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You are what you eat. A truism, a warning, a prescription, a trite comment with little meaning? But in the age of DNA and genetic experimentation, perhaps a new meaning has emerged that gives pause for thought about a well-worn phrase. This issue deals with the very real conundrum: In this age of enormous poverty, hunger and population explosion, can the world feed its people given the present amount and condition of arable land available?

Is this a matter of population control, either through government policy or personal choice? Is it a matter of allowing scientific experimentation with its possible risk, that suggests that by manipulating DNA we can create a "magic" food supply? Can the world's hungry be fed by social manipulation of land allotment and reassignment of ownership? Still other questions arise as the issue of feeding the hungry, of preventing thousands, if not millions, of babies and children from dying from lack of adequate nourishment, plagues this fruitful earth. Some of the arguments for and against genetic engineering of the food supply are presented here, in hopes of stimulating further research, and certainly further discussion.

This edition of Issues is organized around the central notion that food—one of life's essentials—has become subject to controversy over the potential advantages and risks of the introduction of biotechnological innovations to improve both the quality and quantity of the world's food supply.

FOOD THROUGH SCIENCE: PROMISE OR THREAT?

THE ISSUE

Food: A Fundamental Human Right

From the Food and Agricultural Organization (FAO) of the United Nations

[The main objective of the FAO is ensuring humanity's freedom from hunger. *Ed.*]

Despite the fact that the right to food is recognized directly or indirectly by all countries in the world, hunger, whether caused by war, drought, natural disaster or poverty, continues to cause widespread suffering. And poverty, one of the causes of hunger, is also a consequence of it.

Hunger dulls intellects and thwarts productivity, keeping entire societies from realizing their potential. For poor families in developing countries, hunger-related illness adds to household costs and increases the burden of care for healthy family members often already struggling for subsistence. When this hardship is multiplied by millions of families worldwide, it creates a devastating ripple effect that imperils global development.

At the 1996 World Food Summit, leaders from 185 countries and the European Community reaffirmed, in the Rome Declaration on World Food Security, "the right of everyone to have access to safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger." They further pledged to cut the number of the world's hungry people in half by 2015.

Eradicating hunger is not merely a lofty ideal. Ensuring the right to adequate food and the fundamental right to be free from hunger is a matter of international law, specifically enshrined in a number of human rights instruments to which states around the world have committed themselves.

WHAT IS THE RIGHT TO FOOD?

Since its inception, the United Nations has identified access to adequate food as both an individual right and a collective responsibility. The 1948 Universal Declaration of Human Rights proclaimed that "everyone has the right to a standard of living adequate for the health and well-being of himself and his family, including food . . ." Nearly 20 years later, the International Covenant on Economic, Social and Cultural Rights (1966) developed these concepts more fully, stressing "the right of everyone to . . . adequate food" and specifying "the fundamental right of everyone to be free from hunger."

So, what is the distinction between the right to be free from hunger and the right to adequate food? The right to freedom from hunger is fundamental. This means that the state has an obligation to ensure, at the very least, that people do not starve. As such, this right is intrinsically linked to the right to life. In addition, however, states should also do everything possible to promote full enjoyment of the right to adequate food for everyone within their territory—in other words, people should have physical and economic access at all times to food that is adequate in quantity and quality for a healthy and active life. For food to be considered adequate, it must also be culturally acceptable and it must be produced in a manner that is environmentally and socially sustainable. Finally, its provision should not interfere with the enjoyment of other human rights—for example, the acquisition of sufficient food for an adequate diet should not be so costly as to threaten the satisfaction of other socio-economic rights, or be fulfilled to the detriment of civil and political rights.

The rights connection

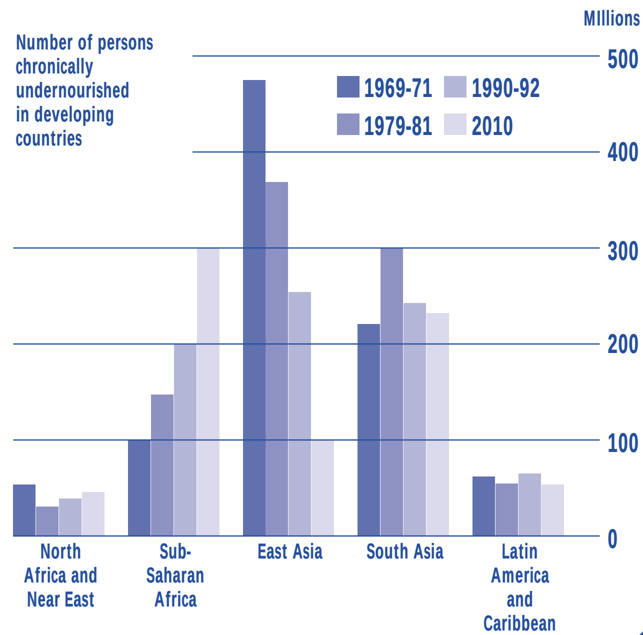
The civil, cultural, economic, political and social rights proclaimed in the Universal Declaration are considered interdependent, interrelated, indivisible and equally important. To be able to enjoy the right to food fully, people need access to health care and education, respect for their cultural values, the right to own property and the right to organize themselves economically and politically.

Without adequate food, people cannot lead healthy, active lives. They are not employable. They cannot care for their children, and their children cannot learn to read and write. The right to food cuts across the entire spectrum of human rights. Its fulfilment is essential to the fight against poverty, and it is at the heart of FAO's mandate to ensure a world free from hunger.

Source: Adapted from <http://www.fao.org.FOCUS/E/rightfood/right1.htm> (Jan 1, 2002).

Global Hunger – widespread, persistent, unacceptable

If decisive action is not taken, the number of chronically undernourished persons will be substantially the same in 15 year's time. The greatest suffering will be in sub-Saharan Africa, where food output has not kept pace with population growth. Reversing these trends will require rapid and sustainable production gains as well as measures to make food accessible to those who need it.



This graph identifies the major problem confronting the peoples of the earth: in the future will we be able to adequately feed the billions of people around the world? In areas of the world where population appears to be exploding, the food supply has not kept up in a like manner. Some have proposed that the solution lies not in present land/farm arrangements, but rather in the scientific improvement of basic crops by genetically engineering them to greater productivity and greater disease resistance so as to increase yield and thus meet the demand. Given this situation, there is a need to recognize that there is also, according to the United Nations, a universal human right to food adequate to keep people fed and healthy.

Source: <http://www.fao.org/news/factfile/ff9602-e.htm> (Jan 15, 2002).

What Is Genetic Engineering?

[There is, indeed, a population-food relationship that needs to be resolved not only for humanitarian reasons, but also because it generates the vast potential for unrest in many areas of the world. Biotechnology may well offer the solution to both productivity and improved nutrition.

The Union of Concerned Scientists has been in the forefront of raising cautions regarding genetic engineering. This cautionary statement was issued against blind acceptance of scientific genetics as applied to everyday life. This section is provided as a "quick" definitional statement about the nature of biotechnology. *Ed.*]

Genetic engineering refers to a set of technologies that are being used to change the genetic makeup of cells and move genes across species boundaries to produce novel organisms. The techniques involve highly sophisticated manipulations of genetic material and other biologically important chemicals.

Genes are the chemical blueprints that determine an organism's traits. Moving genes from one organism to another transfers those traits. Through genetic engineering, organisms are given new combinations of genes—and therefore new combinations of traits—that do not occur in nature and, indeed, cannot be developed by natural means. Such an artificial technology is radically different from traditional plant and animal breeding.

Novel organisms

Nature can produce organisms with new gene combinations through sexual reproduction. A brown cow bred to a yellow cow may produce a calf of a completely new color. But reproductive mechanisms limit the number of new combinations. Cows must breed with other cows (or very near relatives). A breeder who wants a purple cow would be able to breed toward one only if the necessary purple genes were available somewhere in a cow or a near relative to cows. A genetic engineer has no such restriction. If purple genes are available anywhere in nature—in a sea urchin or an iris—those genes could be used in attempts to produce purple cows. This unprecedented ability to shuffle genes means that genetic engineers can concoct gene combinations that would never be found in nature.

New risks

Contrary to the arguments made by some proponents, genetic engineering is far from being a minor extension of existing breeding technologies. It is a radically new technology for altering the traits of living organisms by inserting genetic material that has been manipulated by artificial means. Because of this, genetic engineering may one day encompass the routine addition of novel genes that have been wholly synthesized in the laboratory.

Novel organisms bring novel risks, however, as well as the desired benefits. These risks must be carefully assessed to make sure that all effects—both desired and unintended—are benign. UCS advocates caution, examination of alternatives, and careful case-by-case evaluation of genetic enginering applications within an overall framework that seeks to move agricultural systems of food production toward sustainability.

Source: Briefing: "What is Genetic Engineering?" Union of Concerned Scientists, <http://www.ucsusa.org/agriculture> (Jan 15, 2002).

For further information about the topic, use one of a variety of search vehicles. For information *supporting* genetically modified organisms: Biotechnology Industry Organization <http://www.bio.org>; those searching for information *opposing*, should look at the web site of the Union of Concerned Scientists <http://www.ucausa.org>.

What Is Genetically Modified Food?

By Deborah B. Whitman

The term GM [genetically modified] foods or GMOs [genetically-modified organisms] is most commonly used to refer to crop plants created for human or animal consumption using the latest molecular biology techniques. These plants have been modified in the laboratory to enhance desired traits such as increased resistance to herbicides or improved nutritional content. The enhancement of desired traits has traditionally been undertaken through breeding, but conventional plant breeding methods can be very time consuming and are often not very accurate. Genetic engineering, on the other hand, can create plants with the exact desired trait very rapidly and with great accuracy. For example, plant geneticists can isolate a gene responsible for drought tolerance and insert that gene into a different plant. The new genetically-modified plant will gain drought tolerance as well. Not only can genes be transferred from one plant to another, but genes from non-plant organisms also can be used. The best known example of this is the use of B.t. genes in corn and other crops. B.t., or *Bacillus thuringiensis*, is a naturally occurring bacterium that produces crystal proteins that are lethal to insect larvae. B.t. crystal protein genes have been transferred into corn, causing it to produce its own pesticides against insects such as the European corn borer.

Source: Excerpted from Whitman, Deborah B., "Genetically Modified Foods: Harmful or Helpful?" Cambridge Scientific Abstracts. April 2000. <http://www.csa.com/hottopics/gmfood/overview.html > (Jan 12, 2002).

Future Foods: The New Genetic Menu

Restaurants and grocery stores will offer future diners far more exotic choices than ever before, thanks to genetic engineering that permit flavors, textures, and other properties from one species to be introduced into another.

Some items on tomorrow's menu might include:

- "Protrout," super-protein trout
- Ultra-lean "Pig-No-More"
- "Octo-squid"
- "Beetatoes"
- "Beefison:" meat with venison's flavor and beef's bulk
- "Shrimpsters:" less-squishy oysters produced with shrimp genes
- Swordfish-flavored tuna
- Duck-flavored pork
- Seaweed dip seasoned with spring onion genes
- A quail-chicken transgenic fowl dubbed "quicken"

Source: Adapted from 2025: Scenarios of US and Global Society Reshaped by Science and Technology, by Joseph F. Coates, John B. Mahaffie and Andy Hines (Oakhill Press,1997) as quoted in O'Meara, Mehlinger, Krain, Eds. (2001): Globalization and the Challenges of the New Century. Bloomington and Indianapolis: Indiana University Press. p. 373.

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THE ADVANTAGES

Ten Reasons Why Biotechnology Will Be Important to The Developing World

By Martina McGloughlin, University of California, Davis

[This article was a response to another article that is not included here. Where references to the other article appeared they have been omitted, but the citation is included at the end should the reader desire to read the entire presentation, and, perhaps to refer to the original article to which Professor McGloughlin responded. The points that Professor McGloughlin makes, however, stand alone as a justification for the continuation of biotechnology in food production. The author's references can be found in the original article. *Ed.*]

Biotechnology companies, national and international organizations, including the Consultative Group on International Agricultural Research (CGIAR), and numerous academics (e.g., Ruttan 1999) have continued to argue for the need to increase agricultural productivity so that sufficient food supplies exist to meet the demand forthcoming from a swelling world population. Despite [the assertion of others], population density is hardly the issue. In the absence of significant productivity gains, or expansion of agriculture into marginal lands (e.g., forests), there will not be sufficient food quantities to feed the projected levels of population. This simple reality is independent of income distribution or the location of the population. And hardly anyone . . . will argue about the pragmatism of population projections. So in the absence of good alternatives and in the face of a proven slowdown in the productivity gains from the Green Revolution, biotechnology is by default our best, and maybe only, way to increase production to meet future food needs.

My objective in this article is to challenge misconceptions often put forward about biotechnology.

1] The argument that hunger is a complex socioeconomic phenomenon, tied to lack of resources to grow or buy food, is correct. Equally correct is the argument that existing food supplies could adequately feed the world population. But how food and other resources (e.g., land, capital) are distributed among individuals, regions, or the various nations is determined by the complex interaction of market forces and institutions around the world. Unless our civic societies can come up quickly with an economic system that allocates resources more equitably *and* more efficiently than the present one, 50 years from now we will be faced with an even greater challenge. Calorie for calorie there will not be enough food to feed the projected population of about 9 billion. With the purchasing power and wealth concentrated in the developed countries, and over 90 percent of the projected population growth likely to occur in developing and emerging economies, it is not difficult to predict where food shortages will occur. Unless we are ready to accept starvation, or place parks and the Amazon Basin under the plough, there really is only one good alternative: discover ways to increase food production from existing resources . . .

2] The assertion that most innovations in biotechnology are *not* need driven is incorrect. Here are a few well-documented examples of biotechnology innovations targeting pressing needs:

• Development of a rice strain that has the potential to prevent blindness in millions of children whose diets are deficient in Vitamin A. Vitamin A is a highly essential micronutrient and widespread dietary deficiency of this vitamin in rice-eating Asian countries has tragic undertones: five million children in Southeast Asia develop an eye disease called xerophthalmia every year, and 250,000 of them eventually become blind. Improved vitamin A nutrition would alleviate this serious health problem and, according to United Nations International Children's Education Fund (UNICEF), could also prevent up to two million infant deaths because vitamin A deficiency predisposes them to diarrheal diseases and measles . . .

• Improvements to hybrid rice by introducing the gene of interest directly into maintainer or restorer lines. Early results of transforming rice with the nodulin gene indicate that this staple can be colonized by bacteria that fix nitrogen from the atmosphere. This would improve productivity in the absence of synthetic fertilizers, which are typically unavailable to resource- poor farmers in less developed countries (LDCs).

• Edible vaccines, delivered in locally grown crops, could do more to eliminate disease than the Red Cross, missionaries and United Nations (UN) task forces combined, at a fraction of the cost.

Biotechnology is being advanced and directed towards resource-poor farmers and locations . . . . In market-driven economies, need and profit are closely connected. Companies, large and small, profit only when they offer products and services that address needs and induce willingness to pay. Bt (*Bacillus thuringiensis*) and Roundup Ready technologies have been adopted faster than any other agricultural innovation on record. These adoption levels have taken place despite abundant supplies of conventional seed with which farmers can exercise their "age-old right to save and replant." The reason for the quick adoption, of course, is that farmers profit from the use of such technologies through reduced chemical sprays, improved yields, labor savings, shifts to reduced tillage systems and other benefits. Over half of all economic benefits generated by these technologies have gone to farmers, more than what has been appropriated by biotechnology and seed companies combined.

3] The argument that the integration of chemical pesticides and seed-use has led to lower returns for farmers is incorrect. Several comprehensive studies point to increased net returns and reduced chemical loads. Because of their improved production economics, the introduction of Bt and herbicide-resistant crops have forced tremendous competition in herbicide and insecticide markets. Prices of many herbicides and insecticides have been slashed by over 50% in these markets in order to compete with the improved economics of biotechnology seed/chemical solutions. Such price reductions have led to significant discounting of weed and insect control programs and have benefitted even farmers who have not adopted biotechnology crops. Because of lower prices and reduced volumes synthetic pesticides from the use of biotechnology crops, the agrichemicals sector has experienced significant financial losses over the last two-three years.

4] The assertion that "genetically engineered seeds do not increase the yield of crops" is misleading. Generally, Bt-type technologies are expected to increase yields while herbicide- resistant technologies are expected to reduce costs and input use. Conventional weed control programs applied on conventional seed may be as effective in controlling weeds as herbicide resistant plants and are expected to yield similarly. However, conventional weed treatment programs are expected, on average, to cost more and involve larger amounts of synthetic pesticides. In addition herbicide-tolerant crops eliminate the need for pre-emergent spraying with far less benign herbicides. On the other hand, Bt crops enjoy greater protection from hard-to-control insect pests relative to conventional plants that are applied to chemical insecticides. As a result, when insect pests exceed certain thresholds, Bt crops are expected to yield better. Such effects will tend to vary from one region to another and from one year to another as insect pest pressures and weed infestations tend to be variable . . .

5] The assertion that "there are potential risks of eating (bioengineered) foods" is alarmist. Citing unspecified "recent evidence," [critics] fail to acknowledge the extensive scientific evidence that consistently finds that the use of biotechnology methods and biotechnology products poses risks no different from those presented by other genetic methods and products.

The Food and Drug Administration (FDA) has evaluated technical evidence on all proteins produced through biotechnology and currently in commercial food products. All of the proteins that have been placed into foods through the use of biotechnology and are currently in the market are non-toxic, sensitive to heat, acid and enzymatic digestion, and hence rapidly digestible, and have no structural similarities with proteins known to cause allergies. Under their oversight structure, the FDA does not routinely subject foods from new plant varieties to pre- market review or to extensive scientific safety tests, although there are exceptions. The agency has judged that the usual safety and quality control practices used by plant breeders, such as chemical and visual analyses and taste testing, are generally adequate for ensuring food safety. Additional tests are performed, however, when suggested by the product's history of use, composition, or characteristics.

Similarly, the argument that insertion of new DNA can alter the metabolism of plants or animals causing them to produce new allergens and toxins is deceptive. For one thing, these kinds of changes can happen through natural mutations or with any type of plant transformation (e.g., through traditional breeding or bioengineering). For another, newly developed plants (resulting from traditional breeding or bioengineering) are subjected to extensive testing that demonstrates that such plants look [normal] and grow normally, and have the expected levels of nutrients and toxins. Extensive scientific evidence suggests that there are no food safety issues with bioengineered plants. Presence of a substance that is completely new to the food supply or of an allergen presented in an unusual or unexpected way (for example, a peanut protein transferred to a potato) invokes greater scrutiny by the agency. This focus by the FDA on safety-related characteristics, rather than on the method by which the plant was genetically modified, reflects the scientific consensus that "the same physical and biological laws govern the response of organisms modified by modern molecular and cellular methods and those produced by classical methods," and, therefore, "no conceptual distinction exists."

Over the years, scientists working on bioengineered crops have used strict scientific principles and thorough analyses to confirm for themselves and the public that the genes and techniques used are safe for the consumer and the environment. The most we can ask is that all foods produced by whatever method receive the same level of evaluation. Millions of people have already consumed the products of genetic engineering and no adverse effects have been reported or demonstrated. Scientists are confident in the validity of the system that regulates and oversees the food supply.

6] The argument that the new bioengineered varieties will fail, as pests develop resistance to the natural Bt-toxins produced by these varieties because they violate the basic principles of integrated pest management (IPM), is misleading. Pests tend to overcome any control mechanism, including those introduced through biotechnology, synthetic pesticides, or even . . . broader integrated approaches . . . In biology no solutions are permanent. Once selection pressure is applied on a population, that population is effectively enriched for resistant organisms. That is why it is imperative to develop a multi-pronged approach. Integrating crop rotation and ecology with biotechnology is not only feasible but also the logical way to progress. Indeed biotechnology companies like Ecogen and AgraQuest use biotechnology to identify and enrich natural predators of damaging pests.

However, biotechnology supplies yet one more mode of defense. For instance, many variations and combinations of Bt genes are currently being produced to minimize pest selection pressure . . . Biotechnology is striving for a "one pest-many genes" paradigm. Molecular biologists recognize the need to study and apply multiple and diverse mechanisms for controlling pests and pathogens to reduce selection pressure. Simultaneous or sequential deployment of different resistance genes has the same rationale as crop rotation. Pathogen evolution is less able to overcome a changing environment or an environment made inhospitable by an array of resistance genes.

. . . The recent refuge regulation introduced by the Environmental Protection Agency (EPA) targets long-term protection from selection and development of resistance among pests. In conclusion, not only can biotechnology be integrated with ecological and other pest management methods, it also supplies several new modes of action . . .

7] The argument that biotechnology crops have been commercialized without proper testing while posing risks to human health and the environment is incorrect. Biotechnology crops and foods have been massively tested over the years both in the laboratory and in controlled natural environments under the oversight of the EPA, the FDA and the Animal & Plant Health Inspection Service/United States Department of Agriculture (APHIS-USDA). Over 4,000 field tests have been performed in some 18,000 sites throughout the United States over the last 15 years for efficacy, performance and suitability for release in the environment. Thousands of similar field tests have been performed in other countries around the world. Volumes of data have been generated on the food safety of bioengineered foods as well, with no evidence of safety risks as indicated above.

Effective procedures of field testing and food safety assessment have been developed after careful consideration and subject to scientific standards (for example, see National Research Council, 1989; Report of a Joint Food & Agriculture Organization/World Health Organization (FAO/WHO) Consultation, 1991; Organisation for Economic Co-operation and Development (OECD), 1993).

8] Many [of the critics']"unanswered ecological questions regarding the impact of transgenic crops" are not unanswered. Indeed, there is a substantial body of knowledge and volumes of data on both the environmental and food safety of biotechnology crops and foods demonstrating their overall suitability. This is not to say that environmental and other impact assessment of biotechnology crops should not be expanded. Indeed, more impact assessment studies are needed to augment and expand the existing empirical evidence, answer any unanswered questions and put risks and benefits of biotechnology crops and foods in a proper perspective. This need is explicitly recognized in a recent report of a Task Force reporting to the Land Grant University and Extension Service administrators which placed high priority on assessment studies.

9] [The critics] misrepresent the position of CGIAR and their research direction. Indeed, Ismail Serageldin, Chairman of the CGIAR, noted that, *a priori*, biotechnology could contribute to food security by helping to promote sustainable agriculture centered on smallholder farmers in developing countries. Furthermore, they misrepresent the potential of "rotations, inter-cropping and biological control agents" as singular solutions for environmentally sound and productive agriculture. Despite . . . indirect references to scientific evidence which they report has confirmed repeatedly the dramatic effects of such methods, the evidence in the published literature remains scant.

Crop rotation has been with us since the manor system of medieval times. And although there are no regulatory or technological barriers to its use, it has had only modest adoption by producers because of the limitations it places on resource management and because of its economics. In and of itself crop rotation has not proven to be the singular solution to our increasing food demand problem.

Use and commercialization of biological agents in crop production has also been limited despite decades of research both in the private and public sector. Companies like Ciba, DuPont, American Cyanamid and various startups like Mycogen invested millions of dollars in research of biopesticides and biological agents and, ultimately, disposed of them as uneconomical. Even companies that specialize in biological agents and biopesticides, like Ecogen and Agraquest, have focused primarily on high value markets with few chemical pesticide alternatives.

The most misleading aspect of many critics' arguments, however, is the artificial dichotomy they draw between biotechnology versus agroecology. As amply described above, biotechnology and agroecological approaches are synergistic and should be combined to improve the sustainability of our agriculture and food systems.

10] [The critics] extend their artificial dichotomy further to pass judgement on what kind of agriculture we should have. "Small farmers using agroecological approaches and low input practices," who are presumably discovering better ways to yield more in environmentally benign and socially responsible ways, is the way to go. Again, there is nothing inherent in biotechnology that justifies the small versus large farm dichotomy. Biotechnologies are size-neutral and can benefit smallholders and large commercial farmers alike. As Florence Wambugu, director of the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) in Kenya notes, the great potential of biotechnology to increase agriculture in Africa lies in its "packaged technology in the seed," which ensures technology benefits without changing local cultural practices. In the broader context, one must also question the wisdom of an opposing argument. In the presence of the social, environmental and economic advantages they describe, why are smallholder agroecological production systems not quickly dominating?

. . . As populations rise, inefficient farming will destroy a much greater quantity of wilderness and its associated wildlife as farming infringes in those areas.

Source: Adapted from McGloughlin, Martina (1999). "Ten Reasons Why Biotechnology Will Be Important to the Developing World." AgBioForum, 2(3&4), pp. 163-174. <http://www.agbioforum.org> (Jan 1, 2002. © 1999 AgBioForum)

THE RISKS

Risks of Genetic Engineering

[The following material was adapted from information supplied by the Union of Concerned Scientists. While no attempt has been made to match one for one the arguments of Professor McGloughlin, the reader will certainly be able to see how they interact with each other; a pro and con section below attempts to summarize these arguments and others. *Ed.*]

Many previous technologies have proved to have adverse effects unexpected by their developers. DDT, for example, turned out to accumulate in fish and thin the shells of fish-eating birds such as eagles and ospreys. And chlorofluorocarbons turned out to float into the upper atmosphere and destroy ozone, a chemical that shields the earth from dangerous radiation. What harmful effects might turn out to be associated with the use or release of genetically engineered organisms?

This is not an easy question. Being able to answer it depends on understanding complex biological and ecological systems. So far, scientists know of no generic harms associated with genetically engineered organisms. For example, it is *not* true that *all* genetically engineered foods are toxic or that *all* released engineered organisms are likely to proliferate in the environment. But specific engineered organisms may be harmful by virtue of the novel gene combinations they possess. This means that the risks of genetically engineered organisms must be assessed case by case and that these risks can differ greatly from one gene-organism combination to another.

So far, scientists have identified a number of ways in which genetically engineered organisms could potentially adversely impact both human health and the environment. Once the potential harms are identified, the question becomes, how likely are they to occur? The answer to this question falls into the arena of risk assessment.

In addition to posing risks of harm that we can envision and attempt to assess, genetic engineering may also pose risks that we simply do not know enough to identify. The recognition of this possibility does not by itself justify stopping the technology, but does put a substantial burden on those who wish to go forward to demonstrate benefits.

Potential Harms to Health

Here are some examples of the potential adverse effects genetically engineered organisms may have on human health. Most of these examples are associated with the growth and consumption of genetically engineered crops. Different risks would be associated with genetically engineered animals and, like the risks associated with plants, would depend largely on the new traits introduced into the organism.

New Allergens in the Food Supply

Transgenic crops could bring new allergens into foods that sensitive individuals would not know to avoid. An example is transferring the gene for one of the many allergenic proteins found in milk into vegetables like carrots. Mothers who know to avoid giving their sensitive children milk would not know to avoid giving them transgenic carrots containing milk proteins. The problem is unique to genetic engineering because it alone can transfer proteins across species boundaries into completely unrelated organisms.

Genetic engineering routinely moves proteins into the food supply from organisms that have never been consumed as foods. Some of those proteins could be food allergens, since virtually all known food allergens are proteins. Recent research substantiates concerns about genetic engineering rendering previously safe foods allergenic. A study by scientists at the University of Nebraska shows that soybeans genetically engineered to contain Brazil-nut proteins cause reactions in individuals allergic to Brazil nuts.

Scientists have limited ability to predict whether a particular protein will be a food allergen if consumed by humans. The only sure way to determine whether a protein will be an allergen is through experience. Thus importing proteins, particularly from nonfood sources, is a gamble with respect to their allergenicity.

Antibiotic Resistance

Genetic engineering often uses genes for antibiotic resistance as "selectable markers." Early in the engineering process, these markers help select cells that have taken up foreign genes. Although they have no further use, the genes continue to be expressed in plant tissues. Most genetically engineered plant foods carry fully functioning antibiotic-resistance genes.

The presence of antibiotic-resistance genes in foods could have two harmful effects. First, eating these foods could reduce the effectiveness of antibiotics to fight disease when these antibiotics are taken with meals. Antibiotic-resistance genes produce enzymes that can degrade antibiotics. If a tomato with an antibiotic-resistance gene is eaten at the same time as an antibiotic, it could destroy the antibiotic in the stomach.

Second, the resistance genes could be transferred to human or animal pathogens, making them impervious to antibiotics. If transfer were to occur, it could aggravate the already serious health problem of antibiotic-resistant disease organisms. Although unmediated transfers of genetic material from plants to bacteria are highly unlikely, any possibility that they may occur requires careful scrutiny in light of the seriousness of antibiotic resistance.

In addition, the widespread presence of antibiotic-resistance genes in engineered food suggests that as the number of genetically engineered products grows, the effects of antibiotic resistance should be analyzed cumulatively across the food supply.

Production of New Toxins

Many organisms have the ability to produce toxic substances. For plants, such substances help to defend stationary organisms from the many predators in their environment. In some cases, plants contain inactive pathways leading to toxic substances. Addition of new genetic material through genetic engineering could reactivate these inactive pathways or otherwise increase the levels of toxic substances within the plants. This could happen, for example, if the on/off signals associated with the introduced gene were located on the genome in places where they could turn on the previously inactive genes.

Concentration of Toxic Metals

Some of the new genes being added to crops can remove heavy metals like mercury from the soil and concentrate them in the plant tissue. The purpose of creating such crops is to make possible the use of municipal sludge as fertilizer. Sludge contains useful plant nutrients, but often cannot be used as fertilizer because it is contaminated with toxic heavy metals. The idea is to engineer plants to remove and sequester those metals in inedible parts of plants. In a tomato, for example, the metals would be sequestered in the roots; in potatoes, in the leaves. Turning on the genes in only some parts of the plants requires the use of genetic on/off switches that turn on only in specific tissues, such as leaves.

Such products pose risks of contaminating foods with high levels of toxic metals if the on/off switches are not completely turned off in edible tissues. There are also environmental risks associated with the handling and disposal of the metal-contaminated parts of plants after harvesting.

Enhancement of the Environment for Toxic Fungi

Although for the most part health risks are the result of the genetic material newly added to organisms, it is also possible for the removal of genes and gene products to cause problems. For example, genetic engineering might be used to produce decaffeinated coffee beans by deleting or turning off genes associated with caffeine production. But caffeine helps protect coffee beans against fungi. Beans that are unable to produce caffeine might be coated with fungi, which can produce toxins. Fungal toxins, such as aflatoxin, are potent human toxins that can remain active through processes of food preparation.

Unknown Harms

As with any new technology, the full set of risks associated with genetic engineering has almost certainly not been identified. The ability to imagine what might go wrong with a technology is limited by the currently incomplete understanding of physiology, genetics, and nutrition.

Potential Environmental Harms

Increased Weediness

One way of thinking generally about the environmental harm that genetically engineered plants might do is to consider that they might become weeds. Here, weeds means any plants in places where humans do not want them. The term covers everything from Johnson grass choking crops in fields to kudzu blanketing trees to melaleuca trees invading the Everglades. In each case, the plants are growing unaided by humans in places where they are having unwanted effects. In agriculture, weeds can severely inhibit crop yield. In unmanaged environments, like the Everglades, invading trees can displace natural flora and upset whole ecosystems.

Some weeds result from the accidental introduction of alien plants, but many were the result of purposeful introductions for agricultural and horticultural purposes. Some of the plants intentionally introduced into the United States that have become serious weeds are Johnson grass, multiflora rose, and kudzu. A new combination of traits produced as a result of genetic engineering might enable crops to thrive unaided in the environment in circumstances where they would then be considered new or worse weeds. One example would be a rice plant engineered to be salt-tolerant that escaped cultivation and invaded nearby marine estuaries.

Gene Transfer to Wild or Weedy Relatives

Novel genes placed in crops will not necessarily stay in agricultural fields. If relatives of the altered crops are growing near the field, the new gene can easily move via pollen into those plants. The new traits might confer on wild or weedy relatives of crop plants the ability to thrive in unwanted places, making them weeds as defined above. For example, a gene changing the oil composition of a crop might move into nearby weedy relatives in which the new oil composition would enable the seeds to survive the winter. Overwintering might allow the plant to become a weed or might intensify weedy properties it already possesses.

Change in Herbicide Use Patterns

Crops genetically engineered to be resistant to chemical herbicides are tightly linked to the use of particular chemical pesticides. Adoption of these crops could therefore lead to changes in the mix of chemical herbicides used across the country. To the extent that chemical herbicides differ in their environmental toxicity, these changing patterns could result in greater levels of environmental harm overall. In addition, widespread use of herbicide-tolerant crops could lead to the rapid evolution of resistance to herbicides in weeds, either as a result of increased exposure to the herbicide or as a result of the transfer of the herbicide trait to weedy relatives of crops. Again, since herbicides differ in their environmental harm, loss of some herbicides may be detrimental to the environment overall.

Squandering of Valuable Pest Susceptibility Genes

Many insects contain genes that render them susceptible to pesticides. Often these susceptibility genes predominate in natural populations of insects. These genes are a valuable natural resource because they allow pesticides to remain effective as pest-control tools. The more benign the pesticide, the more valuable the genes that make pests susceptible to it.

Certain genetically engineered crops threaten the continued susceptibility of pests to one of nature's most valuable pesticides: the *Bacillus thuringiensis* or Bt toxin. These "Bt crops" are genetically engineered to contain a gene for the Bt toxin. Because the crops produce the toxin in most plant tissues throughout the life cycle of the plant, pests are constantly exposed to it. This continuous exposure selects for the rare resistance genes in the pest population and in time will render the Bt pesticide useless, unless specific measures are instituted to avoid the development of such resistance.

Poisoned Wildlife

Addition of foreign genes to plants could also have serious consequences for wildlife in a number of circumstances. For example, engineering crop plants, such as tobacco or rice, to produce plastics or pharmaceuticals could endanger mice or deer who consume crop debris left in the fields after harvesting. Fish that have been engineered to contain metal-sequestering proteins (such fish have been suggested as living pollution clean-up devices) could be harmful if consumed by other fish or raccoons.

Creation of New or Worse Viruses

One of the most common applications of genetic engineering is the production of virus-tolerant crops. Such crops are produced by engineering components of viruses into the plant genomes. For reasons not well understood, plants producing viral components on their own are resistant to subsequent infection by those viruses. Such plants, however, pose other risks of creating new or worse viruses through two mechanisms: recombination and transcapsidation.

Recombination can occur between the plant-produced viral genes and closely related genes of incoming viruses. Such recombination may produce viruses that can infect a wider range of hosts or that may be more virulent than the parent viruses.

Transcapsidation involves the encapsulation of the genetic material of one virus by the plant- produced viral proteins. Such hybrid viruses could transfer viral genetic material to a new host plant that it could not otherwise infect. Except in rare circumstances, this would be a one-time- only effect, because the viral genetic material carries no genes for the foreign proteins within which it was encapsulated and would not be able to produce a second generation of hybrid viruses.

Unknown Harms

As with human health risks, it is unlikely that all potential harms to the environment have been identified. Each of the potential harms above is an answer to the question, "Well, what might go wrong?" The answer to that question depends on how well scientists understand the organism and the environment into which it is released. At this point, biology and ecology are too poorly understood to be certain that question has been answered comprehensively.

(Continued on p.11)

Genetic Engineering of Food Crops for the Third World: An Appropriate Response to Poverty, Hunger and Lagging Productivity?

By Peter Rosset

[Here is yet another vision of the problem of hunger, scarcity and the development of scientific strains of new food derivatives. It may not be a question of technology, but of finding more efficient ways to use present resources, and the social policies of governments involved. *Ed.*]

ABSTRACT

In this essay I refer primarily to agricultural production of foodstuffs for domestic consumption. When we speak of national markets, we find that small and peasant farmers, despite their disadvantaged position in society, are the primary producers of staple foods, accounting for very high percentages of national production in most third-world countries.

Their agriculture is complex, diverse and risk prone. This is because they have historically been displaced into marginal zones characterized by broken terrain, slopes, irregular rainfall, little irrigation, and/or low soil fertility; and because they are poor and are victimized by pervasive anti- poor and anti-small farmer biases in national and global economic policies.

In order to survive under such circumstances, and to improve their standard of living, they must be able to tailor agricultural technologies to their variable but unique circumstances, in terms of local climate, topography, soils, biodiversity, cropping systems, market insertion, resources, etc. For this reason such farmers have over millennia evolved complex farming and livelihood systems which balance risks—of drought, of market failure, of pests, etc.—with factors such as labor needs versus availability, investment needed, nutritional needs, seasonal variability, etc. Typically their cropping systems involve multiple annual and perennial crops, animals, fodder, even fish, and a variety of foraged wild products. Under such highly varied circumstances, uniform varieties, such as those put forth under the green revolution, or newer genetically engineered or "transgenic" varieties, are unlikely to be widely adopted or found useful by many such farmers.

When transgenic varieties, carrying Bt insect resistance, for example, are "forced" into such cropping systems, the risks are much greater than in green revolution, large, wealthy farmer systems, or farming systems in Northern countries. For example, in the Third World there will typically be more sexually compatible wild relatives of crops present, making pollen transfer to weed populations of insecticidal properties, virus resistance, and other genetically traits more likely, with possible food chain and super-weed consequences. Such farmers are unlikely to plant refuges, making resistance evolution by insects more likely. Horizontal transfer of genetic material is also highly risky in such circumstances.

Furthermore, the widespread crop failures reported for transgenics (i.e., stem splitting, boll drop, etc.) pose economic risks which can affect poor farmers much more severely than wealthy farmers. If consumers reject their products, economic risks are equally high. Also, the high costs of transgenics introduce an anti-poor bias.

The risks seem to outweigh the potential benefits for such farmers, especially when we consider the factors that currently limit their ability to improve their livelihoods, and the proven agroecological, participatory and empowering alternatives available to them.

It is not a lack of technology which holds such farmers back, but rather pervasive injustices and inequities in access to resources, including land, credit, market access, etc., and other anti-poor policy biases. Two approaches make the most sense under such conditions: 1) technologies which have pro- poor diseconomies of scale, like agroecology, and 2) organization into social movements capable of exerting sufficient political pressure to reverse policy biases. There is little useful role that genetic engineering can play.

Dr. Peter Rosset is Co-Director of Food First/Institute for Food and Development Policy, Oakland, CA.

Source: Excerpted from a presentation at the International Conference on Sustainable Agriculture in the New Millennium—The Impact of Modern Biotechnology on Developing Countries, Albert Hall, Brussels, May 28-31 2000, Friends of the Earth Europe. <http//: www.foodfirst.org/progs/global/biotech/belgium-gmo.html> (Jan 04, 2002).

Continued from p. 9

Risk Assessment

Having identified a list of possible harms that might occur as a result of using or releasing genetically engineered organisms, the next question is, how likely are any of these to occur? Like the original "brainstorming" of potential harms, the answer to this question depends greatly on how well the organisms and their interaction in the environment are understood. Risks must be assessed case by case as new applications of genetic engineering are introduced. In some circumstances, it is possible to assess risks with great confidence. For example, it is unlikely that genetically engineered palm trees will thrive in the Arctic regardless of what genes have been added. But for many potential harms, the answers are far less certain.

Risk assessments can be complicated. Because even rigorous assessments involve numerous assumptions and judgment calls, they are often controversial when they are used to support particular government decisions. For example, the approval of the first genetically engineered squash by the United States Department of Agriculture involved a controversial risk assessment.

Under the current US regulatory framework for biotechnology, some sort of risk assessment is routinely produced before decisions to allow commercialization of products under the Federal Plant Pest Act; the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); and the Toxic Substances Control Act (TSCA). In the case of the Plant Pest Act, risk assessments are done according to the procedure specified by the National Environmental Policy Act (NEPA). Under NEPA, risk assessments could lead to full-blown environmental impact statements, but so far all evaluations of engineered agricultural organisms have led to the legal conclusion that no environmental impact statement is needed.

For the most part, risk assessments are done by scientists and policymakers in the relevant agencies (USDA or EPA) with information provided by the companies seeking the approvals. The public often has a brief opportunity to review and comment on the risk assessments.

There is no standard set of questions that risk assessments must answer because of the great range of potential impacts of biotechnology products. A risk assessment for a microbial pesticide, for example, would be substantially different from a risk assessment for genetically engineered salmon. Like all efforts at risk evaluation, risk assessments done for regulation depend on the base of scientific knowledge for generation of list of possible harms to be assessed.

Source: Union of Concerned Scientists <http://www.ucsusa.org/food/gen.risks.htm> (Jan 1, 2002).

THE ETHICS

Key Issues for Ethical Consideration

Food safety, the environment and GMO [genetically modified organisms] are linked in the minds of consumers who, through their purchasing, will play a pivotal role in influencing decisions regarding the future of this technology. A number of consumers' concerns can be classified according to the following six issues:

Food safety. The foundation of consumers' concern about GMOs is food safety. Because of experiences with non-GMO food problems such as allergens, pesticide residues, microbiological contaminants and, most recently, bovine spongiform encephalopathy ("mad cow" disease) and its human counterparts, consumers are sometimes wary of the safety of foods produced with new technologies.

Environmental impact. The potential of GMOs to upset the balance of nature is another concern of the public. GMOs are "novel" products which, when released, may cause ecosystems to adjust, perhaps in unintended ways. There is also concern about the possibility that genetic "pollution" will result from outcrossing with wild populations. As with non-GMOs, an issue is whether pre- release testing (especially when limited to laboratories or computer models) is an adequate safeguard for the environment or whether post-release monitoring is also necessary. The extent of post-release monitoring needed to protect ecosystems, especially with long-lived species such as forest trees, becomes an ethical as well as a technical issue.

Perceived risks and benefits. In forming their views about GMOs, consumers weigh the perceived benefits of accepting a new technology against the perceived risks. Since practically none of the currently available or forthcoming plant and animal GMOs present obvious benefits to consumers, they question why they should assume possible risks. It is said that consumers take the risks while the producers (or the suppliers or companies) reap the benefits.

Transparency. Consumers have a legitimate interest in and right to information with regard to GMOs in agriculture. This begins with rules for the transparent sharing of relevant information and the communication of associated risks. Science-based risk analysis seeks to enable experts to make deci-

"Recombinant DNA technology faces our society with problems unprecedented not only in the history of science, but of life on the Earth. It places in human hands the capacity to redesign living organisms, the products of some three billion years of evolution . . . . It presents probably the largest ethical problem that science has ever had to face."

George Wald

sions that minimize the probability of hazards in the food supply system and the environment. Consumers, however, may also wish for more transparency to protect their right to exercise informed consent on their own. An often-discussed set of means intended to protect these rights is the labelling of products, whether or not they are derived from GMOs.

Accountability. Consumers may wish to be more involved in local, national and international debates and in policy guidance. At present, there are very few forums available to the public to discuss the wide range of issues relating to GMOs. A shortage of forums can, understandably, lead to advocates concerned with one aspect of GMOs, such as environmental impact, pushing their concerns into a forum set up for another aspect, such as labelling. A related issue is how to bring the private sector transparently into public forums and, subsequently, how to hold public and private sector agencies accountable.

Equity. So far, the development of GMOs in agriculture has mainly been oriented towards cost- reduction at the farm level, primarily in developed countries. Societies have ethical standards that acknowledge the importance of ensuring that those who cannot satisfy their basic food needs receive adequate means to do so. Ethical analysis can consider the moral responsibility of societies, communities and individuals to ensure that economic growth does not lead to an ever- widening gap between the poor majority and the wealthy few. When appropriately integrated with other technologies for the production of food, other agricultural products and services, GMOs may, among other biotechnologies, offer significant potential for assisting in meeting the human population's needs in the future. An ethically salient issue that then emerges is how the development and use of GMOs in agriculture can be oriented towards improving the nutrition and health of economically poor consumers, especially in developing countries.

Source: Adapted from "GMOs, Consumers, Food Safety and the Environment." May 2001. Rome: FAO <http://www.fao.org/DOCREP/003/X9602E/x9602e04.htm> (Jan 1, 2002).

Ethical Dangers of Genetic Engineering

By Ron Epstein

What will it be like in a future world where your life started with your parents designing your genes? In addition to screening for unwanted genetic diseases, they select for sex, height, eye-, hair-, and skin-color. Pressured by the current social fads, they may also choose genes whose overall functions are not clearly understood but are rumored to be connected with temperament, intelligence, mindfulness, and perhaps sexual orientation. You may be genetically engineered to be an enhanced clone of one of your parents, or of a celebrity whose genetic heritage your parents have purchased at great price. If your parents are poor, they may be paid to design you with genes tailored for a particular occupation, together with a prebirth contract for future employment. As in the film "Gattaca," you probably belong to a clearly defined social class according to the degree of your genetic enhancement. Of course there may still be a few weird, unenhanced naturals-by-choice living in the mountains.

From the very first milk you suckle, your food is genetically engineered. The natural world is completely made over, invaded and distorted beyond recognition by genetically engineered trees, plants, animals, insects, bacteria, and viruses, both planned and run amok. Illnesses are very different too. Most of the old ones are gone or mutated into new forms, yet most people are suffering from genetically engineered pathogens, either used in biowarfare, or mistakenly released into the environment, or recombined in toxic form from originally harmless but rapidly mutating engineered organisms. Genetic engineering is so commonplace, you start your own simple experiments with it in elementary school.

Present Causes Lead to Future Effects

That future is a lot more plausible than you might think. How can it come about? Probably from a combination of misplaced, naïve altruism, the short-sighted quest for short-term corporate profit, great new scientific power-domination, and just plain emotionally fueled vengeance. In the 1950s, the media were full of information about the miracle that was going to make it possible to kill to all of the noxious insects in the world, wipe out insect-borne diseases and feed the world's starving masses. That was DDT. In the 1990s, the media are full of information about the coming wonders of genetic engineering. Everywhere are claims that genetic engineering will feed the starving, help eliminate disease, and so forth. The question is the price tag. As has been our experience with most technologies, such as DDT and nuclear energy, the promise of benefit in the short term is overwhelmed by long-term disasters.

Unlike most other technologies, genetic engineering does not leave room for mistakes. Results of flaws in this technology cannot be recalled and fixed, but become the negative heritage of countless future generations.

An Early Warning

In 1976 George Wald, Nobel Prize winning biologist and Harvard professor, wrote:

Recombinant DNA technology [genetic engineering] faces our society with problems unprecedented not only in the history of science, but of life on the Earth. It places in human hands the capacity to redesign living organisms, the products of some three billion years of evolution . . . . It presents probably the largest ethical problem that science has ever had to face. Our morality up to now has been to go ahead without restriction to learn all that we can about nature. Restructuring nature was not part of the bargain . . . For going ahead in this direction may be not only unwise but dangerous. Potentially, it could breed new animal and plant diseases, new sources of cancer, novel epidemics.

Ethical Clarity and Scientific Genius Don't Always go Together

On the other hand, co-discoverer of the DNA code and Nobel laureate Dr. James D. Watson has consistently disregarded the risks of genetic engineering. In 1979 he wrote this about possible diseases that might be inadvertently created through genetic engineering: "I would not spend a penny trying to see if they exist." Claiming that "until a tiger devours you, you don't know that the jungle is dangerous," he wants to plunge forward regardless of the consequences. If Watson wants to go off into the jungle and put himself at risk of being eaten by a tiger, that is his business. When genetically engineered organisms are released into the environment, they put us all at risk, not just their creators. These statements by a great scientist clearly show that we cannot necessarily depend on the high priests of science to make our ethical decisions for us. Too much is at stake.

Yet Watson himself saw some of the problems very clearly when he stated:

This [genetic engineering] is a matter far too important to be left solely in the hands of the scientific and medical communities. The belief that . . . science always moves forward represents a form of laissez-faire nonsense dismally reminiscent of the credo that American business if left to itself will solve everybody's problems. Just as the success of a corporate body in making money need not set the human condition ahead, neither does every scientific advance automatically make our lives more "meaningful."

Although not a geneticist, Stephen Hawking, the renowned physicist and cosmologist, has commented often and publicly on the future role of genetic engineering. One possibility he suggests is that once an intelligent life form reaches the stage we're at now, it proceeds to destroy itself. He's an optimist, however, preferring the notion that people will alter DNA, redesigning the race to minimize our aggressive nature and give us a better chance at long-term survival. "Humans will change their genetic makeup to give them more intelligence and better memory," he said.

If that were the case, why would we be about to destroy ourselves in the first place? Is Hawking assuming that genes control IQ and memory, and that they are equivalent to wisdom, or is Hawking claiming there is a wisdom gene? All these assumptions are extremely dubious. The whole notion that we can completely understand what it means to be human with a small part of our intellect, which is in turn a small part of who we are, is, in its very nature, extremely suspect. If we attempt to transform ourselves in the image of a small part of ourselves, what we transform ourselves into will certainly be something smaller or at least a serious distortion of our human nature.

Those questions aside, Hawking does make explicit that for the first time in history, natural evolution has come to an end and has been replaced by humans meddling with their own genetic makeup. With genetic engineering science has moved from exploring the natural world and its mechanisms to redesigning them.

Here are some specific examples of ethical problems with the use of genetic engineering.

Biowarfare

It is generally acknowledged that secret work is going forward in many countries to develop genetically engineered bacteria and viruses for biological warfare. International terrorists have already begun seriously considering their use. It is almost impossible to regulate because the same equipment and technology that are used commercially can easily and quickly be transferred to military application.

After reading about the dangers of genetic engineering in biowarfare, the president of the United States, Bill Clinton, became extremely concerned, and, in the spring of 1998, made civil defense countermeasures a priority. Yet his administration has systematically opposed all but the most rudimentary safety regulations and restrictions for the biotech industry. (Continued on p. 15)

Some Major Issues to Be Resolved

Environmental safety

Will modified plants transfer their introduced genes into wild relatives growing nearby?

Will modified plants that produce new compounds (such as insecticides) disrupt the balance of nature in some way?

Could the planting of a restricted number of cultivars leave crop plants more susceptible to diseases?

Could the planting of a restricted number of cultivars lead to a reduction in biodiversity (crop plants, weeds, insects and microflora in the fields in question)?

Will genetically modified plants be able to avoid the factors that regulate natural populations and thereby change the usual balance between populations?

Food safety and nutrition

Will food from modified crops be safe?

Could the products of marker genes have unforeseen effects on consumers?

Could marker genes be transferred to other organisms, for example, bacteria in the human digestive system?

Will food from modified plants have a different nutritional quality from that of the food it replaces?

Social and economic effects

How will the structure of farming (particularly in developing countries) be affected by biotechnology?

How will patent laws affect traditional breeders (for example, the right to save seed from one year to the next)?

Will plant breeding be left increasingly in the hands of a few companies, and if so, what effects might this have?

Will some countries be plundered for their genetic resources?

What share of public resources (both financial and human) is to be diverted to biotechnology research?

Analysis of short- and long-term economic and social costs and benefits.

Ethical and moral issues

What will consumers be told about the new food products (right of the consumer to know)?

What are the implications of introducing animal/bacterial genes into plants?

Is it acceptable to interfere with nature through genetic engineering?

Do we have the right not to use all means available to improve crop plants, especially when so many people are undernourished or malnourished?

Do we have alternate strategies/tested technologies to improve food productivity to provide food to the malnourished sector of the society?

Regulatory issues

Do current regulations give sufficient protection to farmers, consumers, those who have invested in research, and those engaged in research?

Is there sufficient international legislation to ensure environmental protection?

Do current regulations compromise the competitiveness of biotechnology companies by being excessively restrictive?

Labeling of genetically modified crops

Financial investment by the government and industries in biotechnology

Need to ensure transfer of technology to farmers and access to seeds.

Source: Excerpted from Paroda, R. S. 1999, The Hindu Survey of Indian Agriculture, Chennai: Kasturi and Sons Limited. 208 pp. Tata Energy Research Institute, Habitat Place, New Delhi, India <http://www.teriin.org/gmp/issues.htm> (Jan 14, 2002).

A Summary of Pros and Cons

PROS:

- **Resistance to Disease**
- **Resistance to Pests**
- **Resistance to Herbicides**
- **Cold tolerance**
- **Drought tolerance**
- **Salinity tolerance**
- **Enhanced nutrition**
- **New delivery systems for pharmaceuticals**
- **New types of plants**

CONS:

- **Harm to nearby organisms**
- **Reduced effectiveness of pesticides**
- **Gene transfer to non-targeted species**
- **Allergic reactions**
- **Unknown effects on human health**
- **Expensive process/marketing costs**
- **Patent enforcement**
- **Uncertain safety regulations**
- **Poor or inadequate testing procedures**

Classroom Approaches

Teachers might consider some of the following strategies:

1. Have students research the extent of genetically modified foods that presently exist in the stores of their community. A quick reference point from which to start would be the Greenpeace web site <http://www.truefoodnow.org/shopping_list.html> which lists current foods that are and are not genetically modified. Students might pursue their search by checking this list, and trying to find others, and noting whether or not the product labels indicate whether any or all of the contents are genetically modified.

2. Several controversies have cropped up in the news over the past several years, raising some concerns and disputes. Students might select one of these topics for deeper research and reporting back to the class:

   a. The development of "Golden Rice" and its potential impact on children with vitamin A deficiencies.

   b. Possible extinction of the Monarch Butterfly through the development and use of genetically modified corn as planted in certain areas of Mexico that are a prime breeding area.

   c. The labeling of GMF as "Frankenstein Food" as a result of the mad cow disease in Europe, but particularly in Great Britain.

3. Have students research and report out on the controversy over whether GMF should be especially labeled when issued to stores. Further investigation should lead to the Cartagena Protocol on Biosafety. Did this solve the problem?

4. After the class has studied the topic of GMF, have them organize a class debate on the merits of GMF versus "natural breeding." Check their perception as to whether what farmers have been doing in cross breeding for centuries, has, indeed, been GMF after all.

5. Given class study, have the students examine the lists given here of "Issues to be Resolved" and "Pros and Cons," to see whether these adequately summarize some of the issues currently being addressed in the media.

(Continued from p. 13)

By doing so, Clinton has unwittingly created a climate in which the production of the weapons he is trying to defend against has become very easy for both governments and terrorists.

The former Soviet Union had 32,000 scientists working on biowarfare, including military applications of genetic engineering. No one knows where most of them have gone, or what they have taken with them. Among the more interesting probable developments of their research were smallpox viruses engineered either with equine encephalitis or ebola virus.

Human Genes

As more and more human genes are being inserted into non-human organisms to create new forms of life that are genetically partly human, new ethical questions arise. What percent of human genes does an organism have to contain before it is considered human? For instance, how many human genes would a green pepper have to contain before you would have qualms about eating it? This is not merely a hypothetical query. The Chinese are now putting human genes into tomatoes and peppers to make them grow faster. You can now be a vegetarian and a cannibal at the same time! For meat-eaters, the same question could be posed about eating pork with human genes. What about the mice that have been genetically engineered to produce human sperm? How would you feel if your father was a genetically engineered mouse?

Plastic Plants

So that we would not have to be dependent on petroleum-based plastics, some scientists have genetically engineered plants that produce plastic within their stem structures. They claim that it biodegrades in about six months. If the genes escape into the wild, through cross-pollination with wild relatives or by other means, then we face the prospect of natural areas littered with the plastic spines of decayed leaves. However aesthetically repugnant that may seem, the plastic also poses a real danger. It has the potential for disrupting entire food-chains. It can be eaten by invertebrates, which are in turn eaten, and so forth. If primary foods are inedible or poisonous, then whole food-chains can die off.

Assessing the Price

For all the advantages claimed for genetic engineering, in the overwhelming number of cases the price seems too high to pay. In order to ensure megaprofits for multinational corporations well into the next century, we will have to mortgage the biosphere, seriously compromise life on the planet, and even risk losing what it means to be a human being. Genetic engineering poses serious risks to human health and to the environment. It raises serious ethical questions about the right of human beings to alter life on the planet for the benefit and curiosity of a few.

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ISSUES IN GLOBAL EDUCATION ISSUES IN GLOBAL EDUCATION ISSUES IN GLOBAL EDUCATION ISSUES IN GLOBAL EDUCATION ISSUES IN GLOBAL EDUCATION ISSUES IN GLOBAL EDUCATION

ISSUES IN GLOBAL EDUCATION

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