CEI's Monthly Planet

Fighting For Freedom

October 2004 Competitive Enterprise Institute Volume 17, Number 8

The Origins of "Biotechnology"

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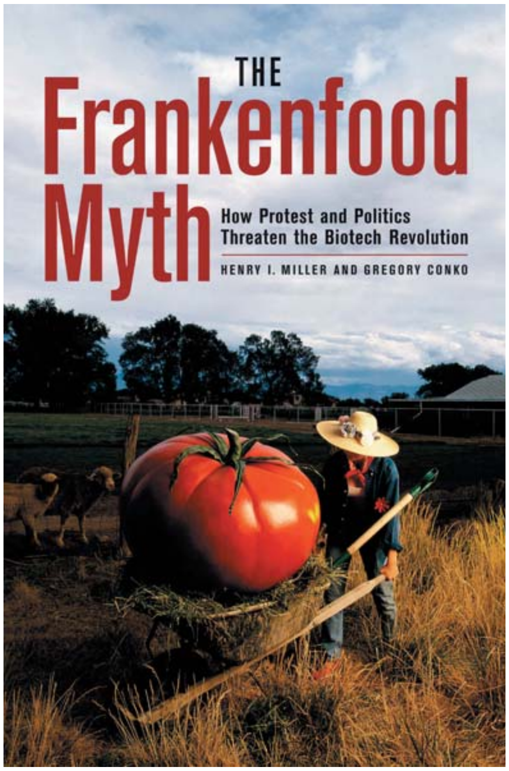
Excerpted from Chapter 1 of *The Frankenfood Myth: How Protest and Politics Threaten the Biotech Revolution*, by Henry I. Miller and Gregory Conko (Praeger, 2004).



Thirty years ago, headlines in scientific journals and popular media announced the arrival of a "biological revolution" and the resulting transformation of research, industries, and consumer products in ways never thought possible. "Biotechnology" would convert bacteria into miniature factories to make drugs and fine chemicals; and "genetically engineered" plants and animals would be used for food products with characteristics unachievable through traditional breeding. Companies were founded by the hundreds, private investment soared, and stock markets couldn't get enough of their newfound darlings.

With the advantage of hindsight, would we now characterize this biotechnological new era as revolution, or merely evolution? Certainly the latter. But in order to understand why, some background is necessary.

Today, "biotechnology" is often used interchangeably with other terms, such as "genetic engineering," "genetic modification," and "bioengineering"—each of which may at times mean something very different to scientists, consumers, lawyers, government regulators, or laymen.

Since the invention in the early 1970s of recombinant DNA technology, biotechnology has come to connote the use of these techniques for genetic improvement at the molecular level. But the term was coined by Hungarian agricultural engineer Karl Ereky, who first used the word in 1917 to describe his use of an improved pig feed supplemented with sugar beets to carry out more intensive animal husbandry.

More generally, "biotechnology" has been used by scientists to describe the use of living organisms to create consumer or industrial products. This broad definition clearly encompasses a spectrum of old

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and new processes and products as different as fish farming, the production of enzymes for laundry detergents, and the genetic modification of bacteria to enable them to clean up oil spills or synthesize human insulin.

The ancients practiced early biotechnology by using yeasts to produce alcoholic beverages and by selecting and hybridizing plants with desirable traits in order to retain and exaggerate them. Many people are surprised to learn that one of the ubiquitous uses of pre-recombinant-DNA genetically improved organisms is the vaccination of human and animal populations with live, weakened viruses.

In agriculture, the old biotechnology includes not only virtually every plant that is cultivated commercially but also a wide spectrum of organisms used in pest control—including many organisms often considered to be pests themselves in other settings. Insect release was used successfully to control troublesome weeds in Hawaii in the early 20th century and "Klamath weed" in California in the 1940s and 1950s.

The crowning glory of improved genetic varieties used in agriculture is surely the collection of plants that created the "Green Revolution," which has dramatically increased human longevity and improved the quality of life in developing countries. Long before the advent of recombinant DNA methods, 20th century plant breeders sought ways to take advantage of useful genes and gradually found a progressively wider range of plant species and genera on which to draw.

Beyond Simple Hybridization

Early plant improvement relied on using selection pressures to choose plants with the best characteristics for the following year's seed stock. Next came the intentional mating of two plants of the same species or variety. Most non-experts still believe that selection and hybridization between closely related varieties remained the only options for plant improvement until the advent of gene-splicing techniques in the 1970s, but nothing could be farther from the truth.

Breeders first achieved interspecies hybridization in the early 20th century, transferring "alien" genes between different but related species. Next came ways to perform even wider crosses, between members of different genera. These "wide cross hybrids," which by definition break the "species barrier" much revered by biotechnology's opponents, routinely introduce thousands or tens of thousands of entirely new genes into crop plants.

Critics of the new biotechnology often disparage it as "unnatural," but context is critical. Wide crosses, whose fruits we enjoy every day, are at least as "unnatural" as gene-splicing—if by that term one means a process that does not occur in nature.

Most wide crosses cannot exist in nature, because the resulting embryos have an abnormal endosperm and will die shortly after fertilization. But with the development of tissue culture techniques in the early 20th century, wide-cross hybrid embryos could be "rescued" and cultured in a laboratory environment. Even when such rescued embryos do grow to maturation, however, they typically produce sterile offspring. Using yet another unnatural technique, breeders can occasionally make them fertile again by dousing plants with chemicals that cause the plant cells to mutate and create additional sets of chromosomes.

The plant triticale, an artificial hybrid of wheat and rye, is one such example of a wide-cross hybrid made possible solely by the existence of embryo-rescue and chromosome-doubling techniques. And it is unnatural in that triticale is not found in nature and sophisticated laboratory equipment was necessary to create it. Yet gene splicing, or molecular biotechnology, played no role at all in its development.

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Many such unnatural combinations are grown commercially in the United States and abroad. Other wide-cross hybrids include familiar and widely used varieties of tomato, potato, oat, sugar beet, bread and durum wheat, rice, and squash. Many, if not most, of the bread wheat and durum pasta wheat varieties grown by farmers in the United States are the products of wide-cross breeding programs.

Another pre-recombinant DNA breeding technique is mutation breeding, in which breeders expose seeds or young plants to chemicals or ionizing radiation—such as X-rays or gamma rays—to induce random genetic mutations. These treatments most often kill the plants or seeds, or cause deleterious genetic changes. On rare occasions, though, the result is a desirable mutation—for example, one producing altered height, more seeds, or larger fruit. But because of the severe and random DNA alteration, breeders have no real knowledge of the exact nature of the genetic mutation that produced the useful trait or of what other mutations might have occurred in the plant.

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Nevertheless, more than 2,250 mutation-bred varieties of corn, wheat, rice, squash, beans, and dozens of other crop species have been introduced over the last half-century. These crops and their offspring have been grown in more than 50 countries around the world, including the United States. Many are still being cultivated. Wheat, which itself resulted from the more-or-less natural combination of three different grass species from two different genera, has been among the most commonly mutated species. Nearly 200 different varieties of bread wheat have been produced with mutation breeding, as well as some 25 varieties of durum pasta wheat.

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Nature and the New Biotechnology

These are just some of the methods categorized as "conventional" plant breeding that are neither opposed by critics of biotechnology nor scrutinized case-by-case by regulators. Unless one's diet is limited to wild berries, wild mushrooms, wild-caught fish and shellfish, and wild game, it is virtually impossible to avoid these "unnatural" genetically modified organisms (GMOs).

That is the irony of those who oppose or have reservations about GMOs, or so-called Frankenfoods. By enabling plant breeders and biologists to identify and transfer single genes encoding specific traits of interest, recombinant DNA techniques have greatly refined the less precise, brute-force methods of "conventional" genetic modification. Breeders can now readily transfer selected and well-characterized genetic material from virtually any source in nature, exploiting nature's ingenuity, and greatly increasing the diversity of useful genes and germplasm available for crop improvement.

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In addition, the safety assessment of plants and food is enhanced by the greater sensitivity and precision of recombinant DNA techniques. If a new plant variety differs from its antecedent by only the introduction of a single gene, it is far easier to assess its agronomic traits, and to perform pharmacological, toxicological, and ecological testing, than if thousands of new genes were introduced or modified.

Indeed, compared to the "unnatural" brute-force methods of conventional plant breeding as it is now practiced, many rDNA techniques are relatively "natural." Gene splicing relies on naturally occurring enzymes to cut DNA at defined sequences and rejoin the fragments to form linked recombinant DNA molecules. And scientists first learned how to bioengineer plants by observing a natural soil bacterium insert some of its own genes into plant cells, which would then integrate the bacterial DNA into the plant's genome. Scientists simply piggyback on this natural process by replacing the bacteria's infectious DNA with useful genes to produce a new plant variety with improved traits.

Of course, what is and is not natural is irrelevant, since what actually matters is comparative safety. Many natural things, such as diseases, toxins, hunger, and poverty are quite dangerous. We rely on man-made technologies to protect us from those threats. So it is with gene-splicing and the new biotechnology. We can use this improved technique of crop modification to make our world and our lives safer.

Tragically, it is this more precise and predictable method of plant breeding that is attacked as dangerous. We have had two decades of widespread pre-commercial and commercial cultivation of environment-friendly, enhanced-productivity crops—including more than 100 million acres annually for most of the last decade—and yet the new biotechnology remains widely misrepresented and beleaguered by anti-technology and anti-globalization activists, poorly defended by its own practitioners, and discriminated against in public policy.

We will discuss some of these problems, and our recommendations for how to resolve them, in the next issue of the *Monthly Planet*.

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