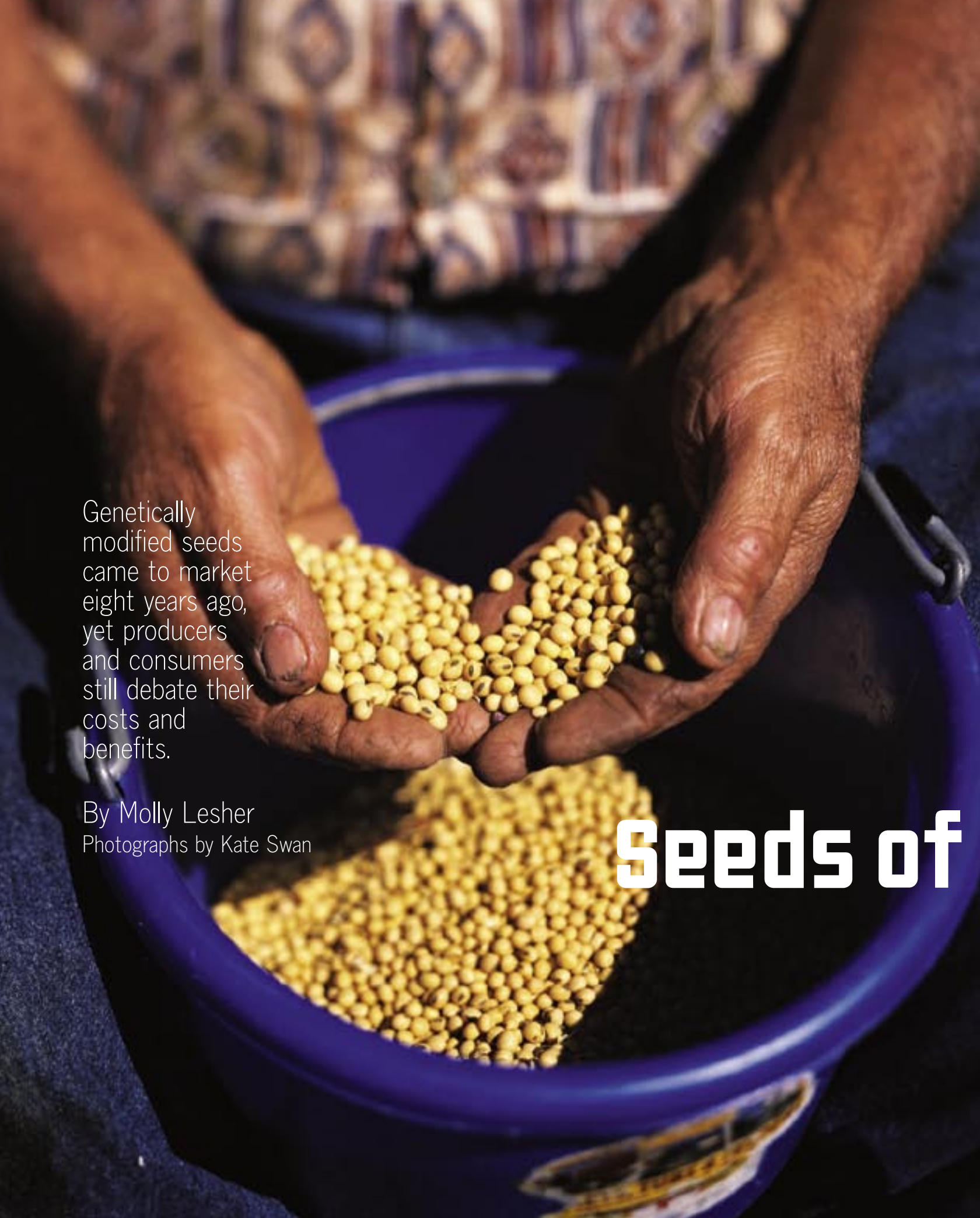


Seeds of

Genetically modified seeds came to market eight years ago, yet producers and consumers still debate their costs and benefits.

By Molly Lesher
Photographs by Kate Swan

In 2003, U.S. farmers grew two-thirds of the world's biotech harvest. So, consumer acceptance, both at home and abroad, affects the country's producers.

change

For centuries, scientists have found ways to refashion the foods we eat to make them healthier, tastier, and easier to grow. And these innovations benefited both farmers and consumers. So, when scientists introduced gene-altering biotechnology techniques into food production, it didn't take long for farmers to start planting the seeds. In the mid 1990s, U.S. farmers began widely cultivating genetically modified grains—particularly soybeans and corn. Farmers believed in the technology's potential to reduce costs and chemicals, and U.S. consumers did not voice many complaints about the new products. Today, the majority of U.S. processed foods contain at least some genetically modified ingredients.

But a number of consumers in other countries and environmental groups reacted differently. In the late 1990s, Greenpeace and Friends of the Earth made genetically modified crops a signature issue, intensively lobbying public opinion and governments. Some took an even more militant stance, vandalizing labs engaged in "Frankenfood" research and disrupting field experiments. European consumer sentiment turned hostile, and E.U. authorities responded in 1998 with a temporary ban on most imports of genetically modified crops. Likewise, Japanese officials limited the percentage of genetically modified content allowed in the country's grain imports.

This opposition directly affects U.S. farmers—especially farmers of soybeans and corn. The United States exports more soybeans and corn than any other country in the world, with about one-third of U.S. soybean and one-fifth of U.S. corn production bound for other countries. And while much of the global grain harvest goes into animal feed, where consumers accept genetically modified content more readily, the European Union and Japan still significantly decreased their importation of U.S. soybeans and corn due to strong consumer resistance.

But as U.S. farmers plant more acres of genetically modified seeds, the world moves further away from an easy choice about biotechnology in our diet. Cross-pollination and imperfect grain-handling procedures further scramble the food chain, as conventional and organic crops increasingly test positive for genetically modified content. As time passes, creating truly segmented markets for conventional and genetically modified grains becomes more difficult and more costly.

It's been eight years since genetically modified seeds first came on the market, yet consumers abroad are still wary. This sustained resistance compels decision-makers to think carefully about the relative costs and benefits of genetically modified foods. Have farmers seen significant cost savings? What are the key environmental and food safety concerns? Why do some consumers reject genetically modified foods and how changeable are these attitudes?

All of us—farmers, consumers, seed companies, food processors and distributors, and government regulators—need to understand these issues to make informed choices about the future of biotechnology in the food supply.

SLICING AND SPLICING GENES

Biotechnology was born almost 150 years ago in the monastery garden of Gregor Mendel, who bred and crossbred pea plants to create new combinations of height, color, and shape. The insights he derived about genetic inheritance eventually allowed plant breeders in the twentieth century to create higher-yielding "hybrid" seeds. When combined with chemical inputs, hybrid seeds increased many crop yields dramatically.

In the 1970s, scientists pushed past Mendel's crossbreeding techniques when they discovered how to remove genes from one organism and insert them into another completely unrelated one, creating life forms that could not otherwise occur. This new, more precise approach opened the door to a wide range of possibilities for new and improved agricultural products by gene swapping among plants, animals, and organisms such as bacteria. Modern biotechnology now allows lab technicians to implant an Arctic flounder gene that resists cold temperatures into a strawberry plant to defend against frost. Similarly, scientists can also insert daffodil genes that induce vitamin A production into rice to help prevent blindness in the developing world.

Biotechnology was born 150 years ago in Me

Yet the technology also raised concerns. In 1994, a small biotech company introduced the first genetically engineered food into U.S. supermarkets—the FlavrSavr tomato. The novelty of this tomato was that it would continue to ripen after being picked, without softening and while maintaining a deep red color and sweet taste. But, as with many genetically modified organisms,

ndel's garden; today, gene guns have replaced his cross-pollination techniques.

Reinventing the Atlantic salmon

The AquAdvantage salmon matures twice as fast as its conventional relatives.

COURTESY OF AQUA BOUNTY TECHNOLOGIES

Genetic modification of agriculture is not restricted to plants. Since the 1980s, scientists have been altering the genes of animals for medicinal purposes (cows that produce anthrax antibodies), industrial uses (goats that form spider silk in their milk), and human consumption (faster-growing fish). U.S. regulators classify genetically modified animals as "new animal drugs," and unlike plant biotechnology, a single agency approves them for consumer use—the Food and Drug Administration (FDA). Currently, no genetically modified animals are authorized for human consumption in the United States. But the FDA is reviewing several applications, and a decision could come soon.

It is likely that the first genetically modified animal to hit supermarket shelves will hail from the sea. Fish are popular animals for scientists to alter genetically because they produce a large quantity of eggs that develop outside of the body. Aqua Bounty Technologies, headquartered in Waltham, Massachusetts, is at the forefront of genetic modification of fish. The firm has a pending FDA application for its AquAdvantage salmon, a genetically modified Atlantic salmon designed to grow to market size in half the time of its conventionally farmed cousins.

The AquAdvantage salmon grows faster by producing growth hormone year-round, unlike conventional salmon that produce most of their growth hormone only in the summer months. To ensure continuous growth, scientists construct an artificial gene that contains genetic material from a Chinook salmon (to promote growth hormone production) and genetic material from an Arctic pout (to switch on the growth hormone in the winter). Scientists then insert the artificial gene into the salmon eggs, and breed the fish for four generations to ensure stable inheritance of the trait.

> Americans are less comfortable with scientists altering the genetic make-up of animals than they are with gene swapping in the plant world.

The primary motivation for the AquAdvantage salmon—and most genetically engineered aquaculture—is to lower costs. Fish farmers expect cost reductions from lower overhead, as the fish reach market size in less time, and from lower feed costs, since these fish convert food into body mass more efficiently. This last factor is potentially very important since feed costs represent one of the biggest expenses in fish farming. Aqua Bounty researchers estimate that costs will fall by about 40 to 50 percent.

But will consumers eat a genetically modified animal? The Pew Institute's 2003 survey of American consumers shows that 58 percent oppose research on genetically modified animals. As with soybeans and corn, concerns about the environment and food safety come into play, but ethical issues also emerge. It seems that changing the genetic codes of animals strikes a little too close to home, as some envision a slippery slope into the controversial modification of human genes.

Yet many in the fish farming industry remain sanguine, as they believe cost savings will overcome these concerns. Joseph McGonigle from Aqua Bounty noted, "The AquAdvantage salmon will probably require a price discount—consumer research suggests around 15 percent—but fish farmers will still come out ahead." Only time will tell whether genetically modified animals pass the consumer taste test.

scientists spliced a gene marker into the tomato to indicate whether the target trait implanted correctly. In the case of the FlavrSavr tomato, the gene marker consisted of the target trait (delayed ripening) and the marker trait (antibiotic resistance). Researchers then grew the tomato plant in a mixture of water and antibiotics; if the plant lived, they knew that the delayed ripening trait had inserted correctly.

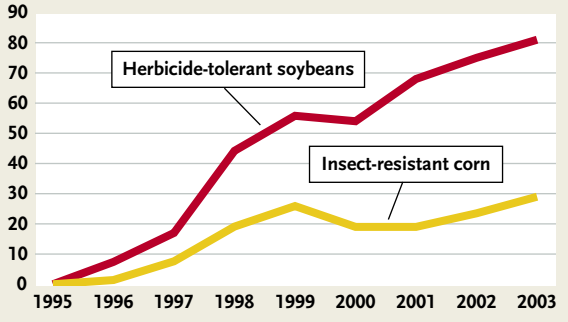
But gene markers contain proteins that become part of the plant, and unless processing destroys them, we consume the new proteins in our food. This led some consumer advocates to worry that people eating the FlavrSavr tomato might develop resistance to medication. So while the tomato tasted better than the average grocery-store variety, safety concerns dominated, and the tomato disappeared. Concerns about gene markers largely abated over time, but most research into producing higher-quality foods shifted to the back burner, focusing instead on making production cheaper, easier, and less polluting.

Seed developers fared better with two other types of genetic modifications—herbicide tolerance and insect resistance. Herbicide-tolerant crops contain an extra enzyme that renders the plant resistant to a particular herbicide. This allows farmers to remove weeds by spraying herbicide over an entire field, rather than taking care to distinguish the weeds from the soybean plants. Insect-resistant crops are genetically modified to contain the soil bacterium *Bacillus thuringiensis (Bt)*, which kills corn borers and cotton worms. Because applying the insecticide can harm farmers, many prefer to plant genetically modified seeds to reduce the danger from spraying and inhaling the chemicals.

Industry analysts expect firms to continue on the current research and development path of breeding herbicide tolerance, insect resistance, and a combination of the two traits into more varieties of the major genetically modified crops. Today, herbicide-tolerant soybeans and canola and insect-resistant corn and cotton dominate genetically modified agriculture. These crops are grown in Argentina, China, South Africa, Canada, and the United States. In 2003, U.S. producers planted two-thirds of the global harvest of genetically modified crops, with 81 percent of U.S. soybean and 40 percent of U.S. corn acreage devoted to some form of genetically modified production.

Farmers go biotech

PERCENT OF U.S. ACRES PLANTED WITH SELECT GENETICALLY MODIFIED SEEDS



SOURCE: USDA

COST SAVINGS

The expansion of genetically modified crops in the United States suggests that farmers have seen some cost savings from using the seeds. After all, genetically modified seeds cost more, so farmers choose to adopt them only when the anticipated benefits exceed the costs. But how much do genetically modified seeds actually reduce farmers' costs?

Farmers planting herbicide-tolerant soybeans have seen cost savings. Soybean farmers decreased their exposure to the most toxic chemicals and reduced the number of herbicide applications, both cutting labor costs and markedly diminishing harm to themselves and consumers. However, genetically modified soybean yields are currently about 3 percent less than some conventional hybrids because it takes time to integrate the trait into higher-yielding varieties. Moreover, agricultural policy analysts note an increase in the amount of herbicides used in soybean production between 1995 and 1998—the most current data available—controlling for the growth in soybean acreage. At least part of this increase could be attributed to the fact that herbicide-tolerant soybean farmers spray herbicide less selectively and thus use more of the chemical. But while lower yields and higher overall herbicide use decreased farmers' anticipated cost savings, farmers still cut costs, as genetically modified soybean acreage continues to increase.

Current research on biotech foods focuses on weed and insect control.

Farmers planting insect-resistant corn, on the other hand, anticipated cost reductions from decreased pesticide use and increased yields. But the evidence on actual cost savings is less clear. These farmers face a complicated cost calculation because corn borer infestations, unlike weed levels, fluctuate widely. From year to year, farmers do not know how much damage corn borers will cause, making it hard to know whether buying the higher-priced seeds will be profitable. Moreover, unpredictable insect levels led U.S. farmers to spray corn borer insecticides on only 5 percent of their fields prior to the introduction of insect-resistant seeds. This may explain why insect-resistant corn seeds have not significantly reduced average pesticide use—and thus average costs.

The uncertainty surrounding insect-resistant corn seeds led the American Corn Growers Association—the largest trade association that promotes the interests of U.S. corn farmers—to create the "Farmer Choice - Customer First" program. This program aims to provide unbiased information to farmers about the potential pluses and minuses of planting genetically modified seeds. Ultimately, farmers who consistently experience higher-than-average corn borer infestations—due to weather or geography—see substantial cost savings from yield increases and decreased exposure to harmful insecticides. But the advantages appear significant for only a subset of farmers, and analysts forecast flat or declining adoption rates going forward.


Biotech food safety is a

THE ENVIRONMENT AND FOOD SAFETY

Farmers aren't the only ones who are looking closely at the effects of genetically modified agricultural products. Some scientists are wondering about the safety of genetically modified foods, although the size of the potential danger remains unclear.

The most serious environmental threats involve a loss of valued species and the movement of genetically modified genes to nontarget plants, insects, and animals. Concerns about the disappearance of certain species first emerged when Cornell University entomologist John Losey published a 1999 study in *Nature* suggesting that the pollen from insect-resistant corn harms the Monarch butterfly, which like the corn borer and the cotton worm, evolves through a caterpillar stage of development. This finding galvanized both environmental and consumer advocacy groups. They worried that other insects and animals could also be at risk, which could lead to an uncertain alteration to the delicate balance of ecosystems.

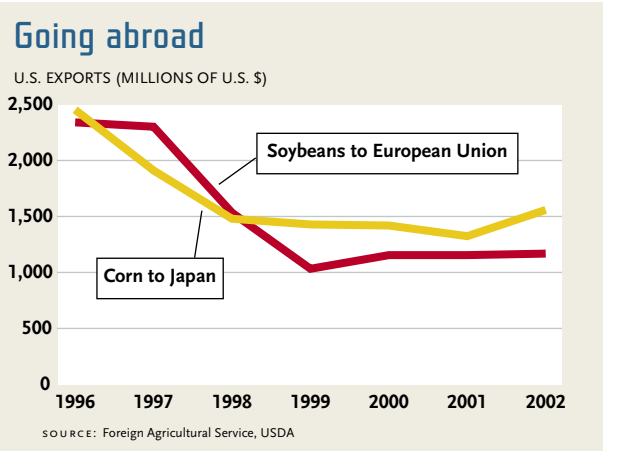
Gene flow—the transfer of genetically modified genes to nontarget organisms by natural processes, such as drifting pollen—also has raised concerns. Some worry that insects could develop a resistance to the *Bt* insecticide, or that herbicide-tolerant genes could spread to wild weeds to produce new breeds that would be increasingly difficult to eradicate. Although resistance is a natural part of evolution, and organisms instinctively become immune to chemicals that would have killed their ancestors, opponents of genetic modification raise the specter of "super" insects and weeds impervious to traditional chemicals. Gene flow also makes conventional and organic farmers uneasy, as pollen from genetically modified plants could drift into their fields rendering them unable to sell their products as "nongenetically modified" or "organic." And farmers planting genetically modified seeds worry about being sued if pollen drift from their fields is responsible for this intermingling.

hot topic among scientists and consumers.

Gene flow of this sort also reduces the possibility that marketers can untangle the mix of genetically modified and conventional products in the U.S. grain distribution system. And handlers compound the problem because they are not always equipped to accurately segregate the grains once they arrive at storage and transport facilities. The inadvertent mixing of genetically modified and conventional stocks has already caused trouble. In 1998, the Food and Drug Administration (FDA) approved genetically modified Starlink corn for use in animal feed, but it withheld approval for human consumption because of concerns that humans might be allergic to a new protein that it contained. Yet Starlink corn somehow found its way into taco shells (October 2000) and into bread rolls (March 2001). The ensuing controversies forced the maker of Starlink to discontinue its production at a loss of millions of dollars and to recall almost 300 food products from around the globe.

The Starlink episode raises another key issue—food safety. Gene markers, the downfall of the FlavrSavr tomato, were the first food safety concern associated with genetically modified foods. Gene markers can code for just about any trait, but antibiotic-resistant markers are inexpensive and easy to use, making them standard in agricultural biotechnology research. Today, most experts believe that gene markers pose few risks to humans, including resistance to antibiotics.

Yet scientists don't always know how new genes will function within a plant, in other organisms up the food chain, and ultimately in the human body. Because interaction effects are not always predictable, some worry that newly formed proteins will cause unforeseen and possibly dangerous human allergic reactions. And if products are not labeled, as in the United States, it is difficult to guard against allergens. This led researchers at the National Academy of Sciences (NAS) to study whether genetically modified foods are more dangerous than foods altered by other means. They conclude that all foods containing new genetic combinations should be examined for safety, regardless of whether the changes occurred by conventional breeding, genetic engineering, or another such method. But NAS researchers also find that the chances of unanticipated genetic changes—like new allergens—increase as the relationship between the target gene and the host grows more distant.



CONSUMERS SPEAK UP

U.S. farmers are the world's largest producers and exporters of soybeans and corn. So it is only profitable for them to plant genetically modified foods if consumers will buy them.

In the United States, consumer sentiment appears favorable. The International Food Information Council (IFIC), an organization that communicates scientific information about food safety and nutrition to consumers, has surveyed how the U.S. public feels about genetically modified foods since their introduction. The IFIC asks participants whether they think "[agricultural] biotechnology will provide benefits for you and your family within the next five years." In 2003, a majority of those surveyed—62 percent—believed that the technology would provide benefits. However, this is down from 78 percent in 1997, so support has diminished. U.S. consumers also think that firms should inform them if they are eating genetically modified products. Researchers at California Polytechnic State

and the National University of Ireland found that 81 percent of respondents feel that mandatory labeling for genetically modified foods is "somewhat" to "very" important.

Other parts of the world seem more skeptical—like residents of the European Union, a major U.S. trading partner. The latest Eurobarometer survey on biotechnology sampled 16,000 European consumers and found that acceptance of genetically modified foods has continued to decline. Yet support also varies a great deal by country—81 percent of Greeks oppose genetically modified foods, as compared with only 30 percent of Spaniards. This consumer opposition led E.U. officials to introduce a stringent regulatory regime for genetically modified imports this year, although other motives aimed at punishing the United States may have also played a role.

Different cultural values at least partially explain the disparate consumer attitudes in the United States and Europe. Longstanding cultural mores about food, for instance, affect consumer sentiment. In Europe, native dishes and cooking styles are traditions that residents hold dear. Europeans spend more time than their U.S. cousins do on food preparation and a larger percentage of their budget on food (controlling for higher food prices), and three-hour meals are not uncommon. In contrast, U.S. consumers value quick service and convenience.

Cultural beliefs about how society should balance technological innovation with the preservation of nature also influence the cross-national differences in consumer purchasing decisions.

Moreover, these attitudes may be slow to change. Across cultures, food choices are bound up in many parts of life—religion (the sacred cow for Hindus), cultural identity (apple pie for U.S. residents), and social cohesion (cappuccino for Italians). As a result, the foods we eat often evoke an intimate and deeply emotional response. For instance, in the United States guinea pigs are pets; in parts of South America they are gastronomic delicacies. And advertising may not be able to easily change such closely held views. In fact, U.S. and European researchers find that increased media coverage about genetically modified products—even if it is positive—heightens concern.

So what does this mean for U.S. farmers and firms in the food business? In surveys on both sides of the Atlantic, consumers say that they are willing to pay significantly more for nongenetically modified alternatives—16 to 38 percent more in the United States and up to 50 percent more in parts of Europe. These premiums are much higher than the cost reductions associated with genetically modified seeds. However, perhaps talk is cheap, as people could be overestimating their willingness to pay more for nongenetically modified products.

FOOD FOR THOUGHT

Many firms are beginning to respond to consumer interest in nongenetically modified products. Companies like Frito Lay, McDonald's, and Gerber baby food (whose parent company, ironically, manufactures genetically modified seeds) have set

Food choices are deeply rooted in emotion and cultural identity.

Researchers at Ghent University found that Belgian consumers rejected genetically modified foods primarily because of negative attitudes toward biotechnology generally, rather than from a consideration of the pros and cons of a particular genetically modified food item. Further, Europeans appear to value environmental preservation more than those in the United States do, as demonstrated by Europe's early support for recycling and the Kyoto Protocol. Meanwhile, U.S. consumers tend to adopt new technologies more quickly than do Europeans (apart from the cell phone), as shown by high U.S. adoption rates of home computers and personal digital assistants.

Recent experiences may be another key factor. Many U.K. consumers are dubious about their government's ability to regulate food, in part because of their memories of its mishandling of the mad cow epidemic still resonate. In fact, a 2001 survey by researchers at the University of Illinois asked U.K. and U.S. consumers whether they believed that "the government ensures the safety of the overall food supply." The survey found that only 25 percent of U.K. consumers trust their government to guarantee food safety, compared to 76 percent in the United States.

Differences like these will make selling genetically modified foods in Europe—and perhaps in other parts of the world—difficult. Consumers in Japan, Australia, New Zealand, South Korea, and Indonesia have also been wary of biotech foods, and as a result their governments have imposed import restrictions.

limits on the genetically modified ingredients used in their products. These voluntary restrictions came about because of the desire to sell in the European and Asian markets, as well as increasing pressure from Greenpeace and other advocacy groups. And as U.S. consumers show an appetite for natural and organic foods—organic sales were up 20 percent last year—natural food stores continue to sprout up across the country.

But segmented markets for genetically altered and conventional grains might cause other problems—including price increases for consumers. Crops must be stored and shipped separately, and verification testing is time-consuming and expensive. Further, costs will rise as pressure to reduce identification errors increases. One study estimates that a zero tolerance for genetically modified content might raise soybean costs as much as 50 percent, but a 1 percent tolerance might increase costs by only 15 percent. So while large-scale segregation may seem like an easy solution, the consequences are not clear-cut.

As with most new technologies, agricultural biotechnology is neither a panacea nor Pandora's box. But as different ideologies and attitudes continue to clash, the debate about biotechnology in the global food supply persists. History shows that science alone will not transform opinions. In fact, deeply felt emotions may make it quite difficult to change consumer attitudes. And while nobody can foretell the future, it is clear that both economic and social concerns matter. ✻

Regulating genetically modified foods

BILL VARIE/CORBIS

The United States and the European Union, along with other countries such as Japan and Australia, have each developed procedures for testing and introducing foods produced by genetic engineering into the marketplace. Most developing countries do not have such rules, and no overarching framework of international law exists.

In the United States, the creation of genetically modified organisms did not prompt new rules or substantial changes to existing laws governing food and environmental safety. U.S. regulators look at the chemical properties of genetically modified foods with a mass spectrometer, and if they line up with the conventional variety—as all genetically modified crops have to date—regulators determine that the plants are "substantially similar." This means that the regulation of genetically modified foods falls under three different jurisdictions—the Environmental Protection Agency (EPA), the United States Department of Agriculture (USDA), and the Food and Drug Administration (FDA).

The patchwork approach to regulation allows countries to tailor the rules to reflect their own attitudes, but it also creates confusion and overlap.

The EPA regulates pesticide, herbicide, and fertilizer use and sets limits on the amount of harmful chemicals allowed in agriculture production. So, if a genetically modified food incorporates a chemical into the plant, as with insect-resistant corn, then the EPA plays a role in the approval process. The USDA issues permits for field trials and reviews petitions by seed developers to commercially release genetically modified seeds. The FDA has the broadest mandate as the supervisor and coordinator of licensing and testing of genetically modified foods (excluding meat, poultry, and dairy, which the USDA monitors). Seed developers must also consult other U.S. laws, including various state seed certification rules. U.S. law currently does not require labels for genetically modified food products.

In contrast to U.S. regulators, E.U. authorities consider genetically modified crops "novel foods," in part because they contain proteins that do not exist in conventional varieties. In 1998, the European Union temporarily banned most new genetically modified foods from crossing its borders while officials created a new regulatory regime. In the meantime, they continued to import a small number of crops approved prior to the ban, but with detailed labeling requirements. The European Union recently unveiled their new regime, which includes strict admission, labeling, and tracking requirements, as well as a 0.9 percent threshold for "accidental contamination" of both food and feed grains as they move through the supply chain. Individual E.U. countries may also have additional rules, such as crop registration procedures. In May 2004, a variety of insect-resistant corn became the first new genetically modified food allowed into the European Union in six years. But biotechnology supporters should be cautious, as the approval process was slow, difficult, and costly.

Two sets of international agreements also apply to genetically modified foods. The first is the Cartagena Protocol on Biodiversity, ratified in 2003 by 82 countries including European nations and Japan, but not the United States. The Protocol seeks to protect countries from risks associated with imports of genetically engineered organisms. Among other things, the Protocol requires exporting countries to provide information about the way scientists modified the food item, label all genetically modified products, and adhere to the importing country's national biosafety laws and risk assessment procedures.

The other body of international law concerning genetically modified foods resides in the World Trade Organization (WTO). To prevent discrimination based on nationality, the WTO requires a country refusing imports to base its decision on scientific evidence of food or environmental safety. It was on this basis that in the summer of 2003, the United States, Canada, and Argentina began the WTO process of challenging the legality of the European Union's moratorium on new genetically modified organisms. Such disputes, a direct result of the patchwork approach to regulating genetically modified foods, will endure so long as nations cannot agree to a single set of standards.