



WORLD HEALTH ORGANIZATION

Genetically Modified Organisms

By Guy A. Edouard

Introduction

Grains of “golden rice” have the same size and shape as other varieties of rice. In fact, if not for their distinct yellow color, it would be impossible to distinguish golden rice from other varieties. Color, however, is not the only trait of golden rice that sets it apart. Golden rice, a genetically modified organism (GMO), is a strain of rice **genetically modified (GM)** to produce β -carotene in rice grains. In humans, β -carotene is converted into Vitamin A. It occurs naturally in the leaves of plants, plays a role in photosynthesis, and is responsible for both the color and high Vitamin A content of carrots and other brightly colored fruits and vegetables.

The World Food Program (WFP), the branch of the United Nations (UN) which oversees the organization’s food aid efforts, estimates that one in seven people is undernourished or malnourished. The World Health Organization (WHO) estimates that 250,000 to 500,000 children become blind each year due to Vitamin A-deficiency alone. In 2000, a series of press releases publicized golden rice as the solution to Vitamin A-deficiency. Opponents of golden rice warned of possible health risks of widespread consumption of GM foods, arguing that genetic engineering should not be used to provide a nutrient readily accessible in vegetables and vitamin supplements. Ultimately, golden rice fell from the world stage when it was realized that a full serving only provided 25% of a human’s daily recommended intake of vitamin A. Research into the development of varieties of golden rice with higher β -carotene content continues today.

The controversy surrounding golden rice highlights the greater, international debate surrounding GMOs. Across the globe, scientists busily alter **genomes** with hopes of increasing yields and nutritional value of crops, livestock, and fish. This work is more than just a matter of scientific curiosity. The United Nations Population Division (UNPD) estimates that the world’s population will surpass 9 billion by the year 2050. Today, the WFP estimates that one billion people, or roughly 1/6 of the population, live on less than US\$1 a day, the threshold of absolute poverty. The WFP has also reported a 33% increase in the price of maize, a 50% increase in cost of rice, and a 73% jump in the price of vegetable oil purchased for food aid in the past year. With the increased demand of a growing middle class in developing nations, particularly India, China, and Southeast Asia, this trend looks as though it will continue in the future. Although some look to the increased yields prom-

Genetically modified—*genetic material that has been altered using genetic engineering techniques, which combines molecules to create a new set of genes.*

Genomes—*a full set of chromosomes; all the inheritable traits of an organism.*

ised by GMOs as the solution to a signs of a looming international food crisis, many believe that GMOs are unsafe and should be highly regulated, if not banned. For several decades, the WHO has extensively studied the issue of genetic engineering. As members of the WHO, you will meet in an effort to address growing concern about the development of GMOs and to discuss what role GMOs should play, if any, in the 21st century.

Explanation of the Problem

The Industrial Revolution

Animals and plants have been genetically altered by humans for almost 11,000 years through the process of domestication. Domestication is necessary, because, in the words of Dr. Nigel G. Halford, a British geneticist and agricultural chemist: “Plants did not evolve to be eaten.” For example, modern-day maize (or corn) was domesticated from teosinte, a hardy wild grass which produces a handful of inedible kernels per plant. Teosinte is highly tolerant of dry, dusty soil conditions. Through centuries of breeding, farmers have selected for a set of genes that caused teosinte plants to divert more resources from roots and leaves to their kernels, creating higher kernel count and quality. These same genes make maize less tolerant of drought and more susceptible to being out-competed by weeds and other plants. A similar case exists with domesticated animals, which carry more meat than their wild relatives, but require protection from predators, a steady food source, and shelter to thrive. Because domesticated plants and animals exist in close proximity in fields or pens, they are also highly susceptible to disease and infection in ways in which their wild relatives are not.

Thus, at a fundamental level, global supply of food is dependent upon how effectively farmers can protect crops and livestock from pests, predators, and disease. Prior to the 1800s, farmers used human labor to weed, to lay down organic waste as fertilizer, and to construct basic irrigation systems. During the **Industrial Revolution** at the turn of the 19th century, new machinery allowed fields to be fertilized, sowed, and reaped more efficiently. Throughout history, advancements in farming technology and biotechnology consistently result in increased yields and food supply, as they compensate for traits linked to the survivability of wild plants lost in the process of domestication.

The “Genetic Revolution”

The first generation of chemical pesticides and fertilizers were developed and patented in the first half of the 20th century, between WWI and WWII. Interestingly, many of these **agrochemicals** were designed using technology originally developed for the purposes of chemical warfare. These advancements played a major role in sustaining the

Industrial Revolution—period in the late 18th and early 19th centuries when major changes in agriculture, manufacturing, production, and transportation had a profound effect on socioeconomic and cultural conditions worldwide.

Agrochemicals—agricultural chemical, such as pesticides and insecticides.

global population boom between 1950 and 2000, which UNPD records show more than doubled from 2.5 billion in 1950 to nearly 6.2 billion people at the turn of the century.

Several years after the end of WWII, in 1953, Francis Crick and James Watson were the first to correctly identify the function of deoxyribonucleic acid (DNA). Over the next few decades, rapid scientific advancement gave geneticists the tools necessary to identify, insert, remove, and manipulate genes from plant and animal genomes. In the 1970s and 1980s, this new biotechnology was primarily used to identify genes in wild plants which might confer useful traits to related species of domesticated plants. For example, scientists have long known that a set of “dwarfing genes” cause plants to put a disproportionate amount of resources into their leaves and stems. This results in shorter, sturdier “dwarf” plants that are less likely to topple over in stormy, windy weather. Using genetic engineering, scientists identified the so-called “dwarfing gene”, cross-pollinated crops with pollen from dwarf plants, and then isolated seedlings from the cross that inherited the dwarfing gene. Dwarfing in the 1980s was bred into a wide variety of plants, giving farmers access to more robust and **resilient** crops.

The “Flavr-Savr” Tomato

Scientists quickly realized that **conventional farming** techniques of crossing plants had a critical limitation – specificity. When two plants are crossed, many genes other than the target gene are interchanged, making cross-pollination a low fidelity breeding technique. In addition, only very closely related plant species can be crossed. Thus a beneficial gene from a breed of corn cannot be crossed into a breed of cotton. To overcome these problems, scientists turned towards the technique of genetic engineering.

The first commercial planting of a GMO took place in 1995 in the US. The crop was a tomato sold under the brand name “Flavr-Savr” by Calgene, an American biotech firm. The Flavr-Savr was genetically engineered to ripen more slowly than conventional tomatoes. Although the GM tomato had an extended shelf life, it was pulled off the market when Calgene fell into financial trouble. During the 1990s, genetically modified (GM) maize, soybeans, rapeseed, and cotton were also marketed commercially. GM strains of papaya, potato rice, squash, and sugar beet were also developed, but were not widely marketed.

Controversy and the Call for Regulation

In the late 1990s, a string of research papers and media reports were published questioning the safety of GMOs. In an example from 1999, a research team at Cornell University found that monarch butterfly caterpillars that consume pollen from insect resistant maize suffer higher mortality rates than butterflies that feed on non-GM plants. The

Resilient—*recovering readily from adversity; springing back.*

Conventional farming—*the classic style of farming that involves chemical plant protectants, chemical fertilizers and intensive mass animal farming.*

science behind such studies was criticized because it required extrapolating laboratory results to complex ecological systems, but, nonetheless, these reports of the dangers of GMOs had a major impact on public confidence. The most significant of these occurred in 2000 and involved GM maize marketed under the name StarLink.

StarLink was a breed of corn genetically engineered by Aventis, a biopharmaceutical company that was taken over a few years after what has been nicknamed the “StarLink Fiasco.” In 1998, the US Environmental Protection Agency (EPA) ruled that StarLink was safe for animal consumption but could not be used in or sold as food for consumers. Inevitably, StarLink maize was grown close enough to natural varieties of maize that cross pollination occurred, and in September of 2000 the US Food and Drug Administration (FDA) mandated a recall; Aventis stopped selling StarLink seed. Although Aventis bought back the entire 2000 crop of StarLink, it estimated that the 1999 corn crop was not completely cleared from the food chain until 2004.

The StarLink fiasco worried government officials far beyond the borders of the US. Importers of foodstuffs from the US and other GMO-producing countries feared that shipments might contain plant or animal products unsafe for human consumption. The issue came to a boil in 2002, when a food aid shipment sent by the US to southern Africa in response to a devastating drought in the region was found to contain unlabeled GMOs. Many Southern African countries turned down the food aid, citing concerns that the GMO maize might be planted and mixed with their exports. Ultimately, the US arranged to mill the maize shipment before it was distributed, creating white rice that was acceptable to most countries in the region. It is interesting to note that despite this compromise, Zambia refused the 2002 US food aid shipment. The WFP estimates that only one-half of the 21,000 ton goal set by experts to aid victims of the drought in Southern Africa was able to be collected from non-GMO producers. This event highlighted the need for clear, comprehensive regulations regarding GMOs in the international community and played a critical role in the signing of a landmark international treaty regarding GMOs the following year.

The Cartagena Protocol

The issue of regulating GMOs had been raised well before the 2002 GM food aid crisis. On a regional level, in the early 1990s the European Union (EU) set regulations that resulted in a **de facto moratorium** on the import and sale of GMOs. The approval process for growing and selling GMOs was both strict and lengthy, and drove large agrochemical and biotechnological companies to other regions with less stringent regulations.

The new policies regarding GMOs set in place by the EU did not go unnoticed by the developing world. At the UN Convention on Bio-

De facto moratorium—an unofficial, but effective, suspension of activity.

logical Diversity (CBD) in 1992, developing countries demanded that international regulations be placed on GMOs, fearing that they would become a testing ground for these products through food aid shipments. Initially, this stance was opposed by both the EU and US. Treaty negotiations continued throughout the 1990s with agreement being reached at the First and Second Conferences of Parties to the CBD (COP-1 & COP-2) in 1994 and 1995. In 1999, the EU suspended its decision-making process for new GM products, and some of its member states went as far as banning GMOs which had already gained EU approval. This change in the position of the EU led to progress towards a treaty at the next COP meeting (Ex-COP) in Cartagena, Colombia in 1999 and the completion of the Cartagena Protocol on Biosafety (CPB) in January of 2003. The CPB entered effect in 2003. The treaty is based primarily around the principle of advanced informed agreement, in which GMO-producing countries must inform importers of actual or potential GMOs in their goods. These goods are then subject to a safety review and **risk assessment** prior to import. The CPB also laid the groundwork for the Biosafety Clearing House (BCH), which is a means by which countries can exchange information regarding GMOs in an effort to speed up the process by which parties to the CPB approve imports.

Risk assessment—the determination of quantitative or qualitative value of risk related to a concrete situation and a recognized threat.

Recent Developments

World Trade Organization Suit Against EU

In 2003, shortly after the ratification of the CPB, the three leading GMO-producing countries at the time—the US, Canada, and Argentina—brought suit against the EU through the World Trade Organization (WTO). Egypt was originally listed as a co-complainant but withdrew, ostensibly to maintain trade relations with EU member states, an important market for its crops. The suit was based primarily on an alleged lack of “sound science” supporting the EU moratorium on the import and development of GMOs. In February of 2006, the WTO found that the EU was in breach of its rules and in violation of its international trade laws. No appeal was filed by the EU.

It is debatable what effect, if any, the WTO ruling had on international trade. EU regulations were revised during the lawsuit in the spirit of the CPB in 2004, and the countries which brought **suit** against the EU admitted after the WTO rulings that the revisions were tantamount to a lifting of the 1999 moratorium. Furthermore, EU member states require clear labeling of all foods which contain GMOs. Given the choice between conventionally grown crops and GMOs, most consumers chose to purchase the conventionally grown crop. It is unlikely that the 2006 WTO decision or future such decisions will cause wary consumers to choose GMOs over non-GMO options, leaving the financial future of GMOs very much in limbo.

Suit—a lawsuit; an action brought before a court to redress a grievance.

International Regulation of GMOs Since CPB

Since the adoption of the CPB in 2003, there has been little in the way of further international regulation of GMOs. The WHO has updated the **Codex Alimentarius** to reflect new issues regarding food safety raised by GMOs. The codex contains principles and guidelines for GMO risk analysis as well as standards for toxicity, allergenicity, and even gene stability. The WHO also supports the development of regional and national agencies responsible for evaluating potential public health and environmental risks of GMOs being developed domestically or considered for import. The CPB's effectiveness is contingent upon nation-states having the experts and technology necessary to objectively evaluate the safety of GMOs, which makes capacity building a top priority of the WHO. The WTO supports and encourages similar efforts through its Food Safety Program (FSP), focusing on working with industrialized countries (major exporters of foodstuffs) to help developing countries create the agencies necessary to properly evaluate GMOs, using the industrialized countries infrastructure as a model.

Codex Alimentarius—*a collection of internationally recognized standards, codes of practice, guidelines and other recommendations relating to foods, food production and food safety.*

Current Prevalence of GMOs

Today, the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) estimates that 114.3 million hectares or roughly 8% of farmland is currently used for the cultivation of GM plants. Approximately 99% of GM plants are grown in seven countries: the US, Argentina, Canada, Brazil, China, Paraguay, and South Africa. GM livestock and fish are exceedingly rare, and far more likely to be found in a research setting where they are grown for experimentation rather than commercial use. For purposes of comparison, according to the International Foundation of Organic Agriculture Movements (IFOAM), about 31 million hectares or 2% of farmland is being used for the cultivation of **organically grown crops**.

Organically grown crops—*crops grown with biological pest control and mechanical cultivation in lieu of pesticides and machine cultivation.*

GM Plants Bioengineered for Consumers

A top priority of geneticists developing GMOs is reducing the toxicity of food products derived from plants. Many plants use a wide variety of chemicals to protect themselves from insects, herbivores, and pathogens. These are the molecules responsible for causing allergic reactions in parts of the population and making some plants inedible. Rapeseed, the plant from which canola oil is produced, was originally so toxic that it was used to make a cheap form of motor oil during WWII. Extensive breeding was necessary to develop a plant with oil suitable for cooking. Today, scientists are also experimenting with lowering the saturated fat content of foods derived from plants as well as maximizing the amount of beneficial plants oils.

The first commercially produced GMO, Flavr-Savr, was designed to deactivate the enzyme in tomatoes that produces a chemical

known as ethylene, which drives the process by which tomatoes ripen. In supermarkets, tomatoes are generally delivered unripe and sprayed with ethylene to promote ripening before sale. Flavr-Savr tomatoes could ripen on the vine and be brought to food stores without rotting. Another variety of tomato produced around the same time was genetically engineered to produce a greater amount of proteins which contributed to fruit firmness. The unintended result was a tomato that made thicker, fuller paste when processed. This breed, produced by Zeneca, was unable to gain retroactive approval during the 1999 EU moratorium and is no longer marketed commercially.

GM Plants Bioengineered for Growers

Although an important goal of genetic engineering of crops is providing a superior product to the consumer, its primary goal is increasing the yields and sustainability of modern agriculture. The vast majority of currently available GMOs have been designed to be better able to fend off weeds, insects, and pathogens.

In 1996, Monsanto, a major agrochemical company, produced “Roundup Ready” soybeans. “Roundup” is the trade name of a chemical known as glyphosate, an herbicide taken up through the foliage of plants. Glyphosate interferes with the pathway responsible for the essential amino acids and is deadly to plants. Unlike the vast majority of pesticides, glyphosate is completely safe for humans, fish, birds, and insects because higher organisms obtain these essential amino acids from consuming plants rather than by synthesizing these molecules. Roundup Ready soybeans are genetically modified to be able to detoxify glyphosate, and quickly convert it into a harmless molecule, meaning that farmers can use glyphosate on their crops with **impunity** to prevent weed growth.

In the US, the first country to grow Roundup Ready soybeans on a large scale, the National Council for Food and Agriculture (NCFA) estimates that US\$220 million was saved in annual herbicide expenditure by soybean grows. By 2001, only five years after its initial release, half of all soybeans grown in the US were Roundup Ready. Since 1996, the glyphosate tolerance trait has been introduced in cotton, oilseed rape, maize, and beets.

Bacillus thuringiensis (Bt) has been a bacteria of great interest to farmers and agrochemists for an many years. The bacterium secretes a family of proteins known as *Cry* toxins, each of which is specific for a different insect. Interestingly, these proteins have no toxicity to mammals, birds, or fish. Despite clear advantages over comparable industrial pesticides, Bt has seen little commercial use because it is quickly washed away and degraded in fields through the watering of crops. Bioengineers have designed both “Bt cotton” and “Bt maize”, which are genetically engineered to secrete *Cry* toxins to defend against insects.

Impunity—*exemption from punishment.*

Studies have found that Bt crops also decrease myotoxins produced by fungi. Myotoxins are potent carcinogens, and develop primarily in tropical climates where grain is stored in warm and humid climates.

For farmers, viruses are as dangerous as insects and weeds, with the potential to destroy individual fields as well as the crops of an entire region. Plants do not have a dedicated immune system and their defenses against pathogens are poorly understood. In 1998, papaya ringspot virus (PRSV) spread rapidly through papaya crops in Hawaii and was poised to destroy the Hawaiian papaya growing industry. That year, bioengineers introduced a breed of papaya genetically engineered to produce a viral protein in each of its cells. This low level of viral protein production induced a defense response in the papaya plants that rendered them immune to PRSV. These PRSV resistant papayas are credited with saving the small Hawaiian papaya industry, and experts believe the same strategy could be applied to protect a wide variety of other crops, as well as reduce myotoxin content of crops in tropical climates.

Future GMOs

The biotech industry has several GMOs under active development. In theory, plants could be genetically modified to produce **antibodies**. A plant which contains an antibody to *Streptomyces mutans*, the bacteria responsible for most tooth decay, could be processed and used as a toothpaste additive. Similar technology could be used to produce edible vaccines. Although insuring proper dosage would be a concern, the ease of transporting and administering such vaccines could prove useful, especially in the developing world.

Increasing the hardiness or survivability of plants would do much to increase the yields of crops. Current research and development is geared towards making crops salt and drought resistant. Modern irrigation techniques pull salt onto fields from rivers, and although plants are designed to trap and store excess sodium in their leaves, in theory GM plants could be designed to do this more effectively and aid in detoxifying fields. Geneticist and professor Pamela C. Ronald at the University of California-Davis identified the genes necessary for conferring drought resistance in a breed of wild rice in the late 1990s, and this could be applied to other plants. Cold resistance of animals and plants in less temperate climates is another trait under study that would do much to protect crops from frost.

Genetic modification of livestock and fish has been restricted primarily to basic research, medical research, and pharmaceuticals. Efforts to increase organism size by altering growth-promoting genes which cause animals to produce higher than normal amounts of growth hormone generally result in health problems and mortality. However, researchers have found it relatively easy to target the genes of molecules

Antibodies—*proteins found in the blood that are used in the immune system to identify and neutralize bacteria and viruses.*

secreted into milk. In 2005, the first GM cow which secreted antibodies in its mammary glands was born. These antibodies protect the mammary glands from common infections. Researchers are also interested in modifying the content of milk to make it healthier for consumers. In 2007, the Argentine biotech corporation Bio Sidus announced the birth of cows bioengineered to produce insulin in their milk. Bio Sidus has estimated that 25 insulin-producing cows would be enough to supply insulin to Argentina's 1.5 million diabetics.

Some experimental work has been completed on fish to increase the sustainability of the fishing industry. In 2003, enhanced-growth Atlantic salmon were bred using a growth hormone gene from Chinook salmon. This hormone increases the rate of growth three to five times compared to wild Atlantic salmon. Work has been done to make carbohydrate digestion in trout and salmon more efficient. As carnivorous creatures, both species are limited by their prey, and such modifications would help regions support larger fish populations. To this date, there are no widespread commercial plans for GM livestock or GM fish.

Conflicting International Regulations after the CPB

Although 147 countries have ratified the CPB, a fundamental difference of opinions remains between GMO producers and non-producers. The negotiations leading up to CPB, particularly COP-1 and COP-2, revealed a divide between those in favor of relatively light regulations of GMOs, nicknamed the "Miami Group", and those nations in favor of stringent, more prohibitive regulation of GMOs, called the "Like-Minded Group." The Miami Group consisted of developing countries that were leading GMO producers: Argentina, Australia, Canada, Chile, the USA, and Uruguay. The Like-Minded Group consisted of the EU and developing nations. GMOs in the US are loosely monitored by the US Department of Agriculture (USDA), the Environmental Protection Agency (EPA), and the Food and Drug Administration (FDA). Similar sets of regulation agencies exist in most of the countries of the Like-Minded Group, and decisions are based on a policy of "substantial equivalence." Products that are, for the most part, equivalent to their conventionally produced counterparts are approved for sale. This is an example of vertical regulation.

In the EU, **horizontal regulation** has been applied to GMOs and biotechnology. The EU evaluates the risk of GMOs through what is known as "precautionary principle." At every step of development, GMOs are under production under rigorous risk assessments, and regulation consistently errs on the side of caution. Developing nations have taken a similar approach to regulation.

It is interesting to note that the CPB has a **tenuous** relationship with WTO regulations, as illustrated by the 2006 decision in the case brought against the EU by Argentina, Canada, and the US. WTO regu-

Horizontal regulation—restrictions that have been put in place uniformly at the same level.

Tenuous—thin; lacking in clarity.

lations of GMOs are based on the “Principle of Non-Discrimination (PND).” According to the PND, the standard for trade between nations is that of the most-favored nation—that is, any favorable market access available to one nation’s imports must be allowed to all foreign nations. PNF governs the trade of “like products.” In the CPB, nations are asked to adhere to a Principle of Advance Informed Agreement (PAIA). Although these regulations are not directly in conflict, there is some ambiguity as to what sort of regulations a country can put in place after being given advance information regarding genetic modification. In addition, the CPB does not specify any penalties for violations of its policies, nor does it outline a means by which to resolve disputes.

Consumer Confidence

The state of **consumer confidence** regarding GMOs is highly relevant to their success. Of course, regulations regarding GMOs are inconsequential if consumers refuse to purchase GM food products. Introduction of GM soybeans and corn in food in Europe in the late 1990s were met with public demonstrations and protests. Much of the public outcry was due to the outbreaks of a new variant of Creutzfeldt-Jakob disease (nvCJD). nvCJD can be contracted by eating beef from cows infected with Bovine Spongiform Encephalopathy (BSE), more commonly known as Mad Cow Disease. BSE was traced to a similar disease known to infect sheep. Experts determined that the disease entered the cow population through feed contaminated with ground up livestock, including sheep. Using parts of animals unfit for human consumption in animal feed reduced the cost of producing the feed, but caused the outbreaks of BSE and nvCJD. Studies show that EU consumers with accessible, non-GM options generally choose conventionally produced foods over GM foodstuffs. Though unrelated, a great deal of concern remains that GMOs will cause a disaster much like the nvCJD outbreaks of the 1990s.

For the most part, consumers in the Americas have been free of similar food crises, and trends show them to be far more open regarding GMOs. In the developing world, hesitance towards GMOs comes from fear of contamination of domestic crops and compromised access to the European market. There is also some suspicion that GMOs from developed nations will be “tested out” on the inhabitants of developing countries, especially through food aid, in order to improve consumer confidence.

Organic Farming, Conventional Farming, and GMOs

Currently, there are three methods by which crops are grown: organic farming, conventional farming, and farming with GMOs. Proponents of GM crops argue that organic and conventional farming are no more or less “natural” than genetic engineering, pointing to the fact

Consumer confidence—the degree of optimism on the state of the economy that consumers are expressing through their activities of savings and spending.

that much of the plant breeding done for organic and conventional farming is carried out between commercial crops and exotic varieties with desirable traits – crosses that would not occur in nature. In some cases, radiation and chemical mutagenesis are employed to create new breeds with useful traits, an accepted practice since the 1920s. Whereas GM crops have a select gene or set of genes transferred from one species to another, breeding techniques which do not use bioengineering result in the transfer of hundreds and hundreds of genes, many of which have unknown functions.

On the other hand, the precision and accuracy of genetic engineering comes at a price. When creating a GMO, scientists typically link the gene of interest to a **marker gene** to track its location. Marker genes conferring antibiotic resistance allow scientists to quickly identify which plants have been GM and which have not, but critics complain that releasing antibiotic resistance genes into the wild may result in the creation of “super bugs”, or bacteria and viruses highly resistant to drug treatment regimens. As of now, there are no scientific studies regarding this concern.

GMOs stand to greatly reduce pesticide usage through aforementioned techniques of secreting naturally occurring compounds toxic to pests and conferring resistance to herbicides which only effect unwanted plants and not humans. The FAO has been recommending a reduction in pesticide usage for several years. In Africa alone, over 50,000 tons of so called persistent organic pollutants (POPs) exist in varying levels of storage. POPs are a risk to the laborers who handle them as well as those in the communities where they are stored. Although organic farmers do not use pesticides, they are responsible for increased yield and reduced food cost. Thus, the alternative of reduced pesticide GMO products is preferable to that of pesticide-free organic products, in terms of insuring low food costs.

Farmers and the Agrochemical Industry

The major players in the agrochemical industry are Monsanto, Dupont, and Syngenta. Mergers and takeovers between the agrochemical sector and the biotechnology sector have made these three corporations the top global seed firms as well as the top global agrochemical firms. The WTO’s Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement provides for the patenting of plants and other life forms across countries. Similar agreements, of course, protect chemicals used as pesticides. It takes an average of 6 years to bring a GMO to market, whereas it can take nearly 10 years to do the same for a conventionally produced crop. The industrial chemicals produced by the agrochemical industry in the 1970s and 1980s are running out and recently manufactured generic alternatives have begun to cut into profits from these chemicals. The logical next step for the agrochemical indus-

Marker gene—used in molecular biology to determine if a piece of DNA has been successfully inserted into the host organism.

try would be the introduction of GMO products, protected through international patent treaties.

This clear financial incentive behind GMO products has concerned analysts and farmers alike. Many farmers fear that the lucrative GMO market will overshadow their concerns about the safety of GMOs. The use of general use restriction technologies (GURT) is also an issue of contention. Through a simple genetic modification, agrochemical corporations have been able to produce plants that have infertile seeds. Those within the industry have not widely employed the technology, arguing that it was only developed to prevent GM plants from being pollinated by wild plants or commercial crops, but also that it could be used to prevent future generations of GMO crops from growing impossible to control with chemicals.

Focus of the Debate

Safety and Risk Assessment

A primary risk of a widespread introduction of GMOs is that of **gene transfer**, particularly among plants. The spread of pollen is nearly impossible to control and could result in wild plants gaining resistance to commonly used pesticides. A wild plant or animal with the added competitive advantage of a GM trait could potentially outcompete other organisms in its ecosystem, compromising biodiversity. An ecosystem being overrun by a “super weed” or a “super bug” could have disastrous consequences, and eventually lead to farms being overrun. Such risks cannot be accurately assessed in laboratory trials and are best evaluated through long-term field testing. However, there is little consensus regarding what is an accurate testing period given that it may take many generations – decades of growth – before the effects of gene transfer are readily observable.

Measuring the risk to human health of GM foods suffers from the same difficulties in terms of accuracy. The testing of GM foods on animals in a laboratory setting does not accurately predict its effect on humans. With Europe only a decade removed from the nvCJD crises that temporarily crippled its meat producing industries, a critical issue regarding GMOs is the safety for human consumption.

It is worth noting that the pharmaceutical industry has flown under the radar on the issue of GMOs, though GMOs have been used in laboratory research for several decades. In fact, the majority of insulin necessary to treat Type I diabetes, which is characterized by a decrease or loss of insulin-producing cells in the pancreas, is obtained from GM *E. Coli*. This strain of *E. Coli* is bioengineered using recombinant DNA technology to secrete insulin when given proper nutrients. Prior to the advent of genetic engineering, insulin was obtained from the pancreas of livestock. Again, no real public outcry has been raised concerning ei-

Gene transfer—*process in which an organism incorporates genetic material from another organism without being the offspring of that organism.*

E. Coli—*Bacterium that is commonly found in the lower intestine of warm-blooded animals.*

ther the pharmaceutical industry's use of genetic engineering to produce insulin or its continuing research into using similar systems to produce other medicines.

Organic, Conventional, or Genetically Modified?

The techniques of organic cultivation, conventional cultivation, and genetic engineering each have unique risks and benefits. The FAO estimates 30% of the world's ice free land and one-fifth of the world's greenhouse gases are involved in livestock production. The majority of corn and soy grown feeds cattle, pigs, and chicken. Experts contend that it takes two to five times more grain to produce the same amount of calories through livestock as direct grain subsidies. Although there is no consensus regarding the yields of organic farming compared to farming techniques which employ genetic engineering of chemical pesticides and fertilizers, most agree that organic farming results in decreased yields. Advocates of organic farming argue that these yields are most sustainable in the long term and would be sufficient to meet world food demands if consumers accepted changes in their diet. The issue of adoption of GMOs inevitably begs the question of whether GMOs are actually necessary. So long as hunger and malnutrition continue to affect one-sixth of the world's population, a solution must be found.

Labeling of GMOs

A major issue for GMO producers is that of labeling. There remains a fear that consumers, given a clear choice between GM food products and conventionally produced food products will choose not to purchase GMOs. Advocates of widespread adoption of GMOs argue that such labeling is unfair without some sort of consumer regulation program. To this day, there have not been any instances where GMOs have been responsible for any outbreak of disease or illness.

NGO Perspectives

Greenpeace

Greenpeace is vehemently opposed to the adoption of GMOs and stands firmly in support of organic methods. The organization argues that GMOs are a threat to **biodiversity**, unsafe for human consumption, and amount to a means by which corporate giants are trying to gain control of the international food market. It advocates the labeling of GM ingredients and the segregation of genetically engineered crops from conventional ones. Critics have accused Greenpeace's stance of lacking a scientific basis, but those on both sides of the argument must admit that scientific studies on the issue of GMOs are limited at best, with results varying widely depending on the group that conducted the study.

Biodiversity—the variation of life forms within a given ecosystem, biome, or for the entire Earth.

Oxfam International

Oxfam International soundly condemned the US distribution of food aid containing GMOs to Africa in 2002. Despite this incident, the organization has expressed support of GM foods as a potential solution to poverty in the third world and has expressed great interest in the implementation of GM crops. Oxfam has been accused of straddling the fence on the issue of GMOs; however, for the most part, their stance is that of cautious support, with sensitivity towards the prevention of exploitation of the poor and disadvantaged.

Red Cross

The Red Cross has not taken a strong position on the debate regarding GMOs. The organization understands the role food plays in good health. Should GMOs be declared safe, their most consistent stance would be support. In the past, the Red Cross has supported what were at the time regarded to be controversial scientific advances, such as vaccination. The possibility of plants with increased nutritional content, livestock (particularly cows) able to produce medicine in milk, and crops with medicinal or pharmaceutical properties would be highly useful to the organization's international relief efforts.

Possible Solutions

Further International Regulation

A recommendation to create a new subcommittee or international agency to evaluate the risks associated with various GMOs may put an end to the controversy surrounding GMOs. Unfortunately, the staffing of such a committee or agency would be a contentious issue. Qualified experts capable of conducting such evaluations are far and few between, making it difficult to insure equal representation from all countries. Ensuring the **objectivity** of risk assessors would also be difficult, given the interests the agrochemical industry, governments, and NGOs would have in their findings.

Objectivity—*not influenced by personal feelings, interpretations, prejudice, based on facts; unbiased.*

A GMO Moratorium

The WHO could recommend a moratorium on the production of GMOs until their effects on biodiversity and human health are better understood. This action would be the most conservative response to the issue. Implementation of such a moratorium would be extraordinarily difficult, and mainly be a matter of major importers banning GMOs and effectively closing the market for global trade of GMOs. Consumer confidence would be significantly affected by the moratorium, and even if GMOs were later approved for the market, could very well affect consumer confidence with regard to GMOs for decades. Alternatively, the WHO could recommend reduced meat consumption and a move towards

more **sustainable** agriculture. Again, it is unclear how much of an effect such recommendations would have on domestic policy.

Sustainable—*the capacity to maintain a certain process or state indefinitely*

Support of GMOs

A WHO recommendation in full support of the cultivation and sale of GMOs would be met with a mixed global reaction. It would be difficult to predict effects on the global marketplace of this recommendation, and it may not be enough to result in widespread acceptance of GMOs.

An irony is that GMOs are well suited to be grown through organic techniques. If deemed safe, GMOs with genes conferring resistance to insects, weeds, pests, and trace chemicals in soils could be grown without the use of chemical pesticides or fertilizers with yields comparable to conventional crops. Thus, a compromise involving regulations regarding some GMOs might satisfy most parties involved.

Questions for Policymakers

An effective resolution must answer the question: Are there legitimate risks associated with some or all GMOs? If any GMOs can be deemed safe, specifically those not primarily produced to enter the market for human or livestock feed, an attempt should be made to assert the safety of such products. For such crops, how can consumer confidence be increased? Where uncertainty exists, how can studies and research over the next several decades fill gaps of knowledge? Should safety concerns be dealt with on a case-by-case basis? If not, then what **overarching** regulations regarding GMOs should be made? What environmental implications result from using genetically modified organisms, and how can we minimize the risks posed by cross-breeding between non-modified and modified organisms? How can farmers, especially those in developing countries, most benefit from innovations in genetically modified crops and livestock? Above all, a critical question is how the global community can evaluate the health risks associated with GMOs in a way that does not stifle their development.

Overarching—*to be encompassing or overshadowing everything.*

Conclusion

At the conclusion of the World Food Summit of 1996, the global community resolved to work towards “food security.” In words drafted at the summit: “Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.” Over ten years later, little progress has been made in bringing food security to those suffering from hunger and malnutrition. Though scientific advances have propelled food availability forward by leaps and

bounds, these technological advancements must be used **judiciously** and responsibly. The idea of food security has never before been so complicated, and the debate has escalated accordingly. With the capacity to engineer our food supply comes the difficulty of doing so safely. A WHO resolution regarding the future of agriculture will do much to serve as a catalyst for a renewed effort to achieve international food security.

Judiciously—using or showing judgment as to action or practical expediency; prudently.

Guide to Further Research

Genetically modified food is a significant topic, with impacts that could touch virtually every life on the planet. When considering the intricacies of the debate, you should research the following subtopics: the latest scientific advances in genetically modified organisms, the legal and ethical issues of creating genetically modified organisms at all, the safety concerns of using genetically modified foods, especially when not all uses have been tested, as well as market implications for and by genetically modified foods. There are certainly other topics to consider, but these basic points will provide a sound basis of understanding the topic. To do the research, a few websites and sources will certainly prove useful:

- <http://www.who.int/foodsafety/biotech/en/>
First, consider the WHO website's biotech and food safety related content. This will provide information not only on the latest in the global debate on the safety of genetically modified food, but will also give insight into the WHO perspective. The website covers everything from general information to recent discussion on genetically modified foods.
- <http://www.centerforfoodsafety.org/geneticall7.cfm>
This organization, a non-profit public interest and advocacy group promoting sustainable agriculture, will provide a counterargument to the benefits of genetically modified food. Writers and staffers for this group have been a part of many landmark decisions, such as the StarLink controversy and court cases decided against food technology companies. Their website provides somewhat radical views against genetically modified food.
- <http://www.agnic.org/browse>
The Agriculture Network Information Center (or AgNic) is a voluntary alliance of nearly 60 member institutions and organizations that are devoted to distributing agricultural information. From the browse page, you can find an outline of topics

covered by AgNic, including breeding and genetic improvement. This will offer scientific detail beyond what is necessary for committee discussion, but it will give you a sense of what new developments are arising.

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