SCIENCE AT THE CROSSROADS

Genetically Modified Foods and the Attack on Nature

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Beginning three decades ago scientists learned how to sequence DNA and transfer it from one kind of organism to another. Since that time, claims about the power of the gene to determine and transform the properties of living forms have been unremitting in academic and popular venues. When proposals were first made to improve foods and other crop plants by introducing exogenous genes (experimental transgenesis, a type of genetic engineering), unsurprisingly, questions were raised about the capability of the methods to also induce harmful effects. Scenarios included the impairment of the quality and safety of fruits and vegetables, making them allergenic or toxic to humans and nonhumans who consume them, and the creation of superweeds, which could disrupt wild or farmed ecosystems. By 2005, however, when more than 90 percent of the annual soybean crop and 50 percent of the corn crop in the United States had come to be genetically engineered—a transformation in agricultural production that took less than a decade—efforts at regulation that had once made precautionary sense were increasingly portrayed as irrational. A constant stream of articles and books by ideological technophiles and recipients of corporate largesse portray resistance to, and even reservations about, genetically modified (GM) food as scientifically ignorant, economically suicidal, and cruel to the hungry of the world.

However, so far virtually all genetic modification of food and fiber crops has focused on the economic aspects of production (i.e., making crops resistant to herbicides and insect damage, increasing transportability and shelf-life) rather than improving nutrition or flavor, goals that have proved more elusive. In addition to introducing biological qualities that enhance production and transport efficiencies (some of which, indeed, are antithetical to improving the eating experience), branding and patenting—i.e., industrial hegemony—have been the major motivation for introducing genetically engineered plant varieties.

There have thus been enormous financial incentives associated with introducing genetic engineering methods into agriculture, with little concomitant benefit to the consumer other than, in certain cases, pricing. But even the benefit of lower prices from any efficiencies in production that may result from genetic engineering are questionable in the long term. This is because since GM products were first introduced in 1996, they have enabled agribusiness corporations to tighten their grip on food and other crop production by achieving legal prohibitions on replanting saved seed as well as exerting pressure on farmers by banks and governmental agencies to conform to an alleged dependable standard that discourages farmers from using traditionally bred alternatives.

Some early food safety concerns appear to have been allayed, at least for certain GM products and some of their consumers. For example, soybeans that have been endowed with a bacterial gene rendering them resistant to the Monsanto herbicide Roundup appear not to have enhanced allergenicity in humans. Studies of other GM crops, however, are less reassuring. “Bt corn” contains a foreign gene whose protein product enables the crop to resist damage by insect pests. When grown in soil in which Bt corn had previously been cultivated, nematode worms, important organisms in soil ecology, had significantly reduced reproduction and growth compared with worms reared on soil from plots of non-GM corn. Honeybees whose food was laced with the distinctive protein of Bt corn had disturbed feeding behavior and learning performance. Mammals are also vulnerable: rats fed over three generations on a diet containing Bt corn experienced pathological changes in their livers and kidneys.

While the safety of deliberately produced GM crops can, in principle, be assessed (recognizing that there are ongoing debates on what is relevant to measure), it is virtually impossible to keep track of all the ecological and evolutionary ramifications of inadvertent transfer of foreign genes, via pollen, to wild relatives of the GM varieties. Evidence for robust occurrence of this phenomenon is uncontested, although studies of whether it has already led to superweeds has been impeded by lack of cooperation by seed companies. Ecologically, transfer of an herbicide-resistance gene into a weed can convert it into a superweed. And from an evolutionary perspective, "lateral gene transfer"—that is, natural transgenesis—into plants from non-plant sources has been extremely rare in the history of life. In cases where it has been confirmed to have occurred, it has had major consequences to the plant's overt biological identity, or "phenotype." Existing varieties of plants with enhanced ranges (e.g., superweeds) and plants which represent true evolutionary novelties both have the potential to disrupt ecosystems that are already under threat from climate change.

While the technology holds clear benefits to agribusiness, few compelling benefits to the general public have been demonstrated, and as we have seen, there are some real liabilities. This creates a dilemma for the industry and its supporters. Sales opportunities can be found within aid agencies that pressure impoverished nations to accept GM crops as food aid. Societies in a better position to protect their cultural valuation of food, such as India, Western Europe, and communal movements of resistance in rural Columbia, have proved more difficult markets to crack. Anglo-American societies, which are traditionally less centered on food quality and provenance, have been readier recruits to the new agriculture. But it is also true that this effort was helped by a campaign to downplay and dismiss significant safety and environmental concerns about GM organisms that remain to this day, despite the fact that significant proportions of several important traditionally bred food crops (soybeans, corn, canola, and cotton) have come to be replaced by GM counterparts in the United States over the last thirteen years.

A succession of bizarre institutional threats and punitive actions meted out to challengers of the GM-friendly narrative is worth noting. These included the firing by a Scottish research institute of a respected scientist who unexpectedly found that feeding rats with a GM potato caused intestinal lesions; the initial administrative denial of tenure (despite strong department and committee recommendations) to a University of California, Berkeley ecologist critical of the use of GM crops and university concessions to biotechnology corporate funders; and an influential journal's "sandbagging" of a researcher, who found adverse reproductive and health effects of Roundup ready soybeans in rats, by inviting her to summarize her previously unpublished research in a semi-technical feature article and then including hostile commentaries on her partially described methods in the same article.

Much more interesting from a cultural-historical perspective than the attack on individual scientists in the campaign for GM foods, however, was the attack on the concept of the "natural." Nature, in the sense of a world independent of human activity, is fundamental to any materialist conception of science. In particular, the structure of atoms, the earth's topography, and the anatomical plans and physiology of most organisms existed before there were humans. The extent to which technologically untransformed nature represents a positive value is open to question, as is the point in any practice at which the natural and the artifactual become inextricable. That there is a conceptual difference between the natural and the human-made, however, is not open to question. Despite this truism, a 1999 report by the influential Nuffield Council on Bioethics on the social and ethical issues surrounding GM crops stated "[t]he 'natural/unnatural' distinction is one of which few practicing scientists can make much sense."

This *faux-naif* provocation is emblematic of an intellectual strategy taken by agribusiness and its academic allies directed toward collapsing all distinctions between the natural and artificial in biology, a maneuver I have termed "biological postmodernism." Before GM crops were placed on the market in the United States and Europe, a series of reports that had considered potential hazards of GM crops were published by national and international deliberative bodies. Among the earliest and most influential of these was the document "Field Testing Genetically Modified Organisms: Framework for Decisions," published in 1989 by the National Research Council, an arm of the U.S. National Academy of Science. Although there were earlier discussions at the National Academy itself and throughout the international scientific community that acknowledged some of the complexities and pitfalls of transgenic manipulations mentioned above, the NRC report stated quite simply that "…no conceptual distinctions exist between genetic modification of plants and microorganisms by classical methods or by molecular techniques that modify DNA and transfer genes."

Since the "classical" methods referred to were spontaneous and induced change in DNA sequence—"mutagenesis"—it is helpful to compare these methods with those employed in genetic engineering. In conventional agronomy, breeders select phenotypic variants associated with spontaneous mutations of genes that have co-evolved with all the other genes of the particular plant over tens or hundreds of millions of years. Methods of chemical or radiation-induced DNA mutagenesis used earlier in the 20th century, prior to the GM era, can change the sequence or rearrange the position in the chromosomes of the co-evolved genes. These classic mutagenesis methods and some newer genetic engineering techniques which simply inactivate existing genes may have unpredictable effects on the organism's morphological phenotype (i.e., shape, form, arrangement of parts), but they do not add molecular functionalities uncharacteristic of the species. In contrast, transgenesis, the most commonly used GM technique, involves introducing genes from distant species into a plant's or animal's genome—bacterially derived herbicide- or pest-resistance factors in soybeans and corn, or fish-derived antifreeze proteins in tomatoes, for example. Throwing an entirely new component into a plant's biological mix can potentially change the levels of the hundreds to thousands of potentially toxic molecules every plant is capable of manufacturing. Moreover, different insertions of the same "transgene" into the same plant can result in vastly different phenotypes due to variations in the position of insertion in the chromosomes. In addition, GM transgenesis can inadvertently induce extensive scrambling of the genome.

Scientific advocates of GM crops take comfort in the observation that "phenotypes and metabolic pathways tend to be buffered from the effects of mutations." However, such buffering mechanisms, whereby a plant or animal can develop into a form characteristic of its species despite alteration or even complete inactivation of many genes, are products of integration of the genome through co-evolution of genes and natural selection for developmental stability. They would only fortuitously and inexactly pertain to transgenic organisms. The assertion that the outcomes of transgenesis are more predictable than traditional breeding or mutagenesis because the manipulations are more precise at the DNA level simply ignores the findings of cell physiology and evolutionary biology.

The main conclusion of the NRC's report mentioned above was that "the *product* of genetic modification and selection constitutes the primary basis for decisions on the environmental introduction of a plant or microorganism, and not the *process* by which the product was obtained." Four years later, when the joint U.S.-E.U. Organization for Economic Cooperation and Development met to produce a report on "Safety Evaluation of Foods Derived by Modern Biotechnology," the U.S. position, which was based on the NRC's dismissal of any special issues arising from genetic modification of crops, held sway, crystallizing into the OECD's doctrine of "substantial equivalence" of GM and traditionally bred plants.

While initially serving as a basis for international consensus on the global marketing of GM foods, the substantial equivalence doctrine came under increasing attack in the U.K. and other E.U. countries over the next decade as new data from field and laboratory tests exposed it as unscientific and ill-defined. In the United States, however, it remained the operative principle governing the regulation of transgenic GM crops. But despite some technical advances, there are still no adequate testing methods in place to screen for phenotypes harmful to the environment or human and animal health potentially generated by transgenic GM techniques. While this is also true for conventionally bred crops, as noted above, the phenotypic novelties that may arise from transgenesis are likely to be different from those latent in the population or inducible by alteration of existing co-evolved genes.

With the doctrine of substantial equivalence in hand, corporate leaders in the agricultural biotechnology sector and their academic allies took up the gauntlet of negotiating the natural/unnatural boundary, getting the Clinton Administration's Secretary of Agriculture, Dan Glickman, to propose U.S. Department of Agriculture (USDA) standards to make GM food (as well as food irradiated to increase shelf life or grown with the aid of toxic sewage sludge), eligible for labeling as "organic." The original organic standards were delineated in 1990 by the U.S. Congress in a directive to the USDA. Though not a scientific term, "organic" on a label was meant to assure people that food crops have been produced by a management system that "promotes and enhances biodiversity, biological cycles and soil biological activity...based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony." Imprecise as this may be, it is clear what kinds of processes and products consumers of organic food favor: as distant as feasible from the high-tech, chemical-intensive, monoculture characteristic of the large-scale, absentee-owned, contract-farmed agricultural enterprises.

Apart from questions of whether or not organic farming embodies all the health and environmental advantages claimed by its supporters is the issue of people's right to know what they are eating. The debate over the definition of organic food is thus an example of what science and technology analyst Sheila Jasanoff refers to as "boundary work" by which the demarcation between the natural and the unnatural is negotiated in any society.

With the doctrine of substantial equivalence in disrepute everywhere but in the United States and the U.S. government's campaign to get GM foods labeled as organic a failure after a massive public protest in the form of several hundred thousand letters prevented the USDA in 2000 from implementing this proposal, deregulating the technology entirely so as to end all public awareness and scrutiny of it moved to the top of the industry's agenda. The final arrow in the biological postmodernists' quiver was therefore released: the denial of any distinctiveness whatsoever to genetic engineering technology.

In 2003 a commentary on new research on the origins of maize was published in the journal *Science*. The article itself was an unexceptionable summary of what is known about the cultivation of maize over the past 4,000 years, placed in the context of current knowledge of the genes involved. The only reference to present-day technology was the last sentence, which concluded that "the rapid adoption of superior GM crops today…is far from a new phenomenon," in effect denying that GM foods represent novel agricultural products. It did this by the maneuver of defining all cultivated crops, extending back to the New Stone Age, as genetically engineered. The author, an academic scientist and a member of the board of directors of Sigma-Aldrich, a company that markets pharmaceutical products extracted from transgenic corn, was not explicit about her intention of shifting the discourse concerning genetic engineering of crops by obfuscating its differences from traditional breeding practices until she was confronted by other scientists in *Science*'s letters column. And indeed the magazine's editors colluded in helping her slip this "reframing" of the field past readers and into the scientific literature when they permitted her to give the article its provocative title and allowed her to leave her corporate affiliation off the author's note.

Some of the comments received by *Science* in response to the article are instructive. One correspondent stated, "N.V. Fedoroff's Perspective 'Prehistoric GM corn'…seems calculated to obscure important issues in the debate over the safety of genetically modified organisms (GMOs)," while another asserted, "It is not a question of whether genetic engineering is good, bad, or irrelevant, but clarity of understanding requires that a distinction be recognized." In her reply Fedoroff stated, "[I]t is time to eliminate the altogether artificial boundary between what humans did before molecular techniques were developed and what they do now to improve their crop plants," and then went on to conflate spontaneous mutations, radiation-induced mutations, and transgenesis. As noted above, the last of these, the characteristic method for producing GM crops, is entirely different from the first two.

Introduction of products based on novel technologies traditionally have been advertised as "new and improved" or even "revolutionary"; in particular, their differences from existing counterparts have been emphasized and portrayed as beneficial. With regard to

GM food, it became clear early on that this strategy of differentiation would not work; people were too suspicious of significant changes in what they eat for them to respond positively to such claims. It became necessary instead to reassure the public that nothing in the nature of their food crops would change despite the new methods used to produce them—methods, which, paradoxically, were sold to potential investors as unprecedented in their power.

By conflating GM transgenesis with conventional mutagenesis, traditional selective breeding, and evolution itself, and portraying it as nothing new—and indeed "organic"—agribusiness and its allies successfully sold GM foods to the greater, largely unaware and ill-informed public, as well as, more importantly, to governmental officials. At this point the die is cast; GM crops are here to stay. However, rather than fitting the conventional notion of a revolutionizing technology, the "killer app," GM agriculture will likely continue to be problematic, with environmental and health effects occasionally rising to a noticeable level, along with the rare and probably transient, success and a consistent theme of industrial concentration and hegemony over food production.

Finally, it is important to recognize that bringing GM agriculture to the necessary level of acceptance could not be accomplished on the technology's merits. It required an attack on the very idea that there is a natural world conceptually separate from the products of commercial technology. It would be a mistake, however, to imagine that this work was performed solely by corporate flacks and grantees cynically pursuing individual gain. The academic and think-tank intellectuals that have bought into and are advancing this may be misguided, but they need to be taken seriously. As with the debate over evolutionary theory and the battle for public acceptance of the relevant facts, clashes of ideology encompassing questions of materialism and idealism, determinism and emergence, and social conflict around the definition and appropriation of nature rage at levels deeper than the deepest pockets.