Sowing Pandora's Fields

by Jane Nielson and Howard Wilshire*

> In the process that carries knowledge from the laboratory to the market, there is not enough fear
>
> Wendell Berry, *Life is a Miracle*, 2000

American agriculture is becoming part of a great genetic experiment for natural forces to play with. Mid-20th century advances in molecular biology identified Ribonucleic acid (RNA) and Deoxyribonucleic acid (DNA) as the keys to genetic inheritance. After brilliant research confirmed RNA and DNA as the means of replicating and passing genetic traits to offspring, mere mortals suddenly worked out ways to access the genetic codes and genetic functions of all life forms--the very building blocks of life. Today, DNA is little more than another industrial material.

Chemical laboratories began quietly developing genetically modified (GM), or transgenic, crop plants in the early 1980s. The first field tests of GM plants in 1987 led to the commercial planting of GM FlavrSavr™ tomatoes in 1988. Although practically no acreage supported GM crops in 1994,[1] GM planting expanded hugely the very next year, and by 2004 GM crops covered 200 million acres--roughly 2 percent of the world's cultivated land--mostly planted in corn, soybeans, cotton, and canola. About 118 million of those acres were in the U.S.[2]

Even though the so-called "green revolution," the previous technological solution for world hunger, put new pressures on fossil fuels and water, and worsened rural poverty, by 1995 pesticide producers trumpeted extravagant claims that the new field will eventually feed an ever growing world population, give farmers a life of convenience and leisure, increase crop yields, reduce pesticide applications, and decrease costs--all the while improving the environment.[3]

At the speed of drifting pollen, GM applications expanded from modifying cotton and feed crops for animals, to producing pharmaceuticals (drugs) and industrial products from plants,[4] and changing the way plants develop and store nutrients. But GM food crops--such as the ill-fated FlavrSavr™ tomato and various potatoes, including varieties that glow when they need water[5]--have not sold well. Schemes to grow rich from American faddism are driving plans to make vari-colored grasses for individualized lawns, enrich vegetables in whatever vitamin currently is deemed essential, and devise new fountains of youth. Failing perpetual youth, bored consumers can meditate on glowing fish.[6]

By far the largest transgenic crop acreage is planted in varieties with the greatest potential to pose serious problems for the environment, and possibly to human health.[7] In spite of government and industry protestations to the contrary, this is a vast experiment that so far lacks much reflection or oversight, even though it could have hazardous consequences for all life on earth.

New Genes In Old Plants

Controversies germinated as soon as the nature of GM lab experiments and their promise for--or threat to--the immediate future[8] became generally known, and led quickly to international disagreements with threats of trade wars. Both inflammatory "frankenfood" rhetoric[9] and GM-industry press releases[10] obscured legitimate concerns about potential impacts of genetically modified organisms on human health and the environment, including: new allergens and toxins in foods;[11] shifting toxin-producing sites in a plant--an example might be a rhubarb that expressed cyanide in the stems as well as in the leaves;[12] and pleiotropy, or multiple visible or functional effects from introducing new genes or variants of existing genes.[13] Other surprises are turning up, mostly in research encouraged by governments other than the U.S.[14]

The biotech industry and many academic and industry scientists contend that genetic engineering is no different from conventional approaches to plant breeding, that GM foods presently on the market are not different from conventional products, and are not known to be harmful to the people who eat them.[15] But the industry once insisted that L-tryptophan, a dietary product marketed as an "all natural" food supplement, as also safe for human consumption. One L-tryptophan manufacturer's use of a genetically modified bacterium in the fermentation process led to a 1989 epidemic of a debilitating disease, Eosinophilia-Myalgia Syndrome. Although directly linking the genetically engineered bacteria remains controversial, the pills of that one manufacturer were responsible for the epidemic. This experiment on an unwitting public left 5,000 to 10,000 people sick, about 100 dead, and 1,500 permanently disabled throughout the U.S.[16]

Many scientists argue that the differences between GM and conventional hybrids are many and significant. But genetic engineers place DNA for desired traits directly into the host's chromosome, while traditional plant breeding selects out desired traits using natural plant reproduction, aided by human fertilization with human-selected pollen, between plants of the same or similar species. Some unwanted traits generally come along in the pollen, so breeders must grow seed from the crossed plants, observe the traits expressed, and repeat the process as many times as necessary to develop a constellation of desired attributes and eliminate the undesirable ones. Depending on how fast the plants grow and produce seed, the process can take many years.

Before GM seeds reached the markets, conventional hybridization already had pushed beyond combining traits within species, to so-called wide crosses between related species and horizontal gene transfers between distantly-related plants incapable of reproducing in nature.[17] Yet even these more radical crosses never mix genes from radically unlike organisms, nor disturb the chromosome composition, nor the sequence of genes in the chromosomes.[18] Extreme forms of conventional breeding--exposing plants to chemicals or radiation to force genetic mutations in plant tissue--are more invasive,[19] but the novel genes created by those methods arise within the plants themselves. In contrast, GM breeding can transfer genes between vastly different plant species, or between widely different plant types, and can splice genes from bacteria, viruses--and even animals--into plant DNA. Even some biotech pioneers think radical mixes of genetic traits are unnecessary, if not unwise.[20]

Genetic engineers currently convey DNA through plant cell walls in three main ways: via a bacterial carrier (or "truck"); with a "gene gun" device that shoots DNA-carrying metal particles into cells; or through chemical or electrical "phoric" treatments that open pores in plant cell walls. The usual bacterial truck is *Agrobacterium tumefasciens*, which in nature causes a plant cancer called Crown Gall Disease. *Agrobacterium* is one of a very few organisms having a natural ability to insert its own DNA into plant cells, and then to the plant's own DNA.[21]

The GM technique, called "*Agrobacterium*-mediated transfer" (AMT), starts by replacing *Agrobacterium*'s cancer-causing genes with DNA for the trait to be transferred. Fragments of plant tissue (usually leaves) are soaked in a solution containing modified *Agrobacterium* in a laboratory dish, so that the bacteria can transfer their modified DNA into the plant's cells. The DNA enters the host cell's nucleus and inserts itself into the plant's chromosomes.[22]

Added DNA sequences constitute a package, including the genes for a desired trait, plus a plant-recognizable "promoter" gene mounted in front of the trait sequence, and a "terminator" gene following it. Promoters help the host plant recognize foreign genes and express the desired traits--without the promoter, no plant could ever express traits transplanted from bacterial or animal DNA. The most commonly used promoter is a powerful gene from the Cauliflower Mosaic virus, which in nature gives the virus its ability to take over and destroy a plant. The viral promoter in an engineered DNA sequence incites even transferred plant genes to express themselves 100 to 1,000 times more strongly than a natural plant promoter gene would allow.[23]

DNA insertions using gene guns or phoric treatments similarly require helper compounds or energy sources to break DNA strands in cells, letting foreign genetic material link with the host chromosome's DNA. Like AMT, the new genetic material is equipped with plant-recognizable promoter and terminator DNA sequences, but chemical treatments may still be needed for the plant to optimally express the added traits.

Another difference between direct gene transfer and traditional breeding is the use of antibiotic-resistance genes as markers. To accomplish gene transfers, large numbers of plant cells are soaked in solutions containing foreign genetic sequences with the desired traits, but generally very few cells actually take up the new DNA. Markers included in the transfer DNA distinguish the few transformed cells from all others. Antibiotic-resistance genes are easy markers: they allow all the plant cells to be immersed in a lethal concentration of the antibiotic so that all the untransformed cells die, leaving the transformed ones unharmed.[24]

Genetic insertion processes are not particularly precise--the DNA can land anywhere within the target plant's chromosome, or in other cellular structures outside the nucleus.[25] As Harvard geneticist Dr. Richard Lewontin told writer Michael Pollan, Monsanto's oft-repeated comparison of genetic engineering to programming a computer "… implies you feed a program into a machine and get predictable results. But the genome is very noisy. If my computer made as many mistakes as an organism does [in interpreting its DNA], I'd throw it out."[26] In most cases, bad placements result in plants that won't grow, but many transgenic plants that can survive and reproduce have unstable characteristics--much less stable than varieties developed by conventional plant breeding and hybridization.[27] In addition, chemical promoters can enhance unwanted traits, and plant series resulting from the same laboratory process can show a range of different traits (pleiotropy), depending on the proteins generated by a particular genetic placement.

From all this uncertainty, gene insertion must be followed up by the traditional techniques of growing the plants, selecting seeds from ones that express the desired traits to the greatest degree, and growing plants from the seeds. This process must be repeated to make sure that the desired genetic traits appear consistently in subsequent generations. But long after testing and field trials, unforeseen weaknesses can be triggered by unusual weather or climatic conditions--or when introduced into a new environment, a minor genetic characteristic in a well known plant can suddenly find a dominant expression and make the plant invasive, or prone to disease. Natural pollination can transfer the transgenes to related plants, with destructive consequences.[28]

"Easy Farming"

Most GM food crops are engineered for farming convenience--for growing, harvesting, and marketing perishable products. At this writing, U.S. farmers are growing two dominant types of transgenic crops, both designed to fight insects or weeds. One type can survive applications of particular herbicides, and the other type creates pesticide-secreting plants.

Herbicide resistant crop plants are able to thrive after both crop and weeds are doused with a specific chemical. Only the weeds die--or, at least, most of the weeds die.[29] Herbicide-resistant food crops now growing in the U.S. and Canada include corn, soybeans, and canola. Ideally, this crop trait should allow farmers to apply smaller amounts of costly herbicides, saving money and reducing pesticide residues in food. Insecticidal varieties all express a gene from the *Bacillus thuringiensis* (*Bt*) bacterium that secretes *Bt* toxin, a natural pesticide. Splicing the *Bt* -producing gene into a plant's DNA adds insect-killing *Bt* toxin to all the tissues, including the edible parts.

Current and future plans for direct genetic modifications include plants that can resist frost, or thrive in saline soils. Frost resistance would limit crop damage for some fruit growers, and salt compatibility could reduce losses of farming land to salt build up, or salination, from excess irrigation. The FlavrSavr™ tomato, the earliest marketed genetically modified plant, carried a gene that helped it resist softening and rot to extend its commercial shelf life. Other transgenic experiments, already underway, modify plants to synthesize a range of commercial compounds in their tissues. Some would synthesize human and veterinary vaccines, drugs, and other pharmaceutical compounds. Avidin, a transgenic maize (corn) that expresses compounds for various medical diagnostic procedures, has been grown commercially since 1997. Tests are underway on plants that express enzymes, hormones, blood substitutes and anticoagulants, and other proteins for healing wounds and for treating conditions such as anemia, cirrhosis, cystic fibrosis, diarrhea, HIV, and hepatitis B and C. Other crops could yield various industrial chemicals for manufacturing paper, plastics, personal care items, and laundry detergents.[30]

GM "Golden rice" is engineered to express betacarotene in rice grains.[31] The human body processes betacarotene into Vitamin A. Rice husks contain Vitamin A, but in many Asian countries where people eat polished rice as the diet staple, children commonly have severe Vitamin A deficiencies. Engineering food plants to develop high levels of particular nutrients is an expensive way to fulfill constant promises of feeding the world. Golden rice could be a remedy for Vitamin A deficiencies, but the problem might be more cheaply addressed through educating parents on the benefits of feeding their children whole grain rice.

Biological Pollution

Interactions between human inventions and the natural world are unavoidable. From the earliest voyages of world exploration, the catalog of plants taken from their native community of plants and animals, or ecosystem, to new environments is paralleled by a catalog of ecosystem invasions and habitat destruction wrought by many of the exotic transplants.[32] All the way back to Luther Burbank's time, interbreeding between wild plants and commercial human hybrids--including conventionally bred varieties--have had bad unforeseen effects on natural ecosystems and farmers alike.

Genetic engineering opens a significant new potential for unanticipated, possibly negative environmental effects from new plant varieties. The effect of a gene on an organism is largely dictated by its location within the DNA, but the locations that spliced genes occupy are not under laboratory control--nor are their full effects.[33] The hazard is similar to putting synthetic chemicals into the environment, and much later finding unexpected adverse effects on human health and wildlife. As Harvard University geneticist, Dr. Richard Lewontin, has observed, "… there's no way of knowing what the downstream effects will be or how it might affect the environment. We have such a miserably poor understanding of how the organism develops from its DNA that I would be surprised if we *don't* get one rude shock after another."[34]

Novel GM organisms, having genetic assemblages never previously known on earth, cannot be evaluated ahead of their release, and their full potential for negative interactions with nature and humans may not be known for decades. Until newly developed plants grow outdoors, their possible interactions with other organisms on farms and in adjacent wildlands are unknown.

Once planted on farms, transgenic plants have the potential to spread uncontrollably, as have many conventionally bred varieties. Transgenes are likely to spread in pollen, from GM plants to compatible farm raised and wild ones. All of these possibilities have unforseeable consequences for crops, farms, and natural environments--and after release into the world, much severe damage can be done before the potential even is suspected.[35]

The hazards of GM plants come under the heading of "biological pollution,"[36] and can include toxic effects from a transgene--as happened with L-tryptophan--or from a promoter or marker gene spliced into DNA along with the desired trait. British weed invasion authority Mark Williamson wrote, "There are no universal characteristics that distinguish weeds and pathogens from their harmless relatives … and the genetic differences between invasive species and those that fail to invade may often be small."[37] Just since the 1960's, conventionally hybridized sugar beets have cross bred with non-invasive sea beets producing offspring with an invasive trait acquired from the sugar beets. The offspring now are persistent weeds in European sugar beet fields, which severely reduce yields.[38]

Making Weeds and Health Threats

Some crop scientists, including University of California population geneticist Norman Ellstrand, warn that once commercial agriculture converts to widespread GM crop planting, natural processes inevitably will transfer GM traits to weeds. And it doesn't take a high rate of hybridization--Ellstrand predicts that new or more powerful weeds are likely to arise from "… far less than 1 percent of the [GM] products, [but] within 10 years we will have a moderate-to-large scale ecological or economic catastrophe, because there will be so many [GM] products being released."[39]

Experiments have shown already "appreciable and effective hybridization" between canola oil seed and a distantly-related weedy wild radish and hoary mustard "… with effective gene flow from crop to weed."[40] Another study showed that virus-resistant GM oats could hybridize with weedy wild oats, potentially giving the weed oats a growth advantage over domesticated varieties, and turning the wild oats into aggressive invaders. Researchers also have reported unexpected findings that genes from a transgenic crop may persist in weedy relatives for many generations, enhancing the likelihood that they will spread farther.[41]

Like the weed invasions from conventionally hybridized plants, GM plants can develop into weeds that overwhelm agricultural fields and natural habitats. Relatively non-invasive plants can become invasive if insects or other animals do not eat their seeds, so GM varieties with low nutritional values or unpalatable characteristics could produce invaders.[42]

Long distance pollen transport could transmit DNA from fields growing pharmaceutical or industrial-product crops to food crops, a still more serious problem. Since canola pollen can spread long distances, Norman Ellstrand warned that "canola might not be a good plant to engineer for growing pharmaceuticals or anything else that should stay out of the food supply."[43] Rice is another product that arouses fears of pharmacological products getting into food crops.

California-based Ventria Bioscience also has tested rice for growing proteins to use in anti-diarrhea treatments. Ventria's planned expansion to commercial production galvanized 2004 opposition in some California counties targeted for growing the pharma rice, and in foreign countries that buy U.S. rice. San Luis Obispo County Supervisors expressed annoyance at having no say in a matter affecting their top industry, and then-California State Senator Byron Sher requested an environmental review. "In Japan, the influential Rice Retailer's Association said it would seek a ban on California rice imports if … GM rice is grown commercially in the United States."[44]

Breeding plants with apparently beneficial genetic traits can make them highly vulnerable to disease. An example is the conventionally bred U.S. corn variety with so-called "Texas cytoplasm," which bestows the trait of male sterility. Using male sterile corn reduces the work load of growing hybrid corn varieties--but unfortunately it also renders the corn highly susceptible to fungus, opening a whole agricultural sector to disease and devastation. Male-sterile corn varieties constituted 85 percent of the U.S. corn crop by 1970, when a fungus blighted or killed 15 percent of the U.S. crop. Nearly every variety of hybrid corn grown in the U.S. now carries the male-sterile trait, so fungus-related devastation is likely to revisit U.S. cornfields.[45]

GM approaches to plant breeding are likely to produce their own disease-vulnerable varieties. Cross pollinating between common plants and GM varieties could cause nutritional changes in that starve or poison insects and other wildlife. A particularly important habitat in this regard is the ecosystem that constitutes a healthy soil.

The antibiotic resistance genes added to some GM plants as markers could affect human health. As clever as it may seem to identify treated cells with a lethal antibiotic solution to destroy all but the antibiotic resistance transgene-carrying cells,[46] the antibiotic-resistance genes are still effective when their job as markers is done. When used together with bacterial DNA promoter sequence, the antibiotic-resistance genes in crop plants may eventually be eaten by humans, or domestic or wild animals, and could transfer antibiotic resistance to bacteria that infect farm animals.

The people who eat GM foods also could encounter bacteria with antibiotic resistance. As a result, the use of antibiotic genes for GM markers only add to the pressures that have reduced, and may eventually eliminate, the power of many antibiotics to fight bacterial diseases.[47] To reduce this possibility, antibiotic resistance markers are being replaced with herbicide resistance and other marker genes in many new GM organisms. But the plants containing antibiotic resistance genes remain in our ecosystems. How long they will be there is unknown.

Rounding-up Problems

Growing herbicide-resistant crops requires destroying all other plants in a field by dousing everything with broad spectrum herbicides, such as Roundup™ (glyphosate), and Liberty™ (glufosinate ammonium). The giant Monsanto chemical corporation sells farmers a license to plant its seed, which will grow into plants that Monsanto's Roundup™ herbicide cannot kill. The herbicide-resistant crops are probably the chemical companies' biggest profit makers, because they own patents on both the seeds and their trademarked pesticide. Monsanto gets paid for the license, the seed, and the pesticide--and also charges a per-acre "technology fee."[48]

The Roundup™ formulation contains a surfactant that is 30 to 70 times more toxic than the glyphosate "active" ingredient alone, and glyphosate plus the surfactant is still more toxic.[49] Although considered a benign pesticide, glyphosate harms or kills beneficial insects that eat insect pests, such as lacewings, predatory wasps, and ladybird beetles, and is lethal to aquatic and terrestrial amphibians.[50] Many of the non-crop plants in and near farm fields are important food sources for birds, so widespread weed eradication with Roundup Ready™ and other GM-compatible herbicides impairs croplands as wildlife habitat.[51]

Glyphosate also may increase the spread of a root-colonizing soil fungus that causes crop blights. Various blight outbreaks in both herbicide-resistant and non-GM soy and wheat varieties may be related to intensive glyphosate applications on Roundup Ready™ crops.[52] Unanticipated GM crop weaknesses have already appeared in Monsanto's Roundup Ready™ soybeans. Where soil temperatures reach 100° to 120°F, the GM soybean plants grow stunted and their stems tend to split open more easily than non-GM soybeans, with crop losses of up to 40 percent. At soil temperatures around 110°F, stem splitting affects 100 percent of GM, but only about 58 percent of non-GM soybean plants.[53]

GM Roundup™ herbicide-resistant soybeans, and Liberty™ herbicide-resistant canola do not contain antibiotic-resistance gene markers,[54] but may pose other human health problems. Farmers with high exposure levels to the Roundup™ formulation--appear to have increased risk of miscarriages, premature births, and non-Hodgkins lymphoma. Animal studies also show chronic effects from glyphosate exposure, including stomach inflammation and genetic damage, lowered sperm counts, and higher cancer incidence.[55]

All control strategies, whether chemicals or manual and mechanical weeding, increase the population of weeds that can survive each tactic.[56] Weeds have variable vulnerabilities and herbicide tolerances. In the same way that insects develop resistance to both targeted and broad scale insect pesticides, weed plants commonly develop resistance to weed killers. The weed resistance effects are heightened for GM crops resistant to a single herbicide, because standard doses generally do not kill every kind of weed in a field. After the most highly vulnerable weeds die, the herbicide-tolerant types can release their seed and grow without much competition. As a result, the weed population quickly shifts to resistant varieties. Chemical weed control then must expand to multiple herbicide applications--or to new, often more toxic, herbicides[57]--inviting further invasions of other herbicide-tolerant weeds.[58] Weed shift may be the first step toward generating pesticide resistant insects, able to survive chemical applications.[59] For all these reasons, growing herbicide-resistant GM crops only temporarily decreases pesticide applications on American farms.[60]

Herbicide-resistant weeds are every farmer's nightmare. Crop plants that tolerate or resist herbicides can themselves become weeds. GM herbicide-resistance can be spread large distances in the pollen of light-weight seed crops, such as canola.[61] The herbicide-resistance transgenes can flow from crop plants to wild relatives--even distant relatives--creating herbicide-resistant weeds and accelerating herbicide resistance in problem plants.[62] Roundup™ herbicide was introduced to Australia in 1974, and by 1995, Roundup™ resistance had appeared in Australian weeds and insects--much quicker than expected for weed shifts to appear after applying a new pesticide on conventional crops. In 2003, U.S. scientists reported a Roundup™ resistant weed, signaling the first significant breakdown in the effectiveness of Roundup Ready™ technology.[63]

Cases already have been reported of herbicide-resistant GM crops invading natural settings near farmlands, or appearing as weeds in both fallowed agriculture fields and non-GM fields of the same or different crops.[64] In regions growing multiple herbicide-resistant GM canola varieties--each engineered by a different company, and resistant only to that company's patented herbicide--gene flow from natural pollination has brought forth canola plants resistant to multiple herbicides. As may be expected, these plants are especially difficult to control.[65]

After 2004 many of the nation's 17,000 golf courses are likely to sprout Roundup-Ready™ bentgrass, the first widespread U.S. perennial GM plant, which grows well without cultivation. At least a dozen wild plants can easily hybridize with the GM bentgrass, potentially creating and spreading bentgrass superweeds. And we now know that genes from bentgrass can spread much farther (at least 13 miles) than previously known, with the potential to adversely affect all 175 national forests as well as other public and private lands.[66]

Bt Quandary

The stems, leaves, and all other parts of a *Bt* plant all contain the *Bt* toxin, which kills insects--but also provides them an opportunity to develop *Bt* resistance more rapidly than they develop resistance to conventional pesticides, applied periodically.[67] Pesticidal GM cotton, corn, and potatoes currently are under cultivation. Insects able to resist *Bt* are bound to proliferate, in time requiring new strategies to combat them.[68] *Bt* pesticides applied topically to protect cabbage and related crops against diamondback moths already have generated some resistant moth populations.[69]

Bt bacteria preparations have long been available as commercial pesticides for topical application, and are widely but sparingly used on organic farms. Kansas State University researchers have found that "corn borers, the insects that *Bt* corn is supposed to kill, are already developing resistance" to the *Bt* insecticide in GM plants.[70] These *Bt* resistance problems are not large or immediate so far but organic farmers fear that widespread planting of GM *Bt* crops will promote widespread pest resistance, rendering *Bt* toxin useless to them.

The U.S. Environmental Protection Agency (EPA) requires farmers to take "routine cautionary measures" to delay the development of herbicide-resistant insects and weeds. One measure is creating *refugia* within their GM crop fields--either by alternating rows of GM and non-GM plants, or by planting a few acres of non-GM crops within large GM fields, and not spraying the non-GM sections with any pesticide. But few farmers plant *refugia* among their fields, and many view the requirement as a joke.[71]

Croplands provide habitat for many animals that depend on insects either for their food, or for feeding their prey. Monarch butterfly larvae feed on plants that commonly grow near cornfields. Although monarchs are not corn pests, and were not the targets of *Bt* plant engineering, they are closely related to European corn borers and may be vulnerable to the same insect toxins.[72] The apparent deaths of monarch larvae after feeding on *Bt* corn became the first ecological problem to emerge from GM crops. Larger wildlife living in and near cropland habitats include mice, birds, and deer--and all are potentially vulnerable to crops that yield pharmaceutical and industrial compounds.[73]

Bt also threatens healthy soils, which are ecosystems that support a rich diversity of life. Toxins such as *Bt* are harmful to the insects and their relatives with critical roles in the natural processes of humus formation, which enrich soil.[74] Any toxins in GM plants can enter the soil in at least three ways: when plant roots secrete toxins directly into the soil,[75] when toxin-bearing pollen and plant leaves fall to the ground, and when farmers plow toxin-bearing crop residues into the soil.[76]

Blind Optimism

Many prominent scientists, from molecular biologists to field ecologists, have expressed concerns about GM agriculture, but largely are ignored by federal regulators. Primary responsibility for overseeing GM products resides with the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS). APHIS approval is required before transgenic plants can be grown outside the walls of a laboratory, where genetic material (pollen) can get into the agricultural environment and natural ecosystems.[77] But federal regulations allow chemical and biotechnical companies to perform their own tests, make their own risk assessments, and report the results to regulators without supporting evidence that is independently reviewed for accuracy and completeness.

The biotech industry's position that conventional and genetically modified crops are not discernibly or materially different serves as the basis for these lax federal regulations governing GM foods. The government has accepted industry's contention that a GM potato is no different from any other potato, whether developed by conventional breeding or engineered to resist pests. This assumption underlies the Food and Drug Administration's (FDA) 1992 regulations, which required no GM food labeling for consumer's information, while permitting biotech companies to determine whether their own engineered food products are "generally recognized as safe" (GRAS).[78] Ecologist Michelle Marvier concluded, "In essence, current regulations assume that a transgenic crop is safe unless it is shown otherwise."[79] Some FDA scientists have felt that the agency's 1992 rules read "very pro-industry, especially in the area of unintended effects."[80]

APHIS established and oversees a "notification" system for field testing GM products, which does not actually require a permit from APHIS. Companies must submit the notification before field testing transgenic crops on unrestricted acreages. After the field tests, they apply for permission to commercialize their products through a "deregulation petition." APHIS must receive test results before issuing notification approval. If the results are cautionary--indicating, for example, that the plants can harm plant and animal species other than the targeted ones--they are supposed to trigger a permitting process that may be overseen by APHIS or the EPA, or both.[81]

With a permanent staff allotment of only 10 positions, APHIS oversees about a thousand notifications per year, but APHIS staff provide in-the-field evaluation for only 6 percent of notification-approved projects. Understandably, the staff is plagued by rapid staff overturn, and chronic vacancies.[82] None of the thousands of notification approvals APHIS had issued since 1986 received any external review or input, either from the public or scientific experts.[83]

The information that applicant companies provide for these notification approvals is so laden with items marked "CBI" (Confidential Business Information), that independent experts would be hard pressed to evaluate the products' safety or hazard potential. Called upon to advise a committee of the British Parliament on GM regulations for Britain and countries of the European Union, ecologist (and GM supporter) Mark Williamson described the system starkly: "… of course, in America, this is a notification procedure and nobody gives a damn."[84]

Products that may harm non-target species, and have pesticidal or pharmaceutical properties, can be--and are--grown under the notification process. Approval requires only the applicant's declaration that the intended uses of the GM plant have no "intent" to harm other organisms. Good intentions were cold comfort when a National Academies of Sciences committee found that the transgenic maize Avidin, grown for pharmaceutical use, is potentially toxic to a broad array of organisms both in the field and after harvest.[85]

A company also can petition for deregulation, at base a disclaimer of the need for any government oversight. This process features the same cursory, non-public, oversight as applications for notification. APHIS can only approve or disapprove a petition--it cannot, for example, approve a petition with the condition that the crop be monitored for unintended effects after it is in commercial cultivation. Even though some staff are inadequately trained to understand the implications of giving approvals on the notifications or petitions for deregulation,[86] no other agency or external peer review oversees APHIS decisions.

In December 2005, the U.S. Department of Agriculture's Inspector General released a scathing report[87] on the deficiencies of the APHIS approval program. Since 1986, the USDA has approved more than 10,600 applications for more than 49,300 field tests of GM products. Among many deficiencies the Inspector General mentioned: a common lack of precise locations for field tests, some being known only by the county in which the test was performed; failing to review applicants' plans for containing and preventing GM products persisting in the environment; failing to require reporting where pharmaceutical and industrial harvests from test plots end up, since they might pose a threat to food crops; failing to adequately document application reviews, including the scientific bases for approving field tests; and failing to obtain required reports on field test results, including any harmful environmental effects.

GM Cat Out of Bag

Under "notification" and "deregulation," unrestricted transgenic plant cultivation goes on with effectively no organized monitoring. No federal program inventories the characteristics of either conventional crops or natural ecosystems, so there is no basis for interpreting data from transgenic crop monitoring, should that prove necessary. No regulatory system that could be tied to monitoring results is planned.

APHIS approval of a petition for deregulation is absolute, and applies not only to the plant for which approval is sought, but also to all of its descendants. Since genes can be moved by crossbreeding into other varieties of the same or different species, this likely means that the permitting process will apply to only the first formulation of a transgenetic plant. Later, a company could circumvent notification by employing the descendants of an approved transgenic plant for other purposes.[88]

Although the companies supposedly undertake exhaustive tests of GM products, in effect, the GRAS formulation allows GM foods to be considered safe if they look and taste like the traditional foodstuff.[89] Government regulatory agencies anticipate no unexpected multiple (pleiotropic) effects of single gene splicing, even though the FDA's own scientists have vigorously disputed that assumption, and expressed serious doubts about the safety of GM foods.[90] FDA's Division of Contaminants Chemistry commented that pleiotropic effects occur in genetically engineered plants at frequencies up to 30 percent, and some undesirable effects--such as new toxicants; increased ability to concentrate pesticides, heavy metals, and other toxic substances from the environment; and alterations in nutrient levels--may pass unnoticed through subsequent breeding and selection procedures.[91]

In contrast, the UK recently completed a comprehensive series of studies on genetically modified beets, canola, and maize, which found that the beets and canola had significant adverse effects on wildlife and native plants compared to their non-GM counterparts, and demonstrated the critical need for rigorously field testing GM crops. GM maize (corn) was better environmentally because the crops coexisted with large weed populations that support a variety of wildlife.[92]

A 2002 National Academies of Sciences (NAS) committee report opined that the scientific justification for transgenics regulations "is not dependent on historical precedents for not regulating conventionally modified plants." Acknowledging that even conventional crops might need regulation, the committee stopped short of recommending that course.[93] Since this NAS committee recognized the same categories of risk for conventional and transgenic plants, as well as numerous major ecological and economic problems due to misguided intentional or unintentional introductions of non-GM kudzu, tamarisk, and various aquatic plants and animals to new environments,[94] the time for regulation of new plant varieties, both non-GM and GM, would seem to be at hand.[95]

Nearly a decade after the meteoric rise of GM food, pharmaceutical, and industrial crop plantings began, another NAS report revealed the very preliminary state of knowledge about how genetically engineered plants, animals, microbes, and fungi--or their engineered traits--can be prevented from dispersing widely through the environment. Little work has been done on developing and testing methods for keeping the GM genie bottled up in these plants, even though the potential impacts of containment failures locally, nationally, and globally, are very great and sobering. The government currently is permitting the release of unknown organisms with a blind optimism that nothing untoward is likely to happen. In contrast, the NAS noted, "The evaluation of whether and how to confine cannot be an afterthought in the development of a transgenic organism."[96]

In spite of industry claims, and National Academies of Sciences endorsements, U.S. insurance companies remain concerned enough to refuse to write policies that indemnify the biotech industry and GM food producers against lawsuits for potential harm from edible GM products.[97]

The Wrong Revolutions

Many grand agricultural experiments have unexpectedly gone wrong. Even the most recent, much-heralded, Green Revolution exemplifies the need for regulation of even conventional food crops. "Green Revolution" embraces a technical and managerial package exported to undeveloped nations, featuring high-yielding, laboratory-developed staple crop strains of wheat, maize, and rice, selected by plant geneticists for their responsiveness to chemical fertilizer and irrigation water, and for pest resistance. All the strains also had short statures and stems strong enough to hold up heavy seed heads without breaking, to make them more compatible than traditional grains with mechanized harvesting.[98]

The crops did produce extraordinary increases in yields--but also imposed chemical fertilizer and pesticide use on traditional cultures, and forced a shift from diverse crops to monocultures. In many places, the traditional crops grew well without irrigation but the novel crops required abundant water. Over the long run, the Green Revolution lowered farmers' productivity and depleted their soils. The expensive fertilizers and pesticides also contributed to impoverishing many small farmers.[99]

The Green Revolution ended up moving people off the land and into the world's most severe poverty, especially in Africa. According to writer Richard Manning, it was "… the worst thing that has ever happened to the planet."[100] As in the U.S., corporate farmers took over the small farms, expanded industrial farming and fostered huge increases in fossil fuel consumption, with attendant pollution problems. Pest-resistant crops quickly lost their resistance, forcing farmers to more and stronger pesticide applications, which were killing an estimated 20,000 people per year worldwide by 1990--not to speak of the wildlife holocaust.

Huge increases in fertilizer applications contributed to widespread eutrophication, or oxygen depletion, of surface waters. Groundwater withdrawals to meet irrigation demands led to aquifer collapses and permanent losses in their underground water storing capacity. Continued irrigation demands helped drive huge dam-building projects that took surface water supplies away from downstream populations and contributed to erosion problems. The Green Revolution has vastly reduced the number of staple crop varieties worldwide, diminishing genetic diversity. This invites any fast spreading pathogen to bring on a future catastrophe resembling the late 19th century's Irish potato famine. Nature has not yet accepted this grisly invitation, but the full consequences hang over America's agriculture.[101]

Unsustainable Food

In a recent annual report, the giant Monsanto Corporation declared that "current agricultural technology is not sustainable….," meaning that the high productivity of U.S. industrial agriculture cannot be sustained without "enormous amounts of chemical fertilizer, pesticide, machinery and fuel, a set of capital-intensive inputs, as they're called, that saddle the farmer with debt, threaten his health, erode his soil and destroy its fertility, pollute the ground water and compromise the safety of the food we eat."[102] Similarly, trying to feed the world through biotechnology will impose a huge financial burden on the countries and people most in need. The costs of engineered seed plus chemicals have skyrocketed since 1988, and are still going up: in 1999 Roundup Ready™ soybeans cost nearly $69 per acre just for the seed and chemicals, not including the per-acre technology fees.

The rising trend of petroleum prices is likely to extend into the foreseeable future. We must realize that America's conventional agriculture is a system for turning large amounts of oil into food with very much lower energy contents. And feeding the world is not the main interest of agribusiness--instead, "The rising prominence of the private sector in setting R+D priorities and shaping farming systems is shifting emphasis from problem solving and societal needs to preserving and creating high profit margins in proprietary technologies."[103]

Organic farming, the most prominent reform movement in American agriculture, is increasingly popular with consumers. But organic farming depends on raising diverse crop types--and often growing livestock along with crops--to build soil fertility and manage pests. Relying on low level fertilizer and pesticide inputs, organic agriculture requires constant management oversight and more intensive labor than conventional farming, and does not scale up to the level of the uniform monocultures that produce America's record crop yields. Going the hi-tech route, crop varieties developed from splicing genetic material, many dependent on patented chemicals, allows conventional farmers to continue their former practices. This approach is more appealing to agricultural chemical companies because it promises a future of adequate profit margins.

GM agriculture is unlikely to be any more sustainable than the methods it hopes to rescue. Current knowledge about GM plants suggests that growing them is no different in scope and impact from the unsustainable monoculture farming that has severely degraded American soils, polluted its waterways, poisoned its wildlife, and impoverished its small farms. Worse, GM agriculture requires at least as much energy, fertilizer, and pesticides--plus much larger outlays for patented seeds, the license to use them, and per-acre charges. The licenses restrict farmers from keeping seed from one year's crop for planting in subsequent years to save money.

So-called "terminator technology" for engineering sterile seeds could supplant GM license restrictions. The USDA and a seed company first developed plants with sterile seeds, to prevent farmers from saving harvested seed for re-use. Crop plants that yield sterile seeds enslaves farmers to commercial seed producers, preventing them from even selecting and growing the seeds best suited to local environments. The United Nations Convention on Biological Diversity (CBD) in 2000 adopted a de facto moratorium on sterile seed technologies ("Genetic Use Restriction Technologies"), and Monsanto publicly pledged not to commercialize terminator technology. But in February, 2006, Monsanto decided to apply the technology for non-food crops--and for any other use it deems appropriate.[104] Australia, Canada, and New Zealand all supported Monsanto’s move, which calls for case-by-case risk assessments. Although the CBD reaffirmed its moratorium in March 2006, the issue is likely to resurface before long.

The National Academy of Sciences[105] has found that making herbicidal and herbicide-dependent crops as the primary solution to pest problems "violates fundamental unifying principles and cannot be sustainable." In addition, all toxin-based pest management control schemes, whether conventional or GM, are defeated by natural "countermoves that neutralize their effectiveness." The most critical problem of engineered pest resistance, however, is its irreversibility--"with an herbicide or pesticide, no matter how toxic, you can stop spraying and eventually it will break down in the environment. In contrast, genetic modification and genetic pollution can be completely irreversible. We cannot eradicate many of our invasive species. Similarly, we cannot easily recall transgenes once they have escaped into wild populations."[106]

The impressive variety and ingenuity of GM organisms would overwhelm even a robust regulatory system designed to assure their safety. They easily overwhelm the Agriculture Department, making Americans dependent on the manufacturers' disclosing the tests they conduct and the test outcomes. Agribusiness public relations assures us there is "no evidence" that any GM foodstuffs currently in the markets are harmful, but genetically engineered foods in the grocery store are unlabeled--so how would we know?

Food and fiber crops, genetically engineered to produce pharmaceuticals and industrial products, have extraordinary health and environmental ramifications. Agribusiness public relations tells us that these products, which are expanding extraordinarily in the middlewestern U.S., are exhaustively tested before they ever hit the market. But a look inside the regulatory agencies shows that is not the case. There is no federal government testing of products or meaningful regulatory control over the producers. The short safety tests industry routinely performs should be replicated by other labs, but commonly are not.[107]

No system is foolproof--but untested products, broadly deployed, are more likely to yield disasters on a more frequent basis than tested products that come more cautiously into production.[108] The consequences of such experiments gone awry are so profound that we need to restructure the way GM products are brought to market, instilling the process with an appropriate measure of fear, skepticism, and caution.

Accountability for inadvertent transfers of unwanted genetically engineered plants to organic farms, for one example, is slowly focusing on farmers who plant GM crops, rather than on the claimed ownership rights of GM seed manufacturers. Recently Germany and Denmark enacted laws that will punish farmers planting GM crops if they contaminate crops or fields of non-GM farmers causing a loss of value. Farmers incurring losses will be compensated by the government and the costs recouped from farmers whose crops caused the problem.

Thinking Ahead, Finally

The very short period of time (less than 10 years) since widespread use of GM crops began almost certainly makes the industry and government claims of safety premature, as well as the denials that humans are the guinea pigs for a giant experiment. Similar safety claims accompanied the introduction of such extremely harmful pesticides as DDT, and decades elapsed before their ill effects were documented and their use circumscribed. Among numerous other presumably "harmless" substances introduced into the environment, nobody predicted that chlorofluorocarbons could destroy the earth's protective stratospheric ozone layer, or that very low levels of toxins could combine to poison humans and other organisms.[109] As Professor Williamson has noted, "Many pest invaders have not been recognised as such for many years, often decades." The commercial GMOs that become problems will be widely distributed quickly--as a result, the problems they create will be difficult to control, even if spotted early.[110]

The claims that GM crops would increase yields have not come true, in fact since the beginning of GM soybean propagation, yields have decreased an average of 5.3 percent across all varieties tested. Nor are the claims of reduced pesticide applications borne out--an improbable objective for pesticide merchants, after all. Roundup™ herbicide-tolerant crops initially required greater applications than conventional crops. Many weeds that Roundup™ once killed have developed resistance, increasing the perceived need for additional herbicide applications.[111] When weed populations shifted to herbicide-resistant types, many late-germinating weeds escaped Roundup™ applications and built up overwinter seedbanks, worsening the farmer's problem and his bottom line.

Spreading GM-based agriculture to developing countries will intensify social inequalities spawned by the Green Revolution, separating rich individuals and countries from the people and nations who cannot afford the increasing costs of technological farming. Perhaps most wrenching, western U.S. farmers may find themselves among the casualties--for mechanization and the Green Revolution have "reduced family and regional autonomy, enmeshing farmers in a world of banks, seed banks, plant genetics, fertilizer manufacturers, extension agents, and water bureaucrats." With genetic engineering, the continuing agricultural revolution has "sought to harness nature tightly, to make it perform to the utmost, to make it maximally subservient to humankind … and it sharply increased output, making us dependent upon its perpetuation."[112] It takes great faith to believe that this system could be sustainable, and even if it were sustainable--at what cost?

It is well to bear in mind the words of George Wald, expressed early in the history of genetic engineering: "Recombinant DNA technology [genetic engineering] faces our society with problems unprecedented, not only in the history of science, but of life on the Earth.... Now whole new proteins will be transposed overnight into wholly new associations, with consequences no one can foretell, either for the host organisms or their neighbors.... It is all too big and is happening too fast.... For going ahead in this direction may not only be unwise but dangerous. Potentially, it could breed new animal and plant diseases, new sources of cancer, novel epidemics."[113]

For the present, the GM explosion is concentrated in the southern and Midwestern states. Many fewer fields and crops are planted in the western United States, especially in California. There still is time to slow the GM takeover of American agriculture, and wait for confirmation or invalidation of the claims that GM varieties are really safe.

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Endnotes

1. Conventional plant breeding does change the genetic makeup of plants, but current use of the term "genetically modified organisms" (GMOs) is understood to mean modifications through modern molecular techniques, meaning direct transfer of DNA into chromosomes (National Academies of Sciences, National Research Council, *Genetically Modified Pest-Protected Plants, Science and Regulation* (Washington, DC, National Academy Press 2000), 5); GMOs include modified organisms produced both by gene transfer from plants (or animals, bacteria, viruses, etc.) to other plants (or animals), and including gene transfers across plant and animal kingdoms. Many authors use the term "transgenic" to mean any organism created by direct DNA transplantation, although others restrict the term to transfer of DNA between unrelated organisms (Leo Horrigan et al., How Sustainable Agriculture Can Address the Environmental and Human Health Harms of Industrial Agriculture, *Environmental Health Perspectives* 110 (2002), 449).

2. A useful abbreviated chronology of major events leading to commercial development of GM crops is given by P.F. Lurquin, *High Tech Harvest* (Boulder, Colorado, Westview Press 2002), xv-xvii.U.S. acreage planted in GM crops has grown hugely, from 75 million acres in 2000, to 88 million acres in 2001, to 96.3 million acres in 2002 (Horrigan et al., How Sustainable Agriculture Can Address the Environmental and Human Health Harms of Industrial Agriculture, 449). Since 1996, the United States has consistently planted more GM crops than any other country, in 2003 accounting for over two-thirds of all corn, cotton, soybeans, canola, squash, and papaya biotechnology crops globally (The Pew Charitable Trusts, Genetically Modified Crops in the United States, *The Pew Initiative on Food and Biotechnology*. [Online]. Available: http://pewagbiotech.org/resources/factsheets/display.php3?FactsheetID=2; see also, Jim Giles, Damned If They Do, Damned If They Don't, *Nature* 425 (2003): 656-659.

3. Charles Benbrook, Evidence of the Magnitude and Consequences of the Roundup™ Ready Soybean Yield Drag from University-Based Varietal Trials in 1998, *Ag Bio Tech Info Net* Technical Paper Number 1 (July 13, 1999), 17 p.; Wes Jackson, Clear-Cutting the Last Wilderness, Compromising the Genomes of Our Major Crops, *The Land Report*, Number 65 (Fall 1999).

4. Crops engineered to synthesize pharmacological and industrial compounds include corn, rice, tomato, barley, alfalfa, sugarcane, soybean, lettuce, lupine, tobacco, and rapeseed (canola) (Margaret Mellon, Who's Minding the Pharm? *Catalyst* 1 (2002): 2-6).

5. This genetic modification involves manipulating the plants' own genes, to either retard or advance the flowering time. Retarding prolongs the time before spinach bolts, and advancing allows more crops to be harvested per season. Modifications also enlarge leaf area to increase photosynthesis; make roots more aggressive at extracting water, to combat drought; and numerous other applications. Most or all of these changes will have significant effects on pollinators, pests, pest predators, soil nutrients, and soil moisture (A.S. Moffat, Can Genetically Modified Crops Go Greener? *Science* 290 (2000): 253-254); see also Natalie Goldstein, *Earth Almanac*, 2nd edition (Westport Connecticut, Oryx Press 2002), 381..

6. Michelle Marvier, Ecology of Transgenic Crops, *American Scientist* 89 (2001): 160-167. An excellent, readable account of some major problems involved with GM crops. The Glofish, a fluorescent zebra fish, apparently slipped through the porous regulatory net because no federal agency oversees biotech house pets.

7. The new biotechnology goes far beyond conventional breeding methods, which were limited to species-level transformations until recently, and rarely created new genera. Genetic engineering can create many more combinations of genes and new organism traits than traditional breeding, and fearlessly moves genes between plant and animal kingdoms, greatly reducing the ability to predict the safety of any engineered organism on the basis of past experience (Marvier, Ecology of Transgenic Crops, 160; Mark Tester, Some GM Facts, *Science* 298 (2002): 1341-1342).

8. National Academies of Sciences, *Introduction of Recombinant DNA-Engineered Organisms Into the Environment* (Washington, DC, National Academy Press 1987).

9. Lurquin, High Tech Harvest, Chapter 7. GMO proponents commonly argue that GM technology is an extension of conventional breeding practices, and should not be feared. (Tester, Some GM Facts; Rachel Massey, Biotech, The Basics, Part 2, *Rachel's Environment & Health News* #717 (2001), 2 p.). Even if GM were like conventional breeding, the comparison instills little confidence in those aware of the poor regulation of new conventionally bred plants and animals, and the genetic weaknesses of many hybrids (National Academies of Sciences, National Research Council, Genetically Modified Pest-Protected Plants, 6; National Academies of Sciences, National Research Council, *Environmental Effects of Transgenic Plants, The Scope and Adequacy of Regulation* (Washington, DC National Academy Press 2002), 5).

10. Sheldon Rampton and John Stauber, *Trust Us, We're Experts!* (New York, Jeremy P. Tarcher/Putnam 2001), Chapter 7. The State of New York successfully sued Monsanto to remove claims made on Roundup™ labels, such as that glyphosate products are "safer than table salt," safe for people, pets, and the environment, and degrade "soon after application", because they are not substantiated by Monsanto's own research, and violate the Federal Insecticide, Fungicide and Rodenticide Act (Caroline Cox, Glyphosate (Roundup), *Journal of Pesticide Reform* 19 (1998, updated September 2002): 9). In states other than New York, Roundup™ labels can still carry these claims.

11. Lurquin, High Tech Harvest, 150 says "transgenic foods are analyzed extensively for the presence of known toxic compounds, including allergens, and so far, none have been found in the engineered plants we eat." The problem with this assertion is that experimenters cannot identify all toxic or allergenic compounds. Introduced allergens came close to creating a major problem when Pioneer Hybrid seed company added a Brazil nut gene to soybeans for a better protein nutrient balance. Tests showed the product could induce allergic reactions in people sensitive to Brazil nuts. This product likely would have gone to market if the allergenic potential of Brazil nuts had not been previously known, leading to specific tests (Sheldon Rampton and John Stauber, *Trust Us, We're Experts* (New York, Tarcher/Putnam 2001), 175). Another recently discovered allergy problem came from transfering a gene for expressing an insecticide protein from a bean to a pea, which provoked allergic reaction in mice fed the transgenic

pea (V.E. Prescott et al., Transgenic Expression of Bean-Amylase Inhibitor in Peas Results in Altered Structure and Immunogenicity, *Journal of Agriculture and Food Chemistry* 53 No. 23 (2005): 9023-9030).

12. National Academies of Sciences, National Research Council, Genetically Modified Pest-Protected Plants, 72, 129; Rachel's Environment & Health Weekly, Biotech in Trouble, Part 2 # 696, *Rachel's Environment & Health Weekly* (2000), 2 p.; a harmless example of unexpected results is an early German experiment that engineered petunias with a corn gene to produce salmon red flowers. Some 30,000 transgenic petunias were grown, with the anticipation that 1 in 100 to 1 in 100,000 might not have the salmon color. Since petunias produce as many as 50 flowers in a season, it came as a big surprise that 8.4 percent of early flowers and fully 62 percent of late flowers from the same plants had colors different than expected (P. Meyer et al., Endogenous and Environmental Factors Influence 35S Promoter Methylation of a Maize A1 Gene Construct in Transgenic Petunia and its Colour Phenotype, *Molecular Genes and Genetics* 231 (1992): 345-352).

13. Public Employees for Environmental Responsibility, *Genetic Genie, The Premature Commercial Release of Genetically Engineered Bacteria*, White Paper (January 25, 2000), vi-vii (EPA scientists prepared this white paper, which is highly critical of the EPA's procedures for approving release of transgenic plants. The scientists are not named to protect them from agency reprisal); Rachel's Environment & Health Weekly, Biotech in Trouble, 2 p.

14. Recent studies show that impacts of transgenic soy on mice livers, which form rapidly even in adults, disappear when the mice go back to eating nontransgenic soy (M. Malatesta et al., Reversibility of Hepatocyte Nuclear Modifications in Mice Fed on Genetically Modified Soybean, *European Journal of Histochemistry* 49 (2005): 237-242). A catalyst for genetically modifying a plant can provoke gene expression in cultured human cells, an effect not previously known (M.R. Myhre et al., The 35S CaMV Plant Virus Promoter Is Active in Human Enterocyte-Like Cells, *European Food Research and Technology* 222 (2006): 185-193).

15. National Academies of Sciences, National Research Council, Genetically Modified Pest-Protected Plants, 8.

16. Rampton and Stauber, Trust Us, We're Experts!, 176-178; A. N. Mayeno et al., Characterization of 'Peak E,' a novel Amino Acid Associated with Eosinophilia-Myalgia Syndrome, *Science* 250 (1990): 1707-1708; J.M. Smith, *Seeds of Deception* (Yes! Books, Fairfield, Iowa 2003), Chapter 4.

17. M.K. Hansen, Genetic Engineering Is Not An Extension of Conventional Plant Breeding, How Genetic Engineering Differs From Conventional Breeding, Hybridization, Wide Crosses, And Horizontal Gene Transfer, *Consumers Union, Consumer Policy Institute*. [Online]. Available: http://www.biotech-info.net/wide_crosses.html.

18. Public Employees for Environmental Responsibility, Genetic Genie; Union of Concerned Scientists, Food and Environment, *Union of Concerned Scientists* (1999). [Online]. Available: http://www.ucsusa.org.

19. M.K. Hansen, *Bt Crops: Inadequate Safety Testing*, Conferencia Impatos del Libre Comercio, Plaguicidas y Transgenicos en la Agriucultura de America Latina, Universitdad Autonoma, Chapingo, Cancún, Mexico, (August 1-2, 2002).

20. Lurquin, High Tech Harvest 123, 162-164.

21. Lurquin, High Tech Harvest, 77-94.

22. Contrary to some critical discussions of AMT, the Agrobacterium itself does not enter the plant, and none of the disease-causing characteristics of either Agrobacterium or the Cauliflower Mosaic virus are present in genetically modified plant cells.

23. Hansen, Genetic Engineering is not an Extension of Conventional Plant Breeding.

24. Lurquin, High Tech Harvest, 142.

25. M.K. Hansen, *Bt* Crops: Inadequate Safety Testing.

26. Michael Pollan, Playing God in the Garden, *New York Times* (October 25, 1998); this article has numerous insights based on enlightened questions to experts, those with vested interests in pesticide products, and farmers.

27. Hansen, Genetic Engineering is not an Extension of Conventional Plant Breeding. The term "gene splicing" obscures much of the uncertainty and imprecision of genetic modifications. At present it is not known in advance where in a plant's DNA the inserted genes will wind up, although gene sequencing analysis can determine the positions after the fact. Some (Lurquin, High Tech Harvest, 150) believe that scientists eventually will come to know "with the highest confidence that this process will have no deleterious effects on plant metabolic pathways." Without waiting for that ability, gene guns shoot metal slivers coated with DNA of one organism into cells of another, in the hope that the transported genes will implant themselves in the optimal chromosomal positions. (Sheldon Rampton and John Stauber, *Trust Us, We're Experts!* (New York, Jeremy P. Tarcher/Putnam 2001), 175-176).

28. M.H. Williamson, The Release of Genetically Engineered Organisms, in *Plant Invasions: Ecological Mechanisms and Human Responses*, ed. U. Starfinger, K. Edwards, I. Kowaricj, and M.H. Williamson (Leiden, The Netherlands, Backhuys Publishers 1998), Chapter 6.5.

29. Transcript of panel discussion sponsored by the *Pew Initiative on Food and Biotechnology*, Environmental Savior or Saboteur? (February 4, 2002).

30. Mellon, Who's Minding the Pharm?

31. Lurquin, High Tech Harvest, 113-114; the difficulties with commercializing GM food products has dampened enthusiasm, partly because of the dearth of evidence that such crops would improve farmers' welfare. Recent research in China claims that small and poor farmers benefit from using GM varieties of rice by increased yields and reducing required pesticides, with consequent health benefits (Jikun Huang et al., Insect-Resistant GM Rice in Farmers' Fields: Assessing Productivity and Health Effects in China, *Science* 308 (2005): 688-690). But similar benefits also were promised for non-food GM crops. A nine-year study shows that the pesticide benefits were lost after three years due to changes in weed communities (to favor more hardy types) and resistance developed in particular weed species. (Benbrook, Evidence of the Magnitude and Consequences of the Roundup™ Ready Soybean Yield Drag). Also, GM crops come to need more and more pesticide applications. By 2005, this amounted to an increase of about 4.1 percent (122 million pounds) of pesticides applied to the 3 dominant GE crops (corn, soybeans, cotton) in the U.S. (C.M. Benbrook, Genetically Engineered Crops and Pesticide Use in the United States: The First Nine Years, *BioTech InfoNet* Technical Paper No. 7 (October 2004), 53 p.).

32. M.H. Williamson, Minutes of Evidence, House of Lords Select Committee on European Communities, answer to question 491 (1998). [Online]. Available: http://www.parliament.the-stationery-office.co.uk/pa/ld199899/ldselect/ldeucom/11/8072201.htm).

33. M.K. Hansen, Genetic Engineering is not an Extension of Conventional Plant Breeding. DNA splicing techniques cannot control the locations that inserted genes come to occupy in the plant genome. In many cases, the gene location prevents plant growth, or renders the grown plant sterile. But even when growing stages do not identify a problem, completely unanticipated harmful effects may arise from some placements. For example, one experiment inserted multiple copies of a naturally occurring yeast gene into yeast DNA, producing a 40 to 200-fold increase in a potent mutagenic toxin. Other experiments involving a natural herbicide-tolerant plant unexpectedly transformed the species from an inbreeder to one that readily cross breeds.

34. Quoted by Pollan, Playing God in the Garden.

35. N.C. Ellstrand, Dangerous Liaisons, When Crops Mate With Their Wild Relatives (Baltimore, Maryland, Johns Hopkins University Press; 2003), Chapter 6.

36. Andrew Kimbrell, director of the Center for Technology Assessment in Washington, quoted by Pollan, Playing God in the Garden.

37. M.H. Williamson, The Release of Genetically Engineered Organisms, in *Plant Invasions: Ecological Mechanisms and Human Responses*, ed. U. Starfinger, K. Edwards, I. Kowaricj, and M.H. Williamson (Leiden, The Netherlands, Backhuys Publishers 1998), Chapter 6.5. Williamson is a British authority on environmental threats due to introduced species from other parts of the world -- plants that became weeds "merely by being taken to new regions." According to Williamson, "the study of invasions suggests that the probability of detecting undesirable products at an early stage is not large."

38. Ellstrand, Dangerous Liaisons. Ellstrand and colleagues have demonstrated that 12 of the world's 13 most important food crops hybridize with wild relatives in some part of their distribution (N.C. Ellstrand et al., Gene Flow and Introgression From Domestic Plants Into Their Wild Relatives, *Annual Review of Ecology and Systematics* 30 (1999): 539-563).

39 Quoted in Rachel's Environment & Health News, Against the Grain, Part 2, *Rachel's Environment & Health News* #638 (1999), 2 p.; see also Marvier, Ecology of Transgenic Crops, 163-164. As of July 2000, the USDA had approved 50 petitions to allow commercial cultivation, 14 of which were for insect-resistance traits using *Bt* toxin. Williamson (M. Williamson, Invaders, Weeds and the Risk From Genetically Manipulated Organisms, *Experientia* 49 (1993): 219-224) also points out that while the probability of successful invasions is low, small genetic changes can cause large ecological changes. Inasmuch as GMOs will have characteristics entirely new to that species' evolutionary history, a few moving into natural or crop settings can be ecologically and economically damaging.

40. M.H. Williamson, Can the Risks from Transgenic Crops Be Estimated? *Tibtech* 14 (December, 1996). Canola hybridizes with wild radishes, even though they are different genera in the same family of plants. Other studies indicate hybridization between canola and its wild relative, *B. rapa*, which occurs infrequently as an agricultural weed and along waterways (M.J. Wilkinson et al, Hybridization Between *Brassica napus* and *B. rapa* on a National Scale in the United Kingdom, *Science* 302 (2003): 457-459; see also, John Heritage, Will GM Rapeseed Cut the Mustard? Science 302 (2003): 401-402; A-M Chévre et al., Gene Flow From Transgenic Crops, *Nature* 389 (1997): 924.

41. Jocelyn Kaiser, Superweeds, and a Sinking Feeling on Carbon Sinks, Breeding a Hardier Weed, *Science* 293 (2001): 1425-1426.

42. M.H. Williamson, Minutes of Evidence (answer to question 505).

43. Quotation from Erik Stokstad, A Little Pollen Goes a Long Way, *Science* 296 (2002): 2314.

44. The California Department of Food and Agriculture (CDFA) must approve the plan to expand pharma rice planting in California. A panel set up by State legislators, but composed of rice Industry representatives, "approved a set of procedures that would allow Ventria to become the nation's first commercial-scale producer of plant-made pharmaceuticals. The goal was to ensure the company's rice doesn't mix with food rice." CDFA's first review of the plan brought over a thousand letters, mostly in opposition to growing drug components in open fields, but a few supported the idea on the industry presumption that it will eventually provide cheaper drugs (Mike Lee, Biotic Rice Plan Draws Fire, *Sacramento Bee* (June 1, 2004).

45. Wes Jackson, Clear-Cutting the Last Wilderness, (Fall 1999); CBWinfo.com, Southern Leaf Blight, Essential Data. [Online]. Available: http://www.cbwinfo.com/Biological/Plant Path/BM.html. Conventional plant breeders developed male-sterile varieties to ease the hand labor for controlling pollination in the field, required to combine the desired traits of different corn varieties. Before development of male-sterile corn, the tassels that bear corn pollen had to be removed or covered with bags, but male-sterile corn plants do not grow tassels. The male-sterile trait is related to the composition of cell cytoplasm, the material surrounding the cell nucleus. After 1970 weather conditions favored the spread of *Bipolaris maydis* fungus, which blights and kills corn, sorghum, and teosinte (a corn-like fodder grass), researchers found the male sterility trait, so-called "Texas cytoplasm," carries an unforeseen and unknown genetic weakness that makes those corn varieties vulnerable to fungus. (Don't Mess with Texas Cytoplasm: To accompany the *Georgia Agricultural Education Curriculum*, Courses 01.431-2.2, 6.4 & 02.471-5.4. [Online]. Available: aged.ces.uga.edu/.../cd2/Class%20starters,%20Mental%20Set,%20Facts,%20Figures,%20 Ideas/Corn_T_Cytoplasm.doc).

46. Lurquin, High Tech Harvest, 142.

47. Public Employees for Environmental Responsibility, Genetic Genie; Union of Concerned Scientists, Food and Environment, 1. The modern practices that promote antibiotic resistance include: overusing antibiotics, especially for treating human viral infections; and non-therapeutic antibiotics overfeeding to livestock for enhancing weight gain. Professor M.H. Williamson stated in his 1998 testimony to a committee of the House of Lords, "… my plant molecular biology people say that the idea of putting an active bacterial antibiotic into something you are going to feed to cows which are already full of antibiotics for various other reasons does show a total lack of imagination on the part of the company and they should not have ever started down that road."

(M.H. Williamson, Minutes of Evidence, answer to question 521).

48. Benbrook, Evidence of the Magnitude and Consequences of the Roundup™ Ready Soybean Yield Drag, 11.

49. Glyphosate itself is only slightly toxic to fish and other aquatic organisms (Cox, Glyphosate (Roundup), 11-12; A. Hilbeck et al., Effects of Transgenic *Bacillus thuringiensis* Corn-Fed Prey on Mortality and Development Time of Immature *Chrysoperia carnea* (Neuroptera: Chrysopidae), *Environmental Entomology* 27 (1998): 480-487).

50. Cox, Glyphosate (Roundup); R.A. Relyea, The Lethal Impact of Roundup on Aquatic and Terrestrial Amphibians, *Ecological Applications* 15 (2005): 1118-1124.

51. Planting crops resistant to such broad-spectrum herbicides as glyphosate (in Roundup™), may denude fields of non-GM plant life, eradicating the seeds and insects that feed farmland birds (Trisha Gura, The New Battlefields of Britain, *Nature* 412 (2001): 760-763). Simulation studies indicate that spraying herbicide-tolerant sugarbeets with glyphosate could eradicate the wild herb (*Chenopodium album*), severely impacting skylark populations (A.R. Watkinson et al., Prediction of Biodiversity Response to Genetically Modified Herbicide-Tolerant Crops, *Science* 289 (2000): 1554-1556).

52. Root-colonizing *Fusarium solani* soil fungus. (The Institute for Science in Society, Roundup Ready Sudden Death Syndrome: *The Institute for Science in Society* (ISIS) (November 30, 2003). [Online]. Available: http://www.i-sis.org.uk/full/RRSDFull.php.).

53. Andy Coghlan, Splitting Headache, *New Scientist* No. 2213 (November 20, 1999), 25.

54. Lurquin, High Tech Harvest, 144.

55. Cox, Glyphosate (Roundup), (updated September 2002), 4-7; L.P. Walsh et al., Roundup Inhibits Steroidogenesis by Disrupting Steroidogenic Acute Regulatory (STAR) Protein Expression, *Environmental Health Perspectives* 108 (2000): 769-776.

56. Bob Hartzler, Are Roundup Ready Weeds in Your Future? *Iowa State University, Weed Science* (1998), 3. [Online]. Available: http://www.weeds.iastate.edu.

57. National Academies of Sciences, National Research Council, Genetically Modified Pest-Protected Plant, 9; M.A. Marvier et al., How Do the Design of Monitoring and Control Strategies Affect the Chance of Detecting and Containing Transgenic Weeds? in Eds. K. Ammann, Y. Jacot, G. Kjellsson, and V. Simonson, *Methods for Risk Assessment of Transgenic Plants*, volume 3 (Basel, Birkhauser Press 1999), 109-128; Rachel's Environment & Health Weekly, Sustainability and Ag Biotech, *Rachel's Environment & Health Weekly* # 686 (2000), 2 p.

58. Benbrook, Evidence of the Magnitude and Consequences of the Roundup Ready™ Soybean Yield Drag, 6; in 1998 species with a relatively high tolerance to Roundup™ were responsible for numerous Roundup™ control failures (Hartzler, Are Roundup Ready Weeds in Your Future?).

59. The propensity for herbicide applications to build pesticide resistance in insects and other non-weed organisms was demonstrated in controlled experiments. (Hartzler, Are Roundup Ready Weeds in Your Future?).

60. Charles Benbrook, Do GM Crops Mean Less Pesticide Use?, Pesticide Outlook (2001). [Online]. Available: http://www.mindfully.org/Pesticide/More-GMOs-Less-Pesticide.htm; Benbrook, Genetically Engineered Crops and Pesticide Use in the United States: The First Nine Years.

61. Studies have demonstrated cross pollination between GM and non-GM canola crops over distances of 2 miles (M.A. Rieger et al., Pollen-Mediated Movement of Herbicide Resistance Between Commercial Canola Fields, *Science* 296 (2002): 2386-2388), and comparable cross pollination distances between different GM canola crops is evident from hybrid types with resistance to two or three herbicides specific to different GM crops (see endnote 56). Current studies of plant pathogen and other organic materials transported on dust particles make it clear that pollens can be distributed globally.

62. National Academies of Sciences, National Research Council, Genetically Modified Pest-Protected Plants, 9. In mentioning damage to non-target species, this National Academy panel said that conventional crop management also hurts non-target species, and that broad-spectrum pesticides kill even more of them, concluding that the more benign pesticides used with or created by transgenic crops will be an environmental plus, a statement unsupported by evidence. In mentioning potential problems from gene flow by pollen transfer, the panel broadly estimated that only trace amounts of pollen are distributed more than a few hundred feet, and suggested that the unfortunate appearance of pesticide resistance might require a return to more harmful pesticides, or even to novel control techniques with less known environmental and health impacts. Human error is another, not-so-novel, mechanism of long-distance transgene transfer -- genetically engineered tomato seeds were shipped across the world for seven years because scientists at the University of California, Davis, did not know the seeds contained biotech genes (Mike Lee and Edie Law, Biotech Seeds Shipped in Error, *Sacramento Bee* (December 19, 2003).

63. C. M. Benbrook, *GMOs, Pesticide Use, and Alternatives Lessons from the U.S. Experience*, speech presented at the Conference on GMOs and Agriculture, Paris, France (June 20, 2003). [Online]. Available: http://www.organicconsumers.org/ge/070903_ge_food.cfm.

64. A Canadian farmer who discovered some Monsanto Roundup Ready™ canola from a neighbor's farm on land he was trying to fallow. He tried unsuccessfully to kill the invaders with two applications of herbicide before calling Monsanto in frustration, telling them to "Take your product and get it the hell off my land" (quoted by Rampton and Stauber, Trust Us, We're Experts!, 175); according to other studies GM and conventional oilseed rape, potato, maize, and sugarbeet sown in 12 different natural habitats did not survive beyond 4 years in a 10 year study, and so did not become weed problems (M.J. Crawley et al., Transgenic Crops in Natural Habitats, *Nature* 409 (2001): 682-683). Unfortunately, biological invasions are very complex and "simple comparisons of fecundity and survival do not adequately predict invasiveness." Variations in the competitive environment and the time a species is introduced can confound predictions, and for reasons as yet unknown, decades can elapse between an introduced species getting established and subsequently expanding its population and range. Much can depend on whether birds and rodents eat the seeds (L.L. Wolfenbarger and P.R. Phifer, The Ecological Risks and Benefits of Genetically Engineered Plants, *Science* 290 (2000): 2088-2093).

65. Three different companies manufacture transgenic canolas that resist different herbicides: Monsanto, glyphosate (Roundup); Aventis, glufosinate ammonium (Liberty); BASF, imidazolinone (Clearfield). Individual canola plants apparently resistant to all three herbicides have been discovered, posing especially difficult weed-control problems (Massey, Biotech, The Basics, Part 3, 2 p.; Biotechnology Industry Organization. [Online]. Available: www.bio.org/er/agri_products.asp; see also http://www.ag.ndsu.nodak.edu/minot/weeds/1998/9807.htm). As a result of the highly successful Roundup Ready™ soybeans, two other companies have developed transgenic soybeans resistant to imidazolinone (IMI) (American Cyanamid), and sulfonylurea (STS) (Dupont) (Benbrook, Evidence of the Magnitude and Consequences of the Roundup™ Ready Soybean Yield Drag); the fate of canola may also await soybeans if GM traits are transferred to wild relatives.

66. Caroline Cox, Coming Soon, Roundup Ready Grass on Golf Courses, *Journal of Pesticide Reform* 24 (2004): 5; L.S. Watrud et al., Evidence for Landscape-Level, Pollen-Mediated Gene Flow From Genetically Modified Creeping Bentgrass With CP4 EPSPS As A Marker, *Proceedings of the National Academy of Science* 101 (2004): 14533-14538. The U.S. EPA reported GM bentgrass growing in the wild in central Oregon in August 2006.

67. Goldstein, Earth Almanac, 382.

68. Lurquin, High Tech Harvest, 146-147; a recent report indicating that larvae of the diamondback moth actually can digest and use *Bt* toxin as a "supplemental food" may spell a quicker doom for *Bt* crops than anticipated, and would pose an even greater threat to organic farming than had previously been imagined (Geoffrey Lean, Insects Thrive on GM 'Pest-Killing' Crops, *The Independent* (Britain) (March 30, 2003).

69. Erik Stokstad, First Light on Genetic Roots of *Bt* Resistance, *Science* 293 (2001): 778.

70. Goldstein, Earth Almanac, 382.

71. Lurquin, High Tech Harvest, 147; Pollan, Playing God in the Garden; F. Gould et al., Initial Frequency of Alleles for Resistance to *Bacillus thuringiensis* Toxins in Field Populations of *Heliothis virescens*, *Proceedings of the National Academy of Science*, USA 94 (1997): 3488-3490. Gould and colleagues predict that a 4 percent refuge area not treated with any insecticides could help *Bt* cotton remain effectively resistant to tobacco budworm for 10 years, but *Bt* cotton has less resistance to pests such as cotton bollworm and European corn borer, so they predict a boom cycle of only 3 to 4 years for the current *Bt* variety of cotton (C.S. Prakash, Boom and Bust of Insect Resistant *Bt* Cotton? *ISB NewsReport* (July 1997); B.E. Tabashnik, Seeking the Root of Insect Resistance to Transgenic Plants, *Proceedings of the National Academy of Science*, USA 94 (1997): 3488-3490). In 2002, the USDA reported that 19 percent of *Bt* maize (corn)-growing farms in Iowa, Minnesota, and Nebraska failed to plant the required refuges, but these are generally small farms and no problem has yet been documented, possibly because only 25 percent of maize grown in the midwest contains *Bt*. This situation may change with introduction of new *Bt* maize that is designed to control a root pest, which is expected to be planted much more widely (Tom Clarke, Pest Resistance Feared as Farmers Flout Rules, *Nature* 424 (2003): 116).

72. J.E. Losey et al., Transgenic Pollen Harms Monarch Larvae, *Nature* 399 (1999): 214; Rachel Massey, Biotech, The Basics, Part 3, *Rachel's Environment & Health News* #718 (February 15, 2001), 2 p.; Dan Ferber, GM Crops in the Cross Hairs, *Science* 286 (1999): 1662-1666.

73. Mellon, Who's Minding the Pharm?, 2-6.

74. Insects are arthropods, related to crayfish, lobster, etc., and a number of very small creatures found in soils. (Cox, Glyphosate (Roundup), 11-12; National Academies of Sciences, National Research Council, Genetically Modified Pest-Protected Plants, 75).

75. Deepak Saxena et al., Insecticidal Toxin in Root Exudates from *Bt* Corn, *Nature* 402 (1999): 480; *Bt* toxin exuded through the roots of transgenic plants is very stable, binds to soil particles, and persists in the soil for 243 days, all the while remaining toxic to soil biota. Hence, *Bt* toxin released from GM corn roots is augmented by toxin from plant residues later in the fall and winter (C.M. Benbrook, Commentary on Insecticidal Toxin in Root Exudates from *Bt* Corn. [Online]. Available: http://www.biotech-info.net).

76. National Academies of Sciences, National Research Council, Genetically Modified Pest-Protected Plants, 75; Union of Concerned Scientists, Food and Environment.

77. APHIS regulations were adopted in 1987 and variously amended in 1993, 1997, and 2001. An excellent, thorough account of APHIS responsibilities, case histories of APHIS notification approvals, and analysis of the approval process is given by the National Academies of Sciences, Environmental Effects of Transgenic Plants, Chapters 3-5.

78. Rachel Massey, Biotech-The Basics, Final Part, *Rachel's Environment & Health News* #719 (2001), 2 p. Products considered GRAS (Generally Recognized As Safe) *by their manufacturers* are not subject to pre-market safety testing.

79. Marvier, Ecology of Transgenic Crops, 167.

80. Comments from records released under discovery for a lawsuit against the FDA (Rachel's Environment & Health Weekly, Review of 1999, Part 6, Trouble in the Garden, *Rachel's Environment & Health News* #685 (February 3, 2000), 2 p.).

81. National Academies of Sciences, Environmental Effects of Transgenic Plants, Chapters 3-5. In August 2006 a federal court ruled against USDA for granting permission for outdoor plantings of GM pharmaceutical corn and sugar-cane crops on hundreds of acres in Hawaii without having assessed potential impacts to that state's numerous endangered species.

82. National Academies of Sciences, Environmental Effects of Transgenic Plants, Chapters 3-5; Marvier, Ecology of Transgenic Crops, 164-166; National Academies of Sciences, Environmental Effects of Transgenic Plants, 182.

83. National Academies of Sciences, Environmental Effects of Transgenic Plants, 177-178.

84. M.H. Williamson, Minutes of Evidence, answer to question 521. Williamson favors GM technology, especially for growing pharmacological products. In saying "The differences in technology between medicine and agriculture are negligible," (answer to question 488) he meant that most vaccines are produced in animals, and he believes that growing them in plants will be cheaper and easier, in spite of the fact that he expects future problems from weed invasions and other GM-related problems.

85. National Academies of Sciences, Environmental Effects of Transgenic Plants, 180-181.

86. National Academies of Sciences, Environmental Effects of Transgenic Plants, 182.

87. U.S. Department of Agriculture, Office of Inspector General Southwest Region, Audit Report: Animal and Plant Health Inspection Service Controls Over Issuance of Genetically Engineered Organism Release Permits, *U.S. Department of Agriculture, Office of Inspector General Southwest Region*, Audit 50601-8-Te (2005), 75 p.

88. National Academies of Sciences, Environmental Effects of Transgenic Plants, 183-184.

89. The statement "No foods in history have been subjected to as much scrutiny in advance by the federal government as those improved through biotechnology" is ascribed to Michael J. Phillips. After serving as director of a National Academies of Sciences panel reviewing safety of GM foods, Phillips became executive director of the GM industry's main lobby group, the Biotechnology Industry Organization (Rampton and Stauber, Trust Us, We're Experts!, 181). The fact that companies which manufacture and market transgenic crops are responsible for assessing their product's safety entitles the public to an element of suspicion, and even that assessment is bypassed under the FDA regulations if the manufacturer simply declares a food product to be generally recognized as safe (GRAS).

90. Public Employees for Environmental Responsibility, Genetic Genie.

91. Rachel's Environment & Health Weekly, Review of 1999, Part 6, Trouble in the Garden.

92. The 3-year field test compared GM with non-GM beets, canola (rape seed), and maize at more than 200 sites across Britain, after the crops had passed the usual regulatory approvals. The results of these important studies show that alleged benefits of the tested GM crops do not exist, and raise the question of how biodiversity benefits can be balanced with profitable crop production (G.T. Champion et al., Crop Management and Agronomic Context of the Farm Scale Evaluations of Genetically Modified Herbicide-Tolerant Crops, *Philosophical Transactions of the Royal Society of London* 358 (2003): 1801-1818; M.S. Heard et al., Weeds In Fields With Contrasting Conventional and Genetically Modified Herbicide-Tolerant Crops. I. Effects on Abundance and Diversity, *Philosophical Transactions of the Royal Society of London* 358 (2003): 1819-1832; M.S. Heard et al., Weeds In Fields With Contrasting Conventional and Genetically Modified Herbicide-Tolerant Crops. II. Effects On Individual Species, *Philosophical Transactions of the Royal Society of London* 358 (2003): 1833-1846; D.R. Brooks et al., Invertebrate Responses to the Management of Genetically Modified Herbicide-Tolerant and Coincentional Spring Crops. I. Soil-Surface-Active Invertebrates, *Philosophical Transactions of the Royal Society of London* 358 (2003): 1847-1862; A.J. Haughton et al., Invertebrate Responses to the Management of Genetically Modified Herbicide-Tolerant and Coincentional Spring Crops. II. Within-Field Epigeal and Aerial Arthropods, *Philosophical Transactions of the Royal Society of London* 358 (2003): 1863-1877; D.B. Roy et al., Invertebrates and Vegetation Of Field Margins Adjacent to Crops Subject to Contrasting Herbicide Regimes in the Farm Scale Evaluations of Genetically Modified Herbicide-Tolerant Crops, *Philosophical Transactions of the Royal Society of London* 358 (2003): 1879-1898; C. Hawes et al., Responses Of Plants and Invertebrate Trophic Groups to Contrasting Herbicide Regimes in the Farm Scale Evaluations of Genetically Modified Herbicide-Tolerant Crops, *Philosophical Transactions of the Royal Society of London* 358 (2003): 1899-1913; see also, Erik Stokstad and Gretchen Vogel, Mixed Message Could Prove Costly for GM Crops, *Science* 302 (2003): 542-543).

93. National Academies of Sciences, Environmental Effects of Transgenic Plants, 5.

94. Ellstrand, Dangerous Liaisons.

95. In 1999, the U.S. rejected the opportunity to join with some 130 other nations in a treaty to regulate trade in genetically modified organisms and safeguard what is left of the world's biological resources. According to the New York Times (February 24, 1999), "Attempts to forge the world's first treaty to regulate trade in genetically modified products failed this morning when the United States and five other big agricultural exporters [Canada, Australia, Argentine, Chile, and Uruguay] rejected a proposal that had the support of the rest of the roughly 130 nations taking part." Earlier, the George H.W. Bush administration had rejected the protocol on the grounds that it threatened the U.S. biotechnology industry and would impose unfair financial burdens on the U.S. The Clinton administration signed the treaty, but it was never ratified by the Senate (Beth Burrows, Resurrecting the Ugly American, *Rachel's Environment & Health Weekly* #655 (June 17, 1999), 2 p.).

96. National Academies of Sciences, National Research Council, *Biological Confinement of Genetically Engineered Organisms* (Washington, DC, National Academy Press 2004), 219 p. This excellent report is filled with cautionary observations that ought to turn the approval procedures for GMOs upside down.

97. Labeling of genetically modified food products has been vigorously opposed by the industry for years, leading to widespread public suspicion, as well as anger at being denied an element of choice in what they eat (Rachel's Environment & Health Weekly, Part 6, Trouble in the Garden). Two-thirds of foodstuffs available in U.S. markets probably have some genetically engineered component (Rachel's Environment & Health Weekly, Biotech in Trouble, Part 1, #695, *Rachel's Environment & Health Weekly* (2000), 2 p.). Industry opposition contrasts with the requirement that bottled distilled water list nutritional values (zero for all categories) (Lurquin, High Tech Harvest, 148). The U.S. government argues that GM food labeling may be misleading because traditional crops and GM crops are "substantially equivalent." Thus the federal government regards genetically engineered New Leaf potatoes substantially equivalent to normal potatoes despite the fact that every cell of the New Leaf potato itself is pesticidal, and the New Leaf potato is required to be registered as a pesticide with the EPA.

98. J.R. McNeill, Something New Under the Sun, An Environmental History of the Twentieth-Century World (New York, W.W. Norton & Company 2000), 219-227. This book provides a fascinating history of development of Green Revolution crops, the crosscurrents of motivations to spread them, and consequences of unintended effects; for a different view, expressing optimism that genetic engineering can feed the world's exploding population: Nina Fedoroff and N.M. Brown, *Mendel in the Kitchen: A Scientist's View of Genetically Modified Foods* (Washington, DC, Joseph Henry Press 2004), 366 p.

99. Angus Wright, *The Death of Ramón González, The Modern Agricultural Dilemma* (Austin, Texas, University of Texas Press 1990), 244-285; Jackson, Clear-Cutting the Last Wilderness; Richard Manning, *Against the Grain, How Agriculture Has Hijacked Civilization* (New York, North Point Press 2004),105-115.

100. Richard Manning, The Oil We Eat, Following the Food Chain Back to Iraq, *Harper's Magazine* (February 2004): 41).

101. McNeill, Something New Under the Sun.

102. Michael Pollan, Playing God in the Garden, *New York Times* (October 25, 1998); this article has numerous insights based on enlightened questioning of experts, those with vested interests in pesticide products, and farmers who use them.

103. C.M. Benbrook, World Food System Challenges and Opportunities, GMOs, Biodiversity, and Lessons from America's Heartland, *University of Illinois World Food and Sustainable Agriculture Program* (January 27, 1999). [Online]. Available: http://www.pmac.net/IWFS.pdf), 43 p.

104. The "suicide seed" technology of Monsanto and other major seed producers is aimed at cornering the world market for seeds. This is not only an assault on poor farmers of the world, but in widespread use would be a dangerous experiment (Jim Thomas and Lucy Sharratt, Monsanto Turns About on Terminator, *Truthout Report* (February 22, 2006).

105. W.J. Lewis et al., A Total System Approach to Sustainable Pest Management, *Proceedings of the National Academy of Sciences* 94 (1997): 12,243-12,248; see also Benbrook, Do GM Crops Mean Less Pesticide Use?.

106. Michelle Marvier, written communication 2004.

107. Marvier, Ecology of Transgenic Crops, 164-166.

108. Hansen, Genetic Engineering is not an Extension of Conventional Plant Breeding.

109. Marvier, Ecology of Transgenic Crops, 160; Union of Concerned Scientists, Food and Environment, 1.

110. Williamson, The Release of Genetically Engineered Organisms.

111. Benbrook, Evidence of the Magnitude and Consequences of the Roundup™ Ready Soybean Yield Drag; Herbicide Resistance Action Committee, International Survey of Herbicide Resistant Weeds, Weed Science Society of America. [Online]. Available: http://www.weedscience.org/in.asp; Benbrook, Do GM Crops Mean Less Pesticide Use?

112. McNeill, Something New Under the Sun, 227.

113. George Wald, "The Case Against Genetic Engineering," in eds. Jackson and Stich, *The Recombinant DNA Debate*, 127-128 (Reprinted from *The Sciences*, Sept./Oct. 1976).

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