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tomato was developed and brought to market and why it failed. Written by a member of the Calgene team that originated the project.

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Astrid Ferszt

Genetically Modified Foods: Recent Developments

The intentional alteration of an organism’s genetic material by means that could not occur naturally through mating or recombination is commonly referred to as “genetic engineering” or “genetic modification.” It often involves the isolation, manipulation, and reintroduction of DNA into an organism where scientists select specific genes from one organism, and introduce them into another, to pass along a desired trait. The goal of this process is to introduce new genetic characteristics to an organism to increase its usefulness. The resulting organism is said to be “genetically modified.” Methods of genetic modification—including plasmid, vector, and biolistic techniques—are different than traditional breeding methods in two significant ways. First, these techniques make it easier for scientists to isolate genes and to introduce new traits without simultaneously introducing many other, potentially undesirable, traits. Second, using these techniques, scientists can cross biological boundaries that could not be crossed by traditional breeding, for example, transferring traits from bacteria or animals into plants.

For purposes of genetically modified (GM) food, scientists might try to increase the yield of a crop, introduce a novel characteristic, or produce a new protein or enzyme. Scientists could also give crops increased resistance to environmental and biological stresses such as heat, drought, nutrient deficiencies, insects, and diseases. But the principal agricultural biotechnology products marketed to date have been crops genetically modified to tolerate particular herbicides and resist specific pests. The best-known example of insect resistance is the use of Bacillus thuringiensis (Bt) genes in maize (corn) and other crops. Bt is a naturally occurring bacterium that produces crystal proteins that are lethal to insect larvae. Bt crystal protein genes have been transferred into corn, enabling the corn to produce its own pesticides against insects such as the European corn borer, thereby providing protection throughout the entire plant. Herbicide-tolerant crops were developed to survive certain herbicides that previously would have destroyed the crop along with the targeted weeds and to allow farmers to use them as postemergent herbicides, providing an effective weed control. The most common herbicide-tolerant crops are resistant to glyphosate, an herbicide effective on many species of grasses, broadleaf weeds, and sedges.

History. During the 1980s and 1990s, biotechnology became a boom industry, moving from the laboratory onto farms. At the end of the 1980s, the first GM food made it through the U.S. regulatory process to become a commercial reality. The first product approved by the U.S. Food and Drug Administration (FDA) was chymosin, an enzyme used in the production of firm cheeses. Estimates suggest that 70 percent or more of cheese made in the United States is now produced using genetically engineered
chymosin. Recombinant bovine somatotropin (rBST), a growth hormone given to cows to increase milk production, followed chymosin in 1993. Farmer use of rBST in dairy production has been, and continues to be, modest. In 1994, Calgene introduced the “Flavr Savr” tomato with the benefits of genetic modification marketed directly to consumers. Initially bearing a voluntary label, the Flavr Savr tomato eventually failed commercially for lack of sales and production difficulty. Although there was some initial fanfare, and little public concern, it never sold well and was off the market by 1997.

Following these earlier examples of genetic modification, it was the introduction of commodity crops containing GM traits that made GM food widely available. In 1996, the first year of widespread commercialization, farmers in six countries planted more than 4 million acres of crops containing GM traits. By 2010, farmers in twenty-nine countries planted more than 365.7 million acres (roughly equivalent to the land mass of Alaska) of crops containing GM traits. The five largest producers of crops with GM traits are the United States (165 million acres), Brazil (62.8 million acres), Argentina (56.6 million acres), India (23.2 million acres), Canada (21.7 million acres), and China (8.6 million acres). The United States alone accounts for as many acres of crops with GM traits as the next four nations combined. In addition to the twenty-nine countries that planted crops with GM traits, thirty countries imported GM crop products, for a total of fifty-nine countries that approve of either the planting or importing of GM crops. Developing countries grew 48 percent of global GM crops in 2010 and are predicted to grow more GM crops than industrial countries by 2015.

Worldwide, more than three-quarters of all soybeans, more than one-half of cotton, more than one-quarter of maize (corn), and one-quarter of all canola grown is genetically modified. U.S. farmers have embraced GM crops at an even higher rate. Roughly 90 percent of all soybeans, more than three-quarters of cotton, and more than 80 percent of maize planted in the United States is genetically modified. Although some U.S. farmers have grown GM varieties of potatoes, papaya, squash, and zucchini, they are rare in most markets. An overwhelming majority of the GM content in food currently comes from just four major crops: soybeans, corn, canola, and cotton (as cottonseed oil). Although not often consumed as whole foods, food manufacturers use these commodity crops and their derivatives as ingredients in a vast array of processed foods. Just a few examples include such common corn-based ingredients as cornstarch, corn flour, corn oil, and corn-based sweeteners like high-fructose corn syrup. Common soy-based ingredients include soybean oil, soy flour, soy lecithin, and soy protein extracts. Similarly, food manufacturers use canola and cottonseed oils in many products, including salad dressings, margarines, processed cheese, potato chips, cookies, and pastries. As a result, 2005 estimates suggested that three-fourths of all processed foods in the United States contain a GM ingredient. In light of the fact that the genetic modification of key commodity crops used in the majority of processed foods has greatly increased since 2005, the three-fourths estimate is likely conservative. Precise numbers are not available because the United States does not require labeling GM food as such.

Although there is relatively little diversity among available GM products, the United States Department of Agriculture (USDA) lists several products “in the pipeline” for future production. Among these are varieties of insect-resistant fruits and vegetables, improved healthfulness and functionality of food oils, naturally decaffeinated coffee beans, nicotine-free tobacco, and grains with radically enhanced nutritional properties and vitamin content. Significantly, the FDA is seriously considering approval of GM salmon, developed by a company called AquaBounty, that grows at twice the normal rate. As these GM products arrive on shelves or if GM foods were required to be labeled as such, Americans would likely become more aware of agricultural biotechnology. However, consumers will still have to trust the judgments of the countless experts and organizations that ensure the safety of their food.
**Regulation.** The U.S. government agencies treat GM foods as substantially equivalent to those produced through traditional means if the GM variety does not introduce allergens or substantially alter the nutritional value of the food. The objective of such an approach is not to establish absolute safety but to consider whether a GM food is as safe as its conventional, generally recognized as safe, counterpart. The 1986 "Coordinated Framework for Regulation of Biotechnology" reflected a position that GM foods could be adequately regulated through the existing federal infrastructure by adapting existing laws to these new technologies. Under the Coordinated Framework, the responsibilities for evaluating and regulating GM organisms are divided among the FDA, the USDA, mainly through the Animal and Plant Health Inspection Service (APHIS), and the U.S. Environmental Protection Agency (EPA). Depending on its characteristics, a product may be subject to review by one or more of these agencies; their responsibilities are usually complementary, but in some cases, their responsibilities overlap. Before humans or animals can consume a new GM crop variety, the FDA must evaluate its safety. The USDA monitors field trials and evaluates the potential impact of widespread environmental release of the plant. The EPA investigates the pesticide levels in GM crops; this jurisdiction extends to both human health and environmental impacts of the pesticide. While the United States has adopted a policy of substantial equivalence, other countries adhere to a precautionary principle in their regulations. As such, there are remarkable differences in regulations for GM foods around the world, often leading to international political and legal disputes surrounding international trade and environmental law.

**Industrial Production.** Though often overlooked by casual observers, there is a complex institutional ecology involved in the production and distribution of food within the United States. In basic outline, the food production and distribution chain begins when firms (such as Monsanto, Dupont, or Syngenta) sell their crop seeds to farmers, who plant and grow them. Farmers, in turn, sell their crops to grain elevators or handlers (such as Archer Daniels Midland or Cargill), who sell the grain to food processors; food and grain processors (such as ConAgra Foods and Nabisco) transform grain into a range of products from bread to cooking oil to snack foods. Processors then sell these goods to food retailers (such as WalMart, Kroger, Costco, or Safeway). It is from these retail outlets that most people in the United States obtain their food. Consequently, the final consumers of GM foods are not the direct customers of the agricultural biotechnology firms. Because American regulators treat GM foods as equivalent to those produced through conventional means, food manufacturers rarely handle them differently. As such, the commodity chain of industry-related firms is the same for GM and non-GM crops.

In the mid-1970s, agricultural chemical companies began acquiring seed companies, perhaps anticipating a time when biology would replace their agricultural chemicals. Sandoz, later to become a part of Syngenta, acquired Rogers Seeds; Monsanto acquired Jacob Hart; and DuPont acquired Pioneer, then one of the world's largest seed companies. Bayer, Advanta, and Limagrain also acquired companies, and by 2005, these six owned almost half the commercial seed sales capacity in the world. In addition, the six plus the multinational chemicals manufacturing corporation, BASF, accounted for over 80 percent of GM crop field trials and controlled over 40 percent of private-sector agricultural biotechnology patents issued in the United States.

The concentration of crop seed production in the hands of a few multinational companies has generated vocal opposition by advocacy organizations. They seize on issues such as the possible accidental transmission of transgenes into Mexican maize or toxic effects on Monarch butterflies and mingle them with information about seed industry concentration, farmers' rights, and gene patenting with the terms "biopiracy, Frankenfoods, genetic pollution, and corn grenade" in a virtual war against GM crops (Miller and Conko, 2005). One fear is that the largest companies will control the supply of seeds and food and may eventually control the fundamental rights
of access to food, similar to industry's control of the price of pharmaceuticals.

**Intellectual Property.** The continued consolidation in the agricultural chain of production, combined with intellectual property regulations that favor industry concerns, may lock farmers into a system in which they have little choice over what to grow, with which chemicals, whom to sell to, and at what price. When planting GM seeds, farmers sign legally binding agreements that forbid them to save and replant the seed. In regions of the world with customary seed-saving and exchanging norms, this model of agricultural practice creates a potentially destructive relationship. Moreover, the regulatory infrastructure created by patent law provides a uniquely privileged position and great influence over farming practice to the companies that control the technology. As industry enforces their intellectual property right, activists fear that adoption of GM crops will transfer agricultural resources from the public sphere to private ownership in the form of patents owned by multinational corporations. As a result, the World Trade Organization's controversial Trade Related Aspects of Intellectual Property Rights (TRIPs) agreement, which requires nations to establish some form of protection for plant varieties, has become the focus of international scrutiny.

**Public Reaction.** Public opinion regarding GM food continues to be varied around the world. For example, in the United States, the public remains largely unaware and unsure and public opinion is generally negative in Europe. Though some scientists and industry stakeholders have assumed that public resistance stems from ignorance, this notion is largely unsupported. Detailed analyses of the relationship between attitudes toward biotechnology, including GM food, and knowledge of the underlying science have continued to show remarkably weak statistical relationships.

In relation to social controversies like GM food, social scientists who study public discourse and the effect of media have identified "agenda setting" and "framing" as among the most powerful shapers of public opinion. Agenda setting is the process of defining which particular problems are considered significant. Framing is the process of defining and delimiting which aspects of these problems are significant. To the extent that various groups consider the impact of GM food on the world food supply as an important issue, there will be competing "frames" influencing its interpretation. One frame will view GM food as a solution to worldwide agricultural issues; another frame with view GM food as problematic.

How GM crops affect farmers in the developing world is only one example of competing frames among many. Other concerns and perceived risks are not directly economic in character at all. Some people may object to GM foods for religious reasons, feeling it is inherently wrong to tamper with divine design. Others may claim that it is intrinsically wrong to change nature, or they may point to the risks associated with altering the ecosystem, citing the long history of damage that has been done by "harmless" pesticides and the elimination of "useless" species. Others are worried about accidental commingling of GM food crops, particularly in the case of biopharming, where scientists genetically modify crops such as corn to produce medicines. Some are worried about the uncertainties introduced by complex interactions of science, technology, and ecology that are difficult for even experts to evaluate. Many people will probably continue to worry about the health effects of eating "unnatural" foods, especially if they perceive the regulatory oversight for novel foods to be weak. Yet others may object to the acceleration of larger-scale corporate agriculture that they associate with industrial agriculture dominated by the Global North.

Current controversies surrounding GM foods and crops commonly focus on human and environmental safety, labeling and consumer choice, intellectual property rights, ethics, food security, poverty reduction, and environmental conservation. The next decade will see exponential progress in GM product development as researchers gain increasing and unprecedented access to genomic resources that are applicable to multiple organisms. As these products
become more commonplace, more, and more intense, controversy may occur. Looking at some previous episodes of controversy may help anticipate future issues.

**Major Controversies.** Though not the first controversy, one of the more public scientific debates about GM food took place in England during 1998. At the center of the controversy was Dr. Arpad Pusztai, author of more than 270 research articles on food safety and member of the Rowett Institute, one of the United Kingdom’s leading food safety research labs. Pusztai appeared on a television broadcast and declared that GM potatoes had stunted growth and suppressed immunity in rats. He speculated that the GM device used to carry the new gene into the potatoes might be the source of the problem. Following his television appearance, politicians, scientists, and the biotechnology industry vigorously attacked Pusztai and his research. The Rowett Institute removed Pusztai from research projects and his employment contract was subsequently not renewed at the end of 1998.

A year later, Ewen and Pusztai (1999) detailed the controversial scholarship in *The Lancet.* The article carefully maintained that the data were preliminary and not generalizable, and the conclusions were weak and tentative. Many of the scientific reviewers had concerns about the design and execution of this particular research. However, as the editor noted in the explanation of their decision to publish the findings, the debate was no longer about the merit of the research itself, but on the framing of science and dissemination of information to the public. Pulled into the debate were academics, scientific journals, various media outlets, government officials, industry executives, and numerous advocacy groups.

In 1999, a similar controversy emerged over preliminary research conducted at Cornell University. A research letter published in *Nature* stated that pollen from Bt corn had toxic effects on Monarch butterfly larvae. Caterpillars, the larval stage of Monarch butterflies, feed on milkweed plants. Because some milkweed grows next to cornfields, Losey and his colleagues suggested that Bt corn pollen may drift onto milkweed and inadvertently harm the Monarch larvae. The research garnered a tremendous amount of media coverage and gave antibiotechnology advocates a poster species. Though there were some initial attempts to discredit the research, a second study confirmed some of the initial scientific findings. In the following year, the EPA, biotechnology industry, and university researchers studied the potential impact of Bt corn pollen on the Monarch butterfly and related species and found that Bt poses little risk of harm to their larvae.

Despite attacks on Losey and his research, Losey himself called for more study and a measured approach to the issue. Again, the fight was not only about the science, but it was about framing of the debates. As a marker of the initial scientific debates, Monarch butterflies have come to symbolize the potential risks of GM crops. Until then, the official risk assessment had managed to avoid considering the effect of the Bt toxin on nontarget insects. In this context, the criticism about the methodological limitations of the study reinforced its message that serious consequences can come from unintended interactions with the broader environment. While the Cornell study did not prove that Bt corn kills Monarch butterflies, it raised the question of why such experiments were not performed earlier.

Just two years later, in 2001, Quist and Chapela published findings in *Nature* that indicated that pollen from GM corn (maize) had spread into non-GM corn in Mexico. How this pollen spread was a source of mystery and speculation. Mexico had a moratorium on the planting of GM crops in force for three years by the time the contaminated samples were collected. Moreover, the closest region where farmers and industry had ever officially planted GM corn was sixty miles away and therefore wind-assisted contamination was impossible. Quist and Chapela suggested that contamination might have occurred due to fresh hybridization events with illegally cultivated GM crops, or as the result of “escaped” GM genes that had persisted in traditional corn since the government-imposed moratorium. This second possibility was controversial.
In 2002, the editor of *Nature* withdrew support for the article, despite the original peer review, due to insufficient evidence. Regardless of whether parts of Quist and Chapela’s study were technically flawed, they focused attention on an important concern deserving careful analysis and evaluation. Some of the controversy occurred because maize is a staple, historic crop with immense cultural significance in Mexico. Furthermore, Mexico is the world’s repository of maize genetic diversity, so this threat gave a vibrant, real-world example to match previously hypothetical concerns that GM crops could unintentionally spread and take over traditional forms of agriculture. Moreover, corn is the species that companies use for much of their research into further uses of biotechnology, including biopharming, the “growing” pharmaceutical compounds using crops. As such, the concern that GM strains could accidentally spread to non-GM crops and contaminate them takes on even more potentially serious health and safety issues when pharmaceutical compound are concerned.

The controversy also gathered momentum because Chapela had been leading a fight against a controversial research partnership between the biotechnology firm Novartis (now Syngenta) and the University of California at Berkeley. Novartis had agreed to provide up to $25 million in research funds in exchange for first rights to patent discoveries made over the five-year period. Chapela was a vocal critic of the arrangement and was often quoted in the press. As such, his struggles became a symbol of the erosion of academic independence from corporate influence. This even extended to his tenure case. Chapela was only awarded tenure after a two-year-long public fight, including a drawn-out appeals process, an international protest, and a lawsuit against the university.

Again, the scientific conclusions were only part of the story. The ecological and agricultural consequences of the contamination that Chapela and Quist reported are worrisome for some. The concern that GM crops could surreptitiously find their way into conventional crops raises concerns about environmental contamination, genetic drift, and agricultural sovereignty. For many, industry has yet to fully establish the environmental impact of GM crops. A related concern, about industry oversight and regulation of GM food, played out during the StarLink controversy.

StarLink is the trademark for a variety of corn that has been genetically modified to produce its own pesticidal protein, Cry9C; Aventis, the owner of StarLink, had obtained approval to sell the corn for animal feed but not for human consumption. Aventis informed farmers of the limited approval and produced guidelines for growing the seed that were intended to keep the crop separated from the human food supply. But that honor-code-like system failed. In fall 2000, StarLink corn residue was found throughout the human food supply, resulting in widespread food recalls by the FDA and significant disruption of the food supply. Moreover, traces of StarLink corn would be found in bulk maize shipments and in processed foods products in Japan, Korea, Nicaragua, and Mexico. The scope and magnitude of industry missteps and regulatory failures during this episode has led many to call for policy change and strengthening of regulatory oversight.

These scientific controversies, involving researchers doing work in the United States, England, and Mexico, make it evident that a multitude of stakeholders are influencing discussions about genetic modification. Some people criticized these researchers for using questionable science to advance personal agendas. Food manufacturers, government agencies, environmental groups, and other social actors hijacked scientific arguments about GM food to serve other agendas and, as a result, some of the GM food controversies have become largely symbolic in content.

**Assessment.** In the case of GM food, as with other controversies, contested interests and symbolic battles characterize scientific judgments and evaluations over claims of expertise. Multinational biotechnology corporations use their power to challenge the scientific authority of those who question their products. In turn, opponents of these corporations, of the industrialization of agriculture, of U.S.
policy, and of globalization, have found a common rallying point with environmental and consumer advocacy groups. Differences in public perceptions, interest group dynamics, political systems, and industrial structure have driven European and U.S. agricultural biotechnology policy in opposing directions. In the United States, technology firms and large farmers have pushed for and obtained comparatively permissive regulatory standards; in the European Union, advocacy groups have urged highly precautionary regulation of GM food.

We all depend on food with adequate nutrition and relatively free of harmful substances and pathogens to live. Our food system largely governs what foods we have available and their amounts and qualities. As the history of GM food in the United States illustrates, such systems are neither accidental nor free of controversy. Given the sociocultural, political, economic, and philosophical factors that influence food production and consumption, it is safe to say that debates about GM food will continue.

[See also Flavr Savr; Food and Drug Administration.]

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German American Food

Because Germany was not a unitary country until the 1870s, German American identity has historically been defined by language rather than by national origin. German speakers emigrating from many different countries have been counted as German Americans, whereas English-, French-, and Spanish-speaking immigrants have been divided and subdivided by national origin, religion, and even regional identity. Since the early eighteenth century, German Americans have been the largest non-British group in America. Between 1790 and 1910, more than 10 percent of all Americans spoke German.

Because the German presence has been so large and continuous, German Americans do not always receive credit for such all-American foods as casseroles, cheesecake, cream cheese, cream soups, hot dogs, jelly doughnuts, meatballs, meat loaf, milk gravy, potato salad, pretzels, sauerkraut, sticky buns, whoopie pies, and numerous types of pickles, cakes, and cookies. American beer is lager—like German beer and unlike British ale. On the other hand, German Americans are often falsely credited with hamburgers. The German American ethnic group is so large that it has become involved in almost every other kind of American food, from the cuisine of the German Cajuns who settled in Louisiana during Spanish colonial times to the many uses of Spam on Hawaiian tables. Especially among the immigrants of the 1840s and 1850s, German Americans included many professional bakers, brewers, butchers, chefs, grocers, restaurateurs, and wine merchants, who dispersed to farm and frontier as well as major cities. German Americans started the well-known midwestern breweries as well as wineries in New York and Missouri.

The major founding stock German American population was the Pennsylvania Dutch, who were distinguished from later immigrants by a uniquely American dialect of Low German and by their prominent Protestant sects. Another distinctive subgroup was Germans from Russia, who in the 1870s began homesteading the prairie states in groups. Smaller groups of German Jews, Transylvanian Saxons, Danube Swabians, and German-speaking populations from Eastern Europe have maintained ethnic customs in food and culture distinct from the German American mainstream. The major story of German American food and drink has been how so