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BIOTECHNOLOGY IN AGRICULTURE: AN ANALYSIS OF SELECTED TECHNOLOGIES AND POLICY IN THE UNITED STATES

H. PATRICIA HYNES
Institute on Women and Technology, P.O. Box 338, North Amherst, MA 01059, U.S.A.

Synopsis—The first applications of biotechnology in U.S. agriculture are bovine growth hormone and herbicide-resistant plants. I analyze and debunk the mythology that these technologies are necessary, progressive, and inevitable. Proposed regulation and policy are used to protect the technologies so they can survive conflict, public distrust, and even failure. Public policy, ethical analysis and analysis of the risks of the biotechnologies lag behind technology development. The risk-benefit analysis does not take into consideration the social, political, and spiritual price paid by those on whom the technologies are used. The biotechnologies are not presented as one among many solutions to a problem, but as the dominant one. The alternatives to these technologies are shut out.

The atomic bomb was the mid-century touchstone of male dominance, with nature as the instrument of destruction. Rachel Carson told students of Scripps College in 1962 that "in the days before Hiroshima," she thought that there were powerful and inviolate realms of nature, like the sea and vast water cycles, which were beyond man's destructive power. "But I was wrong," she continued. "Even these things, that seemed to belong to the eternal verities, are not only threatened but have already felt the destroying hand of man." (Carson, 1962b: 8). However, the history of the atomic bomb, which holds such romance for new generations of dominance-driven scientists, also gives us critical guideposts by which to judge the new biotechnologies. Let us use them.

The bomb was developed in secret. Once it was deployed, it became an inevitable and necessary part of defense. Nuclear weapons build-up was encased in a mythology of freedom and security through military dominance. Then "peacetime" uses of the atom were rapidly developed to make the nuclear industry respectable. Regulation and policy do not stop its continued development and use; rather they ensure it. Those responsible for national and international regulation of nuclear power ignore the substantive question of whether it is necessary or it ought to be employed. Instead, they draw media attention to derivative issues, such as treating the effects of radiation exposure, international reporting and information systems in the event of an accident, evacuation plans in case of an accident, controlling who has access to nuclear arms, and keeping weapons-grade plutonium out of the "wrong" hands.

There were alternatives to dropping the bomb in Japanese cities, but those who developed it insisted on its use. They blunted the growing critique among some scientists involved in the Manhattan Project of using the bomb, and they sheltered the military and political decision-makers from that critique. The decision to use the bomb was made quickly, in secret, and in an atmosphere of crisis. In that environment, the alternatives were shut out from consideration.

The bomb's technical effectiveness was better analyzed and understood than

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its health effects on human beings. The extensive radiation sickness suffered by Hiroshima victims had not been anticipated by American scientists. So when Japanese reported the vast number of people suffering from radiation sickness, they were not believed. A second bomb was then dropped on Nagasaki (Pacific War Research Society, 1972; Wyden, 1984).

Although the bomb was developed for a specific war situation and a specific target, nuclear weapons have proliferated beyond the reasons for which they were developed. There is no earthly or atmospheric sanctuary from them. The bomb has shrunken the vastness and power of nature; nothing is inviolate from nuclear holocaust.

These guideposts, taken from the development of the atomic bomb, will direct my analysis of the new biotechnologies in agriculture. In summary, they are:

- A mythology encases the technology to make it necessary and acceptable. Once it becomes technically possible, it becomes inevitable.
- Regulation and policy are used to protect the technology, to ensure that it can profit ably survive conflict, public distrust, and even failure.
- Public policy, ethical analysis and analysis of the technologies' risks lag behind the technology development. In the absence of an ethical analysis, the proponents of the technologies generate a plethora of derivative issues which distract from the central ones and which eventually come to replace them (e.g., the legality of patents for genetically altered plants and animals). The derivative issues, complex in themselves, replace the fundamental questions of whether the technologies should exist at all and what the preferred alternatives to the technologies are, where a genuine need or problem exists.
- Those who develop the technologies, who promote them and stand to profit most from them, are not those who suffer their risks. The analysis of the technologies is biased towards their use because the technology promoters generally lack the expertise and the incentive to analyze the risks of the technologies for human health and the environment. In their risk-benefit analysis, the technologists do not take into consider ation the social, political and spiritual price paid by those on whom the technologies are used.
- The new technology is not presented as one among many solutions to a problem, but as the dominant one. The alternatives to the technology are shut out.[1]

Biotechnology is commonly called a "revolution," which offers hope to feed the world in the twenty-first century as developing countries "explode" in population. It is justified on the premises that, first, the technologies guarantee self-sufficiency and self-determination and, second, that no matter what the social impacts from their use, people have the right to these technical turnkeys to self-determination. Driven by twin engine partnerships of scientific "initiative" and commercial interests, biotechnologies in agriculture rely on the reduction of the "raw material": plants, microbes, and animals—to parts of themselves: genes. The reconstructed whole is the sum of dismembered and re-combined parts.

Biotechnology in agriculture is called a revolution by its developers and users in the most expectant sense of the word: "an assertedly momentous change." There are, however, two other definitions of revolution which more truthfully describe what kind of revolution is taking place: (a) "a turning or rotational motion about an axis"; and (b) "a forcible substitution of rulers or ruling cliques." (American Heritage Dictionary, 1981).

The new biotechnologies in agriculture will, in some cases, ensure the continued and increased use of herbicides in agriculture: more of the old cycle of chemical-intensive agriculture. In other cases, they will force farmers into high-yield technologies for which farmers, already strapped with surpluses, are not asking. But the choice facing U.S. farmers will be either to use them, or to foreclose on farming. Vertically integrated ownership of agriculture—from seeds, patents on plants, microbes and animals, to fertilizer, herbicides and pesticides, together with the political power that such economic power wields—is shaping and forcing the biotechnology revolution in agriculture.

BIOTECHNOLOGY IN AGRICULTURE

1. Bovine growth hormone

There are enormous surpluses of milk, butter, cheese and nonfat milk, so much so that, under a 1985 farm bill, the United States Department of Agriculture (USDA) is paying dairy farmers to remain out of dairying for five years. The government buyouts are intended to reduce the amount of dairy products by 8 percent, thus to relieve dairy farmers of low prices which result from surpluses and to cut government surplus storage costs. At the same time that dairy cows are being slaughtered for meat and exported because too much milk is being produced, a bovine growth hormone is about to be approved for commercial use in the United States.

Major chemical companies, like Monsanto, American Cyanamid and DuPont, who recognize the market potential of biology-based technologies in agriculture, have retooled for the Age of Biology. One of the biotechnologies closest to fruition is use of growth hormones in cattle. Scientists have isolated the genes in a cow's cell that control the synthesis of bovine growth hormone (BGH). The BGH gene has been transplanted into microbes which manufacture commercial quantities of the hormone. The synthesized hormone is injected on a daily basis into the dairy cattle. The increased growth hormone boosts the cow's appetite in part by diverting more of her food from ordinary metabolism to milk production. Eating more fodder, cows have produced between 10 and 25 percent more milk during their peak milking period that follows calving. The effect of these growth hormones on the animal is to burn her out rapidly, so that within a few years she is exhausted from the speeding up of her biological processes. Already Holstein cows which should be able to produce milk for about 15 years are finished within four or five years because of other "enhancement" techniques. As for health effects, cows treated with BGH have more infections, particularly mastitis, an infection of the mammary glands. They become more sensitive to heat, so they suffer more from heat stress; and their fertility is reduced. These health effects have been observed only incidentally during "milk production trials." They are not from comprehensive studies on the health of animals treated with growth hormones (MacKenzie, 1988: 28). Although Monsanto denies any human health risks, others have suggested that residual traces of BGH, which resembles a human growth hormone, could turn up in the milk and cross the species barrier into humans (Andrews, 1986: 18).

The U.S. Food and Drug Administration has approved experiments on cattle with BGH and the marketing of milk produced from experiments. Approval for commercial use is expected to follow by 1989.

The social impacts of this biotechnology will never be calculated in the corporate cost-benefit analysis of it. With the surplus of dairy products which BGH will create—some predict the already existing surplus will triple—dairy prices will drop. Small dairy farmers and entire dairy communities will be economically and socially devasted. Only large corporate farms, which will be able to absorb the initial losses and costs, will survive and adjust. The industry pushing the growth hormone sees the eventual bankruptcy of what may amount to half of

American dairy farmers, as salutary. It will weed out the inefficient from the efficient (Andrews, 1986: 18).

Bovine growth hormone is "the thin edge of a biotechnical wedge" which is forcing open the door of agriculture for the entry of recombinant DNA technologies (MacKenzie, 1988: 29). The forward march of a technology—which is cruel to animals, which is not sought by dairy farmers, and which is not needed by a country with milk surpluses—demonstrates how much the "ruling clique" controlling and driving the new biotechnologies have come to dominate the discourse and direction of agriculture. This is a repugnant revolution, which is forcibly substituting dairy farming as caretaking of animals with an industrialized farming that reduces animals to fast-food factories.

2. Herbicide-resistant crops

The biotechnology revolution in agriculture was heralded by its proponents as a way out of pesticide-based agriculture. They even called it ecological. Genes for pesticide-resistance inserted into plants would enable plants to resist insects and thus lessen agricultural use of toxic insecticides. However, the first most aggressive use of biotechnology in agriculture is the engineering of herbicide-resistant plants. This revolution merely deepens the grooves of the senescent circle trod by agribusiness around the axis of a chemical-based agriculture.

In the agrichemical industry, more than 30 companies are engineering crops to make them genetically resistant to specific herbicides. Chemical companies, like Monsanto, Ciba-Geigy, Stauffer Chemical, W. R. Grace and Dupont have teamed up with biotechnology companies and university scientists to engineer resistance and to regulate growth in plants. In May 1988, the Monsanto chemical company field tested a strain of canola, a variety of rapeseed used for cooking and salad, which was genetically engineered to resist Monsanto's herbicide Roundup.

Ciba-Geigy is funding research to develop a soybean that is resistant to the herbicide atrazine, a herbicide sold by Ciba-Geigy and which is widely used on corn. Corn contains enzymes which enable the plant to detoxify atrazine, but soybeans do not. If farmers rotate their corn crop with soybeans, the beans are damaged by residual atrazine in the soil. Scientists studied how weeds develop an immunity to the herbicide through mutation in their DNA. They have isolated and cloned the atrazine-resistant gene and are working to transfer the gene to soybeans and other crop plants.

Researchers at DuPont have developed tobacco strains resistant to two Dupont herbicides, "Glean" and "Oust." Scientists studied chemical-induced and random mutation in bacteria that are resistant to these two herbicides. The gene responsible for resistance was then transferred to the tobacco plant. Until now, Glean has only been able to be used on cereals, since it kills most other crop plants. The market for these herbicides will dramatically increase with the development of herbicide-resistant strains of agricultural crops.

Herbicide-resistant research is being conducted by all major herbicide manufacturers, for all major crops, including corn, alfalfa, soybeans, tobacco, and cotton. Prior to biotechnology scientists achieved herbicide-resistance by observing which varieties could tolerate a given herbicide, and then crossbreeding that variety with others. Tissue culture techniques have speeded the process of developing herbicide-resistant mutated varieties. Plant tissue is cultured and then exposed to lethal doses of herbicide. Survivors are plated out for regeneration into whole plants, then transplanted into fields, and treated with herbicide. Those variants are identified which have field resistance to herbicide.

Genetically-engineered herbicide-resistance in agricultural crops is a logical outgrowth of both the agrichemical industry in quest of new markets for herbicides and also the bias for chemical agriculture within existing pesticide law and law enforcement. The industry argues that it is only doing what has been observed in nature: transferring the genetic capability to resist or detoxify a herbicide to crops which do not have it. Gene transfer just speeds up the process. As one biotechnologist put it, "'Nature took her own sweet time, but with genetic engineering, you can speed up evolution.'" (Ellington, 1988: 17).

What is being proposed here is more of the same chemical-based agriculture. It is now being extended with the assistance of new biology techniques. Nothing changes in this revolution, except the scale of the problem. The shift in agriculture from traditional methods of weed control—cultivation and crop rotation—to herbicides was hastened with the advent of "no-till" method of weed control (planting seeds through the stubble of old crops and relying on chemicals to control insects and weeds). It will be further hastened with herbicide-resistant crops. This marriage of biology with chemistry will augment herbicide sales for industry. Farmers will increase herbicide use without fear of losing their major cash crop now engineered for herbicide resistance. Farmworkers will be exposed to more herbicides. Soil and ground water contamination will increase. As insecticides resulted in increased insect resistance and created an insecticide treadmill, so with herbicides. While herbicides may control weeds on a short-term basis,; in the long-term, they may worsen the problem they were intended to control.

During the 25 years that atrazine has been used, over 30 types of weeds have developed resistance to the herbicide. Dr. Ross Feldberg, a Tufts University biochemist, warns that herbicide resistance may be transferred by engineered plants to surrounding weeds. The combination of genetically-engineered crop strains, together with increased application of herbicides which those crop strains can tolerate may set up the conditions that lead to gene transfer between plant species (Matthiessen and Kohn, 1985: 23). This could accelerate herbicide-resistance in weeds and cause an upwardly-spiralling use of herbicides. Dr. David Pimental of Cornell has studied corn exposed to the herbicide 2, 4-D. He concludes that the herbicide has increased insect and pathogen pests on corn; the sprayed plots of corn were attacked by larger numbers of insects and insects which were bigger and laid more eggs. He found that herbicides also stress and weaken the plant's resistance to disease; corn exposed to 2, 4-D had significantly more southern leaf blight lesions than unsprayed corn (Zwerdling, 1977: 18).

In 1987 the chemical industry sold more than $4 billion worth of herbicide poisons to control weeds. Herbicide resistance engineered into agricultural crops is going to accelerate the use of hazardous chemicals in agriculture rather than end it, as Utopian biotechnologists had forecast. There are no line items in the biotechnology industry's cost-benefit calculus of herbicide-resistant crops to account for the costs of an increasingly herbicide-based agriculture to human health, soil and ground water, and weed resistance.

3. Genetically-engineered microorganisms

The widespread spraying of agricultural crops with synthetic chemicals which began after World War II can seem crude today by comparison with genetic engineering of plants, animals and microbes for use in agriculture. The biotechnology industry anticipates inserting viral, yeast or bacterial genes into plants to make the plants resistant to pathogens and organisms; and inserting genes into or excising genes from bacteria which are cultured and released into agricultural fields for a variety of agricultural purposes. "The genetic engineer can take a gene from any organism and add that gene to the chromosome of another organism. The recipient cell does not have to be related to the donor. Scientists are adding bacterial genes to plants, plant genes to bacteria, animal genes to plants, etc." (Brill, 1986: 6).

Genes, inserted into plants or microorganisms, may speed up a plant's uptake of fertilizer or its rate of nitrogen fixation. Genetically altered bacteria may slow ice-formation on a plant's vegetative surface. Or they might act as a fungicide, herbicide or insecticide to protect plants from pathogens, weeds, or insects. Here is a partial list of genetically engineered organisms and their potential uses in agriculture which EPA published in October 1986.

> *Engineered marine algae.* Protoplast fusion and other recombinant DNA techniques are being used in marine algae to increase their production of beta-carotene, agar, and other algal by-products.
>
> *Fungus strains altered by ultraviolet irradiation.* Four strains of the fungus, *Sclerotinia sclerotiorum,* which are genetically mutated with ultravoilet radiation, are being tested for their efficacy as herbicides against Canada thistle and spotted knapweed.
>
> *Cell fusion product for fungus control.* A genetically altered strain of the fungus, *Trichoderma harzanium,* was produced by fusing cells of two closely related strains of the fungus. The new strain is being studied for its ability to control fungi responsible for damping off and plant rot diseases. The hybrid fungus will be applied to pea and cucumber seeds.
>
> *Baculoviruses as pesticides.* Researchers are attempting to enhance the pesticidal ability of baculoviruses by genetically manipulating the organization and expression of viral chromosomes.
>
> *Killed bacteria as pesticide.* The delta-endotoxin gene from the bacterial pesticide *Bacillus thuringiensis(Bt)* is cloned and inserted into a species of *Pseudo-monas* which is cultured to produce large amounts of the protein that acts as a pesticide. The bacteria are then killed, their cell walls fixed, and the resulting toxin used as an insecticide. Monsanto is working on a similar product using live *Pseudomonas flourescens* with the Bt gene.

The most publicized case of a bacteria genetically engineered for use in agriculture is the "ice-minus" bacteria. A University of California, Berkeley scientist Steven Lindow, discovered that there are two kinds of bacteria which populate the vegetative surface of most plants, *Pseudomonas syringae* and *Pseudomonas fluorescens,* that facilitate the ice-forming process which causes frost damage to crops and fruit trees. Frost damage occurs as moisture on the plant's surface begins to freeze. Expanding ice crystals puncture and dehydrate the plants cells. Ice forms on plants only around certain kinds of impurities which serve as a nucleus for ice crystal formation. It is thought that these two bacteria contain molecules on their cell membranes which react with the water molecules. The bacteria serve as the nucleus of ice formation when ambient temperature is at or below freezing, 32 degrees Fahrenheit. Lindow found that in more than one hundred different agricultural crops, these two bacteria were the center of frost formation. He found that plants that had the bacteria removed from their leaves could survive without frost damage to temperatures of 23 degrees Farenheit. He experimented with killing and inhibiting the bacteria, using antibiotics and chemical compounds applied as plant nutrients which disrupted the arrangement of molecules on the bacteria. With two colleagues at Berkeley, Lindow found that he could remove a gene in both bacteria which governed the arrangement of molecules on the bacteria's membrane that supported ice nucleation. Testing bacteria from which the ice-nucleating gene had been removed on laboratory plants, he found that the plants survived temperatures as low as 23 degrees Farenheit.

The next step was to test the genetically altered bacteria's performance in the field. Lindow was funded by Advanced Genetic Sciences, a firm interested in the agricultural applications of "ice-minus" bacteria as well as in the development of other genetically altered strains for artificial snow-making. Since his work was in part funded by The National Institutes of Health (NIH), he was required to obtain approval for the field test from the Recombinant DNA Advisory Committee of the National Institutes of Health. The approval was granted. However, the test was halted by a court injunction won by a coalition of environmentalists.

The environmental plaintiffs argued that the environmental impacts of the open air test had not been comprehensively evaluated. NIH's Recombinant DNA Advisory Committee which approved the field test was dominated by molecular biologists and had no ecologists, botanists, plant pathologists, or population geneticists. They were not qualified, therefore, to make the evaluation of possible environmental impacts, an assessment which is required by the National Environmental Policy Act. The expertise to tinker with nature, to alter bacteria genetically and achieve a specific effect was there. But the scientific depth and expertise to understand the potential impacts of releasing genetically altered organisms on the larger ecosystem was not.

The specific risks, which the environmentalists raised in their suit against the field study of the "ice-minus" bacteria, demonstrate the critical lag which exists between the laboratory know-how and an ecological and ethical analysis of the new biotechnologies. The environmentalists suggested that frost-preventing bacteria could be swept up into the upper atmosphere, where ice-nucleating bacteria have been found, and ultimately affect local and global climate. A senior scientist with the Humane Society testified that the proposed action could have adverse impacts on animal life, since frost kills or arrests certain microorganisms which cause disease in animals. Eugene Odum, a nationally recognized ecologist, wrote in an affidavit that the project of introducing microorganisms into the environment is especially hazardous because of their high reproductive potential and their interrelationships with other organisms in the environment, which are not well understood. He pointed out that higher plants, like trees and crops, are slow to develop immunity to new microorganisms (Doyle, 1985: 238).

Genetic engineering of microbes can increase the mutational frequency of organisms far beyond their natural rate of mutation in the environment. What happens when microorganisms with a gene implanted or excised are introduced into the environment? Cornell's Dr. Martin Alexander says that no one can predict their survival ability. Although the likelihood may be low that they will persist, "the probability of persistence for an unknown organism . . . is not zero" (Doyle, 1985: 240). Genetically modified microbes and plants will be used in agricultural ecosystems, systems which ecologists consider simplified. Agricultural environments consist of crop and animal monocultures, environments which are less diverse and in which one small genetic change could have more significant consequences than in more natural, diverse ecosystems. Ecologist Frances Sharpies warns that it may be difficult to keep genes inserted into bacteria isolated in those bacterial strains. Bacteria can transmit certain genetic material by means of plasmids from one species to another and from one genus to another (Doyle, 1985: 243).

Only since 1983 have government and science begun to consider what would happen with the release of genetically engineered organisms in the environment. In February 1985, the Cornell University Ecosystems Research Center concluded that the methods for predicting the survival and proliferation of bioengineered microorganisms in nature are crude and the effects are unpredictable. Only since June 1985 have ecologists and molecular biologists begun a formal scientific dialogue on the subject. In 1986, EPA's Scientific Advisory Board echoed the same concerns as the Cornell Ecosystems Research Center. Eighty to 90 percent of soil microbes have never been cultured in the laboratory and are unnamed. It is possible to measure if microbes have "died back"; but it is not possible to tell when microbes have died back completely (Doyle, 1986: 8). The consensus among ecologists is that no one can predict the outcome of introducing a new species into the environment[2].

At this juncture in the recent history of recombinant DNA and using genetically engineered organisms in agriculture, there is a profound sense of deja vu. Has anything changed, I pondered, as I re-read "The Obligation to Endure" in *Silent Spring*. Writing of the intensive use of synthetic organic chemicals in agriculture and forestry, Rachel Carson cautioned:

> The rapidity of change and the speed with which new situations are created follow the impetus and heedless pace of man rather than the deliberate pace of nature . . . The chemicals to which life is asked to make its adjustment are no longer merely the calcium and silica and copper and all the rest of minerals washed out of the rocks and carried in rivers to the sea; they are the synthetic creations of man's inventive mind, brewed in his laboratories, and having no counterpart in nature (Carson 1962a: 17).

What has changed from the era of spraying broad-spectrum pesticides to the era of introducing specific, genetically mutated organisms into nature are the metaphors. Chemical companies openly declared war on nature with synthetic pesticides. The biotechnologists present their technologies as assisting nature. "Farming, in the future, will be based more on biology than chemistry. Biotechnology means going 'back to nature,'" said one bioentrepreneur (Brill, 1986; p. 7). And it means improving on nature. "You will be able to find more variability than you can in nature," said another, referring to plant genetic engineering which could someday generate genetic varieties not naturally present in cultivated plants (Doyle, 1985: 197). The entire plant world will become one open-ended gene pool in which, for example, genes from a tree species resistant to a fungus can be spliced into a wheat strain which is susceptible to that fungus.

In other words, as plants and animals are going extinct at an increasing rate, biotechnology is selling itself on its ability to create genetic diversity in agriculture. It is being offered as a technical band-aid for a tragedy in nature, that "species are disappearing at rates never before witnessed on this planet" (World Commission on Environment and Development, 1987: 148) in tropical forests, temperate forests, mangrove forests, coral reefs, savannahs, grasslands, and arid zones. But, even with concocting their own genetic varieties, biotechnologists will still need a continual source of genetic diversity from plants and animals in the wild, which happen to be richest in the tropics, subtropics and regions such as the Mediterranean basin. So biotechnology companies, major corporations, and national governments of industrial countries are all trying to "collect, save, and in some cases, own, the genes of the Old World" (Doyle, 1985: 198). A new form of "First World" dominance of "Third World" is emerging, this time for gene wealth. Nature in the wild has come to interest biotechnology, as a source of genes and germ plasm, which become all the more valuable a raw material for the genetic technologies' industry as wild flora and fauna become scarce and endangered. The more genetic material the biotechnology industry can collect, save, and own today and the more ingenious their preservation and storage methods, the more dispensable wild nature becomes tomorrow.

Preserving genetic diversity in a species-endangered world is one part of the mythology which encases biotechnology development. The other element of the mythology is that this "green-gene revolution," will solve the growing world population's food needs. This is, again, a technical band-aid offered for the profound human tragedy of hunger and malnutrition. People dying from hunger when surplus food stands in silos elsewhere is not a failure of agricultural technology. This tragedy is caused by militarism which uses hunger as a weapon and siphons off countries' economic resources for guns, tanks and planes that should be used for sustainable agriculture. It is caused by economic and agricultural development which depletes and erodes soils rather than replenishing and sustaining their fertility. It is caused by structures of poverty which drive people in developing countries to live in and wear out fragile ecosystems. It is caused by agricultural policies in the West which use food surpluses as cheap aid to developing countries and, thus, undercut their indigenous agricultural economies.

Writing on global food production and global hunger, the World Commission on Environment and Development of the United Nations concludes that the problem of hunger is now primarily social and political, not technical. "The agricultural resources and the technology needed to feed growing populations are available . . . Agriculture does not lack resources; it lacks policies to ensure that food is produced where it is needed and in a manner that sustains the rural poor" (World Commission on Environment and Development, 1987: 118).

A similar analysis was presented by Robert W. Kates, Director of Brown University's World Hunger Program to the American Association of the Advancement of Science 1988 annual conference in Boston. The end of hunger is in sight, he said. World food production first matched global food needs in the 1960's and continues to increase. Hunger and famine are failures of human institutions. "Today the basic dietary needs of the world's 5 billion people can be met with only 80 percent of the world's food production . . . but the failure of human values and institutions has skewed worldwide food allocations, creating waste in the face of starvation" (Murphy, 1988: 36).

Since the causes of hunger are primarily social and political, so ought the solutions to ending hunger and famine be social and political ones, for which safe and predictable agricultural technologies serve as appropriate tools. But who will ensure that only safe and predictable agricultural technologies and technology products are approved for use?

It will not be the federal government which has not and will not allow the regulation of chemicals or biotechnologies to stifle their economic potential for industry. David Kingsbury of the National Science Foundation developed a policy framework on regulating biotechnology for the White House. Biotechnology will affect the United States economy substantially, he says, to as much as $40 billion by the year 2000. Although the United States is currently the leader in this field, he warns that Japan and many European countries will probably get special government financial assistance and special regulatory treatment. They may surpass the United States if "an irrational or burdensome regulatory climate . . . fatally impede(s) the eventual introduction of products now under development and lead(s) to future disinterest in this area"[3]. (Kingsbury, 1986: 5). In Kingsbury's view the major goal of regulating agencies is to educate the public out of "irrational" fears about the risks of the biotechnologies.

The biotechnology industry is also forcing its view of the purpose of regulation on those federal agencies which were established to protect human health and the environment against the hazards and risks of technologies. Winston Brill, Vice President of Research and Development of the biotechnology firm Agracetus, writes that ". . . The release of genetically engineered organisms into the environment . . . brings EPA into the picture. The task of EPA and also of the U.S. Department of Agriculture is to regulate released organisms without inhibiting the advance of biotechnology as a whole" (Brill, 1986: 6).

And EPA, which expects to have the primary role in regulating all of biotechnology in the development of pesticides, backs down from the bullish biotechnology industry and speaks in synchronicity with Kingsbury who speaks for the White House (and the biotechnology industry). When EPA's Assistant Administrator for Pesticides and Toxic Substances was asked what the greatest risk in the emerging field of biotechnology is, he said that it is people who distrust the technologies and the regulatory agencies: "The greatest risk we face right now is failure to develop public confidence in the process that leads from the laboratory to the marketplace" (Developing confidence in biotechnology, 1986: 2).

The real risk EPA faces in the emerging field of biotechnology is that it will end up enforcing laws whose primary intent is to protect the economic benefits of the U.S. biotechnology industry. EPA's role will be merely risk management and risk communication: analyzing the risk of biotechnologies to human health and the environment in such a limited way that, like agricultural chemicals, the technologies become acceptable and can go forward; and convincing people that risks of releasing mutated organisms into nature can be managed and that they have to be lived with.

Risk/benefit analysis is a limited, rationalistic tool which cannot comprehend values which are deep, long-lived, far-reaching, cultural, philosophical or existential, and essentially unquantitative. How do we measure what is lost when agriculture—the culture of life and living land—becomes agribusiness, with farmers as business clients of major chemical and biotechnology companies. A U.S. farmer and philosopher, Wendell Berry, expresses some of the nonquantifiable losses in the transition from agriculture to chemical and biotechnical food production. He says that agriculture is not and cannot be an industry. Agriculture has to do with life and life processes; industry uses inert materials and mechanistic processes. A factory has a limited life; tools and buildings wear out and depreciate over time. Topsoil, if well cultivated, will not wear out; some agricultural soils have been farmed for four to five thousand years or more. Finally, industry takes raw materials, uses and exhausts them, and pollutes. Agribusiness uses methods of the factory, not replenishing organic soil fertility, polluting soil and groundwater, treating animals, plants and soil as minable raw materials to be used, manufactured into new products, and exhausted. Farming is a "replenishing economy" which takes, makes and returns fertility to the soil, not just a physical organic fertility but also care and respect (Berry, 1987: 123–124).

How do we measure in cost-benefit terms the effect that the new biotechnologies will have on developing countries? The technology know-how is in the industrially developed countries. Those uses which will be commercialized first will be ones in their own self-interest, like the bovine growth hormone and herbicide-resistant crops. These technologies, then, will exacerbate the problem of food surpluses in the global market and depress further the agricultural economy of the Third World. There are those who say that the biotechnologies in the right hands—the hands which need them, the Third World nations—could pull those countries above famine and malnutrition into the era of scientific agriculture. The biotechnologies could be used for developing drought-resistant crops, more productive food plants, and livestock that grow more quickly. However, these new plant and animal life forms will have patents held by First World commercial companies who will require Third World farmers to pay royalties for extended periods of time. The royalties will become another form of economic bondage. This analysis of the technologies in the right hands presumes also that the technologies are progressive, beneficent and will work. If, as the agriculture analyst Jack Doyle has written, "one unforseen mutation or errant gene could bring down the whole system" (Doyle, 1986: 9), is it con-scionable to risk agricultural catastrophe in developing countries where food supply is still precarious?[4]

How do we measure the risk to the ecosystem, whether it be in the First World or Third World or both, of this new revolution, when many ecosystem accidents cannot be calculated in advance? With recombinant DNA technologies, there will be linkages, writes Perrow, between parts of ecosystems thought to be independent, which will create new relationships and sequences of activity in nature. They will not be expected, understood, or easily traced, once it is apparent that they have taken place. "Knowledge of the behavior of the human-made material in its new ecological niche is extremely limited by its novelty" (Perrow, 1984: 296).

To make this analysis of the risk of the unexpected more tangible, let us look at an example. Two New Zealand plant scientists, K. L. Giles and H. C. M. Whitehead, used a cell fusion technique to combine the genetic material of a fungus, *Rhizopogon sp.,* which lives symbiotically on the roots of the pine tree, *Pinus radiata,* with a nitrogen-fixing bacteria, *Azotobacter vinelandii.* They hoped to create a modified strain of fungus with the ability to fix nitrogen. In the laboratory, Giles and Whitehead applied the new fungus to pinetree seedlings. Some of the test seedlings exposed to the modified fungus died. Analysis of their roots showed that the new hybrid fungus had penetrated the cells of the root cortex. The root cells appeared dead and empty of cytoplasm. There was no intercellular growth on the pine seedlings' roots by wild strains and control strains of fungus. While the scientists did not know whether the genetically modified fungus killed the root cells or just entered the cells when they had died, they feared that the new organism might be pathogenic and destroyed the remaining plants and organisms (Doyle, 1985: 243–244).

Even with the novel risks posed by these biotechnologies, this biotechnology revolution is not new. It recalls an earlier one, in which the unexpected risks of chemical pesticides became reason to write *Silent Spring.* Rachel Carson chronicled the movement of pesticide: from point of application to soil, then washed by rain to streams and into groundwater, carried on wind beyond agricultural fields, and ultimately transported through plants, herbivores and carnivores, from insects and worms to birds, from animals and fish to humans, bio-magnifying at each step in the food chain. It was possible to render a species extinct without killing a single individual, she wrote of birds laying infertile eggs or eggs whose shells were too thin to withstand the adult bird's weight during incubation. It did not occur to the agrichemical industry that persistent synthetic pesticides would have such pathways and relationships in nature. They disputed and denied the significance of these links when they were chronicled. They trivialized Carson's research and they sexualized their contempt for a woman who would challenge their masculinist worldview: that nature exists for their use and convenience and should be taken by force.

The force, then, was an armament of synthetic chemical pesticides, broadcast like a "chemical rain of death." Now it is the reduction of nature to a pool of genetic units which can be spliced and recombined—bacterial gene to plant, plant gene to bacteria, animal gene to plant, etc.—with the arrogant claim of manufacturing life better than nature can.

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At their fortieth anniversary reunion in Los Alamos, New Mexico, 70 of 110 physicists who had worked on the atomic bomb signed a statement in support of nuclear disarmament. Many had changed their minds about the bomb long ago (Wyden, 1984: 362–366).

It is probably unprecedented in science that the brightest physicists of their day have admitted that the most notable work of their lives was a colossal mistake. Yet this collective turning point is irrelevent to those scientists who would valorize their own work by comparing it to the atomic bomb project. Gauging by the "new frontier" frenzy of biotechnologists, whose time in the science sun has come with genetic engineering and the new reproductive technologies, it will be 40 years—time enough to win Nobel Prizes—before the majority regret what they have done and defect from the brotherhood of these biotechnologies.

ENDNOTES

1. I apply this same analysis to the new reproductive technologies in *The Recurring Silent Spring,* to be published by Pergamon Press in March 1989. However, there is a major difference between the proliferation of the genetic engineering technologies and the new reproductive technologies. The genetic engineering revolution in agriculture is unabashedly worldwide—every country, every farm, every international agricultural development project is envisaged. This revolution, begun in test tubes, carried out in virtual silence, directed from corporate towers with no public involvement, is ready to happen. Yet, with its readiness and gargantuan economic power, the applications in agriculture are hamstrung by regulatory confusion and court injunctions. On the other hand, the new reproductive technologies, which were supposedly developed for a small number of women, whose infertility was caused by blocked or absent fallopian tubes, are flourishing in hundreds of clinics throughout the world. Increasing numbers of women are now being prescribed *in-vitro* fertilization, whether they are infertile or not. Neither court injunctions nor a lack of regulatory framework are keeping them from proliferating.

2. In 1987 Advanced Genetic Sciences (AGS) did win a court challenge to field test ice-minus bacteria. In April 1987 scientists sprayed a strawberry field in north ern California. It was the first *authorized* outdoor release of genetically engineered bacteria in the United States. The Environmental Protection Agency had fined AGS for injecting the bacteria into trees growing on a laboratory roof in 1985. In March 1988, EPA approved field tests of a bacterium genetically engineered to increase nitrogen fixation. The bacterium *Rhizobium meliloti* grows naturally on alfalfa roots. BioTechnica Inc. of Cambridge, Massachussets has reinserted genes responsible for nitrogen fixation back into the organism, giving it two copies of the same gene.

3. This image of U.S. biotechnology strapped by regulation while Japan and Europe are specially protected contradicts Yale sociologist, Charles Perrow's findings. He writes that the current laissez-faire attitude toward DNA research among American biotechnology researchers distinguishes them from European and Japanese counterparts. In Britain, for example, gene-splicing technology is constrained by a stricter set of standards and containment levels than in the United States. Japan has implemented a strict set of policies patterned after the original NIH guidelines, which have since been sof tened in the United States. "The [U.S.] economic projection, the great interest of private, for-profit firms and the popularity of such U.S. firms as Genetech(sic) in our stock market may have something to do with this international difference" (Perrow, 1984: 301).

David Kingsbury is currently under investigation for his ties to a British biotechnology company according to *Science* and *New Scientist.* In 1986, Kingsbury reelected himself to the board of directors of IGB, Inc., a medical diagnostics research company and part of Porton International PLC (Anderson and Connor, 1987: 24; Crawford, 1987: 742).

4. Tanzania has embarked on a new national agricultural policy which now emphasizes improving the peasants' agriculture through crop rotation, composting and village-based agriculture over the high-tech practices of the Green Revolution. Originally, President Nyerere sought to modernize the country's agriculture by imitateing the American and Canadian model: mechanization, chemical fertilizers, chemical pesticides, and herbicides. Compost making was no longer taught in agricultural schools, because it was discredited as old-fashioned. Farmers, however, found themselves dependent on an unreliable supply of chemicals. Returning to indigenous methods of organic agriculture gives them a self-reliance which they had lost (Doyle, 1985: 275–276).

There may be another reason for the return to indigenous farming in Tanzania. Women do most of the agricultural field work, yet the government alloted the new hybrid maize seeds, fertilizer and pesticides to men. The Tanzanian women neglected the new crop because the profits from Green Revolution agriculture would go to the men. Women—who work an average of 3,069 hours , per year to men's 1,929—continued with indigenous agriculture (Dankelman and Davidson, 1988: 3, 18). This fact, that women boycotted Green Revolution agriculture, may be the crux of why the high tech revolution in agriculture failed in Tanzania, and the country returned to indigenous methods of organic agriculture.

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