

**FRANKENFOOD: MONSTER OR MIRACLE?**

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## FRANKENFOOD: MONSTER OR MIRACLE?

Gene-splicing is a form genetic engineering and it is one of the most promising plant-breeding technologies ever developed. The implementation of this technology, however, is being stalled by widespread misinformation designed to create the perception that genetically-engineered plants and the foods made from them are dangerous and unnatural.

### **The Controversy:**

Some environmental groups, religious organizations, public interest groups, professional associations, scientists and government officials have raised concerns about genetically-modified<sup>1</sup> (GM) foods and are working to pressure government agencies throughout the world to increase regulatory constraints on biotechnology research and to ban the planting of GM crops.

These groups also promote their views through mass-media campaigns to influence the general public. Their goal is to persuade the public to join with them to pressure government regulators but, more importantly, to create a perception of danger and fear that will prevent the acceptance of GM foods in the regular food channels, denying biotech companies a market and choking off their access to capital and talent. These groups describe GM foods as "Frankenfood<sup>2</sup>" in an attempt to create the perception that GM foods are dangerous and unnatural.

These groups have been effective in spreading misinformation and causing widespread misperceptions around the world as to the safety of GM foods. In the United States, Europe and Africa the effort to ban or stigmatize GM food has turned into a kind of social movement, aimed at protecting the public from vague and hidden dangers.

These groups have many claims, but the primary criticisms of GM foods are that:

- o GM foods create "new" risks to human health
- o GE foods create "new" risks to the environment
- o GE foods are untested and unregulated

### **Genes and Gene-Splicing:**

Genes are segments of DNA and are the unit of heredity that carries identifiable traits<sup>3</sup> from generation to generation. Genes transmit identifiable traits through the production (encoding) of proteins that provide instructions to cells regarding their particular functions. More precisely, genes are DNA sequences that code for proteins (each gene codes for *one* protein) using a universal genetic code and they can be moved easily between different organisms without losing their identity or changing their function. Genes can be thought of as instruction sets or recipes, which dictate exactly how an organism grows, what it looks like and how it functions.

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<sup>1</sup> Also referred to as transgenic or genetically-engineered (GE) foods.

<sup>2</sup> The word Frankenfoods was first applied to genetically-modified food by Paul Lewis, a Boston College English professor in a letter to the New York Times in 1992.

<sup>3</sup> One of the many characteristics that define an organism, eg., the color of a plant's flowers.

All living things, including the grains, fruits and vegetables that we eat, contain genes and proteins produced by genes.

A 19<sup>th</sup> century monk, Gregor Mendel, used pea plants to demonstrate that genes in plant pollen (the male part of the plant) and genes in the plant ovule (the female part of the plant) combined in the reproductive process to pass certain characteristics from one generation to the next. Mendel's classic paper<sup>4</sup> in 1865 explained how dominant and recessive genes<sup>5</sup> produced the traits we see and which could be passed to offspring. Mendel's ideas became the basis of our present understanding of heredity and genetics.

In 1953, James Watson and Francis Crick described the structure of deoxyribonucleic acid (DNA) to be the carrier of genes. They described the DNA molecule as a complex three-dimensional double helix structure that resembles a ladder. The sides of the ladder alternate between sugar and phosphate molecules and the rungs are nitrogenous bases<sup>6</sup> between the sugar molecules. There are only four different kinds of nitrogenous bases in DNA and the sequence of these bases differs from gene to gene. The sequence of these bases is what defines the gene.

Chromosomes are tightly coiled strands of DNA containing genes. Chromosomes contain most of a cell's DNA. Each species has a characteristic number of chromosomes. Bacterial and viral cells contain a single chromosome, corn cells have 10 pairs of chromosomes, mice cells have 19 pairs and human cells have 23 pairs of chromosomes. In organisms with pairs of chromosomes, half of each pair comes from the paternal parent and half comes from the maternal parent.

Every organism has a unique genome, which is the entire complement of genetic material present in each cell of that organism, which is the complete set of chromosomes and genes inherited as a unit from each parent. The human genome contains less than 40,000 genes, *Arabidopsis thaliana*, a weed used for genetic study, contains about 26,000 genes and the fruit fly contains about 13,000 genes.

The genes in all living organisms share the same code for DNA and the synthesis of proteins and other basic functions of life processes. At the molecular level, all living things are more alike than different. That is one of the reasons genes can be moved so successfully between such different organisms as plants and bacteria. Genes are not unique to the organisms from which they came. There aren't really "tomato genes" but there are genes from tomatoes that are the same as genes from very different organisms.

Gene-splicing is a form of genetic engineering in which specific genes from a bacterium, plant or animal are directly transferred into a host plant to confer a desired trait. By analogy, it is a process for cutting a specific gene or genes from one organism and then pasting them into the host plant. The tools and process of cutting and pasting the genes are referred to as recombinant DNA technology and the resulting plant is referred to as a transgenic, genetically-engineered (GE) or genetically-modified (GM) plant.

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<sup>4</sup> Experiments With Plant Hybrids, Gregor Mendel, 1865.

<sup>5</sup> Alleles are different versions of the same gene at a single locus. For example, there are three versions of the gene that determines ABO blood type in humans.

<sup>6</sup> Also referred to as nucleotides. The four bases are thymine (T), cytosine (C), adenine (A) and guanine (G).

There are two ways that genes are inserted into the genomes of a plant. One method uses a naturally occurring soil microbe, *Agrobacterium tumefaciens*, which is capable of moving part of its DNA into a plant cell. Scientists can replace the microbe's DNA with the DNA they wish to transfer and the bacterium will then introduce that DNA into the plant cell. Another method uses a "gene gun" to shoot tiny particles coated with the DNA to be transferred into the cells, where the genetic information comes off the bullet and incorporates itself into the genome of the plant cell. With both techniques, after the DNA has been transferred into a plant cell, the cell must be cultured to re-form an entire plant, each cell of which then has the new DNA in its genome.

### **Genetically-Engineered Plants:**

The number of different genetically-engineered plants is very small. The worldwide acreage of the relatively small number of GM crops, however, is large and increasing rapidly.

Most biotechnology research has been directed at large acreage crops like corn, wheat, soybean, canola and cotton. These crops provide large worldwide markets for genetically-engineered seed varieties, which are necessary to support the enormous costs associated with this technology.

The principal genetically-engineered crops developed to date have been modified to tolerate herbicides and/or resist insect pests. Crops carrying herbicide-tolerant genes were developed so farmers can spray their fields to eliminate weeds without damaging the crop. Likewise, insect resistant crops have been engineered to contain a gene for a protein from the soil bacterium, *Bacillus thuringiensis* (Bt<sup>7</sup>), which is toxic to certain insects. When this gene is inserted into a plant, the plant itself becomes resistant to targeted insect pests like the European corn borer or cotton boll worm. Other pest-resistant GM crops on the market today have been engineered to contain genes that confer resistance to specific plant viruses.

In addition to herbicide, pest and disease resistance, other plant modifications being developed and tested include (a) cold, drought and salinity tolerance, (b) improved nutritional properties, (c) reduced allergenicity, (d) special pharmaceutical properties and (e) phyto-remediation properties.

Few genetically-engineered fruits or vegetables have been developed. In the early 1990s, several genetically-engineered fruits and vegetables were commercially grown and marketed including the FlavrSavr tomato, NewLeaf potato, high solids tomatoes, and Freedom squash. Most have since been taken off the market. The only genetically-engineered whole fruits or vegetables commercially available currently are papaya and some types of squash, both engineered for improved viral resistance and sweet corn, modified for corn ear worm protection.

While the number of genetically-engineered whole foods is small, the percentage of processed foods containing ingredients from genetically-engineered plants is high, probably about 75 percent<sup>8</sup>. For example, most of the vegetable oils produced from corn, soybeans, canola and cottonseed are produced from genetically-engineered varieties and these vegetable oils are used widely in processed foods.

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<sup>7</sup> Bt-based pesticides have been used for over 30 years to control insect pests and are especially favored by organic farmers, who consider them natural and not synthetic.

<sup>8</sup> Biotechnology Basics: Some of the Science and Some of the Issues, Peggy Lemaux, California Cotton Review, UC Cooperative Extension Service, University of California, Volume 73, December 2004.

According to a 2004 report from the Pew Initiative on Food and Biotechnology<sup>9</sup>, in 1998 about 69.5 million acres of GM crops were planted worldwide and since then, global acreage has increased by about 20 million acres a year, an average increase of nearly 20 percent a year. GM crops were planted on more than 167 million acres worldwide in 2003, which was about 25 percent of the 672 million acres of land under cultivation.

United States farmers are by far the largest producers of GM crops and account for nearly two-thirds of all biotechnology crops planted globally. The main GM crops grown by US farmers are corn, soybeans and cotton, but GM canola, squash and papaya are also produced. Other major producers of GM crops include Argentina, Canada, Brazil, China and South Africa. Other countries where GM crops are grown include Australia, Mexico, Romania, Bulgaria, Spain, Germany, Uruguay, Indonesia, the Philippines, India, Columbia and Honduras.

#### Major Producers of Genetically-Modified Crops, 2003

Country	Mil Acres	Percent	Main GM crops
United States	105.7	63	Corn, soybean, cotton, canola
Argentina	34.4	21	Soybean
Canada	10.9	7	Canola
Brazil	8.4	5	Soybeans, cotton
China	6.9	4	Cotton
South Africa	1.0	1	Cotton
Other	*	-	
<b>Total</b>	<b>167.2</b>	<b>100</b>	

Source: International Service for the Acquisition of Agri-biotech Applications (ISAAA) Global Review of Transgenic Crops 2003.

GM crops have been rapidly adopted by US farmers and represent significant percentages of the total acreage planted to corn, soybeans, cotton and canola. As shown in the table below, in 2004 85 percent of the soybean acreage, 76 percent of the cotton acreage and 45 percent of the corn acreage in the US was genetically-modified.

#### Major United States Genetically-Modified Crops Acres Planted To GM Crops and Percent of Total Acres Planted To GM Crops

Crop	Million Acres				Percent of Total Acres			
	2001	2002	2003	2004	2001	2002	2003	2004
Corn	19.7	25.3	31.6	36.5	26	32	40	45
Soybean	50.4	54.0	59.7	63.6	68	75	81	85
Cotton	10.9	10.4	10.2	10.6	69	71	73	76

Source: Pew Initiative on Food and Biotechnology, 2004.

As shown above, during the last four years GM corn has increased from 26 percent to 45 percent of all US corn acres, GM soybean has increased from 68 percent to 85 percent of all soybean

<sup>9</sup> Genetically-modified Crops in the United States, The Pew Initiative on Food and Biotechnology, 2004.

acres and GM cotton has increased from 69 percent to 76 percent of all US cotton acres. About 54 percent of all canola grown in the US in 2001 was genetically-modified according to industry estimates and more than 50 percent of all papayas grown in the US are genetically-modified.

### **Conventional Plant Breeding:**

Since farmers began to cultivate crops, they have attempted to improve the plants they worked with to produce more and better food and fiber. The purpose of plant breeding is to develop new plant varieties with improved traits. All plant-breeding techniques involve manipulation of a plant's genes and, therefore, all conventionally-bred plants are also genetically-modified plants.

The leading conventional plant-breeding techniques include (a) selection, (b) cross-breeding and (c) induced mutation.

**Selection** is the oldest technology that has been used for crop improvement. The earliest forms of selection were accomplished inadvertently when wild seed crops were first cultivated. One of the problems early farmers faced was that most of the seeds on each plant did not mature at the same time and were not well-attached to the stalks, so a large portion would fall to the ground before or during the harvest and would not be recovered. Natural mutations among plants, however, created some plants with seeds that matured at the same time and some plants with seeds that were more strongly-attached to the stalk. Since these seeds were more likely to be recovered during the harvest, they were inadvertently "selected" and replanted the following year. Each season, the similar-maturity and strong-attachment seeds represented a higher proportion of the seeds that were planted and, over time, the plant's characteristics--its traits--improved.

When early farmers realized this, the art and science of plant breeding began. Farmers began to look for individual plants with different but desirable characteristics--mutations--in their fields and selectively cultivated them to quickly improve their crops. The disadvantage of the early selection process was that the farmer had to be lucky and patient. Luck was necessary to identify a single plant with a mutation that was desirable and patience was necessary since it took a number of generations to obtain a meaningful quantity of seed for farming.

Modern plant breeders still scrutinize their fields and some even travel to foreign countries searching for individual plants with desirable traits. Such traits occasionally arise spontaneously, but the natural rate of mutation is too slow and unreliable to produce all the plants that breeders would like to see.

**Cross-breeding** is the method that was used to create most of the commercial crops being grown today. It involves selectively applying pollen (male cells) from one plant variety with the desired trait to the ovule (female cells) of another variety, then growing plants from the seeds of the "crossed" plants and examining them with the hope of finding a plant with the desired trait.

An important feature of this technique is that breeders cannot control which genetic information is kept and which is lost. They can only observe the resulting plants and choose the ones that appear to have the characteristics they want.

By analogy, if the genome of a wheat cell were represented by alphabetic letters, it would take a book with 1.7 million pages to contain all of the genetic information. During a "cross" of two wheat varieties, genetic information is exchanged between two different genome books--the male cell's genome book and the female cell's genome book. The offspring wheat variety will have a new 1.7 million page genome book and exactly half of its pages will be from the male plant's genome book and half of its pages from the female plant's genome book. The pages from the male plant's book and female plant's book, however, are selected randomly. The plant breeder cannot control which pages (broadly, which genes) are selected. The plant breeder can only select the male and female plants to cross.

Plant varieties used for crosses have many different characteristics or "traits" and predicting exactly which traits the new varieties will have after a cross is made is difficult. New methods, based on recently-developed genetic mapping techniques, are available to help plant breeders identify which plants from a cross have the characteristics they want--ones that cannot be readily determined by looking at the plants. This method is called "marker-assisted breeding" and involves the breeder looking in the plant's genome for a specific marker gene known to produce a desired trait in the genetic information of one of the parent plants and, following the cross, looking for the marker gene in the next generation plants. If a breeder finds the marker gene, it is highly likely that the trait they want will also be present in the plant.

**Induced mutation** is a plant-breeding technique in which plant cells are subjected to a special chemical or to irradiation in an attempt to cause a mutation that will be desirable. This is a refinement of the earliest selection techniques, but instead of hoping to find a plant with a desirable trait, this technique is designed to cause mutations, with the hope that a plant with a desirable trait will be produced.

This technique first appeared during the late 1920s and was particularly popular during the 1970s. Almost half of the 2,252 officially released mutation breeding varieties were released during the last fifteen years.

Many popular plant varieties have been produced through induced mutation breeding. The most popular red grapefruit variety, Rio Red, was developed by exposing grapefruit buds to thermal neutron radiation at Brookhaven National Laboratory in 1968.

The chemical colchicine was applied to a sterile hybrid of rye and durum wheat in 1950 to create a new fertile grain called triticale which by the mid 1980s was being grown on over two million acres worldwide and is now a very popular "natural food". Colchicine is also used to make fruits seedless, including the seedless watermelon.

Of the hundreds of varieties of bread wheat grown around the world, almost 200 were created using X-rays, gamma rays, neutrons or various chemicals to cause mutations. Most of bread wheat used today is from varieties developed with induced mutation.

Another method for increasing the number of mutations in plants is called tissue culture. Tissue culture is a technique for growing cells, tissues and whole plants on artificial nutrients under sterile conditions, often in small containers. Tissue culture was not developed with the intention

of causing mutations, but the discovery that plant cells and tissues grown in tissue culture would mutate rapidly increased the range of methods available for mutation breeding.

### **The Critic's Concerns Answered:**

As noted above, the critics of gene-splicing and genetically-engineered foods have concerns based primarily on the following issues:

- o GM foods create "new" risks to human health
- o GE foods create "new" risks to the environment.
- o GE foods are untested and unregulated.

### **New Risks To Human Health:**

The main concerns about human health include concerns about (a) allergenicity, (b) antibiotic resistance, (c) eating foreign DNA and (d) changed nutrient levels.

**Allergenicity:** Many people are concerned that GE foods are more likely to cause allergic reactions than other foods. There is, however, no evidence that GE foods pose more of a risk for allergic reaction than conventional foods. The genetic engineering process itself does not create allergens. It is the nature of the genes that are chosen for transfer that determines whether allergens are introduced into the genetically-engineered plant.

The FDA reviews proposed transgenic foods and compares possible allergens to a checklist of characteristics that have been found to be associated with allergenicity. In many years of testing, only two potential problems have been uncovered. One was a soybean with a Brazil nut gene that was never marketed and the other was Starlink corn.

Pioneer Hi-Bred seed company developed a soybean that was modified with a gene from the Brazil nut to improve its nutritional qualities. Because allergies to nuts are common, the company focused its testing on people who had allergic reactions to Brazil nuts and found that these people were also allergic to the GM soybeans. In light of these results, Pioneer decided not to ask for approval to market the soybean and it was never commercialized.

Starlink corn was developed by the Aventis Company as an all-purpose corn variety, but concern that it might have allergenic properties led to its approval in 1997 and 1998 only for animal feed. Shortly after the 2000 corn harvest, it was reported<sup>10</sup> that taco shells containing traces of the Starlink corn had been found and this announcement was soon followed by reports of people suffering allergic reactions after eating the taco shells. Following a recall of all Starlink corn and related products in distribution, careful testing was performed on those that had complained of allergic reactions and it was determined that while they had experienced allergic reactions, their reactions were not likely the result of contact with the Starlink corn. The cost to Aventis to cover losses from transportation, storage and testing was estimated at over \$100 million.

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<sup>10</sup> The *Washington Post* reported that a company called Genetic ID had detected the presence of Starlink corn in Taco Bell taco shells. The environmental group Friends of the Earth, contracted with Genetic ID to perform the tests.

**Antibiotic Resistance:** As part of the gene-splicing process, DNA that codes for resistance to certain antibiotics is included with the genes that are inserted and this DNA often becomes a part of the final product although it serves no purpose beyond the laboratory stage. This raises the concern that GE foods may contribute to the growing problem of widespread antibiotic resistance.

This concern has two elements, the concern for (a) the "horizontal transfer" of antibiotic resistance genes from one organism to another and (b) the direct resistance effects of enzymes produced by antibiotic resistance genes in our stomachs.

*Horizontal transfer* means the transfer of DNA from one organism to another outside the parent-to-offspring channel. Transfer of a resistance gene from transgenic food to micro-organisms that normally inhabit our mouth, stomach and intestines or to bacteria that we ingest along with food, could help those micro-organisms to survive an oral dose of antibiotic medicine.

Horizontal transfer of DNA does occur in selected settings. Small pieces of DNA move from *E. coli* to several other organisms and *Agrobacterium tumefaciens* facilitates the horizontal transfer of DNA to produce the disease known as crown gall in plants. Outside of these selected natural cases, however, horizontal transfer of DNA occurs at a very low frequency even under laboratory conditions.

Whether such a transfer could happen in the human gastrointestinal tract is not known, but several circumstances would work against it. The acid environment of the stomach degrades DNA and most organisms have mechanisms that destroy foreign DNA.

A 1999 study by Mercer<sup>11</sup> found that the acid environment of the stomach degrades DNA within 30 seconds. Researchers at the University of Newcastle<sup>12</sup> reported that no genetically-modified DNA was taken up by microorganisms present in research subjects with intact digestive systems, however, modified DNA was found in four percent of the subjects which had colostomy procedures in which their lower intestines had been removed. In this test, the DNA was from an herbicide resistance gene rather than an antibiotic resistance gene, but the results suggest that horizontal transfer in the human digestive tract can occur under some circumstances. Generally, scientists believe that a successful transfer of DNA from transgenic plants would not occur frequently enough to be detectable or to cause health problems.

*Direct resistance.* Some resistance genes work by producing an enzyme that destroys or inactivates the targeted antibiotic. If this enzyme was present in foods made from GM plants, our stomachs might contain a small amount of the enzyme which could inactivate an orally administered antibiotic.

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<sup>11</sup> Mercer, K.K., K.P. Scott, W.A. Bruce-Johnson, L.A. Glover, and H.J. Flint, 1999. Fate of free DNA and transformation of the oral bacterium *Streptococcus gordonii* DL1 by plasmid DNA in human saliva. *Applied and Environmental Microbiology* 65(1): 6-10.

<sup>12</sup> Netherwood, T., S.M. Martin-Orue, A.G. O'Donnel, S. Gockling, H.J. Gilbert and J.C. Mathers, 2002, Transgenes in genetically modified Soya survive passage through the human small bowel but are completely degraded in the colon, Department of Biological and Nutritional Sciences and Department of Agricultural and Environmental Sciences, University of Newcastle upon Tyne.

In tests performed during the approval process for the FlavSavr tomato which contained a gene for resistance to kanamycin, neomycin, gentamicin A and gentamicin B, all of which are used to fight infections in humans, the FDA found that the enzyme produced by the antibiotic resistance genes was degraded by stomach acids before it could attack orally administered antibiotics.

While the risk from antibiotic resistance genes in transgenic plants appears to be low, steps are being taken to reduce the risk and to phase out their use.

***Eating Foreign DNA:*** When scientists make a genetically-engineered plant, they insert genes--which are DNA--into a plant that did not occur in that plant and may have come from entirely different species such as viruses or bacteria.

There is no evidence that DNA inserted into GE crops is somehow different or more dangerous to us than the DNA in the conventional crops that we have been eating all of our lives. As noted above, the genes in all living organisms share the same code for DNA and the synthesis of proteins and other basic functions of life processes. At the molecular level, all living things are more alike than different. That is one of the reasons genes can be moved so successfully between such seemingly different organisms, such as plants and bacteria. Genes are not unique to the organisms from which they came. There aren't really "tomato genes" but there are genes from tomatoes that are the same as genes from very different organisms.

From a biological standpoint, most of the DNA we eat is broken down into more basic molecules when we digest a meal. A small amount is not broken down and is either absorbed into the blood stream or excreted in the feces. The body's normal defense system eventually destroys this DNA.

A special kind of foreign DNA singled out as a particular concern is the CaMV promoter. When scientists insert a new gene into a plant, they put in additional pieces of DNA to direct the activity of that gene. Each gene needs a "promoter" to turn it on under specified conditions. The most widely used promoter is the cauliflower mosaic virus 35S promoter, often abbreviated as the CaMV promoter or the 35S promoter.

This promoter was obtained from the virus that causes cauliflower mosaic disease in several vegetables such as cauliflower, broccoli, cabbage and canola. Other promoters are available, but the CaMV promoter is used most often because it causes abundant production of the transgenic protein in a wide variety of situations. While this characteristic is an advantage for gene-splicing, there are concerns that the CaMV promoter might be harmful if it were to invade our cells and turn on our genes.

People, however, have been eating CaMV promoter for hundreds of years when they eat vegetables that are infected with the disease. Although vegetables heavily infected with CaMV are unappetizing, there have been no documented negative effects on health from eating the virus or its promoter.

***Nutritional Quality:*** When plant breeders genetically-engineer a plant, there is a concern that they may have accidentally changed its nutritional value.

Most of the transgenic crops in production today were modified for pest and herbicide resistance rather than for improved nutritional properties. Consequently, there have been only a few studies performed comparing the nutritional quality of genetically-modified plants to conventionally bred plants. The studies that have been performed, however, suggest that there is no material difference between the nutritional value of GM plants and conventionally bred plants.

Isoflavone is a nutritional component of soybeans that has been studied because of its potential for preventing heart disease, breast cancer and osteoporosis. A comparison of the results from studies by Lappe<sup>13</sup> in 1999 and Monsanto employees Padgette<sup>14</sup> in 1996 and Taylor<sup>15</sup> in 1999 reveals only small differences in isoflavone content between GM soybeans and conventionally-bred soybeans.

#### **New Risks to the Environment:**

The main concerns about the environment include (a) unintended harm to other organisms, (b) crop-to-weed gene flow and (c) skepticism about promised reductions in chemical spraying.

***Unintended Harm to Other Organisms:*** In a 1999 study in *Nature*, Losey<sup>16</sup> reported that pollen from corn genetically-modified with Bt genes caused high mortality rates in Monarch butterfly caterpillars. In the Losey studies, caterpillars fed milkweed leaves, their preferred food in the wild, dusted with Bt corn pollen died within a few days. The report received worldwide sensational media coverage and soon the Monarch butterfly became a symbol for anti-biotechnology activities.

Later, however, a series of more thorough studies<sup>17</sup> conducted by a consortium of university and government scientists in the US and Canada confirmed that the effect of Bt corn on Monarch butterfly populations was negligible. These studies showed that:

- o The particular GM corn variety used in the Losey study (a) was engineered with a Bt gene that produced significantly higher Bt protein in pollen than the Bt genes used in other GM corn varieties and (b) this GM corn variety is used on a very small and decreasing acreage.
- o Corn pollen is shed for only about two weeks of the summer whereas Monarchs produce several generations of offspring over the course of a summer, so some generations of caterpillars will not be exposed to pollen.

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<sup>13</sup> Lappe, M.A., E.B. Bailey, C. Childress and K.D.R. Setchell, 1999, Alterations in clinically important phytoestrogens in genetically modified, herbicide-tolerant soybeans, Children's Hospital Medical Center, Cincinnati, Ohio.

<sup>14</sup> Padgette, S.R., N.B. Taylor, D.L. Nida, M.R. Bailey, J. MacDonald, L.R. Holden and R.L. Fuchs. 1996. The composition of glyphosate-tolerant soybean seeds is equivalent to that of conventional soybeans. *Journal of Nutrition* 126:702-716.

<sup>15</sup> Taylor, N.B., R.L. Fuchs, J. MacDonald, A.R. Shariff and S.R. Padgette. 1999. Compositional analysis of glyphosate-tolerant soybeans treated with glyphosate. *Agricultural and Food Chemistry* 47:4469-4473.

<sup>16</sup> Losey, J.E., L.S. Rayor and M.E. Carter. 1999. Transgenic pollen harms monarch larvae. *Nature* 399:214.

<sup>17</sup> Hellmich, R.L. (2001), Oberhauser, K.S. (2001), Pleasants, J.M. (2001), Sears, M.K. (2001), Stanley-Horn, D.E. (2001), Zangeri, A.R. (2001).

- o Rain washes some of the pollen off of the leaves, so caterpillars are exposed to much less than the potential maximum amount of pollen, depending on the frequency and severity of rainfall during the pollen shed period.
- o Most of the pollen produced in a corn field falls within the field or nearby, so caterpillars feeding on milkweed plants a short distance from corn fields are unlikely to encounter any pollen.

The alternative to genetically-engineered pest resistant plants is the current practice of spraying organophosphate pesticides onto crops. These chemicals also kill indiscriminately and can cause unintended harm to other organisms. While GM pest resistant plants can cause unintended harm to other organisms, they are no worse than the existing method of chemical spraying and significantly better from the standpoint that their control properties are effective only on a fairly-narrow range of pests.

***Crop-To-Weed Gene Flow:*** Cross-pollination between fields of GE plants and nearby weeds may create hybrid weeds with undesirable traits like herbicide resistance.

Gene flow from crops to weeds requires (a) the presence of sexually compatible wild or weedy relatives close to the crop, (b) an overlap of flowering times between crop and the wild relatives and (c) the presence of a pollinating agent.

Many cultivated crops have sexually compatible wild relatives with which they hybridize under favorable circumstances. Examples in the US include (a) wheat and jointed goatgrass and (b) rice and red rice as well as (c) commercial varieties of alfalfa, asparagus, blueberry, bermuda grass, carrot, celery, chicory, clover, cranberry, lettuce, oats, rapeseed, quinoa, radish, rice, tobacco, sorghum, squash, strawberry, sunflower, walnut and wheat and their wild relatives with the same name. A report by the European Environment Agency assessed the potential for gene flow to the natural environment for six major crops, including oilseed rape, sugar beet, potatoes, maize, wheat and barley.

The EPA has prohibited or restricted the use of biotech crops in areas where a wild relative exists, but the danger exists that GM crops approved for use in a specified area might be used in unapproved areas.

The fact that some of the most widely-adopted GM crops have been modified with herbicide-resistance traits does suggest that crop-to-weed gene flow, and the creation of herbicide-resistant weeds is a special risk. However, consider the fact that the herbicides used on the weeds growing in and around the GM crops are the same herbicides that are used to treat the weeds growing in and around the conventional crops. The repeated application of a single herbicide on the weeds over time, is likely to result in the targeted weed population developing resistance to that herbicide through natural mutation. Whether herbicide-resistant GM crops are grown or conventionally-bred crops are grown, the outcome--herbicide-resistant weeds--is the same.

Farmers have been coping with resistance problems since ag chemicals were first introduced. As in the issue of unintended harm to other organisms, it is true that crop-to-weed gene flow is a risk

associated with GM crops, however, the basic risk--herbicide-resistant weeds--is not new and not unique to the use of GM crops.

***Skepticism About Promised Reductions In Chemical Spraying:*** One of the most appealing arguments in favor of GE plants is the potential for reducing the frequency and/or the toxicity of the agricultural chemicals applied to control insect pests, weeds and diseases. Many critics of GM crops are skeptical about claims that the frequency and toxicity of the chemicals used in farming can be reduced.

A USDA Economic Research Service report<sup>18</sup> released in 2000 indicated a decline in pesticide use in Bt cotton and a report by Benbrook<sup>19</sup> in 2001 concluded that Bt cotton had allowed substantial decreases in pesticide use.

Apart from USDA's Economic Research Service report that concluded that pesticide use had declined because of Bt corn, claims that the use of Bt corn has reduced chemical spraying are difficult to support. This, however, has more to do with the fact that most of the corn grown in the US is field corn which is not generally sprayed with insecticides apart from about eight percent of the acreage which is sprayed to combat European corn borer. A report by Benbrook in 2001 concluded that the use of insecticides on corn has remained stable despite the introduction of Bt corn.

One reason that insecticide spraying on field corn has not decreased is that farmers growing conventionally-bred field corn have noticed that yields of nearby Bt corn are significantly higher and have concluded that they have not been adequately treating their fields for these insect pests.

Although transgenic technology may result in reduced chemical spraying in some cases, it does not always do so. Bt cotton is the only crop for which claims of reduced spraying are clear.

#### **GM Foods Are Untested and Unregulated:**

It is not true that GE foods are untested, but it is true that biotech companies conduct this testing prior to commercialization as occurs with drugs in pharmaceutical companies, and this testing is voluntary. The data from these tests are then reviewed by federal agencies like the FDA and EPA, which can require further testing.

While this part of the process is voluntary, the companies have the most to lose if a problem occurs, as happened with Starlink corn, which cost Aventis about \$100 million. The testing done on GE foods includes (a) nutrient equivalence to demonstrate that the vitamins, minerals proteins, carbohydrates and fats are the same for GE and conventional foods, (b) animal testing for toxicity and (c) allergenicity testing.

In the US, three government agencies have jurisdiction over GM foods. The EPA evaluates GM plants for environmental safety, the USDA evaluates whether the plant is safe to grow and the FDA evaluates whether the plant is safe to eat. The EPA is responsible for regulating substances

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<sup>18</sup> Genetically Engineered Crops: Has Adoption Reduced Pesticide Use, Agricultural Outlook, Economic Research Service, USDA, August 2000.

<sup>19</sup> Benbrook, C., 2001. Do Gm crops mean less pesticide use? Pesticide Outlook 12(5): 204-207.

such as pesticides or toxins that may cause harm to the environment. Crops genetically-engineered for insect or pesticide resistance but not foods modified for their nutritional value are evaluated by EPA. The USDA is responsible for GM crops that do not fall under the EPA's umbrella, such as drought-tolerant or disease-resistant crops, crops grown for animal feeds or whole fruits, vegetables and grains for human consumption. The FDA is concerned with pharmaceuticals, cosmetics and food products and additives, not whole foods.

Under current guidelines, a genetically-modified ear of corn sold at a produce stand is not regulated by FDA because it is a whole food, but a box of cornflakes is regulated because it is a food product. The FDA's stance is that GM foods are substantially equivalent to unmodified "natural" foods and therefore not subject to FDA regulation.

**Conclusion:**

Gene-splicing is one of the most promising crop-improvement technologies ever developed. The implementation of this technology, however, is being retarded by misinformation and misperception, denying producers and consumers enormous benefits.

While it cannot be claimed that GE crops pose no risks to human health or to the environment, it can be claimed that GE crops pose no "new" risks. The threat posed by any plant—genetically-engineered, conventionally bred or wild—has solely to do with the traits it expresses. Risk has nothing to do with how or even if a plant was modified.

Many scientific bodies, including the National Academy of Sciences and the American Medical Association have concluded that gene-splicing techniques themselves are actually safer than traditional breeding methods because breeders know which new genes are being added to plants and exactly what function those genes perform. Accordingly, GE plants are less likely, not more likely, to pose environmental or human health risks than are conventionally bred plants with similar traits. Critics of biotechnology, however, use out-of-context scare stories about such risks to argue for increasing the regulation of bioengineered crops and to persuade the public that genetically-engineered foods are dangerous and unnatural.

Without better public understanding and changes in the regulations constraining the development of new gene-spliced plants, we will miss out on major improvements that can result in more healthful foods, a cleaner environment and a worldwide ability to produce more food at lower cost on less land, using less water and fewer and safer chemicals.

Hopefully, enlightened consumers and governments will question the misleading claims of the activist groups and support this exciting and promising technology.

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