectare resulting from technological innovations (e.g., high-yield strains, mechanization) increased biodiversity in land protected from cultivation.

One final link between biotechnology and biodiversity is uniquely associated with the creation of novel species. New techniques that enable scientists to create intergeneric crosses of plants, animals, and microorganisms, promise an artificially created biodiversity. This initiative may take several forms. Substitution of hardier strains of plants and animals able to survive new environments affected by human development represents one path. Also, plant and animal germ plasm can be banked for withdrawal if a crisis of extinction arises. The fictional dinosaur park in *Jurassic Park* offers an extreme view of an artificially constructed ecological system reinstituting extinct species. The symbol of Jurassic Park is precisely what the biotechnology industry seeks to avoid: the introduction of uncontrollable and possibly irreversible risks in an effort to create greater diversity.

Agricultural-Industrial Inversion

The rapid industrialization and corporatization of farming in the last fifty years does little for the image of the farm as the embodiment of pastoral life. Despite the transformation of agriculture and the decline of agrarian culture in many industrial nations, the farm is still the place where germ plasm, sun, water, and earth are transformed to basic foodstuffs. With the exception of certain fruits and vegetables, most food undergoes some processing before it reaches the marketplace.[31] The trend is toward fewer unprocessed crops. Even apples are routinely sprayed with pesticides and chemical ripening agents and cucumbers are waxed before going to market.

The distinction of farm and city has always been a central theme in American cultural history. While we understand that modern large-scale farms are not pristine habitats and well-balanced sustainable ecosystems, there is still enough in the practice of farming, particularly its dependence on sunlight, soil, plants, and animals, to distinguish it from industrial manufacture, characterized by a closed system of production and nonrenewable sources of energy. Moreover, the romantic view of the traditional farm as a place where food is grown without synthetic chemicals remains a powerful anchor for the advocacy work of numerous groups that refuse to accept the premise that the tradeoff for modernization is the abandonment of chemically free agriculture.

Biotechnology, however, raises the possibility of an industrial-agricultural inversion, which has two characteristics. First, the farm will increasingly be used to manufacture products traditionally produced in industrial settings. Second, food production will take place to a greater degree outside of the farm, in enclosed continuous-process bioreactors. In "Food Without Farms" Walter Truitt Anderson describes a process of food production involving plant tissues, enzymes, and a basic nutrient feedstock.[32] He also describes research in which citrus juice vesicles are produced from cells in culture without need for the orange, grapefruit, or lemon. The change of food production from a land-based system to a tissue-culture system would give food producers much greater control over the output. First, food production would not be seasonally dependent, since tissue cultures can be grown in controlled industrial settings in a continuous process. This change promises the ultimate liberation of food production from abiotic and biotic factors affecting food security, including droughts, floods, crop diseases, and cutoff of fossil fuel supplies. The feedstock in the tissue-culture production system would still be agriculturally derived, and would still require some land-based farming. But crops grown only for use as feedstock would be much less vulnerable to environmental threats. "If the basic crops were trees or brush, they would require less fertilizer and water, and they would probably need less expended effort to help them fight off their enemies." So instead of farms as we know them, with their seasonal crops, we would have plantations of trees or brush that would be harvested periodically as needed. The wood would then be broken down by a biochemical process into simple sugar syrups, eventually transported to food factories.[33]

The trend in agricultural biotechnology is to allocate land-based agriculture for the raw materials of production. Differentiation of food products, once controlled by farmers, may begin to shift to industrial tissue-culture farms, just as food processing gained prevalence after the World War II when improved refrigeration and transport technologies were employed.

Proteins harvested from bacteria (called single cell proteins) are already being used as a source of animal feed,[34] as microorganisms convert an inexpensive waste feedstock into protein. Jeffcoat cites as possible feedstocks carbon dioxide, methane, methanol, sugars, and various hydrocarbons.[35] Even if the feedstock for microbial fermentation derives from land-based agriculture, the new metaphor of the farm may more closely approximate a mining industry in which raw materials (carbohydrates and sugars) are "mined" and subsequently processed into consumer products (proteins).

Traditional boundaries between agriculture and industry, particularly in drug and chemical manufacture, are becoming blurred. Transgenic animals have been modified with foreign genes that express scarce human proteins. Through this process, called "gene pharming," useful pharmaceutical products have been produced in the milk of sheep, goats, and cows. A Dutch company called Gene Pharming Europe BV genetically engineered the world's first bull with a gene that allows his daughters to produce human milk protein.[36] This process is beneficial because the cost of producing drugs in animal milk is only a fraction of the cost of producing them in a traditional bioreactor. Gene pharming typifies the role reversal that occurs when industrial production is transferred to the farm.

At another blurred boundary between agriculture and industry, genetically modified tobacco plants are being used to produce enzymes for the food industry. Polyhydroxybutyrate (PHB) is a biodegradable thermoplastic derived from many species of bacteria. The genes from a bacterium that encodes the enzymes required for synthesizing PHB were placed in a tobacco plant virus, which then may infect a plant by inserting the desired genes. If this promising technique works, it may be the initial step toward producing novel biopolymers in plants through genetic engineering.[37]

Although biotechnology calls into question the distinction between products of industrial and agricultural origin, the blurring of that distinction has considerable precedent. The modern high-efficiency farm uses Tayloristic assembly-line practices. The machinery must be supplied from sources outside of the farm's operation. And the Industrial Revolution created a new demand for selected agricultural crops such as cotton, wool, jute, rubber, and vegetable oils.[38] Food crops themselves may undergo processing or treatment prior to distribution in consumer markets. Innovations in biotechnology are thus emphasizing an agricultural-industrial nexus that has evolved for more than a century.

The distinction between rural and urban contributions to an industrialized society can no longer be grounded in an essentialist view of production sector contributions to the economy, lifestyles, cultural values, or production modalities. Food, fibers, and commercial chemicals may come either from an industrial processing plant or from land-based agriculture. If biotechnology is successful, one analysis predicts that

> the elimination of major portions of the farming enterprise [will] displace farmers and farmworkers on a scale never before possible. . . . [W]e can expect the not-so-gradual reduction of spatial, temporal, and climatic barriers to food and fiber production. This change alone will bring with it substantial social upheavals as the location of production changes. In addition, we can expect the elimination of major portions of the farming enterprise if field crops are grown in vitro."[39]

These changes notwithstanding, the concept of the traditional small family farm rooted in a popular mythology persists, possibly because of its significance in the nation's history (over a million small farms still operate in the United States) and secondarily because the farm is an archetypal symbol of family values and independent entrepreneurship that people refuse to give up easily.

Conclusion: Genetic Power and Techno-Mythmaking

Every ancient culture has created myths. They are the stories in which fantasy, reality, moral education, sacred values, cosmogony, life's lessons, and the passing on of valued traditions are mixed together. In the many studies of myths in history, scant attention has been given to mythmaking in contemporary society. Perhaps the arrogance of scientific secularism prohibits science from seeing itself as creating myths, an activity it views as relegated to prescientific societies and studies of folklorists. Mythmaking, after all, is a revelatory approach to truth and a substitute for scientific rationality.

But if we view mythmaking as a process of inventing powerful new symbols that introduce a set of values or expectations, that explain our origins or our essential being, and that help define a path to the future — then it is possible to see the roles that myths have held in contemporary societies.

Cultural anthropologists have learned that myths are more than expressions of primitive wisdom. Some have observed that myths are the precursors to a system of law and moral truths in that they provide a unifying cognitive structure for social cohesion. Myth fulfills an indispensable function in primitive culture: It expresses, enhances, and codifies belief; it safeguards and enforces morality; it vouches for the efficiency of ritual and contains practical rules for the guidance of human actions.[40]

Mythmaking in contemporary science has less to do with practical rules for the guidance of individual human behavior than it does with the choice of future pathways for societal progress. Techno-myths, as I call them, provide hopeful symbols and comforting beliefs during periods of uncertainty, anxiety, and change. These beliefs may be speculations, exaggerations, or even false notions of hope, but they are designed to achieve social commitment to unanimity of purpose. Scientific myths are anchors of belief in a selected conception of modernity. "Myth is above all a cultural force . . . an indispensable ingredient of all culture."[41] For example, each technological revolution has its power myth. Nuclear energy was going to produce so much inexpensive electricity we would not have to meter it. The myth of nuclear energy was replaced with the myth of fusion power, according to which energy would be not only plentiful but also compatible with a safe environment. We witnessed the myth of DDT, a safe and universal solution for the eradication of insect pests, followed by a grander myth about a chemical utopia built on synthetic organic molecules.

After decades of studying myths in native cultures, anthropologists began to recognize the parallels in functional roles between ancient and modern myths. Mythmaking is ultimately about securing beliefs.

Every culture creates and values its own myths, not because it may not be able to distinguish between truth and falsity but because the function of myths is to maintain and preserve a culture against disruption and destruction. Myths serve to keep people struggling against defeat, frustration, and disappointment; and they preserve institutions and institutional processes.[42]

A generally, although perhaps not universally, accepted tenet is that genetic technology is capable of transforming biological entities significantly beyond what could be achieved with traditional technology. Modern biotechnology has brought biology from a predominantly analytical phase to a new synthetic phase in its historical evolution. The possibilities for rearranging species are for all practical purposes unlimited. Various interests are involved in a struggle over the power images of modern biology. Power is central to current mythmaking. For staunch supporters of biotechnology, genetic power translates into investor confidence. Venture capitalists ride the wave of biotechnological power while the established corporate sectors reinforce the notion that genes hold the key to a new economic order.

In the postchemical phase of industrialization a new folklore of a healing technology has emerged. According to this new wisdom biotechnology will reestablish our balance with nature; it will offer a cornucopia of curative and safe products. The same promoters of biotechnology are not blind to the critics who also embrace the metaphor of genetic power. In this case, however, power is read as the potential for a technological disaster. For this reason power must be played down, especially in communications with the media. The abundant discourse on biotechnology cites its power to cross species barriers and to introduce completely new traits into indigenous organisms.[43] Periodically, scientists dispute this message, as a *Boston Globe* headline illustrates "Splice Genes? Nature Did It Long Before Geneticists."[44] There is no dearth of inconsistency in how the science media report on the power of genetic technology.

Promoters of biotechnology must walk a fine line in this game of symbols. They accept the power metaphor but interpret it as inherently safe power, like the power of solar energy. The grand techno-myth is that with genetic engineering we can fine-tune nature, preserve its diversity while reaping its bounty. Organisms can be genetically modified "in less time and with greater precision, predictability and control than possible with traditional methods."[45]

In the cultural sphere of environmental activism, the use of the power metaphor evokes apprehension. Political activists exploit the power metaphor by emphasizing risk and uncertainty. There is no safe power. The means by which one controls a powerful technology is not with more technology. Therefore, unless the social values are worked out in advance, genetic power is greeted with suspicion. While critics emphasize genetic power as a threat, they also dismiss it as a false power that will not solve societal problems.[46] In the social arena, stakeholders who may disagree about the value of biotechnology continue to advance the myth of genetic power. Not only has the mythology developed around the power of techniques, according to a recent study by Ruth Hubbard and Elijah Wald, the gene sui generis has been afforded a special metaphysical status. "The myth of the all-powerful gene is based on flawed science that discounts the environmental context in which we and our genes exist."[47] Ultimately, as the myth of genetic power gains in significance, less emphasis is placed on alternative technologies and on social determination as opposed to corporate determination of technological futures. Myths are social constructions designed to protect beliefs and invoke order. If this interpretation is correct, then the strongest effort at mythmaking for biotechnology is expected in those periods where the greatest threat to the success of commercialization of biotechnology takes root, for example, periods of social mobilization against specific products or technologies.

Once embedded in public consciousness, techno-myths are difficult to displace. For this reason different constituent groups view as essential the struggle to control the images of biotechnology at the outset. Successful techno-myths will blunt society's critical perspective. New information inconsistent with the orthodox view is easily discredited or ignored. An independent intelligentsia has the responsibility of comparing the constructed images of biotechnology with empirical reality. If that role is relinquished, biotechnology will become self-reifying. Neither the media, the general public, nor much of science will be in a position to distinguish appearance from reality.

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Notes

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2. The following propositions that contribute to the mythmaking potential of biotechnology will not be addressed in this paper: Biotechnology will (will not) feed the world's hungry people; biotechnology will (will not) provide cures for the world's major diseases; biotechnology will (will not) lead us to renewable resource economies. These claims have also been used to advance the biotechnology research agenda and to implant the idea in the minds of the general public that biotechnology is synonymous with progress.

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