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Will Frankenfood Save the Planet?

Over the next half century genetic engineering could feed humanity and solve a raft of environmental ills—if only environmentalists would let it

BY JONATHAN RAUCH

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That genetic engineering may be the most environmentally beneficial technology to have emerged in decades, or possibly centuries, is not immediately obvious. Certainly, at least, it is not obvious to the many U.S. and foreign environmental groups that regard biotechnology as a bête noire. Nor is it necessarily obvious to people who grew up in cities, and who have only an inkling of what happens on a modern farm. Being agriculturally illiterate myself, I set out to look at what may be, if the planet is fortunate, the farming of the future.

It was baking hot that April day. I traveled with two Virginia state soil-and-water-conservation officers and an agricultural-extension agent to an area not far from Richmond. The farmers there are national (and therefore world) leaders in the application of what is known as continuous no-till farming. In plain English, they don't plough. For thousands of years, since the dawn of the agricultural revolution, farmers have ploughed, often several times a year; and with ploughing has come runoff that pollutes rivers and blights aquatic habitat, erosion that wears away the land, and the release into the atmosphere of greenhouse gases stored in the soil. Today, at last, farmers are working out methods that have begun to make ploughing obsolete.

At about one-thirty we arrived at a 200-acre patch of farmland known as the Good Luck Tract. No one seemed to know the provenance of the name, but the best guess was that somebody had said something like "You intend to farm this? Good luck!" The land was rolling, rather than flat, and its slopes came together to form natural troughs for rainwater. Ordinarily this highly erodible land would be suitable for cows, not crops. Yet it was dense with wheat—wheat yielding almost twice what could normally be expected, and in soil that had grown richer in organic matter, and thus more nourishing to crops, even as the land was farmed. Perhaps most striking was the almost complete absence of any chemical or soil runoff. Even the beating administered in 1999 by Hurricane Floyd, which lashed the ground with nineteen inches of rain in less than twenty-four hours, produced no significant runoff or erosion. The land simply absorbed the sheets of water before they could course downhill.

At another site, a few miles away, I saw why. On land planted in corn whose shoots had only just broken the surface, Paul Davis, the extension agent, wedged a shovel into the ground and dislodged about eight inches of topsoil. Then he reached down and picked up

a clump. Ploughed soil, having been stirred up and turned over again and again, becomes lifeless and homogeneous, but the clump that Davis held out was alive. I immediately noticed three squirming earthworms, one grub, and quantities of tiny white insects that looked very busy. As if in greeting, a worm defecated. "Plant-available food!" a delighted Davis exclaimed.

This soil, like that of the Good Luck Tract, had not been ploughed for years, allowing the underground ecosystem to return. Insects and roots and microorganisms had given the soil an elaborate architecture, which held the earth in place and made it a sponge for water. That was why erosion and runoff had been reduced to practically nil. Crops thrived because worms were doing the ploughing. Crop residue that was left on the ground, rather than ploughed under as usual, provided nourishment for the soil's biota and, as it decayed, enriched the soil. The farmer saved the fuel he would have used driving back and forth with a heavy plough. That saved money, and of course it also saved energy and reduced pollution. On top of all that, crop yields were better than with conventional methods.

The conservation people in Virginia were full of excitement over no-till farming. Their job was to clean up the James and York Rivers and the rest of the Chesapeake Bay watershed. Most of the sediment that clogs and clouds the rivers, and most of the fertilizer runoff that causes the algae blooms that kill fish, comes from farmland. By all but eliminating agricultural erosion and runoff—so Brian Noyes, the local conservation-district manager, told me—continuous no-till could "revolutionize" the area's water quality.

Even granting that Noyes is an enthusiast, from an environmental point of view no-till farming looks like a dramatic advance. The rub—if it is a rub—is that the widespread elimination of the plough depends on genetically modified crops.

t is only a modest exaggeration to say that as goes agriculture, so goes the planet. Of all the human activities that shape the environment, agriculture is the single most important, and it is well ahead of whatever comes second. Today about 38 percent of the earth's land area is cropland or pasture—a total that has crept upward over the past few decades as global population has grown. The increase has been gradual, only about 0.3 percent a year; but that still translates into an additional Greece or Nicaragua cultivated or grazed every year.

Farming does not go easy on the earth, and never has. To farm is to make war upon millions of plants (weeds, so-called) and animals (pests, so-called) that in the ordinary course of things would crowd out or eat or infest whatever it is a farmer is growing. Crop monocultures, as whole fields of only wheat or corn or any other single plant are called, make poor habitat and are vulnerable to disease and disaster. Although fertilizer runs off and pollutes water, farming without fertilizer will deplete and eventually exhaust the soil. Pesticides can harm the health of human beings and kill desirable or harmless bugs along with pests. Irrigation leaves behind trace elements that can accumulate and poison the soil. And on and on.

From the archives:

"The Next American Dust Bowl ... and How to Avert It" (July 1979)
Serious large-scale farmers are giving organic methods a try, with startling success.
By William Tucker
The trade-offs are fundamental. Organic farming, for example, uses no artificial fertilizer, but it does use a lot of manure, which can pollute water and contaminate food. Traditional farmers may use less herbicide, but they also do more ploughing, with all the ensuing environmental complications. Low-input agriculture uses fewer chemicals but more land. The point is not that farming is an environmental crime—it is not—but that there is no escaping the pressure it puts on the planet.

In the next half century the pressure will intensify. The United Nations, in its midrange projections, estimates that the earth's human population will grow by more than 40 percent, from 6.3 billion people today to 8.9 billion in 2050. Feeding all those people, and feeding their billion or so hungry pets (a dog or a cat is one of the first things people want once they move beyond a subsistence lifestyle), and providing the increasingly protein-rich diets that an increasingly wealthy world will expect—doing all of that will require food output to at least double, and possibly triple.

But then the story will change. According to the UN's midrange projections (which may, if anything, err somewhat on the high side), around 2050 the world's population will more or less level off. Even if the growth does not stop, it will slow. The crunch will be over. In fact, if in 2050 crop yields are still increasing, if most of the world is economically developed, and if population pressures are declining or even reversing—all of which seems reasonably likely—then the human species may at long last be able to feed itself, year in and year out, without putting any additional net stress on the environment. We might even be able to grow everything we need while *reducing* our agricultural footprint: returning cropland to wilderness, repairing damaged soils, restoring ecosystems, and so on. In other words, human agriculture might be placed on a sustainable footing forever: a breathtaking prospect.

The great problem, then, is to get through the next four or five decades with as little environmental damage as possible. That is where biotechnology comes in.

ne day recently I drove down to southern Virginia to visit Dennis Avery and his son, Alex. The older Avery, a man in late middle age with a chinstrap beard, droopy eyes, and an intent, scholarly manner, lives on ninety-seven acres that he shares with horses, chickens, fish, cats, dogs, bluebirds, ducks, transient geese, and assorted other creatures. He is the director of global food issues at the Hudson Institute, a conservative think tank; Alex works with him, and is trained as a plant physiologist. We sat in a sunroom at the back of the house, our afternoon conversation punctuated every so often by dog snores and rooster crows. We talked for a little while about the Green Revolution, a dramatic advance in farm productivity that fed the world's burgeoning population over the past four decades, and then I asked if the challenge of the next four decades could be met.

"Well," Dennis replied, "we have tripled the world's farm output since 1960. And we're feeding twice as many people from the same land. That was a heroic achievement. But we have to do what some think is an even more difficult thing in this next forty years, because the Green Revolution had more land per person and more water per person—"

"—and more potential for increases," Alex added, "because the base that we were starting from was so much lower."

"By and large," Dennis went on, "the world's civilizations have been built around its best farmland. And we have used most of the world's good farmland. Most of the good land is already heavily fertilized. Most of the good land is already being planted with high-yield seeds. [Africa is the important exception.] Most of the good irrigation sites are used. We can't triple yields again with the technologies we're already using. And we might be lucky to get a fifty percent yield increase if we froze our technology short of biotech."

"Biotech" can refer to a number of things, but the relevant application here is genetic modification: the selective transfer of genes from one organism to another. Ordinary breeding can cross related varieties, but it cannot take a gene from a bacterium, for instance, and transfer it to a wheat plant. The organisms resulting from gene transfers are called "transgenic" by scientists—and "Frankenfood" by many greens.

Gene transfer poses risks, unquestionably. So, for that matter, does traditional crossbreeding. But many people worry that transgenic organisms might prove more unpredictable. One possibility is that transgenic crops would spread from fields into forests or other wild lands and there become environmental nuisances, or worse. A further risk is that transgenic plants might cross-pollinate with neighboring wild plants, producing "superweeds" or other invasive or destructive varieties in the wild. Those risks are real enough that even most biotech enthusiasts—including Dennis Avery, for example—favor some government regulation of transgenic crops.

What is much less widely appreciated is biotech's potential to do the environment good. Take as an example continuous no-till farming, which really works best with the help of transgenic crops. Human beings have been ploughing for so long that we tend to forget why we started doing it in the first place. The short answer: weed control. Turning over the soil between plantings smothers weeds and their seeds. If you don't plough, your land becomes a weed garden—unless you use herbicides to kill the weeds. Herbicides, however, are expensive, and can be complicated to apply. And they tend to kill the good with the bad.

In the mid-1990s the agricultural-products company Monsanto introduced a transgenic soybean variety called Roundup Ready. As the name implies, these soybeans tolerate Roundup, an herbicide (also made by Monsanto) that kills many kinds of weeds and then quickly breaks down into harmless ingredients. Equipped with Roundup Ready crops, farmers found that they could retire their ploughs and control weeds with just a few applications of a single, relatively benign herbicide—instead of many applications of a

complex and expensive menu of chemicals. More than a third of all U.S. soybeans are now grown without ploughing, mostly owing to the introduction of Roundup Ready varieties. Ploughless cotton farming has likewise received a big boost from the advent of bioengineered varieties. No-till farming without biotech is possible, but it's more difficult and expensive, which is why no-till and biotech are advancing in tandem.

In 2001 a group of scientists announced that they had engineered a transgenic tomato plant able to thrive on salty water—water, in fact, almost half as salty as seawater, and fifty times as salty as tomatoes can ordinarily abide. One of the researchers was quoted as saying, "I've already transformed tomato, tobacco, and canola. I believe I can transform any crop with this gene"—just the sort of Frankenstein hubris that makes environmentalists shudder. But consider the environmental implications. Irrigation has for millennia been a cornerstone of agriculture, but it comes at a price. As irrigation water evaporates, it leaves behind traces of salt, which accumulate in the soil and gradually render it infertile. (As any Roman legion knows, to destroy a nation's agricultural base you salt the soil.) Every year the world loses about 25 million acres—an area equivalent to a fifth of California—to salinity; 40 percent of the world's irrigated land, and 25 percent of America's, has been hurt to some degree. For decades traditional plant breeders tried to create salt-tolerant crop plants, and for decades they failed.

Salt-tolerant crops might bring millions of acres of wounded or crippled land back into production. "And it gets better," Alex Avery told me. The transgenic tomato plants take up and sequester in their leaves as much as six or seven percent of their weight in sodium. "Theoretically," Alex said, "you could reclaim a salt-contaminated field by growing enough of these crops to remove the salts from the soil."

His father chimed in: "We've worried about being able to keep these salt-contaminated fields going even for decades. We can now think about *centuries*."

One of the first biotech crops to reach the market, in the mid-1990s, was a cotton plant that makes its own pesticide. Scientists incorporated into the plant a toxin-producing gene from a soil bacterium known as *Bacillus thuringiensis*. With Bt cotton, as it is called, farmers can spray much less, and the poison contained in the plant is delivered only to bugs that actually eat the crop. As any environmentalist can tell you, insecticide is not very nice stuff—especially if you breathe it, which many Third World farmers do as they walk through their fields with backpack sprayers.

Transgenic cotton reduced pesticide use by more than two million pounds in the United States from 1996 to 2000, and it has reduced pesticide sprayings in parts of China by more than half. Earlier this year the Environmental Protection Agency approved a genetically modified corn that resists a beetle larva known as rootworm. Because rootworm is American corn's most voracious enemy, this new variety has the potential to reduce annual pesticide use in America by more than 14 million pounds. It could reduce or eliminate the spraying of pesticide on 23 million acres of U.S. land.

All of that is the beginning, not the end. Bioengineers are also working, for instance, on

crops that tolerate aluminum, another major contaminant of soil, especially in the tropics. Return an acre of farmland to productivity, or double yields on an already productive acre, and, other things being equal, you reduce by an acre the amount of virgin forest or savannah that will be stripped and cultivated. That may be the most important benefit of all.

f the many people I have interviewed in my twenty years as a journalist, Norman Borlaug must be the one who has saved the most lives. Today he is an unprepossessing eighty-nine-year-old man of middling height, with crystal-bright blue eyes and thinning white hair. He still loves to talk about plant breeding, the discipline that won him the 1970 Nobel Peace Prize: Borlaug led efforts to breed the staples of the Green Revolution. (See "Forgotten Benefactor of Humanity," by Gregg Easterbrook, an article on Borlaug in the January 1997 *Atlantic*.) Yet the renowned plant breeder is quick to mention that he began his career, in the 1930s, in forestry, and that forest conservation has never been far from his thoughts. In the 1960s, while he was working to improve crop yields in India and Pakistan, he made a mental connection. He would create tables detailing acres under cultivation and average yields—and then, in another column, he would estimate how much land had been saved by higher farm productivity. Later, in the 1980s and 1990s, he and others began paying increased attention to what some agricultural economists now call the Borlaug hypothesis: that the Green Revolution has saved not only many human lives but, by improving the productivity of existing farmland, also millions of acres of tropical forest and other habitat—and so has saved countless animal lives.

From the 1960s through the 1980s, for example, Green Revolution advances saved more than 100 million acres of wild lands in India. More recently, higher yields in rice, coffee, vegetables, and other crops have reduced or in some cases stopped forest-clearing in Honduras, the Philippines, and elsewhere. Dennis Avery estimates that if farming techniques and yields had not improved since 1950, the world would have lost an additional 20 million or so square miles of wildlife habitat, most of it forest. About 16 million square miles of forest exists today. "What I'm saying," Avery said, in response to my puzzled expression, "is that we have saved every square mile of forest on the planet."

Habitat destruction remains a serious environmental problem; in some respects it is the most serious. The savannahs and tropical forests of Central and South America, Asia, and Africa by and large make poor farmland, but they are the earth's storehouses of biodiversity, and the forests are the earth's lungs. Since 1972 about 200,000 square miles of Amazon rain forest have been cleared for crops and pasture; from 1966 to 1994 all but three of the Central American countries cleared more forest than they left standing. Mexico is losing more than 4,000 square miles of forest a year to peasant farms; sub-Saharan Africa is losing more than 19,000.

That is why the great challenge of the next four or five decades is not to feed an additional three billion people (and their pets) but to do so without converting much of the world's prime habitat into second- or third-rate farmland. Now, most agronomists agree that some substantial yield improvements are still to be had from advances in conventional breeding, fertilizers, herbicides, and other Green Revolution standbys. But it

seems pretty clear that biotechnology holds more promise—probably much more. Recall that world food output will need to at least double and possibly triple over the next several decades. Even if production could be increased that much using conventional technology, which is doubtful, the required amounts of pesticide and fertilizer and other polluting chemicals would be immense. If properly developed, disseminated, and used, genetically modified crops might well be the best hope the planet has got.

f properly developed, disseminated, and used. That tripartite qualification turns out to be important, and it brings the environmental community squarely, and at the moment rather jarringly, into the picture.

Not long ago I went to see David Sandalow in his office at the World Wildlife Fund, in Washington, D.C. Sandalow, the organization's executive vice-president in charge of conservation programs, is a tall, affable, polished, and slightly reticent man in his forties who holds degrees from Yale and the University of Michigan Law School.

Some weeks earlier, over lunch, I had mentioned Dennis Avery's claim that genetic modification had great environmental potential. I was surprised when Sandalow told me he agreed. Later, in our interview in his office, I asked him to elaborate. "With biotechnology," he said, "there are no simple answers. Biotechnology has huge potential benefits and huge risks, and we need to address both as we move forward. The huge potential benefits include increased productivity of arable land, which could relieve pressure on forests. They include decreased pesticide usage. But the huge risks include severe ecological disruptions—from gene flow and from enhanced invasiveness, which is a very antiseptic word for some very scary stuff."

I asked if he thought that, absent biotechnology, the world could feed everybody over the next forty or fifty years without ploughing down the rain forests. Instead of answering directly he said, "Biotechnology could be part of our arsenal if we can overcome some of the barriers. It will never be a panacea or a magic bullet. But nor should we remove it from our tool kit."

Sandalow is unusual. Very few credentialed greens talk the way he does about biotechnology, at least publicly. They would readily agree with him about the huge risks, but they wouldn't be caught dead speaking of huge potential benefits—a point I will come back to. From an ecological point of view, a very great deal depends on other environmentalists' coming to think more the way Sandalow does.

Biotech companies are in business to make money. That is fitting and proper. But developing and testing new transgenic crops is expensive and commercially risky, to say nothing of politically controversial. When they decide how to invest their research-and-development money, biotech companies will naturally seek products for which farmers and consumers will pay top dollar. Roundup Ready products, for instance, are well suited to U.S. farming, with its high levels of capital spending on such things as herbicides and automated sprayers. Poor farmers in the developing world, of course, have much less buying power. Creating, say, salt-tolerant cassava suitable for growing on hardscrabble

African farms might save habitat as well as lives —but commercial enterprises are not likely to fall over one another in a rush to do it.

If earth-friendly transgenics are developed, the next problem is disseminating them. As a number of the farmers and experts I talked to were quick to mention, switching to an unfamiliar new technology—something like no-till—is not easy. It requires capital investment in new seed and equipment, mastery of new skills and methods, a fragile transition period as farmer and ecology readjust, and an often considerable amount of trial and error to find out what works best on any given field. Such problems are only magnified in the Third World, where the learning curve is steeper and capital cushions are thin to nonexistent. Just handing a peasant farmer a bag of newfangled seed is not enough. In many cases peasant farmers will need one-on-one attention. Many will need help to pay for the seed, too.

Finally there is the matter of using biotech in a way that actually benefits the environment. Often the technological blade can cut either way, especially in the short run. A salt-tolerant or drought-resistant rice that allowed farmers to keep land in production might also induce them to plough up virgin land that previously was too salty or too dry to farm. If the effect of improved seed is to make farming more profitable, farmers may respond, at least temporarily, by bringing more land into production. If a farm becomes more productive, it may require fewer workers; and if local labor markets cannot provide jobs for them, displaced workers may move to a nearby patch of rain forest and burn it down to make way for subsistence farming. Such transition problems are solvable, but they need money and attention.

In short, realizing the great—probably unique—environmental potential of biotech will require stewardship. "It's a tool," Sara Scherr, an agricultural economist with the conservation group Forest Trends, told me, "but it's absolutely not going to happen automatically."

So now ask a question: Who is the natural constituency for earth-friendly biotechnology? Who cares enough to lobby governments to underwrite research—frequently unprofitable research—on transgenic crops that might restore soils or cut down on pesticides in poor countries? Who cares enough to teach Asian or African farmers, one by one, how to farm without ploughing? Who cares enough to help poor farmers afford high-tech, earth-friendly seed? Who cares enough to agitate for programs and reforms that might steer displaced peasants and profit-seeking farmers away from sensitive lands? Not politicians, for the most part. Not farmers. Not corporations. Not consumers.

At the World Resources Institute, an environmental think tank in Washington, the molecular biologist Don Doering envisions transgenic crops designed specifically to solve environmental problems: crops that might fertilize the soil, crops that could clean water, crops tailored to remedy the ecological problems of specific places. "Suddenly you might find yourself with a virtually chemical-free agriculture, where your cropland itself is filtering the water, it's protecting the watershed, it's providing habitat," Doering told me. "There is still so little investment in what I call design-for-environment." The natural

constituency for such investment is, of course, environmentalists.

ut environmentalists are not acting as such a constituency today. They are doing the opposite. For example, Greenpeace declares on its Web site: "The introduction of genetically engineered (GE) organisms into the complex ecosystems of our environment is a dangerous global experiment with nature and evolution ... GE organisms must not be released into the environment. They pose unacceptable risks to ecosystems, and have the potential to threaten biodiversity, wildlife and sustainable forms of agriculture."

Other groups argue for what they call the Precautionary Principle, under which no transgenic crop could be used until proven benign in virtually all respects. The Sierra Club says on its Web site,
In accordance with this Precautionary Principle, we call for a moratorium on the planting of all genetically engineered crops and the release of all GEOs [genetically engineered organisms] into the environment, *including those now approved*. Releases should be delayed until extensive, rigorous research is done which determines the long-term environmental and health impacts of each GEO and there is public debate to ascertain the need for the use of each GEO intended for release into the environment. [italics added]
Under this policy the cleaner water and healthier soil that continuous no-till farming has already brought to the Chesapeake Bay watershed would be undone, and countless tons of polluted runoff and eroded topsoil would accumulate in Virginia rivers and streams while debaters debated and researchers researched. Recall David Sandalow: "Biotechnology has huge potential benefits and huge risks, and we need to address both as we move forward." A lot of environmentalists would say instead, "*before* we move forward." That is an important difference, particularly because the big population squeeze will happen not in the distant future but over the next several decades.

For reasons having more to do with politics than with logic, the modern environmental movement was to a large extent founded on suspicion of markets and artificial substances. Markets exploit the earth; chemicals poison it. Biotech touches both hot buttons. It is being pushed forward by greedy corporations, and it seems to be the very epitome of the unnatural.

Still, I hereby hazard a prediction. In ten years or less, most American environmentalists (European ones are more dogmatic) will regard genetic modification as one of their most powerful tools. In only the past ten years or so, after all, environmentalists have reversed field and embraced market mechanisms—tradable emissions permits and the like—as useful in the fight against pollution. The environmental logic of biotechnology is, if anything, even more compelling. The potential upside of genetic modification is simply too large to ignore—and therefore environmentalists will not ignore it. Biotechnology will transform agriculture, and in doing so will transform American environmentalism.