Select an event that you have personally experienced that has an intense and profound meaning to you. Compose a description of that experience that makes use of powerful analogies to communicate your thoughts and feelings.

USING ANALOGIES TO SHAPE OUR WORLD

As we have seen, analogies are often visually evocative and can stimulate us to think about things in fresh, creative ways. However, modern research is discovering that analogies play an even more fundamental role in the way we shape our world and give it meaning. Read carefully the following article, "Thinking Literally: The Surprising Ways that Metaphors Shape Your World," by Drake Bennett, and then answer the questions that follow.

Thinking Passage

THINKING LITERALLY

The Surprising Ways That Metaphors Shape Your World

by Drake Bennett

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Metaphors are literary creations—good ones help us see the world anew, in fresh and interesting ways, the rest are simply cliches: a test is a piece of cake, a completed task is a load off one's back, a momentary difficulty is a speed bump.

But whether they're being deployed by poets, politicians, football coaches, or realtors, metaphors are primarily thought of as tools for talking and writing—out of inspiration or out of laziness, we distill emotions and thoughts into the language of the tangible world. We use metaphors to make sense to one another.

Now, however, a new group of people has started to take an intense interest in metaphors: psychologists. Drawing on philosophy and linguistics, cognitive scientists have begun to see the basic metaphors that we use all the time not just as turns of phrase, but as keys to the structure of thought. By taking these everyday metaphors as literally as possible, psychologists are upending traditional ideas of how we learn, reason, and make sense of the world around us. The result has been a torrent of research testing the links between metaphors and their physical roots, with many of the papers reading as if they were commissioned by Amelia Bedelia, the implacably literal-minded children's book hero. Researchers have sought to determine whether the temperature of an object in someone's hands determines how "warm" or "cold" he considers a person he meets, whether the heft of a held object affects how "weighty" people consider topics they are presented with, or whether people think of the powerful as physically more elevated than the less powerful.

What they have found is that, in fact, we do. Metaphors aren't just how we talk and write, they're how we think. At some level, we actually do seem to understand temperament as a form of temperature, and we expect people's personalities to behave accordingly. What's more, without our body's instinctive sense for temperature—or position, texture, size, shape, or weight—abstract concepts like kindness and power, difficulty and purpose, and intimacy and importance would simply not make any sense to us. Deep down, we are all Amelia Bedelia.

Metaphors like this "don't invite us to see the world in new and different ways," says Daniel Casasanto, a cognitive scientist and researcher at the Max Planck Institute for Psycholinguistics in the Netherlands. "They enable us to understand the world at all." Our instinctive, literal-minded metaphorizing can make us vulnerable to what seem like simple tweaks to our physical environment, with ramifications for everything from how we build polling booths to how we sell cereal. And at a broader level it reveals just how much the human body, in all its particularity, shapes the mind, suggesting that much of what we think of as abstract reasoning is in fact a sometimes awkward piggybacking onto the mental tools we have developed to govern our body's interactions with its physical environment. Put another way, metaphors reveal the extent to which we think with our bodies.

"The abstract way we think is really grounded in the concrete, bodily world much more than we thought," says John Bargh, a psychology professor at Yale and leading researcher in this realm.

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George Lakoff, a professor of linguistics at the University of California at Berkeley, and Mark Johnson, a philosophy professor at the University of Oregon, see human thought as metaphor-driven. But, in the two greatly influential books they have co-written on the topic, "Metaphors We Live By" in 1980 and "Philosophy in the Flesh" in 1999, Lakoff and Johnson focus on the deadest of dead metaphors, the ones that don't even rise to the level of cliche. They call them "primary metaphors," and they group them into categories like "affection is warmth," "important is big," "difficulties are burdens," "similarity is closeness," "purposes are destinations," and even "categories are containers."

Rather than so much clutter standing in the way of true understanding, to Lakoff and Johnson these metaphors are markers of the roots of thought itself. Lakoff and Johnson's larger argument is that abstract thought would be meaningless without bodily experience. And primary metaphors, in their ubiquity (in English and other languages) and their physicality, are some of their most powerful evidence for this.

"What we've discovered in the last 30 years is—surprise, surprise—people think with their brains," says Lakoff. "And their brains are part of their bodies."

Inspired by this argument, psychologists have begun to make their way, experiment by experiment, through the catalog of primary metaphors, altering one side of the metaphorical equation to see how it changes the other.

Bargh at Yale, along with Lawrence Williams, now at the University of Colorado, did studies in which subjects were casually asked to hold a cup of either iced or hot coffee, not knowing it was part of the study, then a few minutes later asked to rate the personality of a person who was described to them. The hot coffee group, it turned out, consistently described a warmer person—rating them as happier, more generous, more sociable, good-natured, and more caring—than the iced coffee group. The effect seems to run the other way, too: In a paper published last year, Chen-Bo Zhong and Geoffrey J. Leonardelli of the University of Toronto found that people asked to recall a time when they were ostracized gave lower estimates of room temperature than those who recalled a social inclusion experience.

In a paper in the current issue of *Psychological Science*, researchers in the Netherlands and Portugal describe a series of studies in which subjects were given clipboards on which to fill out questionnaires—in one study subjects were asked to estimate the value of several foreign currencies, in another they were asked to rate the city of Amsterdam and its mayor. The clipboards, however, were two different weights, and the subjects who took the questionnaire on the heavier clipboards tended to ascribe more metaphorical weight to the questions they were asked—they not only judged the foreign currencies to be more valuable, they gave more careful, considered answers to the questions they were asked.

Similar results have proliferated in recent years. One of the authors of the weight paper, Thomas Schubert, has also done work suggesting that the fact that we associate power and elevation ("your highness," "friends in high places") means we actually unconsciously look upward when we think about power. Bargh and Josh Ackerman at MIT's Sloan School of Business, in work that has yet to be published, have done studies in which subjects, after handling sandpaper-covered puzzle pieces, were less likely to describe a social situation as having gone smoothly. Casasanto has done work in which people who were told to move marbles from a lower tray up to a higher one while recounting a story told happier stories than people moving them down.

Several studies have explored the metaphorical connection between cleanliness and moral purity. In one, subjects who were asked to recall an unethical act, then given the choice between a pencil and an antiseptic wipe, were far more likely to choose the cleansing wipe than people who had been asked to recall an ethical act. In a follow-up study, subjects who recalled an unethical act acted less guilty after washing their hands. The researchers dubbed it the "Macbeth effect," after the guilt-ridden, compulsive hand washing of Lady Macbeth.

To the extent that metaphors reveal how we think, they also suggest ways that physical manipulation might be used to shape our thought. In essence, that is what much metaphor research entails. And while psychologists have thus far been primarily interested in using such manipulations simply to tease out an observable effect, there's no reason that they couldn't be put to other uses as well, by marketers, architects, teachers, parents, and litigators, among others.

A few psychologists have begun to ponder applications. . . . How much of an effect these tweaks might have in a real-world setting, researchers emphasize, remains to be seen. Still, it probably couldn't hurt to try a few in your own life. When inviting a new friend over, suggest a cup of hot tea rather than a cold beer. Keep a supply of soft, smooth objects on hand at work—polished pebbles, maybe, or a silk handkerchief—in case things start to feel too daunting. And if you feel a sudden pang of guilt about some long-ago transgression, try taking a shower.

Questions for Analysis

1. What does the author mean when he says, "Metaphors aren't just how we talk and write, they're how we think. At some level, we actually do seem to understand temperament as a form of temperature, and we expect people's personalities to behave accordingly"?

Thinking Passage

ENVIRONMENTAL ISSUES

The impact of human civilization on the environment has taken on increasing urgency as global warming, the razing of rain forests, the search for sustainable fuel sources, and our dependence on factory-farmed or genetically modified food are discussed and debated in the media. All these factors affect the most basic aspects of our lives, from the quality of our air to the safety of our next meal. In the following article, "Playing God in the Garden," Michael Pollan traces the genetically engineered history of the "New Leaf Superior" potatoes that he is planting in his garden, exploring a variety of disturbing questions as he does so. In counterpoint to this perspective is the article "Eating the Genes" in which Richard Manning argues that genetically modified food is an essential strategy in developing countries, the risks of which are of less consequence than the alternative of starvation and malnutrition. As you read these two articles, watch for the authors' development of different kinds of causal connections, and evaluate the clarity and effectiveness of their arguments.

Playing God in the Garden

by Michael Pollan

Planting

Today I planted something new in my vegetable garden—something very new, as a matter of fact. It's a potato called the New Leaf Superior, which has been genetically engineered—by Monsanto, the chemical giant recently turned "life sciences" giant—to produce its own insecticide. This it can do in every cell of every leaf, stem, flower, root and (here's the creepy part) spud. The scourge of potatoes has always been the Colorado potato beetle, a handsome and voracious insect that can pick a plant clean of its leaves virtually overnight. Any Colorado potato beetle that takes so much as a nibble of my New Leafs will supposedly keel over and die, its digestive tract pulped, in effect, by the bacterial toxin manufactured in the leaves of these otherwise ordinary Superiors. (Superiors are the thin-skinned white spuds sold fresh in the supermarket.) You're probably wondering if I plan to eat these potatoes, or serve them to my family. That's still up in the air; it's only the first week of May, and harvest is a few months off.

Certainly my New Leafs are aptly named. They're part of a new class of crop plants that is rapidly changing the American food chain. This year, the fourth year that genetically altered seed has been on the market, some 45 million acres of American farmland have been planted with biotech crops, most of it corn, soybeans, cotton, and potatoes that have been engineered to either produce their own pesticides or withstand herbicides. Though Americans have already begun to eat genetically engineered potatoes, corn, and soybeans, industry research confirms what my own informal surveys suggest: hardly any of us knows it. The reason is not hard to find. The biotech industry, with the concurrence of the Food and Drug Administration, has decided we don't need to know it, so biotech foods carry no identifying labels. In a dazzling feat of positioning, the industry has succeeded in depicting these plants simultaneously as the linchpins of a biological revolution—part of a "new agricultural paradigm" that will make farming more sustainable, feed the world and improve health and nutrition—and, oddly enough, as the same old stuff, at least so far as those of us at the eating end of the food chain should be concerned.

This convenient version of reality has been roundly rejected by both consumers and farmers across the Atlantic. Last summer, biotech food emerged as the most explosive environmental issue in Europe. Protesters have destroyed dozens of field trials of the very same "frankenplants" (as they are sometimes called) that we Americans are already serving for dinner, and throughout Europe the public has demanded that biotech food be labeled in the market.

By growing my own transgenic crop—and talking with scientists and farmers involved with biotech—I hoped to discover which of us was crazy. Are the Europeans overreacting, or is it possible that we've been underreacting to genetically engineered food?

After digging two shallow trenches in my garden and lining them with compost, I untied the purple mesh bag of seed potatoes that Monsanto had sent and opened up the Grower Guide tied around its neck. (Potatoes, you may recall from kindergarten experiments, are grown not from seed but from the eyes of other potatoes.) The guide put me in mind not so much of planting potatoes as booting up a new software release. By "opening and using this product," the card stated, I was now "licensed" to grow these potatoes, but only for a single generation; the crop I would water and tend and harvest was mine, yet also not mine. That is, the potatoes I will harvest come August are mine to eat or sell, but their genes remain the intellectual property of Monsanto, protected under numerous United States patents, including Nos. 5,196,525, 5,164,316, 5,322,938 and 5,352,605. Were I to save even one of them to plant next year—something I've routinely done with potatoes in the past—I would be breaking Federal law. The small print in the Grower Guide also brought the news that my potato plants were themselves a pesticide, registered with the Environmental Protection Agency.

If proof were needed that the intricate industrial food chain that begins with seeds and ends on our dinner plates is in the throes of profound change, the small print that accompanied my New Leaf will do. That food chain has been unrivaled for its productivity—on average, a single American farmer today grows enough food each year to feed 100 people. But this accomplishment has come at a price. The modern industrial farmer cannot achieve such yields without enormous amounts of chemical fertilizer, pesticide, machinery and fuel, a set of capital-intensive inputs, as they're called, that saddle the farmer with debt, threaten his health, erode his soil and destroy its fertility, pollute the ground water and compromise the safety of the food we eat.

We've heard all this before, of course, but usually from environmentalists and organic farmers; what is new is to hear the same critique from conventional farmers, government officials and even many agribusiness corporations, all of whom now acknowledge that our food chain stands in need of reform. Sounding more like Wendell

Berry than the agribusiness giant it is, Monsanto declared in its most recent annual report that "current agricultural technology is not sustainable."

What is supposed to rescue the American food chain is biotechnology—the replacement of expensive and toxic chemical inputs with expensive but apparently benign genetic information: crops that, like my New Leafs, can protect themselves from insects and disease without being sprayed with pesticides. With the advent of biotechnology, agriculture is entering the information age, and more than any other company, Monsanto is positioning itself to become its Microsoft, supplying the proprietary "operating systems"—the metaphor is theirs—to run this new generation of plants.

There is, of course, a second food chain in America: organic agriculture. And while it is still only a fraction of the size of the conventional food chain, it has been growing in leaps and bounds—in large part because of concerns over the safety of conventional agriculture. Organic farmers have been among biotechnology's fiercest critics, regarding crops like my New Leafs as inimical to their principles and, potentially, a threat to their survival. That's because Bt, the bacterial toxin produced in my New Leafs (and in many other biotech plants) happens to be the same insecticide organic growers have relied on for decades. Instead of being flattered by the imitation, however, organic farmers are up in arms: the widespread use of Bt in biotech crops is likely to lead to insect resistance, thus robbing organic growers of one of their most critical tools; that is, Monsanto's version of sustainable agriculture may threaten precisely those farmers who pioneered sustainable farming.

Sprouting

After several days of drenching rain, the sun appeared on May 15, and so did my New Leafs. A dozen deep-green shoots pushed up out of the soil and commenced to grow—faster and more robustly than any of the other potatoes in my garden. Apart from their vigor, though, my New Leafs looked perfectly normal. And yet as I watched them multiply their lustrous dark-green leaves those first few days, eagerly awaiting the arrival of the first doomed beetle, I couldn't help thinking of them as existentially different from the rest of my plants.

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My New Leafs are different. Although Monsanto likes to depict biotechnology as just another in an ancient line of human modifications of nature going back to fermentation, in fact genetic engineering overthrows the old rules governing the relationship of nature and culture in a plant. For the first time, breeders can bring qualities from anywhere in nature into the genome of a plant—from flounders (frost tolerance), from viruses (disease resistance) and, in the case of my potatoes, from Bacillus thuringiensis, the soil bacterium that produces the organic insecticide known as Bt. The introduction into a plant of genes transported not only across species but whole phyla means that the wall of that plant's essential identity—its irreducible wildness, you might say—has been breached.

But what is perhaps most astonishing about the New Leafs coming up in my garden is the human intelligence that the inclusion of the Bt gene represents. In the past, that intelligence resided outside the plant, in the mind of the organic farmers who deployed Bt (in the form of a spray) to manipulate the ecological relationship of certain insects and a certain bacterium as a way to foil those insects. The irony about the New Leafs is that the cultural information they encode happens to be knowledge that resides in the heads of the very sort of people—that is, organic growers—who most distrust high technology.

One way to look at biotechnology is that it allows a larger portion of human intelligence to be incorporated into the plant itself. In this sense, my New Leafs are just plain smarter than the rest of my potatoes. The others will depend on my knowledge and experience when the Colorado potato beetles strike; the New Leafs, knowing what I know about bugs and Bt, will take care of themselves. So while my biotech plants might seem like alien beings, that's not quite right. They're more like us than like other plants because there's more of us in them.

Growing

To find out how my potatoes got that way, I traveled to suburban St. Louis in early June. My New Leafs are clones of clones of plants that were first engineered seven years ago in Monsanto's $150 million research facility, a long, low-slung brick building on the banks of the Missouri that would look like any other corporate complex were it not for the 26 greenhouses that crown its roof like shimmering crenellations of glass.

Dave Stark, a molecular biologist and co-director of Naturemark, Monsanto's potato subsidiary, escorted me through the clean rooms where potatoes are genetically engineered. Technicians sat at lab benches before petri dishes in which fingernail-size sections of potato stem had been placed in a nutrient mixture. To this the technicians added a solution of agrobacterium, a disease bacterium whose modus operandi is to break into a plant cell's nucleus and insert some of its own DNA. Essentially, scientists smuggle the Bt gene into the agrobacterium's payload, and then the bacterium splices it into the potato's DNA. The technicians also add a "marker" gene, a kind of universal product code that allows Monsanto to identify its plants after they leave the lab.

A few days later, once the slips of potato stem have put down roots, they're moved to the potato greenhouse up on the roof. Here, Glenda DeBrecht, a horticulturist, invited me to don latex gloves and help her transplant pinky-size plantlets from their petri dish to small pots. The whole operation is performed thousands of times, largely because there is so much uncertainty about the outcome. There's no way of telling where in the genome the new DNA will land, and if it winds up in the wrong place, the new gene won't be expressed (or it will be poorly expressed) or the plant may be a freak. I was struck by how the technology could at once be astoundingly sophisticated and yet also a shot in the genetic dark.

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When I got home from St. Louis, I phoned Richard Lewontin, the Harvard geneticist, to ask him what he thought of the software metaphor. "From an intellectual-property standpoint, it's exactly right," he said. "But it's a bad one in terms of biology. It implies you feed a program into a machine and get predictable results. But the genome is very noisy. If my computer made as many mistakes as an organism does"—in interpreting its DNA, he meant—"I'd throw it out."

I asked him for a better metaphor. "An ecosystem," he offered. "You can always intervene and change something in it, but there's no way of knowing what all the downstream effects will be or how it might affect the environment. We have such a miserably poor understanding of how the organism develops from its DNA that I would be surprised if we don't get one rude shock after another."

Flowering

My own crop was thriving when I got home from St. Louis; the New Leafs were as big as bushes, crowned with slender flower stalks. Potato flowers are actually quite pretty, at least by vegetable standards—five-petaled pink stars with yellow centers that give off a faint rose perfume. One sultry afternoon I watched the bumblebees making their lazy rounds of my potato blossoms, thoughtlessly powdering their thighs with yellow pollen grains before lumbering off to appointments with other blossoms, others species.

Uncertainty is the theme that unifies much of the criticism leveled against biotech agriculture by scientists and environmentalists. By planting millions of acres of genetically altered plants, we have introduced something novel into the environment and the food chain, the consequences of which are not—and at this point, cannot be—completely understood. One of the uncertainties has to do with those grains of pollen bumblebees are carting off from my potatoes. That pollen contains Bt genes that may wind up in some other, related plant, possibly conferring a new evolutionary advantage on that species. "Gene flow," the scientific term for this phenomenon, occurs only between closely related species, and since the potato evolved in South America, the chances are slim that my Bt potato genes will escape into the wilds of Connecticut.

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Yet what happens if and when Peruvian farmers plant Bt potatoes? Or when I plant a biotech crop that does have local relatives? A study reported in Nature last month found that plant traits introduced by genetic engineering were more likely to escape into the wild than the same traits introduced conventionally.

Andrew Kimbrell, director of the Center for Technology Assessment in Washington, told me he believes such escapes are inevitable. "Biological pollution will be the environmental nightmare of the 21st century," he said when I reached him by phone. "This is not like chemical pollution—an oil spill—that eventually disperses. Biological pollution is an entirely different model, more like a disease. Is Monsanto going to be held legally responsible when one of its transgenes creates a superweed or resistant insect?"

Kimbrell maintains that because our pollution laws were written before the advent of biotechnology, the new industry is being regulated under an ill-fitting regime designed for the chemical age. Congress has so far passed no environmental law dealing specifically with biotech. Monsanto, for its part, claims that it has thoroughly examined all the potential environmental and health risks of its biotech plants, and points out that three regulatory agencies—the U.S.D.A., the E.P.A., and the F.D.A.—have signed off on its products. Speaking of the New Leaf, Dave Stark told me, "This is the most intensively studied potato in history."

Significant uncertainties remain, however. Take the case of insect resistance to Bt, a potential form of "biological pollution" that could end the effectiveness of one of the safest insecticides we have—and cripple the organic farmers who depend on it. The theory, which is now accepted by most entomologists, is that Bt crops will add so much of the toxin to the environment that insects will develop resistance to it. Until now, resistance hasn't been a worry because the Bt sprays break down quickly in sunlight and organic farmers use them only sparingly. Resistance is essentially a form of co-evolution that seems to occur only when a given pest population is threatened with extinction; under that pressure, natural selection favors whatever chance mutations will allow the species to change and survive.

Working with the E.P.A., Monsanto has developed a "resistance-management plan" to postpone that eventuality. Under the plan, farmers who plant Bt crops must leave a certain portion of their land in non-Bt crops to create "refuges" for the targeted insects. The goal is to prevent the first Bt-resistant Colorado potato beetle from mating with a second resistant bug, unleashing a new race of superbeetles. The theory is that when a Bt-resistant bug does show up, it can be induced to mate with a susceptible bug from the refuge, thus diluting the new gene for resistance.

But a lot has to go right for Mr. Wrong to meet Miss Right. No one is sure how big the refuges need to be, where they should be situated or whether the farmers will cooperate (creating havens for a detested pest is counter-intuitive, after all), not to mention the bugs. In the case of potatoes, the E.P.A. has made the plan voluntary and lets the companies themselves implement it; there are no E.P.A. enforcement mechanisms. Which is why most of the organic farmers I spoke to dismissed the regulatory scheme as window dressing.

Monsanto executives offer two basic responses to criticism of their Bt crops. The first is that their voluntary resistance-management plans will work, though the company's definition of success will come as small consolation to an organic farmer: Monsanto scientists told me that if all goes well, resistance can be postponed for 30 years. (Some scientists believe it will come in three to five years.) The second response is more troubling. In St. Louis, I met with Jerry Hjelle, Monsanto's vice president for regulatory affairs. Hjelle told me that resistance should not unduly concern us since "there are a thousand other Bt's out there"—other insecticidal proteins. "We can handle this problem with new products," he said. "The critics don't know what we have in the pipeline."

And then Hjelle uttered two words that I thought had been expunged from the corporate vocabulary a long time ago: "Trust us."

"Trust" is a key to the success of biotechnology in the marketplace, and while I was in St. Louis, I asked Hjelle and several of his colleagues why they thought the Europeans were resisting biotech food.

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Monsanto executives are quick to point out that mad cow disease has made Europeans extremely sensitive about the safety of their food chain and has undermined confidence in their regulators. "They don't have a trusted agency like the F.D.A. looking after the safety of their food supply," said Phil Angell, Monsanto's director of corporate communications. Over the summer, Angell was dispatched repeatedly to Europe to put out the P.R. fires; some at Monsanto worry these could spread to the United States.

I checked with the F.D.A. to find out exactly what had been done to insure the safety of this potato. I was mystified by the fact that the Bt toxin was not being treated as a "food additive" subject to labeling, even though the new protein is expressed in the potato itself. The label on a bag of biotech potatoes in the supermarket will tell a consumer all about the nutrients they contain, even the trace amounts of copper. Yet it is silent not only about the fact that those potatoes are the product of genetic engineering but also about their containing an insecticide.

At the F.D.A., I was referred to James Maryanski, who oversees biotech food at the agency. I began by asking him why the F.D.A. didn't consider Bt a food additive. Under F.D.A. law, any novel substance added to a food must—unless it is "generally regarded as safe" ("GRAS," in F.D.A. parlance)—be thoroughly tested and if it changes the product in any way, must be labeled.

"That's easy," Maryanski said. "Bt is a pesticide, so it's exempt" from F.D.A. regulation. That is, even though a Bt potato is plainly a food, for the purposes of Federal regulation it is not a food but a pesticide and therefore falls under the jurisdiction of the E.P.A.

Yet even in the case of those biotech crops over which the F.D.A. does have jurisdiction, I learned that F.D.A. regulation of biotech food has been largely voluntary since 1992, when Vice President Dan Quayle issued regulatory guidelines for the industry as part of the Bush Administration's campaign for "regulatory relief." Under the guidelines, new proteins engineered into foods are regarded as additives (unless they're pesticides), but as Maryanski explained, "the determination whether a new protein is GRAS can be made by the company." Companies with a new biotech food decide for themselves whether they need to consult with the F.D.A. by following a series of "decision trees" that pose yes or no questions like this one: "Does . . . the introduced protein raise any safety concern?"

Since my Bt potatoes were being regulated as a pesticide by the E.P.A. rather than as a food by the F.D.A., I wondered if the safety standards are the same. "Not exactly," Maryanski explained. The F.D.A. requires "a reasonable certainty of no harm" in a food additive, a standard most pesticides could not meet. After all, "pesticides are toxic to something," Maryanski pointed out, so the E.P.A. instead establishes human "tolerances" for each chemical and then subjects it to a risk-benefit analysis.

When I called the E.P.A. and asked if the agency had tested my Bt potatoes for safety as a human food, the answer was . . . not exactly. It seems the E.P.A. works from the assumption that if the original potato is safe and the Bt protein added to it is safe, then the whole New Leaf package is presumed to be safe. Some geneticists believe this reasoning is flawed, contending that the process of genetic engineering itself may cause subtle, as yet unrecognized changes in a food.

The original Superior potato is safe, obviously enough, so that left the Bt toxin, which was fed to mice, and they "did fine, had no side effects," I was told. I always feel better knowing that my food has been poison-tested by mice, though in this case there was a small catch: the mice weren't actually eating the potatoes, not even an extract from the potatoes, but rather straight Bt produced in a bacterial culture.

So are my New Leafs safe to eat? Probably, assuming that a New Leaf is nothing more than the sum of a safe potato and a safe pesticide, and further assuming that the E.P.A.'s idea of a safe pesticide is tantamount to a safe food. Yet I still had a question. Let us assume that my potatoes are a pesticide—a very safe pesticide. Every pesticide in my garden shed—including the Bt sprays—carries a lengthy warning label. The label on my bottle of Bt says, among other things, that I should avoid inhaling the spray or getting it in an open wound. So if my New Leaf potatoes contain an E.P.A.-registered pesticide, why don't they carry some such label?

Maryanski had the answer. At least for the purposes of labeling, my New Leafs have morphed yet again, back into a food: the Food, Drug and Cosmetic Act gives the F.D.A. sole jurisdiction over the labeling of plant foods, and the F.D.A. has ruled that biotech foods need be labeled only if they contain known allergens or have otherwise been "materially" changed.

But isn't turning a potato into a pesticide a material change?

It doesn't matter. The Food, Drug and Cosmetic Act specifically bars the F.D.A. from including any information about pesticides on its food labels.

I thought about Maryanski's candid and wondrous explanations the next time I met Phil Angell, who again cited the critical role of the F.D.A. in assuring Americans that biotech food is safe. But this time he went even further. "Monsanto should not have to vouchsafe the safety of biotech food," he said. "Our interest is in selling as much of it as possible. Assuring its safety is the F.D.A.'s job."

Meeting the Beetles

My Colorado potato beetle vigil came to an end the first week of July, shortly before I went to Idaho to visit potato growers. I spied a single mature beetle sitting on a New Leaf leaf; when I reached to pick it up, the beetle fell drunkenly to the ground. It had been sickened by the plant and would soon be dead. My New Leafs were working.

From where a typical American potato grower stands, the New Leaf looks very much like a godsend. That's because where the typical potato grower stands is in the middle of a bright green field that has been doused with so much pesticide that the leaves of his plants wear a dull white chemical bloom that troubles him as much as it does the rest of us. Out there, at least, the calculation is not complex: a product that promises to eliminate the need for even a single spraying of pesticide is, very simply, an economic and environmental boon.

No one can make a better case for a biotech crop than a potato farmer, which is why Monsanto was eager to introduce me to several large growers. Like many farmers today, the ones I met feel trapped by the chemical inputs required to extract the high yields they must achieve in order to pay for the chemical inputs they need. The economics are daunting: a potato farmer in south-central Idaho will spend roughly $1,965 an acre (mainly on chemicals, electricity, water, and seed) to grow a crop that, in a good year, will earn him maybe $1,980. That's how much a french-fry processor will pay for the 20 tons of potatoes a single Idaho acre can yield. (The real money in agriculture—90 percent of the value added to the food we eat—is in selling inputs to farmers and then processing their crops.)

Danny Forsyth laid out the dismal economics of potato farming for me one sweltering morning at the coffee shop in downtown Jerome, Idaho. Forsyth, 60, is a slight blue-eyed man with a small gray ponytail; he farms 3,000 acres of potatoes, corn, and wheat, and he spoke about agricultural chemicals like a man desperate to kick a bad habit. "None of us would use them if we had any choice," he said glumly.

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Idaho farmers like Forsyth farm in vast circles defined by the rotation of a pivot irrigation system, typically 135 acres to a circle; I'd seen them from 30,000 feet flying in, a grid of verdant green coins pressed into a desert of scrubby brown. Pesticides and fertilizers are simply added to the irrigation system, which on Forsyth's farm draws most of its water from the nearby Snake River. Along with their water, Forsyth's potatoes may receive 10 applications of chemical fertilizer during the growing season. Just before the rows close—when the leaves of one row of plants meet those of the next—he begins spraying Bravo, a fungicide, to control late blight, one of the biggest threats to the potato crop. (Late blight, which caused the Irish potato famine, is an airborne fungus that turns stored potatoes into rotting mush.) Blight is such a serious problem that the E.P.A. currently allows farmers to spray powerful fungicides that haven't passed the usual approval process. Forsyth's potatoes will receive eight applications of fungicide.

Twice each summer, Forsyth hires a crop duster to spray for aphids. Aphids are harmless in themselves, but they transmit the leafroll virus, which in Russet Burbank potatoes causes net necrosis, a brown spotting that will cause a processor to reject a whole crop. It happened to Forsyth last year. "I lost 80,000 bags"—they're a hundred pounds each—"to net necrosis," he said. "Instead of getting $4.95 a bag, I had to take $2 a bag from the dehydrator, and I was lucky to get that." Net necrosis is a purely cosmetic defect; yet because big buyers like McDonald's believe (with good reason) that we don't like to see brown spots in our fries, farmers like Danny Forsyth must spray their fields with some of the most toxic chemicals in use, including an organophosphate called Monitor.

"Monitor is a deadly chemical," Forsyth said. "I won't go into a field for four or five days after it's been sprayed—even to fix a broken pivot." That is, he would sooner lose a whole circle to drought than expose himself or an employee to Monitor, which has been found to cause neurological damage.

It's not hard to see why a farmer like Forsyth, struggling against tight margins and heartsick over chemicals, would leap at a New Leaf—or, in his case, a New Leaf Plus, which is protected from leafroll virus as well as beetles. "The New Leaf means I can skip a couple of sprayings, including the Monitor," he said. "I save money, and I sleep better. It also happens to be a nice-looking spud." The New Leafs don't come cheaply, however. They cost between $20 and $30 extra per acre in "technology fees" to Monsanto.

Forsyth and I discussed organic agriculture, about which he had the usual things to say ("That's all fine on a small scale, but they don't have to feed the world"), as well as a few things I'd never heard from a conventional farmer: "I like to eat organic food, and in fact I raise a lot of it at the house. The vegetables we buy at the market we just wash and wash and wash. I'm not sure I should be saying this, but I always plant a small area of potatoes without any chemicals. By the end of the season, my field potatoes are fine to eat, but any potatoes I pulled today are probably still full of systemics. I don't eat them."

Forsyth's words came back to me a few hours later, during lunch at the home of another potato farmer. Steve Young is a progressive and prosperous potato farmer—he calls himself an agribusinessman. In addition to his 10,000 acres—the picture window in his family room gazes out on 85 circles, all computer-controlled—Young owns a share in a successful fertilizer distributorship. His wife prepared a lavish feast for us, and after Dave, their 18-year-old, said grace, adding a special prayer for me (the Youngs are devout Mormons), she passed around a big bowl of homemade potato salad. As I helped myself, my Monsanto escort asked what was in the salad, flashing me a smile that suggested she might already know. "It's a combination of New Leafs and some of our regular Russets," our hostess said proudly. "Dug this very morning."

After talking to farmers like Steve Young and Danny Forsyth, and walking fields made virtually sterile by a drenching season-long rain of chemicals, you could understand how Monsanto's New Leaf potato does indeed look like an environmental boon. Set against current practices, growing New Leafs represents a more sustainable way of potato farming. This advance must be weighed, of course, against everything we don't yet know about New Leafs—and a few things we do: like the problem of Bt resistance I had heard so much about back East. While I was in Idaho and Washington State, I asked potato farmers to show me their refuges. This proved to be a joke.

"I guess that's a refuge over there," one Washington farmer told me, pointing to a cornfield.

Monsanto's grower contract never mentions the word "refuge" and only requires that farmers plant no more than 80 percent of their fields in New Leaf. Basically, any field not planted in New Leaf is considered a refuge, even if that field has been sprayed to kill every bug in it. Farmers call such acreage a clean field; calling it a refuge is a stretch at best.

It probably shouldn't come as a big surprise that conventional farmers would have trouble embracing the notion of an insect refuge. To insist on real and substantial refuges is to ask them to start thinking of their fields in an entirely new way, less as a factory than as an ecosystem. In the factory, Bt is another in a long line of "silver bullets" that work for a while and then get replaced; in the ecosystem, all bugs are not necessarily bad, and the relationships between various species can be manipulated to achieve desired ends—like the long-term sustainability of Bt.

This is, of course, precisely the approach organic farmers have always taken to their fields, and after my lunch with the Youngs that afternoon, I paid a brief visit to an organic potato grower. Mike Heath is a rugged, laconic man in his mid-50's; like most of the organic farmers I've met, he looks as though he spends a lot more time out of doors than a conventional farmer, and he probably does: chemicals are, among other things, labor-saving devices. While we drove around his 500 acres in a battered old pickup, I asked him about biotechnology. He voiced many reservations—it was synthetic, there were too many unknowns—but his main objection to planting a biotech potato was simply that "it's not what my customers want."

That point was driven home last December when the Department of Agriculture proposed a new "organic standards" rule that, among other things, would have allowed biotech crops to carry an organic label. After receiving a flood of outraged cards and letters, the agency backed off. (As did Monsanto, which asked the U.S.D.A. to shelve the issue for three years.) Heath suggested that biotech may actually help organic farmers by driving worried consumers to the organic label.

I asked Heath about the New Leaf. He had no doubt resistance would come—"the bugs are always going to be smarter than we are"—and said it was unjust that Monsanto was profiting from the ruin of Bt, something he regarded as a "public good."

None of this particularly surprised me; what did was that Heath himself resorted to Bt sprays only once or twice in the last 10 years. I had assumed that organic farmers used Bt or other approved pesticides in much the same way conventional farmers use theirs, but as Heath showed me around his farm, I began to understand that organic farming was a lot more complicated than substituting good inputs for bad. Instead of buying many inputs at all, Heath relied on long and complex crop rotations to prevent a buildup of crop-specific pests—he has found, for example, that planting wheat after spuds "confuses" the potato beetles.

He also plants strips of flowering crops on the margins of his potato fields—peas or alfalfa, usually—to attract the beneficial insects that eat beetle larvae and aphids. If there aren't enough beneficials to do the job, he'll introduce ladybugs. Heath also grows eight varieties of potatoes, on the theory that biodiversity in a field, as in the wild, is the best defense against any imbalances in the system. A bad year with one variety will probably be offset by a good year with the others.

"I can eat any potato in this field right now," he said, digging Yukon Golds for me to take home. "Most farmers can't eat their spuds out of the field. But you don't want to start talking about safe food in Idaho."

Heath's were the antithesis of "clean" fields, and, frankly, their weedy margins and overall patchiness made them much less pretty to look at. Yet it was the very complexity of these fields—the sheer diversity of species, both in space and time—that made them productive year after year without many inputs. The system provided for most of its needs.

All told, Heath's annual inputs consisted of natural fertilizers (compost and fish powder), ladybugs and a copper spray (for blight)—a few hundred dollars an acre. Of course, before you can compare Heath's operation with a conventional farm, you've got to add in the extra labor (lots of smaller crops means more work; organic fields must also be cultivated for weeds) and time—the typical organic rotation calls for potatoes every fifth year, in contrast to every third on a conventional farm. I asked Heath about his yields. To my astonishment, he was digging between 300 and 400 bags per acre—just as many as Danny Forsyth and only slightly fewer than Steve Young. Heath was also getting almost twice the price for his spuds: $8 a bag from an organic processor who was shipping frozen french fries to Japan.

On the drive back to Boise, I thought about why Heath's farm remained the exception, both in Idaho and elsewhere. Here was a genuinely new paradigm that seemed to work. But while it's true that organic agriculture is gaining ground (I met a big grower in Washington who had just added several organic circles), few of the mainstream farmers I met considered organic a "realistic" alternative. For one thing, it's expensive to convert: organic certifiers require a field to go without chemicals for three years before it can be called organic. For another, the U.S.D.A., which sets the course of American agriculture, has long been hostile to organic methods.

But I suspect the real reasons run deeper, and have more to do with the fact that in a dozen ways a farm like Heath's simply doesn't conform to the requirements of a corporate food chain. Heath's type of agriculture doesn't leave much room for the Monsantos of this world: organic farmers buy remarkably little—some seed, a few tons of compost, maybe a few gallons of ladybugs. That's because the organic farmer's focus is on a process, rather than on products. Nor is that process readily systematized, reduced to, say, a prescribed regime of sprayings like the one Forsyth outlined for me—regimes that are often designed by companies selling chemicals.

Most of the intelligence and local knowledge needed to run Mike Heath's farm resides in the head of Mike Heath. Growing potatoes conventionally requires intelligence, too, but a large portion of it resides in laboratories in distant places like St. Louis, where it is employed in developing sophisticated chemical inputs. That sort of centralization of agriculture is unlikely to be reversed, if only because there's so much money in it; besides, it's much easier for the farmer to buy prepackaged solutions from big companies. "Whose Head Is the Farmer Using? Whose Head Is Using the Farmer?" goes the title of a Wendell Berry essay.

Organic farmers like Heath have also rejected what is perhaps the cornerstone of industrial agriculture: the economies of scale that only a monoculture can achieve. Monoculture—growing vast fields of the same crop year after year—is probably the single most powerful simplification of modern agriculture. But monoculture is poorly fitted to the way nature seems to work. Very simply, a field of identical plants will be exquisitely vulnerable to insects, weeds, and disease. Monoculture is at the root of virtually every problem that bedevils the modern farmer, and that virtually every input has been designed to solve.

To put the matter baldly, a farmer like Heath is working very hard to adjust his fields and his crops to the nature of nature, while farmers like Forsyth are working equally hard to adjust nature in their fields to the requirement of monoculture and, beyond that, to the needs of the industrial food chain. I remember asking Heath what he did about net necrosis, the bane of Forsyth's existence. "That's only really a problem with Russet Burbanks," he said. "So I plant other kinds." Forsyth can't do that. He's part of a food chain—at the far end of which stands a long, perfectly golden McDonald's fry—that demands he grow Russet Burbanks and little else.

This is where biotechnology comes in, to the rescue of Forsyth's Russet Burbanks and, if Monsanto is right, to the whole food chain of which they form a part. Monoculture is in trouble—the pesticides that make it possible are rapidly being lost, either to resistance or to heightened concerns about their danger. Biotechnology is the new silver bullet that will save monoculture. But a new silver bullet is not a new paradigm—rather, it's something that will allow the old paradigm to survive. That paradigm will always construe the problem in Forsyth's fields as a Colorado potato beetle problem, rather than as a problem of potato monoculture.

Like the silver bullets that preceded them—the modern hybrids, the pesticides, and the chemical fertilizers—the new biotech crops will probably, as advertised, increase yields. But equally important, they will also speed the process by which agriculture is being concentrated in a shrinking number of corporate hands. If that process has advanced more slowly in farming than in other sectors of the economy, it is only because nature herself—her complexity, diversity, and sheer intractability in the face of our best efforts at control—has acted as a check on it. But biotechnology promises to remedy this "problem," too.

Consider, for example, the seed, perhaps the ultimate "means of production" in any agriculture. It is only in the last few decades that farmers have begun buying their seed from big companies, and even today many farmers still save some seed every fall to replant in the spring. Brown-bagging, as it is called, allows farmers to select strains particularly well adapted to their needs; since these seeds are often traded, the practice advances the state of the genetic art—indeed, has given us most of our crop plants. Seeds by their very nature don't lend themselves to commodification: they produce more of themselves ad infinitum (with the exception of certain modern hybrids), and for that reason the genetics of most major crop plants have traditionally been regarded as a common heritage. In the case of the potato, the genetics of most important varieties—the Burbanks, the Superiors, the Atlantics—have always been in the public domain. Before Monsanto released the New Leaf, there had never been a multinational seed corporation in the potato-seed business—there was no money in it.

Biotechnology changes all that. By adding a new gene or two to a Russet Burbank or Superior, Monsanto can now patent the improved variety. Legally, it has been possible to patent a plant for many years, but biologically, these patents have been almost impossible to enforce. Biotechnology partly solves that problem. A Monsanto agent can perform a simple test in my garden and prove that my plants are the company's intellectual property. The contract farmers sign with Monsanto allows company representatives to perform such tests in their fields at will. According to Progressive Farmer, a trade journal, Monsanto is using informants and hiring Pinkertons to enforce its patent rights; it has already brought legal action against hundreds of farmers for patent infringement.

Soon the company may not have to go to the trouble. It is expected to acquire the patent to a powerful new biotechnology called the Terminator, which will, in effect, allow the company to enforce its patents biologically. Developed by the U.S.D.A. in partnership with Delta and Pine Land, a seed company in the process of being purchased by Monsanto, the Terminator is a complex of genes that, theoretically, can be spliced into any crop plant, where it will cause every seed produced by that plant to be sterile. Once the Terminator becomes the industry standard, control over the genetics of crop plants will complete its move from the farmer's field to the seed company—to which the farmer will have no choice but to return year after year. The Terminator will allow companies like Monsanto to privatize one of the last great commons in nature—the genetics of the crop plants that civilization has developed over the past 10,000 years.

At lunch on his farm in Idaho, I had asked Steve Young what he thought about all this, especially about the contract Monsanto made him sign. I wondered how the American farmer, the putative heir to a long tradition of agrarian independence, was adjusting to the idea of field men snooping around his farm, and patented seed he couldn't replant. Young said he had made his peace with corporate agriculture, and with biotechnology in particular: "It's here to stay. It's necessary if we're going to feed the world, and it's going to take us forward."

Then I asked him if he saw any downside to biotechnology, and he paused for what seemed a very long time. What he then said silenced the table. "There is a cost," he said. "It gives corporate America one more noose around my neck."

Harvest

A few weeks after I returned home from Idaho, I dug my New Leafs, harvesting a gorgeous-looking pile of white spuds, including some real lunkers. The plants had performed brilliantly, though so had all my other potatoes. The beetle problem never got serious, probably because the diversity of species in my (otherwise organic) garden had attracted enough beneficial insects to keep the beetles in check. By the time I harvested my crop, the question of eating the New Leafs was moot. Whatever I thought about the soundness of the process that had declared these potatoes safe didn't matter. Not just because I'd already had a few bites of New Leaf potato salad at the Youngs but also because Monsanto and the F.D.A. and the E.P.A. had long ago taken the decision of whether or not to eat a biotech potato out of my—out of all of our—hands. Chances are, I've eaten New Leafs already, at McDonald's or in a bag of Frito-Lay chips, though without a label there can be no way of knowing for sure.

So if I've probably eaten New Leafs already, why was it that I kept putting off eating mine? Maybe because it was August, and there were so many more-interesting fresh potatoes around—fingerlings with dense, luscious flesh, Yukon Golds that tasted as though they had been pre-buttered—that the idea of cooking with a bland commercial variety like the Superior seemed beside the point.

There was this, too: I had called Margaret Mellon at the Union of Concerned Scientists to ask her advice. Mellon is a molecular biologist and lawyer and a leading critic of biotech agriculture. She couldn't offer any hard scientific evidence that my

New Leafs were unsafe, though she emphasized how little we know about the effects of Bt in the human diet. "That research simply hasn't been done," she said.

I pressed. Is there any reason I shouldn't eat these spuds?

"Let me turn that around. Why would you want to?"

It was a good question. So for a while I kept my New Leafs in a bag on the porch. Then I took the bag with me on vacation, thinking maybe I'd sample them there, but the bag came home untouched.

The bag sat on my porch till the other day, when I was invited to an end-of-summer potluck supper at the town beach. Perfect. I signed up to make a potato salad. I brought the bag into the kitchen and set a pot of water on the stove. But before it boiled I was stricken by this thought: I'd have to tell people at the picnic what they were eating. I'm sure (well, almost sure) the potatoes are safe, but if the idea of eating biotech food without knowing it bothered me, how could I possibly ask my neighbors to? So I'd tell them about the New Leafs—and then, no doubt, lug home a big bowl of untouched potato salad. For surely there would be other potato salads at the potluck and who, given the choice, was ever going to opt for the bowl with the biotech spuds?

So there they sit, a bag of biotech spuds on my porch. I'm sure they're absolutely fine. I pass the bag every day, thinking I really should try one, but I'm beginning to think that what I like best about these particular biotech potatoes—what makes them different—is that I have this choice. And until I know more, I choose not.

Questions for Analysis

1. What does it mean to say that a plant has been genetically "modified" or "engineered"? What is the New Leaf Superior potato able to do as a result of being genetically modified?
2. Unlike Europe where produce that is genetically modified is clearly indicated on the label, people in the United States have no idea whether the food they are eating has been genetically modified. Why are Europeans so concerned? Why isn't our produce clearly labeled?
3. What are the potential risks to the environment of growing genetically engineered food? What are the potential risks to people in eating food that has been genetically modified?
4. Genetically modified food is designed to reduce the pesticides that farmers must use to protect their crops. What dangers does this heavy use of pesticides pose for the public?
5. How is organic farming able to avoid the heavy use of pesticides? Why isn't organic farming a larger share of the market?
6. Rank in order what your produce grown preferences would be (if you knew what you were eating by clear labeling!) and explain your reasoning.
   - Plants grown using traditional farming methods with repeated applications of pesticides
   - Genetically modified plants
   - Organically grown plants

Eating the Genes: What the Green Revolution Did for Grain, Biotechnology May Do for Protein

by Richard Manning

Fears that genetically engineered foods will damage the environment have fueled controversy in the developed world. The debate looks very different when framed not by corporations and food activists but by three middle-aged women in saris working in a Spartan lab in Pune, India. The three, each with a doctoral degree and a full career in biological research, are studying the genes of chickpeas, but they begin their conversation by speaking of suicides.

The villain in their discussion is an insidious little worm, a pod borer, which makes its way unseen into the ripening chickpea pods and eats the peas. It comes every year, laying waste to some fields while sparing others. Subsistence farmers expecting a bumper crop instead find the fat pods hollow at harvest. Dozens will then kill themselves rather than face the looming hunger of their families. So while the battle wages over "frankenfood" in the well-fed countries of the world, here in this Pune lab the arguments quietly disappear.

A generation ago the world faced starvation, and India served as the poster child for the coming plague, occupying roughly the same position in international consciousness then that sub-Saharan Africa does today. The Green Revolution of the 1960s changed all that, with massive increases in grain production, especially in India, a country that now produces enough wheat, rice, sorghum, and maize to feed its people. Green Revolution methods, however, concentrated on grains, ignoring such crops as chickpeas and lentils, the primary sources of protein in the country's vegetarian diet. As a consequence, per capita production of carbohydrates from grain in India tripled. At the same time, largely because of population growth, per capita protein production halved.

The gains in grain yield came largely from breeding plants with shorter stems, which could support heavier and more bountiful seed heads. To realize this opportunity, farmers poured on nitrogen and water: globally, there was a sevenfold increase in fertilizer use between 1950 and 1990. Now, artificial sources of nitrogen, mostly from fertilizer, add more to the planet's nitrogen cycle than natural sources, contributing to global warming, ozone depletion, and smog. Add to this the massive loads of pesticides used against insects drawn to this bulging monoculture of grain, and one begins to see the rough outlines of environmental damage the globe cannot sustain.

During this same revolutionary period, India and other countries, including Mexico, Brazil, Chile, and Cuba, developed scientific communities capable of addressing many of their own food problems. High on their list is the promise of genetic engineering (see "New Markets for Biotech"). In India, researchers have found a natural resistance to pod borers in two other crops, the Asian bean and peanuts, and are trying to transfer the responsible gene to chickpeas. If they are successful, farmers will not only get more protein; they will also avoid insecticides. "The farmer has not to spray anything, has not

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to dust anything," D. R. Bapat, a retired plant breeder, told me. He need only plant a new seed.

This is the simple fact that makes genetic modification so attractive in the developing world. Seeds are packages of genes and genes are information—exceedingly valuable and powerful information. Biotech corporations can translate that information into profits. Yet when those same packets of power are developed by public-sector scientists in places like India, they become a tool, not for profit, but for quickly distributing important information. There is no more efficient means of spreading information than a seed.

The above argument built only slowly in my mind in the course of researching a book (*Food's Frontier: The Next Green Revolution*) that profiled nine food projects in the developing world, all of which were carried out largely by scientists native to the countries I visited. I expected to encounter low-technology projects appropriate for the primitive conditions of subsistence agriculture in the developing world—and I did. But I also found, in all nine cases, a sophisticated and equally appropriate use of genetic research or genetic engineering.

A lab in Uganda, for example, could not regularly flush its toilets for lack of running water, but could tag DNA. This tagging ability, used in six of the projects I studied, allows researchers to understand and accelerate the breeding of new strains. Typically, an effort to breed a disease- or pest-resistant strain of a crop can involve ten years of testing to verify the trait. Using genetic markers cuts that time in half—a difference that gains urgency in countries where test plots are surrounded by poor farmers whose crops are failing for want of that very trait.

In this manner, by allowing researchers to accelerate the development of new, pest-resistant sources of protein, genetic engineering can help fulfill the decades-old promise of the Green Revolution. Our last revolution created a world awash in grain. But if Uganda is to get better sweet potatoes, Peru better mashua, and India better chickpeas, then research on those orphan crops will have to catch up rapidly. Biotechnology can help.

Food researchers in developing countries are understandably worried they will be hampered by the controversy over genetically modified foods. Meanwhile, they have a hard time understanding why genetic engineering is the focus of such concern. The gains of the Green Revolution, after all—and for that matter the gains of 10,000 years of agriculture—have in many cases come from mating unrelated species of plants to create something new and better. Every new strain has brought with it the potential dangers now being ascribed with apparent exclusivity to genetic engineering, such as the creation of superresistant pests. Genetic engineering merely refines the tools.

When viewed from labs surrounded by subsistence farmers, where food research is a matter of life and death rather than an intellectual debate, genetic engineering is a qualified good—not without problems and dangers, but still of great promise. Genetic modification of foods becomes a natural extension of the millennia-old practice of plant breeding, less environmentally damaging than many modern alternatives. In the end, DNA is knowledge, which we can hope will build to wisdom, from which we may one day create an agriculture that both supports our population and coexists peacefully with our planet.