Features

The psychology of GMO

Despite receiving the seal of approval from scientists, genetically modified food continues to be unpalatable in many parts of the world. As **Cyrus Martin reports**, a combination of factors, including economics and culture, may help to explain the differences.

To label or not? That was on the California ballot during last year's US elections, owing to a push from food safety advocates to have genetically modified food advertised as such, as has been standard in Europe for years. Those lined up in favor of the food labeling initiative argued that the consumer has a right to know what they're eating. But in a counter-attack, a coalition of agribusinesses and grocers was able to sow doubt in the minds of voters and apparently convinced many that food-labeling laws would increase fear in the market and lead to costly government regulation, all leading to a bigger grocery bill. In the end, the proposition failed, so when your typical American soccer mom scrutinizes that box of corn flakes on the supermarket shelf, she will see mention of "milled corn, malt flavoring, and sugar" but not genetically modified organisms (GMO).

The differences between the US and the rest of the world, and Europe in particular, on this issue are striking. During the mid-90s, when herbicide- and pest-resistant GM crops were first introduced on the market, there was an uproar in Europe. GM food was portrayed as 'frankenfood', the product of irresponsible scientists meddling with nature. Activists tried to block the introduction of GM foods in European markets though sabotage, in one case even going so far as to relieve themselves on stores of GM grain. This is despite reassurances from the European Food Safety Authority (EFSA), the equivalent of the Food and Drug Administration (FDA) in the US, that GM food is safe to eat. The activists cite a long list of health and environmental risks associated with GM food. On the consumer side, there is the worry that GM food might contain harmful carcinogens or allergens, for example. As a case in point, a study from Séralini *et al*. published in the *Journal of Food and Chemical Toxicology* claimed that feeding rats GM corn causes tumors, setting off a firestorm of sensational stories and panic, leading to a special EFSA investigative panel. And on the environmental side, there is the concern that GM crops promote an increased use of herbicides, that these practices will lead to herbicide-resistant weeds, and that the genes introduced into GM crops have the potential to spread in the wild, potentially disrupting ecosystems.

Like Europeans, Americans have certainly been made aware of the criticisms lodged against GM food. Michael Pollan, for instance, through documentaries such as *Food Inc*. and several articles in the *New York Times*, makes many of the same arguments as his counterparts in Europe do. But for some reason Americans seem unconcerned, at least based on the labeling initiative in California. So while in Europe the cultivation of GM crops has been banned in many countries and there are strict labeling laws in place, the US has no labeling laws and the cultivation of GM crops has soared in the last 15 years. According to GMO Compass, the acreage of GM maize has increased from ~10% of the total in 1997 to 85% in 2009. And it's estimated that 80% of the packaged food on supermarket shelves in the US contains GM products.

The politics of food labeling: Protestors came out in droves in November to support a proposition on the California ballot that would mandate the labeling of genetically modified food. But grocers and agribusinesses made the case that new legislation would result in higher food prices, an argument that apparently resonated with voters, as the proposition was defeated. (Photo: Courtesy of Ann Marie Michaels. http://villagegreennetwork.com/.)

So why the difference in the attitude? Keith Lindsey, a plant scientist at Durham University who sits on a panel charged with advising the British government on GMO, points out that the initial reception of GM food in Europe was actually positive, but the relationship quickly soured due to a combination of suspect science and media sensationalism. Lindsey notes, "Originally in the UK, in the mid 90s, the first GM product (Flavr Savr tomato) was very popular in the UK and elsewhere — I bought some from the local supermarket, and it sold very well at the time. The turning point was later, with some flawed experiments on GM potatoes, not peer-reviewed but seized on by the popular press, which in turn was seized on by environmentalist campaigners." Indeed, this same scenario seems to have played out in the case of the recent Séralini study as the panel of experts appointed by the EFSA have discredited the paper, citing a combination of small sample sizes and inadequate statistics. Unfortunately for proponents of GM food, reporting on the EFSA findings in the popular media has been scant, in contrast to when the story first broke.

A long history of genetic modification

In addition to bogus science, undoubtedly part of GM food's rebuke stems from the idea of mad scientists perverting Nature to create their so-called frankenfood. But, of course, the modification of our food's genetic makeup is nothing new, only the means. This process first began around 10,000 years ago when man started to cultivate wild varieties of grains like wheat, maize, and barley. Whether consciously or unconsciously, seeds from the most desirous plants were sown for the next harvest, and through a process of artificial selection these important food crops evolved into their present forms. As an example, genomic studies in the past decade have shown that maize evolved from a species of teosinte growing in the valleys of southwestern Mexico, though the layperson would struggle to see any affinity between the two. The cob, for example, has expanded from 5 to 12 kernels in teosinte, to over 500 in maize. And, through the hand of selection, the hard, stony covering protecting the fruit has been done away with, leaving the succulent kernels exposed. These and a number of other modifications have transformed maize into a calorie-generating dynamo, satisfying the nutritional demands of both man and beast all over the world. Interestingly, recent genetic studies suggest that only a few genetic mutations, perhaps arising *de novo* or present in existing populations, explain the most dramatic of these changes.

The process of crop modification continued in the 20th century but took on a more deliberate, scientific aspect. Most notably, Norman Borlaug was able through breeding programs in the 1950s to produce new varieties of wheat and rice that were able to capitalize more effectively on the use of fertilizer. The dwarfed plants that Borlaug bred were able to funnel more nutrients into the grain without toppling under the weight of the swollen fruit. These stocky plants, together with modern farming techniques, ushered in dramatic, many-fold increases in crop yields in both modern and developing countries. The programs were so successful that this era has been dubbed the 'green revolution'. Again, as in domesticated maize, the power of modern genetics has been brought to bear. In the case of the dwarfing phenotype, for example, we now know that genetic changes specifically affecting the activity of a class of plant hormones called gibberellins explain this dramatic change in morphology.

Although the plants that emerged from the last 10,000 years of farming have obviously been genetically modified— this is the basis of evolution after all — by convention that term has been reserved for plants subjected to recombinant DNA technology, which first emerged in the 1970s. Instead of waiting for Nature to provide desirous traits, the new technology allowed scientists to rapidly introduce useful genes directly into the genomes of various crops. As Lindsey noted above, the first GM food to make it to the market was the Flavr Savr tomato, which was engineered to express an anti-sense RNA that would theoretically increase the shelf-life of the fruit. However, the Flavr Savr did not fully live up to the claims and Calgene, the company that brought the product to market, failed to turn a profit.

But the failure of Calgene was followed by a string of successes with GM crops engineered not to improve the quality of the product but to increase yields and lower costs of production. Chief among these developments was the creation of herbicide- and pest-resistant plants. The so-called Roundup Ready crops developed by the agribusiness giant Monsanto, for example, express an altered form of the enzyme targeted by the herbicide glyphosate (tradename Roundup). The modified enzyme is not recognized by the chemical, allowing farmers to rid their fields of weeds with Roundup (also marketed by Monsanto) without worry of damaging their crop. Also from Monsanto are the Bt crops, which express a gene from a soil bacterium that encodes a toxin specific for certain insect pests, like the European corn borer. At this stage, many of the major food and fiber plants have been transformed into Roundup Ready and/or Bt versions. Such crops are planted extensively in the US, and a global survey reveals that they have also been embraced next door in Canada and in certain South American countries. However, as noted above, GM crops are scarcely planted in Europe.

The fallacy of frankenfood: Genetically modified food has come under attack because it is perceived as unnatural — a manmade perversion of nature. But this view ignores the fact that humans have been genetically modifying their crops for thousands of years by artificial selection. A dramatic example is the transformation of teosinte (left) into maize (right). Recent studies have revealed that this transformation involved large-effect changes in a surprisingly small number of genes. (Photo courtesy of J. Doebley.)

The future of GMO: Many new food technologies are already at hand or on the horizon, but if the opposition to current GM crops is any indicator, the implementation of these technologies may require some public relations finesse. An example is golden rice, which has been engineered to produce beta-carotene, giving it its yellow color. By providing a vital micronutrient, golden rice could potentially help prevent blindness in the developing world but its dissemination has been stymied by unsubstantiated health concerns. (Photo: International Rice Research Institute (IRRI).)

The psychology of GM food

If the full history of man's relationship with food is considered, a reasonable question to ask is whether it is rational for the consumer to put GM food in a different category than traditionally cultivated crops. As is clear in the case of the teosinte to maize transformation, our crops have undergone extensive genetic modification over the millennia, long before modern genetic tools emerged. But there seems to have been a line crossed in the consumer's mind when it comes to transgenic plants, and the media and environmental groups have certainly helped fan these embers of doubt. But other scientists close to the GM debate feel that, at least in Europe, there may be other mitigating factors — the economy for instance. Hanspeter Naegeli, a toxicology expert who sits on a GM advisory panel for the EFSA, says, "since the end of WWII, there has been no major economic, financial or political crisis in Western Europe and in these countries we have a very high quality of life with prosperity and a well implemented welfare system. The cost of food declined enormously when compared to the overall costs of living such that people are not dependent on a cheap agricultural production and can afford to buy more expensive products (i.e. organic food)."

Coupled to a favourable economic climate in which the consumer can afford to turn their nose up at a genetically modified potato, Naegeli senses an anti-big business current running through Europe, explaining, "there is also a negative attitude against large multinational companies. The economies of Western European countries are traditionally built upon small and medium-sized enterprises and larger international companies are considered suspicious." Ironically, Naegeli thinks that the stranglehold that big business enjoys is also a product of the reforms environmentalists lobbied for, explaining that, "because of the extensive experimental testing required for approval, GM crops are mainly a domain of such large multinationals."

But are the US and Europe really so different when one compares these socio-economic factors? On the one hand, for example, the standard of living as measured by GDP per capita is greater in the US compared to the European Union. On the other hand, however, we see from the California initiative that the American consumer may be more frugal than the average European, perhaps reflecting the greater income disparities in the US. One other factor to consider is how both technology and business may be viewed differently. When asked specifically about the cultural differences, Keith Lindsey replied, "In the US, I think the population generally is more pro-science and technology, more entrepreneurial generally, so they don't see this [GM crops] as such a big deal." Naegeli offers a similar take on the situation, saying "…there is a general mistrust of scientists and scientific institutions [in Europe], which is certainly much stronger than in the US. I'm always surprised that science-based decisions have much more weight in the US than in Europe." While this explanation may hold in the case of GM food, there is some evidence to suggest that Americans are willing to abandon or ignore science and technology in special cases. For example, a recent Gallup poll estimated that 41% of the US population does not believe that humans are responsible for global warming. And, in the case of religion, which is often at odds with science on many issues, such as the existence of free will and human origins, we see that science often takes a back seat to faith in the US.

What is the science telling us?

In a recent opinion piece for *Trends in Genetics*, Nina Fedoroff wrote, "In the USA, each newly modified crop must be shown to be equivalent to the original crop and the products encoded by the added genes must be independently tested for toxicity and allergenicity, making GM crops the most extensively tested crops ever introduced into the human food supply." And the upshot of such studies in both the US and Europe is that GM and 'organic' crops are identical, from a toxicological standpoint. So, despite the consumer's continuing skepticism, the science on the health of GM food currently on the market is essentially settled — GM food is safe to eat.

But that leaves the other side of the coin: the potential environmental impacts. For instance, what might be the impact of introducing an insecticide-expressing plant on the local ecosystem? A 2006 study on Bt-cotton (Cattaneo *et al*. (2006). Proc. Natl. Acad. Sci. USA *103*, 7571–7576), for example, found that there was a negative impact on arthropod populations. However, context is the key. In the case of the cotton study, it was found that both transgenic and non-transgenic varieties had an equivalent negative impact. Indeed, participants in a 2007 workshop sponsored by the National Academy of Sciences, entitled 'Genetically Engineered Organisms, Wildlife, and Habitat', agreed on the importance of proper comparisons. Referring to the findings of meeting participant LaReesa Wolfenbarger from University of Nebraska, a summary of the workshop said, "The conclusion Wolfenbarger drew from these studies was that GE crops do affect wildlife food, but that variations in agricultural practices, including cultivation itself, and the use of insecticides, can have larger effects."

The other significant concern among environmentalists and scientists alike is the potential for gene flow between GM crops and wild flora to erode biodiversity. The worry is that if GM crops are grown in close proximity to wild species that are closely related, hybridization between the two could lead to genetic contamination. This is especially likely if the gene introduced into the wild population confers a fitness advantage, allowing it to spread via natural selection. The issue has been of particular concern in places like Mexico where numerous landraces of maize and its wild progenitors are grown next to each other. In fact, the Mexican government has banned the planting of GM maize since 1998. Despite the ban, several recent studies have found evidence of GM genetic material in cultivated maize grown in Mexico, though it's unclear from where this material originated.

At this stage, there are many unknowns when it comes to the potential impact on biodiversity. In those cases where the potential for hybridization is low, such as maize grown in the US, the risk is likely minimal. But what about crops like sunflowers, pecans, blueberries, and some squashes, which are native to the US? Should GM versions of these crops emerge, is there cause for concern? As advocated in the 2007 workshop, when the potential for hybridization does exist, it will be necessary to both quantify the extent of gene flow between populations and, importantly, assess the potential fitness advantages conferred by the genes in question. However, as in the question of food safety, it's not clear that the environmental issues raised by GM crops should be any different from traditionally created varieties. Both have the potential to affect wild gene pools.

Weighing the risks

As with any technology, at some point there has to be a cost/benefit analysis done. While all of the food safety scares surrounding GM food continue to be debunked as fast as they materialize, there are no doubt potential risks that are not yet fully understood, as can be seen in the ecology aspect of the debate. And there is nothing to say that new varieties of GM food could, in principle, potentially be harmful. On the other side of the ledger, however, we have the enormous challenge of feeding the world's population, which is rapidly growing on a planet with finite resources. Of course, malnourishment has many causes, including local politics and war, but agricultural technology will certainly factor importantly. And GM food has lived up to its promise of providing increased yields with less pesticide use and at a lower cost to the consumer. Not only this, but genetic engineering has the potential to provide much needed micronutrients (i.e., vitamins) to the malnourished of the world. A case in point is the recent development of an engineered form of rice that produces a precursor of vitamin A, dubbed 'golden rice'. This remarkable and easily implementable technology has the potential to mitigate hundreds of thousands of cases of blindness in the developing world, and yet it remains shelved due to unsubstantiated health concerns.

Many western consumers can afford to stock their refrigerators with organic produce, but can the rest of the world? Do the potential risks really trump malnourishment and starvation? While the interested parties continue to debate, science marches on. On the horizon are GM crops that can grow in inhospitable corners of the earth, such as the dry and salty environs. And we are now seeing the application of GM technology to animals, such as salmon engineered to reach market weight more quickly through the expression of genes encoding growth hormones. Whether these technologies are taken up or left to gather dust on the shelf will likely depend on the ability of scientists and the government to make a convincing case to the public. If they fail, we potentially handcuff ourselves and will be forced to rely on 20th century technology to solve 21st century problems.

Cyrus Martin is Senior Scientific Editor at *Current Biology*.

Does the gut microbiome hold clues to obesity and diabetes?

As high-throughput genome sequencing technology now enables researchers to study the microbiota in our digestive system both in breadth and in detail, the hope is that mysteries of common problems, including obesity and diabetes, will finally be solved. **Michael Gross** reports.

In antiquity, soothsayers used to inspect the entrails of animals, specifically the liver and intestines, to derive information about people's fates. One famous example of the practice resulted in the warning to Julius Caesar to "beware the Ides of March".

Modern times have been quick to dismiss this procedure, known as extispicy, which was widespread from the Hittites through to the Etruscans and Romans, as pure superstition. Now that we have learned to decipher DNA sequences, the fate of each living thing and each person (apart from unpredictable external influences) is surely to be read from their genomes.

Accordingly, researchers have studied genomes in great detail and learned a lot about evolution, development, and biological function, but they still haven't discovered the ultimate causes for common problems like obesity, heart disease, diabetes, and autism.

Maybe the clues to a person's fate are in the intestines after all? Since the publication of the first catalogue of microbial genes from human guts, the 'gut microbiome' (i.e. the collective genome of the resident species) in 2010, genomic analysis of our commensal bacteria has become a widely used approach that could even be called fashionable. But first signs are indicating that some of the long-lost answers to important medical questions may actually show up in the intestines.

Life inside us

In March 2010, researchers from the BGI in Shenzhen, China, and the international MetaHIT (Metagenomics of the Human Intestinal Tract) consortium reported a catalogue of 3.3 million different gene sequences from human intestines, representing around 150 times as many genes as are found